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SIMULATORS, FLIGHT

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U.S. AIR FORCE GUIDE SPECIFICATION

SIMULATORS, FLIGHT

This specification is approved for use within the Air Force and is available for use within the distribution limitations noted.

1. SCOPE

1.1 Scope. This specification establishes the requirements and verifications for the development of aircrew training devices.

1.2 **Use.** Users of this document will need the results of preceding reviews, trade studies from the SON, ROC, Manpower Personnel Training process, etc, which determine the subsystems allocations required for a particular aircrew training device.

This specification cannot be used for contractual purposes without supplemental information relating to the performance requirements of that weapon system.

1.2.1 **Structure.** The supplemental information required is identified by blanks within the specification.

1.2.2 **Instructional handbook.** The instructional handbook, which is contained in the appendix herein, provides the rationale for specified requirements, guidance for inclusion of supplemental information, and a lessons-learned repository.

1.3 **Deviation.** Any projected design for a given application which will result in improvement of system performance, reduced life cycle cost, or reduced development cost through deviation from this specification, or where the requirements of this specification result in compromise in operational capability, shall be brought to the attention of the procuring activity for consideration of change.

2. APPLICABLE DOCUMENTS

2.1 Government documents

2.1.1 **Specifications, standards, and handbooks.** The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation.

STANDARDS

Federal

FED-STD-595	Colors

Military

MIL-STD-210	Climatic Extremes for Military Equipment
MIL-STD-454	Standard General Requirements for Electrical Equipment
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-STD-1800	Human Engineering Performance Requirements for Systems
MIL-STD-1801	User/Computer Interface

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia PA 19120-5900.)

2.1.2 **Other Government documents, drawings, and publications.** The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

AFR 100-45	Communications Security Policies, Procedures, and Instructions
AFSC DH 1-3	Human Factors Engineering
AFSC DH 1-6	System Safety
SPEXDLMS2	Defense Mapping Agency Product Specification for Digital Landmass System Data Base (Application for copies should be addressed to DMA Aerospace Center, 3200 S. Second, St. Louis MO 63118.)

2.2 **Non-Government publications.** The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the issue of the DoDISS specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation.

NFPA Std 70-84	National Electrical Code
NFPA Std 72E-84	Automatic Fire Detectors

(Application for copies should be addressed to National Fire Protection Association, 470 Atlantic Avenue, Boston MA 02210.)

(Nongovernment standards and other publications are normally available from the organizations which prepare or which distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 **Order of precedence.** In the event of a conflict between the text of this specification and the references cited herein (except for associated detail specifications, specification sheets, or MS standards), the text of this specification shall take precedence. Nothing in this specification, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 **System description.** The _____(a)_____ aircrew training device (ATD) shall be used to train _____(b)_____.

3.1.1 **Major components (subsystems).** The ATD shall consist of the following major components: __________.

3.1.2 **System interface requirements**

3.1.2.1 **Facility interface.** The ATD shall be physically and functionally compatible with the facility in which it is to be installed. As a minimum, the following areas shall be considered: __________.

3.1.2.1.1 **Primary electrical power.** A Government-furnished 4-wire, wye-connected, 3-phase, 60-Hertz, 120/208- and/or 277/480-volt electrical power source shall be provided and utilized by the ATD.

3.1.2.1.2 **Primary power grounding system.** The neutral bus of each power service shall be connected to earth potential outside the trainer at a single point only, which shall be at the primary (or derived) power grounding point as defined in accordance with Article 250 of the National Electrical Code.

3.1.2.2 **Subsystem interface.** The subsystems shall be physically and functionally compatible with each other and shall produce properly correlated cues during all modes of training. Detailed interface requirements are ________________.

3.2 **System performance requirements.** The performance of the ATD shall be as specified herein and in accordance with the design criteria. As used herein, "design criteria" is the entire body of data which describes all aspects of the aircraft. Simulator performance characteristics shall not be perceptibly different from characteristics of the real world aircraft. The aircraft equations of motion and critical aerodynamics functions shall be computed at a minimum iteration rate of ________________ iterations per second.

3.2.1 **Fidelity-critical areas.** The contractor shall provide realistic simulation of the following functional areas considered critical: ________________.

3.2.1.1 **System delays.** The simulator shall be designed to minimize temporal mismatches between simulator and actual aircraft events. The following requirement shall apply: ________________.

3.2.1.2 **Tolerances (general).** The simulator shall be designed to operate in accordance with the approved design criteria within the tolerances specified herein. These tolerances shall be applicable throughout the entire range of operation. Unless otherwise specified, percentage tolerances are with respect to the approved design criteria for the same conditions as established in the simulator. The tolerances specified herein shall be applicable at any place the values may be read--for example, at the computer, instructor station, cockpit, etc.

3.2.1.3 **Pressure, wind, temperature (PWT) simulation.** Pressure, wind, and temperature simulation shall provide a weather environment that appropriately affects aerodynamics, control systems characteristics, ground speed and ground track during simulated flight operations.

3.2.1.3.1 **PWT performance gaming area.** PWT shall automatically provide continuously variable wind speed and direction, atmospheric pressure, and outside air temperature along a flight path at constant true altitude, and variation of the same parameters with altitude changes by means of a preprogrammed model. These parameters shall be related according to the laws of physics. Wind speed shall be variable from ____(a)____, wind direction through 360 degrees and pressure altitude from ____(b)____, and outside air temperature from ____(c)____. Any amount of variation within the parameter ranges shall be possible between geographic points, a maximum of ____(d)____ apart. Additional data base requirements are in 3.10.

3.2.1.4 **Integrated combat environment simulation.** An integrated environment simulation shall be provided. It shall include correlated presentations of fixed Jammer, artillery, radar, and missile systems (JARMs) in the visual, radar and electronic combat simulations. It shall also include correlated cues for moving targets in these systems. All JARMs and moving targets shall be observable in the same position and exhibit the same dynamics. The cues observable by the aircrew shall be consistent. For example, an airborne interceptor shall be correctly displayed both in the visual and in the radar simulations with the electronic combat simulation indicating the interceptor's radar is in the correct mode based on its relative position. The control of moving targets shall be from a single source. The integrated environment simulation shall be an integral part of a preprogrammed training exercise.

3.2.1.4.1 **Moving targets.** Moving targets shall be available in any training exercise representing specific capabilities and radar cross sections of the following: ____(a)____. Moving targets shall be in motion and displayed simultaneously on appropriate aircraft systems. These moving targets shall consist of ____(b)____ airborne interceptors (AI), ____(c)____ hostile early warning aircraft and/or friendly aircraft, ____(d)____ naval ships, and ____(e)____ moving ground targets. Flight-paths, sea paths, or ground tracks shall be controlled via pre-programmed training exercises. Path simulation shall include the capability for the moving targets to respond to ownship maneuvers with realistic tactics. Tactics shall be editable as part of the preprogrammed training exercise. Manual control of moving targets shall be provided as follows: ____(f)____.

3.3 **Air vehicle subsystem**

3.3.1 **Flight performance.** The flight performance of the simulator shall be as specified herein and in accordance with the approved design criteria. As used herein, "design criteria" is the entire body of data which describes all aspects of the actual aircraft including flight test data. The contractor is responsible for obtaining all design criteria and reducing it as required for simulator use. All design criteria is subject to approval by the procuring agency.

3.3.1.1 **Performance characteristics.** The simulator's performance and handling qualities shall not be perceptibly different from the aircraft.

3.3.2 **Tolerances for air vehicle subsystem design.** Performance tolerances not covered by a specific tolerances herein shall be in accordance with approved design criteria with the following listed general tolerances applicable:

a. Total Mass ____(a)____

b. Moments of inertia ____(b)____

c. Angular acceleration ____(c)____

d. Linear accelerations ____(d)____

3.3.3 **Environmental effects.** Pressure, wind, and temperature (PWT) simulation shall be provided to allow a simulation of PWT effects on the aircraft aerodynamic and static performance. A standard, hot and cold atmosphere (IAW MIL-STD-210) shall be modeled from 0 to ________ ft. Means shall be provided at the instructor/operator console to vary sea level ambient temperature and sea level barometric pressure.

3.3.3.1 **Ground/cruise winds.** The instructor/operator shall be able to select ground winds from ground level to ____(a)____ feet and cruise winds from ____(a)____ feet to ____(b)____ feet. Ground winds shall be selectable from ____(c)____ knots with ____(d)____-knot resolution and from ____(e)____ degrees with ____(f)____-degree resolution. Cruise winds shall be selectable in direction from ____(g)____ degrees with ____(h)____ degree resolution and magnitude from ____(i)____ knots with ____(j)____-knot resolution. All transitions from one wind condition to another shall be smooth and linear without any perceptible discontinuities.

3.3.3.2 **Turbulence/gusts.** The instructor/operator shall be able to select random turbulence and gusts. Turbulence shall be selectable in levels from ____(a)____. Gusts shall be selectable from ____(b)____ knots in ____(c)____-knot increments. The type of turbulence model and the gust signature shall be determined at PDR.

3.3.3.3 **Airframe icing conditions.** Airframe ice accumulation and sublimations shall be simulated and produce the appropriate effects on the aerodynamic characteristics of the simulator. In addition, pitot tube, total temperature probe and engine icing shall also be simulated. Student activation of aircraft anti-icing controls shall have the appropriate effects on simulator performance. The instructor/operation station shall have means for selecting variable icing conditions from light to heavy.

3.3.4 **Aural simulation.** Sounds which are perceptible in the aircraft crew compartments during all phases of flight and ground operations shall be simulated with respect to approximate location, frequency, and amplitude. These sounds shall at least include the following: ________________.

3.3.4.1 **Ambient noise.** Ambient noise from simulator systems, such as the hydraulic system, motion system, motors, etc. shall not be audible to the crew when the aural simulation equipment is in normal operation.

3.3.5 **Crash.** Indications of crash shall be provided and shall consist of visual and/or aural indications. When a crash occurs, the simulator shall freeze (i.e., all indicators shall remain fixed) and remain frozen until reset. Means shall be provided to quickly reset from a crash condition.

3.3.5.1 **Crash effects.** Crash effects shall occur in accordance with the design criteria and shall be the result of the following conditions: ________________.

3.3.5.2 **Crash override.** A crash override capability shall be provided for the instructor to override the effects of crash before they occur and allow the simulation to continue.

3.3.6 **Auto-trim.** An automatic trim feature shall be provided to null all simulator angular accelerations and rates as a consequence of freeze, reset, or reinitialization. Flight controls shall be driven automatically, smoothly, and safely to correspond to the new trim conditions.

3.3.7 **Aircraft systems.** Unless otherwise specified herein, the simulator shall include a complete and automatic simulation of all aircraft systems to include normal degraded and emergency operation. Characteristics of system components such as motors, valves, regulators, etc, shall be included to produce the correct static and dynamic system performance. System transients shall be simulated in accordance with the approved design criteria. The simulator shall include the following aircraft systems: ________________.

3.3.7.1 **Flight control system.** The simulator flight control system shall operate as in the aircraft and include all primary, secondary, and automatic flight controls and the stability augmentation system (SAS). Appearance, displacement, and "feel" of the simulated flight controls shall be the same as in the actual aircraft. Operation of the controls shall result in simulated deflection of the appropriate control surfaces creating proper responses and instrument indications. Simulated instrument, visual, and motion indications shall be correct in magnitude, rate of change, and direction of movement. The "feel" of the simulated control system shall accurately duplicate the feel of the aircraft during all flight conditions with and without SAS engaged.

3.3.7.2 **Propulsion system.** The engines shall be simulated for all modes of operation throughout all performance flight regimes as defined by the approved design criteria and within the tolerances provided in Annex A of FAA Regulation 120-40. The engine modes of operation shall include operations with all bleed and horsepower extraction configurations. The effects of outside air temperature, altitude, mach, angle of attack, and sideslip angle shall be simulated to meet the performance in the approved design criteria. The engines shall be simulated to perform as operational engines throughout all performance flight regimes. The effects of properly applied stall and surge recovery procedures shall be simulated. The engine systems to be simulated shall include, but not be limited to: ________________.

3.3.7.3 **Starting system.** The starting system shall be simulated in accordance with the approved design criteria. Appropriately marked starter switches shall provide correct functional operation. It shall be necessary to follow the correct starting procedures for ground and airstarts before engine operation is indicated. Airstarting characteristics shall be correctly affected by airspeed, altitude, and outside air temperatures in accordance with the approved design criteria. Incorrect procedures shall result in appropriate engine system reactions, e.g., failure to start, fire, overheat, etc.

3.3.7.4 **Ignition system.** The ignition system shall be simulated in accordance with the approved design criteria. The ignition switches shall provide correct functional operation when correct ignition procedures are followed.

3.3.7.5 **Electrical system.** The aircraft electrical power supply system shall be simulated in accordance with the approved design criteria, unless otherwise specified herein.

3.3.7.6 **Fuel system.** Normal and emergency operation of the fuel system shall be simulated in accordance with the approved design criteria. All switches, knobs, handles, instruments, indicators, and lights associated with the fuel system, in normal and emergency operation, shall be provided and shall duplicate the actual aircraft in function, location, and appearance. Fuel tank capacity (usable and unusable fuel), transfer, flow rates, and boost pump operation shall be simulated.

3.3.7.7 **Hydraulic system.** The full functional capability of the hydraulic system shall be modelled. The effects of simultaneous demands from flight control surfaces and utilities shall be included. Normal and emergency operating modes of the hydraulic system (including single and dual engine operation) shall be modeled along with their effects on applicable aircraft systems.

3.3.7.8 **Cockpit air conditioning.** The cockpit air conditioning system shall be a replica of the aircraft system and include all outlets, controls, switches, panels, and instruments. Means shall be provided to maintain the temperature within the simulator cockpit between ________________ °F under continuous operating conditions. Sufficient ventilation shall be provided to all cockpit equipments to prevent hot spots or local overheating.

3.3.7.9 Oxygen system. The simulated oxygen system shall duplicate in function and appearance all aspects of the aircraft oxygen system including both normal and emergency operation. However, breathing air which is pure, dry, and free of oil shall be used in lieu of oxygen. It shall be possible to use the standard pilot oxygen mask without danger of contamination. The capability to sample breathing air shall be provided.

3.3.7.10 Pilot ejection system. Performance of proper pilot ejection procedures shall cause an appropriate aural cue and the simulator to enter the freeze mode until reset.

3.3.7.11 Engine fire and overheat detection/suppression system. The fire warning and overheat detection/suppression system shall be simulated and shall function in accordance with the approved design criteria. All lights, knobs, and switches associated with the system shall be provided and shall function as in the aircraft.

3.3.7.12 Lighting. The aircraft cockpit lighting system shall be simulated and shall function in accordance with the approved design criteria. Light levels, lenses, covers, controls and utility lights shall be provided as in the actual aircraft.

3.3.7.13 Personal equipment. Equipment such as the oxygen mask and flight helmet shall not be provided but provisions shall be made for connection of the crew's personal equipment in accordance with the approved design criteria. Connections for the crew's communciation equipment shall be provided and shall operate through the simulated communciation equipment. Storage space shall be provided as in the aircraft.

3.4 Computational subsystem. The ATD shall include a computational subsystem for operation, support, and maintenance of all major subsystems defined herein. It shall consist of all digital processing equipment, interface hardware, peripheral equipment, other associated computer equipment, and computer software (including the computer programs/data portion of firmware) to activate and support the ATD. Other subsystems such as visual, radar, and motion may include computers, embedded micro-processors, and computer software; in which case the computational subsystem requirements shall apply to the other subsystems to the extent specified in those subsystem requirements.

3.4.1 Computational subsystem performance characteristics. Each computer configuration in the trainer computational subsystem shall satisfy the performance requirements and possess the characteristics specified herein.

3.4.1.1 Interrupt provisions. Each computer configuration in the computational subsystem shall include a priority interrupt system to support the real-time, event-driven nature of the training device. This system shall (1) provide a capability to distinguish between and identify the sources of simultaneous hardware generated interrupts, queuing them for service depending on their priorities, and (2) allow computer program generated interrupts (for example, supervisor calls). An interrupt (hardware or computer program generated) shall cause the execution of an interrupt service routine unique to the device or function to which the interrupt pertains.

3.4.1.2 Interval timing provisions. Each computer configuration in the computational subsystem shall include at least one programmable interval timer accessible to each processing unit in the configuration. The interval timers shall be capable of generating both periodic (repetitive) and one-shot (single occurance) interrupts. Each interval timer shall be settable under program control, readable under program control, and shall provide interrupts to its processing unit with a resolution of at least ________________.

3.4.1.3 **Time function provisions.** The computational subsystem shall include a real-world time function to support timing requirements. The time function shall (1) be accessible to all processing units in the computational subsystem, (2) include julian date and time of day, and (3) have a resolution of at least ________________. If multiple time functions are provided, they shall be synchronized so all reflect the same value.

3.4.1.4 **Training system ready provision.** The computational subsystem shall provide the capability to load all real-time and support software required to initiate a training mission. This process shall be automated with minimum inputs required from a single on-line terminal. The total time to complete this provision shall be less than __________ minutes.

3.4.1.5 **Power failure provisions.** Each computer configuration shall include the capability for the orderly shutdown of the computational subsystem in the event of trainer power loss, reduction, or interruption. This capability shall be designed to prevent damage to the computational subsystem in the event of a power failure, surge, or reduction.

3.4.2 **Computational subsystem hardware.** Hardware shall be selected for the ATD which shall be capable of processing all computer software and data in all modes of operation. All digital processing equipment shall be architecturally identical or of the same computer vendor's series number (i.e., upward compatible). Computer vendor hardware shall not be modified.

3.4.2.1 **Computer/multiprocessor/multicomputer system.** Any computational subsystem hardware used to meet the requirements specified herein shall also meet the following requirements:

a. Shall buffer data and instructions for communicating and downloading between processors, random access memory (RAM), and mass storage equipment.

b. Each computer configuration (mini or micro) shall be capable of being loaded, initialized, and reinitialized independent of all other computer configurations so that in the event of a software failure of that computer configuration and the associated computer programs/data, the entire computational complex will not require reinitialization resulting in the loss of the training mission.

3.4.2.2 **Peripheral equipment.** Peripheral equipment shall be provided as specified in the following paragraphs and functional subsystem sections (as required) of this specification. All peripheral equipment shall be taken into account (i.e., I/O requirements shall be established) for the verification of required spare capacities (spare I/O capacity, spare time). Peripheral equipment not explicitly required by this specification but required to operate or support the trainer shall be taken into account for the verification of required spare capacities.

3.4.2.3 **Mass storage equipment.** Mass storage equipment shall be provided as specified in the following subparagraphs. The capability shall be provided to copy between all units of mass storage. The mass storage equipment shall be compatible with, and shareable between, the computer configurations in the computational subsystem which require access to mass storage devices.

3.4.2.3.1 **Primary mass storage.** Mass storage equipment shall be provided and used for storing and loading the operational programs and for on-line, real-time, and non-real-time data access. The type, size, and complexity of the equipment shall be a function of the computational subsystem design, operational load size, and the total system requirements for on-line, real-time, and non-real-time information flow and timing.

3.4.2.3.2 **Secondary mass storage.** Mass storage equipment shall provide for the installation of software changes sent from the trainer support activities or computer vendors.

3.4.2.4 **Operator/support interface equipment.** Operator/support interface equipment shall be provided that allows flexible control and support of the computational subsystem.

3.4.2.4.1 **Operator terminals.** Operator terminals(s) shall be provided to facilitate operator interaction with the computational subsystem. The operator terminals(s) shall be the primary communication device(s) for the control of the computational subsystem. The operator terminals(s) shall satisfy the following requirements: ________________.

3.4.2.4.2 **Support terminals.** ________________ support terminals shall be provided to facilitate interface with all trainer support functions requiring the use of computational subsystem resources.

3.4.2.4.3 **Hardcopy equipment.** Equipment shall be provided to produce hardcopy output of all data which is displayable on any peripheral display equipment controlled by the computational subsystem. That is, if a graphics terminal is included in the deliverable peripheral equipment, then a graphics hardcopy capability shall be provided. The hardcopy equipment shall accommodate hardcopy throughput requirements (taking into account the number of functions which may require hardcopy capability concurrently). Non-standard hardcopy media such as thermal paper or photo-sensitized paper is not acceptable. The hardcopy equipment, interface, and computer program(s) driving the equipment shall produce hardcopy output during real-time and shall not introduce any perceptible delays in the operation of any other equipment, subsystems, subsystem features, or functions of the trainer.

3.4.2.4.4 **Master operations console.** A master operations terminal shall be provided to facilitate a single location for system loading, initialization, and real time control.

3.4.2.5 **Additional peripheral equipment.** Any additional peripheral equipment necessary to operate or support the trainer shall be provided. Peripheral equipment not required explicitly by this specification but provided and required to operate or support the trainer shall also be taken into account for the verification of required spare capacities.

3.4.2.6 **Computational subsystem spare capacity and expansion capability.** Each computer configuration in the computational subsystem hardware shall provide spare capacities as specified in the following subparagraphs. The capability shall be provided to verify the spare capacities specified. In addition, the computational subsystem shall be expandable in a fashion that does not require existing equipment to be replaced.

3.4.2.6.1 **Spare processing time.** The computational subsystem shall include a minimum of percent spare processing time. The spare processing time requirement shall apply separately to each processing unit (that is, CPU, IPU, and APU) in each computer configuration.

3.4.2.6.2 **Spare memory or memory expansion capability.** ________________ percent usable spare memory and ________________ memory expansion capability shall be provided. This requirement shall apply separately to each type of memory (static, dynamic, etc) in each computer configuration, and also to both common and private memory.

3.4.2.6.3 **Input/output expansion.** The total number of I/O channels in each computer configuration shall be increasible by ________________ percent. The available information transfer capacity shall be increasable by the same percentage without degrading the performance of the trainer. However, the spare I/O channels must be evenly distributed across all computer configurations and I/O channel types.

3.4.2.6.4 **Interface Hardware spare capacity.** ____(a)____ percent of each type of interface hardware ____(b)____ shall be provided as spare. This spare interface hardware shall be usable without degrading the performance of the trainer (i.e., the computational subsystem shall be capable of driving both the used and spare interface hardware at their fully loaded capacities). The spare capacity shall be evenly distributed across each interface element in the computational subsystem (i.e., the spare interface hardware shall be accessible to any computer configuration in the computational subsystem).

3.4.2.6.5 **Primary mass storage spare and growth.** Each unit of primary mass storage equipment shall have an on-line, spare storage capacity that is at least ____(a)____ percent of its total capacity. Also, the on-line storage capacity provided for primary mass storage shall be increasable by ____(b)____ percent (without requiring further change to the computational subsystem).

3.4.3 **Computational subsystem computer software.** Computer software shall be provided which supports all modes of trainer operation, including training, student evaluation, support, and maintenance and test. These programs shall perform all real-time computations and input/output functions at rates sufficient to satisfy all requirements in this specification. A standard computer vendor operating system shall be provided and used in each digital computer in the computational subsystem during all modes of trainer operation. The operating system (OS) configuration used while training is in progress (i.e., executing real-time software) shall provide for the concurrent execution of background software. The entire collection of software called for in this specification shall be considered a part of the computer program system (CPS).

3.4.3.1 **Programming language.** The computer programs shall be written in the programming language. The compiler used shall support the full language, not a subset. The particular constructs used shall be appropriate to the function being coded.

3.4.3.2 **CPS organization and preparation.** The CPS shall be organized into computer software divisions to provide insight to the development and configuration management of the CPS. There shall be a computer software division for each major component subsystem. Each division shall contain those computer software components (CSCs), computer software units (CSUs), and computer data files (CDFs) unique to its major component subsystem. Additional divisions (as necessary) shall be organized for those CSCs, CSUs, and CDFs which are common to more than one major component subsystem. Each major component subsystem division shall include subsystem support computer programs and maintenance and test computer programs in addition to the programs necessary to fulfill simulation requirements. The CPS shall ________. Any programming language features and structured programming techniques that are used shall not preclude normal updates to the current configuration of computer vendor products as they are released.

3.4.3.3 **Supervisor/executive software.** Computer software shall be provided which shall maintain and direct the problem flow and establish priority controls over all computation. The highest level of abstraction shall consist of one or more supervisor/executive routines which shall control the execution of tasks. Tasks shall be composed of functionally related CSCs. CSCs shall be composed of simple, independent CSUs and CDFs which, when grouped together, complete functionally identifiable parts of the trainer CPS. The CSUs and CDFs shall be at the lowest level in the hierarchy. Each CSU shall consist of a unit of computer program code which shall be independently compiled and/or assembled. These programs shall provide all functions necessary to control any multiple iteration rate task structure and shall provide synchronization such that spare processing time can be measured.

3.4.3.4 **Debug computer software.** Computer software shall be provided to assist maintenance personnel in debugging computer programs and testing computational subsystem hardware. These programs shall operate in real-time during normal trainer operation. User interaction with these programs shall occur through a support terminal. These programs shall satisfy the following requirements: ________________. Commercially available software shall be used for this requirement if it satisfies all of the requirements above.

3.4.3.5 **Mass storage copy/comparator software.** Software shall be provided which satisfies the following functional requirements between all mass storage units, regardless of hardware type, in both the primary and secondary mass storage systems: ________________ These programs shall be operable through an operator or support terminal and shall allow the error output to be optionally directed to hardcopy. Commercially available software shall be used for this requirement if it satisfies all of the above requirements.

3.4.3.6 **Computer equipment diagnostic computer software.** A complete set of diagnostic computer software shall be provided to isolate equipment failures in the computational subsystem. Except for the portions of the test that check whether or not inputs can be received from, and outputs transmitted to, the equipment in question, all diagnostics shall be fully automatic. This means that once the user has loaded the diagnostic and set-up initial conditions, the program will automatically generate error indications (if any) on the terminal and hardcopy device. These programs shall be capable of automatic execution as a total package and as individual diagnostic checks. The diagnostics shall check each computer configuration and its options, and all memory units, peripheral units, and input/output units. Programs shall also be included for computer equipment embedded in and dedicated to subsystem processing or any other special processors as defined herein. Commercially available software shall be used for these requirements if it satisfies all of the above requirements.

3.4.3.7 **Interface hardware diagnostic computer software.** Computer software shall be provided to perform functional checkout of all trainer interface hardware controlled by the computational subsystem at performance rates and with test values characteristic of real-time operation. This shall include the checkout of instructional subsystem interfaces, I/O controllers, multiplexers, demultiplexers, signal conversion equipment, special interface equipment, and any other interface hardware that is functionally testable with computer software. Trainer equipment normally driven by this interface hardware during real-time operation shall be automatically disconnected during the performance of these tests when necessary to prevent equipment damage. All disconnection and reconnection shall be accomplished under computer control. The programs shall perform automatic range checking of the user inputs to prevent equipment damage caused by out-of-range values.The programs shall also perform the tests and meet the requirements specified in the following subparagraphs for the specified types of interface hardware. Testing shall be performed in a closed-loop fashion. Upon detecting a malfunction, the programs shall automatically indicate the failing hardware on the terminal and in hardcopy. Commercially available software shall be used for the following requirements if it satisfies all of the requirements.

3.4.3.7.1 **Discrete input and output diagnostics.** The interface hardware diagnostic computer software shall check the proper functioning of all the discrete input and output channels, including spares, in a closed-loop fashion.

3.4.3.7.2 **Analog input and output diagnostics.** The interface hardware diagnostic computer software shall exercise all of the analog interface hardware through its full range of operation. This shall be accomplished in a closed-loop fashion. The tests shall be designed so that accuracy criteria have defaults or can be overridden by the user. Tests shall include a dynamic test which enables the user to specify (on the console) the amplitude of a test signal to a specified channel.

3.4.3.8 **Trainer equipment test computer software.** Computer software shall be provided to check the proper functioning of all remaining equipment in the trainer which is driven by the computational subsystem that cannot be tested in a closed-loop fashion.

3.4.3.9 **Calibration test computer software.** Computer software shall be provided to enable all instruments and controls driven by the computational subsystem to be (1) calibrated and (2) tested to verify calibration. The programs shall allow both static and dynamic test signals to be applied to each instrument (as appropriate) to verify the instrument's accuracy, dynamic range, and general ability to model the performance of its real-world counterpart (e.g., lack of perceptible stepping). Values and destinations of test signals shall be by operator input.

3.4.3.10 **Operational readiness computer software.** Computer software and procedures shall be provided to verify that the trainer is operationally ready for crew training. These programs and procedures shall test the operational readiness of all major component subsystem equipment which operates under computer control. The programs shall generate outputs to all instruments, controls, lights, and equipment whose operation can be verified with a visual or aural check. The sequence of outputs shall be cyclic with provisions to stop the sequence at any point. These programs are not intended as calibration programs but rather as quick system operational checks and are normally run on a daily basis before the start of the day's training. The time required to complete the operational readiness procedures shall not exceed ________________.

3.4.3.11 **Spare capacity verification computer software.** Computer software to verify the specified spare capacities (3.4.2.5) shall be provided. Optional hardcopy output shall be selectable when exercising these programs.

3.4.3.11.1 **Spare processing time verification computer software.** Computer software shall be provided and used to measure the actual frame and cycle time durations (execution times) on each computer configuration in the computational subsystem during the execution of the trainer operational computer programs. These programs shall be a permanent part of the real-time trainer operation. Control of and interface with these programs shall be through a support terminal. The output to be computed and displayed shall include: ________________.

3.4.3.11.2 **Spare memory/on-line primary mass storage verification computer software.** Computer software shall be provided to verify the spare capacities specified for memory (3.4.2.5.2) and on-line primary mass storage (3.4.2.5.5). These programs shall provide the data from which calculations will be made to verify compliance. The spare memory data shall be obtained from the trainer operational computer program configuration which produces the maximum memory utilization. Computer vendor operating system built-in functions or utilities may be used if all requirements are satisfied.

3.5 **Instructional subsystem.** An instructional subsystem shall be provided to fulfill the mission training objectives and shall be configured to permit an effective man/machine interface. The instructional subsystem shall provide the instructor with the capability to instruct the student and control, monitor, and evaluate the training exercise. The instructional subsystem shall serve as the primary control center for the simulator. The instructional subsystem shall be designed for ____(a)____ instructors and for an operator/cockpit ratio of ____(b)____. The location of the instructor/operator station shall be ____(c)____. Instructional computational resources shall meet all requirements in 3.4 except ____(d)____.

3.5.1 **Functional subsystem configuration.** The instructional subsystem design shall comply with the principles and criteria of ________________. This shall result in a convenient work area that allows the instructor and/or operator to perform their tasks comfortably and effectively. The design shall also enhance operation, interpretation and sequences of actions. Minimal time and effort shall be required of the instructor to initialize and control the simulator training sessions. The information and selection of options necessary to provide an effective man/machine interface shall be available to the user at each step of the training exercise.

3.5.2 **Training exercise control.** The instructor shall be provided with a software design that is easy to manipulate, presents information in easily used formats, and facilitates problem control. As an enhancement to instructor efficiency, ____(a)____ preprogrammed mission training exercises shall be provided following the establishment of the training requirements. The preprogrammed training exercises shall automatically control the sequence of events within the training session and shall be tailored to student training objectives to facilitate practice of particular missions and procedures. The programmed training exercises shall include provisions for initial conditions and ____(b)____ programmed malfunctions, the combat environment and other required data bases. The time and number of actions required by the operator to select, alter, and enter data off-line shall be minimized and shall require no programming skills. The simulator shall also include all hardware and software necessary for Air Force support personnel to accomplish major edits to the preprogrammed training exercises and to create new training exercises. User-friendly software shall be incorporated to accomplish this task. Software design and user support features shall be consistent with MIL-STD-1801, "User/Computer Interface". Manual exercise control shall provide for on-line editing of initial conditions, preprogrammed malfunctions, and the combat environment. On-line software insertion shall not exceed ____(c)____ minutes for a complete set of initial conditions, a complete set of preprogrammed malfunctions, and minor changes to the combat environment.

3.5.2.1 **Manual instructor controls.** To aid instruction, the following features shall be provided: ____(a)____. Response to control inputs shall occur within ____(b)____ seconds.

3.5.2.2 **Self instruction.** A self-paced and self-administered program of instruction covering the capabilities and use of the flight simulator and support features shall be provided in the form of a "help" function and/or in the form of the following modes of instruction:

a. ________________.

b. ________________.

c. ________________.

Response to instructor or student inputs shall occur within (a) seconds.

3.5.3 **Data entry devices.** Data entry devices including ____(a)____ shall be incorporated in the instructor station design on the basis of their potential to support the instructional training objectives. Data entry devices and their respective controls shall conform to ____(b)____. The number of shifts among various methods of data entry shall be minimized. Responses to data entries and generation of associated displays shall occur within ____(c)____ seconds.

3.5.4 **Display devices.** The following display devices shall have the capability to provide pertinent information to the instructor and be capable of monitoring selected events of the training exercise: ____(a)____. Glare shall be minimized. Graphics display devices shall be state-of-the-art. Minimum acceptable resolution for an instructor station shall be 512 by 512 pixels. Interactive control/display relationships shall be explicit, straightforward, and conform to ____(b)____. Display control options shall be provided to adjust display brightness, contrast, and focus.

3.5.4.1 **Display format.** An easy-to-read, uncluttered, standardized format shall be used. The presentation of information shall be consistent with the limitations of human perception and memory in order to minimize user interpretive effort and alleviate confusion. The display format and content coding shall conform to the following: ________.

3.5.5 **Interphone communication system.** An interphone system shall be provided to permit communication among the student, instructor, and the operator. The system design shall permit selective monitoring and transmission over any of the simulated radios and include the following equipment: ________. In addition, an independent hard-wired channel shall be provided to permit emergency communication between personnel within the cockpit enclosure and anyone in the immediate area outside the cockpit. (See 3.12.10.7.)

3.6 **Motion simulator subsystem.** Motion simulation devices shall display task-critical motion and force information to the ____(a)____ and shall include ____(b)____.

3.6.1 **Motion system components.** The major components to be provided are:

a. Motion system with capability in the following degrees-of-freedom: ________.

b. Operating and maintenance controls and displays for the motion and control loading systems.

c. Personnel access device.

3.6.2 **Motion system performance characteristics.** A ________ motion system shall be provided. Within its performance envelope, the motion system shall provide cues to the simulator crew members which correspond to those they would perceive in the actual aircraft under the environmental and mission conditions being simulated.

3.6.2.1 **Simulated motions.** The motion system shall at all times perform smoothly and without hunting. The motion system movement shall be determined by computer computations based on the six degrees of aircraft freedom. The motion system computations shall be executed at iteration rates sufficiently high to ensure no noticeable discrepancy exists between the time the respective simulator and aircraft motion cues are experienced in response to the same ________ Sequencing of the motion computations relative to other programs and relative to the processing of analog-to-digital converters shall minimize the delay from a cockpit control input to the display of the corresponding motion cue. The frequency of occurence of new cues shall be maximized; during position washout, new cues shall be accepted in any direction constrained only by the position and velocity limits of the system and the threshold of perception of the crew member(s). Spurious motion and washout shall at no time be noticeable to the crew member(s).

3.6.2.1.1 **Motion activity.** As a minimum, the following motions shall be simulated: ________.

3.6.2.2 **Worst-case maneuvers.** The motion system shall smoothly and correctly perform the worst-case maneuvers the simulated vehicle and its pilot shall demand, i.e., those maneuvers which cause demands on the power supply sub-system greater than the active components can supply (such as a rapid series of demanding flight maneuvers).

3.6.2.3 **Payload weight.** Performance requirements shall be met at normal operating weight, computed as ______(a)______ station, plus ______(b)______, plus all on board personnel, plus ______(c)______ pounds for growth.

3.6.2.4 **Step response.** The response of the motion platform to a 0.2-Hz square wave with an amplitude of ______(a)______ shall be initiated in less than ______(b)______ seconds following a change in state of the square wave.

3.6.2.5 **Excursion and velocities.** The motion system shall perform about the neutral operating point in accordance with the criteria shown in table I and table II. Each degree-of-freedom is defined individually with respect to a non-moving coordinate system centered at the centroid of the platform in its neutral position. The requirements of tables I and II are nonsimultaneous requirements which are to be met without exceeding the normal operational stroke of any actuator or engaging any distinct actuator over-travel device. The motion system must satisfy each of the requirements, using only one degree of freedom at a time, with only that amount of actuator travel which is useable in a normal training configuration. However, the excursion envelope about the neutral operating position shall allow simultaneous movements to the limits specified in table III.

TABLE I. Motion system excursion.

Degree-of-Freedom	Excursion Requirements
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches

It is not required that heave and pitch excursion capabilities be symmetric about the neutral operating position; however, the total excursion capability shall be maintained.

TABLE II. Motion system velocity.

Degree-of-Freedom	Velocity Requirements at the Neutral Operating Point
(a)	(b) inches per second
(a)	(b) inches per second
(a)	(b) inches per second
(a)	(b) inches per second
(a)	(b) inches per second
(a)	(b) inches per second

TABLE III. Motion system simultaneous excursion.

Degree-of-Freedom		Simultaneous Excursion Requirements	
(a)	±	(d)	inches
(a)	±	(d)	inches
(a)	±	(d)	inches
(a)	±	(d)	inches
(a)	±	(d)	inches
(a)	±	(d)	inches

3.6.2.6 **Specific force and rotational acceleration.** The motion system shall meet the minimum criteria given in table IV at the neutral operating point.

TABLE IV. Motion systems specific forces and rotational accelerations.

Degree-of-Freedom		Velocity Requirements at the Neutral Operating Point	
(a)	±	(b)	g
(a)	±	(b)	g
(a)	±	(b)	g
(a)	±	(b)	deg/sec/sec
(a)	±	(b)	deg/sec/sec
(a)	±	(b)	deg/sec/sec

3.6.2.7 **Frequency response.** The closed-loop response of the motion system in ____(a)____ degrees-of-freedom shall comply with the following criteria. The response shall be measured from the command input to the resulting platform response.

TABLE V. Motion system closed-loop response.

Frequency Range (hertz)	Maximum Phase Shaft (degrees)	Maximum Attenuation (decibels)
____(b)____ - ________	____(c)____	____(d)____
____(b)____ - ________	____(c)____	____(d)____
____(b)____ - ________	____(c)____	____(d)____
____(b)____ - ________	____(c)____	____(d)____

3.6.2.8 **Damping.** The response of the motion platform to a 0.2 Hertz square wave with an amplitude of ____(a)____ in ____(b)____ shall (without washout) exhibit no more than a ____(c)____ percent overshoot. There shall be no more than a single overshoot.

3.6.2.9 **Smoothness.** There shall be no spurious acceleration transients greater than ____(a)____ peak at the aircrew station with any or all of the actuators being driven with a sinusoidal input signal of ____(b)____ percent of the maximum voltage at a frequency of ____(c)____ Hertz.

3.6.2.10 **Stability.** For any static position or constant velocity, there shall be no instabilities in the motion simulator or its servomechanisms which impart load accelerations greater than ________ g peak.

3.6.2.11 **Static accuracy.** Static error between actual and commanded platform position shall be less than ________ percent of full scale.

3.6.2.12 **Crosstalk.** Movement coupled into non-driven servo actuators shall not exceed ____(a)____ percent of the driven actuator, when the driven actuator is driven at ____(b)____ percent of full scale at ____(c)____ Hertz.

3.6.3 Motion system design considerations

3.6.3.1 **Motion simulator power, control, and maintenance features.** The system shall be controlled ____(a)____ and powered ____(b)____. It shall consist of a self-contained, fully integrated system of ____(c)____.

3.6.3.1.1 **Power subsystem.** The ____(a)____ powered subsystem shall include the following items: ____(b)____.

3.6.3.1.2 **Power subsystem action.** The ____(a)____ powered motion system during normal operation shall not exhibit the following characteristics: ____(b)____.

3.6.3.1.3 **Power subsystem maintenance concept.** The ____(a)____ powered motion system shall incorporate adequate provisions for maintenance operations including ____(b)____.

3.6.3.1.4 **Peak energy storage devices.** The following equipment shall be provided to protect the ____(a)____ powered motion system during worst-case maneuvers: ____(b)____.

3.6.3.1.5 **Power subsystem fire safety/power medium temperature stabilizer.** The following item(s) shall be provided as a fire safety item to stabilize the characteristics of the power medium in the ____(a)____ powered motion system: ____(b)____.

3.6.3.1.6 **Power subsystem protection.** To provide protection for the ____(a)____ powered medium, the following items shall be included in the motion system: ____(b)____.

3.6.3.1.7 **Energy transfer medium and control.** The following items shall be included in the ____(a)____ powered motion system to provide a medium for energy transfer and control: ____(b)____.

3.6.3.1.8 **Energy potential safety devices.** The following safety devices shall be included in the ____(a)____ powered motion system to assure that it is maintained in a proper working order: ____(b)____.

3.6.3.1.9 **Maintenance access.** The motion system shall permit ease of access for maintenance duties by including the following items: ________.

3.6.3.1.10 **Personnel access.** A powered ____(a)____ shall be provided for personnel entry and exit onto the motion system. Safety interlocks shall be included to ensure that the access ____(b)____ is physically removed from the operating envelope of the motion system when it is engaged. The system shall incorporate provisions to prevent a physical collision between the access ____(c)____ and motion system and to prevent injury to personnel by movements of the access ____(d)____.

3.6.3.1.11 **Structural design criteria.** The design of all structural members shall incorporate acceptable design practices and shall provide for the safe and efficient use of the simulator by crew members, operating personnel, observers, and maintenance personnel. The rated load of the motion system is defined as that load or combination of forces which the moving platform must support or resist in a static condition. The design load of the motion system shall be based upon a load of not less than ____(a)____ times the rated load. Stress levels, under the static rated load condition, at any point in the structure shall be limited to a level that provides a factor of safety of ____(b)____ against permanent deformation. Where dynamic factors induce loads that exceed ____(c)____ times the rated load, then the stress levels at any point in the structure shall be limited to a level that provides a factor of safety of ____(d)____ against permanent deformation induced by dynamic loads.

3.6.3.1.12 **Acoustic noise--maintenance areas.** The contractor shall analyze the intensity and frequency spectrum of acoustic noise emanating from the motion system power subsystem. If the noise level requires ear protection devices, the contractor shall recommend such devices to the procuring agency. Noise data shall be provided to the procuring agency for use in design of soundproofing for the room housing noisy components.

3.6.3.2 **Motion simulator controls and indicators.** In addition to adhering to the principles of MIL-STD-1472, the control and indicator system shall comply with the following paragraphs.

3.6.3.2.1 **Instructor station.** Controls shall be provided at the instructor's station to engage or disengage the motion simulator and access system, if applicable (see 3.5).

3.6.3.2.2 **Crew station.** A momentary action type "motion consent" switch or other means shall be provided in the crew station to assure crew readiness for motion engagement. Engagement of the motion system from the instructor's station shall be possible only when the "consent" switch is simultaneously being actuated by the crew member.

3.6.3.2.3 **Maintenance and control features.** The following maintenance and control features shall be provided and located within view of the motion simulator: ______________.

3.6.3.2.4 **Energy medium controls.** Controls and indicators shall be provided and located adjacent to the energy source and shall incorporate the following capabilities: ______________.

3.6.4 **Structural interface with the facility.** The contractor shall provide a detailed design of the motion system support structure and design criteria for use in preparing the training facility site for installation. Reaction mass composition, tie-down means, and complete interface shall be included in the support design. The support structure shall be designed for installation in soil of ______________ bearing capacity.

3.6.5 **Motion system design safety.** Devices shall be provided to protect crew members, operating personnel, observers, and maintenance personnel from injury. These shall include ______________.

3.6.5.1 **Design safety factors.** All hydraulically powered motion systems components shall be pressure rated at least ______________ percent higher than the maximum working pressure of the system. Energy absorbing devices shall be provided to absorb the greatest kinetic energy the system can develop if runaway occurs.

3.6.5.2 **Rapid motion.** At no time shall either the motion system or the crew station controls move unexpectedly. "Freezing" or release from a simulator computer "freeze" condition shall not result in rapid motion system movement, even if crew station control movements have been made during the "freeze" state. Engaging the motion system shall result in a non-rapid low velocity transition from the settled position to the normal operating position in less than ____(a)____ seconds. Other computer-controlled changes in motion system position such as transition to initial conditions, automatic demonstration modes, etc, shall not be rapid. A rapid motion simulator movement shall be defined as any movement(s) which imparts an acceleration greater than ____(b)____ g to the crew members.

3.6.5.2.1 **Abrupt motion.** Disengagement of the motion system shall not result in abrupt motion system movement. Abrupt motion system movement shall not occur when power subsystem components are deactivated unexpectedly, nor if line power failure or fluctuation occurs. An abrupt system movement shall be defined as any movement which imparts an acceleration greater than ______________ g to the crew members.

3.6.5.3 **Motion limits.** Actuators shall be equipped with limit sensors (translational and rotational) to automatically disengage the motion simulator if actuator overtravel occurs.

3.6.5.4 **Settling of motion system.** When the motion system is shut down or disengaged, the platform shall return to a settled, level egress position. The platform shall not assume unusual attitudes or undergo unusual movements during descent to a settled position. A means shall be provided to automatically activate settling of the motion system when an electrical power failure occurs.

3.6.5.5 **Electrical interlocks.** The motion system shall be protected by automatic interlocks so that proper sequencing for power-up or power-down is assured and so that abnormal conditions inhibit the application of power to the motion platform. As a minimum, interlocks shall be provided on ________________. It shall not be possible to engage the motion system unless all interlocks are in a safe position; the motion system shall then be engaged when the proper controls are activated. The reverse sequence (control switch is activated, interlocks moved to safe position, motion system responds) shall not occur. If the interlock circuit is broken when the motion system is engaged, the motion system shall immediately disengage. Subsequent engagement of the system must adhere to normal control switch procedures.

3.6.5.6 **Emergency egress.** In the event of an emergency, it shall be possible to open the canopy (or cockpit door) from the inside and from the outside. The time required for the motion simulator to move to the egress position shall not exceed ________________ seconds.

3.6.5.7 **Warning signs.** Illuminated warning signs shall be provided at all entrances to the motion system or crew station areas. These signs shall provide warnings appropriate to the location of the entrance. Warning lights shall be provided as necessary to alert personnel that ________________.

3.6.5.8 **Safety barrier.** A safety barrier shall be provided and shall surround the motion system base to the degree necessary. Gates shall be provided as necessary for ________________. The design shall be adapted to the facility.

3.6.5.9 **Motion system failures.** Worst-case failures shall not impose more than _______(a)_______ g on the crew station. Special attention shall be paid to the cases of _______(b)_______. A design goal shall be to safely return the motion platform to the settled position subsequent to any failure.

3.6.6 **In-cockpit motion and force display requirements**

3.6.6.1 **In-cockpit motion display--major components.** The major components to be provided are: _______(a)_______.

3.6.6.2 **Vibration and buffet system.** A vibration and buffet system shall be provided to generate vibration/buffet inputs to the _______(a)_______ seat. The system shall be under software control and shall be designed to generate _______(b)_______ in accordance with the design criteria. The system shall also provide cues which represent _______(c)_______.

3.6.6.2.1 **Vibration and buffet system performance requirements.** The _______(a)_______ seats(s) shall be capable of vibration excursion up to ± _______(b)_______ parallel to the Z body axis of the simulated aircraft. The frequency spectrum between _______(c)_______ Hz shall be within _______(d)_______ percent of the approved data. The amplitude and frequency shall be continuously variable over the specified ranges and shall be controlled by the software to allow for non-linear response and ease of software modification. The system shall be designed to prevent application of specific forces in excess of 2-g units.

3.6.6.2.2 **Vibration and buffet system control.** _______(a)_______ shall be provided to turn the vibration system on and off at the _______(b)_______. Means shall be provided to allow the instructor/operator to readily control the amplitude profile of the system. An interlock shall be provided to require that the seat belt(s) be fastened before the system can operate.

3.6.6.3 **Anti-g suit system.** A simulated anti-g suit system shall provide the ____(a)____ with sustained g cues. The simulated anti-g suit system shall provide an anti-g pressure schedule representative of that in the aircraft with a pressure range from ____(b)____ to a maximum of ____(c)____ psi. Fail-safe means shall be provided to prevent pressurization above this specified maximum. The "pressure onset" (g-intercept at zero psi) shall be variable from at least ____(d)____ to ____(e)____ g's. The "slope(s)" of the pressure curve (psi/g) shall be adjustable from at least ____(f)____ to ____(g)____ psi/g. During a simulator "freeze" condition, the anti-g suit shall be pressurized to that level corresponding to the one-g state.

3.6.6.3.1 **Anti-g suit control.** The anti-g suit control system shall provide proportional control of the steady-state suit pressure as a function of simulated aircraft vertical acceleration. The constant of proportionality shall be within ____(a)____ percent of the specified "slope". Suit pressurization for the simulated g level less than or equal to the selected "pressure onset" value, shall not deviate from zero by more than ____(b)____ psi. "Pressure onset" and "slope" shall be selectable at the ____(c)____.

3.6.6.3.2 **Anti-g suit inflation/deflation rates.** The anti-g suit shall respond to a full range commanded step change in pressurization by reaching 63 percent of its final value within ____(a)____ seconds for inflation and ____(b)____ seconds for exhaust.

3.7 **Visual system.** A ____(a)____ visual system shall be provided to generate out-the-window visual scenes for ____(b)____. The visual system shall be capable of ____(c)____ operations within the ____(d)____ aircraft flight envelope. The visual system shall include a visual environment or data base, an image generator, a display system, and all other hardware and software necessary to provide the visual cues required to train ____(e)____, and maintain and control the visual system. These tasks are defined further in 3.7.1 and subparagraphs. The visual system shall be designed to process and display data bases which contain the information required to train the above listed tasks. The visual system shall provide sufficient field-of-view, image quality, and positional accuracy to train the above listed tasks. The system shall be capable of simulating various atmospheric and weather effects, and shall provide ____(f)____. Transport delay and unwanted visual artifacts shall not impair training for the above listed tasks.

3.7.1 **Training tasks and visual cues.** The visual system shall be designed to provide high fidelity simulation with appropriate scene content and visual cues to support training task requirements throughout the complete mission profile and within the full ________ flight envelope.

3.7.1.1 **Taxi, takeoff, and landing.** The visual system shall generate and display the visual cues required for taxi, takeoff, approach, landing, and other airfield and ramp operations. Real-world airfield models shall be provided for ____(a)____. The capability to include ____(b)____ relocatable generic airfields shall be provided. The generic airfields shall be located anywhere in the world with any desired runway heading and elevation. A minimum of ____(c)____ mile radius of the area surrounding the airfield shall be provided as part of the gaming area. This area shall provide the necessary terrain and cultural definition, including buildings and lights, to support the takeoff and landing tasks. The immediate airfield area shall provide the runways, taxiways, and ramp areas with appropriate surface markings, markers, signs, and lights; appropriate buildings including hangars, control towers, and other structures; other aircraft; and ground vehicles. Lights shall be simulated with their appropriate flashing and directional characteristics. In addition, a model for a companion ____(d)____ aircraft shall be provided for formation taxi and takeoff. The simulation of ownship landing and taxi light effects shall include ____(e)____.

3.7.1.2 **Aerial refueling.** The visual system shall provide the visual cues required to train the aerial refueling task. Rendezvous, approach, precontact, contact, operation within the refueling envelope, disconnect, and emergency maneuvers shall be simulated. The visual system shall accurately depict the ________________ tanker aircraft and moveable refueling boom, along with sky and clouds and receiver relative motion. The tanker, boom, and all other cues shall appear in the proper perspective and position. Curved surfaces and other appropriate detail on the tanker shall appear proper with respect to cockpit references as well as to each other. All tanker lights, including director lights, and tanker illumination effects shall be properly portrayed in accordance with range, visibility, and function. The boom shall automatically connect once the receiver aircraft has manuevered into and stabilized in the contact position, and shall maintain the connection as long as the receiver remains within the contact envelope, or until normal disconnect occurs. The capability shall be provided to allow the instructor to initiate an automated demonstration of boom envelope limits.

3.7.1.3 **Low level flight.** The visual system shall provide the required cues to train low level flight, and shall support descent to low level, low level flight ____(a)____, and withdrawal from low level. The purpose of the low level flight capability shall be ____(b)____. The terrain model to support low level flight shall correlate with ____(c)____. Cultural features to be portrayed include ____(d)____. Texture is required to provide the necessary altitude and velocity cues.

3.7.1.4 **Air-to-air combat.** The visual system shall provide the required cues to train the air-to-air combat task. These cues shall include ________________.

3.7.1.5 **Air-to-ground weapons delivery.** The visual system shall provide the required cues to train the air-to-ground weapons delivery task. These cues shall include ________________.

3.7.2 **Image generation.** The image generator shall process the visual environment data to generate the display scene for the appropriate viewpoint. The displayed scene shall be computed using the ownship position and attitude within the simulated environment. The result of this transformation shall be a video signal which is fed directly to the display system. The visual scenes created by the image generator shall have the characteristics discussed in the following subparagraphs.

3.7.2.1 **Scene elements.** The visual imagery produced by the image generator shall appear as recognizable real-world scenes. These scenes shall be constructed with the scene elements and characteristics discussed below.

3.7.2.1.1 **Edge/surface capacity.** The image generator shall be capable of computing ____(a)____ edges or ____(b)____ surfaces per frame. A potentially visible edge or surface is one which is within the field-of-view, faces the observer, and would normally be visible unless occulted by some other object.

3.7.2.1.2 **Lights--image generation.** The image generator shall be capable of generating a minimum of ____(a)____ lights per frame. These shall include ____(b)____. All lights shall vary in brightness as a function of range and visibility. The instructor shall have the capability to control ____(c)____.

3.7.2.1.3 **Surface shading.** Surface shading or color shall be computed as a function of object structure, illumination angle, range from the eyepoint, and visibility limitations. A minimum of ________________ shall be provided. The capability to selectively apply curved surface shading to simulate curved surfaces shall be provided to be used in the presentation of other aircraft, storage tanks, etc.

3.7.2.1.4 **Texture--image generation.** The image generator shall have the capability to display a minimum of ________________ texture patterns simultaneously to provide relative altitude and velocity cues. Texture capability shall be in addition to the edge/surface processing capacity specified herein. Texture patterns shall be assignable to any surface or feature in the visual environment. Texture shall remain stationary with respect to the surface, and shall maintain the proper perspective, occulting, and contrast/color relationships for the surface.

3.7.2.1.5 **Cultural features--image generation.** The image generator shall display appropriate culture features as necessary to train the tasks specified herein. There shall be no limitations in the display of cultural features other than the overall image generator edge/surface and light capacity as specified herein.

3.7.2.1.6 **Terrain--image generation.** The image generator shall display the appropriate terrain structure as defined in 3.7.3.1.4 and 3.7.3.2.1. There shall be no limitations in the display of terrain information other than the overall image generator edge/surface capacity specified herein.

3.7.2.1.7 **Moving models--image generation.** The image generator shall be able to portray a minimum of ________________ moving models simultaneously. The moving models shall be independently controllable and shall include any combination of surface or airborne moving models. The capability to select desired models from the moving model library and insert them into the training scenario shall be provided. Models shall be capable of being controlled by the instructor or following a predefined motion path. The motion path of surface moving models shall conform to the terrain and culture structure defined in the visual environment.

3.7.2.2 **Computed visual range.** The image generator shall have the ability to compute a visual scene from the eyepoint to a range of ________________ nautical miles, regardless of the effects of visibility limitations discussed in 3.7.2.3 and subparagraphs.

3.7.2.3 **Atmospheric simulation.** The image generator shall have the capability to provide the following simulated atmospheric conditions.

3.7.2.3.1 **Ambient light.** The image generator shall provide simulated ambient light levels for ________________, to be controllable by the instructor. Sun illumination angle shall be controllable, and the effects of sun angle shall be portrayed on all features in the visual scene.

3.7.2.3.2 **Haze/visibility.** The image generator shall simulate the effects of reduced visibility due to atmospheric conditions. Visibility attenuation shall be computed for all features in the visual scene for all visual tasks. Haze/visibility shall be controllable over a range of _______(a)_______ in _______(b)_______ increments.

3.7.2.3.3 **Clouds.** The image generator shall simulate clouds and overcast conditions. Textured cloud portrayal shall be used to enhance relative motion cues for aerial refueling. Cloud conditions shall include as a minimum clear, overcast/smooth, and overcast/rugged (scud). Cloud thickness shall be controllable in _______(a)_______ increments over the range of _______(b)_______. Cloud ceiling shall be controllable in _______(c)_______ foot increments over the range of _______(d)_______ and in _______(e)_______ increments over the range of _______(f)_______. The instructor shall be able to insert/delete scud cloud effects. The simulated horizon shall be portrayed when the aircraft position is above the defined cloud height.

3.7.2.3.4 **Horizon.** The horizon shall be simulated for all ambient light conditions. The day horizon shall be simulated to include atmospheric light dispersions. The night horizon shall consist of a band of illumination which decreases in intensity as it extends upward from the horizon. All features in the scene shall exhibit fading effects, as a function of range, toward a controllable color shade at the horizon.

3.7.2.3.5 **Thunderstorm/lightning.** The visual system shall simulate thunderstorm and lightning conditions. The simulation of the thunderstorm conditions shall include the effects of gradual visibility attenuation due to precipitation as a function of range to the storm and intensity of the storm. Lightning associated with the storm condition shall be simulated. The simulation of lightning conditions shall include lightning bolts, and rapid and random intensifying in the out-the-window visual scene at an occurrence rate dependent on storm intensity. Thunderstorm conditions shall include, as a minimum, light, medium, and heavy, with lightning on/off control for all conditions. On/off control of the thunderstorm condition shall be controllable by the instructor. All thunderstorm conditons shall be controllable by the instructor.

3.7.2.4 **Environment retrieval.** The image generator shall have the capability to retrieve and process the appropriate environment (gaming area) data to be used in creating the visual scene. The system shall retrieve and process that portion of the environment in the immediate vicinity of the ownship position, where immediate vicinity is defined to include all data within the computed visual range, as specified herein, in all directions from the eyepoint. As the ownship moves through the environment, new environment data shall be accessed and shall replace data which has moved out of the immediate vicinity of the viewpoint. This process shall not cause distracting visual effects in the visual scene. Image generator processing capacity shall not be wasted on features which are outside the field of view or face away from the viewpoint.

3.7.2.5 **Load management.** The image generator shall be designed to constantly monitor and control its own processing load so that a near-capacity load is maintained. The capability to gracefully degrade the simulated imagery to prevent and recover from overload conditions shall be provided. This shall be accomplished by temporarily reducing the processing load by eliminating scene detail in a structured and non-distracting manner, so that features of minimal importance to the current training task are eliminated or portrayed in lower levels of detail, and features of higher importance are preserved.

3.7.2.6 **Concentration of scene detail.** The image generator shall be designed such that it concentrates scene detail in the immediate vicinity of the viewpoint or where training requirements dictate. This shall be accomplished as appropriate to the training task without creating distracting visual effects. Transitions from one level of detail to another shall be gradual and shall exhibit no distracting effects.

3.7.2.7 **Dynamic priority/occulting.** The image generator shall eliminate features or parts of features that are occulted by other features in the line of sight. The proper occulting relationships shall be provided for static and moving features for all flight paths and viewing angles in the simulated environment.

3.7.2.8 **Anti-aliasing computation.** The image generator shall compute the contributions of scene edges/polygons to each displayed picture element (pixel) on a subelement basis to reduce quantization effects. A minimum of 4 X 4 (16) subpixels shall be computed for each pixel.

3.7.2.9 **Distracting visual effects.** The image generator shall be designed so as to minimize the occurrence of distracting visual effects. Distracting visual effects shall be limited to ____(a)____ occurrences per one hour training period, and shall have a maximum duration of ____(b)____ seconds. Distracting visual effects include but are not necessarily limited to breakup, dropout, streaking, flashing, noise, and/or discontinuities of any part of the visual image; staircasing, quantization, scintillation, and any other spatial aliasing effects; abrupt changes in image detail; apparent movement of objects in the scene due to detail transitions; repetitive or periodic motion of the visual scene not computed in the host simulator flight system; mach bands or lines separating different colors on curved shaded surfaces; and abrupt shifts in color, texture, or ambient brightness of a display window or subset.

3.7.2.10 **Transport delay.** Visual system transport delay shall be defined as the interval from the time that ownship position and attitude data are available at the input of the image generator until the time that the display of the first field of the new image computed from that information is complete. Transport delay shall not exceed ________ milliseconds during normal processing.

3.7.2.11 **Update rate.** The image generator shall compute a new scene from the visual environment using a new position and attitude update at least ________ times per second to assure a smooth dynamic response to all ownship and moving model manuevers.

3.7.2.12 **Dynamic response.** The image generator shall have the capability to provide imagery consistent with all velocities and accelerations within the performance envelope of the ________________ aircraft, for all normal and emergency manuevers. The image generator shall be capable of simulating the motion of other moving models with the proper translational and rotational rates. There shall be no visual system restrictions on the relative position and attitude between the ownship and any other static or moving object in the environment.

3.7.2.13 **Special effects.** The system shall simulate all special effects required to support the training tasks, including ________________.

3.7.2.14 **Simulator compatibility.** The image generator shall respond to all control commands from the host simulator, including initialization, repositioning, freeze, and ________________.

3.7.2.15 **Positional range and accuracy.** The image generator shall generate an image that is positioned within the following tolerances when presented on the cockpit displays. The tolerances are with respect to the inputs provided to the image generator. Simulated angular position shall be within ____(a)____ degrees. Simulated altitude shall be within ____(b)____ inches. Simulated horizontal position shall be within ____(c)____ inches. Moving model position shall be presented within ____(d)____ inches horizontally and ____(e)____ inches vertically. Moving model attitude shall be within ____(f)____ degrees. In addition, the data base coordinate system and image generator processing shall be designed to support world-wide flight.

3.7.2.16 **Crash detection and display.** The image generator shall detect collision of the ownship aircraft with ____(a)____. When a crash is detected, the image generator shall provide a crash indication to the air vehicle system. When the air vehicle system indicates a crash condition, the visual system shall rapidly ____(b)____.

3.7.3 **Visual environment.** A visual environment shall be developed and shall be processed by the image generator to produce the required real-time visual imagery. The visual environment shall be provided for ________________. The environment shall also include libraries of models to support the required training tasks.

3.7.3.1 **Visual data base libraries.** A set of libraries shall be provided to support data base generation and realtime display of the visual imagery. These libraries shall include specific models of important features, portrayed in multiple levels of detail where necessary. The following libraries shall be included.

3.7.3.1.1 **Moving model library.** This library shall contain models for ________________. The specific requirements for each of these models is defined as follows.

3.7.3.1.1.1 **Companion aircraft.** A model shall be provided to represent a companion ____(a)____ aircraft. Details to be portrayed shall include ____(b)____. Lights to be portrayed shall include ____(c)____

3.7.3.1.1.2 **Tanker aircraft.** A model shall be provided to portray the ____(a)____ tanker aircraft. Details to be portrayed shall include ____(b)____. Lights to be portrayed shall include ____(c)____.

3.7.3.1.2 **Mission model library.** This library shall be developed to support the portrayal of ____(a)____ to be used in a particular training mission or session. The features in this library may be static, or they may have associated dynamic effects, including missile launch, artillery fire, or portrayal of damage as a result of ownship attack. This library shall contain at least ____(b)____ models.

3.7.3.1.3 **General model library.** This library shall be developed to support the portrayal of required three dimensional features. Models shall be developed for features important to the training tasks and stored in the library for automated or manual insertion into the visual environment at proper or desired locations.

3.7.3.1.4 **Airfield model library.** Models shall be provided for ____(a)____ ____(b)____ airfields. These airfields shall be placed ____(c)____. Each airfield model shall include a high-fidelity portrayal of the immediate airfield area, along with the surrounding terrain and culture within a ____(d)____ mile radius. Seasonal effects shall be modelled, including ____(e)____. The airfields shall contain the following details, as appropriate.

3.7.3.1.4.1 **Airfield area structures and markings.** The airfield shall contain detailed models for the runways, taxiways, and ramps, including texture and surface markings. Airbase buildings, including control tower and hangers, shall be provided. The area surrounding the airfield shall contain appropriate terrain and landmarks, including towns, roads, bridges, trees, lakes, rivers, etc. Texture shall be employed in the airfield areas and especially along the approach path to provide the required motion cues. Surface markings shall be provided, including ________.

3.7.3.1.4.2 **Airfield lights.** Airfield lights shall be modelled as appropriate, and shall include special purpose lights for the rotating beacon, VASI lights, and approach strobe lights. Lighting effects shall be provided for runway remaining markers. Runway definition lights shall include ________. In addition, general cultural lighting shall be provided in the area surrounding the airfield for night cues.

3.7.3.2 **Low-altitude data base.** The low altitude data base shall be developed for ____(a)____ using ____(b)____.

3.7.3.2.1 **Terrain model.** The terrain shall be modelled in multiple levels of detail as appropriate to the training task. The terrain model shall be designed and constructed such that no distracting visual effects occur in the real-time imagery at the level-of-detail transition boundaries. There shall be no perceptible regular or artificial visible effects due to the structure of the terrain model. As a goal, the terrain model shall be adaptable to the terrain roughness, such that edge/polygon density is higher in areas of rough terrain and lower in areas of flat terrain.

3.7.3.2.2 **Culture features (data base).** The data base shall portray all culture features required to support the training tasks. Culture features shall be portrayed as two-dimensional or as three-dimensional objects in the data base. ____(a)____ shall be portrayed in either two or three dimensions. ____(b)____ shall be portrayed in three dimensions up to a density of at least ____(c)____ features per square nautical miles. Culture features shall be modelled in multiple levels of detail to allow for a recognizable presentation and display at appropriate ranges without overloading the image generator.

3.7.3.2.3 **Texture (data base).** All terrain surfaces shall be portrayed as textured in the low altitude data base. In addition, all mission-relevant culture features shall be portrayed as textured, including ________.

3.7.3.2.4 **Lights (data base).** Lights shall be placed in the low-altitude data base to simulate traffic, residential areas, industrial areas, etc. in order to support appropriate dusk and night training conditions. General cultural lights shall be associated with appropriate cultural features. Cultural features which are considered vertical obstructions shall have associated obstruction lights.

3.7.3.2.5 **Accuracy.** For real-world environments, the terrain model shall portray the terrain to within ____(a)____ of the actual source data elevations at a visual range of ____(b)____. Prominent terrain features, including peaks, ridges, and valleys, shall be preserved. Cultural features shall be portrayed within ____(c)____ of their source data locations at a visual range of ____(d)____.

3.7.3.3 **Data base generation/modification.** The capability to generate new data base areas and update existing areas shall be provided. Update capabilities shall include the ability to create, add, delete, move, or modify library models or any data base features.

3.7.4 **Visual display system.** A visual display system shall be provided. It shall be mounted on the simulator cockpit/motion platform with a display structure that is capable of withstanding all g-forces within the range of the motion system without damage to any visual system components. Neither the display components nor any support or mounting structure shall penetrate or interfere with the full-scale accurate representations of the cockpit, windscreens, structural framework, glareshields, panels, or head up display.

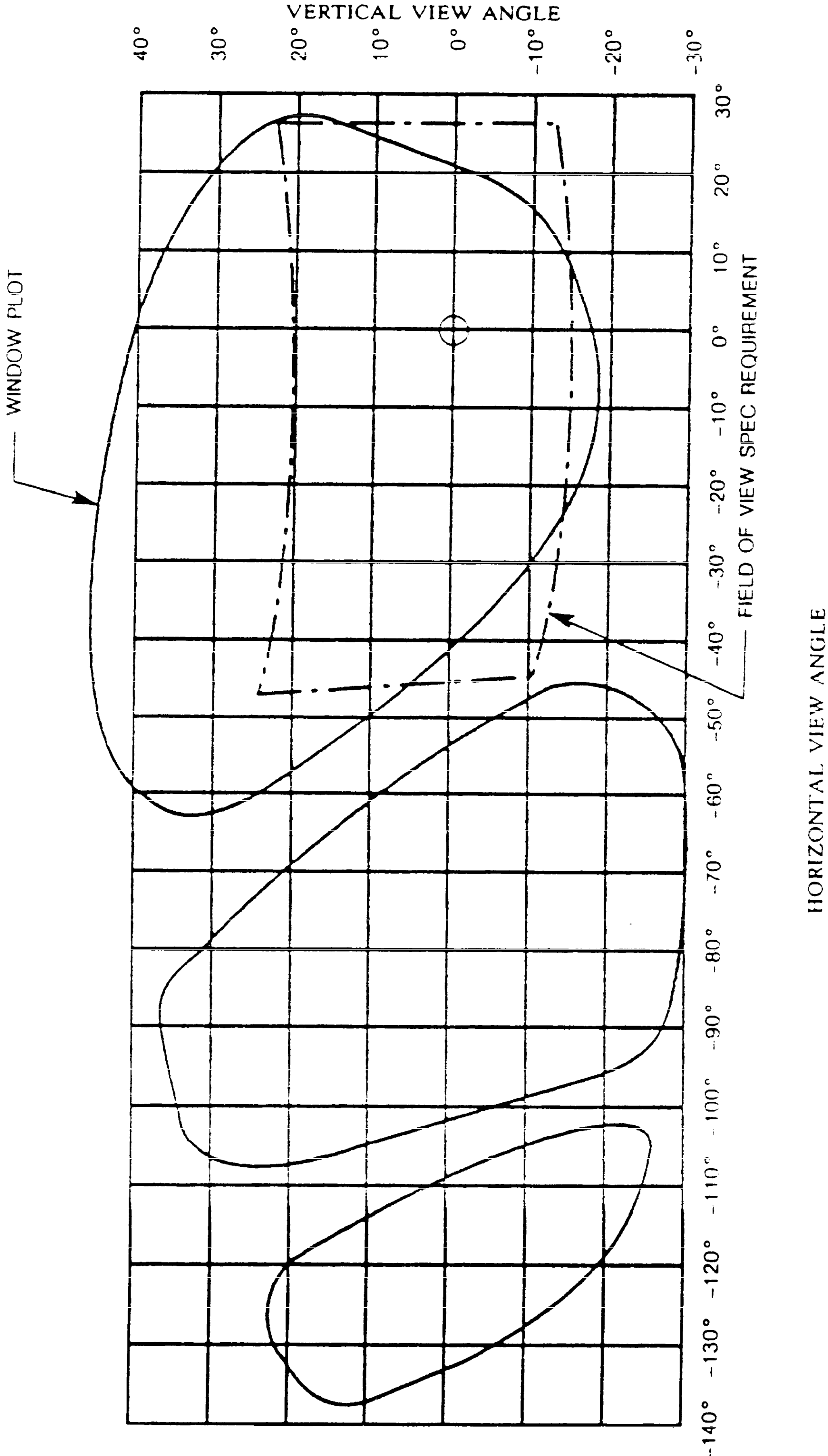
3.7.4.1 **Field of view.** The display system shall present a minimum instantaneous field of view of ____(a)____. Instantaneous field of view is that seen from the design eyepoint. The total field of view shall be no less than ____(b)____. Total field of view includes any area that can be seen by moving the eyepoint around within the viewing volume. The horizontal and vertical fields of view shall be optimized for the nominal eyepoint. The loss of display field-of-view due to any gaps between display windows shall be minimized, and shall be limited to a minimum instantaneous gap angle of ____(c)____ or less. The position of the horizontal and vertical fields of view shall be adjusted to cover the areas of interest shown in figure 1.

3.7.4.2 **Brightness.** The minimum highlight brightness of the maximum intensity area of the window test pattern shall be ____(a)____ foot-lamberts. Brightness uniformity shall be within + ____(b)____ percent of the center of the screen highlight brightness. The brightness variation from any display edge to an adjacent display edge shall not vary more than ____(c)____ percent.

3.7.4.3 **Resolution/modulation transfer function.** When viewed from the display nominal eyepoint, the horizontal and vertical resolution shall meet or exceed the data listed in table VI.

TABLE VI. **Display image resolution.**

Resolution	Modulation near the center of each display within a circle equal to picture height	Five degrees from any corner of each display outside a circle equal to picture height
____(a)____	____(b)____	____(c)____
____(a)____	____(b)____	____(c)____
____(a)____	____(b)____	____(c)____
____(a)____	____(b)____	____(c)____



EXT PILOT'S FIELD OF VIEW PLOT

FIGURE 1. Field of view.

3.7.4.4 **Contrast ratio.** Contrast ratio shall be defined as:

$$CR = (W - B) / B$$

where:

CR = contrast ratio
W = peak while brightness (measured in ft-lm)
B = Black brightness (measured in ft-lm)

Across the entire field of view of each display the contrast ratio shall be no less than ____(a)____ for angular separation of ____(b)____. Contrast shall be maintained in each display individually when all other displays are displaying a typical daylight scene.

3.7.4.5 **Collimation quality.** For a collimated display, the image presented to the nominal eyepoint shall be displayed at or near infinity. Collimation errors, as measured within the exit pupil, shall not exceed ____(a)____ diopters divergent from the display or ____(b)____ diopters convergent from the display. Dipvergence shall not exceed ____(c)____ milliradians. Rays converging toward the nominal eyepoint shall be minimized at the expense of rays diverging toward the nominal eyepoint. For real image displays such as domes, the minimum distance from the pilot's eyepoint to the image surface shall be greater than or equal to ____(d)____ feet.

3.7.4.6 **Viewing volume.** The exit pupil shall be a minimum of a ________ inch diameter sphere centered at the nominal eyepoint position. A larger viewing volume is desirable. All visual display specifications shall be met from any point within the viewing volume.

3.7.4.7 **Geometric distortion.** The total geometric distortion for each display shall not exceed ____(a)____ of the total picture height within a circle of diameter equal to the picture height, and shall not exceed ____(b)____ percent of the total picture height outside a circle of diameter equal to the total picture height. Alignment of the displays shall be such that the maximum distortion anywhere within the field of view shall be less than ____(c)____ of the picture height.

3.7.4.8 **Color convergence.** For each display, within a circle of diameter equal to the picture height, the three primary colors shall be converged to an accuracy of ____(a)____. Outside the circle, the convergence shall be to an accuracy of ____(b)____.

3.7.4.9 **Video signal-to-noise ratio.** The signal-to-noise ratio as measured at the output of the final amplifier of the video display device shall be greater than ________.

3.7.4.10 **Sweep signal-to-noise ratio.** The signal-to-noise ratio as measured at the final output of the deflection amplifiers shall be greater than ________.

3.7.4.11 **Blemishes.** No defects in CRT screen or display object surface, envelope, display optical package, or projection screens shall be larger than ____(a)____. There shall be no more than ____(b)____ defects larger than ____(c)____ anywhere within the active picture area.

3.7.4.12 **Image continuity.** Where multiple display units or multiple images sources such as projectors are used with no gaps between channels, the images shall match across the boundary. Accuracy of the image continuity shall be equal to or better than ________ anywhere along the joint, edge, or seam.

3.7.4.13 **Swimming.** No swimming of the visual image shall be observable as the observer's eyepoint is moved within the viewing volume.

3.7.4.14 **Spurious images.** There shall be no objectionable spurious images or reflections apparent to the viewer. Spurious images include light leaks, mirror imperfections, optical or CRT imperfections, reflections on the glare shield or windscreen, or reflections from opposing displays.

3.7.4.15 **Grey scale.** The display system shall be capable of presenting a ____(a)____-step linear grey scale. With this ____(a)____-step grey scale input, the displayed brightness difference between any two adjacent steps shall be within ____(b)____ of the total brightness difference between black and white.

3.7.4.16 **Display refresh rate.** The display of the visual scene shall be refreshed at least ________ times per second to insure constant brightness and flicker-free presentation.

3.7.4.17 **Shrouding and access.** The cockpit displays shall be enclosed in a lightproof shroud to permit operation in a lighted facility. The shrouding shall prevent loss of air conditioned ambient air provided by the simulator cockpit air conditioning unit in the event that windscreens are removed to improve optical effects. Maintenance access shall be provided for display equipment mounted on the simulator. All shrouding shall be designed for rapid removal and replacement to facilitate maintenance on the visual displays and other portions of the simulator.

3.7.4.18 **Maintenance of the visual display.** Modularized construction techniques and maintenance test points shall be incorporated into the design of the display system. Recommended cleaning procedures for all optical elements in the display system shall be established, and a dustproof enclosure shall be provided to prolong the useful life of the visual display system.

3.7.4.19 **Repeater monitor.** A repeater monitor shall be provided, and shall be capable of displaying any selected video channel from the visual system. The repeater monitor need not be the same size as the actual display units, but must have adequate resolution and brightness to be used as a troubleshooting and/or instructor aid. If practical, the repeater shall be movable to other areas within the simulator facility.

3.7.4.20 **Remote alignment control.** The primary visual display alignment controls shall be easily accessible for maintenance. It shall be possible to view the displayed scene either directly or indirectly (for example, reflected from mirror) during alignment. If multiple display units are used, a remote alignment box shall be provided so that any display can be aligned while viewing the display from the pilot's eye position. A jack (or multiple jacks if necessary) shall be provided in the cockpit so that the remote alignment box can be removed and stored when not in use.

3.8 **Electronic combat simulation.** The electronic combat (EC) simulation shall consist of the simulation of equipment functions and the associated environment.

3.8.1 **Electronic combat equipment simulation.** The following EC equipment suite shall be simulated in accordance with design criteria: ________. All equipment shall interact as they do in the weapon system.

3.8.2 **Electronic combat environment (ECE)**

3.8.2.1 **Jammer, artillery, radar, missile (JARM) systems**

3.8.2.1.1 JARM library. A JARM library shall be provided which includes all the JARMS to be simulated. This library shall include at least the following JARMs: ____(a)____. Each JARM in the library shall include all characteristics needed to meet the requirements of the specification. As a minimum this shall include ____(b)____. The capability shall be provided to expand the library as new JARMs are defined.

3.8.2.1.2 JARM simulation. JARM simulation shall consist of the observable characteristics of each JARM, including the signal structure (frequency, PRI, pulse length) and the dynamics (modes, tactics, networking) in accordance with design criteria.

3.8.2.1.3 JARM platforms/JARM sites. JARM sites shall have fixed locations. JARM platforms shall be assigned to any moving targets as specified by 3.2.1.4.1. There shall be no other limit on the distribution of JARM sites and platforms. The capability to relocate JARM sites during a mission shall be provided. The capability to alter the EC environment by inserting or deleting any JARM shall be provided.

3.8.2.1.4 JARM countermeasure evaluator and tactics. A countermeasures evaluator shall be developed for each JARM which shall evaluate the effects of ownship actions against the JARM. JARM tactics shall be simulated (mode changes, frequency changes, etc) based on the dynamic interaction with the ownship both for the individual JARM and in collaboration with other networked JARMs.

3.8.2.1.5 JARM weapons. JARM weapons shall include those weapons associated with specific JARMs. The weapon simulation shall be correlated with the electronic signal environment (search, track, lock-on, guidance, etc) and shall correlate with other functional subsystem simulations (visual, radar). Weapons dynamics shall be in accordance with design criteria. A lethality algorithm shall be provided for each terminal encounter. Ownship damage shall be simulated based on hit/miss criteria and indications of damage shall be in the form of malfunctions and/or a kill.

3.8.2.1.6 JARM editing. The capability to create or modify JARMs and associated data shall be provided to the user. Air Force support personnel shall be able to perform this editing at the computer support center using skills covered by the ________ course.

3.8.2.2 Mission electronic combat environment. The mission electronic combat environment (MECE) is a set of JARMs that make up the entire electronic environment which may interact with the EC equipment during any mission. The MECE for any mission shall consist of at least ____(a)____ JARMs and ____(b)____ JARM signals. The capability to simulate any set of JARMs identified in the JARM library within these constraints shall be provided. The MECE is an integral part of a preprogrammed training exercise.

3.8.2.3 Instantaneous electronic combat environment. The instantaneous electronic combat environment (IECE) is a set of JARMs that can interact with the EC equipment at any point in space. The IECE shall consist of at least ____(a)____ JARMs and ____(b)____ JARM signals. The entire content of the IECE shall be updated at least every ____(c)____ seconds. The IECE shall be selected from the MECE based on range and importance of the JARMs. The capability for the instructor to modify the IECE shall be provided. There shall be no limit in the distribution of JARMs around the ownship. At least ____(d)____ JARMs in the IECE shall exhibit tactics. At least ____(e)____ JARM weapons shall be capable of being in flight simultaneously.

3.8.2.3.1 JARM occulting. For each JARM in the IECE, the occulting status shall be updated at least every ________ seconds.

3.9 Digital radar landmass subsystem. A digital radar landmass simulator (DRLMS) system shall simulate the characterictistics and capabilities of the ________________.

3.9.1 General DRLMS requirements

3.9.1.1 **DRLMS system accuracy**. The DRLMS system shall be designed to satisfy the accuracies specified in the following paragraphs. These required accuracies are functions of range scales and modes and are defined at the display with respect to the appropriate level of the Defense Mapping Agency's (DMA) digital data base (DDB). These required accuracies include transformations, storage, processing, and display of the DMA data.

3.9.1.1.1 **Terrain elevation accuracy**. Terrain elevation accuracy requirements are defined as a function of a terrain roughness index which is defined below. Terrain elevation accuracies are specified as ________________.

3.9.1.1.2 **Planimetry elevation accuracy**. Planimetry elevation accuracies apply to all DMA-defined feature elevation. Planimetry elevation accuries are specified as ________________.

3.9.1.1.3 **Planimetry location accuracy**. Planimetry location accuracies are defined in two ways, an absolute value and a relative value. The absolute planimetry location accuracies apply to vertices and line segments not deleted or replaced by a process of the transformation program (common to both the radar and DMA DDBs). The relative planimetry location accuracies apply to feature vertices with respect to all other intrafeature vertices which have not been deleted or replaced by a process of the transformation program. The absolute and relative planimetry location accuracy requirements in no way compromise the feature fidelity and system resolution requirements. Planimetry location accuracies are specified as ________________.

3.9.1.1.4 **Planimetry orientation accuracy**. The true orientation of a real and lineal features is defined by the respective feature coordinates in the DMA DDB. The orientation tolerances are inherent in the accuracy and feature fidelity requirements. Orientation of point features shall be within ________________ degrees of the orientation defined in the DMA DDB. Features which are aligned with respect to each other in the DMA DDB (along streets, other thoroughfares, runways, etc) shall appear to be aligned on the display such that cardinal effect can be simulated.

3.9.1.2 **DRLMS system resolution**. The DRLMS shall simulate both the range and azimuth resolution of the actual aircraft radar, (e.g., one half a pulse width for range resolution and one half the power beam width in azimuth). Two targets separated by a relatively small distance, which can be "broken out" on the actual radar system shall likewise be "broken out" in the simulated radar system.

3.9.1.3 **DRLMS processing**. All data within the field-of-view of the radar shall be processed and displayed by the DRLMS. Processing shall in no way contribute towards quantization or discrete time effects which would be perceived by a crew member under any combination of control settings and aircraft/topographic geometry. If any data compression technique (gridding, listing, truncating, etc) is employed in the representation and processing of the data contained in the DMA data base, then said technique shall not degrade the performance of the radar simulation.

3.9.1.4 **Data base coordinate system.** The coordinate system(s) which are either explicit or implicit in the radar data base and real time radar processing shall accommodate simulated missions without perceptible interruption of the radar display and within the accuracies specified herein to the geographic extent defined below: ________________.

3.9.1.5 **Correlation with other systems.** The following categories of information processed and displayed by the DRLMS shall correlate with the corresponding information contained in the sensory stimuli provided by the following simulated systems: ________________.

3.9.1.6 **DRLMS positioning.** The capability shall be provided to reset the DRLMS position (aircraft position) or initially position the DRLMS, from any point within the radar data base to any other point within the radar data base, within ________________.

3.9.1.7 **DRLMS terrain occulting.** The DRLMS shall interface with other aircraft systems to provide terrain occulting for the following purposes: ________________.

3.9.2 **Radar controls and displays.** All controls and displays associated with the radar shall be provided and shall be an exact replica of those on the actual system with the following exceptions: ____(a)____. All required radar controls shall be operative and shall permit the required modes and capabilities of the radar to be operated. The interaction among all controls, functions and displays shall be simulated in accordance with design criteria. The simulated radar indicator shall be capable of the following display characteristics: ____(b)____.

3.9.3 **Radar system operational capabilities.** The following operational capabilities of the radar shall be simulated: ________________. The requirements of each of the following paragraphs shall be met for each radar capability:

a. Modes of operation

b. Unique characteristics

c. Malfunctions.

3.9.4 **Radar effects.** Radar effects shall be simulated and shall include those effects associated with the radar sensor and signal processor, the atmospheric environment, and with radar signal interaction with the target/earth's surface. The following specific effects shall be simulated: ________________.

3.9.5 **Radar landmass digital data base**

3.9.5.1 **DMA digital data base.** The DMA DDB shall be the source data base for the DRLMS. This DDB is defined within the Defense Mapping Agency Product Specification for Digital Landmass System Data Base, and will be provided by the Government.

3.9.5.2 **Radar digital data base.** The radar DDB shall be produced from the DMA DDB using the digital data base transformation program (DDBTP). The radar DDB storage devices shall be sufficient to store a minimum of ____(a)____ square nautical miles of data. While the aircraft is "flying" in an undefined (by DMA) area of the radar data base, the DRLMS shall provide a display using ____(b)____.

3.9.5.3 **DDB densities.** The DRLMS system shall be designed to accommodate (transform, store, transfer, process, and display) gaming areas with data densities as defined below:

a. Digital terrain elevation data (DTED): Terrain elevation data density requirements are defined within the DMA Product Specification.

b. Digital feature analysis data (DFAD): Feature analysis data density requirements are defined as follows: ____(a)____. Features may be all point or areal features or any combination of point, lineal or areal features. The DRLMS system shall handle the following total data mix of DMA feature analysis data base levels: ____(b)____.

3.9.5.4 DDB levels. The DMA terrain elevation data, levels of feature analysis data, and the previously defined densities shall be assigned to the selected radar modes and range selections as follows: ________________.

3.9.5.5 Radar reflectivity codes. There shall be at least ____(a)____ basic radar reflectivity codes into which topography shall be quanitized. The assignment of the reflectivity codes to the data in the DMA DDB shall be accomplished by the transformation program. The dynamic range of basic radar returns shall be at least ____(b)____ dB. The dynamic range of basic radar returns for each reflectivity code shall not be restricted with in the ____(b)____ dB range. Once a return level has been assigned to a reflectivity code, it shall be possible to easily modify the return level without changing any other reflectivity code assignment. The ____(a)____ levels shall be used to represent various topography.

3.9.5.6 Object data. A library of objects shall be provided for insertion into any mission. This library shall include EC threat sites, craters, moving targets, beacons, and expendables. Approximate radar cross sections and codes shall be included.

3.9.5.6.1 Electronic combat ground sites. The capability to insert up to ________________ EC ground sites into any mission area shall be provided. Locations shall be correlated with the threat scenario and IECE.

3.9.5.6.2 Air targets. The capability to simulate up to ________________ simultaneous moving targets for display on the radar shall be provided. Moving target positions shall be correlated with other ATD functions. This capability also includes nuclear and non-nuclear debris and associated effects.

3.9.5.6.3 Beacons. The capability to simulate up to ________________ simultaneous beacons for display on the radar shall be provided. These beacon sources shall be airborne or on the ground and shall be capable of being located concurrently with other air targets.

3.9.5.6.4 Expendables. The capability to simulate expendables which are observable by the radar shall be provided.

3.9.6 DRLMS control system and console. The DRLMS shall be provided with a control system and console consisting of hardware and software features to provide complete control and monitoring capabilities for each of the DRLMS modes of operation. Control console hardware shall consist of the following: ____(a)____. The DRLMS control system shall permit the DRLMS to fly within the radar data base while operating in each of the DRLMS modes except for the integrated mode. The following flight control capabilities and parameters shall be provided: ____(b)____. The use of the DRLMS control system and console shall require minimal knowledge of the DRLMS design and minimal technical expertise on the part of the individual operating the system.

3.9.7 DRLMS modes of operation

3.9.7.1 Independent mode. Independent mode operation shall permit the DRLMS to operate in a functionally standalone manner independent of the flight simulator. Independent mode operation shall be controlled by the DRLMS control system and console.

3.9.7.2 Integrated mode. Integrated mode operation shall permit the DRLMS to operate in a fully integrated manner with the flight simulator. Integrated mode operation shall be controlled by the flight simulator. While operating in the integrated mode, the following information shall be displayed at the DRLMS control console: ________________.

3.9.7.3 **Digital data base update mode.** The digital data base update mode shall provide the capability for radar data base modification by the DRLMS control system and update console. The following types of update capabilities shall be provided: ____(a)____.

In addition, the DRLMS shall automatically generate and maintain records of all data base update activities. The following capabilities and specific information shall be provided with the data base management: ____(b)____.

3.9.7.4 **DRLMS test map mode.** DRLMS test maps shall be available as both diagnostic and test tools. The term "verification" in this section refers to diagnostic verification. DRLMS test map mode operation shall take place at the control console. Accompanying each test map being displayed on the radar display, the alphanumerics and graphics necessary to identify the test map function and convey all quantitative and descriptive information needed to complete a diagnostic or test evaluation shall be displayed at the control console. Means shall be provided at the console to position the DRLMS to the correct geographic location, altitude, and heading for a desired test situation by entering a test map identification number after the DRLMS has been placed in the test map mode. In addition, means shall be provided to subsequently reposition the DRLMS to a new location, altitude, and/or heading in a similar manner, if required by the purpose of an individual test map. The test maps shall verify the proper operation of the following functions: ________.

3.10 **Avionics systems simulation/stimulation.** The avionics systems shall be simulated or stimulated in accordance with the approved design criteria. The avionics systems shall include the following subsystems: ________.

3.10.1 **Avionics architecture.** The avionics architecture in the simulator shall be analogous to that of the actual aircraft such that:

a. New avionics subsystems can be added to the simulator's avionics suite in a manner that is consistent with the addition of new avionics to the aircraft avionics suite.

b. Malfunctions of subsystems can be duplicated in accordance with design criteria.

c. Data buses and bus controller characteristics are simulated or stimulated.

3.10.1.1 **Operational flight programs (OFPs).** Avionics functions which include OFPs shall be simulated by ________. Whichever method(s) is (are) used all aircrew perceptible cues shall be provided. In addition, simulator unique controls, (freeze, reset, or others) required by this specification shall be provided.

3.10.2 **Navigation subsystem simulation.** The ________ navigation subsystem shall be simulated in accordance with the approved design criteria.

3.10.2.1 **Navigation subsystem accuracy**

3.10.2.1.1 **Absolute accuracy.** Navigation subsystems' absolute accuracy is defined as a function of required subsystem model fidelity, the simulated quality of subsystem performance, and the simulator equations of motion state conditions compared to an estimate of actual system performance under the same conditions (position, velocity, altitude, acceleration, etc). Navigation subsystems' absolute accuracy requirements are: ________.

3.10.2.1.2 **Relative accuracy.** Navigation subsystem relative accuracy is defined as a function of the required degree of correlation among navigation subsystems. The type of information that is computed and displayed, and the level of performance for each of the navigation subsystems shall correlate with the corresponding information and performance provided by all other simulated subsystems: ________.

3.10.2.2 Navigation controls, displays and indicators. All controls, displays, and indicators associated with each navigation subsystem shall be provided, and shall be exact replications of those on the actual system with the following exceptions: ____(a)____. All required controls shall be functional and shall permit the required modes and capabilities of the navigation subsystem to be operated. The interaction among all controls, functions, displays, and indicators shall be simulated in accordance with the design criteria. Simulated indicators and displays shall ____(b)____.

3.10.2.3 Navigation operational capabilities. The following operational capabilities of each navigation subsystem shall be simulated. The modes of operation, unique characteristics, and malfunctions shall be simulated as follows: ________.

3.10.2.4 Navigation data bases

3.10.2.4.1 Celestial data base. A celestial data base shall be provided for celestial navigation systems or to permit a crew member to practice celestial navigation with a sextant. Celestial simulation of the following bodies shall be provided: ____(a)____. The following errors associated with celestial observations shall be computed: ____(b)____.

3.10.2.4.2 Topographic elevation data base. The required navigational subsystems shall access the ________ data base for topographic elevation.

3.10.2.4.3 Pressure, wind, temperature (PWT) data base. The navigation subsystem shall access the PWT data bases for environment data. The capability to modify the PWT data bases shall be provided.

3.10.2.4.4 Magnetic variation data base. The navigational subsystems shall access the magnetic variation data base. Magnetic variation shall be simulated over ____(a)____. The simulated variation shall match the actual variation to within ____(b)____ degree(s), except for areas within ____(c)____ miles of the magnetic pole. Local magnetic disturbances need not be simulated.

3.10.3 Communications subsystem simulation. All communication equipment included at aircrew members positions shall be simulated in accordance with design criteria. This shall include all types of radios, data communications and air traffic control equipments. Realistic interference shall be simulated which is variable in intensity. Background radio traffic shall be simulated as well as mission specific radio traffic. The on-board interphone shall be simulated.

3.10.4 Mission avionics subsystem simulation. The mission avionics subsystem simulation shall be in accordance with aircraft design criteria.

3.10.4.1 Weapons control. The weapons control computer (sometimes called stores management) shall be simulated. All controls and displays shall be provided. The capability to simulate the status, arming, control, and release of all weapons identified below shall be provided. It shall be possible to modify the weapons load for any specific mission.

3.10.4.2 Weapons. The following weapons shall be simulated in accordance with design criteria ____(a)____. Weapon operation prior to release/launch and all weapons flight characteristics subsequent to release/launch shall be simulated. Weapons scoring shall be provided against any object in the integrated combat environment simulation and at least ____(b)____ points in the radar data base.

3.10.5 Flight management subsystem simulation. The flight management subsystem shall be simulated in accordance with aircraft design criteria. This shall include simulation of the flight control computers, attitude/motion sensors, and terrain-following flight.

3.10.6 Radar simulation. The radar shall be simulated in accordance with 3.10.1 and 3.10.1.1 and additional requirements found in 3.9.

3.10.7 Electronic combat subsystem simulation. The electronic combat (EC) subsystem shall be simulated in accordance with 3.10.1 and 3.10.1.1 and additional requirements found in 3.8.

3.10.8 Avionics controls and displays. All controls and displays shall be simulated/stimulated in accordance with design criteria. This simulation/stimulation shall include the time delays associated with the use of multifunction displays and display processors as well as symbology and menu sequences associated with the specific avionics application.

3.11 Trainer support subsystem. The trainer support subsystem (TSS) shall include all hardware and software (computer programs/data) necessary to provide for the modification support of the trainer. All TSS computational hardware shall be subject to the general system requirements for the computational subsystem hardware. The TSS shall be ________________.

3.11.1 TSS mass storage equipment. Mass storage equipment shall be provided for the TSS which shall be compatible with the secondary mass storage equipment of the computational subsystem. Additional mass storage equipment shall be provided as necessary to provide for the efficient implementation of all modification support activities required for the TSS.

3.11.2 Modification support terminals. Support terminals shall be provided to facilitate user interface with all trainer modification support functions requiring the use of TSS computational hardware.

3.11.3 TSS hardcopy equipment. Capability shall be provided to produce hardcopy output of all data which is displayable on any peripheral display equipment controlled by the TSS computational hardware.

3.11.4 Additional modification support peripheral equipment. In addition to the modification support peripheral equipment specified above, any additional modification support peripheral equipment necessary to support the modification of the trainer shall be provided. Included shall be all equipment necessary to support instructional system displays and all digital storage technologies used in the trainer (such as ROM, PROM, FPLAs, etc). The additional equipment shall be configured to operate alone or in conjunction with the TSS computational hardware as necessary and shall also be taken into account for the verification of required spare capacities.

3.11.5 TSS space memory and growth. ________________ percent space memory and __________ memory expansion capability shall be provided to allow for changing modification support requirements over the life-cycle of the trainer. This requirement shall apply separately to each type of memory in each computer configuration in the TSS computational hardware.

3.11.6 TSS mass storage spare and growth. Each unit of mass storage equipment which is used in a random-access mode of operation shall have an on-line, spare storage capacity that is at least ______(a)______ percent of its total capacity. Also, the total on-line storage capacity of the mass storage equipment shall be increasable by ______(b)______ percent without increase in interface hardware.

3.11.7 TSS I/O expansion. The total number of I/O channels of the TSS computational hardware, in terms of such peripheral equipment as terminals and mass storage, shall be increasable by ________________ percent. The available information transfer capacity shall be increasable by the same percentage.

3.11.8 TSS maintenance and test computer programs. Computer programs/data shall be developed and provided to fully test the operation of the TSS and associated equipment. These programs shall be designed to execute on the deliverable TSS computer configuration(s) and shall be controllable with a single modification support terminal. Hardcopy of the input and output parameters shall be an option at execution time.

3.11.8.1 TSS computer equipment diagnostic computer programs. A complete set of diagnostic programs shall be provided to isolate equipment failures in the TSS. Except for the portions of test that check whether or not inputs can be received from and outputs can be transmitted to the equipment in question, all diagnostics shall be fully automatic. This means that once the user has loaded the diagnostic and set up initial conditions, the program will automatically test the TSS equipment and generate error indications (if any) on the terminal and hardcopy device. These programs shall be capable of automatic execution as a total package and as individual diagnostic checks. The diagnostics shall check each computer configuration and its options, and all memory units, peripheral units, and input/output units in the TSS.

3.11.8.2 TSS equipment test computer programs. Computer programs/data shall be provided to check the proper functioning of all remaining TSS equipment and equipment controlled by TSS computational hardware.

3.11.8.3 Spare memory and mass storage verification computer programs. Computer programs shall be provided to verify the spare capacities specified for memory and mass storage. These programs shall provide the data from which calculations will be made to verify compliance. The spare memory data shall be obtained from the configuration of modification support activity which produces the maximum memory utilization. Computer vendor operating system built-in functions or utilities may be used if all requirements are satisfied. Optional hardcopy output shall be selectable when exercising each program.

3.11.9 Modification support computer programs/data. Computer programs/data shall be provided to support the modification of the TSS computational system and the interfaced major component subsystems to reflect changes in the simulated air-vehicle or crew stations. Computer vendor supplied commercial off-the-shelf (unmodified) computer programs shall be provided wherever possible.

3.11.9.1 TSS operating system. A standard computer vendor operating system (OS) shall be used and provided for each general-purpose digital computer in the TSS computational hardware. The OS must support multi-terminal interactive and batch processing modes of operation. The TSS OS may be the same as that provided for the trainer computational subsystem if all modification support requirements are satisfied. If it is different, then the TSS OS must have the capability to bridge the software between the two systems.

3.11.9.2 Compilers/assemblers. All compilers and assemblers used in the generation of the CPS shall be provided. The use of compilers and assemblers in the generation of the CPS shall be consistent with the programming language requirements of this specification. In addition, any pre-compilers or source-code processors whose output is used as input to the compilers or assemblers shall be provided. Compilers and/or assemblers shall be provided for each type of computer used in the computational system.

3.11.9.3 **Loaders.** All loaders, linking loaders, task builders, and any other computer programs used to establish the operational CPS configuration shall be provided. Standard computer vendor off-the-shelf commercial computer programs shall be used to satisfy this requirement.

3.11.9.4 **Standard libraries.** All computer vendor standard product libraries for all computer configurations used in the development, support, maintenance, and operation of the CPS shall be provided.

3.11.9.5 **Data base management computer programs.** Computer programs/data shall be provided and used to develop and modify data bases which are directly related to hardware which is part of, or controlled by, the computational subsystem. Examples include interface hardware address or configuration tables, mapping tables or data, the visual data base, radar landmass data base, PWT data, and the like.

3.11.9.6 **Text editors.** Computer programs shall be provided to allow computer program source code to be easily altered or created. The programs shall utilize modification support terminals for user input and output. The programs shall allow the modification of all source-code provided with the trainer (for each type of computer). Standard computer vendor off-the-shelf commercial computer programs may be used to satisfy this requirement.

3.11.9.7 **Development tools.** All computer program development tools used in the development of the CPS shall execute on the TSS and be provided. Examples of such computer programs are execution flow tracers, emulators, syntax analyzers, and debug computer programs. The programs shall utilize modification support terminals for user input and output.

3.11.9.8 **Mass storage copy/comparator software.** Software shall be provided which satisfies the following functional requirements between all units (e.g., drives, transports) of similar and dissimilar mass storage in both the primary and secondary mass storage systems (e.g., disc-to-disc, disc-to-tape, tape-to-tape, etc): ________________. These programs shall be operable through an operator or support terminal and shall allow the error output to be optionally directed to hardcopy. Commercially available software shall be used if it satisfies all of the above requirements.

3.11.10 **Computer software tree.** Computer programs and required data base shall be provided to generate and maintain a computer software tree (CST). The generation of the CST shall be an automated process. The CPS generation computer programs required in 3.11.22 shall be designed to use the CST as a source data base. The CST shall provide a detailed breakout of all computer software components, and computer software units which contains at least the following items: ________________. This data base shall portray the hierarchical structure of the computer software from the top level to the smallest separately compilable unit of code. Each element of the computer software (component, unit, etc) shall be listed as a separate element of the tree. The details of each field for each level of the tree are to be filled in as the software evolves and the applicable data becomes available. As the design progresses and specific computer software units (CSUs) are identified, the time and memory estimates shall be entered in the CSU level elements of the tree. All fields shall be presented in the tree. Any fields not applicable to a specific element of the tree shall be so designated with "N/A". Any field that is applicable but the data not yet available shall be designated with the milestone or date at which the information will be available.

3.11.11 **CPS generation computer programs.** Computer programs/data shall be provided to perform a "cold-start" or system generation of the total simulator CPS for execution on the computational subsystem. This shall include the automatic compilation/assembly of all source computer programs/data under the control, and in same order, as shown in the CST. The programs shall be designed to require a minimum of user input and shall allow for the optional generation of hardcopy of all terminal output and all listing files generated by the compilers, assemblers, or loaders utilized in the process. A capability to pause and later resume the system generation without any impact shall be provided.

3.12 **Practical design considerations.** In addition to the design considerations indicated in paragraph 3, Requirements, the following practical design considerations shall be addressed: experience-based ATD system design considerations, safety, reliability, maintainability, availability for training, accessibility, and life cycle cost.

The ATD shall incorporate standard industry design practices except as modified herein.

3.12.1 **Air training device system design considerations.** Air training device system design considerations shall include facility interface, transportability, power interface, grounding, thermal design, and name plate and product marking.

3.12.2 **Environmental conditions.** The training equipment, including all components, shall be designed for operation within the following ambient air environmental limits:

a. Non-hydraulics: ______(a)______

b. The hydraulic pump room equipment shall be designed to operate under the following environmental conditions: ______(b)______.

3.12.2.1 **Thermal design.** Adequate thermal design shall be employed to maintain parts within their operating temperature limits under specified operating conditions. The simplest and most efficient thermal design shall be selected. Thermal design provisions shall incorporate a temperature sensing device for thermal protection which will provide visual or aural warning and which will shut off equipment, as applicable, when critical temperature limits are exceeded. Air filters shall be provided for air intakes for fan and blower cooled units when required. Filters, when used, shall be readily removable for cleaning without disassembly of the equipment. Except in commercial off-the-shelf equipment, ventilation and air exhaust openings shall not be located in the top of enclosures or in front panels. Air exhaust shall be so directed that it will not inconvenience operating personnel. Each separate piece of equipment being cooled shall be marked with the high and low operating temperature to which it is designed, the quantity and characteristics of air required to adequately cool the unit, and the resistance to air flow with respect to the air flow rate.

3.12.2.2 **Detrimental entrained contaminants.** If external cooling air is used, equipment shall be protected from entrained contaminants, including water, by ____________.

3.12.3 **Transportability.** The simulator shall be transportable by: ______(a)______. Adequately located and strengthened tie-down points shall be provided. Hoisting or lifting provisions shall be included in the design. Other transportability conditions include: ______(b)______.

3.12.4 **Mechanical.** The ATD shall be designed and constructed so that no fixed part shall become loose, and no movable part or permanently set adjustment shall shift its setting or position, when subjected to the shock and vibration incident to preparation for shipment, loading, shipping, unloading, and assembly, as well as to training functions and emergency shutdowns. Optical and cathode ray tube systems design, construction, and installation shall be such as to retain alignment and operation within required limits when subject to normal training operation and emergency shutdowns.

3.12.5 **Workmanship.** Workmanship shall be of sufficient quality and assure that manufactured parts are of consistent quality, free of burrs and sharp edges or other defects that could render the part or equipment unsatisfactory or unsafe for the purpose intended. Parts shall be mounted so that markings are visible. PC boards, except for those contained in commercial off-the-shelf equipment, and other easily misidentified parts shall be keyed to assure insertion in correct slots or positions. Electronic card racks shall have a listing and diagram attached to indicate the position of each card in the rack. Parts shall be cleaned of any material of manufacture or foreign agent which might detract from the intended operation, function, or appearance of the equipment. Fasteners shall be tight. Screw-type fasteners shall show no evidence of cross threading or mutilation and rivet heads shall have their heads tightly seated against their bearing surface.

3.12.6 **Electromagnetic compatibility.** The training device shall be electromagnetically compatible with itself, the other equipment in the same facility, and the environment as applicable. Adedquate shielding and circuit separation shall be designed into the training device. Where classified information will be processed, the design shall be in accordance with the guidelines of AFR-100-55, Communications Security Policies, Procedures and Instructions, and ________________.

3.12.7 **Training device electrical system requirements**

3.12.7.1 **Primary power.** The training device manufacturer shall provide the proper National Electrical Manufacturers Association (NEMA) standard equipment for connecting to the Government-furnished branch circuit termination. Transformers and other electrical equipment necessary to distribute and transform power for operation of the mechanical equipment, lighting equipment, and distribution system shall conform to the National Electrical Code and NEMA standards.

3.12.7.2 **Main power distribution panel.** A main power distribution panel shall be provided and wired in a manner to avoid damage to equipment by actuating switches in an indiscriminate sequence. All power requirements for the training device shall be satisfied from this panel, thereby allowing for a single-point turn-on.

3.12.7.2.1 **Utility power.** Utility power circuits shall be designed to operate from the primary power source and shall be operable while the remainder of the training device power is off. These circuits shall contain the utility lights, utility outlets, and maintenance intercom. Outlets for portable tools and equipment shall be 3-wire grounding type utility duplex receptacles. Utility power circuits shall be protected with ground-fault circuit interrupters.

3.12.7.3 **Circuit design.** The circuit design shall include a main power switch to shut off all power to the training device units without disconnecting from the power source. An indicator light shall be provided with each power switch required throughout the training device to indicate when power is on.

3.12.7.3.1 **Tolerances for circuit design.** Unbalanced line currents in the system shall not exceed 7.5 percent of the average simultaneously measured line current. The power factor of the total inputs, measured at the primary power source, shall not be less than 85 percent for any mode of operation. The training device shall be protected from permanent damage and alteration of characteristics due to total power failure.

3.12.7.3.2 **Overload protection.** ________________ shall be provided within the training device for primary circuits and other circuits as necessary for protection of the equipment from damage due to electrical overload. The use of fuses is not permitted except in commercial off-the-shelf equipment. All circuit protection devices shall be readily accessible and replaceable by locating them directly on the front panels of the equipment. All parts that may be subjected to an overload due to circuit malfunctions, poor adjustment, or part failures shall be designed to accommodate such a load. Where parts cannot be designed to accommodate an overload, circuit breakers shall be provided to protect the unit or assembly. The training device shall be designed for protection from overvoltage, undervoltage, and phase power loss for all three phases of line input.

3.12.7.3.3 **Power conditioning.** Power conditioning equipment ________________ shall be provided to minimize the effects of power disturbances and interruptions on simulator operation.

3.12.7.4 **Grounding and grounding systems.** Three separate and isolated reference grounding systems shall be established to control ground-return conducted interference, provide effective shielding and protect personnel from electric shock hazard. These are:

a. Primary power grounding

b. Signal grounding

c. Chassis grounding.

3.12.7.5 **Wire coding/identification.** Wire coding and identification shall be as specified herein except that these requirements shall not apply to commercial off-the-shelf equipment.

3.12.7.5.1 **Conductor identification.** To facilitate testing and locating of faults, all conductors which are coded shall follow the same pattern throughout the equipment. The coding selected for a particular circuit shall run continuously through connectors, plugs and receptacles, or interconnecting circuits. When point-to-point wiring is utilized, internal to a chassis or cabinet, non-coded wiring may be used.

3.12.7.5.2 **Terminal ends.** The terminal ends of each conductor of a jacketed cable or hookup wire harness shall be marked for positive identification.

3.12.8 **Nameplates and product marking.** Unless otherwise specified herein, nameplates and product marking shall be in accordance with ____(a)____. Control panel markings shall be in accordance with ____(b)____. Abbreviations used in marking equipment shall be in accordance with ____(c)____.

3.12.8.1 **Reference symbol designations.** Reference symbol designations shall be assigned to electrical and electronic component assemblies in accordance with ____(a)____. Mechanical symbols shall be in accordance with ____(b)____ Symbols for electrical and electronic diagrams shall be in accordance with ____(c)____.

3.12.8.2 **Precautionary markings.** In all instances where parts, subassemblies, assemblies and units of ground, air or space vehicles or equipments are used in the simulation equipment, and these parts, subassemblies, or assemblies are simulated or have been modified in any way for application to the training equipment, such parts, subassemblies, or assemblies shall be durably marked with the following precautionary marking in a plainly visible position (but not visible to the trainee):

WARNING: FOR GROUND TRAINER USE ONLY

If the simulated or modified part is too small to receive the precautionary marking or identification plate, it shall be necessary to affix the precautionary marking or identification plate at the next higher assembly adjacent to the simulated or modified part.

3.12.9 Reliability and maintainability

3.12.9.1 Reliability. The reliability requirements for the ATD shall be as follows: __________________.

3.12.9.2 Maintainability. The maintainability requirement for the ATD shall be as follows: __________________.

3.12.9.2.1 Time totalizer. Each major component of the training device that is controlled by a simulator main power panel power switch (e.g., hydraulic system, computers, visual) shall be provided with an elapsed time indicator providing a digital readout (four digit minimum) of the elapsed operating time in hours. Each pump shall have an elapsed time indicator.

3.12.10 System safety design. Good commercial practices, in addition to the following design notes (DNs) of AFSC DH 1-6, shall be considered as guidelines in safety designs of training devices:

a. DN 2C2, Man-Machine Safety Design Requirement.

b. DN 2E1, 2, and 3, Introduction, Procedures, and Selection of Safety Analyses.

c. DN 2E4, Resolution of Safety Hazards.

d. DN 4A2, Material Handling Equipment.

e. DN 5D2, Fire Detection.

f. DN 6A1-7, Enviromental Parameters of Man.

g. DN 4E1-2, Electrical/Electronic Equipment.

h. DN 4C1-3, Hydraulic Equipment.

3.12.10.1 Hazardous materials. Materials used in the construction of the training device shall not support the propagation of flame. Where the generation of toxic or noxious gases cannot be eliminated, the design effort will be toward control and minimizing this hazard.

3.12.10.2 Fire detection. The design shall include a complete fire, smoke detection, and alarm system which operates from facility power. Detectors shall be located in all appropriate contractor-furnished equipment, such as computer cabinets and crew stations. When a contractor-furnished motion system is included in the contract, a minimum of two smoke detectors shall be located beneath the platform. A heat sensor wire shall be installed in the crew station umbilical cable. Means shall be provided to rapidly locate any fire or smoke which is detected. The detection and alarm cables shall be separated from electrical power cables. Detectors shall be installed in accordance with NFPA Standard 72E. The guidance of DN 5D2 of AFSC DH 1-6 shall apply.

3.12.10.2.1 Fire alarm. Means shall be provided to alert all personnel throughout the training device complex that a fire or smoke detection has occurred. The specific aural or visual alarm means and locations to be provided shall be determined through safety analysis, and subject to approval by the procuring activity. The design shall ensure that the specific means provided do not present confusing information when compared with stimuli from other alerting devices such as the facility fire alarm, or the means provided in the cockpit to indicate a simulated crash.

3.12.10.2.2 Facility fire control interface. Interconnections with the facility fire control system shall be provided. Simulator smoke detection signals shall be provided to the facility fire control panel to provide a signal to activate the facility fire warning system in the appropriate facility fire zone where the simulator equipment is located. The simulator emergency power off shall be capable of being activated by a signal from the facility fire control panel originating from activation of a facility fire/smoke detector or sprinkler system.

3.12.10.3 Overheat sensing. Critical cooling subsystems provided with training device equipment in areas such as visual systems and motion systems shall be equipped with means to automatically deactivate power to the affected subsystem in the event of cooling system failure.

3.12.10.4 Fire stop sealing. Means shall be provided to seal facility-provided fire stops whenever training device cable runs are installed through the fire stops.

3.12.10.5 Emergency power off. Emergency power off control shall be provided at multiple locations throughout the training complex and shall be fail-safe. The number and location of these controls shall be subject to procuring activity approval at the mockup/PDR. Emergency power off shall also occur automatically when the fire/smoke detection system is activated. When emergency power off is initiated, all power to the training equipment, including utility power, shall be automatically removed, the motion system shall automatically return to the egress position, the motion system access ramp/stairway shall automatically return to the egress position, emergency lighting interior to the crew station shall automatically activate, and means shall be provided to automatically close air conditioning/ventilation dampers to the cockpit area. Alternate escape provisions shall be provided and be subject to approval by the procuring activity.

3.12.10.6 Emergency off switches. All emergency off switches shall consist of red push buttons not less than 1.0 inch in diameter, recessed in black (FED-STD-595, Color 17038) and orange-yellow (FED-STD-595, Color 13538) diagonally striped panels, two inches or larger on a side. The width ratio of orange-yellow to black shall be three to one. The black stripe shall be in one of three widths: 1/16, 1/8, and 1/4-inch. The switch button shall not be integrally illuminated. Alternative lighting designs may be used that meet the requirement that the brightness contrast is sufficient to make the control identifiable under all projected illumination conditions. The control characteristics shall fall in the area labeled "clear seeing" of sub note 3(1) DN 2B2, DH 1-3. The nomenclature "EMERGENCY OFF" shall be placed on each panel, consistent with the remainder of the panel nomenclature.

3.12.10.7 Maintenance/safety intercom. A single-loop maintenance/safety intercom shall be provided and consist of stations located in and around the training equipment. This intercom shall be independent from other communication systems. Each station shall be capable of transmitting or receiving without the need of other station selection. The system shall be adapted to the facility, and shall provide microphone/headset communication lines. The layout and design of the system shall be approved by the procuring activity. The system shall operate from utility power, with a backup power source for operation during facility power loss. Provisions shall be incorporated to prevent feedback noise and crosstalk from occurring.

3.12.10.8 Safety and emergency lighting. When required by facility lighting, low intensity guarded lights shall be provided to illuminate the walkway around the crew station. Crew station interior emergency lighting shall be provided and be activated automatically upon loss of facility power. The system shall also include provisions to turn off the emergency lighting upon deliberate shutdown of facility power. Where batteries are used they shall be rechargeable when power is applied to the ATD.

3.12.10.9 Acoustic noise--user areas

3.12.10.9.1 **Hazardous noise levels.** The sound level and exposure time in all areas of instructor and student stations, and simulator bay areas, shall be held below the values calculated from the following equation:

$$T = \frac{16}{2^{[(L-80)/4]}}$$

where T = Duration of total daily exposure in hours

L = Noise level in dBA

3.12.10.9.2 **Speech interference noise level.** The noise level at student and instructor station(s) shall not exceed an articulation index (AI) of 0.7, where the AI is determined by the octave band method. Exception: Where simulated sounds reflecting actual aircraft conditions for the student(s) violate the AI above, the requirements of this paragraph are void for the time period that such simulated sounds are actuated, except that limits in 3.12.10.9.1 shall not be exceeded.

4. VERIFICATIONS

4.1 **General.** Verification activities shall be conducted by the contractor, by the procuring activity, and by designated representatives of the procuring activity according to the Statement of Work.

The contractor shall be responsible for, and shall conduct all quality assurance activities necessary to insure the simulator meets the requirements of this specification. To meet this responsibility, the contractor may utilize his own facilities, or other facilities or laboratories acceptable to the procuring activity.

Verification shall consist of one or more of the following: testing, demonstration, inspection, and analysis.

The ATD shall be verified and shall be reverified on site.

Verification activities shall be conducted in accordance with an approved Acceptance Test Procedure (ATP). The ATP shall include tests based on design criteria and all requirements of this specification. Additional testing shall include: ________________.

4.1.1 System verification

4.1.2 **System interface verification.** The system interface shall be verified by ________________.

4.2 **System performance verification.** System performance shall be verified by ________________

4.3 Air vehicle subsystem

4.3.1 **Flight performance.** Flight performance shall be verified by ________________.

4.3.1.1 **Performance characteristics.** Performance characteristics shall be verified by ________________. In addition, the USAF shall have the right to conduct any additional tests to verify that performance requirements have been met. The simulator shall be comprehensively tested in accordance with tables VII and VIII. All tests of table VII shall be automated. Individual test cases shall be initialized, conducted, and results output as a consequence of a test number input at the instructor/operator console. Test results shall be scaled appropriately to allow an exact overlay with the flight test acceptance data. Where appropriate, video data from flight testing may be used as table VII criteria. The test to be conducted shall be developed by the contractor and as a minimum shall comply with the requirements specified herein. These tests shall be presented in the test procedures document for USAF review and approval. Table VII performance tests will use flight test data as quantitative criteria. Table VIII functional tests are subjective tests by qualified U.S. Air Force pilots. Simulator characteristics shall be modified to satisfy subjective pilot opinion resulting from table VIII tests. Table VII results will take precedence over pilot opinion should a conflict arise. Tests from tables VII and VIII may be interchanged/modified when authorized by the procuring agency.

TABLE VII. Performance tests.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
1. CONTROL SYSTEM			
a. Static pitch force and control position vs surface position	(1)	Ground	1 lb/0.5° or 5% beyond BOF[2] 0.25 lb/0.25° within BOF
b. Static roll force and control position vs surface position	(1)	Ground	1 lb/0.5° or 5% beyond BOF; 0.25/0.25° within BOF
c. Static pedal force and control position vs surface position	(2)	Ground-SAS on and off	2 lb/0.5° or 5% beyond BOF; 1 lb/0.5° within BOF
d. Dynamic (1) pitch control and surface position vs control force	(5)	Low and high speed at low and high altitude plus PA	5°/10°/20° @ 0.25, 0.5, 1.0 Hz respectively
e. Dynamic (1) roll control and surface position vs control force	(5)	Low and high speed at low and high altitude plus PA	5°/10°/20° @ 0.25, 0.5, 1.0 Hz respectively
f. Dynamic (1) rudder pedal control and surface position vs force	(10)	Low and high speed at low and high altitude plus PA. (SAS on and off)	5°/10°/20° @ 0.25, 0.5, 1.0 Hz respectively
g. Trim control authorities and rates	(9)	Ground, low and high speed (each axis)	0.5 degrees/10%

TABLE VII. Performance tests - continued.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
h. Transient trim control response (surface position vs time)	(9)	Ground, low and high speed (each axis)	.2°/10%
i. Flap and speedbrake authorities and extension/retraction time	(3)	Ground and in-flight (PA and high speed)	0.5°/5%
j. Control surface authorities vs airspeed	(9)	Low, intermediate, high speed at mid altitude (each control axis)	1° or 5%
2. TAKEOFF/CLIMBOUT			
a. Engine idle - value of N1, N2; EPR; W_f; TIT; and TLA	(1)	Ground static std day	Note (5)
b. Ground acceleration (distance vs velocity)	(2)	Light & heavy GW	100 ft or 10%
c. Takeoff power - stabilized EPR; W_f; and TIT		Ground, during takeoff acceleration, std day	Note (5)
d. Minimum unstick speed	(2)	Light & heavy GW	2 kts
e. Initial climbout airspeed rate of climb, N and TIT		Std and hot days	2 kts, 200 fpm and

TABLE VII. Performance tests - continued.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
3. LONGITUDINAL CONTROL AND DYNAMICS			
a. Trim changes (force and stabilizer for gear, flaps, and speedbrakes	(5)	Approach and cruise airspeeds	1 lb, 1 or 10%
b. Speed stability (force and stabilizer) changeover + 20 kts	(6)	Cruise - low & high altitude for low & high speeds; PA-low/high GW	1 lb, 1° or 10%
c. Maneuvering stability (force and stabilizer/G)	(4)	Two altitudes at high and low speeds	0.5 lb/g, 0.2°/g or 10%
d. Short period dynamics (frequency & famping ratio)	(8)	PA-low/high GW: cruise--low, medium, high airspeed at low and high altitude	0.05 HZ, 0.03 DR² or 5%
e. Pitch response (attitude vs time)	(6)	PA, and cruise at low & high altitude for low & high airspeeds	0.5° or 5% for 10 sec
f. Phygoid dynamics (frequency & damping ratio)	(6)	PA-heavy & light GW, Cruise-two altitudes at medium & high speeds	4 sec, 0.03 DR or 10%
g. Buffet and stall AOA and load	(6)	PA at 1 G, cruise at 1 G accelerated G at 2 altitudes at medium & high speed	1°, 0.3 G or 5%

TABLE VII. Performance tests – continued.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
4. LATERAL/DIRECTIONAL CONTROL & DYNAMICS			
a. Roll response (bank angle vs time	(8)	Three airspeeds at 2 altitude in cruise two airspeeds in PA	3° or 5%
b. Directional stability (control forces, surface positions, and bank angle vs sideslip)	(8)	PA-heavy & lilght GW; cruise three airspeeds speeds at two altitudes	5 lbs, 1° or 10%
c. Dutch roll dynamics (frequency & damping ratio)	(8)	PA-heavy & light GW; cruise--three airspeeds at two altitudes	0.05 Hz, 0.03 DR or 10%
d. Spin (turn rate, altitude and airspeed)	(3)	Cruise	± 10 dps/5°/10 kts or 10%
e. Spin recovery (turns for recovery and altitude loss	(3)	Cruise	± 1/2 turn, ± 500 ft or 20%
5. PROPULSION SYSTEM			
a. Motoring Engine speed and oil pressure vs time	(2-6)	All motoring methods for std and non-std day	N2 (RPM) P_{OIL} (2 PSI)

TABLE VII. Performance tests - continued.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
b. Starting Engine instruments vs time	(8-12)	All starting methods for std, hot, cold and high altitude conditions (ground)	N_1 (2 RPM) N_2 (3 RPM) Temp (20 °C) W_f (10% or 200 PPH) P_{OIL} (4 PSI)
c. Throttle Burst/Chop (ground static) - Idle to TRT (or Mil) and return - Mil to max A/B and return (for A/B engines)	(4-16)	For std and non-std conditions, with min and max service bleed/ HP extraction	N_2 (2 RPM) N_1 (2 RPM) Temp (20 °C) W_f (10% or 200 PPH) P_{OIL} (4 PSI)
d. Throttle/Burst/Chop (in -flight) - Idle to Mil power/ normal power and return - Mil power to max A/B and return	(4-10)	For a medium and high altitude, for a low and high speed (and one supersonic speed for supersonic acft), with normal and max bleed/ HP extraction	N_2 (2 RPM) N_1 (2 RPM) Temp (20 °C) W_f (10% or 200 PPH) P_{OIL} (4 PSI)
e. Windmilling (in-flight)	(4-12)	For a medium and high altitude, for a low and high speed (and one supersonic speed for supersonic acft), and with/without a bleed/ HP extraction	N_2 (2 RPM) N_1 (2 RPM) Temp (10 °C) P_{OIL} (4 PSI)

TABLE VII. Performance tests - continued.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
6. FLIGHT PERFORMANCE			
a. Service ceilings (ROC = 100 fpm) and values of N_2, N_1; EPR; TIT; TLA	(4)	High & GW High & low airspeed	Note (5) ± 50 rpm
b. Minimum and maximum airspeeds and values of N_1, N_2; EPR; W_f; TIT; TLA	(8)	Low & high altitudes at high & low GW	± 2 knots See note (5)
c. Time to climb and rate of climb to service ceiling and values of N_1, N_2; EPR; W_f; TIT at three altitudes per climb schedule	(6)	Maximum power for std. hot and cold daya for high and low GW and intermediate power std day	20 sec or 10% 10% ROC See note (4)
d. Sustained G turn performance/ load factor vs airspeed	(6)	Low, med, high airspeed at low & med altitude	0.3 G or 10%
e. Acceleration at max continuous of full A/B --velocity vs time with values of N_1, N_2; EPR; W_f; TIT at mid and end point airspeed	(4)	1.4 v min--.95 v max for low/high GW at low/high altitude	10% See note (4)
f. Deceleration at idle power-- velocity vs time-- with values of N_1, N_2; EPR; W_f; TIT at mid and end point airspeeds	(4)	Low/high drag conf. Low/high altitude (.95 v max--1.4 v min)	10% See note (4)
g. One G trimmed level flight-- with values of N_1, N_2; EPR; W_f; TIT; TLA	(8)	Low/high altitude at low/high GW cruise plus PA configuration	See note (4)

TABLE VII. Performance tests - continued.

TEST	NO. TEST	FLT. CONDITIONS & CONFIGURATIONS	TOLERANCE
7. LANDING/STOPPING			
a. Power approach (ROD)[7] and AOA versus airspeed)	(4)	Hot and cold day Light and heavy weight	50 fpm, 0.5 ° or 10%
b. Crosswind landing approach (cockpit forces vs crosswind velocity)	(2)	10 kts crosswind and TBD crosswind	2 lbf or 10%
c. Stopping distances	(4)	Low and high RCR at high & low GW	200 ft or 10%

TABLE VIII. Functional tests.

TEST	OBJECTIVES
1. Preflight	o Cockpit physically and functionally reflects aircraft
2. Engine start procedures and characteristics	o Verify start procedures and instrufment readings; exercise all engine start methods and verify motoring features
3. Taxi	o Verify turning, braking, thrust response, and engine instrument readings
4. Takeoff and climb	
a. Ground steering	o Verify controllability for low and high speed
b. Normal takeoff	o Verify acceleration distance, rotation speeds, and climbout attitude
c. Initial climb	o Validate altitude, airspeed, rate of climb
d. Rejected takeoff	o Evaluate stopping distance
e. Maximum crosswind takeoff	o Determine maximum crosswind capability
f. Takeoff with engine failure at critical engine	o Verify capabillity
g. failure speed	o Verify controllability
h. Miminum control speed for single engine operation Exericse abnormal/emergency procedures associated with takeoff and climb	o Verify that aircraft procedures apply in same manner to simulator

TABLE VIII. Functional tests - continued.

TEST	OBJECTIVES
5. Maneuverability/Performance	
a. Trimability	o Evaluate capability to rim and maintain desired airspeed and altitude
b. Pitch, roll, yaw response	o Evaluate force and position workload required to make airspeed/altitude changes
c. Maneuverability	o Evaluate force variation with load factor and ease of turn coordination
d. Stalls/buffet	o Evaluate airspeed/AOA for buffet and stalls for load factors at and above IG
e. Engine airstarts	o Evaluate engine assist, crossbleed, and windmill airstart capability/envelope
6. Mission Features	
a. Low altitude bombing	o Evaluate low alt high speed stability and performance and weapons release
b. High altitude bombing	o Evaluate high alt high speed stability and performance and weapons release
c. Missile launch/gun firing	o Verify procedures for missile launch/gun firing and related aircraft stability and performance effects
d. Air refueling/formation flying	o Evaluate stabililty and performance in response to small control and throttle inputs and station keeping
e. Terrain following	o Evaluate stability and performance of low alt high speed flight in response to rapidly changing large control inputs

TABLE VIII. Functional test - continued.

TEST	OBJECTIVES
7. Approach & Landing	
a. Normal system approach and landing	o Evaluate controllability, approach speed, descent rate, and attitude
b. Trim and controllability due to configuation changes	o Evaluate landing gear, speedbrakes and flaps trim changes and controllability
c. Single and dual engine landing	o Evaluate controllability, flare, touchdown and rollout
d. Engine out missed approach	o Evaluate go around performance and controlability

4.3.2 **Tolerances for air vehicle subsystem design.** For parameters where no specific tolerance has been identified, the general tolerances serve as the default acceptance criteria. Thus, verification of this paragraph is accomplished on an "as required" basis.

4.3.3 **Environmental effects.** Quantitative tests shall be conducted which exercise the full capability of the PWT simulation. Measurement of PWT variables shall be taken at several different altitudes including the extremes for standard, hot, and cold days.

4.3.3.1 **Ground/cruise winds.** Both quantitative and qualitative tests shall be performed over the full range of ground and cruise winds at various altitudes including the extremes.

4.3.3.2 **Turbulence/gusts.** Both quantitative and qualitative tests shall be conducted over the full range of turbulence and gusts values at various altitudes.

4.3.3.3 **Airframe icing conditions.** Qualitative tests shall be performed to verify that the icing simulation has the proper effects on the aerodynamic characteristics of the simulator.

4.3.4 **Aural simulation.** Qualitative tests shall be conducted to evaluate the appropriateness of the sound simulation relative to location, frequency and amplitude.

4.3.4.1 **Ambient noise.** Subjective tests shall be performed to verify that simulator unique sounds are not audible to the student pilot when when the aural simulation is in normal operation.

4.3.5 **Crash.** A subjective evaluation of the crash indication shall be made based on the visual and/or aural indications required in the specification.

4.3.5.1 **Crash effects.** Qualitative tests shall be conducted which exercise each crash mode of the simulator individually.

4.3.5.2 **Crash override.** A subjective evaluation should be made of the crash override capability by activating it and then maneuvering the simulator through each crash condition to see if a crash occurs.

4.3.6 **Auto-trim.** Both quantitative and qualitative tests shall be conducted to determine if the auto-trim capability functions properly. Analog and/or digital outputs of appropriate variables shall be recorded before, during and after auto-trim has been activated via a freeze, reset, and reinitialization.

4.3.7 **Aircraft systems.** Both quantitative and qualitative tests shall be performed to verify the correct operation, interaction, and correlation among all aircraft systems included in the simulation. Malfunctions which may be introduced by the instructor and corrective actions taken by the student pilot shall also be evaluated. Tests shall be conducted on the ground and in flight as appropriate.

4.3.7.1 **Flight control system.** Verify by ________________. (See 4.3.7)

4.3.7.2 **Propulsion system.** Verify by ________________. (See 4.3.7)

4.3.7.3 **Starting system.** Verify by ________________. (See 4.3.7)

4.3.7.4 **Ignition system.** Verify by ________________. (See 4.3.7)

4.3.7.5 **Electrical system**. Verify by ________________. (See 4.3.7)

4.3.7.6 **Fuel system**. Verify by ________________. (See 4.3.7)

4.3.7.7 **Hydraulic system**. Verify by ________________. (See 4.3.7)

4.3.7.8 **Cockpit air conditioning**. Verify by ________________. (See 4.3.7)

4.3.7.9 **Oxygen system**. Functional checks of the oxygen system shall be performed along with air sampling tests of the breathing air to determine if it is pure, dry, and free of oil.

4.3.7.10 **Pilot ejection system**. Verify by ________________. (See 4.3.7)

4.3.7.11 **Engine fire and overheat detection/suppression system**. Verify by ________________. (See 4.3.7)

4.3.7.12 **Lighting**. Verify by ________________. (See 4.3.7)

4.3.7.13 **Personal equipment**. A visual inspection and functional check shall be performed to verify that the proper connections have been provided for the student pilots personal equipment (e.g., oxygen mask, communications equipment, etc).

4.4 **Computational subsystem**. Verify by ________________.

4.4.1 **Computational subsystem performance characteristics**. Verify by ________________.

4.4.1.1 **Interrupt provisions**. Verify by ________________.

4.4.1.2 **Interval timing provisions**. Verify by ________________.

4.4.1.3 **Time function provisions**. Verify by ________________.

4.4.1.4 **Training system ready provision**. Verify by ________________.

4.4.1.5 **Power failure provisions**. Verify by ________________.

4.4.2 **Computational subsystem hardware**. Verify by ________________.

4.4.2.1 **Computer/multiprocessor/multicomputer system**. Verify by ________________.

4.4.2.2 **Peripheral equipment**. Verify by ________________.

4.4.2.3 **Mass storage equipment**. Verify by ________________.

4.4.2.3.1 **Primary mass storage**. Verify by ________________.

4.4.2.3.2 **Secondary mass storage**. Verify by ________________.

4.4.2.4 Operator/support interface equipment. Verify by ________________.

4.4.2.4.1 Operator terminals. Verify by ________________.

4.4.2.4.2 Support terminals. Verify by ________________. (See 4.4.2.4.1)

4.4.2.4.3 Hardcopy equipment Verify by ________________.

4.4.2.4.4 Master operations console. Verify by __________.

4.4.2.5 Additional peripheral equipment. Verify by ________________.

4.4.2.6 Computational subsystem spare capacity and expansion capability. Verify by ________________. (See 4.4.2.2).

4.4.2.6.1 Spare processing time. Verify by ________________.

4.4.2.6.2 Spare memory or memory expansion capability. Verify by ________________.

4.4.2.6.3 Input/output expansion. Verify by ________________.

4.4.2.6.4 Interface hardware spare capacity. Verify by ________________. (See 4.4.2.6)

4.4.2.6.5 Primary mass storage spare and growth. Verify by ________________.

4.4.3 Computational subsystem computer software. Verify by ________________.

4.4.3.1 Programming language. Verify by ________________.

4.4.3.2 CPS organization and preparation. Verify by ________________.

4.4.3.3 Supervisor/executive software. Verify by ________________.

4.4.3.4 Debug computer software. Verify by ________________.

4.4.3.5 Mass storage copy/comparator software. Verify by ________________.

4.4.3.6 Computer equipment diagnostic computer software. Verify by ________________.

4.4.3.7 Interface hardware diagnostic computer software. Verify by ________________.

4.4.3.7.1 Discrete input and output diagnostics. Verify by ________________.

4.4.3.7.2 Analog input and output diagnostics. Verify by ________________.

4.4.3.8 Trainer equipment test computer software. Verify by ________________.

4.4.3.9 Calibration test computer software. Verify by ________________.

4.4.3.10 Operational readiness computer software. Verify by ________________.

4.4.3.11 **Spare capacity verification computer software.** Verify by ________________.

4.4.3.11.1 **Spare processing time verification computer software.** Verify by ________________.

4.4.3.11.2 **Spare memory/on-line primary mass storage verification computer software.** Verify by ________________.

4.5 **Instructional subsystem.** Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of the instructional subsystem.

4.5.1 **Instructional subsystem configuration.** Verify by ________________.

4.5.2 **Training exercise control.** Verify by ________________.

4.5.2.1 **Manual instructor controls.** Verify by ________________.

4.5.2.2 **Self instruction.** Verify by ________________.

4.5.3 **Data entry devices.** Verify by ________________.

4.5.4 **Display devices.** Verify by ________________.

4.5.4.1 **Display format.** Verify by ________________.

4.5.5 **Interphone communications system.** Verify by ________________.

4.6 **Motion simulators.** Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of motion simulator subsystems.

4.6.1 **Motion system components.** Verify by ________________.

4.6.2 **Motion system performance characteristics.** Verify by ________________.

4.6.2.1 **Simulated motions.** Verify by ________________.

4.6.2.1.1 **Motion activity.** Verify by ________________.

4.6.2.2 **Worst-case maneuvers.** Verify by ________________.

4.6.2.3 **Payload weight.** Verify by ________________.

4.6.2.4 **Step response.** Verify by ________________.

4.6.2.5 **Excursion and velocities.** Verify by ________________.

4.6.2.6 **Specific force and rotational acceleration.** Verify by ________________.

4.6.2.7 **Frequency response.** Verify by ________________.

4.6.2.8 Damping. Verify by ________________.

4.6.2.9 Smoothness. Verify by ________________.

4.6.2.10 Stability. Verify by ________________.

4.6.2.11 Static accuracy. Verify by ________________.

4.6.2.12 Crosstalk. Verify by ________________.

4.6.3 Motion system design considerations. Verify by ________________.

4.6.3.1 Motion system power, control, and maintenance features. Verify by ________________.

4.6.3.1.1 Power subsystem. Verify by ________________.

4.6.3.1.2 Power subsystem action. Verify by ________________.

4.6.3.1.3 Power subsystem maintenance concept. Verify by ________________.

4.6.3.1.4 Peak energy storage device. Verify by ________________.

4.6.3.1.5 Power subsystem fire safety/power medium stabilizer. Verify by ________________.

4.6.3.1.6 Power subsystem protection. Verify by ________________.

4.6.3.1.7 Energy transfer medium and control. Verify by ________________.

4.6.3.1.8 Energy potential safety devices. Verify by ________________.

4.6.3.1.9 Maintenance access. Verify by ________________.

4.6.3.1.10 Personnel access. Verify by ________________.

4.6.3.1.11 Structural design criteria. Verify by ________________.

4.6.3.1.12 Acoustic noise--maintenance areas. Verify by ________________.

4.6.3.2 Motion system controls and indicators. Verify by ________________.

4.6.3.2.1 Instructor station. Verify by ________________.

4.6.3.2.2 Crew station. Verify by ________________.

4.6.3.2.3 Maintenance and control features. Verify by ________________.

4.6.3.2.4 Energy medium controls. Verify by ________________.

4.6.4 **Structural interface with the facility.** Verify by ________________.

4.6.5 **Motion system design safety.** Verify by ________________.

4.6.5.1 **Design safety factors.** Verify by ________________.

4.6.5.2 **Rapid motion.** Verify by ________________.

4.6.5.2.1 **Abrupt motion.** Verify by ________________.

4.6.5.3 **Motion limits.** Verify by ________________.

4.6.5.4 **Settling of motion system.** Verify by ________________.

4.6.5.5 **Electrical interlocks.** Verify by ________________.

4.6.5.6 **Emergency egress.** Verify by ________________.

4.6.5.7 **Warning signs.** Verify by ________________.

4.6.5.8 **Safety barrier.** Verify by ________________.

4.6.5.9 **Motion system failures.** Verify by ________________.

4.6.6 **In-cockpit motion and force display requirements**

4.6.6.1 **In-cockpit motion display--major components.** Verify by ________________.

4.6.6.2 **Vibration and buffet system.** Verify by ________________.

4.6.6.2.1 **Vibration and buffet system performance requirements.** Verify by ________________.

4.6.6.2.2 **Vibration and buffet system control.** Verify by ________________.

4.6.6.3 **Anti-G suit system.** Verify by ________________

4.6.6.3.1 **Anti-G suit control.** Verify by ________________.

4.6.6.3.2 **Anti-G suit inflation/deflation rates.** Verify by ________________.

4.7 **Visual system.** The performance of the visual system, including the visual data base, visual image generator, and visual display subsystem, shall be verified.

4.7.1 **Training tasks and visual cues.** Analyses, demonstrations, and tests shall be conducted to verify that the visual system is capable of supplying the visual cues required to support the specified training tasks.

4.7.1.1 **Taxi, takeoff, and landing.** The ability of the system to support taxi, takeoff, and landing training shall be verified.

4.7.1.2 **Aerial refueling.** The ability of the system to support aerial refueling training shall be verified.

4.7.1.3 **Low level flight.** The ability of the system to support low level flight training shall be verified.

4.7.1.4 **Air-to-air combat.** The ability of the system to support air-to-air combat training shall be verified.

4.7.1.5 **Air-to-ground weapons delivery.** The ability of the system to support air-to-ground weapons delivery training shall be verified.

4.7.2 **Image generation.** The ability of the image generator to process the data base and present imagery on the display subsystem at real-time rates shall be verified.

4.7.2.1 **Scene elements.** The ability of the image generator to generate visual scenes possessing the characteristics discussed in the following subparagraphs shall be verified.

4.7.2.1.1 **Edge/surface capacity.** A test pattern shall be used to test the system capacity as specified in 3.7.2.1.1. This pattern shall be displayed both statically and dynamically. All edges/surfaces shall be displayed without any distracting visual effects.

4.7.2.1.2 **Lights--image generation.** A test pattern shall be used to test the system light capacity as specified in 3.7.2.1.2. The pattern shall consist of the required mixture of point, perspective, and special purpose lights. The pattern shall be portrayed statically to allow verification of the number of lights. The pattern shall also be displayed dynamically to demonstrate that all lights exhibit the proper characteristcs. The pattern shall include various directional, blink, and color characteristics for special purpose lights. All lights shall be displayed without any distracting visual effects.

4.7.2.1.3 **Surface shading.** The surface shading capability of the system shall be verified. A test pattern with a palette of the available colors or grey shades shall be displayed. A test data base shall also be used to demonstrate that the shading of representative surfaces is affected by surface orientation relative to the simulated sun, ambient light conditions, range from eyepoint, and visibility conditions. The test data base shall also exhibit the curved surface capability.

4.7.2.1.4 **Texture--image generation.** The texture capability of the image generator shall be verified. A test pattern shall be used to demonstrate that the specified number of texture patterns or types can be displayed simultaneously. In addition, a test data base shall be provided to demonstrate that texture can be portrayed in addition to the specified edge/polygon and light capacity of the system. The test data base shall be displayed under dynamic conditions to insure that texture patterns exhibit proper color and positional stability, perspective, occulting, and detail emergence effects.

4.7.2.1.5 **Cultural features--image generation.** The ability of the image generator to display culture features shall be verified.

4.7.2.1.6 **Terrain--image generation.** The ability of the image generator to display the terrain model shall be verified.

4.7.2.1.7 **Moving models--image generation.** The ability of the image generator to portray the specified number of simultaneous moving models shall be demonstrated. This shall include the capability to select a desired mode 1 from the library and display it in a dynamic environment which demonstrates the required freedom of movement. All moving models shall exhibit smooth motion and proper level of detail transitions, and shall be free of distracting visual effects.

4.7.2.2 **Computed visual range.** The capability of the system to provide continuous visual imagery from the eyepoint to the maximum computed visual range shall be verified. This shall be accomplished using an operational data base under known position and velocity conditions. With maximum visibility, the distance at which the lowest level of detail transitions into the scene should be determined. This is the observed maximum computed visual range. Transitions should be smooth and should exhibit no distracting effects.

4.7.2.3 **Atmospheric simulation.** The capability of the image generator to portray ambient light effects and sun illumination, haze and visibility restrictions, clouds, and a horizon shall be verified. A test data base which contains a mixture of terrain and culture features, moving models, lights, texture, and any other special effects shall be used. The proper effect of ambient light and sun position changes on all visual scene elements shall be demonstrated. The proper effect of haze and reduced visibility on all visual scene elements shall be demonstrated with all specified controls and under all ambient light conditions. Clear, overcast smooth, and overcast rugged (scud) cloud conditions shall be demonstrated with all specified controls and under all ambient light conditions. Horizon band effects shall be demonstrated under all ambient light conditions.

4.7.2.4 **Environment retrieval.** The capability of the image generator to retrieve the appropriate areas of the visual data base from mass storage and portray them at the proper levels of detail without any distracting visual effects shall be verified.

4.7.2.5 **Load management.** The capability of the image generator to accommodate overloads, recover gracefully from overloads, and maintain a near-capacity processing load shall be verified.

4.7.2.6 **Concentration of scene detail.** The capability of the image generator to concentrate image detail near the ownship position, or where training requirements dictate, shall be verified.

4.7.2.7 **Dynamic priority/occulting.** The capability of the image generator to properly compute and display the occulting relationships for scenes of the complexity provided by the visual data base shall be demonstrated.

4.7.2.8 **Anti-aliasing computation.** The capability of the image generator to provide effective anti-aliasing techniques shall be verified.

4.7.2.9 **Distracting visual effects.** The ability of the image generator to provide continuous dynamic visual scenes over long duration training sessions with a minimum of distracting visual effects shall be verified.

4.7.2.10 **Transport delay.** The ability of the image generator to operate within the specified limits for transport delay shall be verified.

4.7.2.11 **Update rate.** The ability of the image generator to use positional updates to compute imagery at the specified rate shall be verified.

4.7.2.12 **Dynamic response.** The ability of the image generator to properly react to all translational and rotational motion within the performance envelope of the ownship or specified moving models shall be verified.

4.7.2.13 **Special effects.** The ability of the image generator to portray all specified special effects shall be verified.

4.7.2.14 **Simulator compatibility**. Visual system compatibility with the host simulator shall be verified.

4.7.2.15 **Positional range and accuracy**. The ability of the visual system to portray simulated ownship and moving model position within the specified tolerances shall be verified. In addition, the capability to represent ownship and moving model position in a world-wide coordinate system shall be verified.

4.7.2.16 **Crash detection and display**. The ability of the image generator to detect collision with any object in the visual environment, and to signal a crash to the host computer shall be verified. The ability of the image generator to display a crash condition on command from the host system shall be verified.

4.7.3 **Visual environment**. Analyses, demonstrations, and tests shall be performed to verify the ability of the visual environment (data base) to support the specified training tasks.

4.7.3.1 **Visual system data base libraries**. The required content of the specified visual data base libraries shall be verified.

4.7.3.2 **Low altitude data base**. The character and area of coverage for the low altitude data base shall be verified.

4.7.3.2.1 **Terrain model**. The terrain model shall be verified with respect to requirements for smooth and continuous high fidelity portrayal of terrain from the near scene to the far scene.

4.7.3.2.2 **Culture features--data base**. The culture content of the data base shall be verified.

4.7.3.2.3 **Texture--data base**. The presence of texture descriptors for all specified terrain and culture objects in the data base shall be verified.

4.7.3.2.4 **Lights--data base**. The presence of specified obstruction, traffic, and general cultural lights in the data base shall be verified.

4.7.3.2.5 **Accuracy**. The ability of the data base to support the specified accuracy requirements shall be verified.

4.7.3.3 **Data base generation/modification**. The ability to generate new visual data base areas and update existing areas, as required, shall be verified.

4.7.4 **Visual display system**. Tests shall be conducted to verify the performance of the visual display system.

4.7.4.1 **Field of view**. A theodolite shall be set up at the pilot's eyepoint. If possible, total field of view measurements shall be made without cockpit obstruction. The theodolite may be moved within the specified head motion envelope; however, special precautions must be observed to maintain alignment. All other measurements shall be made from the pilot's eyepoint without moving the theodolite. For each of the specified angular requirements, the measured angle shall meet or exceed the specified requirement.

4.7.4.2 **Brightness.** Brightness shall be measured by setting up a calibrated Pritchard photometer (Photo Research model 1980 or equivalent) at the pilot's eye position. A uniform flat white field surrounding a 9 or 10 step linear grey scale chart shall be displayed. The uniform field should cover the entire field of view. The photometer shall be used to measure the brightness of the peak white in the center, and of the flat field of random locations throughout the field of view.

When measuring area brightness, an aperture which covers at least 10 raster lines shall be used. The center brightness shall meet or exceed the specified brightness. The worst case high and low brightness readings shall be used to determine brightness uniformity. A similar procedure shall be used to determine the performance parameters for multiple window displays.

4.7.4.3 **Resolution/modulation transfer function.** For systems using camera model or pure optical systems, resolution test charts having horizontal and vertical bar charts corresponding to the specified resolutions shall be substituted for the model. For computer generated image systems, the resolution pattern shall be computer generated.

Resolution and MTF shall be measured using the observer camera or similar technique except for display systems using shadow mask CRTs. The observer camera/test equipment shall be one whose (1) output signal is linearly proportional to the brightness of the object observed, (2) MTF lies between 100 percent and 90 percent from 0 to 100 tv lines, (3) lens is chosen such that the observed resolution pattern uses less than 100 tv lines resolution on the observer camera (i.e., long focal length lens), (4) sensitivity is high enough to enable pickup of the low light level image on the display using a relatively small aperture.

The observer camera/test equipment shall be set up in the cockpit at the pilot's eye position. A black to white test pattern shall be observed through the display by the observer camera. The camera shall be focused and the output signal shall represent 100 percent modulation. The resolution test patterns shall then be observed by the camera and the video signal analyzed to determine the percent modulation for each of the specified resolutions. For vertical resolutions, the observer camera must be rotated 90 degrees. The modulations so determined must equal or exceed those specified.

4.7.4.4 **Contrast ratio.** A standard window pattern consisting of a white block inside a black background shall be displayed. The white area shall be approximately half the dimensions of the background (i.e., for a 36 degree by 48 degree field of view, the white block should be about 18 degrees by 24 degrees). A calibrated Pritchard photometer (Photo Research model 1980 or equivalent) with a 15-minute aperture shall be placed at the pilot's eyepoint. The white area and black area shall be placed at the pilot's eyepoint. The white area and black area shall both be measured in ft-lamberts at points approximately 1/2 the specified separation distance from the white/black transition. With this data recorded, the contrast ratio (CR) shall be: ________________ .

4.7.4.5 **Collimation quality.** For collimated displays, a dot pattern consisting of a minimum of 10 rows by 10 columns of equally spaced dots shall be generated by the visual system and fed into the display. Collimation quality shall be measured using a standard parallel telescope consisting of two parallel collimated and calibrated monoculars separated by an interocular distance of 70 mm. One of the monoculars shall have article calibrated in diopters. The test shall be conducted by measuring collimation with the telescope placed at the pilot's eye point. A sufficient number of dots shall be measured to ensure compliance throughout the field of view. Lateral deviations observed through the parallel telescope shall represent convergence/divergence errors. Vertical deviations represent dipvergence.

For real-time displays, the distance from the pilot's design eyepoint to the screen shall be measured at a sufficient number of positions to ensure compliance with the specification. It is also possible to verify this requirement through analysis.

4.7.4.6 **Viewing volume.** The design eyepoint at the center of the viewing volume shall be identified. The display shall be observed from the pilot's eyepoint and from all positions within the specified exit pupil. No excessive gap angles, geometric distortion or other degrading optical effects shall be observable.

4.7.4.7 **Geometric distortion.** A dot pattern consisting of a minimum of 10 rows by 10 columns of equal angularly spaced dots shall be generated by the image generator and fed into the display. A theodolite shall be placed at the pilot's eyepoint and the angular position of the dots in the display shall be measured. Deviations of the actual position from the theoretical dot position expressed as a percentage of the total angular picture height represents the geometric distortion. A sufficient number of points shall be chosen to ensure compliance throughout the field of view. Note: A standard dot pattern may be used if the theoretical angular position of each dot is calculated.

4.7.4.8 **Color convergence.** A dot pattern consisting of a minimum of 10 rows by 10 columns of dots shall be displayed. A theodolite shall be set up at the pilot's eye position. The convergence accuracy shall be determined by measuring the angular displacement of the three primary color dots. A sufficient number of dots shall be measured in each of the specified areas to ensure compliance throughout the field of view.

4.7.4.9 **Video signal-to-noise ratio.** A wide band oscilloscope (Tektronix 7000 series or equivalent) shall be used to measure video signal-to-noise ratio using the tangential method. The signal shall be connected to both channels of the two channel scope with alternate sweep used. For each noise measurement, the identical position shall be aligned on both traces. With both channels identically calibrated, the voltage offset shall be adjusted until the dark band between the two noise traces just disappears. After the signal has been removed from the input, the separation between the two noise-free traces shall represent twice the RMS noise. The peak-to-peak video signal shall equal the difference between the peak white and peak black levels. Pedestal and sync levels shall not be considered as part of the signal level for S/N purposes. Signal-to-noise shall be defined as:

S/N = 20 log (base 10) ((peak-to-peak video)/(RMS noise))

4.7.4.10 **Sweep signal-to-noise ratio.** The sweep signal-to-noise ratio shall be measured using the tangential method as described previously in "video signal-to-noise ratio". The sweep signals shall be measured with a high frequency current probe on the yoke, or with a voltage probe across the deflection feedback resistor. The peak-to-peak signal shall represent the voltage or current differences for the left/right or top/bottom deflection sweep. The sweep signal-to-noise ration shall be defined as:

S/N = 20 log (base 10) ((peak-to-peak sweep)/(RMS noise))

4.7.4.11 **Blemishes.** A flat white field of medium to high intensity shall be displayed. A theodolite shall be placed at the pilot's eye position. The size of each blemish shall be measured in arc-minutes. Each blemish shall be logged onto a blemish map showing relative size and position. The number and size of blemishes shall not exceed those specified.

4.7.4.12 **Image continuity.** A small pattern or target shall be displayed along an edge between two adjacent displays. A theodolite set up at the pilot's eye position shall be used to determine the maximum mismatch between the two images. The error shall not exceed the specified amount.

4.7.4.13 **Swimming.** Swimming shall be verified by inspection.

4.7.4.14 **Spurious images.** Each of the specified spurious images shall be determined by inspection. To ensure a valid test, instrument panel lights shall be set to maximum. A small bright object shall be moved dynamically through the field of view against a dark background. Spurious images may appear as dimmer images traveling in the same or opposite directions form the target image.

4.7.4.15 **Grey scale.** A ____(a)____ step linear grey scale test pattern shall be placed onto the display such that the entire pattern is visible from the pilot's eye position. For camera model or optical systems, this pattern shall be generated by substituting a ____(a)____-step linear reflectance grey scale test chart in place of the model aircraft. For computer generated image systems, the grey scale shall be generated by the computer. Each of the grey step levels shall be measured in the display with a Pritchard Photometer (Photo Research model 1980 or equivalent) placed at the pilot's eye position. The grey scale steps in ft-lamberts shall be ____(b)____ of the total brightness.

4.7.4.16 **Display refresh rate.** The specified display refresh rate shall be verified.

4.7.4.17 **Shrouding and access.** Verify by demonstration.

4.7.4.18 **Maintenance of the visual system display.** Verify by inspection.

4.7.4.19 **Repeater monitor.** Verify by inspection.

4.7.4.20 **Remote alignment control.** Verify by demonstration.

4.8 **Electronic combat simulation.** Tests, demonstrations, inspections, and analyses shall be conducted to verify the EC simulation.

4.8.1 **Electronic combat equipment simulation.** Inspection shall be conducted to verify the present of all required equipment. Tests shall be conducted to verify that the equipment operates correctly when integrated.

4.8.2 **Electronic combat environment.** Verifications identified in subsequent paragraphs shall be conducted.

4.8.2.1 **Jammer, artillery, radar, missile systems**

4.8.2.1.1 **JARM library.** Inspections shall be conducted to verify the presence of all required JARMs and accuracy of JARM data in the library.

4.8.2.1.2 **JARM simulation.** Tests shall be conducted to verify the correct simulation of all JARMs in the library.

4.8.2.1.3 **JARM platforms/JARM sites.** Tests shall be conducted to verify the dynamics of JARM platforms and the control of JARM sites.

4.8.2.1.4 **JARM countermeasures evaluation and tactics.** Inspections and tests shall be conducted to verify the correct tactics are simulated for each JARM and that the effects of ownship actions are correctly interpreted and acted upon.

4.8.2.1.5 **JARM weapons.** Tests shall be conducted to verify the weapons dynamics are correct. Inspections shall be performed to verify the basic algorithms for lethality. Integrated performance of all weapons effects shall be tested as part of the missions.

4.8.2.1.6 **JARM editing.** Tests shall be conducted to verify JARM editing.

4.8.2.2 **Mission electronic combat environment.** Tests shall be conducted to verify the limits of the MECE.

4.8.2.3 **Instanteous electronic combat environment.** Specific tests shall be conducted to verify the limits of each IECE parameter.

4.8.2.3.1 **JARM occulting.** Tests shall be conducted to verify the correctness of the JARM occult function.

4.9 **Digital radar landmass subsystem.** Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of the radar subsystem.

4.9.1 **General DRLMS requirements**

4.9.1.1 **DRLMS system accuracy.** DRLMS system accuracy shall be quantitatively measured.

4.9.1.1.1 **Terrain elevation accuracy.** Terrain elevation accuracy shall be verified by ________________.

4.9.1.1.2 **Planimetry elevation accuracy.** Planimetry elevation accuracy shall be verified by ________________.

4.9.1.1.3 **Planimetry location accuracy.** Planimetry location accuracy shall be verified by ________________.

4.9.1.1.4 **Planimetry orientation accuracy.** Planimetry orientation accuracy shall be verified by ________________.

4.9.1.2 **DRLMS system resolution.** DRLMS system resolution shall be verified in both range and azimuth by ________________.

4.9.1.3 **DRLMS processing.** DRLMS processing requirements shall be verified by ________________.

4.9.1.4 **Data base coordinate system.** Data base coordinate system requirements shall be verified within the limits of geographic coverage by ________________.

4.9.1.5 **Correlation with other systems.** DRLMS correlation with other simulator systems shall be verified by ________________.

4.9.1.6 **DRLMS positioning.** The capability to reset DRLMS position anywhere within the data base within the required time shall be verified by ________________.

4.9.1.7 **DRLMS terrain occulting.** DRLMS capability to compute terrain occulting and provide this information to other simulator systems shall be verified by ________________.

4.9.2 **Radar controls and displays.** Replication of all required controls and displays, and simulation of system operating modes and capabilities shall be verified by ________________.

4.9.3 **Radar systems operational capabilities.** The modes of operation, unique characteristics, and required malfunctions shall be verified by ________________.

4.9.4 **Radar effects.** Each required radar effect shall be verified by ________________.

4.9.5 **Radar landmass digital data base**

4.9.5.1 **DMA digital data base.** Tests shall be conducted to verify the performance of the data base.

4.9.5.2 **Radar digital data base.** The requirements for the DDBTP shall be verified. Verification of DDB mass storage requirements and image generation outside the radar data base shall be accomplished by ________________.

4.9.5.3 **DDB densities.** Accommodations of the required levels of DMA data shall be verified by ________________. DDB density requirements for feature analysis data shall be verified by ________________.

4.9.5.4 **DDB levels.** The required assignment of DMA DDB levels of data to each mode and range selection shall be verified by ________________.

4.9.5.5 **Radar reflectivity codes.** All required levels of reflectivity codes and their required dynamic range shall be verified by ________________.

4.9.5.6 **Object data.** The library of objects shall be verified.

4.9.5.6.1 **Electronic combat ground sites.** Tests shall be conducted to verify that EC ground sites can be inserted into missions and the radar cross sections are correct. At least ________________ samples shall be tested as well as test missions. Positions of EC ground sites shall be checked for correlation.

4.9.5.6.2 **Air targets.** Tests shall be conducted to verify that all air targets can be simulated and that the positions correlate with other functions.

4.9.5.6.3 **Beacons.** Tests shall be conducted to verify that all types of beacons and beacon codes are correctly simulated.

4.9.5.6.4 **Expendables.** Tests shall be conducted to verify the simulation of expendables. These tests shall include each type of expendable and shall include observing the expendable over a period of time.

4.9.6 **DRLMS control system and console.** Operations and control capabilities of the DRLMS control system and console shall be verified by ________________.

4.9.7 **DRLMS modes of operations**

4.9.7.1 **Independent mode.** DRLMS operation in the independent mode shall be verified by ________________.

4.9.7.2 **Integrated mode.** DRLMS operation in the integrated mode shall be verified by ________________.

4.9.7.3 **Digital data base update mode.** Each required data base update capability and the data base management system shall be verified by ________________.

4.9.7.4 **DRLMS test map mode.** Each required DRLMS test map and the associated DRLMS positioning capability shall be verified by ________________.

4.10 **Avionics systems simulation/stimulation.** Inspections shall be performed to verify that all subsystems and equipments are provided.

4.10.1 **Avionics architecture.** Tests shall be conducted to verify that all functions are provided.

4.10.1.1 **Operational flight program.** Tests shall be conducted to verify the performance of OFPs. Each simulated OFP shall be completely exercised through all modes.

4.10.2 **Navigation subsystem simulation.** Tests shall be conducted to verify that the navigation subsystem has been simulated in accordance with the design criteria.

4.10.2.1 **Navigation subsystem accuracy**

4.10.2.1.1 **Absolute accuracy.** Navigation subsystem absolute accuracy requirements shall be verified by ________________.

4.10.2.1.2 **Relative accuracy.** Navigational subsystem relative accuracy requirements shall be verified by ________________.

4.10.2.2 **Navigation controls, displays, and indicators.** Replications of all required controls, displays, and indicators and simulation of system operating modes and capabilities shall be verified by ________________.

4.10.2.3 **Navigation operational capabilities.** The modes of operation, unique characteristics, and required malfunctions shall be verified by ________________.

4.10.2.4 **Navigation data bases**

4.10.2.4.1 **Celestial data base.** The celestial data base content and accuracy shall be verified by ________________.

4.10.2.4.2 **Topographic elevation data base.** Topographic elevation data base content and accuracy shall be verified by ________________.

4.10.2.4.3 **Pressure, wind, temperature (PWT) data base.** Pressure wind temperature data base content and accuracy shall be verified by ________________.

4.10.2.4.4 **Magnetic variation data base.** Magnetic variation data base content and accuracy shall be verified by ________________.

4.10.3 **Communications subsystem simulation.** Verify by ________________.

4.10.4 **Mission avionics subsystem simulation.** Verify by ________________.

4.10.4.1 Weapons control. Verify by ________________.

4.10.4.2 Weapons. Verify by ________________.

4.10.5 Flight management subsystem simulation. Verify by ________________.

4.10.6 Radar simulation. Verify by ________________.

4.10.7 Electronic combat subsystem simulation. Verify by ________________.

4.10.8 Avionics controls and displays. Verify by ________________.

4.11 Trainer support subsystem. Verify by ________________.

4.11.1 TSS mass storage equipment. Verify by ________________.

4.11.2 Modification support terminals. Verify by ________________.

4.11.3 TSS hardcopy equipment. Verify by ________________.

4.11.4 Additional modification support peripheral equipment. Verify by ________________.

4.11.5 TSS memory growth. Verify by ________________.

4.11.6 TSS mass storage spare and growth. Verify by ________________.

4.11.7 TSS I/O expansion. Verify by ________________.

4.11.8 TSS maintenance and test computer programs. Verify by ________________.

4.11.8.1 TSS computer equipment diagnostic computer programs. Verify by ________________.

4.11.8.2 TSS equipment test computer programs. Verify by ________________.

4.11.8.3 Spare memory and mass storage verification computer programs. Verify by ________________.

4.11.9 Modification support computer program/data. Verify by ________________

4.11.9.1 TSS operating system. Verify by ________________.

4.11.9.2 Compilers/assemblers. Verify by ________________.

4.11.9.3 Loaders. Verify by ________________.

4.11.9.4 Standard libraries. Verify by ________________.

4.11.9.5 Data base management computer programs. Verify by ________________.

4.11.9.6 **Text editors.** Verify by ________________.

4.11.9.7 **Development tools.** Verify by ________________.

4.11.9.8 **Mass storage copy/comparator software.** Verify by ________________.

4.11.10 **Computational software tree.** Verify by ________________.

4.11.11 **CPS generation computer programs.** Verify by ________________.

4.12 **Practical design considerations.** Tests, inspections, analyses, and demonstrations shall be conducted as applicable to verify that these requirements have been satisfied.

4.12.1 **Air training device system design considerations.** Tests, inspections, analyses, and demonstrations shall be conducted as applicable, to verify that these requirements have been satisfied.

4.12.2 **Environmental conditions.** Verify by ________________.

4.12.2.1 **Thermal design.** Verify by ________________.

4.12.2.2 **Detrimental entrained contaminants.** Verify by ________________.

4.12.3 **Transportability.** Verify by ________________.

4.12.4 **Mechanical.** Verify by ________________.

4.12.5 **Workmanship.** Verify by ________________.

4.12.6 **Electromagnetic compatibility.** Verify by ________________.

4.12.7 **Training device electrical system requirements.** Verify by ________________

4.12.7.1 **Primary power.** Verify by ________________

4.12.7.2 **Main power distribution panel.** Verify by ________________.

4.12.7.2.1 **Utility power.** Verify by ________________

4.12.7.3 **Circuit design.** Verify by ________________.

4.12.7.3.1 **Tolerances for circuit design.** Verify by ________________.

4.12.7.3.2 **Overload protection.** Verify by ________________.

4.12.7.3.3 **Power conditioning.** Verify by ________________.

4.12.7.4 **Grounding and grounding systems.** Verify by ________________.

4.12.7.5 **Wire coding/identification.** Verify by ________________.

4.12.7.5.1 **Conductor identification.** Verify by ________________.

4.12.7.5.2 **Terminal ends.** Verify by ________________.

4.12.8 **Nameplates and product marking.** Verify by ________________.

4.12.8.1 **Reference symbol designations.** Verify by ________________.

4.12.8.2 **Precautionary markings.** Verify by ________________.

4.12.9 **Reliability and maintainability.** Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of the simulator subsystem.

4.12.9.1 **Reliability.** The minimum acceptable reliability shall be verified in accordance with the following: ________________.

4.12.9.2 **Maintainability.** The minimum acceptable maintainability shall be verified in accordance with the following: ________________.

4.12.9.2.1 **Time totalizer.** Verify by ________________.

4.12.10 **System safety design.** Tests, inspections, analyses, and demonstrations on the ATD shall be conducted and inspections and analyses of the contractors documentation shall be performed to verify the performance of the system safety design.

4.12.10.1 **Hazardous materials.** Verify by ________________.

4.12.10.2 **Fire detection.** Verify by ________________.

4.12.10.2.1 **Fire alarm.** Verify by ________________.

4.12.10.2.2 **Faciiilty fire control interface.** Verify by ________________.

4.12.10.3 **Overheat sensing.** Verify by ________________.

4.12.10.4 **Fire stop sealing.** Verify by ________________

4.12.10.5 **Emergency power off.** Verify by ________________.

4.12.10.6 **Emergency off switches.** Verify by ________________.

4.12.10.7 **Emergency communications.** Verify by ________________.

4.12.10.7.1 **Maintenance/safety intercom.** Verify by ________________.

4.12.10.8 **Safety and emergency lighting.** Verify by ________________.

4.12.10.9 **Acoustic noise--user areas.** Verify by ________________.

4.12.10.9.1 **Hazardous noise levels.** Verify by ________________.

4.12.10.9.2 **Speech interference noise level.** Verify by ________________.

5. PACKAGING

5.1 **Packaging requirements.** All deliverable items shall be prepared for shipment as directed by the procuring activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 **Intended use.** This specification is intended for use in developing flight simulators.

6.2 **Applicable terms**

6.2.1 **Computational terms.** The definition of terms specified herein shall apply to this specification.

6.2.1.1 **Auxiliary processing unit (APU).** An APU is a device which fits the definition of a CPU but is designed to operate in conjunction with a CPU. The instruction set of an APU must be a proper subset of the instruction set of the CPU which it supports.

6.2.1.2 **Background computer programs.** Background computer programs are those programs that are executed in the background mode of the operating system being used while the training mission is in progress. These programs are not time critical and as such their processing can be interrupted and carried over from one cycle to the next. For this specification, background computer programs shall be defined as a subset of the real-time computer programs.

6.2.1.3 **Bootstrap.** A bootstrap is the loading procedure which is followed to load a computer with a program or operating system which is contained on mass storage.

6.2.1.4 **Bussed system.** A bussed system is a system in which the elements of the system are physically mounted on circuit boards which plug into a common hardware bus to achieve interconnection.

6.2.1.5 **Central processing unit (CPU).** A CPU is a device contained in a digital computer which performs operations based upon digital information composed of machine instructions and data, and generates digital information which represents the results of the operations performed. The instruction set of the CPU may be fixed or programmable on a micro instruction level.

6.2.1.6 **Commercially available.** If an item is said to be commercially available, this means that the item is offered for sale to the general public and/or industry at established catalog or market prices.

6.2.1.7 **Computer data file (CDF).** A computer data file is a set of logically related data elements stored as a single entity such as a file on a magnetic disc (e.g., a terrain data file) or in a read-only memory (e.g., a character generator ROM).

6.2.1.8 Computer program component (CPC). A computer program component is a set of CPMs and/or CDFs grouped together as a result of a functional relationship between them. For example, a CPC may be a stand-alone computer program such as a compiler; or a CPC may be a set of modules (one or more) used in one particular functional aspect of the ATD such as driving the motion system (if one exists). In no case, however, shall a CPC be designated as the set of all CPMs and CDFs in the ATD--that designation is reserved for the CPS.

6.2.1.9 Computer program documentation. The descriptive material required to define the informational content and organization of the trainer computer programs is known as computer program documentation. This includes narrative descriptions of the systems being simulated, computer program source code, equations, models, flow charts, etc.

6.2.1.10 Computer program module. A computer program module is a simple, independent set of computer program code, identified such that it may be invoked (called) by other parts of the system, and perform one or more functions of the system. The code within a CPM must be, at a minimum, logically coherent. Ideally, a CPM should exhibit low coupling to the other elements of the system and be functionally coherent. The source code for a CPM must be capable of being compiled and/or assembled independent of all other CPMs.

6.2.1.11 Computer program system. The computer program system is the entire set of hardware, and digital data stored, manipulated, or otherwise utilized by the ATD computational resources.

6.2.1.12 Computer program system support. Those logistic procedures and resources necessary to accomplish trainer life cycle support through maintenance and modification of the computer program system constitute computer program system support. Support includes a configuration management system.

6.2.1.13 Computer program verification. Computer program verification is the determination of the accuracy of a computer program relative to the specified requirements, tolerances, and the approved design criteria.

6.2.1.14 Computer programs/data. In this specification, the expression "computer programs/data" means the same as computer programs and/or computer data (which includes firmware). The term generally implies a collection of computer programs and related computer data (i.e., CPMs and CDFs).

6.2.1.15 Coprocessor (COP). Sometimes referred to as a slave processor or extended processing unit, a coprocessor is a device which is used to enhance the operation of a CPU or APU. High speed floating-point arithmetic processors are forms of coprocessors.

6.2.1.16 CRT terminal. A CRT terminal is an electronic communications device consisting of a cathode ray tube (CRT) display for output and a keyboard for input.

6.2.1.17 Cycle. A cycle is a scheduled sequence of frames such that each unique frame is scheduled at least once. The time duration of a cycle (cycle time) should be greater than or equal to the period (1/f) of the minimum computer program component iteration rate.

6.2.1.18 Digital computer. A digital computer is an electronic machine which is used to perform high-speed computational, control, or data manipulation functions. It is physically composed of a CPU, zero or more APUs, zero or more coprocessors, memory, some form of input and output capability, and other necessary electronic components which enable the machine to function.

6.2.1.19 **Digital processing equipment.** Digital processing equipment includes (but is not limited to) general purpose (GP) digital computers (including GP microcomputers), special processors embedded in and dedicated to subsystem processing and/or interfacing (including other digital computers, microputers, microprocessors, or microcontroller systems) and any other product of digital processing technology.

6.2.1.20 **Disc image.** A disc image is a sector by sector dump of the entire contents of a magnetic disc.

6.2.1.21 **Double precision.** Double precision is that amount of precision which meets the extended precision requirements of a higher order language and is generally greater than single precision (usually double).

6.2.1.22 **Download.** When one processing unit loads the local memories of one or more other processing units with data and/or instructions, this process is known as downloading.

6.2.1.23 **Embedded.** Embedded means physically incorporated into a larger system or subsystem (i.e., integral) such that the larger system function is not general purpose data processing. The application may be hardware intensive or software intensive.

6.2.1.24 **Firmware.** Computer programs and/or computer data contained in electronic devices which cannot be readily modified (i.e., re-programmed) are called firmware. Programs and/or data contained in read-only memories (ROMs), programmable read-only memories (PROMs), erasable programmable read-only memories (EPROMs), micro-control stores, and other operationally read-only devices are considered to be firmware.

6.2.1.25 **Fixed-point arithmetic.** Fixed-point arithmetic is arithmetic in which basic arithmetic operations are performed on operands which are fixed-point numbers.

6.2.1.26 **Fixed point number.** A fixed-point number is a digital representation of an integer. The representation consists of a series of bits (binary number). The number of bits used depends upon the magnitude requirements of the particular application.

6.2.1.27 **Floating-point arithmetic.** Floating-point arithmetic is arithmetic in which basic arithmetic operations (e.g., addition, subtraction, multiplication, and division) are performed on operands which are floating-point numbers.

6.2.1.28 **Floating-point number.** A floating-point number is a digital representation of a real number. The representation consists of two parts, a mantissa and an exponent, each of which is represented as a series of bits (binary number). The number of bits used to represent the mantissa and exponent is dependent upon the precision and magnitude requirements of the particular application.

6.2.1.29 **General purpose digital computer.** A general purpose (GP) digital computer is a digital computer with randomly accessible memory, input/output interfaces, mass storage, power supplies, and any other associated hardware configured as a bussed system which is commercially available and is designed for flexibility in application.

6.2.1.30 **Hardware.** Hardware includes all physical components used in a system. In the case of a component such as a read-only memory, the physical component (i.e., chip) is hardware, while the program or data contained in the component is firmware. The same component may be manufactured with different contents so the contents are not considered to be hardware.

6.2.1.31 **Hardware intensive.** Those processing applications in which the function performed is fixed and for any change to occur, a modification and/or redesign of the hardware would be required are called hardware intensive.

6.2.1.32 **Hierarchical structure.** Hierarchical structure is a system structure in which there exists a relation between system components such that the components may make use of resources in components at a lower level in the hierarchy but may not make use of resources in components at the same or higher level in the hierarchy. This relation defines a partial ordering on the set of system components.

6.2.1.33 **Install.** To install means to make a computer program functional within the computational system.

6.2.1.34 **Instruction set.** The set of valid machine instructions on which a particular CPU will operate is called the instruction set of the CPU.

6.2.1.35 **Interactive computer programs.** Interactive computer programs are those computer programs which require communication (i.e., input/output (I/O)) with the user of the program. The user inputs generally take the form of I/O from a CRT or "user" terminal. Interactive programs may be required to execute as background computer programs (6.2.1.2) depending upon the functional requirements specified for the individual programs. Design of interactive programs does not preclude execution as non-real-time computer programs (6.2.1.45).

6.2.1.36 **Interface equipment.** Interface equipment is the equipment that controls, transmits, encodes, decodes, converts, or buffers analog, digital, discrete, serial, or parallel information passing between any elements of digital processing equipment.

6.2.1.37 **Machine instruction.** A machine instruction is a bit pattern that is interpreted by the executing control hardware in a CPU and causes the execution of a sequence of microinstructions.

6.2.1.38 **Macroinstruction.** A mnemonic instruction which causes a compiler or assembler to generate one or more machine instructions is known as a macroinstruction.

6.2.1.39 **Microinstruction.** A microinstruction is a bit pattern in high speed memory (normally non-volatile) which controls CPU hardware logic.

6.2.1.40 **Microprocessor.** A microprocessor is a CPU which is implemented as a single integrated circuit (chip) or chip-set by utilizing large-scale integration (LSI) or very large scale integration (VLSI) techniques.

6.2.1.41 **Mission support activities.** Mission support activities are those activities required for the day-to-day operation and maintenance of the training devices, and for the accomplishment of the training objectives of each mission (i.e., instructor lesson plan development/preparation).

6.2.1.42 **Modification support activities.** Modification support activities are those activities required for the long-term operational support, maintenance support, and modification of the training device (i.e., data base development/modification). These activities are characterized by the facts that they (1) could be performed at a remote site for later incorporation in the trainer, and (2) are not required in the normal day-to-day functioning of the trainer.

6.2.1.43 **Multicomputer complex.** A multicomputer complex exists when more than one computer configuration is used in the computational system equipment.

6.2.1.44 **Multiprocessor.** A multiprocessor shall be defined as a computer configuration having more than one processing unit.

6.2.1.45 **Non-real time computer programs.** Non-real time computer programs are those programs delivered as part of the computer program system which are executable on the training device while the training mission is not in progress.

6.2.1.46 **Object code.** Object code is code produced by an assembler or compiler consisting of machine instructions which are directly executable by the computer.

6.2.1.47 **Off-line.** Off line means interconnected with the computational system, but not controlled by the real-time executable program nor associated with real-time or non-real time computer programs.

6.2.1.48 **On-line.** On-line means interconnected with the computational system and controlled by the supervisor/executive program, required during operation in real-time or other operating system mode (e.g., background, or non-real time).

6.2.1.49 **Peripheral equipment.** Equipment connected to a digital computer through its input/output system and which is used to support the computer by providing additional non-processing capabilities such as mass storage, hardcopy, human interface, etc. is defined to be peripheral equipment.

6.2.1.50 **Primary mass storage media.** Primary mass storage is the mass storage media which is used to store the computer program system. Primary mass storage media must be compatible with the primary mass storage system.

6.2.1.51 **Processing unit.** The general term "processing unit" or "processor" is used when a requirement is applicable to all types of processing units used in the application. The types of processing units are central processing units (CPUs), auxiliary processing units (APUs), and coprocessors (CoPs). See individual definitions for more information.

6.2.1.52 **Processor word length.** Processor word length is the number of bits in the general purpose registers of processing units (CPUs and APUs) used to perform fixed-point arithmetic and logical operations. This length does not include bits used for parity check, error correcting, or other non-computing bits.

6.2.1.53 **Real-time clock.** A real time clock is a function which provides the real-world time to a computer system. This function can be implemented in either hardware or software as long as accuracy requirements are met.

6.2.1.54 **Real-time computer programs.** The computer programs which implement the simulated systems, control and simulation processing (executives, input/output, aircraft systems, instructional functions, etc) and all other programs which are executed while the training mission is in progress, including programs/data used by special processors whose functional requirements specify operation in "background" (6.2.1.2), are real-time computer programs and shall be considered such for the purposes of spare requirements verification.

6.2.1.55 **Simulator cold start.** A simulator cold start is defined to be the set of actions which must be taken and processes to be performed in order to generate the entire set of operational and support software used in or for the simulator. This shall include activities such as the operating system, assembly/compilation of all available source code, and the linking or task building process by which the software is configured into an operational format. This does not, however, include the source code development process.

6.2.1.56 **Simulator system.** A simulator system consists of the equipment, operational or simulated, which provides the displays, motion, and controls through which the students, instructors, and operators act upon or communicate with the ATD.

6.2.1.57 **Single precision.** Single precision is an amount of precision which meets the basic precision requirements of an HOL with respect to fixed-point and floating point number representation and arithmetic. It usually coincides with a multiple of the word length of the CPU (1x for fixed-point, 2x for floating-point).

6.2.1.58 **Soft failure.** A soft failure of computational equipment is a failure of the system to perform as specified but whose cause is not attributed to faulty hardware. Software failures ("bugs"), memory bit failures due to alpha particle radiation, and all other non-hardware failures are all considered to be soft failures for the purposes of this specification.

6.2.1.59 **Software.** Readily modifiable computer programs and/or computer data which enable a computer configuration (or multicomputer complex) to perform a specified function are known as software. (NOTE: Firmware is considered to be separate from software in this specification.)

6.2.1.60 **Software intensive.** A processing application is software intensive if its functioning can be modified by changing software, without modification to the associated hardware other than the software storage medium (e.g., firmware).

6.2.1.61 **Source code.** Source code is human readable computer program code which is subsequently assembled or compiled into computer executable object code.

6.2.1.62 **Structured programming techniques.** Structured programming techniques are those techniques used to facilitate straightforward design and implementation of computer programs. Included in these techniques are top-down design, modular organization, and the implementation of proper programs. A proper program is defined as a program which contains only one entrance and one exit.

6.2.1.63 **Sysgen.** A "sysgen" is the process used in the generation of a user-configured version of a standard vendor supplied operating system.

6.2.1.64 **Task.** A task is a collection of computer program components which is directly executable by a computer configuration.

6.2.1.65 **Top-down design.** Top-down design is a methodology for the development and organization (hierarchical structure) of a system in which the system is iteratively decomposed into components of increasing detail until the system is fully defined. This design methodology also requires that attention be paid early to component integration and interface design.

6.2.2 **Electronic combat environment (EC).** The electronic combat environment is defined using the following terms:

6.2.2.1 **JARM.** An acronym which stands for jammer, artillery, radar or missile system. It shall be used as a generic term for all simulated friendly and hostile systems external to the simulated aircraft which can search for the simulated aircraft, track the simulated aircraft, launch weapons against the simulated aircraft, or jam the simulated aircraft's electronic sensor systems. It includes simulated airborne and ground-based jamming systems, early warning radars, acquisition radars, height-finder radars, ground control intercept (GCI) radars, anti-aircraft artillery (AAA) systems, surface-to-air missile (SAM) systems, and airborne interceptor (AI) systems. Note that a JARM is the COMPLETE representation of the system, which includes weapons and any radar or other electronic signals as applicable. It does not include the simulation of the vehicle or platform associated with the JARM. A single JARM may have many "signals", and all are included when the JARM is scripted into a mission scenario. A JARM model may also transmit, receive, or be otherwise affected by other signals (such as communications and navigation systems) as required to produce the desired EC environment effects.

6.2.2.2 **Emitter.** The total simulated RF emission system associated with any JARM.

6.2.2.3 **JARM weapons.** The simulation of weapons that can be launched or fired by the system represented by the JARM. JARM weapons include the following for each simulated weapon that can be launched or fired:

a. Weapon visual characteristic (if visual subsystem).

b. Weapon sensor cross-section (if DRLMS, FLIR, etc).

c. Weapon dynamic characteristics.

d. Lethality algorithm (probability of kill, etc).

6.2.2.4 **Instantaneous electronic combat environment (IECE).** That set of JARMs which interact with or act upon the simulated ownship aircraft, or its simulated on-board systems at any instant of time. The IECE is always a subset of the ECE.

6.2.2.5 **JARM list.** The list of systems (friendly, hostile, neutral) which must be represented by JARMs for the EC subsystem. This list is usually classified, because it reveals the defensive/offensive capabilities of the US weapons system represented by the WST.

6.2.2.6 **Weapon visual characteristics.** The simulation of all properties of each JARM weapon required by the visual simulation subsystem (if any).

6.2.2.7 **Weapon dynamic characteristics.** The simulation of all properties of the movement of each JARM weapons system through space which are required for the simulation.

6.2.2.8 **Lethality algorithm.** A model of the damage introduced into the simulated aircraft by the simulated explosion/impact of a JARM weapon. It may be the function of the particular type of JARM weapon, the number of simulated rounds fired, and the spatial relationship between the JARM weapon and the simulated ownship aircraft at the time of explosion/impact.

6.2.3 **Abbreviations.** The following are abbreviations used in this document:

AI - airborne interceptor, articulation index
ANSI - American National Standards Institute
APU - auxiliary processing unit
ASPT - advanced simulator for pilot training
ATD - aircrew training device
CDF - computer data file
CPIN - computer program identification number
CPS - computer program system
CPU - central processing unit
CSC - computer software component
CST - computer software tree
CSU - computer software unit
DDB - digital data base
DDBTP - digital data base transformation program
DFAD - digital feature analysis data
DH - design handbook
DLMS - digital landmass system
DMA - Defense Mapping Agency
DN - design note
DRLMS - digital radar landmass system
DRU - digital remote-control unit
DTED - digital terrain elevation data
EC - electronic combat
ECP - engineering change proposal
FAA - Federal Aviation Administration
FPLA - field programmable logic array
GPS - global positioning system
HOL - higher order language
HUD - head up display
IECE - instantaneous electronic combat environment
INS - inertial navigation system
IPU - internal processing unit
JARM - jammer, artillery, radar, missile
MECE - mission electronic combat environment
NEMA - National Electrical Manufacturer's Association
NFPA - National Fire Protection Association
OFP - operational flight program
OFT - operational flight trainer
OS - operating system
P-P - peak-to-peak
PDL - programmable design language
PDR - preliminary design review
PPU - pre-production unit
PRF - pulse repetition frequency
PRI - pulse repetition interval
PROM - programmable read-only memory
PWT - pressure, wind, temperature
REIL - runway end identification light
ROM - read-only memory
RTS - run-time system
S/N - signal-to-noise (ratio)
SAR - synthetic aperture radar
SAS - stability augmentation system
TA/TF - terrain avoidance - terrain following
TSS - trainer support subsystem
WST - weapon system trainer

6.3 Subject term (key word) listing

acoustic
avionics
cockpit
crash
data base
display
ejection
field of view
interface
interrupt
memory
motion
operator
software
trainer
turbulence
velocity
vibration

6.4 **Specification tree.** Reference documents tree. The following list of documents comprises the first and second tier references. Only first tier references are contractually binding; second tier is for guidance only.

1st Tier		2nd Tier	
FED-STD-595	Colors	FED-STD-141	Paint, Varnish, Lacquer
		MIL-P-21600	Paint System, Fluorescent
		ASTM E 284	Terms Relating to Appearances of Materials
		ASTM E 308	Spectrophotometry and Description of Color in CIE 1931 System
		ASTM D 523	Specular Gloss
		ASTM D 1729	Visual Evaluation of Color Differences of Opaque Materials
		ASTM D 2244	Instrumental Evaluation of Color Differences of Opaque Materials
MIL-STD-210	Climatic Extremes	MIL-STD-810	Environmental Test Methods and Engineering Guidelines
		MIL-STD-1165	Environmental Engineering Terms
MIL-STD-454	Requirements for Electrical Equipment	MIL-I-983	Interior Communication Equipment, Naval Shipboard
		MIL-E-4158	Electronic Equipment, Ground
		MIL-E-5400	Electronic Equipment, Aerospace
		MIL-E-8189	Electronic Equipment, Missiles, Booster and Allied Vehicles
		DOD-E-8983	Electronic Equipment, Aerospace, Extended Space Environment
		MIL-P-11268	Electronic Equipment Parts, Materials, and Processes
		MIL-E-11991	Electronic, Electrical, and Electromechanical Equipment, Guided Missile and Associated Weapon Systems
		MIL-E-16400	Electronic Interior Communication and Navigation Equipment, Naval Ship and Shore
		MIL-F-18870	Fire Control Equipment, Naval Shipboard
		MIL-T-21200	Electronic Test Equipment (Not for New Design)
		MIL-T-28800	Electronic Test Equipment
		FAA-G-2100	Electronic Equipment

1st Tier		2nd Tier	
MIL-STD-1472	Human Engineering Design Criteria	MIL-W-5044	Walkway Compound, Nonslip
		MIL-W-5050	Walkway Coating and Matting, Nonslip, Aircraft Application
		MIL-L-5667	Lighting Equipment, Aircraft Instrument Panel
		MIL-P-7788	Panels, Information, Integrally Illuminated
		MIL-A-8806	Acoustical Noise Level in Aircraft
		MIL-S-008806	Sound Pressure Levels in Aircraft
		MIL-S-9479	Seat System, Upward Ejection, Aircraft
		MIL-M-18012	Markings for Aircrew Station Displays, Design
		MIL-S-18471	System, Aircrew Automated Escape, Ejection Seat Type
		MIL-A-23121	Aircraft Environmental, Escape and Survival Cockpit Capsule System
		MIL-T-23991	Training Devices, Military
		MIL-C-25050	Colors, Aeronautical Lights
		MIL-L-25467	Lighting, Integral, Red, Aircraft Instrument
		MIL-C-25969	Capsule, Emergency Escape
		FED-STD-515/17	Outside Rearview Mirror(s) for Automotive Vehicles
		FED-STD-595	Colors
		MIL-STD-12	Drawings, Specifications, and Standards Abbreviations
		MIL-STD-129	Marking for Shipment and Storage
		MIL-STD-130	U.S. Military Property Identification Markings
		MIL-STD-195	Marking of Connections for Electric Assemblies
		MIL-STD-203	Aircrew Station Controls and Displays for Fixed Wing Aircraft
		MIL-STD-250	Aircrew Station Controls and Displays for Rotary Wing Aircraft
		MIL-STD-280	Item Levels, Item Interchangeability, Models
		MIL-STD-411	Aircrew Station Signals
		MIL-STD-415	Test Provisions for Electronic Systems and Associated Equipment

(Continued)

1st Tier		2nd Tier	
MIL-STD-1472	Human Engineering Design Criteria (Continued)	MIL-STD-454	Requirements for Electronic Equipment
		MIL-STD-490	Specification Practices
		MIL-STD-681	Identification Coding of Hookup and Lead Wire
		MIL-STD-740	Airborne and Structureborne Noise Measurements
		MIL-STD-783	Legends for Use in Aircrew Stations and Airborne Equipment
		MIL-STD-850	Aircrew Station Vision Requirements
		MIL-STD-1179	Lamp, Reflectors and Signalling Equipment
		MIL-STD-1180	Safety Standards for Military Ground Vehicles
		MIL-STD-1247	Designations of Hose, Pipe and Tube lines for Aircraft, Missile, and Space Systems
		MIL-STD-1280	Keyboard Arrangements
		MIL-STD-1294	Acoustical Noise Limits in Helicopters
		MIL-STD-1333	Aircrew Station Geometry
		MIL-STD-1348	Knobs, Control, Selection of
		MIL-STD-1473	Requirements for Color and Marking of Army Materiel
		MIL-STD-1474	Noise Limits for Army Materiel
		DOD-HDBK-743	Anthropometry of US Military Personnel
		MIL-HDBK-759	Human Factors Engineering Design for Army Materiel
		OPNAVINST 5100.23B	Hearing Conservation Program
		AFR 161-35	Hazardous Noise Exposure
		29 CFR 1910	Occupational Safety and Health
		Human Engineering Guide to Equipment Design, 1972 Edition, US Government Printing Office, Washington DC, 20402.	
		Threshold Limit Values, American Conference of Government Industrial Hygenists, 1985.	
		ANSI S1.1 1960	Acoustical Terminology
		ANSI S1.4	Sound Level Meters
		ANSI S1.6 1967	Preferred Frequencies for Acoustical Measurements
		ANSI S3.2 1960	Monosyllabic Word Intelligibility
		ANSI S3.5 1969	Articulation Index
		ASTM E 380-84	Metric Practice
		ISO DIS 2631	Human Exposure to Whole Body Vibration
		SAE J925	Minimum Access Dimensions for Construction and Industrial Machinery

	1st Tier	2nd Tier	
MIL-STD-1800	Human Engineering Performance Requirements	MIL-M-18012	Markings for Aircrew Station Displays
		MIL-D-87213	Displays, Airborne
		FED-STD-595	Colors
		MIL-STD-280	Definitions of Item Levels, Item Exchangeability, Models
		MIL-STD-454	Requirements for Electronic Equipment
		MIL-STD-721	Effectiveness Terms for Reliability, and Maintainability Human Factors, and Safety
		MIL-STD-1472	Human Engineering Design Criteria for Military Systems
		MIL-STD-1776	Aircrew Station and Passenger Accommodations
		MIL-STD-1801	User/Computer Interface
		AFSC DH 1-3	Human Factors
		AFM 11-1	U.S. Air Force Glossary of Standardized Terms
		Emergency and Continuous Exposure Limits for Selected Airborne Contaminants, Volumes 1-5, National Research Council's Committee on Toxicology, National Academy Press, Washington DC, April 1984.	
		Threshold Limit Values and Biological Exposure Indices for 1985-1986, American Conference of Government Industrial Hygenists, 1985 (ISBN: 0-936712-61-9).	
MIL-STD-1801	User/Computer Interface	MIL-STD-12	Abbreviations for Use on Drawings, Specifications, and Standards
		MIL-STD-411	Aircrew Station Signals
		MIL-STD-783	Legends for Aircrew Stations
		MIL-STD-1280	Keyboard Arrangements
		MIL-STD-1472	Human Engineering Design Criteria for Military Systems
		AFM 11-1	U.S. Air Force Glossary of Standardized Terms

6.5 **Responsible engineering office.** The responsible engineering office (REO) for the technical maintenance of this document is ASD/ENETA. Requests for additional information or assistance can be obtained from Mr James Blair, ASD/ENETA, Wright-Patterson AFB OH 45433-6503, AUTOVON 785-4053, commercial (513) 255-4053. Any information relating to Government contracts must be obtained through contracting officers.

6.6 **Changes from previous issue.** Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodian:
Air Force - 11

Preparing Activity
Air Force - 11

Project No. 6930-F019

APPENDIX

SIMULATORS, FLIGHT

HANDBOOK FOR

10. SCOPE

10.1 **Scope.** This appendix provides rationale, guidance, lessons learned, and instructions necessary to tailor sections 3 and 4 of the basic specification (AFGS-87241A) for a specific application.

10.2 **Purpose.** This appendix provides information to assist the Government procuring activity in the use of AFGS-87241A.

10.3 **Use.** This appendix is designed to assist the project engineer in tailoring AFGS-87241A. The blanks of the basic specification shall be filled in to meet operational needs of the equipment being developed.

10.4 **Format.** Each requirement of sections 3 and 4 of the basic specification is discussed in section 30 of this appendix. The order, paragraph numbering, paragraph titles, and text of sections 3 and 4 are repeated exactly in section 30 to facilitate study. The discussion of each requirement is divided into three parts:

a. Rationale - The reason why this requirement exists; the purpose that this requirement advances.

b. Guidance - Instructions and principles for setting the values that are left blank in the basic specification, or for omitting the requirement altogether.

c. Lessons learned - Summaries of field experience relevant to this requirement.

10.5 **Responsible engineering office.** The responsible engineering office (REO) for this appendix is ASD/ENETA, Wright-Patterson AFB OH 45433-6503. The individual who has been assigned the responsibility for this handbook is Mr James L. Blair, ASD/ENETA, Wright-Patterson AFB OH 45433-6503, AUTOVON 785-4053, Commercial (513) 255-4053.

20. APPLICABLE DOCUMENTS

20.1 **References.** The documents referenced in this appendix are not intended to be applied contractually. Their primary purpose is to provide background information for the Government engineers responsible for developing the most appropriate performance values (filling in the blanks) for the requirements contained in the specification proper.

20.2 **Avoidance of tiering.** Should it be determined that the references contained in this appendix are necessary in writing an RFP or building a contract, excessive tiering shall be avoided by calling out only those portions of the reference which have direct applicability. It is a goal of the Department of Defense that the practice of referencing documents in their entirety be eliminated in order to reduce the tiering effect.

20.3 Government documents

SPECIFICATIONS

Military

MIL-H-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft, NATO Code Number H-537

STANDARDS

Military

MIL-STD-12	Abbreviations for Use on Drawings, and in Specifications, Standards and Technical Documents
MIL-STD-17	Mechanical Symbols for Aeronautical, Aerospacecraft, and Spacecraft Use
MIL-STD-130	Identification Marking of US Military Property
MIL-STD-188-124	Grounding, Bonding and Shielding for Common Long Haul/Tactical Communication Systems Including Ground Based Communications—Electronics Facilities and Equipments
MIL-STD-470	Maintainability Program for Systems and Equipment
MIL-STD-471	Maintainability Verification/Demonstration/Evaluation
MIL-STD-781	Reliability Design Qualification and Production Acceptance Tests: Exponential Distribution
MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
MIL-STD-1558	Six-Degree-of-Freedom Motion System Requirements for Aircrewmember Training Simulators
ANSI/MIL-STD-1815	Ada Programming Language
DOD-STD-2167	Defense System Software Development

20.3.1 Other Government documents

AFP 50-58	Handbook for Designers of Instructional Systems
AFM 51-50	Air Navigation
AFR 96-9	How to Establish Requirements for Maps, Charts, Geodetic Surveys, and Related Products and Services
AFR 800-18	Air Force Reliability and Maintainability Program
DODD 5000.29	FAA Reg AC 120-40 Airplane Simulator and Visual System Evaluation
FAA Reg AC 120-40	Airplane Simulator and Visual System Evaluation

Browder, G. B. and S. K. Butrimas. Visual Technology Research Simulator--Visual and Motion System Dynamics. Tech Report Nr NAVTRAEQUIPCEN IH-326. April 1981.

US Air Force. Scientific Advisory Board. Report of the USAF Scientific Advisory Board Ad Hoc Committee on Simulation Technology. April 1978.

US Naval Observatory. Nautical Almanac Office. *Air Almanac*. Washington, DC.

20.4 Nongovernment documents

ANSI X3.9-78	Programming Language FORTRAN
ANSI Y32.16 (IEEE 200-75)	Electrical and Electronics Parts and Equipment, Reference Designations for
ANSI Y32.2	Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Class Designation Letters)

30. PERFORMANCE REQUIREMENTS AND VERIFICATIONS

3.1 System description. The ___(a)___ training device (ATD) shall be used to train ___(b)___.

REQUIREMENT RATIONALE (3.1)

This paragraph generally describes the training device and its purpose.

REQUIREMENT GUIDANCE

a. Name and type of device (B-X WST, F-X OFT, etc).

b. Training objectives of the device, e.g., weapon system operation, instrument flying, normal and emergency procedures, etc.

REQUIREMENT LESSONS LEARNED

3.1.1 **Major components (subsystems).** The ATD shall consist of the following major components: __________.

REQUIREMENT RATIONALE (3.1.1)

This paragraph identifies the major subsystems of the training device.

REQUIREMENT GUIDANCE

A typical list of simulator major subsystems includes:

a. Air vehicle subsystem.

b. Computational subsystem.

c. Instructional subsystem.

d. Motion subsystem.

e. Visual subsystem.

f. Electronic combat subsystem.

g. Radar subsystem.

REQUIREMENT LESSONS LEARNED

3.1.2 **System interface requirements**

3.1.2.1 **Facility interface.** The ATD shall be physically and functionally compatible with the facility in which it is to be installed. As a minimum, the following areas shall be considered: __________.

REQUIREMENT RATIONALE (3.1.2.1)

The ATD must be compatible with the facility in which it will be installed. Thus, these interfaces must be defined "up front."

REQUIREMENT GUIDANCE

Typical interfaces include:

a. Space and layout.

b. Electrical power.

c. Air conditioning.

d. Water requirements.

e. Floor loading.

f. Fire detection and suppression.

g. Safety barriers and interlocks.

REQUIREMENT LESSONS LEARNED

3.1.2.1.1 **Primary electrical power.** A Government-furnished 4-wire, wye-connected, 3-phase, 60-Hertz, 120/208- and/or 277/480-volt electrical power source shall be provided and utilized by the ATD.

REQUIREMENT RATIONALE (3.1.2.1.1)

This paragraph defines the USAF standard primary electrical power source available to which the ATD must connect for safe and proper operation. The contractor must have this information to properly interface the ATD to the facility.

REQUIREMENT GUIDANCE

Provide the appropriate definition of the electrical system available on site to clearly define the electrical system requirements.

REQUIREMENT LESSONS LEARNED

3.1.2.1.2 **Primary power grounding system.** The neutral bus of each power service shall be connected to earth potential outside the trainer at a single point only, which shall be at the primary (or derived) power grounding point as defined in accordance with Article 250 of the National Electrical Code.

REQUIREMENT RATIONALE (3.1.2.1.2)

This paragraph defines the electrical primary power grounding system requirements to which the ATD must interface for safe and proper operation. The contractor must have this design information to properly design and interface the ATD to the facility.

REQUIREMENT GUIDANCE

Use these or another clearly defined grounding system requirement definition, e.g., MIL-STD-188-124A, Military Standard (for) Grounding Bonding and Shielding.

REQUIREMENT LESSONS LEARNED

A quality grounding system is critical to the correct operation of servo-systems as well as electronics hardware.

3.1.2.2 **Subsystem interface.** The subsystems shall be physically and functionally compatible with each other and shall produce properly correlated cues during all modes of training. Detailed interface requirements are ___________.

REQUIREMENT RATIONALE (3.1.2.2)

A correct interface is necessary for correct operation of the system.

REQUIREMENT GUIDANCE

Include the known interface detailed requirements here.

REQUIREMENT LESSONS LEARNED

4.1.2 **System interface verification.** The system interface shall be verified by ________.

VERIFICATION RATIONALE (4.1.2)

To assure compliance.

VERIFICATION GUIDANCE

Verify the interface completely to assure functional compatibility among the subsystems and with the facility.

VERIFICATION LESSONS LEARNED

Generation of the interface verification plan is, of necessity, performed late in the program. There is a tendency to test this area lightly or to check if subsystem testing indicates problems. This testing should not be taken lightly.

3.2 **System performance requirements.** The performance of the ATD shall be as specified herein and in accordance with the design criteria. As used herein, "design criteria" is the entire body of data which describes all aspects of the aircraft. Simulator performance characteristics shall be consistent with the approved design criteria. The aircraft equations of motion and critical aerodynamics functions shall be computed at a minimum iteration rate of ________ iterations per second.

REQUIREMENT RATIONALE (3.2)

This section specifies the minimum modelling and perceptual fidelity requirements of the ATD.

REQUIREMENT GUIDANCE

A minimum iteration rate should be specified. A recommended rule-of-thumb is to assure that this iteration rate is at least high enough to obtain ten samples per cycle of the highest frequency involved in the simulation this usually results in a reasonable mathematical representation of the simulated dynamic. In order to enhance the reduction of the time delays introduced by the simulation, it is advisable to specify an iteration rate which is compatible with (some multiple of) the update rates for the visual system and/or any avionics equipment to be incorporated into the simulator. Historically, simulator sampling rates have been 20 iterations per second or more. This rate has generally been high enough for modelling the aircraft dynamics but not necessarily high enough to satisfy the overall system delay requirements.

REQUIREMENT LESSONS LEARNED

The Advanced Simulator for Pilot Training (ASPT) at AFHRL/OT, Williams AFB AZ, was initially procured with an update rate of only 15 iterations per second. Subsequent experience with that device (particularly after it was decided to use it to simulate the A-10 and F-16 aircraft) led to a decision to upgrade the iteration rates to a minimum of 60 samples per second in order to overcome problems encountered as a result of the low update rate.

The digital simulation of continuous aircraft dynamics introduces both distortions and spurious time delays. The higher the digital sampling (iteration) rates, the closer the digital simulation resembles the modelled continuous plant dynamics--and the lower the attendant distortion and time delay. There is a trade-off which must be made regarding the acceptable distortion and time delay, and the cost involved in increasing sampling rates. It should be recognized that contributors to the spurious time delay include the basic operations of sampling and data reconstruction, lag dynamics in filters preceding the samplers or following the digital-to-analog converters, lag dynamics (and/or transport delays) associated with the display devices, and algorithms employed to approximate mathematical integration in the digital simulation process. A report which provides substantial insight regarding some sources of delays in a flight simulator is Browder, G.B., and S.K. Butrimas, Visual Technology Research Simulator - Visual and Motion System Dynamics, Tech. Rept. Nr. NAVTRAEQUIPCEN IH-326, April 1981.

3.2.1 **Fidelity-critical areas.** The contractor shall provide realistic simulation of the following functional areas considered critical: __________.

REQUIREMENT RATIONALE (3.2.1)

This section specifies those functional areas of critical importance to the training mission.

REQUIREMENT GUIDANCE

A typical list of those functional areas which may be critical follows. Any additional functional areas and that subset of this listing should be consistent with the training mission.

a. High acceleration/high speed flight characteristics.

b. Low speed flight characteristics.

c. Aerodynamic ground effect.

d. Aircraft attitude changes due to thrust changes.

e. Effects due to acceleration and deceleration.

f. Individual landing gear strut dynamics.

g. Asymmetric braking.

h. Nose wheel steering, rudder steering effectiveness, and elevator effectiveness.

i. Ground-air rotation transition.

j. Crosswind takeoff and landing characteristics.

k. Correlation of G-suit, G-seat, visual, cockpit, and subsystem cues.

l. Aircraft reaction to gear, flaps, speed brake movements, stores, weapons release, and gunfire.

m. Loss of braking.

REQUIREMENT LESSONS LEARNED

3.2.1.1 **System delays.** The simulator shall be designed to minimize temporal mismatches between simulator and actual aircraft events. The following requirement shall apply: __________.

REQUIREMENT RATIONALE (3.2.1.1)

This paragraph specifies the tolerance for simulator induced time delays and mismatches.

REQUIREMENT GUIDANCE

Time delay specifications are currently written in terms of the time it takes a particular display device to begin responding to a sharp (step) input. The published FAA requirement for air carriers and commercial operators of large aircraft is worded as follows: "Relative responses of the motion system, visual system, and cockpit (displays) shall be coupled closely to provide integrated sensory cues. These systems shall respond to abrupt pitch, roll, and yaw inputs at the pilot's position within 150 milliseconds of the time, but not before the time, when the aircraft would respond under the same conditions. Visual scene changes from steady state (conditions) shall not occur before the resulting motion onset but within the system dynamic response tolerance of 150 milliseconds." (The comments within parentheses are slightly modified from the stated requirement.) Another way of stating the requirement is taken from Navy specifications: "The delay between a sharp (step) input and system first response shall not exceed that of the design criteria by more than 150 milliseconds. Motion, force, and visual information displayed to the aircrew shall be correlated such that temporal synchronization errors among the information displayed by these systems does not exceed 20 milliseconds." The specific wording used should reflect the configuration of the simulator being procured. There is no empirical evidence that the 150-millisecond tolerance is too loose for some military applications. In fact, the F-16 requirements used 130 milliseconds rather than 150. The specification applied to the F-16 simulator was: "The simulator shall be designed to minimize system delays incurred as a result of the simulation process. Delays between a pilot-induced step input and the simulated system first response (cue onset), as perceived in the visual system, G-seat, instruments, and HUD PDU, shall not exceed a maximum time of 130 milliseconds."

REQUIREMENT LESSONS LEARNED

Minimizing the temporal mismatch may be accomplished by a number of means. The contractor may provide enhancements which include detailed characteristics of small motion aerodynamics, expanded aerodynamic computations to incorporate additional terms, refinements and/or additions to functional coefficients, and the selective structuring of iteration rate assignments to optimally accommodate the critical, visual-associated functions at the highest sampling rates. It should be the contractor's intent to minimize the critical path throughput delays by appropriate ordering of the computations.

3.2.1.2 **Tolerances (general).** The simulator shall be designed to operate in accordance with the approved design criteria within the tolerances specified herein. These tolerances shall be applicable throughout the entire range of operation. Unless otherwise specified, percentage tolerances are with respect to the approved design criteria for the same conditions as established in the simulator. The tolerances specified herein shall be applicable at any place the values may be read--for example, at the computer, instructor station, cockpit, etc.

REQUIREMENT RATIONALE (3.2.1.2)

This requirement establishes the tolerances for the simulator required to provide adequate training.

REQUIREMENT GUIDANCE

Include this paragraph in the basic specification to provide adequate tolerances sufficient for the mission of training.

REQUIREMENT LESSONS LEARNED

3.2.1.3 **Pressure, wind, temperature (PWT) simulation.** Pressure, wind, and temperature simulation shall provide a weather environment that appropriately affects aerodynamics, control systems characteristics, ground speed, and ground track during simulated flight operations.

REQUIREMENT RATIONALE (3.2.1.3)

PWT simulation is required to provide a complete environment simulation since they affect the flight and navigation functions.

REQUIREMENT GUIDANCE

This is an introductory paragraph.

REQUIREMENT LESSONS LEARNED

3.2.1.3.1 **PWT performance gaming area.** PWT shall automatically provide continuously variable wind speed and direction, atmospheric pressure, and outside air temperature along a flight path at constant true altitude, and variation of the same parameters with altitude changes by means of a preprogrammed model. These parameters shall be related according to the laws of physics. Wind speed shall be variable from ___(a)___, wind direction through 360 degrees and pressure altitude from ___(b)___, and outside air temperature from ___(c)___. Any amount of variation within the parameter ranges shall be possible between geographic points, a maximum of ___(d)___ apart. Additional data base requirements are in 3.10.

REQUIREMENT RATIONALE (3.2.1.3.1)

PWT performance parameters are required to establish the scope of the simulation complexity.

REQUIREMENT GUIDANCE

a. Insert the range of wind speed, normally 0 to 200 knots.

b. Insert the pressure altitude range, normally 0 to 3,000 feet.

c. Insert the outside temperature range, normally +50°C to -56°C.

d. Insert the maximum distance between geographic points, normally 50 nautical miles.

For example, the design approach to wind simulation should include the capability for wind direction changes of as much as 180 degrees over a 50-nautical-mile ground distance. The PWT gaming area should be specified, for example, as a rectangular area or hemisphere, and sea level to some altitude such as 50,000 or 60,000 feet.

REQUIREMENT LESSONS LEARNED

3.2.1.4 **Integrated combat environment simulation.** An integrated environment simulation shall be provided. It shall include correlated presentations of fixed jammer, artillery, radar, and missile systems (JARMs) in the visual, radar, and electronic combat simulations. It shall also include correlated cues for moving targets in these systems. All JARMs and moving targets shall be observable in the same position and exhibit the same dynamics. The cues observable by the aircrew shall be consistent. For example, an airborne interceptor shall be correctly displayed both in the visual and in the radar simulations with the electronic combat simulation indicating the interceptor's radar is in the correct mode based on its relative position. The control of moving targets shall be from a single source. The integrated environment simulation shall be an integral part of a preprogrammed training exercise.

REQUIREMENT RATIONALE (3.2.1.4)

The tactics environment must be correlated among all functional subsystem simulations.

REQUIREMENT GUIDANCE

The appropriate paragraphs in each functional subsystem may be referenced for items such as moving targets, fixed ground based targets, etc. The number of moving targets, etc. required to be simulated in each functional subsystem need not be the same. A close examination of the minimum requirements needed for training specific tasks should be analyzed closely since these requirements can significantly affect cost and can significantly influence the complexity and design of the mission generator process. It should be noted that some moving targets and their actions may only be observable on one (or some) subsystem displays. Examples of possible combinations may be provided which relate to the specific mission types to be trained in the ATD.

REQUIREMENT LESSONS LEARNED

3.2.1.4.1 **Moving targets.** Moving targets shall be available in any training exercise representing specific capabilities and radar cross sections of the following: ___(a)___. Moving targets shall be in motion and displayed simultaneously on appropriate aircraft systems. These moving targets shall consist of ___(b)___ airborne interceptors (AI), ___(c)___ hostile early warning aircraft and/or friendly aircraft, ___(d)___ naval ships, and ___(e)___ moving ground targets. Flight-paths, sea paths, or ground tracks shall be controlled via pre-programmed training exercises. Path simulation shall include the capability for the moving targets to respond to ownship maneuvers with realistic tactics. Tactics shall be editable as part of the preprogrammed training exercise. Manual control of moving targets shall be provided as follows: ___(f)___.

REQUIREMENT RATIONALE (3.2.1.4.1)

This requirement provides realistic training against moving targets. Manual control provides the instructor the ability to start, stop, and re-initialize attacks of AIs, naval ships, or ground vehicles.

REQUIREMENT GUIDANCE

a. Specify the visual and radar cross sectional areas of the particular ships, aircraft, and ground based vehicles to be simulated.

b. through e. Select appropriate numbers of moving targets for realistic training. Target motion profiles should be specified to include all degrees of motion. The capability to assign formation targets should also be specified if appropriate.

f. The degree of manual control shall be as follows:

(1) None.

(2) Control of one target on an instructor selectable basis from the instructor station.

REQUIREMENT LESSONS LEARNED

4.2 **System performance verification.** System performance shall be verified by ___________.

VERIFICATION RATIONALE (4.2)

To assure compliance.

VERIFICATION GUIDANCE

After the complete ATD has been fully defined, a comprehensive verification plan can be generated. As a minimum, iteration rates, time delays, tolerances, and PWT simulation will have to be verified at the system level. The same attention to detail should be provided here as was available during generation of the system and subsystem specifications.

VERIFICATION LESSONS LEARNED

The obvious fact that the subsystem specifications must be satisfied is seldom de-emphasized. Caution must be exercised during the difficult phases of system performance verification when factoring in the training need.

3.3 Air vehicle subsystem

3.3.1 **Flight performance.** The flight performance of the simulator shall be as specified herein and in accordance with the approved design criteria. As used herein, "design criteria" is the entire body of data which describes all aspects of the actual aircraft including flight test data. The contractor is responsible for obtaining all design criteria and reducing it as required for simulator use. All design criteria is subject to approval by the procuring agency.

REQUIREMENT RATIONALE (3.3.1)

This paragraph defines the design basis for the flight portion of the simulator and the body of data that will be used for USAF acceptance.

REQUIREMENT GUIDANCE

Basing the simulation on aircraft design criteria is an absolute must where flight test data is the most desirable type data.

REQUIREMENT LESSONS LEARNED

4.3 Air vehicle subsystem

4.3.1 **Flight performance.** Flight performance shall be verified by ________.

VERIFICATION RATIONALE (4.3.1)

To assure compliance.

VERIFICATION GUIDANCE

Inspection of design documentation in conjunction with performance of tests in tables VII and VIII (in specification) should be an adequate means of verification.

VERIFICATION LESSONS LEARNED

3.3.1.1 **Performance characteristics.** The simulator's performance and handling qualities shall be consistent with the approved design criteria.

REQUIREMENT RATIONALE (3.3.1.1)

A realistic simulation of handling characteristics is essential for training that will transfer to the actual aircraft.

REQUIREMENT GUIDANCE

Achievement of this performance goal will require an iterative verification process similar to that used by Federal Aviation Administration (FAA) for specifying commercial simulator requirements and the corresponding acceptance criteria.

REQUIREMENT LESSONS LEARNED

4.3.1.1 **Performance characteristics.** Performance characteristics shall be verified by ___________. In addition, the USAF shall have the right to conduct any additional tests to verify that performance requirements have been met. The simulator shall be comprehensively tested in accordance with tables VII and VIII. All tests of table VII shall be automated. Individual test cases shall be initialized, conducted, and results output as a consequence of a test number input at the instructor/operator console. Test results shall be scaled appropriately to allow an exact overlay with the flight test acceptance data. Where appropriate, video data from flight testing may be used as table VII criteria. The test to be conducted shall be developed by the contractor and as a minimum shall comply with the requirements specified herein. These tests shall be presented in the test procedures document for USAF review and approval. Table VII performance tests will use flight test data as quantitative criteria. Table VIII functional tests are subjective tests by qualified U.S. Air Force pilots. Simulator characteristics shall be modified to satisfy subjective pilot opinion resulting from table VIII tests. Table VII results will take precedence over pilot opinion should a conflict arise. Tests from tables VII and VIII may be interchanged/modified when authorized by the procuring agency.

VERIFICATION RATIONALE (4.3.1.1)

To assure compliance.

VERIFICATION GUIDANCE

Automated test results of table VII may make use of software generated parameters provided calibration curves between these parameters and actual cockpit instrument values (where existing) are validated and included in the test procedures document. (See tables VII and VIII in specification.)

VERIFICATION LESSONS LEARNED

3.3.2 **Tolerances for air vehicle subsystem design.** Performance tolerances not covered by a specific tolerances herein shall be in accordance with approved design criteria with the following listed general tolerances applicable:

a. Total mass ___(a)___.

b. Moments of inertia ___(b)___.

c. Angular acceleration ___(c)___.

d. Linear accelerations ___(d)___.

REQUIREMENT RATIONALE (3.3.2)

Specific tolerances may not be identified for every parameter. Hence, there is a need for some general guidelines to cover these situations.

REQUIREMENT GUIDANCE

a. through d. Tolerances used successfully on past USAF simulators for these parameters include:

(1) 1%.

(2) 1% or 0.1% of maximum value.

(3) 5%.

(5) 5%.

REQUIREMENT LESSONS LEARNED

4.3.2 **Tolerances for air vehicle subsystem design.** For parameters where no specific tolerance has been identified, the general tolerances serve as the default acceptance criteria. Thus, verification of this paragraph is accomplished on an "as required" basis.

VERIFICATION RATIONALE (4.3.2)

To assure compliance for parameters where no specific tolerance is specified.

VERIFICATION GUIDANCE

Measurement of particular parameters should be made wherever outputs of those parameters are available.

VERIFICATION LESSONS LEARNED

3.3.3 **Environmental effects.** Pressure, wind, and temperature (PWT) simulation shall be provided to allow a simulation of PWT effects on the aircraft aerodynamic and static performance. A standard, hot, and cold atmosphere (IAW MIL-STD-210) shall be modelled from 0 to ________ ft. Means shall be provided at the instructor/operator console to vary sea level ambient temperature and sea level barometric pressure.

REQUIREMENT RATIONALE (3.3.3)

To make the flight simulation complete and realistic, the ever-changing environment in which the aircraft operates must be included.

REQUIREMENT GUIDANCE

Fill in the blank with the aircraft ceiling altitude or similar value.

REQUIREMENT LESSONS LEARNED

4.3.3 **Environmental effects.** Quantitative tests shall be conducted which exercise the full capability of the PWT simulation. Measurement of PWT variables shall be taken at several different altitudes including the extremes for standard, hot, and cold days.

VERIFICATION RATIONALE (4.3.3)

To assure compliance.

VERIFICATION GUIDANCE

Use MIL-STD-210B as a basis for testing the PWT simulation.

VERIFICATION LESSONS LEARNED

3.3.3.1 **Ground/cruise winds.** The instructor/operator shall be able to select ground winds from ground level to ___(a)___ feet and cruise winds from ___(a)___ feet to ___(b)___ feet. Ground winds shall be selectable from ___(c)___ knots with ___(d)___-knot resolution and from ___(e)___ degrees with ___(f)___-degree resolution. Cruise winds shall be selectable in direction from ___(g)___ degrees with ___(h)___-degree resolution and magnitude from ___(i)___ knots with ___(j)___-knot resolution. All transitions from one wind condition to another shall be smooth and linear without any perceptible discontinuities.

REQUIREMENT RATIONALE (3.3.3.1)

The instructor should be able to introduce a wide variety of wind conditions into the training mission to achieve comprehensive pilot training.

REQUIREMENT GUIDANCE

Fill in the blanks with values that are consistent with training requirements. Values used successfully on past USAF flight simulators include:

a. 2,000 feet.

b. aircraft ceiling altitude.

c. 0 to 50 knots.

d. 1-knot.

e. 0 to 360 degrees.

f. 1-degree.

g. 0 to 360 degrees.

h. 1-degree.

i. 0 to 150 knots.

j. 1-knot.

REQUIREMENT LESSONS LEARNED

4.3.3.1 **Ground/cruise winds**. Both quantitative and qualitative tests shall be performed over the full range of ground and cruise winds at various altitudes including the extremes.

VERIFICATION RATIONALE (4.3.3.1)

To assure compliance.

VERIFICATION GUIDANCE

In addition to performing tests against specific numbers, subjective tests need to be conducted by experienced pilots relative to the realism of the wind simulation.

VERIFICATION LESSONS LEARNED

3.3.3.2 **Turbulence/gusts**. The instructor/operator shall be able to select random turbulence and gusts. Turbulence shall be selectable in levels from ___(a)___. Gusts shall be selectable from ___(b)___ knots in ___(c)___-knot increments. The type of turbulence model and the gust signature shall be determined at PDR.

REQUIREMENT RATIONALE (3.3.3.2)

Pilots need to practice aircraft maneuvers under all conditions expected in flight without danger to human life.

REQUIREMENT GUIDANCE

Values used successfully on past USAF simulators include:

a. 0 to 10, where 0 indicates no turbulence and 10 indicates maximum turbulence.

b. 0 to 50 knots.

c. 1-knot increments.

REQUIREMENT LESSONS LEARNED

4.3.3.2 **Turbulence/gusts.** Both quantitative and qualitative tests shall be conducted over the full range of turbulence and gusts values at various altitudes.

VERIFICATION RATIONALE (4.3.3.2)

To assure compliance.

VERIFICATION GUIDANCE

Subjective tests as well as quantitative should be performed by experienced pilots with respect to the realism of the simulation.

VERIFICATION LESSONS LEARNED

3.3.3.3 **Airframe icing conditions.** Airframe ice accumulation and sublimations shall be simulated and produce the appropriate effects on the aerodynamic characteristics of the simulator. In addition, pitot tube, total temperature probe, and engine icing shall also be simulated. Student activation of aircraft anti-icing controls shall have the appropriate effects on simulator performance. The instructor/operation station shall have means for selecting variable icing conditions from light to heavy.

REQUIREMENT RATIONALE (3.3.3.3)

Pilots should be able to safely practice the recognition of icing conditions and learn to take proper corrective actions.

REQUIREMENT GUIDANCE

Ice build-up should result in more than the basic weight and drag increase. All flight and engine instruments that rely on pitot tube inputs should be made to fluctuate and give false readings.

REQUIREMENT LESSONS LEARNED

4.3.3.3 **Airframe icing conditions.** Qualitative tests shall be performed to verify that the icing simulation has the proper effects on the aerodynamic characteristics of the simulator.

VERIFICATION RATIONALE (4.3.3.3)

To assure compliance.

VERIFICATION GUIDANCE

Accepted tests for airframe icing include checks for linear changes to the aerodynamic characteristics along with the opinion of seasoned pilots.

VERIFICATION LESSONS LEARNED

3.3.4 **Aural simulation.** Sounds which are perceptible in the aircraft crew compartments during all phases of flight and ground operations shall be simulated with respect to approximate location, frequency, and amplitude. These sounds shall at least include the following: __________.

REQUIREMENT RATIONALE (3.3.4)

Sound effects are an important part of a flight simulator since pilots are very aware of the sounds around them, especially the engine sounds. Unusual or abnormal sounds alert the pilots of potential problems and thus are an important part of training.

REQUIREMENT GUIDANCE

Sounds which are a part of a thorough aircraft simulation include:

a. Engine.

b. Landing gear warning audible system (headset tone).

c. Airflow.

d. Hydraulic system operation.

e. Electrical system operation.

f. Landing gear operation.

g. Compressor stalls.

h. Structural and flow noises resulting from flight at maximum performance.

i. Crash.

j. Canopy jettison/ejection seat.

k. Air conditioning and defog system.

REQUIREMENT LESSONS LEARNED

4.3.4 **Aural simulation.** Qualitative tests shall be conducted to evaluate the appropriateness of the sound simulation relative to location, frequency, and amplitude.

VERIFICATION RATIONALE (4.3.4)

To assure compliance.

VERIFICATION GUIDANCE

Since this is a subjective test, pilots who are current in the particular aircraft are best qualified to perform the critique.

VERIFICATION LESSONS LEARNED

3.3.4.1 **Ambient noise.** Ambient noise from simulator systems, such as the hydraulic system, motion system, motors, etc, shall not be audible to the crew when the aural simulation equipment is in normal operation.

REQUIREMENT RATIONALE (3.3.4.1)

The sounds heard by the simulator aircrew should only be the sounds normally heard during flight. Simulator-peculiar sounds should not be audible to the aircrew during a training mission.

REQUIREMENT GUIDANCE

Ambient noise should be considered early in the design phase as it is always a problem for simulator designers.

REQUIREMENT LESSONS LEARNED

4.3.4.1 **Ambient noise.** Subjective tests shall be performed to verify that simulator unique sounds are not audible to the student pilot when when the aural simulation is in normal operation.

VERIFICATION RATIONALE (4.3.4.1)

To assure compliance.

VERIFICATION GUIDANCE

The most obvious simulator unique sound is that of the hydraulic system pumps. So be sure and run these tests with the pumps operating in their normal mode.

VERIFICATION LESSONS LEARNED

3.3.5 **Crash.** Indications of crash shall be provided and shall consist of visual and/or aural indications. When a crash occurs, the simulator shall freeze (i.e., all indicators shall remain fixed) and remain frozen until reset. Means shall be provided to quickly reset from a crash condition.

REQUIREMENT RATIONALE (3.3.5)

One of the biggest payoffs of training flight simulators is that dangerous aircraft maneuvers can be practiced without endangering human life. However, when conditions occur that would have resulted in a crash in the aircraft, the student pilots need to be made aware immediately so that learning can take place.

REQUIREMENT GUIDANCE

This is an important part of any training flight simulator and should leave no doubt in the student pilot's mind what has occurred.

REQUIREMENT LESSONS LEARNED

4.3.5 Crash. A subjective evaluation of the crash indication shall be made based on the visual and/or aural indications required in the specification.

VERIFICATION RATIONALE (4.3.5)

The student pilot must be immediately made aware that a crash has occurred so that he/she and the instructor can review exactly what caused the crash. Therefore, the crash indication should leave no doubt that a crash has indeed occurred.

VERIFICATION GUIDANCE

Exercise the crash mode of the simulator and critique the immediacy and clarity of the crash signal(s).

VERIFICATION LESSONS LEARNED

3.3.5.1 **Crash effects.** Crash effects shall occur in accordance with the design criteria and shall be the result of the following conditions: __________.

REQUIREMENT RATIONALE (3.3.5.1)

The conditions that will cause the aircraft to crash need to be clearly defined so the simulator can be designed accordingly.

REQUIREMENT GUIDANCE

Normal crash conditions include:

a. At the instant of ground contact if the gear is not down and locked.

b. At the instant of ground contact if the rate of descent exceeds the aircraft structural limitations.

c. At the instant of ground contact if the aircraft attitude is not within the aircraft limits.

d. If aircraft landing point is not within the confines of the runway or runway overrun.

e. In flight when the simulated performance exceeds the aircraft structural limits.

REQUIREMENT LESSONS LEARNED

4.3.5.1 **Crash effects.** Qualitative tests shall be conducted which exercise each crash mode of the simulator individually.

VERIFICATION RATIONALE (4.3.5.1)

To assure compliance.

VERIFICATION GUIDANCE

It is preferable to conduct these tests with an experienced pilot so that he/she can precisely maneuver the simulator into each crash condition.

VERIFICATION LESSONS LEARNED

3.3.5.2 **Crash override.** A crash override capability shall be provided for the instructor to override the effects of crash before they occur and allow the simulation to continue.

REQUIREMENT RATIONALE (3.3.5.2)

Sometimes, usually with novice student pilots, it is desirable to have the capability to prevent frequent or nuisance crashes in order to complete a training session. Crash override provides this capability.

REQUIREMENT GUIDANCE

Crash override should be used with discretion since there is a danger of negative training.

REQUIREMENT LESSONS LEARNED

4.3.5.2 **Crash override.** A subjective evaluation should be made of the crash override capability by activating it and then maneuvering the simulator through each crash condition to see if a crash occurs.

VERIFICATION RATIONALE (4.3.5.2)

To assure compliance.

VERIFICATION GUIDANCE

The purpose of this test is to verify that crash override prevents a crash from occurring. So be sure and at least exercise all known crash modes.

VERIFICATION LESSONS LEARNED

3.3.6 **Auto-trim.** An automatic trim feature shall be provided to null all simulator angular accelerations and rates as a consequence of freeze, reset, or reinitialization. Flight controls shall be driven automatically, smoothly, and safely to correspond to the new trim conditions.

REQUIREMENT RATIONALE (3.3.6)

Some simulator-peculiar features require special attention to the prevention of damage to the equipment and/or operators. The auto-trim requirement supports this theme.

REQUIREMENT GUIDANCE

Auto-trim should be included. It is an important part of any flight simulator since it protects both operator and equipment from damage.

REQUIREMENT LESSONS LEARNED

4.3.6 Auto-trim. Both quantitative and qualitative tests shall be conducted to determine if the auto-trim capability functions properly. Analog and/or digital outputs of appropriate variables shall be recorded before, during, and after auto-trim has been activated via a freeze, reset, and reinitialization.

VERIFICATION RATIONALE (4.3.6)

To assure compliance.

VERIFICATION GUIDANCE

To capture the variable outputs, use a strip chart recorder and/or have the computer print the values in memory of the appropriate parameters at the desired points in time.

VERIFICATION LESSONS LEARNED

3.3.7 **Aircraft systems.** Unless otherwise specified herein, the simulator shall include a complete and automatic simulation of all aircraft systems to include normal, degraded, and emergency operation. Characteristics of system components such as motors, valves, regulators, etc, shall be included to produce the correct static and dynamic system performance. System transients shall be simulated in accordance with the approved design criteria. The simulator shall include the following aircraft systems: ____________.

REQUIREMENT RATIONALE (3.3.7)

To provide a flight simulator that satisfies training needs, certain, if not all, aircraft systems should be provided.

REQUIREMENT GUIDANCE

The aircraft systems included in the simulator should be consistent with training needs. Normally, for a full mission trainer, the following aircraft systems are provided:

a. Flight controls.

b. Propulsion/pneumatic system.

c. Fuel system.

d. Electrical system.

e. Hydraulic system.

f. Cockpit air conditioning, ventilation, and defrosting.

g. Oxygen system.

h. Ejection/canopy system.

i. Caution, warning, indicator light, fire warning and detection system.

j. Lighting system.

k. Communications and electronics.

l. Navigation system.

m. Landing gear.

n. Nose wheel steering system.

o. Cabin pressurization.

p. Stall warning system.

q. Brake system.

r. Anti-icing.

REQUIREMENT LESSONS LEARNED

4.3.7 **Aircraft systems.** Both quantitative and qualitative tests shall be performed to verify the correct operation, interaction, and correlation among all aircraft systems included in the simulation. Malfunctions which may be introduced by the instructor and corrective actions taken by the student pilot shall also be evaluated. Tests shall be conducted on the ground and in flight as appropriate.

VERIFICATION RATIONALE (4.3.7)

To assure compliance.

VERIFICATION GUIDANCE

Use aircraft technical orders (T.O.s) as acceptance criteria and experienced pilots to conduct the tests.

VERIFICATION LESSONS LEARNED

3.3.7.1 **Flight control system.** The simulator flight control system shall operate as in the aircraft and include all primary, secondary, and automatic flight controls and the stability augmentation system (SAS). Appearance, displacement, and "feel" of the simulated flight controls shall be the same as in the actual aircraft. Operation of the controls shall result in simulated deflection of the appropriate control surfaces creating proper responses and instrument indications. Simulated instrument, visual, and motion indications shall be correct in magnitude, rate of change, and direction of movement. The "feel" of the simulated control system shall accurately duplicate the feel of the aircraft during all flight conditions with and without SAS engaged.

REQUIREMENT RATIONALE (3.3.7.1)

This is one of the most critical areas for raising or destroying the pilot's confidence in the simulator. Pilots are very sensitive to the stick forces of the aircraft force feel system. Therefore, special attention must be given to the flight control simulation.

REQUIREMENT GUIDANCE

Simulating the control stick or wheel dynamics correctly is of utmost importance. The natural frequency and damping of the feel system should match the actual aircraft very closely. Otherwise, the pilot's confidence in the realism of the simulator will be destroyed

REQUIREMENT LESSONS LEARNED

4.3.7.1 **Flight control system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.1)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.2 **Propulsion system.** The engines shall be simulated for all modes of operation throughout all performance flight regimes as defined by the approved design criteria and within the tolerances provided in Annex A of FAA Regulation 120-40. The engine modes of operation shall include operations with all bleed and horsepower extraction configurations. The effects of outside air temperature, altitude, mach, angle of attack, and sideslip angle shall be simulated to meet the performance in the approved design criteria. The engines shall be simulated to perform as operational engines throughout all performance flight regimes. The effects of properly applied stall and surge recovery procedures shall be simulated. The engine systems to be simulated shall include, but not be limited to: __________.

REQUIREMENT RATIONALE (3.3.7.2)

For effective training, a comprehensive engine simulation is required. This will allow training under normal and emergency flight conditions.

REQUIREMENT GUIDANCE

The engine systems included in the simulation should be consistent with training needs. The following systems should be considered:

a. The fuel control system.

b. The ignition system.

c. All starting methods.

d. All accessory systems (e.g., pneumatic, hydraulic, electrical).

e. Stall recovery and prevention systems.

f. The oil system.

g. Control system (nozzle, inlet, stators).

REQUIREMENT LESSONS LEARNED

4.3.7.2 **Propulsion system.** Verify by ________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.2)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.3 **Starting system.** The starting system shall be simulated in accordance with the approved design criteria. Appropriately marked starter switches shall provide correct functional operation. It shall be necessary to follow the correct starting procedures for ground and airstarts before engine operation is indicated. Airstarting characteristics shall be correctly affected by airspeed, altitude, and outside air temperatures in accordance with the approved design criteria. Incorrect procedures shall result in appropriate engine system reactions, e.g., failure to start, fire, overheat, etc.

REQUIREMENT RATIONALE (3.3.7.3)

Airstarts have been and still are a real operational problem relative to safety of flight. Hence, pilots should be intimately familiar with proper starting procedures.

REQUIREMENT GUIDANCE

All safety-of-flight related areas should receive special attention in the simulator with respect to duplicating aircraft characteristics exactly.

REQUIREMENT LESSONS LEARNED

4.3.7.3 **Starting system.** Verify by ________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.3)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.4 **Ignition system.** The ignition system shall be simulated in accordance with the approved design criteria. The ignition switches shall provide correct functional operation when correct ignition procedures are followed.

REQUIREMENT RATIONALE (3.3.7.4)

As mentioned above, due to safety of flight, pilots should be intimately familiar with proper starting procedures.

REQUIREMENT GUIDANCE

(See 3.3.7.3 guidance.)

REQUIREMENT LESSONS LEARNED

4.3.7.4 **Ignition system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.4)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.5 **Electrical system.** The aircraft electrical power supply system shall be simulated in accordance with the approved design criteria, unless otherwise specified herein.

REQUIREMENT RATIONALE (3.3.7.5)

For comprehensive training, all pertinent aircraft systems should be included in the simulation.

REQUIREMENT GUIDANCE

A careful study of the aircraft mission and simulator training goals will reveal which aircraft systems need to be included in the simulator.

REQUIREMENT LESSONS LEARNED

4.3.7.5 **Electrical system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.5)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.6 **Fuel system.** Normal and emergency operation of the fuel system shall be simulated in accordance with the approved design criteria. All switches, knobs, handles, instruments, indicators, and lights associated with the fuel system, in normal and emergency operation, shall be provided and shall duplicate the actual aircraft in function, location, and appearance. Fuel tank capacity (usable and unusable fuel), transfer, flow rates, and boost pump operation shall be simulated.

REQUIREMENT RATIONALE (3.3.7.6)

For comprehensive training, all pertinent aircraft systems should be included in the simulation.

REQUIREMENT GUIDANCE

(See 3.3.7.5 guidance.)

REQUIREMENT LESSONS LEARNED

4.3.7.6 **Fuel system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.6)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.7 **Hydraulic system.** The full functional capability of the hydraulic system shall be modelled. The effects of simultaneous demands from flight control surfaces and utilities shall be included. Normal and emergency operating modes of the hydraulic system (including single and dual engine operation) shall be modelled along with their effects on applicable aircraft systems.

REQUIREMENT RATIONALE (3.3.7.7)

For comprehensive training, all pertinent aircraft systems should be included in the simulation.

REQUIREMENT GUIDANCE

(See 3.3.7.5 guidance.)

REQUIREMENT LESSONS LEARNED

4.3.7.7 **Hydraulic system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.7)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.8 **Cockpit air conditioning.** The cockpit air conditioning system shall be a replica of the aircraft system and include all outlets, controls, switches, panels, and instruments. Means shall be provided to maintain the temperature within the simulator cockpit between __________ °F under continuous operating conditions. Sufficient ventilation shall be provided to all cockpit equipments to prevent hot spots or local overheating.

REQUIREMENT RATIONALE (3.3.7.8)

Crew comfort and equipment cooling are major factors in designing a usable and dependable simulator system.

REQUIREMENT GUIDANCE

Fill in the blank with an acceptable temperature range. Normal values are: 65 to 75°F.

REQUIREMENT LESSONS LEARNED

Due to the high utilization (16 hours per day, 6 days per week) of training flight simulators, a greater equipment cooling capability is usually required than in the aircraft.

4.3.7.8 **Cockpit air conditioning.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.8)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.9 **Oxygen system.** The simulated oxygen system shall duplicate in function and appearance all aspects of the aircraft oxygen system including both normal and emergency operation. However, breathing air which is pure, dry, and free of oil shall be used in lieu of oxygen. It shall be possible to use the standard pilot oxygen mask without danger of contamination. The capability to sample breathing air shall be provided.

REQUIREMENT RATIONALE (3.3.7.9)

For a realistic and effective simulation, all the normal interfaces between the pilot and aircraft should be provided such as pilot personal equipment connections.

REQUIREMENT GUIDANCE

For maximum realism, pilot personal equipment connections should be provided in any training flight simulator.

REQUIREMENT LESSONS LEARNED

Since the breathing air used must be pure, dry, and free of oil to prevent contamination of the pilot oxygen mask, some permanent means of testing the breathing air must also be provided. Although this seems obvious, most USAF training flight simulators do not have this capability.

4.3.7.9 **Oxygen system.** Functional checks of the oxygen system shall be performed along with air sampling tests of the breathing air to determine if it is pure, dry, and free of oil

VERIFICATION RATIONALE (4.3.7.9)

To assure compliance.

VERIFICATION GUIDANCE

To perform these tests, the breathing air hardware must be suitably equipped to allow for air sampling. The air sampling capability must be a permanent part of the simulator system to allow for periodic air sampling throughout the life of the simulator.

VERIFICATION LESSONS LEARNED

3.3.7.10 **Pilot ejection system.** Performance of proper pilot ejection procedures shall cause an appropriate aural cue and the simulator to enter the freeze mode until reset.

REQUIREMENT RATIONALE (3.3.7.10)

For comprehensive training, all pertinent aircraft systems should be included in the simulation.

REQUIREMENT GUIDANCE

(See 3.3.7.5 guidance.)

REQUIREMENT LESSONS LEARNED

4.3.7.10 **Pilot ejection system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.10)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.11 **Engine fire and overheat detection/suppression system.** The fire warning and overheat detection/suppression system shall be simulated and shall function in accordance with the approved design criteria. All lights, knobs, and switches associated with the system shall be provided and shall function as in the aircraft.

REQUIREMENT RATIONALE (3.3.7.11)

For comprehensive training, all pertinent aircraft systems should be included in the simulation.

REQUIREMENT GUIDANCE

(See 3.3.7.5 guidance.)

REQUIREMENT LESSONS LEARNED

4.3.7.11 **Engine fire and overheat detection/suppression system.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.11)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.12 **Lighting.** The aircraft cockpit lighting system shall be simulated and shall function in accordance with the approved design criteria. Light levels, lenses, covers, controls, and utility lights shall be provided as in the actual aircraft.

REQUIREMENT RATIONALE (3.3.7.12)

For comprehensive training, all pertinent aircraft systems should be included in the simulation.

REQUIREMENT GUIDANCE

(See 3.3.7.5 guidance.)

REQUIREMENT LESSONS LEARNED

4.3.7.12 **Lighting.** Verify by __________. (See 4.3.7.)

VERIFICATION RATIONALE (4.3.7.12)

To assure compliance.

VERIFICATION GUIDANCE

TBD. (See 4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.3.7.13 **Personal equipment.** Equipment such as the oxygen mask and flight helmet shall not be provided but provisions shall be made for connection of the crew's personal equipment in accordance with the approved design criteria. Connections for the crew's communication equipment shall be provided and shall operate through the simulated communication equipment. Storage space shall be provided as in the aircraft.

REQUIREMENT RATIONALE (3.3.7.13)

For a realistic and effective simulation, all the normal interfaces between the pilot and aircraft should be provided such as pilot personal equipment connections.

REQUIREMENT GUIDANCE

For maximum realism, pilot personnel equipment connections should be provided in any training flight simulator.

REQUIREMENT LESSONS LEARNED

4.3.7.13 **Personal equipment.** A visual inspection and functional check shall be performed to verify that the proper connections have been provided for the student pilot's personal equipment (e.g., oxygen mask, communications equipment, etc).

VERIFICATION RATIONALE (4.3.7.13)

To assure compliance.

VERIFICATION GUIDANCE

Make all the required connections to the pilot's personal equipment and verify that the location and fit is correct.

VERIFICATION LESSONS LEARNED

3.4 **Computational subsystem.** The ATD shall include a computational subsystem for operation, support, and maintenance of all major subsystems defined herein. It shall consist of all digital processing equipment, interface hardware, peripheral equipment, other associated computer equipment, and computer software (including the computer programs/data portion of firmware) to activate and support the ATD. Other subsystems such as visual, radar, and motion, may include computers, embedded micro-processors and computer software, in which case the computational subsystem requirements shall apply to the other subsystems to the extent specified in those subsystem requirements.

REQUIREMENT RATIONALE (3.4)

As an introductory paragraph for the computational subsystem, this paragraph establishes the scope of the computational subsystem.

REQUIREMENT GUIDANCE

No modification of this paragraph is required. The purpose of this section is to assure that the computational subsystem requirements will be applied to all computer resources used in the ATD as a minimum (that is, embedded processors, specialized processing equipment, firmware, etc). Even though this is a subsystem of the ATD, the requirements are "system" requirements that apply to all computational resources in the ATD unless more specific requirements can be identified by the program team. When the program team does the redefinition, all modes of the ATD operation (that is, real time, maintenance, test, and support) must be considered.

REQUIREMENT LESSONS LEARNED

In recent years, several ATDs have been procured containing computer resources which, by the nature of the specification, were considered to be independent of the Computational Subsystem and its associated requirements. As a result, support deficiencies were experienced for these computer resources when no spare time/memory, support, or maintenance computer software or documentation was delivered. In addition, these computer resources were relieved from programming language and documentation requirements which applied to the computational subsystem. In order to assure ourselves that these issues are addressed by all computational resource requirements in the specification, special paragraphs have been added to each subsystem to highlight the choices available to the program team.

4.4 Computational subsystem. Verify by __________.

VERIFICATION RATIONALE (4.4)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted in accordance with an approved Acceptance Test Procedure (ATP) document which will be prepared by the contractor. The ATP shall include step-by-step procedures to verify that all Computational Subsystem requirements are satisfied.

VERIFICATION LESSONS LEARNED

3.4.1 **Computational subsystem performance characteristics.** Any computational subsystem hardware used to meet the requirements specified herein shall also meet the following requirements:

a. Shall buffer data and instructions for communicating and downloading between processors, random access memory (RAM), and mass storage equipment.

b. Each computer configuration (mini or micro) shall be capable of being loaded, initialized, and reinitialized independent of all other computer configurations so that in the event of a software failure of that computer configuration and the associated computer programs/data, the entire computational complex will not require reinitialization resulting in the loss of the training mission.

REQUIREMENT RATIONALE (3.4.1)

This paragraph introduces the terminology which will be used to apply requirements to any computational system architecture the contractor chooses to use in his design. The purpose here is to further establish the scope of the computational system requirements in terms which relate to the potential design of the system. The requirement for "efficient buffering of data and instructions for communicating and downloading between processors, random access memory (RAM), and mass storage equipment" is necessary to provide communication among the processors and computers without dictating the architecture of the computational complex. This requirement is also necessary in order to prevent problems that occur when the system has limited fault-tolerant safeguards designed in. The intent is to eliminate "re-booting" in order to reduce lost training time.

REQUIREMENT GUIDANCE

The requirements of this paragraph should not require modification. They are independent of the complexity of the ATD being procured and the type of computer resources envisioned for use (i.e., super-mini or microcomputer).

REQUIREMENT LESSONS LEARNED

Terminology has always been a big problem in ATD procurements (as well as many other computer-based systems). There are always disputes over what a particular term means in one context as opposed to another. A typical problem is the case where processing requirements like spare time are specified to apply to "each CPU" in the system. Various interpretations of what constitutes a CPU have caused many disputes of this requirement. It is normal in a multiprocessor-based computer to call only one of the processors a CPU and the rest coprocessors, auxiliary processors, or something to that effect. This can have a serious impact on the real "processing spare" that gets delivered. Thus, it is felt that any attempt to reduce the potential for terminology disputes is a step in the right direction, even though it may seem trivial.

4.4.1 Computational subsystem performance characteristics. Verify by __________.

VERIFICATION RATIONALE (4.4.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted in accordance with an approved Acceptance Test Procedure (ATP) which will be prepared by the contractor. The ATP shall include procedures for testing the specified requirements.

VERIFICATION LESSONS LEARNED

3.4.1.1 **Interrupt provisions.** Each computer configuration in the computational subsystem shall include a priority interrupt system to support the real-time, event-driven nature of the training device. This system shall (1) provide a capability to distinguish between and identify the sources of simultaneous hardware generated interrupts, queuing them for service depending on their priorities, and (2) allow computer program generated interrupts (for example, supervisor calls).

REQUIREMENT RATIONALE (3.4.1.1)

This requirement is intended to insure that the contractor will understand the real-time nature of external inputs to the training device (control inputs, etc) and will provide a feasible means to support the real-time requirements.

REQUIREMENT GUIDANCE

The requirement should not be deleted from the specification and should not be waived unless the contractor can prove that the real-time requirements can be met without any interrupt provisions.

REQUIREMENT LESSONS LEARNED

4.4.1.1 Interrupt provisions. Verify by ___________.

VERIFICATION RATIONALE (4.4.1.1)

To assure compliance.

VERIFICATION GUIDANCE

An assessment of design shall be conducted during design reviews and verified by running the Acceptance Test Procedures and performance evaluation during qualification testing.

VERIFICATION LESSONS LEARNED

3.4.1.2 **Interval timing provisions.** Each computer configuration in the computational subsystem shall include at least one programmable interval timer accessible to each processing unit in the configuration. The interval timers shall be capable of generating both periodic (repetitive) and one-shot (single occurrence) interrupts. Each interval timer shall be settable under program control, readable under program control, and shall provide interrupts to its processing unit with a resolution of at least ________.

REQUIREMENT RATIONALE (3.4.1.2)

Interval timing provisions provide the capability to sample external inputs and to perform iterative computations at regular intervals. This is required in a real-time simulated environment.

REQUIREMENT GUIDANCE

Fill in the blank with an appropriate value. The value selected should be based on an analysis of the real-time interrupt processing needs and the specified spare processing time verification requirements.

REQUIREMENT LESSONS LEARNED

4.4.1.2 **Interval timing provisions.** Verify by ________.

VERIFICATION RATIONALE (4.4.1.2)

To assure compliance.

VERIFICATION GUIDANCE

Quantitative tests shall be performed with specific provisions to verify the specified resolution of the interval timer.

VERIFICATION LESSONS LEARNED

3.4.1.3 **Time function provisions.** The computational subsystem shall include a real-world time function to support timing requirements. The time function shall (1) be accessible to all processing units in the computational subsystem, (2) include julian date and time of day, and (3) have a resolution of at least __________. If multiple time functions are provided they shall be synchronized so all reflect the same value.

REQUIREMENT RATIONALE (3.4.1.3)

A time function is required to provide timing information such as mission durations, logs, etc. This function may be implemented with hardware or software (in conjunction with interval timing provisions).

REQUIREMENT GUIDANCE

The minimum resolution for the time function should be specified here. The value usually specified is one second.

REQUIREMENT LESSONS LEARNED

4.4.1.3 **Time function provisions.** Verify by __________.

VERIFICATION RATIONALE (4.4.1.3)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify the time function is accessible to all processing units, proper data is maintained and if multiple time functions are provided, they are synchronized and reflect same value.

VERIFICATION LESSONS LEARNED

3.4.1.4 **Training system ready provision.** The computational subsystem shall provide the capability to load all real-time and support software required to initiate a training mission. This process shall be automated with minimum inputs required from a single on-line terminal. The total time to complete this provision shall be less than __________ minutes.

REQUIREMENT RATIONALE (3.4.1.4)

This requirement is to assure that the process of preparing the trainer for mission initiation is not so complicated that it becomes operator intensive or so lengthy that it impacts available training time.

REQUIREMENT GUIDANCE

Fill in the blank with an appropriate value. The value selected should be based on an analysis which includes an estimate of the size of the software required to satisfy the training mission initiation requirement, the amount of data that must be loaded to satisfy the functional requirements, and the complexity of the projected computational system. The recommended number can vary from a minimum of 5 minutes for a simple training system to a maximum of 15 minutes for a complex system which requires some pre-processing to handle a large data base.

REQUIREMENT LESSONS LEARNED

Some previous trainer activation procedures have been so complex that they require loading several registers with machine language and then activating several computers in the proper order. These types of procedures are conducive to operator error and may reduce available training time.

4.4.1.4 **Training system ready provision.** Verify by __________.

VERIFICATION RATIONALE (4.4.1.4)

To assure compliance.

VERIFICATION GUIDANCE

Specific tests should be included in the acceptance test procedures to evaluate the complexity and time required to bring the system up to the point where it is ready for initiating a training mission.

VERIFICATION LESSONS LEARNED

3.4.1.5 **Power failure provisions.** Each computer configuration shall include the capability for the orderly shutdown of the computational subsystem in the event of trainer power loss, reduction, or interruption. This capability shall be designed to prevent damage to the computational subsystem in the event of a power failure, surge, or reduction.

REQUIREMENT RATIONALE (3.4.1.5)

Power failure capability, independent of the complexity, is necessary to insure that every computer configuration and associated devices are protected from damage.

REQUIREMENT GUIDANCE

The requirements of this paragraph should not require modification.

REQUIREMENT LESSONS LEARNED

4.4.1.5 **Power failure provisions.** Verify by __________.

VERIFICATION RATIONALE (4.4.1.5)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be performed to insure proper performance of the power failure hardware. The testing shall include temporarily removing power to the computer configuration and an evaluation of the result when power is restored.

VERIFICATION LESSONS LEARNED

3.4.2 **Computational subsystem hardware.** All digital processing equipment shall be architecturally identical or of the same computer vendor's series number (that is, upward compatible). Computer vendor hardware shall not be modified.

REQUIREMENT RATIONALE (3.4.2)

This paragraph defines the general requirements for the computational subsystem hardware. These requirements are necessary to enhance the definition of the scope of the computational subsystem. The requirement that "all digital processing equipment shall be architecturally identical or of the same computer vendor's series number" is required to avoid a proliferation of different computer types and to minimize support and logistics costs of the computational subsystem. In addition, the requirement minimizes the potential for major modification of the computational subsystem hardware and computer software due to changes in or termination of vendor product lines and the associated support of the product over the life-cycle of the ATD.

REQUIREMENT GUIDANCE

Exception to the requirement can be granted on a subsystem level if that particular modification is in the best interest of the Government. In such cases, the specification should reflect only the specific requirement and associated major component subsystem(s) where this exception is warranted (e.g., off-the-shelf visual system).

REQUIREMENT LESSONS LEARNED

The requirements of this paragraph are targeted toward the elimination of supportability problems after the deployment of the ATD. A past trainer was designed using a standard computer vendor product which, by production contract award time, had been discontinued by the vendor as a standard product. This circumstance was brought on by two conditions:

a. The inability of the procuring activity to identify the use of the item due to a competitive procurement and,

b. The contractor's position that the product was not computational system hardware and therefore not subject to the requirements for computational system hardware and software.

Both of these conditions could have been avoided if the specification had levied the requirements of this paragraph. The requirements force the early identification of computer resources with unique support requirements.

Another trainer was developed with a commercially supplied microcomputer dedicated to the "control loading" subsystem. Since the developing contractor (in this case the prime) did not view the microcomputer as part of the computational system, the Air Force did not receive sufficient design review details of the control loading software nor was the software ever documented to the level of computer software requirements. The result was a critical subsystem of the ATD with the following problems:

a. The subsystem introduced unacceptable delays in information flow which severely degraded the performance of the ATD.

b. The microcomputer and the associated microcomputer programs were not adequately documented, thus severely restricting the disclosure of the product design.

c. The lack of documentation impaired the contractor in correcting the design deficiencies.

In addition, the introduction of another vendor's computer resource impacted the support requirements for training, spares, and contract maintenance of computer resources in the ATD.

4.4.2 **Computational subsystem hardware.** Verify by ___________.

VERIFICATION RATIONALE (4.4.2)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted as part of qualification testing to insure the computational subsystem hardware has the processing capability to meet all performance requirements during any mode of operation. The requirement for the processing equipment to be architecturally identical or of the same vendor's series shall be verified as part of the hardware Physical Configuration Audit.

VERIFICATION LESSONS LEARNED

3.4.2.1 **Computer/multiprocessor/multicomputer system.** Any computational subsystem hardware used to meet the requirements specified herein shall also meet the following requirements:

a. Shall buffer data and instructions for communicating and downloading between processors, random access memory (RAM), and mass storage equipment.

b. Each computer configuration (mini or micro) shall be capable of being loaded, initialized, and reinitialized independent of all other computer configurations so that in the event of a software failure of that computer configuration and the associated computer programs/data, the entire computational complex will not require reinitialization resulting in the loss of the training mission.

REQUIREMENT RATIONALE (3.4.2.1)

This paragraph introduces the terminology which will be used to apply requirements to any computational system architecture the contractor chooses to use in his design. The purpose here is to further establish the scope of the computational system requirements in terms which relate to the potential design of the system. The requirement for "efficient buffering of data and instructions for communicating and downloading between processors, random access memory (RAM), and mass storage equipment" is necessary to provide communication among the processors and computers without dictating the architecture of the computational complex. This requirement is also necessary in order to prevent problems that occur when the system has limited fault-tolerant safeguards designed in. The intent is to eliminate "re-booting" in order to reduce lost training time.

REQUIREMENT GUIDANCE

The requirements of this paragraph should not require modification. They are independent of the complexity of the ATD being procured and the type of computer resources envisioned for use (i.e., super-mini or microcomputer).

REQUIREMENT LESSONS LEARNED

Terminology has always been a big problem in ATD procurements (as well as many other computer-based systems). There are always disputes over what a particular term means in one context as opposed to another. A typical problem is the case where processing requirements like spare time are specified to apply to "each CPU" in the system. Various interpretations of what constitutes a CPU have caused many disputes of this requirement. It is normal in a multiprocessor-based computer to call only one of the processors a CPU and the rest coprocessors, auxiliary processors, or something to that effect. This can have a serious impact on the real "processing spare" that gets delivered. Thus it is felt that any attempt to reduce potential terminology disputes is a step in the right direction, even though it may seem trivial.

4.4.2.1 **Computer/multiprocessor/multicomputer system.** Verify by ___________.

VERIFICATION RATIONALE (4.4.2.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted in accordance with an approved Acceptance Test Procedure (ATP) which will be prepared by the contractor. The ATP shall include procedures for testing the specified requirements.

VERIFICATION LESSONS LEARNED

3.4.2.2 **Peripheral equipment.** Peripheral equipment shall be provided as specified in the following paragraphs and functional subsystem sections (as required) of this specification. All peripheral equipment shall be taken into account (i.e., I/O requirements shall be established) for the verification of required spare capacities (spare I/O capacity, spare time). Peripheral equipment not explicitly required by this specification but required to operate or support the trainer shall be taken into account for the verification of required spare capacities.

REQUIREMENT RATIONALE (3.4.2.2)

This is a lead-in paragraph to the detailed requirements for peripheral and auxiliary equipment.

REQUIREMENT GUIDANCE

The types and amount of peripheral equipment will be dictated by the supporting command's support plan and the using command's functional requirements (e.g., mission generation, record/playback).

REQUIREMENT LESSONS LEARNED

4.4.2.2 **Peripheral equipment.** Verify by __________.

VERIFICATION RATIONALE (4.4.2.2)

To assure compliance.

VERIFICATION GUIDANCE

TBD.

VERIFICATION LESSONS LEARNED

3.4.2.3 **Mass storage equipment.** Mass storage equipment shall be provided as specified in the following subparagraphs.

REQUIREMENT RATIONALE (3.4.2.3)

Mass storage equipment is required to (1) store computer programs and data (used by the computational subsystem) while the trainer is not operating, (2) provide a medium which can be used to deliver updates and modifications to the programs, and (3) access the real-time data bases (such as visual) which are needed and which are too large to be resident in memory.

REQUIREMENT GUIDANCE

The requirement for a "capability . . . to copy between all units of mass storage" is dependent upon the support and operational requirements of the particular training device because these will dictate what different types of mass storage are needed. A trainer which requires high-speed access to realtime data bases will most likely incorporate rigid magnetic disc mass storage equipment to satisfy this requirement. However, since a magnetic disc is not a convenient medium on which to deliver updates and modifications, another secondary mass storage technology such as magnetic tape or flexible (floppy) disc would also be selected. This would mandate the copy requirement. On the other hand, a trainer which does not require real-time access to data bases may not need a magnetic disc storage system. Then the copy requirement would not apply.

It should also be noted that the use of "exotic" storage technologies is not desirable unless it has definite proven advantages in cost or performance (keeping supportability and life-cycle cost in mind).

Additional requirements may be stated here if they apply to all types of mass storage equipment selected. These additional requirements would be trainer-unique.

REQUIREMENT LESSONS LEARNED

4.4.2.3 **Mass storage equipment.** Verify by ________.

VERIFICATION RATIONALE (4.4.2.3)

To assure compliance.

VERIFICATION GUIDANCE

TBD.

VERIFICATION LESSONS LEARNED

3.4.2.3.1 **Primary mass storage.** Mass storage equipment shall be provided and used for storing and loading the operational programs and for on-line, real-time, and non-real-time data access. The type, size, and complexity of the equipment shall be a function of the computational subsystem design, operational load size, and the total system requirements for on-line, real-time, and non-real-time information flow and timing.

REQUIREMENT RATIONALE (3.4.2.3.1)

Primary mass storage equipment is required to satisfy requirements (1) and (3) defined in the rationale for 3.4.2.3.1.

REQUIREMENT GUIDANCE

Identify any additional requirements for primary mass storage which are trainer-unique. Minimum mass storage requirements for well-defined digital data bases (e.g., Defense Mapping Agency (DMA), Digital Landmass System (DLMS) data base) may be added to this paragraph. Parameters such as size, format, and record size may be specified if justified.

REQUIREMENT LESSONS LEARNED

4.4.2.3.1 **Primary mass storage.** Verify by ________.

VERIFICATION RATIONALE (4.4.2.3.1)

To assure compliance

VERIFICATION GUIDANCE

An objective comparison shall be made between the acquired system(s) with that determined required by analysis of total system requirements and approved at the Critical Design Review.

VERIFICATION LESSONS LEARNED

3.4.2.3.2 Secondary mass storage. Mass storage equipment shall provide for the installation of software changes sent from the trainer support activities or computer vendors.

REQUIREMENT RATIONALE (3.4.2.3.2)

Secondary mass storage is required to satisfy requirement (2) defined in the rationale for 3.4.2.3.1.

REQUIREMENT GUIDANCE

In order for the contractor to make the best decision as to the type and quantity of secondary mass storage equipment, these parameters are not specified. However, a list of equipment types from which the contractor may choose could be included here if desired. Such a list should also allow the contractor to recommend an alternate type of equipment which is not listed. The purpose of this approach is to assist the contractor in consolidating the secondary mass storage requirements with any other storage media requirements. For example, should Air-Almanac Digital Data (PWT data), or DMA-DLMS data base be specified elsewhere, the magnetic tape equipment used to support those requirements can fulfill the secondary mass storage requirements. Magnetic tape equipment is generally the preferred choice for secondary mass storage since most mini-computer and large mainframe computer vendors provide software support on magnetic tape.

REQUIREMENT LESSONS LEARNED

In the past, devices such as magnetic tape or floppy disc have been explicitly specified in the specification to fulfill the functional requirements identified. This has resulted in perhaps less than optimal choices being made for secondary mass storage just to meet the specification. By not explicitly specifying the type of equipment here, the contractor may make the most cost-effective or efficient choice. However, the contractor's choice of equipment should be finalized by the time of the preliminary design review.

4.4.2.3.2 Secondary mass storage. Verify by __________.

VERIFICATION RATIONALE (4.4.2.3.2)

To assure compliance.

VERIFICATION GUIDANCE

TBD.

VERIFICATION LESSONS LEARNED

3.4.2.4 **Operator/support interface equipment.** Operator/support interface equipment shall be provided that allows flexible control and support of the computational subsystem.

REQUIREMENT RATIONALE (3.4.2.4)

Operator/support interface equipment is required to facilitate interaction and communication of the computational subsystem and allow flexible control and support of the ATD.

REQUIREMENT GUIDANCE

This interface equipment is needed by the operators, instructors, hardware, and software maintenance personnel who access the system through other than simulated aircraft instruments (i.e., non-students).

REQUIREMENT LESSONS LEARNED

4.4.2.4 **Operator/support interface equipment.** Verify by _________.

VERIFICATION RATIONALE (4.4.2.5)

To assure compliance.

VERIFICATION GUIDANCE

TBD.

VERIFICATION LESSONS LEARNED

3.4.2.4.1 **Operator terminals.** Operator terminal(s) shall be provided to facilitate operator interaction with the computational subsystem. The operator terminal(s) shall be the primary communication device(s) for the control of the computational subsystem. The operator terminal(s) shall satisfy the following requirements: __________.

REQUIREMENT RATIONALE (3.4.2.4.1)

It is necessary to have one central point from which the entire computational subsystem can be accessed and controlled.

REQUIREMENT GUIDANCE

Specify the minimum requirements that the operator terminal(s) must satisfy. Requirements such as built-in hardcopy capability (i.e., teletypewriter), data transfer rates, and amounts of data to be displayed at one time should be listed here. If a combination instructor/operator console is required, then this paragraph should be deleted and the requirements should be incorporated into a single paragraph in the "instructional subsystem" section (see 3.5) of the specification.

REQUIREMENT LESSONS LEARNED

4.4.2.4.1 **Operator terminals.** Verify by ________.

VERIFICATION RATIONALE (4.4.2.4.1)

To assure compliance.

VERIFICATION GUIDANCE

Testing will be predicated on the establishment of the final functional requirements based on the overall design of the training device. Quantitative tests shall be performed on each terminal provided.

VERIFICATION LESSONS LEARNED

3.4.2.4.2 **Support terminals.** ________ support terminals shall be provided to facilitate interface with all trainer support functions requiring the use of computational subsystem resources.

REQUIREMENT RATIONALE (3.4.2.4.2)

Support terminals are required to satisfy the support requirements of the trainer.

REQUIREMENT GUIDANCE

The requirements for support terminals will be based on functional requirements levied by the individual subsystems requiring support activities. This paragraph consolidates those requirements and allows the contractor to make the best possible choice in distributing the functional requirements across the terminals.

In most cases this would be one support terminal to handle background processing. Care should be taken in the identification of all types of terminals needed for each particular ATD. The other types could be a digital remote control unit, a visual/radar data base update console, etc. If the requirement for background processing is filled by one of these other consoles elsewhere, delete this requirement.

REQUIREMENT LESSONS LEARNED

4.4.2.4.2 **Support terminals.** Verify by ________.

VERIFICATION RATIONALE (4.4.2.4.2)

To assure compliance.

VERIFICATION GUIDANCE

TBD.

VERIFICATION LESSONS LEARNED

3.4.2.4.3 **Hardcopy equipment.** Equipment shall be provided to produce hardcopy output of all data which is displayable on any peripheral display equipment controlled by the computational subsystem. That is, if a graphics terminal is included in the deliverable peripheral equipment, then a graphics hardcopy capability shall be provided. The hardcopy equipment shall accommodate hardcopy throughput requirements (taking into account the number of functions which may require hardcopy capability concurrently). Non-standard hardcopy media such as thermal paper or photo-sensitized paper is not acceptable. The hardcopy equipment, interface, and computer program(s) driving the equipment shall produce hardcopy output during real-time and shall not introduce any perceptible delays in the operation of any other equipment, subsystems, subsystem features, or functions of the trainer.

REQUIREMENT RATIONALE (3.4.2.4.3)

Hardcopy capability is necessary to provide student feedback, system operation documentation, maintenance information and records, and to enhance the versatility and adaptability of the trainer.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

A previous trainer was acquired with a graphical instructor's console. Hardcopy capability for this console was provided by the line printer (which was a dot-matrix type printer with graphics capability). The problem was that whenever the instructor selected the hardcopy option for a particular display, the console display "froze" for 15 seconds while the display memory was downloaded into the computer memory for spooling to the printer. The solution chosen by the instructors to this problem was to not utilize this "feature" of the instructional system. Thus a capability was paid for which was never utilized--surely not cost-effective. This prompted the requirement for the hardcopy equipment or implementation thereof to not introduce any perceptible delays.

4.4.2.4.3 **Hardcopy equipment.** Verify by __________.

VERIFICATION RATIONALE (4.4.2.4.3)

To assure compliance.

VERIFICATION GUIDANCE

Hardcopy requirements will be determined by the user needs. Tests shall be conducted to verify that required hardcopy can be produced.

VERIFICATION LESSONS LEARNED

All peripheral equipment required to meet the functional and support requirements of the trainer system shall be tested. The tests and procedures shall be included in the Acceptance Test Procedures document.

3.4.2.4.4 **Master operations console.** A master operations terminal shall be provided to facilitate a single location for system loading, initialization, and real time control.

REQUIREMENT RATIONALE (3.4.2.4.4)

Single point loading is required to assure efficiency of the trainer during any exercise requiring bootstrap loading.

REQUIREMENT GUIDANCE

No modification of this paragraph is required. Single point loading requirements will be determined by the user needs.

REQUIREMENT LESSONS LEARNED

4.4.2.4.4 **Master operations console.** Verify by __________.

VERIFICATION RATIONALE (4.4.2.4.4)

To assure compliance.

VERIFICATION GUIDANCE

Single point loading and its attendant master operations console requirements will be determined by the user needs. Tests shall be be conducted to verify that master operations console requirements can be satisfied.

VERIFICATION LESSONS LEARNED

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3.4.2.5 **Additional peripheral equipment.** Any additional peripheral equipment necessary to operate or support the trainer shall be provided. Peripheral equipment not required explicitly by this specification but provided and required to operate or support the trainer shall also be taken into account for the verification of required spare capacities.

REQUIREMENT RATIONALE (3.4.2.5)

This paragraph exists to assure any and all peripheral equipment used to operate or support the trainer will be provided and included in spare capacity considerations.

REQUIREMENT GUIDANCE

Subsystem-unique peripheral equipment should be identified in paragraphs within each functional subsystem section of the specification. It is the responsibility of the functional engineers in charge of those subsystems to assure compliance and compatibility with the requirements of this whole section of the specification.

REQUIREMENT LESSONS LEARNED

4.4.2.5 **Additional peripheral equipment.** Verify by __________.

VERIFICATION RATIONALE (4.4.2.5)

To assure compliance.

VERIFICATION GUIDANCE

All peripheral equipment required to meet the functional and support requirements of the trainer system shall be tested. The tests and procedures shall be included in the Acceptance Test Procedures document.

VERIFICATION LESSONS LEARNED

3.4.2.6 **Computational subsystem spare capacity and expansion capability.** Each computer configuration in the computational subsystem hardware shall provide spare capacities as specified in the following subparagraphs. The capability shall be provided to verify the spare capacities specified. In addition, the computational subsystem shall be expandable in a fashion that does not require existing equipment to be replaced.

REQUIREMENT RATIONALE (3.4.2.6)

Spare capacities and a capacity for system expansion are necessary to insure that the system will have the ability to adapt without overload to changes which are related to factors such as:

a. Changing mission requirements.

b. Equipment upgrades and modifications.

REQUIREMENT GUIDANCE

Specify any general spare capacity or expansion capability requirements for the computer configurations in the computational subsystem as applicable.

REQUIREMENT LESSONS LEARNED

4.4.2.6 Computational subsystem spare capacity and expansion capability. Verify by __________.

VERIFICATION RATIONALE (4.4.2.6)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by running the program required by 3.4.3.11 and an objective analysis of the test output.

VERIFICATION LESSONS LEARNED

3.4.2.6.1 **Spare processing time.** The computational subsystem shall include a minimum of __________ percent spare processing time. The spare processing time requirement shall apply separately to each processing unit (that is, CPU, IPU, and APU) in each computer configuration.

REQUIREMENT RATIONALE (3.4.2.6.1)

Spare capacities are necessary to insure that the system will have the ability to adapt to change.

REQUIREMENT GUIDANCE

The recommended value is 25 percent, but much higher levels (up to 50 percent) may be justified if mission requirements are expected to undergo extensive change or increase.

REQUIREMENT LESSONS LEARNED

Spare time is a real problem. The two main concerns are:

a. The inability of the procuring activity to accurately determine what the actual spare processing time needs of a program will be.

b. The difficulty of verifying that the spare requirements specified are indeed met.

The difficulty of determining spare processing time needs stems from the fact that no two programs are alike. Differences in computer configurations and software coding practices make it impossible to determine in advance just how much spare is needed to implement the estimated number of modifications and mission enhancements envisioned for the program. For example, if two different programmers are assigned to implement a software change, one programmer's implementation may take twice as much processing time as the other's. The best advice is to research previous trainer acquisitions, noting (1) the point in the weapon system's life-cycle at which the trainer acquisition commenced and when it was achieved, (2) the specified spare time requirement, (3) the spare time achieved, and (4) how much of the spare has been used for modifications and enhancements since the trainer became operational, then (5) make a guess.

If the computational system is to be highly modular, with distributed processing, processing power may be added incrementally without affecting the total operation of the system. In such a case, expansion capability should be specified instead of spare processing time.

4.4.2.6.1 Spare processing time. Verify by __________.

VERIFICATION RATIONALE (4.4.2.6.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by running the program required by 3.4.3.11.1 and an objective analysis of the test output.

VERIFICATION LESSONS LEARNED

3.4.2.6.2 Spare memory or memory expansion capability. __________ percent usable spare memory and __________ memory expansion capability shall be provided. This requirement shall apply separately to each type of memory (static, dynamic, etc) in each computer configuration, and also to both common and private memory.

REQUIREMENT RATIONALE (3.4.2.6.2)

Spare capacities are necessary to insure that the system will have the ability to adapt to change.

REQUIREMENT GUIDANCE

Specify the minimum amount of spare or expansion memory to be provided or allowed for as a percentage of the total amount of memory provided. The recommended amount is 25 percent total although as with spare processing time, this amount may be greatly increased (up to 50%) depending upon the envisioned changes to mission requirements.

REQUIREMENT LESSONS LEARNED

As with spare processing time, it is hard to arrive at a numerical value to specify. See 3.4.2.6.1 lessons learned.

4.4.2.6.2 Spare memory or memory expansion capability. Verify by __________.

VERIFICATION RATIONALE (4.4.2.6.2)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by running the program required by 3.4.3.11.1 and an objective analysis of the test output.

VERIFICATION LESSONS LEARNED

3.4.2.6.3 Input/output expansion. The total number of I/O channels in each computer configuration shall be increasable by __________ percent. The available information transfer capacity shall be increasable by the same percentage without degrading the performance of the trainer. However, the spare I/O channels must be evenly distributed across all computer configurations and I/O channel types.

REQUIREMENT RATIONALE (3.4.2.6.3)

Spare capacities are necessary to insure that the system will have the ability to adapt to change.

REQUIREMENT GUIDANCE

The recommended value for this parameter is 50 percent. In addition, you may wish to state that spare slots for I/O boards shall be provided.

REQUIREMENT LESSONS LEARNED

4.4.2.6.3 Input/output expansion. Verify by __________.

VERIFICATION RATIONALE (4.4.2.6.3)

To assure compliance.

VERIFICATION GUIDANCE

Verification shall be by physical inspection as part of the Physical Configuration Audit.

VERIFICATION LESSONS LEARNED

3.4.2.6.4 Interface hardware spare capacity. ____(a)____ percent of each type of interface hardware ____(b)____ shall be provided as spare. This spare interface hardware shall be usable without degrading the performance of the trainer (i.e., the computational subsystem shall be capable of driving both the used and spare interface hardware at their fully loaded capacities). The spare capacity shall be evenly distributed across each interface element in the computational subsystem (i.e., the spare interface hardware shall be accessible to any computer configuration in the computational subsystem).

REQUIREMENT RATIONALE (3.4.2.6.4)

Spare capacities are necessary to insure that the system will have the ability to adapt to change.

REQUIREMENT GUIDANCE

a. The value selected for this parameter should correlate with the spare I/O capacity selected in the previous paragraph. It would not make sense to have more spare interface hardware than there is capability to drive it.

b. The list of hardware types includes the following.

(1) digital to analog output.

(2) discrete to digital input.

(3) digital to discrete output.

(4) digital (parallel and serial) input and output.

(5) digital to synchro output.

(6) special purpose interface hardware (for example, the avionics bus interface).

REQUIREMENT LESSONS LEARNED

The reason spare hardware is specified, rather than expansion, is because the interface hardware is usually not standard vendor hardware. This hardware may be hard to procure as spare parts.

4.4.2.6.4 Interface hardware spare capacity. Verify by __________. (See 4.4.2.6.)

VERIFICATION RATIONALE (4.4.2.6.4)

To assure compliance.

VERIFICATION GUIDANCE

Verification shall be by physical inspection as part of the Physical Configuration Audit.

VERIFICATION LESSONS LEARNED

3.4.2.6.5 **Primary mass storage spare and growth.** Each unit of primary mass storage equipment shall have an on-line, spare storage capacity that is at least ___(a)___ percent of its total capacity. Also, the on-line storage capacity provided for primary mass storage shall be increasable by ___(b)___ percent (without requiring further change to the computational subsystem).

REQUIREMENT RATIONALE (3.4.2.6.5)

Spare capacities are necessary to insure that the system will have the ability to adapt to change.

REQUIREMENT GUIDANCE

a. Specify the minimum acceptable spare capacity for primary mass storage. The recommended value is 50 percent of its total capacity.

b. Specify the growth capability required for primary mass storage. The recommended value is 100 percent (i.e., expansion from one unit to two, or at least the addition of one more entire unit of mass storage equipment).

REQUIREMENT LESSONS LEARNED

4.4.2.6.5 **Primary mass storage spare and growth**

VERIFICATION RATIONALE (4.4.2.6.5)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by running programs required under 3.4.3.11.2 and a design analysis to insure additional units can be added without any redesign.

VERIFICATION LESSONS LEARNED

3.4.3 **Computational subsystem computer software.** Computer software shall be provided which supports all modes of trainer operation, including training, student evaluation, support, and maintenance and test. These programs shall perform all real-time computations and input/output functions at rates sufficient to satisfy all requirements in this specification. A standard computer vendor operating system shall be provided and used in each digital computer in the computational subsystem during all modes of trainer operation. The operating system (OS) configuration used while training is in progress (i.e., executing real-time software) shall provide for the concurrent execution of background software. The entire collection of software called for in this specification shall be considered a part of the computer program system (CPS).

REQUIREMENT RATIONALE (3.4.3)

This paragraph identifies requirements unique to the computational subsystem. The vendor operating system (OS) requirement is to minimize life-cycle support problems due to revision changes to the vendor equipment or software. For this reason, a vendor OS is required for all trainer operating modes. The paragraph also requires that the OS used during training must support execution of "background" computer software. The purpose of this requirement is to assure maximum utilization of the computational subsystem for on-site operational support (mission support and maintenance). This capability will provide for executing computer software in background activities in preparation for the next or future training sessions such as mission scripting (lesson plan development), student performance evaluation, radio/navigational aids modification, etc, while real-time training is being conducted.

REQUIREMENT GUIDANCE

The requirements of this paragraph should be worded so that they don't have to be changed later to account for different computational architectures.

REQUIREMENT LESSONS LEARNED

ATDs have been procured which utilized contractor developed run-time systems (RTSs). Computer programs were developed and compiled on standard vendor OS-based systems and down-loaded to the contractor's RTS-based hardware. The problems encountered as a result were many. In one case, with the normal maintenance of the computer hardware, revisions were incorporated which affected the functioning of the RTS. This forced a revision to the RTS, the cost of which was borne by the government. In another case, it was decided not to incorporate vendor hardware revisions as they were issued with the intent that this would solve the contractor RTS problem, but it created another. It was discovered that over time, replacement parts for the computer equipment would not operate on the trainer hardware because the replacement part design assumed that the computer hardware had been maintained at the latest vendor revision level. This severely impacted the supportability of the trainer. As a final example, in a multi-unit trainer acquisition, the pre-production unit (PPU) software was developed with a FORTRAN-66 compiler on a vendor OS-based system and executed on a contractor-developed RTS. In the time period between the delivery of the PPU and the first production unit, the new FORTRAN-77 standard compiler had been accepted. The SOW for the trainer acquisition stated that all units delivered must utilize the latest version of the compiler available. Programs compiled with the new compiler would not execute within the RTS environment, thus forcing a revision of the RTS. These types of problems prompted the requirement for the use of a vendor OS during all modes of trainer operation and for the incorporation of all OS revisions as they are released in Statements of Work.

The requirement for "background" processing was a result of the constantly increasing computational requirements of trainer support activities. Several newer trainers were delivered with sophisticated training systems incorporating a great deal of flexibility. This flexibility was provided through alteration of the "simulated environment" using software which produced the desired "new environment". The problem with these systems was the fact that no provision had been made to reduce the availability of the trainer so that the "environment alteration" software could be run and no additional computational equipment was available for that purpose. This has resulted in one of two situations:

a. If the "environment alteration" was absolutely necessary in order to satisfy trainer mission requirements, then the planned utilization or availability of the trainer had to be reduced, affecting the entire training program.

b. If the "environment alteration" capability was not absolutely required to satisfy trainer mission requirements, then the capability was not utilized (in other words, it was a waste of money to have acquired the capability).

4.4.3 **Computational subsystem computer software.** Verify by _________.

VERIFICATION RATIONALE (4.4.3)

To assure compliance.

VERIFICATION GUIDANCE

To assure that the latest version of a standard computer vendor operating system is utilized, a comparison shall be made between the latest vendor data publication and the version supplied with the computational subsystem.

VERIFICATION LESSONS LEARNED

3.4.3.1 **Programming language.** The computer programs shall be programmed in Ada programming language in accordance with AFR 800-14. The compiler used shall support the full language, not a subset.

REQUIREMENT RATIONALE (3.4.3.1)

This specification and the governing regulations of the procuring activity require that all ATD computer programs be developed in a higher order language (HOL).

REQUIREMENT GUIDANCE

The DoD has specified a list of approved HOLs for developing defense system software (reference DODD 5000.29). Although USAF AFSC/ASD has directed that JOVIAL J73 be used in all ASD procurements, a waiver has been obtained approving the use of FORTRAN in ATDs. In July, 1984, however, the DoD directed (DODD 5000.31, 10 Jun 83) that Ada (ANSI/MIL-STD-1815A-1983) will be the specified HOL for all "Mission Critical" computer systems (including trainers) entering Full-Scale Engineering Development. Therefore, this blank should be replaced with "ANSI X3.9-78 FORTRAN" or "ANSI/MIL-STD-1815A-1983 Ada", as appropriate.

It should be noted that this requirement may be waived under certain circumstances. For example, if an off-the-shelf, commercial visual CIG system is included in the proposed computational resources, the software running it most probably will not be written in a HOL like FORTRAN or Ada. The waiver should only be granted for those subsystems to which it applies, not a "blanket waiver" for the entire simulator.

REQUIREMENT LESSONS LEARNED

The design of software/firmware written in a non-HOL is usually difficult for an outsider to the design process to comprehend.

4.4.3.1 **Programming language.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.1)

To assure compliance.

VERIFICATION GUIDANCE

The language(s) to be used will be established prior to contract award. Compliance will be assessed during the software development activities, verified by evaluating the delivered compiler(s) and by comparison of source listings to the established criteria.

VERIFICATION LESSONS LEARNED

3.4.3.2 **CPS organization and preparation.** The CPS shall be organized into computer software divisions to provide insight to the development and configuration management of the CPS. There shall be a computer software division for each major component subsystem. Each division shall contain those computer software components (CSCs), computer software units (CSUs), and computer data files (CDFs) unique to its major component subsystem. Additional divisions (as necessary) shall be organized for those CSCs, CSUs, and CDFs which are common to more than one major component subsystem. Each major component subsystem division shall include subsystem support computer programs and maintenance and test computer programs in addition to the programs necessary to fulfill simulation requirements. The CPS shall ___________. Any programming language features and structured programming techniques that are used shall not preclude normal updates to the current configuration of computer vendor products as they are released.

REQUIREMENT RATIONALE (3.4.3.2)

The purpose of this paragraph is to insure that state-of-the-art techniques in software development are used in the development of the CPS. The requirements identified here along with contractual (SOW) requirements for the configuration management of the CPS allow the procuring activity to see the contractor's progress in the development of the CPS.

REQUIREMENT GUIDANCE

Fill in the blank with state-of-the-art software design requirements which do not restrict the hardware design or architecture. At present, the following is recommended:

"The CPS shall be top-down designed and hierarchically structured. The source code and object code for each CSU shall be included in the delivered version of the CPS. Computer data shall be structured into CDFs. Structured programming techniques shall be applied in the design of the CPS to facilitate straight forward, comprehensible program design."

With regard to the structuring requirements, literature is plentiful about the benefits of modular and hierarchical decomposition when applied to large software projects. In most trainers, there is a large amount of software which is repeatedly used by many parts of the CPS. When the CPS is properly organized and structured, maximum use of common software CSUs can be made. These requirements encourage such an approach and apply to all computational system hardware architectures equally well. It is important to emphasize that most of these requirements should also have a corresponding section in the SOW. SOW requirements for configuration management, the generation of software trees, software status reports, CPS organizational data, etc. must be consistent with the requirements of this section. See DOD-STD-2167 for further information.

REQUIREMENT LESSONS LEARNED

Lessons learned for this paragraph relate to the requirement to provide subsystem support computer programs and maintenance and test computer programs for each major component subsystem. In previous ATDs, the requirement for subsystem support computer programs and maintenance and test computer programs appeared only in the requirements for the computational system. The problem was that this requirement was interpreted by the contractor as applying only to the computational system and not as a software requirement for each major component subsystem. This was also partly due to the way the specification was structured. All software requirements for the major component subsystems were specified in a computer program system (CPS) section of the specification and not in each major component subsystem section. As previously emphasized, in this specification it is the responsibility of each major component subsystem functional engineer to specify all software requirements unique to his subsystem.

4.4.3.2 CPS organization and preparation. Verify by ___________.

VERIFICATION RATIONALE (4.4.3.2)

To assure compliance.

VERIFICATION GUIDANCE

Verify that the approved CPS structure and design methodology is followed during system development. All engineering and management activities, including configuration control, program reviews, status tracking and reporting, and documentation from contract award through system acceptance, must reflect and be assessed against the established CPS structure.

VERIFICATION LESSONS LEARNED

3.4.3.3 **Supervisor/executive software.** Computer software shall be provided which shall maintain and direct the problem flow and establish priority controls over all computation. The highest level of abstraction shall consist of one or more supervisor/executive routines which shall control the execution of tasks. Tasks shall be composed of functionally related CSCs. CSCs shall be composed of simple, independent CSUs and CDFs which, when grouped together, complete functionally identifiable parts of the trainer CPS. The CSUs and CDFs shall be at the lowest level in the hierarchy. Each CSU shall consist of a unit of computer program code which shall be independently compiled and/or assembled. These programs shall provide all functions necessary to control any multiple iteration rate task structure and shall provide synchronization such that spare processing time can be measured.

REQUIREMENT RATIONALE (3.4.3.3)

This paragraph establishes the basic requirements for the software which controls the execution of real-time trainer functional software executing on the computational subsystem.

REQUIREMENT GUIDANCE

The requirements of this paragraph should not need modification. The requirements for synchronization are general and do not specify a centralized executive or inhibit a distributive executive. The key requirement is for the executive to activate the software in a structured and "fixed" scheduling such that spare processing time can be measured and utilized for expansion.

REQUIREMENT LESSONS LEARNED

A past trainer utilized an executive/supervisor which incorporated a "floating-frame" scheduling technique. This technique allowed frame start times to "float" within "time-windows" of a certain iteration rate as opposed to occurring at fixed times relative to the other iteration rates. Several problems resulted from this approach:

a. The timing of processing of the different iteration rates relative to each other was not consistent or sufficiently stable and caused wholesale trainer performance degradation under loaded conditions.

b. Spare processing time could neither be measured nor calculated accurately. Also, the spare provided was not usable to provide for expansion of processing at all iteration rates without restructuring and resequencing of the entire real time software. Therefore, any changes required redevelopment and large scale (if not complete) retesting of all trainer performance parameters.

4.4.3.3 Supervisor/executive software. Verify by __________.

VERIFICATION RATIONALE (4.4.3.3)

To assure compliance.

VERIFICATION GUIDANCE

This software program design will be determined by the overall implementation of the real-time trainer programs. Testing shall include exercising the total trainer and running support programs. Tests shall include running the spare time measurement software program.

VERIFICATION LESSONS LEARNED

3.4.3.4 **Debug computer software.** Computer software shall be provided to assist maintenance personnel in debugging computer programs and testing computational subsystem hardware through the master operations terminal and the associated support terminal. These programs shall operate in real-time during normal trainer operation. User interaction with these programs shall occur through a support terminal. These programs shall satisfy the following requirements: __________. Commercially available software shall be used for this requirement if it satisfies all of the requirements above.

REQUIREMENT RATIONALE (3.4.3.4)

This paragraph requires the functional characteristics of what used to be the "digital remote-control unit" (DRU). The DRU was a handheld I/O device used to debug and monitor the performance of the trainer. It could read and write directly to and from the computer CPU and memory.

REQUIREMENT GUIDANCE

The needs served by the old DRU still exist, but the traditional solution--a separate unit--is no longer valid. With the advent of mapped operating systems and "user registers" many of the old functions of the DRU become meaningless or impossible to perform. The maintenance or engineering needs can still be met with a terminal which satisfies the same functional requirements. These requirements should include:

a. The ability to examine and alter the contents of any memory location and processor register, utilizing decimal and either hexadecimal or octal address and data representation.

b. The ability to monitor the contents of a minimum of 40 variable storage areas in memory at a time, each of which is independently preselectable by variable name.

c. The ability to enable and disable a task.

d. The ability to monitor the task structure in memory. (This is usually done by means of a memory map showing task allocations, etc).

REQUIREMENT LESSONS LEARNED

4.4.3.4 **Debug computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.4)

To assure compliance.

VERIFICATION GUIDANCE

Detailed tests with step-by-step procedures covering all requirements shall be included in the Acceptance Test Procedures (ATP) document. In addition to running the ATP, an assessment of the support documentation will be performed to verify clear concise guidance on using these programs.

VERIFICATION LESSONS LEARNED

3.4.3.5 **Mass storage copy/comparator software.** Software shall be provided which satisfies the following functional requirements between all mass storage units, regardless of hardware type, in both the primary and secondary mass storage systems: __________. These programs shall be operable through an operator or support terminal and shall allow the error output to be optionally directed to hardcopy. Commercially available software shall be used for this requirement if it satisfies all of the above requirements.

REQUIREMENT RATIONALE (3.4.3.5)

This capability is necessary for installation of software changes from the various support activities distributed on secondary mass storage media.

REQUIREMENT GUIDANCE

The functional requirements list should include the following:

a. Individual and multiple file copy and verification.

b. File concatenation and merge, file by file and by records within files.

c. File-by-file comparison with suppressible error output for multiple errors, for all file types.

REQUIREMENT LESSONS LEARNED

4.4.3.5 Mass storage copy/comparator software. Verify by ________.

VERIFICATION RATIONALE (4.4.3.5)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by taking sample programs and evaluating each of the specified requirements. Sample programs, with and without differences, will be used to validate the correct performance of the software under test.

VERIFICATION LESSONS LEARNED

3.4.3.6 **Computer equipment diagnostic computer software.** A complete set of diagnostic computer software shall be provided to isolate equipment failures in the computational subsystem. Except for the portions of the test that check whether or not inputs can be received from, and outputs transmitted to, the equipment in question, all diagnostics shall be fully automatic. This means that once the user has loaded the diagnostic and set-up initial conditions, the program will automatically generate error indications (if any) on the terminal and hardcopy device. These programs shall be capable of automatic execution as a total package and as individual diagnostic checks. The diagnostics shall check each computer configuration and its options, and all memory units, peripheral units, and input/output units. Programs shall also be included for computer equipment embedded in and dedicated to subsystem processing or any other special processors as defined herein. Commercially available software shall be used for these requirements if it satisfies all of the above requirements.

REQUIREMENT RATIONALE (3.4.3.6)

Diagnostic programs which test the computer equipment are necessary to maintain the computational subsystem.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

These diagnostic programs are normally supplied by the computer vendor and operate with a specified minimal configuration of equipment and peripherals. It is important that attention be paid to embedded computer equipment. In some applications the configuration of computer equipment may be such that standard vendor diagnostics cannot be used. In such a case, the development of diagnostic capability must be insured.

4.4.3.6 **Computer equipment diagnostic computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.6)

To assure compliance.

VERIFICATION GUIDANCE

The complete set of diagnostic programs shall be exercised to verify the capability to isolate failures in the computer equipment for all possible internal operations and computer dependent operations specified. The diagnostics shall be exercised following the prescribed procedures identified in the operations manuals to insure agreement between the program and documentation.

VERIFICATION LESSONS LEARNED

3.4.3.7 **Interface hardware diagnostic computer software.** Computer software shall be provided to perform functional checkout of all trainer interface hardware controlled by the computational subsystem at performance rates and with test values characteristic of real-time operation. This shall include the checkout of instructional subsystem interfaces, I/O controllers, multiplexers, demultiplexers, signal conversion equipment, special interface equipment, and any other interface hardware that is functionally testable with computer software. Trainer equipment normally driven by this interface hardware during real-time operation shall be automatically disconnected during the performance of these tests when necessary to prevent equipment damage. All disconnection and reconnection shall be accomplished under computer control. The programs shall perform automatic range checking of the user inputs to prevent equipment damage caused by out-of-range values. The programs shall also perform the tests and meet the requirements specified in the following subparagraphs for the specified types of interface hardware. Testing shall be performed in a closed-loop fashion. Upon detecting a malfunction, the programs shall automatically indicate the failing hardware on the terminal and in hardcopy. Commercially available software shall be used for the following requirements if it satisfies all the requirements.

REQUIREMENT RATIONALE (3.4.3.7)

This paragraph defines the interface hardware which must be checked out and the requirements common to the subparagraphs below.

Most often the software for these maintainability requirements is developed by the contractor since it is specific to the design of the trainer.

REQUIREMENT GUIDANCE

There should be no need to modify this paragraph. The requirements here are general enough to apply to all trainers.

REQUIREMENT LESSONS LEARNED

4.4.3.7 **Interface hardware diagnostic computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.7)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify the operation of the real-time interface equipment diagnostics. These diagnostic tests shall include verification of all discrete input and output channels, analog and synchro devices. These tests shall produce hard copy output via on-line output devices.

VERIFICATION LESSONS LEARNED

3.4.3.7.1 **Discrete input and output diagnostics.** The interface hardware diagnostic computer software shall check the proper functioning of all the discrete input and output channels, including spares, in a closed-loop fashion.

REQUIREMENT RATIONALE (3.4.3.7.1)

This paragraph identifies the scope of the tests required for discrete I/O interface hardware.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.4.3.7.1 Discrete input and output diagnostics. Verify by __________.

VERIFICATION RATIONALE (4.4.3.7.1)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.4.3.7.2 **Analog input and output diagnostics.** The interface hardware diagnostic computer software shall exercise all of the analog interface hardware through its full range of operation. This shall be accomplished in a closed-loop fashion. The tests shall be designed so that accuracy criteria have defaults or can be overridden by the user. Tests shall include a dynamic test which enables the user to specify (on the terminal) the amplitude of a test signal to a specified channel.

REQUIREMENT RATIONALE (3.4.3.7.2)

This paragraph identifies the scope of the tests required for analog interface hardware. The requirement for the specified interactive capability is unique to the testing of these analog channels.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.4.3.7.2 **Analog input and output diagnostics.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.7.2)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.4.3.7 guidance.)

VERIFICATION LESSONS LEARNED

3.4.3.8 **Trainer equipment test computer software.** Computer software shall be provided to check the proper functioning of all remaining equipment in the trainer which is driven by the computational subsystem that cannot be tested in a closed-loop fashion.

REQUIREMENT RATIONALE (3.4.3.8)

This paragraph identifies the requirement for test programs to be provided for equipment and subsystems which cannot be tested by the general "closed loop" testing method used for the previously identified trainer equipment.

REQUIREMENT GUIDANCE

This paragraph should not require modification.

REQUIREMENT LESSONS LEARNED

Several trainers have been delivered with insufficient test and diagnostic software to maintain unique and specialized subsystem features. Equipment items such as instructor station displays, voice synthesis equipment, or audio play-back equipment cannot generally be tested in a closed loop fashion and thus little or no diagnostic capability was provided. This paragraph and the inclusion of maintenance and test software requirements in all appropriate sections of the specification are attempts to correct this situation.

4.4.3.8 **Trainer equipment test computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.8)

To assure compliance.

VERIFICATION GUIDANCE

This paragraph in the specification is an attempt to cover all unique and specialized equipment that interfaces with the computational subsystem. The test programs developed for the purpose of checking the proper functioning of this equipment shall be tested in accordance with the approved procedures documented in the Acceptance Test Procedures.

VERIFICATION LESSONS LEARNED

3.4.3.9 **Calibration test computer software.** Computer software shall be provided to enable all instruments and controls driven by the computational subsystem to be (1) calibrated, and (2) tested to verify calibration. The programs shall allow both static and dynamic test signals to be applied to each instrument (as appropriate) to verify the instrument's accuracy, dynamic range, and general ability to model the performance of its real-world counterpart (e.g., lack of perceptible stepping). Values and destinations of test signals shall be by operator input.

REQUIREMENT RATIONALE (3.4.3.9)

Calibration programs are necessary to fine tune the trainer interface system, especially the analog I/O channels.

REQUIREMENT GUIDANCE

Care should be taken to insure that these programs are maintainable.

REQUIREMENT LESSONS LEARNED

4.4.3.9 **Calibration test computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.9)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify that the calibration test programs provide both static and dynamic test signals for all appropriate instruments. Test results will be evaluated against the accuracy and dynamic range of each instrument's real-world performance.

VERIFICATION LESSONS LEARNED

3.4.3.10 **Operational readiness computer software.** Computer software and procedures shall be provided to verify that the trainer is operationally ready for crew training. These programs and procedures shall test the operational readiness of all major component subsystem equipment which operates under computer control. The programs shall generate outputs to all instruments, controls, lights, and equipment whose operation can be verified with a visual or aural check. The sequence of outputs shall be cyclic with provisions to stop the sequence at any point. These programs are not intended as calibration programs but rather as quick system operational checks and are normally run on a daily basis before the start of the day's training. The time required to complete the operational readiness procedures shall not exceed __________.

REQUIREMENT RATIONALE (3.4.3.10)

An operational readiness check helps prevent waste of valuable training time. If these procedures uncover a fault that might adversely affect the training mission, the training session can be postponed until repairs have been made. Since it is a "system" requirement covering all major component subsystems, it must appear in this section of the specification.

REQUIREMENT GUIDANCE

A reasonable time limit must be selected for the completion of these tests and procedures. The suggested value for this parameter is fifteen minutes.

REQUIREMENT LESSONS LEARNED

4.4.3.10 **Operational readiness computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.10)

To assure compliance.

VERIFICATION GUIDANCE

Tests of the operational readiness software shall be conducted to verify that outputs are provided to all instruments, controls, lights, and other equipment necessary to determine the operational readiness of the trainer. A contractor prepared test plan shall include a checklist which shall be used to verify that all equipments are properly exercised. The time required to cycle the complete program shall be measured to verify it meets the specified requirement.

VERIFICATION LESSONS LEARNED

3.4.3.11 Spare capacity verification computer software. Computer software to verify the specified spare capacities (3.4.2.5) shall be provided. Optional hardcopy output shall be selectable when exercising these programs.

REQUIREMENT RATIONALE (3.4.3.11)

It is often desirable to be able to assess the impact of software changes on spare capacity throughout the life of the ATD.

REQUIREMENT GUIDANCE

There should be no need to modify this paragraph. The reference provided for the spare capacities and the design requirements stated are to be applied to all the verification programs.

REQUIREMENT LESSONS LEARNED

4.4.3.11 **Spare capacity verification computer software.** Verify by __________.

VERIFICATION RATIONALE (4.4.3.11)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify that the program provided will accurately determine that the spare capacities can be measured and required hardcopy provided. This includes tests measuring spare computational time, spare memory, and spare on-line primary mass storage.

VERIFICATION LESSONS LEARNED

3.4.3.11.1 **Spare processing time verification computer software.** Computer software shall be provided and used to measure the actual frame and cycle time durations (execution times) on each computer configuration in the computational subsystem during the execution of the trainer operational computer programs. These programs shall be a permanent part of the real-time trainer operation. Control of and interface with these programs shall be through a support terminal. The output to be computed and displayed shall include: __________.

REQUIREMENT RATIONALE (3.4.3.11.1)

An accurate means must be provided to measure spare processing time in order to verify compliance with spare requirements.

REQUIREMENT GUIDANCE

Depending on the software design and the hardware configuration, the output requirements list may include:

a. The cycle number and actual cycle time duration of the longest cycle.

b. The number of cycles executed and the total execution time for all cycles.

c. The average cycle time duration.

d. The maximum frame time duration.

e. The average frame time duration.

f. The cycle number and frame identification of any frame exceeding available frame time.

g. The maximum and average execution times of each task for each iteration rate, separately selectable from items 1 through 6 above. Additional requirements may include a time-burner capability.

REQUIREMENT LESSONS LEARNED

In recent ATD deliveries, the trainers have been accepted with less than specified spare processing capacity. In all cases it has been difficult at best to determine the "usable spare" capacity. It is not simply the spare time remaining, assuming it could be measured, but rather the amount of spare time that is usable before significant and measurable degradation of performance is apparent. This is not always the spare time calculated by the spare time verification software. In many cases it is dependent upon how skillful the contractor is in designing and structuring the software so that the performance is not sensitive to loading up spare time. If spare time is truly usable, then using it will in no way impact the performance of the current structure of the real-time software. Therefore, the "time-burner" requirement has been developed and successfully used to determine the usable spare processing capacity by means of selective measures of key performance parameters, under fully loaded trainer operation, while varying the amount of time "burned" or used.

4.4.3.11.1 **Spare processing time verification computer software.** Verify by ________.

VERIFICATION RATIONALE (4.4.3.11.1)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.4.3.11 guidance.)

VERIFICATION LESSONS LEARNED

3.4.3.11.2 **Spare memory/on-line primary mass storage verification computer software.** Computer software shall be provided to verify the spare capacities specified for memory (3.4.2.5.2) and on-line primary mass storage (3.4.2.5.5). These programs shall provide the data from which calculations will be made to verify compliance. The spare memory data shall be obtained from the trainer operational computer program configuration which produces the maximum memory utilization. Computer vendor operating system built-in functions or utilities may be used if all requirements are satisfied.

REQUIREMENT RATIONALE (3.4.3.11.2)

As with spare time, spare memory and spare on-line primary mass storage capacities must be verified.

REQUIREMENT GUIDANCE

Although verifying spare capacities is just as critical as spare time, the software necessary to accomplish this is not nearly as sophisticated. The requirement is simply for software to be provided which provides the raw data necessary to do an analysis of the memory and primary mass storage loading. Most often this is accomplished by the vendor's linking and file management facilities. However, in the case of newer and less sophisticated microcomputer systems these facilities may not be included in the vendor software package and must be developed by the contractor.

REQUIREMENT LESSONS LEARNED

4.4.3.11.2 Spare memory/on-line primary mass storage verification computer software. Verify by ________.

VERIFICATION RATIONALE (4.4.3.11.2)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.4.3.11 guidance.)

VERIFICATION LESSONS LEARNED

3.5 **Instructional subsystem.** An instructional subsystem shall be provided to fulfill the mission training objectives and shall be configured to permit an effective man/machine interface. The instructional subsystem shall provide the instructor with the capability to instruct the student and control, monitor, and evaluate the training exercise. The instructional subsystem shall serve as the primary control center for the simulator. The instructional subsystem shall be designed for ___(a)___ and for an operator/cockpit ratio of ___(b)___. The location of the instructor/operator station shall be ___(c)___. Instructional computational resources shall meet all requirements in 3.4 except ___(d)___.

REQUIREMENT RATIONALE (3.5)

This requirement emphasizes the importance of the mission scenario and the training requirements. A clear understanding of the mission scenario and definition of the major functions/operations must be established by the user, the designer, and the procurer.

REQUIREMENT GUIDANCE

a. Indicate the number of instructors. There is generally one instructor for each student type within the training simulator environment.

Instructors are personnel familiar with student training objectives and performance evaluation, but less knowledgeable of the detailed simulator operation.

b. Indicate the operator/cockpit ratio. The following information may be used to determine this ratio.

The number of cockpits controlled and monitored simultaneously by one operator at the instructor station ranges from one to four.

Operators are personnel dedicated to the simulator operation but less knowledgeable of the training methodology. Major responsibilities consist of bringing the computer system up or on-line each day and performing mission set-up.

Both operating roles may be filled by one or more instructors.

c. Indicate the location of instructor station from the following listing.

(1) On-board the flight station.

(2) Off-board or remote.

(3) Both on-board and off-board.

The location of the instructor station is generally dependent upon the complexity of the training functions and the aircraft configuration.

d. Select from the requirements listed in 3.4 and subparagraphs. Care must be taken to assure that all operational, support, and maintenance modes of the instructional subsystem are taken into consideration. In most cases, all requirements in 3.4 would be applicable and the sentence would not be tailored. In this case, the "except" would be removed. In every case, the appropriate requirements of 3.4.3.1 (programming language), and 3.11 (support and maintenance) must be included.

If there is more than one instructor's station, or if there are two separate stations (one for the instructor and one for the operator), then write detail requirements for each station.

REQUIREMENT LESSONS LEARNED

Identifying the exact training functions of the simulator can provide the following:

a. Determination of the general size and complexity of the instructor station required for the simulator.

b. Identification of the range of simulator capabilities required and a definition of the ways in which these capabilities may be employed.

c. An effective physical instructor/operator station (IOS) design and related software to reduce the information workload on the instructor, reduce instructor errors, and allow greater emphasis on instructional activities rather than operational activities.

Based on a thorough analysis utilizing ISD or similar procedures (AFP 50-58), the staffing, the training needs for the aircraft crews, and the amount and kind of training activities and goals to be achieved will be identified.

4.5 **Instructional subsystem.** Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of the instructional subsystem.

VERIFICATION RATIONALE (4.5)

To assure compliance.

VERIFICATION GUIDANCE

Visual inspection of the number of instructor, operator, and IOS locations provided shall verify that the requirements are satisfied.

VERIFICATION LESSONS LEARNED

3.5.1 **Functional subsystem configuration**. The instructional subsystem design shall comply with the principles and criteria of __________. This shall result in a convenient work area that allows the instructor and/or operator to perform their tasks comfortably and effectively. The design shall also enhance operation, interpretation, and sequences of actions. Minimal time and effort shall be required of the instructor to initialize and control the simulator training sessions. The information and selection of options necessary to provide an effective man/machine interface shall be available to the user at each step of the training exercise.

REQUIREMENT RATIONALE (3.5.1)

This requirement defines the instructor station design configuration which is critical to user acceptance, performance, and safety.

REQUIREMENT GUIDANCE

The instructor station configuration should be designed to meet human factors specifications for reach envelope, instructor anthropometry, visibility, and ease of operation. The instructor station should be simple and compact, enabling the instructor to easily scan all controls and displays, and improving his ability to control ATD. (If the design is complex, the appearance may overwhelm new instructors.)

Paragraph 5.7 of MIL-STD-1472C details the instructional subsystem configuration requirements. MIL-STD-1800, Human Engineering Performance Requirements for Systems (31 Jan 87) will replace MIL-STD-1472.

REQUIREMENT LESSONS LEARNED

The type of tasks to be taught will guide the complexity of the instructor station configuration. A single crew-member aircraft simulator generally requires a more complex remote instructor station because of the more complex mission tasks to be taught. A multi-crew-member cockpit generally requires a less complex on-board instructor station because there are fewer repeaters since the instructor sits behind or beside the student.

4.5.1 **Instructional subsystem configuration.** Verify by __________.

VERIFICATION RATIONALE (4.5.1)

To assure compliance.

VERIFICATION GUIDANCE

Analyses of documented data shall verify human factors specifications. (Additional verification will be found in MIL-STD-1800 (31 Jan 87).)

VERIFICATION LESSONS LEARNED

3.5.2 **Training exercise control.** The instructor shall be provided with a software design that is easy to manipulate, presents information in easily used formats, and facilitates problem control. As an enhancement to instructor efficiency, ___(a)___ preprogrammed mission training exercises shall be provided following the establishment of the training requirements. The preprogrammed training exercises shall automatically control the sequence of events within the training session and shall be tailored to student training objectives to facilitate practice of particular missions and procedures. The programmed training exercises shall include provisions for initial conditions and ___(b)___ programmed malfunctions, the combat environment and other required data bases. The time and number of actions required by the operator to select, alter, and enter data off-line shall be minimized and shall require no programming skills. The simulator shall also include all hardware and software necessary for Air Force support personnel to accomplish major edits to the preprogrammed training exercises and to create new training exercises. User-friendly software shall be incorporated to accomplish this task. Software design and user support features shall be consistent with MIL-STD-1801, User/Computer Interface. Manual exercise control shall provide for on-line editing of initial conditions, preprogrammed malfunctions, and the combat environment. On-line software insertion shall not exceed ___(c)___ minutes for a complete set of initial conditions, a complete set of preprogrammed malfunctions, and minor changes to the combat environment.

REQUIREMENT RATIONALE (3.5.2)

This requirement specifies the number of preprogrammed mission training exercises, initial conditions, and malfunction sets available to the instructor. The ease with which the instructional system may be used and its utility is largely dependent upon this area.

REQUIREMENT GUIDANCE

a. Indicate the number of preprogrammed mission exercises.

b. Indicate the number of preprogrammed malfunctions.

c. Indicate the maximum time for on-line software changes.

REQUIREMENT LESSONS LEARNED

The ability to make changes to initial conditions, malfunction sets, and preprogrammed training exercises should be tightly controlled and reflect the consensus of the training community. Changes to major data bases and other software require more expertise and place tighter constraints on the simulator software system design.

4.5.2 Training exercise control. Verify by __________.

VERIFICATION RATIONALE (4.5.2)

To assure compliance.

VERIFICATION GUIDANCE

Analyses of documented data shall provide justification for selecting the automated instructional features, initial conditions, and the number of programmed malfunctions and mission data sets. Demonstration of on-line changes shall verify that the time and number of actions required on the part of the user will not exceed the requirements. Inspection of the equipment required for detection, notification and correction of user errors, system response requirements, and system prompting shall verify person/computer operational compatibility.

VERIFICATION LESSONS LEARNED

3.5.2.1 **Manual instructor controls.** To aid instruction, the following features shall be provided: ___(a)___. Response to control inputs shall occur within ___(b)___ seconds.

REQUIREMENT RATIONALE (3.5.2.1)

This requirement defines the instructional features available to the instructor/operator and the system's speed of response to his/her inputs. The usefulness and convenience of the instructor station largely depends on these two qualities.

REQUIREMENT GUIDANCE

a. Select from among the following features.

(1) Reset - permits instructor to "return" the simulated aircraft to a stored set of conditions and parameters.

(2) Total system freeze - permits the instructor to interrupt and suspend simulated flight by freezing all system parameters.

(3) Recorded briefing - permits instructor to provide student with information about a structured training session through an audio/visual media presentation.

(4) Demonstration - permits instructor to demonstrate optimal procedures using prerecorded to aim the eye properly exercises.

(5) Record/playback - permits instructor to record and playback a segment of simulated flight.

(6) Hard copy - provides a record of alphanumeric and/or graphic performance data for debriefing purposes.

(7) Combat environment control - permits instructor to modify preprogrammed combat environment.

(8) Procedures monitoring - permits the instructor to monitor discrete actions performed by the student in sequential order.

(9) Parameters monitoring - permits the instructor to monitor various instrument readings, control settings, aircraft states, or navigational profiles.

b. Select a response time from these categories:

(1) Greater than 15 seconds.

Too slow for conversational dialogue.

Frees instructor/operator from captivity of waiting for system.

Allows user to get answer at own convenience.

Message of expected delay is desirable.

(2) Five to fifteen seconds.

Too slow for interactive conversation.

Frustrates user in problem solving and data entry activities.

Allows unproductive behaviors or shifts to other tasks.

(3) Two seconds.

Too slow for users at high concentration level.

(4) Almost instantaneous.

(5) See section 4.3.5.1 of MIL-STD-1801.

REQUIREMENT LESSONS LEARNED

A functional analysis should be performed and an identification of required features should be established prior to source selection. This will help avoid confusion between "desires" and "needs" and incompatible specifications like "minimal instructor mental workload" and "maximum flexibility in system control". Poor definition of functional needs has resulted in expensive, complex instructional systems that resulted in poor training and gross underuse of the instructional features provided.

4.5.2.1 **Manual instructor controls.** Verify by __________.

VERIFICATION RATIONALE (4.5.2.1)

To assure compliance.

VERIFICATION GUIDANCE

Analyses of documented data shall provide justification for selecting the automated instructional features. Demonstrations shall verify that response to control inputs occurs within specified time.

VERIFICATION LESSONS LEARNED

3.5.2.2 **Self instruction.** A self-paced and self-administered program of instruction covering the capabilities and use of the flight simulator and support features shall be provided in the form of a "help" function and/or in the form of the following modes of instruction:

a. ________.

b. ________.

c. ________.

REQUIREMENT RATIONALE (3.5.2.2)

This requirement provides for on-line guidance and off-line instruction for the instructor/operator and the student.

REQUIREMENT GUIDANCE

a. Initial off-line instructor training shall provide for a step-by-step introduction to all simulation capabilities that are conducted at the instructor station in providing hands-on experience either at a remote terminal or at the instructor station.

Designers must be required to consider the consequences of the casual, novice, or infrequent user. Failure to accommodate the abilities and needs of the instructor who may infrequently use the instructor station can result in poor performance resulting in increased training time, increased error frequency and error recovery time, and reluctance or refusal to use the system.

b. On-line instructor prompting shall be the form of system operation aids and a "help" function. Prompts should be clear and understandable and emphasized by highlighting uniqueness and consistent location. A "help" function should be readily accessible during an exercise in providing information to an instructor/operator who already has a basic knowledge on a specific area.

c. Student self practice. The student shall be provided, in an off-line mode, instruction in setting up the simulator to run in an automatic mode from the student position.

REQUIREMENT LESSONS LEARNED

In many cases, the full capabilities of the simulator are not utilized due to lack of knowledge and understanding. The most effective student training will be attained when instructors are well trained in the use of the simulator and the instructional features and can get guidance quickly on-line.

4.5.2.2 **Self instruction.** Verify by ________.

VERIFICATION RATIONALE (4.5.2.2)

To assure compliance.

VERIFICATION GUIDANCE

Demonstrations shall verify that the self instruction program covers the capabilities and use of the flight simulator and support features. Tests and demonstrations shall verify that response times to instructor or student inputs meet user/computer interface requirements.

VERIFICATION LESSONS LEARNED

3.5.3 **Data entry devices.** Data entry devices including ____(a)____ shall be incorporated in the instructor station design on the basis of their potential to support the instructional training objectives. Data entry devices and their respective controls shall conform to ____(b)____. The number of shifts among various methods of data entry shall be minimized. Responses to data entries and generation of associated displays shall occur within ____(c)____ seconds.

REQUIREMENT RATIONALE (3.5.3)

This requirement specifies the means for the instructor/operator to communicate with the instructor station. The hardware chosen will vary with the complexity of the simulator system and the volume of communications required.

REQUIREMENT GUIDANCE

An analysis of the mission requirements should be provided to maximize the utilization and utility of the instructor station. This analysis should be structured within the framework of a training time-line to reveal the significant functions, operations, and procedures to be simulated. This analysis should provide a solid understanding of the hardware required to support the training objectives.

a. The following is a list of devices often procured.

Keyboard - traditional typewriter-style (the Dvorak, or ergonomic, arrangement should also be considered, ANSI X4.22-83, Office Machines and Supplies--Alphanumeric Machines - Alternate Keyboard Arrangement)

Function keyboard - special keycaps for specific instructor station functions

Pushbuttons - function specific

Joystick, trackball - allows remote flying control by the instructor

Mouse - hand manipulated device for cursor control on graphics display

Light pen - device for selection from display menu

Touch panel - graphics overlay or self-contained device

Programmable pushbuttons - software controlled functions

b. Paragraph 5.15.2 of MIL-STD-1472 details data entry "standards." (Appropriate paragraphs of the "Data entry" section of MIL-STD-1801, Human-Computer Interface, will eventually replace MIL-STD-1472 references.)

c. Specify delays from the ranges listed in 3.5.2.1.

REQUIREMENT LESSONS LEARNED

Data entry equipment shall provide a functional interface which minimizes conditions which may degrade performance or contribute to human error.

4.5.3 **Data entry devices.** Verify by ________.

VERIFICATION RATIONALE (4.5.3)

To assure compliance.

VERIFICATION GUIDANCE

An operational sequence diagram/time line shall verify the hardware selection effort. Inspection of standards for data entry devices and their respective controls shall verify user-friendly requirements. (Test standards for Data Entry section of MIL-STD-1801 will be incorporated.)

VERIFICATION LESSONS LEARNED

3.5.4 **Display devices.** The following display devices shall have the capability to provide pertinent information to the instructor and be capable of monitoring selected events of the training exercise: ___(a)___. Glare shall be minimized. Graphics display devices shall be state-of-the-art. Minimum acceptable resolution for an instructor station shall be 512 by 512 pixels.

Interactive control/display relationships shall be explicit, straightforward, and conform to ___(b)___. Display control options shall be provided to adjust display brightness, contrast, and focus.

REQUIREMENT RATIONALE (3.5.4)

This requirement establishes the devices which will display information the instructor needs during a training exercise.

REQUIREMENT GUIDANCE

Select the display device that best meets functional requirements. Current state-of-the art display systems are CRT-based. The display device should be designed to permit simple manipulation of malfunction insertion, modification of weather, night parameters, and scenes without a multi-step selection process across a series of menus. Associated display device controls, switches, and repeater instruments should be kept to a minimum. Appropriate information should be displayed to the instructor within an allotted time frame to minimize instructor workload. In addition, the instructor workload should be minimized by selecting an optimal user/display system interface. Resolution and glare should be controlled to maximize readability and minimize eye fatigue.

a. Display devices available include:

Alphanumeric/graphic CRT display

Repeaters

Hardcopy printers

Voice output.

b. Paragraph 5.15.4 of MIL-STD-1472 details control/display relationships, menu selection, form filling, interactive control, and command language interactive control. (See "Data Display" chapter of MIL-STD-1801.)

REQUIREMENT LESSONS LEARNED

4.5.4 **Display devices.** Verify by __________.

VERIFICATION RATIONALE (4.5.4)

To assure compliance.

VERIFICATION GUIDANCE

Analysis of documented data shall verify the display selection. If CRT display systems are selected, tests shall be conducted to assure system performance characteristics are satisfied. Demonstration of the interactive display controls shall verify user-friendly requirements. Demonstration shall verify the number and type of modes of operation provided to the user during training exercises. (Additional verifications standards will be found in the "Data Display" chapter of MIL-STD-1801.)

VERIFICATION LESSONS LEARNED

3.5.4.1 **Display format.** An easy-to-read, uncluttered, standardized format shall be used. The presentation of information shall be consistent with the limitations of human perception and memory in order to minimize user interpretive effort and alleviate confusion. The display format and content coding shall conform to the following: __________.

REQUIREMENT RATIONALE (3.5.4.1)

This requirement describes the organization and presentation of data for use.

REQUIREMENT GUIDANCE

Display formats should be carefully defined. Data that is organized in meaningful groups will be perceived faster and more accurately. Windowing and icons also help. (Windowing permits highlighting of relevant data without removing background data. Icons are immediately recognizable pictures that represent actions and objects to the user.) Color can also provide information. Logically related data can be grouped by using color coding. Color should convey meaning commonly associated with the color. For example, red for critical conditions, yellow for caution, and green for normal conditions. Blinking can also be used to alert the instructor to hypercritical data.

Paragraph 5.15.3 of MIL-STD-1472 details display format and content, and coding for alphanumeric, graphic, and audio displays. (See "Data Display" chapter of MIL-STD-1801.)

Display format options available include:

- Border masks
- Editing area for computer entries prior to insertion
- Display area on plot pages for information pertinent to the exercise.

REQUIREMENT LESSONS LEARNED

Results from functional analyses should establish the required visual information needed by the instructor/operator to monitor and evaluate student performance.

4.5.4.1 **Display format.** Verify by __________.

VERIFICATION RATIONALE (4.5.4.1)

To assure compliance.

VERIFICATION GUIDANCE

Inspection of the display format shall ascertain that the requirements are satisfied. (Additional verification standards will be found in the "Data Display" chapter of MIL-STD-1801.)

VERIFICATION LESSONS LEARNED

3.5.5 **Interphone communication system.** An interphone system shall be provided to permit communication among the student, instructor, and the operator. The system design shall permit selective monitoring and transmission over any of the simulated radios and include the following equipment: __________. In addition, an independent hard-wired channel shall be provided to permit emergency communication between personnel within the cockpit enclosure and anyone in the immediate area outside the cockpit. (See 3.12.10.7).

REQUIREMENT RATIONALE (3.5.5)

Communication among the student, instructor, and operator is essential during the training session. In addition, a reliable means of communication between personnel within the cockpit enclosure and those outside is imperative during an emergency.

REQUIREMENT GUIDANCE

Communications equipment options include:

a. Headset/microphones

b. Microphone (pedestal mount)

c. Speakers

d. Communications jacks

e. Communication controls - for both speakers and headset volume, and to control the mode for transmission and reception.

REQUIREMENT LESSONS LEARNED

4.5.5 **Interphone communications system.** Verify by __________.

VERIFICATION RATIONALE (4.5.5)

To assure compliance.

VERIFICATION GUIDANCE

Inspection of the interphone system shall verify that specified subcomponents are present and permit selective communication.

VERIFICATION LESSONS LEARNED

3.6 **Motion simulator subsystem.** Motion simulation devices shall display task-critical motion and force information to the ____(a)____ and shall include ____(b)____.

REQUIREMENT RATIONALE (3.6)

This paragraph specifies the motion simulator devices to be provided and the aircrew members to whom the displayed information shall be presented.

REQUIREMENT GUIDANCE

Motion simulation may not be necessary. See lessons learned, below.

a. Specify the aircrew members who are to receive the displayed information.

b. Specify the motion simulator devices to be provided. These may include (1) a platform motion system to impart whole-body motion cues to the aircrew members (in which case the requirements of 3.6.1 shall apply), or (2) in-cockpit cueing devices which include "G-suits," "dynamic g-seats," or "seat shaker" systems (in which case the requirements of 3.6.6 shall apply).

REQUIREMENT LESSONS LEARNED

Experience has shown that the type of motion simulator acquired is directly related to the task being trained, the task loading of the trainee, and the operational scenario being modeled. To illustrate:

Example 1: EF-111A Simulator

The training requirement indicated this simulator should be primarily a training device for the Electronic Warfare Officer. Motion cues were judged unnecessary.

Example 2: B-52 Defensive Station

In this case, it was clear from training requirements that indicated limited motion cues would be adequate. It was decided to include two degrees-of-freedom, (pitch and roll) plus vibration and buffet.

Example 3: C-130 Operational Flight Trainer

This simulator trains all operational situations for the aircraft. Thus, all motion cues were included in the trainer. It was decided to install a six degree-of-freedom (three rotational and three translational) motion system.

4.6 **Motion simulators.** Tests, inspections, analyses and demonstrations shall be conducted to verify the performance of motion simulator subsystems.

VERIFICATION RATIONALE (4.6)

To assure compliance.

VERIFICATION GUIDANCE

TBD.

VERIFICATION LESSONS LEARNED

3.6.1 **Motion system components.** The major components to be provided are:

a. Motion system with capability in the following degrees-of-freedom: __________.

b. Operating and maintenance controls and displays for the motion and control loading systems.

c. Personnel access device.

REQUIREMENT RATIONALE (3.6.1)

This paragraph summarizes the major motion system components.

REQUIREMENT GUIDANCE

Under this paragraph, specify the major components which the contractor is to provide.

List the degrees-of-freedom required (choices: roll, pitch, yaw, heave, longitudinal translation, and lateral translation). The contractor is free to exceed the requirement, of course.

REQUIREMENT LESSONS LEARNED

The six-degree-of-freedom synergistic motion system offers the advantages of commonality of parts off-the-shelf availability, and relatively good access to the various platform components. Its disadvantages are an increased tendency for cross-talk among degrees-of-freedom, motions in one degree-of-freedom detracting from simultaneous capabilities in other degrees-of-freedom, and, often, the requirement for a larger facility than would be needed for a motion system tailored to specific needs. As a rule of thumb, the cost of the synergistic six-degree-of-freedom system will be approximately the same as the cost of a tailored-to-specification four-degree-of-freedom system. Recommendations regarding four degrees-of-freedom can be found in the "Report of the USAF Scientific Advisory Board Ad Hoc Committee on Simulation Technology", published April 1978.

4.6.1 **Motion system components.** Verify by ___________.

VERIFICATION RATIONALE (4.6.1)

To assure compliance.

VERIFICATION GUIDANCE

Visually identify and verify that each component is present.

VERIFICATION LESSONS LEARNED

Well-structured test procedures have used this test as a mechanism to acquaint test personnel with the location and nomenclature of the major components in the process of their verifying that all components are present.

3.6.2 **Motion system performance characteristics.** A ___________ motion system shall be provided. Within its performance envelope, the motion system shall provide cues to the simulator crew members which correspond to those they would perceive in the actual aircraft under the environmental and mission conditions being simulated.

REQUIREMENT RATIONALE (3.6.2)

This paragraph provides a general statement regarding the nature of the information to be displayed.

REQUIREMENT GUIDANCE

Specify what the moving platform is to move--flight station, navigator station, pilot station. Use nomenclature consistent with the whole of the flight simulator specification.

REQUIREMENT LESSONS LEARNED

4.6.2 **Motion system performance characteristics**

VERIFICATION RATIONALE (4.6.2)

To assure compliance.

VERIFICATION GUIDANCE

Visual inspection shall verify that the proper work station is mounted on the moving platform. Simulator flight tests by experienced crew members shall subjectively verify that the cues displayed are perceptually equivalent to those experienced in flight. Instrumental test data for the motion cues corresponding to simulated aircraft attitude, specific force, and rotational accelerations shall objectively verify that platform motions are correct in each required degree-of-freedom.

Subjective simulator flight tests should be used to generally establish that the motion simulator provides onset and attitude cues in the proper direction. Objective strip chart data will verify that onset motions and attitude cues are in the proper direction in all required degrees-of-freedom.

VERIFICATION LESSONS LEARNED

There are two schools of thought regarding the proper platform steady-state pitch attitude. One side argues that platform pitch should be in the same direction as aircraft pitch; the other side maintains that platform pitch should be in the direction which corresponds to the specific force vector (which often is opposite to the steady-state aircraft pitch attitude). There are no hard training data suggesting which direction is better. Proper steady-state pitch attitude has therefore been determined by user preference, which generally favors following aircraft attitude.

3.6.2.1 **Simulated motions.** The motion system shall at all times perform smoothly and without hunting. The motion system movement shall be determined by computer computations based on the six degrees of aircraft freedom. The motion system computations shall be executed at iteration rates sufficiently high to ensure no noticeable discrepancy exists between the time the respective simulator and aircraft motion cues are experienced in response to the same ___________. Sequencing of the motion computations relative to other programs and relative to the processing of analog-to-digital converters shall minimize the delay from a cockpit control input to the display of the corresponding motion cue. The frequency of occurrence of new cues shall be maximized; during position washout, new cues shall be accepted in any direction constrained only by the position and velocity limits of the system and the threshold of perception of the crew member(s). Spurious motion and washout shall at no time be noticeable to the crew member(s).

REQUIREMENT RATIONALE (3.6.2.1)

This paragraph specifies general servomechanism requirements and gives the contractor guidance regarding timeliness of cues.

REQUIREMENT GUIDANCE

Specify the signal to which the motion system is responding. For example, if the motion platform is moving the flight station, "flight station control input" would be inserted.

REQUIREMENT LESSONS LEARNED

In the past, little attention has typically been paid to properly sequencing computations in order to minimize motion system cue delays. This paragraph, among other things, requires the contractor to attend to proper sequencing of motion-related computations.

4.6.2.1 Simulated motions

VERIFICATION RATIONALE (4.6.2.1)

To assure compliance.

VERIFICATION GUIDANCE

A review of the simulator computational system documentation shall verify that motion simulator computations and processing are sequenced to minimize the delay from control input to display of the motion cues. Simulator flight tests conducted by experienced crew members shall subjectively verify that the motion cues are timely, that the frequency of occurrence of new cues is maximized, and that spurious motion and washout motion are not noticeable. Objective instrumented test data shall provide a further check on the suprathreshold amplitudes and timeliness of the motion simulator's specific amplitude and rotational acceleration cues.

This test should not be conducted until it has been established that the simulated aerodynamics are in accordance with the approved data. Subjective simulator flight tests should then be conducted to establish satisfactory timeliness, frequency of occurrence, and quality of motion cues. Objective data should be obtained on strip chart recorders which compare motion simulator response to simulated aircraft control surface deflections, specific forces, and angular accelerations.

VERIFICATION LESSONS LEARNED

3.6.2.1.1 **Motion activity.** As a minimum, the following motions shall be simulated: ___________.

REQUIREMENT RATIONALE (3.6.2.1.1)

This paragraph specifies a detailed set of cues which the motion system is to display.

REQUIREMENT GUIDANCE

Include all relevant cues in this set. On the other hand, one should include only those required (for example, do not require "runway rumble" in an air-to-air simulator). Carefully consider the items in the list below.

The following is a comprehensive list of cues found relevant in past simulators:

a. Stalls, slides, slips, dives, climbs, banks, spins, and rolls.

b. Release of missiles and/or stores.

c. Touchdown attitude and impact.

d. Movements corresponding to brake applications.

e. Landing gear strut dynamics.

f. Ground dynamics including runway rumble.

g. Movements corresponding to landing gear extension or retraction.

h. Movements corresponding to center of gravity or center of pressure movement.

i. Vibration and buffet dynamics at frequencies approximating actual aircraft frequencies.

j. Effects of rough air and wind buffet in all appropriate degrees-of-freedom.

REQUIREMENT LESSONS LEARNED

4.6.2.1.1 **Motion activity.** Verify by ___________.

VERIFICATION RATIONALE (4.6.2.1.1)

To assure compliance.

VERIFICATION GUIDANCE

Simulator flight tests conducted by experienced crew members shall verify that each member of the required cue set is satisfactorily provided.

This test should be the last simulator test conducted. It is best to first verify all other motion performance requirements and assure that the flight simulator configuration is settled out and finalized prior to beginning this subjective test for the satisfactory presentation of each of the required motion cues. Since motion simulation is still more art than science, this final evaluation is very subjective.

VERIFICATION LESSONS LEARNED

Expect that some adjustments will have to be made to the amplitudes of several of the cues presented. Past experience has shown that the experienced crew members will judge some cue intensities excessive, while others are insufficient. Some tradeoffs may have to be made among cues to arrive at a final optimistic set.

3.6.2.2 **Worst-case maneuvers.** The motion system shall smoothly and correctly perform the worst-case maneuvers the simulated vehicle and its pilot shall demand, i.e., those maneuvers which cause demands on the power supply sub-system greater than the active components can supply (such as a rapid series of demanding flight maneuvers).

REQUIREMENT RATIONALE (3.6.2.2)

This paragraph provides the performance requirement regarding the capacity of the passive peak energy storage devices in conjunction with the active power supply subsystem capacity.

REQUIREMENT GUIDANCE

Generally, it is more cost-effective to permit the contractor to size the active components of the power supply subsystem to the average power required and provide passive peak energy storage devices as a supplement for peak demands. Overall power supply capacity is adequate when motion simulator response to the worst-case maneuvers induced by a rated pilot are smooth and correct.

REQUIREMENT LESSONS LEARNED

It is not the intent of this requirement to cause a contractor to overdesign the power supply subsystem. It is for this reason that the worst-case maneuvers must be representative of operational requirements for the flight simulator. Since the maneuver induced requires more power than the active components can provide, the passive components cannot sustain the maneuver indefinitely and it will always be possible for a test person to bleed the stored energy down. The requirement is that the passive components sustain those maneuvers relevant to the simulated vehicle and its pilot.

4.6.2.2 **Worst-case maneuvers.** Verify by ________.

VERIFICATION RATIONALE (4.6.2.2)

To assure compliance.

VERIFICATION GUIDANCE

The simulated vehicle shall be subjected to a series of worst case maneuvers by a pilot(s). These maneuvers shall be consistent with maneuvers which are performed in the actual vehicle.

The demands placed on the motion system's power supply in this test should be consistent with the operational requirement for the flight simulator. It is therefore essential that the conductor of this test be a pilot(s) representative of the user population, and that the maneuvers be representative of operational worst-case maneuvers.

VERIFICATION LESSONS LEARNED

There have been occasions where test personnel, who were not pilots, have conducted this test with negative results on systems which were in fact adequately designed for the operational requirements.

3.6.2.3 **Payload weight.** Performance requirements shall be met at normal operating weight, computed as ___(a)___ station, plus ___(b)___, plus all on-board personnel, plus ___(c)___ pounds for growth.

REQUIREMENT RATIONALE (3.6.2.3)

This paragraph specifies the minimum payload weight capability under which all operational performance requirements are to be met.

REQUIREMENT GUIDANCE

Since the operational performance capabilities of a motion system are generally impacted by the payload weight, it is recommended that care be exercised to assure that the weight specified allows for all simulator components to be mounted on the moving platform, and also that allowance is made for future growth. In polling contractors to determine current off-the-shelf or projected payload capabilities, be sure you understand the contractor's definition of "payload"; contractors typically include upper joints and the moving platform as well. When filling in the blanks in the specification, use wording that is not overly specific, but that is sufficiently detailed to make the requirement clear. Wording may be adapted from the list below.

The following requirements have been successfully used in the past in defining "normal operating weight":

a. Flight station (or other appropriate station).

b. Specify the visual system weight or provision for visual system weight.

c. Typically, 2,000 pounds is specified; however, if the visual system weight has already been included, specify at least 1,000 pounds. (If no visual system weight has already been included, specify at least 4,000 pounds).

REQUIREMENT LESSONS LEARNED

4.6.2.3 **Payload weight.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.3)

To assure compliance.

VERIFICATION GUIDANCE

Inspection of drawings, analyses, and inspection of the motion system shall verify that a test payload of the required weight is mounted on the platform.

The contractor's drawings should contain sufficient information (e.g., dimensions, density, and location) of the test payload to ascertain that the total test payload weight satisfies the requirements. Density values provided should be consistent with values found in engineering manuals or other credible source materials. The contractor should also provide a rationale for placement of the payload components in terms of mimicking the worst case center-of-gravity for anticipated visual or other on-platform subsystems. An inspection of the platform should be conducted to verify that the load components are mounted in accordance with the drawings.

VERIFICATION LESSONS LEARNED

3.6.2.4 **Step response.** The response of the motion platform to a 0.2-Hz square wave with an amplitude of ___(a)___ shall be initiated in less than ___(b)___ seconds following a change in state of the square wave.

REQUIREMENT RATIONALE (3.6.2.4)

This paragraph specifies the maximum pure time delay (transport delay) permitted.

REQUIREMENT GUIDANCE

a. A reasonable value for amplitude is 5 percent of the displacement in each degree-of-freedom. If a particular degree-of-freedom requires simultaneous excursion of all actuators, this specification can be levied against that particular degree-of-freedom only.

b. Servomechanisms employed in motion systems typically have some inherent transport delay. This specification is included to guard against excessive transport delays. Specify values no larger than 0.05 seconds.

REQUIREMENT LESSONS LEARNED

Transport delays typically encountered in hydraulically powered motion systems are on the order of 10 to 50 milliseconds. Response within 0.05 second should not be a problem with state-of-the-art devices.

4.6.2.4 **Step response.** Verify by ________.

VERIFICATION RATIONALE (4.6.2.4)

To assure compliance.

VERIFICATION GUIDANCE

The motion system shall be instrumented and objective data obtained to verify that transport delays are not excessive

Monitor the response of the motion system to the 0.2 Hertz square wave on a strip chart recorder. A 0.2 Hertz frequency is low enough that the motion system will settle out at the commanded value well before each change in state of the square wave--hence, the step response will be obtained. Conduct the test for each degree-of-freedom specified in the test requirement.

VERIFICATION LESSONS LEARNED

3.6.2.5 **Excursion and velocities.** The motion system shall perform about the neutral operating point in accordance with the criteria shown in tables I and II. Each degree-of-freedom is defined individually with respect to a non-moving coordinate system centered at the centroid of the platform in its neutral position. The requirements of tables I and II are nonsimultaneous requirements which are to be met without exceeding the normal operational stroke of any actuator or engaging any distinct actuator over-travel device. The motion system must satisfy each of the requirements, using only one-degree-of-freedom at a time, with only that amount of actuator travel which is useable in a normal training configuration. However, the excursion envelope about the neutral operating position shall allow simultaneous movements to the limits specified in table III.

TABLE I. Motion system excursion.

Degree-of-Freedom	Excursion Requirements
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches
(a)	± (b) inches

It is not required that heave and pitch excursion capabilities be symmetric about the neutral operating position; however, the total excursion capability shall be maintained.

TABLE II. Motion system velocity.

Degree-of-Freedom	Velocity Requirements at the Neutral Operating Point
___(a)___	± ___(c)___ inches per second
___(a)___	± ___(c)___ inches per second
___(a)___	± ___(c)___ inches per second
___(a)___	± ___(c)___ inches per second
___(a)___	± ___(c)___ inches per second
___(a)___	± ___(c)___ inches per second

TABLE III. Motion system simultaneous excursion.

Degree-of-Freedom	Simultaneous Excursion Requirements
___(a)___	± ___(d)___ inches
___(a)___	± ___(d)___ inches
___(a)___	± ___(d)___ inches
___(a)___	± ___(d)___ inches
___(a)___	± ___(d)___ inches
___(a)___	± ___(d)___ inches

REQUIREMENT RATIONALE (3.6.2.5)

The primary constraint on motion system cues is imposed by the minimum excursion and velocity capabilities. This paragraph specifies the minimum excursion and velocity requirement.

REQUIREMENT GUIDANCE

Insert in the appropriate blanks.

a. The relevant degrees-of-freedom.

b. Excursion requirements (in inches).

c. Velocity requirements (in inches per second) for each of the relevant degrees-of-freedom.

d. Excursion requirements (in inches).

Note that if the "simultaneous movement" requirements are the same as the "table I, excursion requirements," synergistic motion systems will probably be ruled out.

REQUIREMENT LESSONS LEARNED

A synergistic six-degree-of-freedom motion system geometry program is available in ASD/ENET which provides specific capabilities for current synergistic systems. Generic requirements for synergistic six-degree-of-freedom motion systems currently in use are:

Degree-of-Freedom	Simultaneous Excursion Required	Table I Excursion Requirements	Table II Excursion Requirements
Vertical (Heave)	±6 inches	±34 inches	24 inches per second
Lateral	±6 inches	±34 inches	24 inches per second
Longitudinal	±6 inches	±34 inches	24 inches per second
Pitch	±4 degrees	±25 degrees	17.5 degrees per second
Roll	±4 degrees	±20 degrees	20 degrees per second
Yaw	±4 degrees	±20 degrees	20 degrees per second

4.6.2.5 **Excursion and velocities.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.5)

To assure compliance.

VERIFICATION GUIDANCE

For synergistic motion systems, the requirements shall be validated via a combination of inspection of drawings, geometric analyses, inspection of the motion system, and direct measurement. For cascaded motion systems, validation shall be conducted by direct measurement alone.

Since cascaded motion systems have uncoupled motion capabilities in each of the required degrees-of-freedom, a direct measurement of the excursion capabilities can be easily conducted using calibrated tapes and/or inclinometers. Velocities can be measured by calibrating the follow-up sensor voltage outputs in terms of excursions, and then measuring the maximum slew rates of these voltages. It is not wise to simply rely on direct measurement for synergistic systems however, since the results can be misleading.

For synergistic motion systems, use the following procedures:

a. Conduct a geometric analysis to determine the worst-case actuator excursions and velocities necessary to meet all requirements.

b. Verify that the delivered hardware geometry does in fact correspond to the drawings by taking direct measurements of the main joint dimensions.

c. By direct measurement, verify the actuator excursions meet or exceed the worst-case requirements determined by the geometry analysis.

d. Calibrate the actuator follow-up sensor output voltages in terms of actuator excursions.

e. Using a sinusoidal command, drive each actuator and monitor its follow-up voltage on a strip chart recorder. Select a test signal amplitude approximately 50 percent of rated actuator excursion (the precise value is not critical). Select a frequency, f, such that the peak velocity demanded (6.28 f • Peak Amplitude) is equal to the worst case actuator velocities required from the geometric analysis. Verify that each actuator is capable of this worst-case velocity requirement.

VERIFICATION LESSONS LEARNED

In the past, some test results from tests conducted on synergistic motion systems have been misleading because these tests relied on direct measurements alone.

3.6.2.6 **Specific force and rotational acceleration.** The motion system shall meet the minimum criteria given in table IV at the neutral operating point.

TABLE IV. Motion systems specific forces and rotational accelerations.

Movement	Minimum specific forces and rotational accelerations
______(a)______	± ______(b)______ g
______(a)______	± ______(b)______ g
______(a)______	± ______(b)______ g
______(a)______	± ______(b)______ deg/sec/sec
______(a)______	± ______(b)______ deg/sec/sec
______(a)______	± ______(b)______ deg/sec/sec

REQUIREMENT RATIONALE (3.6.2.6)

The requirement levied by this paragraph guarantees that the actuators can develop sufficient forces to move the payload at reasonable suprathreshold levels.

REQUIREMENT GUIDANCE

Insert in the appropriate blanks:

a. The relevant degrees of freedom.

b. The minimum values of specific forces (in g units) and rotational accelerations (in degrees per second per second) required.

REQUIREMENT LESSONS LEARNED

Typical and reasonable values for minimum specific force and rotational acceleration capabilities are listed below. State-of-the-art motion systems should have no problem meeting these requirements.

Degree-of-Freedom	Minimum specific forces and rotational accelerations
Vertical (Heave)	±0.8 g
Lateral	±0.6 g
Longitudinal	±0.6 g
Pitch	±60 degrees/second/second
Roll	±60 degrees/second/second
Yaw	±60 degrees/second/second

4.6.2.6 **Specific force and rotational acceleration.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.6)

To assure compliance.

VERIFICATION GUIDANCE

Mount accelerometers to the platform with their sensitive axes aligned along the appropriate degrees-of-freedom. (Note: Linear accelerometers measure specific force, not linear acceleration. This misnomer often leads to confusion.) Apply a test signal to drive the motion system in each applicable degree-of-freedom. Monitor the accelerometer outputs on a strip chart recorder. It is convenient to use a 0.2 Hertz square wave as the forcing function as this is equivalent to the low frequency relative to the motion system's response. Select an amplitude just high enough to demonstrate that the requirements are satisfied.

VERIFICATION LESSONS LEARNED

3.6.2.7 **Frequency response.** The closed-loop response of the motion system in ___(a)___ degrees-of-freedom shall comply with the following criteria. The response shall be measured from the command input to the resulting platform response.

TABLE V. **Motion system closed-loop response.**

Frequency Range		Maximum Phase Shift (degrees)	Maximum Attenuation (decibels)
(b)	- ____	(c)	(d)
(b)	- ____	(c)	(d)
(b)	- ____	(c)	(d)
(b)	- ____	(c)	(d)

REQUIREMENT RATIONALE (3.6.2.7)

The steady-state frequency response (the phase lag in particular) of the motion system is one of the most critical factors affecting timeliness of the motion cues displayed. This paragraph specifies the minimum requirements in this regard.

REQUIREMENT GUIDANCE

a. If applied to a synergistic six-degree-of-freedom motion system, the frequency response should be levied only in the heave degree-of-freedom in order to avoid compounding nonlinear effects. If applied to a cascaded motion system, the frequency response should be levied against each degree-of-freedom.

b, c, and d. A typical frequency response requirement which has been satisfied by state-of-the-art, off-the-shelf synergistic six degree-of-freedom motion systems is the following:

Frequency Range (Hertz)	Maximum Phase Shift (degrees)	Maximum Attenuation (decibels)
0.1-0.5	-15°	0.5 dB
0.5-1.0	-30°	1.5 dB
1.0-1.7	-60°	2.5 dB
1.7-5.0	Not Applicable	Perceptible Cue

REQUIREMENT LESSONS LEARNED

This requirement has been driven more by state-of-the-art capability than by data on human performance. The phase lag, particularly in the region up to about 1.7 Hz, can usually be characterized as an equivalent pure time delay or "transport delay" (a pure time delay has unity gain and a phase lag proportional to frequency) in the steady-state frequency domain. The relationship is the following:

$$\tau = \phi / (360f)$$

where:

τ is the effective transport time in seconds

ϕ is the phase angle in degrees

f is the frequency in Hertz

Hence, a pure time delay of 83 milliseconds would produce a phase angle of -15 degrees at 0.5 Hz. A lesser phase shift would be equivalent to a correspondingly shorter delay. This delay adds to that of computational frame time and any filtering necessitated to smooth out computer command updates. The "Report of the USAF Scientific Advisory Board Ad Hoc Committee on Simulation Technology", dated April 1978, page 8, suggests a maximum τ = -60 milliseconds (they assumed a maximum computer introduced delay of 40 milliseconds and a maximum permissible overall delay of 100 milliseconds). Note that this delay would yield ϕ = -10.8 degrees at 0.5 Hz, ϕ = -21.6 degrees at 1.0 Hz, and ϕ = -36.7 degrees at 1.7 Hz. (This would be satisfied with a second order servo bandwidth of 25 radians per second with a damping ratio of 0.707.)

4.6.2.7 **Frequency response.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.7)

To assure compliance.

VERIFICATION GUIDANCE

Utilize a servo analyser to measure the frequency response of the motion system in each degree-of-freedom. Select a forcing function amplitude which will cause the motion system to operate in its linear region in order that the results be meaningful.

VERIFICATION LESSONS LEARNED

3.6.2.8 **Damping.** The response of the motion platform to a 0.2 Hertz square wave with an amplitude of ___(a)___ in ___(b)___ shall (without washout) exhibit no more than a ___(c)___ percent overshoot. There shall be no more than a single overshoot.

REQUIREMENT RATIONALE (3.6.2.8)

This paragraph is included to assure that the motion system is not too lightly damped.

REQUIREMENT GUIDANCE

a. and b. For synergistic six-degree-of-freedom motion systems, an amplitude of 5 percent of the displacement in heave is recommended. For cascaded motion systems, an amplitude of 5 percent of the displacement in each degree-of-freedom should be specified.

c. An overshoot of no more than 5 percent is recommended. The relationship between peak overshoot and the damping ratio in second order systems is the following:

$$\text{Peak Overshoot} = \epsilon \left(\frac{-\pi Z}{\sqrt{1 - Z^2}} \right)^{1/2}$$

where:

Z is the dimensionless damping ratio

Note that a damping ratio of 0.7 yields a peak overshoot of 4.6 percent. Some allowance should also be made for minor non-linear effects.

REQUIREMENT LESSONS LEARNED

Current motion simulators have met the requirement that overshoot shall not exceed 2 percent, corresponding to a damping ratio of 0.8.

4.6.2.8 **Damping.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.8)

To assure compliance.

VERIFICATION GUIDANCE

Inject a 0.2 Hertz square wave forcing function of appropriate amplitude. Monitor the motion system's response on a strip chart recorder, and verify that the requirement is satisfied. Repeat in each applicable degree-of-freedom.

VERIFICATION LESSONS LEARNED

3.6.2.9 **Smoothness.** There shall be no spurious acceleration transients greater than ___(a)___ g peak at the aircrew station with any or all of the actuators being driven with a sinusoidal input signal of ___(b)___ percent of the maximum voltage at a frequency of ___(c)___ Hertz.

REQUIREMENT RATIONALE (3.6.2.9)

This paragraph is included to help assure that the motion simulator operates smoothly.

REQUIREMENT GUIDANCE

State-of-the-art hydraulic motion systems incorporate hydrostatic bearings in their actuator design.

a. These systems can easily meet the requirements that there be no spurious transients greater than 0.04 g peak.

b and c These measurements have generally been made using sinusoidal input signals 10 percent of the maximum voltage at a frequency of 0.5 Hertz.

REQUIREMENT LESSONS LEARNED

In hydraulic motion systems, actuator stiction introduces a distracting phenomenon known as "turn-around bump." This "bump" is discernible at levels as low as 0.02 g in operational motion systems if one attends to it sufficiently. Under normal workload conditions, however, 0.04 g peak is a reasonable permissible upper limit.

4.6.2.9 **Smoothness.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.9)

To assure compliance.

VERIFICATION GUIDANCE

Mount an accelerometer(s) of appropriate sensitivity at the aircrew station with the sensitive axis aligned along the appropriate degree(s)-of-freedom. (Note: For synergistic six degree-of-freedom systems, it is sufficient to use one accelerometer aligned with the heave axis. In this case, execute the test by driving all six actuators simultaneously, i.e., in the heave degree-of-freedom.) Apply a sinusoidal test forcing function of the specified amplitude and frequency. Monitor the accelerometer output(s) on a strip chart recorder.

VERIFICATION LESSONS LEARNED

Note carefully the transients at turnaround.

3.6.2.10 **Stability.** For any static position or constant velocity, there shall be no instabilities in the motion simulator or its servomechanisms which impart load accelerations greater than __________ g peak.

REQUIREMENT RATIONALE (3.6.2.10)

This requirement is imposed to assure stable actuator servomechanisms.

REQUIREMENT GUIDANCE

For hydraulic motion systems, use a maximum value of 0.015 g peak.

REQUIREMENT LESSONS LEARNED

In hydraulic actuators, good servomechanism designs have resulted in levels of induced noise to values less than 0.015 g peak. This has proven acceptable.

4.6.2.10 **Stability.** Verify by __________.

VERIFICATION RATIONALE (4.6.2.10)

To assure compliance.

VERIFICATION GUIDANCE

Mount accelerometers as in 4.6.2.9. Apply a forcing function comprising of a triangular wave. Use a low frequency (on the order of 0.05 Hertz). An amplitude of 60 to 80 percent of full excursion should work well. Monitor the accelerometer output(s) on a strip chart recorder. Allow the turnaround transient to decay; look for instability transients during the constant velocity portion of the response.

VERIFICATION LESSONS LEARNED

3.6.2.11 **Static accuracy**. Static error between actual and commanded platform position shall be less than __________ percent of full scale.

REQUIREMENT RATIONALE (3.6.2.11)

This requirement is imposed to assure that servomechanism components are properly aligned.

REQUIREMENT GUIDANCE

It is reasonable to expect that proper servo design should reduce static accuracy errors to less than 1 percent of full scale. If the feedback element signals are not carefully calibrated, there can be coupling of motions among degrees-of-freedom. This is especially a problem in synergistic geometry designs.

REQUIREMENT LESSONS LEARNED

Proper servo calibration and alignment procedures have, at times, not been followed by simulator vendors. This has resulted in static inaccuracies well in excess of 1 percent of full scale, with attendant cross-coupled motions in synergistic systems. Enforcement of this requirement has rectified the problems insofar as static alignment is concerned.

4.6.2.11 **Static accuracy**. Verify by __________.

VERIFICATION RATIONALE (4.6.2.11)

To assure compliance.

VERIFICATION GUIDANCE

Direct measurements shall verify that the static accuracy requirement is satisfied.

Apply a constant voltage level to each of the actuators. Predict the actuator excursion based upon contractor supplied scale factors. Measure the actuator excursion with a calibrated tape or inclinometer, as appropriate. Tabulate predicted versus measured values, and determine whether the differences (errors) satisfy the requirements. Repeat at several levels across the complete range of excursion for each actuator.

VERIFICATION LESSONS LEARNED

The results of this test provide the calibrated voltage scale factors needed for other performance tests. This test has uncovered serious miscalibration problems in the past.

3.6.2.12 Crosstalk. Movement coupled into non-driven servo actuators shall not exceed ___(a)___ percent of the driven actuator, when the driven actuator is driven at ___(b)___ percent of full scale at ___(c)___ Hertz.

REQUIREMENT RATIONALE (3.6.2.12)

This paragraph guides the contractor regarding the maximum acceptable levels of actuator crosstalk.

REQUIREMENT GUIDANCE

Crosstalk is motion induced in a non-driven actuator due to the movement of a driven actuator. In synergistic geometry designs, crosstalk is largely due to changes in the load reflected into the non-driven actuators.

a. and b. It is recommended that crosstalk not exceed 2 percent of the amplitude of the driven actuator when that actuator is driven at 10 percent of full scale.

c. Select a frequency such that the peak specific force developed by the driven actuator is approximately 100 percent of the required specific force level specified for the relevant degree-of-freedom (use an average value for synergistic systems) and the peak velocity is within the required velocity limits. The relationship among these parameters for sinusoidal motion is:

$$A = \frac{386.07G}{(2\pi f)^2}$$

$$V = 6.28fA$$

A is the peak amplitude in inches

V is the peak velocity in inches per second

g is the peak specific force in g units

f is the frequency in Hertz

REQUIREMENT LESSONS LEARNED

Experience on hydraulically powered synergistic systems has indicated that crosstalk, under constant acceleration of the driven actuator, is reasonably constant across the frequency spectrum. Synergistic systems designed with 2 percent maximum crosstalk measured at 0.7 g levels have been found satisfactory.

4.6.2.12 Crosstalk. Verify by __________.

VERIFICATION RATIONALE (4.6.2.12)

To assure compliance.

VERIFICATION GUIDANCE

Monitor the follow-up voltages of all actuators simultaneously on a strip chart recorder. Drive each of the actuators one at a time, at the specified amplitude and frequency. Verify that movement of the non-driven actuators does not exceed the specified level.

VERIFICATION LESSONS LEARNED

3.6.3 Motion system design considerations

3.6.3.1 Motion simulator power, control, and maintenance features. The system shall be controlled ___(a)___ and powered ___(b)___. It shall consist of a self contained, fully integrated system of ___(c)___.

REQUIREMENT RATIONALE (3.6.3.1)

This paragraph provides a general top-level description of the motion system's major power control and maintenance subcomponents. It lists the general guidelines the contractor should follow in the design of these components.

REQUIREMENT GUIDANCE

a. and b. State-of-the-art motion systems are controlled electrically and powered hydraulically. Although other control and power concepts may exist, they are not currently available commercially.

c. Hydraulically powered systems should consist of a self-contained, fully integrated system including the following subcomponents:

(1) Controls.

(2) Reservoirs.

(3) Pump(s).

(4) Distribution system.

(5) Accumulators.

(6) Manifolds.

(7) Heat exchanger(s).

(8) Other components as necessary.

REQUIREMENT LESSONS LEARNED

One must keep in mind when composing the motion system specification that state-of-the-art technology is desirable. Specifically, when completing the paragraph, state-of-the-art methods of power, control and subcomponents should be inserted in the blanks.

4.6.3 **Motion system design considerations**

4.6.3.1 **Motion system power, control, and maintenance features.** Verify by ________.

VERIFICATION RATIONALE (4.6.3.1)

To assure compliance.

VERIFICATION GUIDANCE

Visual inspection shall ascertain that the motion system power supply is of the type required and controlled as required and that all required subcomponents are included.

Visually verify that the requirements are satisfied and that all specified subcomponents are present.

VERIFICATION LESSONS LEARNED

Well structured test procedures have used this test as a mechanism to acquaint test personnel with the location and nomenclature of the power supply components.

3.6.3.1.1 **Power subsystem.** The ___(a)___ powered subsystem shall include the following items: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.1)

This paragraph discusses the power medium previously selected. A detailed description of power subsystem components and simulator system interactions are also included. The state of the art drives this requirement. The items inserted are used as general guidance by the contractor.

REQUIREMENT GUIDANCE

a. This paragraph describes the general layout of the hydraulically powered subsystem. Interactions with the control loading system are also discussed.

b. The following design features have typically been required:

(1) All hydraulic pumps are the pressure compensated, variable displacement type.

(2) A separate pump is utilized for the control loading system.

(3) The control loading pump supplies flow through its own distribution lines from the pump area to the vicinity of the motion base.

(4) The control loading system is normally a self-contained system independent and separate from the motion system.

(5) If any system component is common to both the motion system and control loading system (for example, hydraulic fluid), it is required that a manual crossover network from the motion supply be provided to allow simultaneous operation of the control loading system and the motion system when the control loading pump is inoperative.

REQUIREMENT LESSONS LEARNED

4.6.3.1.1 **Power subsystem.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.1.1)

To assure compliance.

VERIFICATION GUIDANCE

Visual inspection of the hardware and any necessary drawings shall ascertain that the requirements are satisfied.

VERIFICATION LESSONS LEARNED

Well structured test procedures have used this test as a mechanism to acquaint test personnel with the location and nomenclature of the components.

3.6.3.1.2 **Power subsystem action.** The ___(a)___ powered motion system during normal operation shall not exhibit the following characteristics: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.2)

This requirement is levied to prevent problems that may cause an unsafe or undesirable response of the motion system during normal operation.

REQUIREMENT GUIDANCE

The items to be listed are undesirable and some cases can cause severe damage to the motion system. Thus, it should be clear to the contractor that the motion system must be designed without these problems present.

a. Insert "hydraulically" as appropriate.

b. The negative characteristics include:

(1) Cavitation occurring in the pump, control valves, or other components of the hydraulic system during normal operation.

(2) Pressure pulses caused by the pump exciting resonance on the motion system.

(3) Motion system self-excited resonance or resonance found on other subsystems or portions of the simulator induced by the motion system.

(4) Transient pressure pulses perceptible to crew members.

(5) Transient pressure pulses causing damage to the hydraulic system.

(6) Valve chatter.

REQUIREMENT LESSONS LEARNED

4.6.3.1.2 **Power subsystem action**

VERIFICATION RATIONALE (4.6.3.1.2)

To assure compliance.

VERIFICATION GUIDANCE

Observe that the power subsystem action is in accordance with the specification under all control actions.

VERIFICATION LESSONS LEARNED

Well structured test procedures have used this test as a mechanism to acquaint test personnel with power supply operations.

3.6.3.1.3 **Power subsystem maintenance concept.** The ___(a)___ powered motion system shall incorporate adequate provisions for maintenance operations including ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.3)

This paragraph lists and describes the general maintenance provisions and related equipment that should be incorporated into the motion system. This insures that the system can be properly serviced throughout its lifetime.

REQUIREMENT GUIDANCE

a. and b. Hydraulic systems designed previously have included the following maintenance provisions and associated equipment:

(1) Hydraulic fluid sampling.

(2) Hydraulic fluid draining from the lowest point.

(3) System cleaning.

(4) System bleeding.

(5) System filling.

(6) Shut-off valves.

(7) Drain ports.

REQUIREMENT LESSONS LEARNED

Care should be taken to include all the desired maintenance functions and related equipment. In some cases, depending upon the motion system to be purchased, it may be necessary to obtain information directly from the manufacturer so that the maintenance capabilities can be determined.

4.6.3.1.3 **Power subsystem maintenance concept.** Verify by ______.

VERIFICATION RATIONALE (4.6.3.1.3)

To assure compliance.

VERIFICATION GUIDANCE

Contractor supplied mechanical drawings and maintenance procedures should provide sufficient information to ascertain that the requirement are satisfied.

VERIFICATION LESSONS LEARNED

3.6.3.1.4 **Peak energy storage devices.** The following equipment shall be provided to protect the ___(a)___ powered motion system during worst-case maneuvers: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.4)

This paragraph provides the underlying reason for peak energy storage devices which are utilized to accommodate transient energy pulses self-generated, or demanded by, the power subsystem.

REQUIREMENT GUIDANCE

Peak energy storage devices should be sized to the application to supplement the peak power requirements.

a and b. In hydraulically powered systems, peak energy storage devices are known as hydraulic accumulators which contain inert gas to assist flow requirements during maximum hydraulic demand. Specifying accumulator pressure drop may be done in terms of percentage of the system pressure drop. Note: Initial procurement costs of additional pump capacity is approximately the same as comparable accumulator capacity. Power costs for pumping are in excess of the operating costs of the accumulator (bladder replacement). Accumulator capacity may be approximated using the following equation set:

$P_1V_1 = P_2V_2$	(assuming an isothermal process)
P_1:	system design pressure
P_2:	lowest allowable system pressure
$V_2 - V_1$	volume of fluid potentially available for peak demand
$V_P + (V_2 - V_1)$	maximum pump volume plus accumulator supply should equal or exceed the maximum expected demand.

REQUIREMENT LESSONS LEARNED

Peak energy storage devices should be utilized to allow the power subsystem to be sized to approximately the average power required. These devices also provide storage for energy spikes which otherwise could damage the power subsystems.

4.6.3.1.4 **Peak energy storage device.** Verify by ________.

VERIFICATION RATIONALE (4.6.3.1.4)

To assure compliance.

VERIFICATION GUIDANCE

Inspection of the hardware, aided as necessary by contractor documentation, shall verify that the devices are provided.

VERIFICATION LESSONS LEARNED

3.6.3.1.5 **Power subsystem fire safety/power medium temperature stabilizer.** The following item(s) shall be provided as a fire safety item to stabilize the characteristics of the power medium in the ___(a)___ powered motion system: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.5)

This paragraph provides power medium safety information. Control of the operating characteristics of the control medium is also included. If the power medium is flammable or its operating characteristics vary with temperature, this paragraph is applicable. This includes natural hydrocarbon and some synthetic hydraulic fluids.

REQUIREMENT GUIDANCE

a. Insert "hydraulically" if appropriate.

b. State-of-the-art hydraulically powered motion systems have heat exchangers utilizing liquid as a cooling medium. These heat exchangers shall be regenerative, closed-cycle systems. Means shall be provided to monitor the efficiency of contractor-provided heat exchangers. These heat exchangers should be sized to handle at least the energy content in the internal hydraulic servo valve leakage. The typical servo valve "leaks" approximately two gallons per minute of hydraulic fluid internal to the valve. (A small amount of this fluid is true leakage, the rest serves to power the shuttle.) The leakage energy is the lower bound for sizing the heat exchanger and is calculated as: ________.

$$E = \frac{2 \text{ gal/min}}{\text{servo valve}} \times 6 \text{ servo valves} \times 231 \frac{\text{in.}^3}{\text{gal}} \times P_s \frac{\text{lbs}}{\text{in.}^2} \times \frac{1 \text{ BTU}}{778 \text{ ft lb} \times 12 \text{ in./ft}}$$

P_s = supply pressure

$$E = 0.2969 \times (P_s) \frac{\text{BTU}}{\text{min}} = \text{leakage energy}$$

The energy dissipation calculated in this manner is approximately half the power drawn by the electric motors driving the hydraulic pumps during "idle" periods. This is consistent with experience and theory.

REQUIREMENT LESSONS LEARNED

4.6.3.1.5 **Power subsystem fire safety/power medium stabilizer.** Verify by ________.

VERIFICATION RATIONALE (4.6.3.1.5)

To assure compliance.

VERIFICATION GUIDANCE

Inspection and test of the hardware, complemented as necessary by contractor supplied documentation and analysis, shall verify compliance with the requirements.

The contractor should provide a sound basis for sizing this device. Indicators and/or gages are required which allow one to monitor the power medium to determine if it is sufficiently stabilized (see 3.6.3.1.7). Observe these indicators/gages while the motion system is undergoing the operational requirements tests called out in the subparagraphs of 4.6.2).

VERIFICATION LESSONS LEARNED

3.6.3.1.6 **Power subsystem protection.** To provide protection for the ___(a)___ powered medium, the following items shall be included in the motion system: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.6)

This paragraph provides for personal safety in and around the simulator and also simulator subsystem safety.

REQUIREMENT GUIDANCE

a. and b. In the past, hydraulically powered systems have included the following protective items and features:

(1) Spray shields and drip pans are provided by the contractor as necessary to collect leaking hydraulic fluid.

(2) Electrical components and cables and hydraulic components are positioned to prevent damage to cabling as a result of fluid leaks.

(3) The number of leaks and flow rate of leaking fluid is minimized, with the procuring agency judging the acceptability of the system's tightness.

REQUIREMENT LESSONS LEARNED

Care should be taken in writing this paragraph to include all the necessary items to provide safe and efficient operation of the motion system's power subsystem. High pressure leaks in the hydraulic system can cause system as well as personal damage if not properly accounted for.

4.6.3.1.6 **Power subsystem protection.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.1.6)

To assure compliance.

VERIFICATION GUIDANCE

Observe that the required protective devices are present, and that any fluid leakage is within specified tolerances.

VERIFICATION LESSONS LEARNED

3.6.3.1.7 **Energy transfer medium and control.** The following items shall be included in the ___(a)___ powered motion system to provide a medium for energy transfer and control: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.7)

The medium of energy transfer is stated to assure that power transfer is done correctly and efficiently without undue strain on the individual components of the power subsystem.

REQUIREMENT GUIDANCE

a. and b. A hydraulically powered motion system utilizes hydraulic fluid for energy transfer and for parts lubrication. In the past, the following items have been specified:

(1) Hydraulic fluid shall comply with MIL-H-83282.

(2) Oil temperature sensing gages shall be provided with audio and/or visual over-temperature warning devices.

(3) Excessive oil temperature shall automatically activate shutdown of the overheated hydraulic system.

(4) Reservoirs of adequate capacity with sight gage shall be provided.

(5) Automatic shutdown of the motion system shall occur if the fluid level is too low for normal operation or if the system pressure drops below a predetermined settable value.

REQUIREMENT LESSONS LEARNED

Include all the necessary temperature sensing and warning devices needed to ensure that the desired energy transfer medium functions correctly. This will also ensure maximum service life for the power transfer subsystem.

4.6.3.1.7 **Energy transfer medium and control.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.1.7)

To assure compliance.

VERIFICATION GUIDANCE

Simulator tests shall be conducted to assure that all audio and visual indicators and all automatic shutdown devices operate as required.

VERIFICATION LESSONS LEARNED

3.6.3.1.8 **Energy potential safety devices.** The following safety devices shall be included in the ___(a)___ powered motion system to assure that it is maintained in a proper working order: ___(b)___.

REQUIREMENT RATIONALE (3.6.3.1.8)

A general description of the necessary equipment needed to keep the energy transfer medium under proper control is provided. This will keep the overall system from overreaching its capabilities and thus prevent severe damage from occurring.

REQUIREMENT GUIDANCE

a. and b. The hydraulically powered motion system utilizes pressure relief valves to prevent overpressure and filters to keep the hydraulic medium clean of debris. Past specifications have incorporated the following requirements on pressure relief valves and hydraulic filters:

(1) Pressure relief valves shall be installed in the system and shall open if the maximum design working pressure is exceeded.

(2) Replaceable or recleanable filters shall be provided throughout the system as necessary to ensure reliable operation.

(3) Coarse filters (25-micron maximum) shall be installed near the pump pressure outlets.

(4) Fine filters (10-micron maximum) shall be placed upstream of servo control valves.

(5) Additional filters shall be provided as necessary to ensure reliable operation, including special means to clean pump contaminants.

(6) All filters shall be equipped with differential pressure switches to provide a remote indication (at the maintenance control panel) that the filter needs servicing.

(7) Additionally, a local differential-pressure indicator shall be provided on each filter assembly.

(8) If the filter is equipped with a bypass, a differential pressure switch will actuate before the bypass opens (that is, at a lower differential pressure).

(9) All filters shall be easily accessible for servicing.

REQUIREMENT LESSONS LEARNED

Before specifying that crash detection be completely performed by the image generator, consider the option of doing some types of crash detection in other simulator subsystems. For example, the host computer can sometimes perform crash detection for moving objects, since it is computing their motion path.

4.6.3.1.8 **Energy potential safety devices.** Verify by ________.

VERIFICATION RATIONALE (4.6.3.1.8)

To assure compliance.

VERIFICATION GUIDANCE

Verify that the required components are installed. Review product documentation as necessary to verify that the design is in compliance with requirements.

VERIFICATION LESSONS LEARNED

3.6.3.1.9 **Maintenance access.** The motion system shall permit ease of access for maintenance duties by including the following items: ________.

REQUIREMENT RATIONALE (3.6.3.1.9)

In this paragraph is described the method of access necessary to perform maintenance tasks. This allows these tasks to be performed simply and efficiently.

REQUIREMENT GUIDANCE

The following items in the case of a hydraulically powered motion platform have been incorporated in past specifications in regard to maintenance access.

a. The motion system design shall permit ease of access for maintenance duties.

b. A skid-proof walkway shall permit personnel to walk completely around the cockpit.

REQUIREMENT LESSONS LEARNED

Maintenance access and safety go hand in hand.

4.6.3.1.9 **Maintenance access**

VERIFICATION RATIONALE (4.6.3.1.9)

To assure compliance.

VERIFICATION GUIDANCE

Observe that the required maintenance access is provided.

VERIFICATION LESSONS LEARNED

3.6.3.1.10 **Personnel access.** A powered ____(a)____ shall be provided for personnel entry and exit onto the motion system. Safety interlocks shall be included to ensure that the access ____(b)____ is physically removed from the operating envelope of the motion system when it is engaged. The system shall incorporate provisions to prevent a physical collision between the access ____(c)____ and motion system and to prevent injury to personnel by movements of the access ____(d)____.

REQUIREMENT RATIONALE (3.6.3.1.10)

A description of the method of crew access into the cockpit is required.

REQUIREMENT GUIDANCE

a, b, c, and d. Typically, either a stairway, walkway, or ramp is specified.

REQUIREMENT LESSONS LEARNED

4.6.3.1.10 **Personnel access.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.1.10)

To assure compliance.

VERIFICATION GUIDANCE

Test for proper operation of all access ramps and safety interlocks. Verify that any anti-collision features are effective.

VERIFICATION LESSONS LEARNED

There have been instances when faulty safety interlocks have resulted in personnel injury. One situation resulted because a crew member was able to open the cockpit door and exit the platform before the access ramp was in position.

3.6.3.1.11 Structural design criteria. The design of all structural members shall incorporate acceptable design practices and shall provide for the safe and efficient use of the simulator by crew members, operating personnel, observers, and maintenance personnel. The rated load of the motion system is defined as that load or combination of forces which the moving platform must support or resist in a static condition. The design load of the motion system shall be based upon a load of not less than ___(a)___ times the rated load. Stress levels, under the static rated load condition, at any point in the structure shall be limited to a level that provides a factor of safety of ___(b)___ against permanent deformation. Where dynamic factors induce loads that exceed ___(c)___ times the rated load, then the stress levels at any point in the structure shall be limited to a level that provides a factor of safety of ___(d)___ against permanent deformation induced by dynamic loads.

REQUIREMENT RATIONALE (3.6.3.1.11)

The absolute stress levels that the motion simulator must withstand before permanent deformation can occur are specified in this paragraph.

REQUIREMENT GUIDANCE

a. Analyses and studies of past motion simulators and safety standards have shown that the design load of the equipment must not be less than three times the rated load.

b. Under static rated load conditions, stress levels at any point in the motion simulator structure should be limited to a level that provides a safety factor of three against permanent deformation.

c. This is the case where dynamic loads exceed 1.5 times the rated load.

d. The stress level at any point in the structure should be limited to a level that provides a factor of two against deformation induced by dynamic loads.

REQUIREMENT LESSONS LEARNED

Stress levels will be different for various load configurations. Thus, one must include all load cases. Safety dictates that all load factors be no less than those listed.

4.6.3.1.11 **Structural design criteria.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.1.11)

To assure compliance.

VERIFICATION GUIDANCE

The most effective way to assure that the motion system structure is in fact designed with an adequate safety factor is to submit it to a structural integrity proof test, as defined in this paragraph, with a proof test load some factor of safety greater than the rated load.

VERIFICATION LESSONS LEARNED

A reasonable and acceptable value for the proof test load is two times the rated load.

3.6.3.1.12 Acoustic noise--maintenance areas. The contractor shall analyze the intensity and frequency spectrum of acoustic noise emanating from the motion system power subsystem. If the noise level requires ear protection devices, the contractor shall recommend such devices to the procuring agency. Noise data shall be provided to the procuring agency for use in design of soundproofing for the room housing noisy components.

REQUIREMENT RATIONALE (3.6.3.1.12)

This requirement helps reduce claims against the Air Force for hearing loss.

REQUIREMENT GUIDANCE

The contractor must provide the necessary data regarding noise levels and protective device requirements for the specific equipment being supplied.

REQUIREMENT LESSONS LEARNED

Pump room noise levels have been sufficiently high on past simulators to warrant the use of protective ear devices.

4.6.3.1.12 Acoustic noise--maintenance areas

VERIFICATION RATIONALE (4.6.3.1.12)

To assure compliance.

VERIFICATION GUIDANCE

Ascertain that the required data were provided to the procuring agency.

VERIFICATION LESSONS LEARNED

3.6.3.2 Motion simulator controls and indicators. In addition to adhering to the principles of MIL-STD-1472, the control and indicator system shall comply with the following paragraphs.

REQUIREMENT RATIONALE (3.6.3.2)

This is a general paragraph stating that a control and indicator system is necessary for the function and operation of the motion simulator. All guidance and lessons learned will be found in subsequent paragraphs relating to this subject.

REQUIREMENT GUIDANCE

The principles of MIL-STD-1472 should be incorporated in the basic design stage.

REQUIREMENT LESSONS LEARNED

3.6.3.2.1 **Instructor station.** Controls shall be provided at the instructor's station to engage or disengage the motion simulator and access system, if applicable (see 3.5).

REQUIREMENT RATIONALE (3.6.3.2.1)

This requirement is needed to assure control at the appropriate physical point.

REQUIREMENT GUIDANCE

Include this requirement to assure control at the instructor's station.

REQUIREMENT LESSONS LEARNED

4.6.3.2 **Motion system controls and indicators**

4.6.3.2.1 **Instructor station.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.2.1)

To assure compliance.

VERIFICATION GUIDANCE

Verify that the instructor station controls operate as required.

VERIFICATION LESSONS LEARNED

3.6.3.2.2 **Crew station.** A momentary action type "motion consent" switch or other means shall be provided in the crew station to assure crew readiness for motion engagement. Engagement of the motion system form the instructor's station shall be possible only when the "consent" switch is simultaneously being actuated by the crew member.

REQUIREMENT RATIONALE (3.6.3.2.2)

This paragraph assures that the motion engagement controls are available for the crew member(s) at the crew station. This also assures simultaneous consent of crew member(s) and instructor(s).

REQUIREMENT GUIDANCE

Motion engagement at the crew station is accomplished by means of a motion consent switch. Past simulator designs have utilized the push (momentary contact) type of switch. In those systems where the instructor's station is located on-board the motion platform (as in the C-130), the consent switch may be located only at the instructor's station.

REQUIREMENT LESSONS LEARNED

Both the crew and the instructors must be ready and paying attention at the moment the motion system is turned on. If minds are wandering, injury and equipment damage can result.

4.6.3.2.2 Crew station. Verify by ________.

VERIFICATION RATIONALE (4.6.3.2.2)

To assure compliance.

VERIFICATION GUIDANCE

Verify that the crew station controls operate as required.

VERIFICATION LESSONS LEARNED

3.6.3.2.3 **Maintenance and control features.** The following maintenance and control features shall be provided and located within view of the motion simulator: ________.

REQUIREMENT RATIONALE (3.6.3.2.3)

Provisions for an off-board maintenance control subsystem are listed in this paragraph. This subsystem contains all the necessary indicators for maintaining the motion simulator. Also located within this subsystem are the controls which allow extension of each actuator and therefore control over the position of the platform. These actuator and platform controls provide stand-alone off-board motion testing capability.

REQUIREMENT GUIDANCE

Maintenance and control panel specifications for past motion simulators have incorporated the following provisions:

(1) The maintenance and control subsystem to be provided shall be located within full view of the motion simulator.

(2) The subsystem shall provide controls to drive each actuator to any safe position desired by the operator.

(3) On-off and engage-disengage controls shall be provided.

(4) An "Emergency Stop" switch shall be provided to shut down the system.

(5) A key-operated "mode" switch shall be provided for "maintenance" or "normal" operation.

(6) The "normal" position shall deactivate maintenance panel controls, except for "emergency stop" control.

(7) The "maintenance" position shall deactivate instructor motion controls, returning full control to the maintenance operator.

(8) Other interlocks shall be provided as necessary for safe, convenient operation.

(9) Visual status indicators of pressure, fluid contamination, filters, temperature, control positions, and other pertinent information shall be provided.

REQUIREMENT LESSONS LEARNED

The maintenance indicators to be provided on the display should be visually self-evident and easily read. Some type of remote sensors should be present within the system to monitor such things as the filters, fluid temperature, pressures, etc. The exact parameters to be monitored are a function of the motion simulator being purchased and the desires of the user.

4.6.3.2.3 **Maintenance and control features.** Verify by ________.

VERIFICATION RATIONALE (4.6.3.2.3)

To assure compliance.

VERIFICATION GUIDANCE

Observe that the required features are provided. With the exception of "Emergency Stop", test the operation of all controls for compliance with the requirements. Defer "Emergency Stop" testing to an overall "simulator emergency stop test", (wherein emergency stop controls throughout the simulator are tested) as this removes power to the total simulator.

VERIFICATION LESSONS LEARNED

Well-structured test procedures use these tests to acquaint test personnel with the location, nomenclature, and function of motion system controls.

3.6.3.2.4 **Energy medium controls.** Controls and indicators shall be provided and located adjacent to the energy source and shall incorporate the following capabilities: ________.

REQUIREMENT RATIONALE (3.6.3.2.4)

This paragraph specifies the controls and indicators necessary for proper operation at the remote control subsystem.

REQUIREMENT GUIDANCE

With the hydraulically powered motion simulator, the energy medium remote site is the hydraulic pump control room. In past specifications the following items have been included:

a. Controls and indicators shall be provided on a control panel located in the pump room to permit local control and monitoring of the pumps, as well as power-on and power-off operation.

b. These controls and indicators shall be similar to those on the maintenance control panel.

c. Quantitative pressure and temperature displays shall be provided for the control loading pump(s) and motion simulator pump(s).

d. Interlocks shall be provided as necessary for safe, convenient operation.

REQUIREMENT LESSONS LEARNED

As with the maintenance and control subsystem, the desired controls and indicators for the energy medium remote site are a function of the type of motion system and the needs for proper control and maintenance.

4.6.3.2.4 **Energy medium controls.** Verify by __________.

VERIFICATION RATIONALE (4.6.3.2.4)

To assure compliance.

VERIFICATION GUIDANCE

Observe that the required features are provided. With the exception of "Emergency Stop", test the operation of all controls for compliance with the requirements. Defer "Emergency Stop" testing to an overall "Simulator Emergency Stop Test" wherein "Emergency Stop" controls throughout the simulator are tested, as this removes power to the total simulator.

VERIFICATION LESSONS LEARNED

Well-structured test procedures use these tests to acquaint test personnel with the location, nomenclature, and function of power supply controls.

3.6.4 **Structural interface with the facility.** The contractor shall provide a detailed design of the motion system support structure and design criteria for use in preparing the training facility site for installation. Reaction mass composition, tie-down means, and complete interface shall be included in the support design. The support structure shall be designed for installation in soil of __________ bearing capacity.

REQUIREMENT RATIONALE (3.6.4)

This information is necessary to prepare the training facility site for proper installation of the motion simulator.

REQUIREMENT GUIDANCE

A standard value for soil bearing capacity which may be used is 1,500 pounds per square foot. This is the value used in MIL-STD-1558, dated 22 February 1974.

REQUIREMENT LESSONS LEARNED

Soil bearing capacity varies with geographical location. Specific values may be determined from the civil engineering group responsible for the site preparation.

4.6.4 **Structural interface with the facility.** Verify by __________

VERIFICATION RATIONALE (4.6.4)

To assure compliance.

VERIFICATION GUIDANCE

Ascertain that the required data were provided to the procuring agency.

VERIFICATION LESSONS LEARNED

3.6.5 **Motion system design safety.** Devices shall be provided to protect crew members, operating personnel, observers, and maintenance personnel from injury. These shall include __________.

REQUIREMENT RATIONALE (3.6.5)

This general paragraph is provided in the specifications to assure that necessary protective/safety devices are included.

REQUIREMENT GUIDANCE

For the hydraulically powered motion system, protective/safety devices should be provided in the mechanical, electrical, and hydraulic systems.

REQUIREMENT LESSONS LEARNED

Do not compromise on safety.

3.6.5.1 **Design safety factors.** All hydraulically powered motion systems components shall be pressure rated at least __________ percent higher than the maximum working pressure of the system. Energy absorbing devices shall be provided to absorb the greatest kinetic energy the system can develop if runaway occurs.

REQUIREMENT RATIONALE (3.6.5.1)

This paragraph is needed to assure that the motion system structure does not fail under demands of high stress loading.

REQUIREMENT GUIDANCE

Past experience suggests that all hydraulic system components should be pressure rated at least 50 percent higher than the system's maximum working pressure.

REQUIREMENT LESSONS LEARNED

When designing a motion simulator, the safety factor should be computed using very conservative techniques. Over the lifetime of the system, structural fatigue takes its toll. A conservative safety factor will help assure safe operation during the life of the system.

4.6.5 **Motion system design safety**

4.6.5.1 **Design safety factors.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.1)

To assure compliance.

VERIFICATION GUIDANCE

Contractor-supplied documentation shall verify that system components which conduct a pressurized energy medium are pressure rated in accordance with the requirements. The ability of the energy absorbing devices to absorb system kinetic energy shall be tested in conjunction with the Proof Load Test in 4.6.3.1.11.

VERIFICATION LESSONS LEARNED

3.6.5.2 **Rapid motion.** At no time shall either the motion system or the crew station controls move unexpectedly. "Freezing" or release from a simulator computer "freeze" condition shall not result in rapid motion system movement, even if crew station control movements have been made during the "freeze" state. Engaging the motion system shall result in a non-rapid low velocity transition from the settled position to the normal operating position in less than ___(a)___ seconds. Other computer-controlled changes in motion system position such as transition to initial conditions, automatic demonstration modes, etc, shall not be rapid. A rapid motion simulator movement shall be defined as any movement(s) which imparts an acceleration greater than ___(b)___ g to the crew members.

REQUIREMENT RATIONALE (3.6.5.2)

Any unexpected movements of the motion system are potential safety hazards. This paragraph is intended to prevent rapid motions which could cause injury and damage to personnel and equipment.

REQUIREMENT GUIDANCE

a. Motion system transit time from the settled position to the normal operating position represents a trade-off between acceptable acceleration levels and the length of time the user is willing to wait for erection to complete. A maximum of 15 seconds is reasonable, and has been found acceptable in the past.

b. Rapid motion acceleration should be limited to no more than 0.10 g. This value is easily realized in today's equipment, and has generally been acceptable to simulator users.

REQUIREMENT LESSONS LEARNED

The time for erection can vary from system to system. A reasonable range of values for this requirement may be expected. Rapid motion acceleration of 0.01 g is reasonable in terms of equipment and personnel distress.

4.6.5.2 **Rapid motion.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.2)

To assure compliance.

VERIFICATION GUIDANCE

The motion system shall be instrumented and objective data obtained to verify that rapid motion is not excessive.

Mount an accelerometer(s) of appropriate sensitivity at the aircrew station with the sensitive axis aligned along the appropriate degree-of-freedom. (Note: For synergistic six degree-of-freedom systems, it is sufficient to use one accelerometer aligned with the heave axis.) Monitor the accelerometer output(s) on a strip chart recorder. Exercise all appropriate control functions. Verify that the specified specific force level is never exceeded.

VERIFICATION LESSONS LEARNED

3.6.5.2.1 Abrupt motion. Disengagement of the motion system shall not result in abrupt motion system movement. Abrupt motion system movement shall not occur when power subsystem components are deactivated unexpectedly, nor if line power failure or fluctuation occurs. An abrupt system movement shall be defined as any movement which imparts an acceleration greater than __________ g to the crew members.

REQUIREMENT RATIONALE (3.6.5.2.1)

Prevention of abrupt motion and its damaging effects to personnel and equipment is the goal of this paragraph.

REQUIREMENT GUIDANCE

Typically, 0.4 g is the maximum acceptable acceleration due to safety considerations.

REQUIREMENT LESSONS LEARNED

In hydraulically-powered motion systems, unexpected failure or deactivation of the hydraulic pumps can cause or lead to abrupt motion. This should be a design consideration.

4.6.5.2.1 **Abrupt motion.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.2.1)

To assure compliance.

VERIFICATION GUIDANCE

Mount an accelerometer(s) of appropriate sensitivity at the aircrew station with the sensitive axis aligned along the appropriate degree-of-freedom. (Note: For synergistic six degree-of-freedom systems, it is sufficient to use one accelerometer aligned with the heave axis.) Monitor the accelerometer output(s) on a strip chart recorder. Exercise all appropriate control functions. Verify that the specified specific force criterion is never exceeded.

VERIFICATION LESSONS LEARNED

3.6.5.3 **Motion limits.** Actuators shall be equipped with limit sensors (translational and rotational) to automatically disengage the motion simulator if actuator overtravel occurs.

REQUIREMENT RATIONALE (3.6.5.3)

Motion limits contribute to equipment and personnel safety. There may be simulator configurations in which it is possible to attain unsafe angular orientations within the travel limits of the actuators.

REQUIREMENT GUIDANCE

When designing the geometrical configurations and payload centers-of-gravity for synergistic six degree-of-freedom motion systems ("six post" configuration), contractors can ensure that unsafe angular orientations are not obtainable within actuator travel limits. For this motion system configuration, angular limit sensors are not needed, but an additional requirement should be added: "The motion simulator geometrical configuration shall not permit the system to achieve unsafe orientations or attitudes for any combination of actuator positions."

REQUIREMENT LESSONS LEARNED

4.6.5.3 **Motion limits.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.3)

To assure compliance.

VERIFICATION GUIDANCE

Calibrate each actuator's output versus excursion and monitor this voltage on a strip chart recorder. Apply an input signal to each actuator which causes it to enter each overtravel region. Verify that the motion system is disengaging upon entering any actuator overtravel region.

VERIFICATION LESSONS LEARNED

3.6.5.4 **Settling of motion system.** When the motion system is shut down or disengaged, the platform shall return to a settled, level egress position. The platform shall not assume unusual attitudes or undergo unusual movements during descent to a settled position. A means shall be provided to automatically activate settling of the motion system when an electrical power failure occurs.

REQUIREMENT RATIONALE (3.6.5.4)

This paragraph is included to assure that the simulator settles in a safe manner in case of failure or shut-down of the motion system.

REQUIREMENT GUIDANCE

For hydraulically powered motion systems, a passive mechanical-hydraulic system has sufficed as a means of activating the settling sequence.

REQUIREMENT LESSONS LEARNED

4.6.5.4 **Settling of motion system.** Verify by ___________.

VERIFICATION RATIONALE (4.6.5.4)

To assure compliance.

VERIFICATION GUIDANCE

Manually establish one or several extreme attitudes of the motion system. Shut down the motion system (by removing electrical power at least one time), and observe that the platform returns to a settled, level egress position without assuming any unusual attitudes or movements in transit.

VERIFICATION LESSONS LEARNED

3.6.5.5 **Electrical interlocks.** The motion system shall be protected by automatic interlocks so that proper sequencing for power-up or power-down is assured and so that abnormal conditions inhibit the application of power to the motion platform. As a minimum, interlocks shall be provided on ___________. It shall not be possible to engage the motion system unless all interlocks are in a safe position; the motion system shall then be engaged when the proper controls are activated. The reverse sequence (control switch is activated, interlocks moved to safe position, motion system responds) shall not occur. If the interlock circuit is broken when the motion system is engaged, the motion system shall immediately disengage. Subsequent engagement of the system must adhere to normal control switch procedures.

REQUIREMENT RATIONALE (3.6.5.5)

Inclusion of interlocks in the specification is intended to prevent injury to the simulator's operators or occupants or damage to simulator hardware.

REQUIREMENT GUIDANCE

The following electrical interlocks have been included in previous motion simulators.

a. Cockpit canopy.

b. Cockpit door.

c. Entrance gate.

d. Access stairway.

e. Within pressure pads at the entrance.

In addition, interlocks have also been installed at maintenance electrical cabinets and in conjunction with an installed "maintenance in progress" switch/light. Note: Some simulators may contain a cockpit canopy or cockpit door or both.

REQUIREMENT LESSONS LEARNED

4.6.5.5 **Electrical interlocks.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.5)

To assure compliance.

VERIFICATION GUIDANCE

Test each of the interlocks for proper operation in disengaging the motion system. If the interlocks are connected in series (as is typically the case), it will be necessary to test for proper engage/disengage sequencing with only one of the series-connected interlocks. Contractor documentation may be consulted to determine which interlocks are connected in series.

VERIFICATION LESSONS LEARNED

3.6.5.6 **Emergency egress.** In the event of an emergency, it shall be possible to open the canopy (or cockpit door) from the inside and from the outside. The time required for the motion simulator to move to the egress position shall not exceed __________ seconds.

REQUIREMENT RATIONALE (3.6.5.6)

This paragraph requires the contractor to provide means for a rapid exit from the simulator in case of danger and/or emergency.

REQUIREMENT GUIDANCE

Safe emergency exit from the simulator can be accomplished after the motion has returned to a settled position. Sufficient time must be allowed for this action to occur. For reasons of safety, accept no time greater than necessary.

REQUIREMENT LESSONS LEARNED

Fifteen seconds has proven achievable, but 20 seconds has provided a smoother descent.

4.6.5.6 **Emergency egress.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.6)

To assure compliance.

VERIFICATION GUIDANCE

Manually position the platform to some extreme position. Shut down the motion system and observe the transit time to the egress position. Verify that this transit time satisfies the criterion.

VERIFICATION LESSONS LEARNED

3.6.5.7 **Warning signs.** Illuminated warning signs shall be provided at all entrances to the motion system or crew station areas. These signs shall provide warnings appropriate to the location of the entrance. Warning lights shall be provided as necessary to alert personnel that __________.

REQUIREMENT RATIONALE (3.6.5.7)

The contractor is required to provide appropriate warning signs around the simulator area to protect all off-board personnel from accidentally venturing within the area of the motion platform when operating.

REQUIREMENT GUIDANCE

The following two warning indicators have been judged essential for hydraulically powered motion systems:

a. The motion pumps are on.

b. The motion system is engaged.

REQUIREMENT LESSONS LEARNED

Warning signs can be effective only if heeded. Posting too many different warning signs may defeat the purpose.

4.6.5.7 **Warning signs.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.7)

To assure compliance.

VERIFICATION GUIDANCE

Vary the motion system power supply and engage status through all appropriate states. Observe that warning signs are appropriately placed and illuminated in accordance with the requirements.

VERIFICATION LESSONS LEARNED

3.6.5.8 **Safety barrier.** A safety barrier shall be provided and shall surround the motion system base to the degree necessary. Gates shall be provided as necessary for __________. The design shall be adapted to the facility.

REQUIREMENT RATIONALE (3.6.5.8)

This requirement improves safety.

REQUIREMENT GUIDANCE

Gates are required for equipment and personnel ingress/egress. Additional gates may be added, as necessary.

REQUIREMENT LESSONS LEARNED

While the safety barrier is a specified item, the number of gates is not. It is wise to specify only those gate(s) necessary. The type of safety barrier to be provided should not be specified. This is the choice of the contractor and the user. The facility layout may also be a contributing factor to the safety barrier.

4.6.5.8 **Safety barrier.** Verify by __________.

VERIFICATION RATIONALE (4.6.5.8)

To assure compliance.

VERIFICATION GUIDANCE

Visually verify that the required barrier and gates are present.

VERIFICATION LESSONS LEARNED

3.6.5.9 **Motion system failures.** Worst-case failures shall not impose more than ___(a)___ g on the crew station. Special attention shall be paid to the cases of ___(b)___. A design goal shall be to safely return the motion platform to the settled position subsequent to any failure.

REQUIREMENT RATIONALE (3.6.5.9)

It is necessary to specify simulator behavior during failures to protect users from injury.

REQUIREMENT GUIDANCE

a. A worst-case failure should not impose more than 2.5 g on the crew station occupants.

b. For hydraulically powered motion simulators, the following are instances of worst-case failures:

(1) An actuator(s) reaching its full extension at maximum velocity.

(2) A sudden null or reverse signal being applied to a servo-mechanism(s) while the actuator(s) is moving at maximum velocity.

REQUIREMENT LESSONS LEARNED

Safety dictates that the "g" limit for a worst-case failure not exceed the limit stated below. As for the special failures to be tested, one must consider the type of motion system being acquired. One must also consider the conditions under which the motion system can be driven to a worst-case failure.

3.6.6 **In-cockpit motion and force display requirements**

3.6.6.1 **In-cockpit motion display--major components.** The major components to be provided are: ____(a)____.

REQUIREMENT RATIONALE (3.6.6.1)

This paragraph summarizes the major in-cockpit motion display devices to be provided.

REQUIREMENT GUIDANCE

In-cockpit display devices previously used in operational training simulators include vibration and buffet (seat shaker) systems, controlled g-suit inflation/deflation, and dynamic seats ("g-seats").

Specify the applicable device types, such as:

a. Vibration and buffet systems (3.6.6.2 and subparagraphs).

b. Anti-g suit systems (3.6.6.3 and subparagraphs).

c. Dynamic seat system (If specified, then specify the degrees-of-freedom in which cues are to be provided and any active elements--such as seat pan, back rest, lap belt--required.)

REQUIREMENT LESSONS LEARNED

In-cockpit seat shaker (or vibration and buffet) systems have been used to provide higher frequency motion cues to aircrew members without subjecting non-trainees and cockpit mounted equipment to the vibration stress. Since these devices provide high frequency motion cues, only small displacements (a total of two inches) are normally required. One word of caution - since human eyeballs are stabilized in space by the vestibular-ocular reflex mechanism, instrument legibility may be different from the real-world situation if only the human, rather than the whole cockpit, is subjected to vibration.

There is a relatively small body of literature regarding the utility of dynamic seat cueing. The results reported to date are largely mixed (reference Puig, Harris, and Ricard, 1978, *Motion in Flight Simulation: An Annotated Bibliography*, Tech Report NAVTRAEQUIPCEN IH-298).

ASD is currently working with AF AAMRL to determine whether proper selection of drive laws combined with an effective design configuration will enhance the training utility of these devices for onset cueing. The Navy also is pursuing some research in this area of motion cueing. As data become available regarding drive laws/hardware configuration leading to effective dynamic seat onset cueing, this section will be updated. At present, there is some evidence that dynamic seats may provide useful sustained g-cue information, but it is not very compelling. Until more data become available, anti-g suit cueing provides a relatively inexpensive alternative to providing g-loading cues.

4.6.6 In-cockpit motion and force display requirements

4.6.6.1 In-cockpit motion display--major components

VERIFICATION RATIONALE (4.6.6.1)

Visual inspection shall assure compliance.

VERIFICATION GUIDANCE

Visually identify and verify that each required major in-cockpit motion display device is present.

VERIFICATION LESSONS LEARNED

3.6.6.2 **Vibration and buffet system.** A vibration and buffet system shall be provided to generate vibration/buffet inputs to the ___(a)___ seat. The system shall be under software control and shall be designed to generate ___(b)___ in accordance with the design criteria. The system shall also provide cues which represent ___(c)___.

REQUIREMENT RATIONALE (3.6.6.2)

This paragraph states the cues which the vibration and buffet (seat shaker) system is meant to impart.

REQUIREMENT GUIDANCE

a. Specify the aircrew member(s) to whom the cues are to be displayed.

b. Specify the primary cue set for which there are specific design criteria. For example, these may include pre- and post-stall buffet in all appropriate flight regimes, and speed brake buffet.

c. Specify the secondary cue set for which there are no specific design criteria. These may include gunfire vibration, weapon release, touchdown when landing, runway roughness/expansion strips, hits by enemy fire, and aircraft malfunction effects.

REQUIREMENT LESSONS LEARNED

4.6.6.2 **Vibration and buffet system.** Verify by __________.

VERIFICATION RATIONALE (4.6.6.2)

Visual inspection shall verify that a vibration and buffet device is present at each required location. Simulator flight tests by experienced aircrew members shall subjectively verify that the cues presented are representative of those experienced in the aircraft.

VERIFICATION GUIDANCE

This simulator test should not be conducted until the hardware performance of the vibration and buffet system has been validated. Further, sufficient testing of the aero-dynamic math models should have been accomplished to assure that the software inputs to the vibration and buffet drive laws are correct prior to executing these tests. Subjective tests, conducted by experienced aircrew members, shall be carried out to validate that each of the primary and secondary cues is representative of the actual environment.

VERIFICATION LESSONS LEARNED

3.6.6.2.1 **Vibration and buffet system performance requirements.** The ___(a)___ seats(s) shall be capable of vibration excursion up to ± ___(b)___ parallel to the Z body axis of the simulated aircraft. The frequency spectrum between ___(c)___ Hz shall be within ___(d)___ percent of the approved data. The amplitude and frequency shall be continuously variable over the specified ranges and shall be controlled by the software to allow for non-linear response and ease of software modification. The system shall be designed to prevent application of specific forces in excess of 2-g units.

REQUIREMENT RATIONALE (3.6.6.2.1)

This paragraph specifies the operational requirements for the vibration/buffet system.

REQUIREMENT GUIDANCE

a. Specify the aircrew member(s) to whom the vibration and buffet system cues apply.

b. Specify the peak excursion requirement.

c. Specify the frequency range over which cues are to be provided.

d. Specify the tolerable mismatch from the approved data.

Generally, a peak excursion of ±1 inch over a frequency range of 0 Hz to 20 Hz is sufficient. In the past, a tolerance of 20 percent deviation from the approved data has been used.

REQUIREMENT LESSONS LEARNED

4.6.6.2.1 **Vibration and buffet system performance requirements.** Verify by __________.

VERIFICATION RATIONALE (4.6.6.2.1)

Instrumented hardware tests shall assure compliance.

VERIFICATION GUIDANCE

By direct measurement, assure that each of the applicable seats is capable of excursion parallel to the simulated aircraft Z body axis over the required range. Instrument each applicable seat with an accelerometer (align its sensitive axis along the vibration and buffet device's degree-of-freedom) with a range exceeding 2-g units (but sensitive enough to provide meaningful output). Assure that the vibration and buffet system's power spectrum matches the approved data within the specified tolerance. Assure that the system will not impart forces to the seat(s) which result in specific forces in excess of 2 g-units.

VERIFICATION LESSONS LEARNED

3.6.6.2.2 Vibration and buffet system control. ___(a)___ shall be provided to turn the vibration system on and off at the ___(b)___. Means shall be provided to allow the instructor/operator to readily control the amplitude profile of the system. An interlock shall be provided to require that the seat belt(s) be fastened before the system can operate.

REQUIREMENT RATIONALE (3.6.6.2.2)

This paragraph specifies a convenient location for the on/off control for system operation. A convenient means to modify the vibration amplitude is also required--primarily as a means to reduce the vibration exposure of trainees undergoing extensive training sessions. The interlock requirement is for personnel safety.

REQUIREMENT GUIDANCE

a. Specify the means by which on/off control is to be initiated at the location specified at (b).

b. An on/off switch is typically located at the instructor/operator station.

REQUIREMENT LESSONS LEARNED

A switch is the preferred means of on/off control since it can be directly actuated (important if the system must be shut down quickly). An on/off switch is typically located at the Instructor/Operator Station.

4.6.6.2.2 Vibration and buffet system control. Verify by __________.

VERIFICATION RATIONALE (4.6.6.2.2)

To assure compliance.

VERIFICATION GUIDANCE

Assure that the vibration and buffet system can be turned on and off at the specified location by the specified means. Assure that the system cannot be turned on unless the seat belt(s) is fastened. Assure that a means is provided for instructor/operator control of the amplitude profile.

VERIFICATION LESSONS LEARNED

3.6.6.3 Anti-g suit system. A simulated anti-g suit system shall provide the __(a)__ with sustained g cues. The simulated anti-g suit system shall provide an anti-g pressure schedule representative of that in the aircraft with a pressure range from __(b)__ to a maximum of __(c)__ psi. Fail-safe means shall be provided to prevent pressurization above this specified maximum. The "pressure onset" (g-intercept at zero psi) shall be variable from at least __(d)__ to __(e)__ g's. The "slope(s)" of the pressure curve (psi/g) shall be adjustable from at least __(f)__ to __(g)__ psi/g. During a simulator "freeze" condition, the anti-g suit shall be pressurized to that level corresponding to the one-g state.

REQUIREMENT RATIONALE (3.6.6.3)

This paragraph specifies the general requirements for the anti-g suit simulation system.

REQUIREMENT GUIDANCE

a. Specify the aircrew member(s) to whom the sustained g-cues are to be provided.

b. Specify the low end of the suit pressurization range.

c. Specify the maximum pressure permissible. (NOTE: Suit pressures in a one-g environment should be substantially lower than those in the bonafide g-loading environment since the suit will not be counteracting an actual pooling of blood in the lower extremities.)

d. Specify the required minimum g intercept at zero psi.

e. Specify the required maximum g intercept at zero psi.

f. Specify the minimum psi/g pressure slope.

g. Specify the maximum psi/g pressure slope.

REQUIREMENT LESSONS LEARNED

Various users have had different preferences regarding the "onset" and "slope" of the suit pressurization. Some users have, in fact, found it useful to set these such that there is some residual pressurization at the simulated one-g level; this has been done so that negative g-loading cues could also be provided. Because of these varying preferences, a means to permit the simulator operator to adjust these parameters has been required. The minimum pressurization level has generally been specified at zero psi while the maximum value was 7 psi. Typically, pressure "onset" has been adjustable over a range of at least zero to 2 g's. The "slope" has been adjustable over a range of at least 0.5 to 1.5 psi/g.

4.6.6.3 **Anti-g suit system**. Verify by ________.

VERIFICATION RATIONALE (4.6.6.3)

To assure compliance.

VERIFICATION GUIDANCE

A pressure transducer placed in the anti-g suit air line(s) shall be used to instrument this device(s) for test. Hardware tests shall be conducted to assure that the suit(s) can be pressurized over the specified pressure range. Inspection of vendor drawings, computer control mechanisms, and/or hardware tests (as appropriate) shall be conducted to assure that the suit(s) cannot be pressurized beyond the specified maximum. Simulator tests shall verify that the "pressure onset" and "slope(s)" are adjustable over the required ranges. Simulator tests shall verify that a "freeze" condition results in suit pressure returning to that level corresponding to 1 g.

VERIFICATION LESSONS LEARNED

3.6.6.3.1 **Anti-g suit control.** The anti-g suit control system shall provide proportional control of the steady-state suit pressure as a function of simulated aircraft vertical acceleration. The constant of proportionality shall be within ___(a)___ percent of the specified "slope." Suit pressurization for the simulated g level less than or equal to the selected "pressure onset" value, shall not deviate from zero by more than ___(b)___ psi. "Pressure onset" and "slope" shall be selectable at the ___(c)___.

REQUIREMENT RATIONALE (3.6.6.3.1)

This paragraph specifies the tolerances for the proportional suit pressurization control. The location at which the values for "pressure onset" and "slope" may be selected is also specified.

REQUIREMENT GUIDANCE

a. Specify the maximum permissible deviation of the steady-state pressurization schedule ("slope") as a percentage.

b. Specify the maximum permissible residual steady-state pressure (in psi) at the g level at which the suit should nominally be depressurized.

c. Specify the location at which the "pressure onset" and "slope" are to be selectable.

REQUIREMENT LESSONS LEARNED

Typically the "pressure onset" and "slope" have been selectable at the instructor/operator station.

4.6.6.3.1 **Anti-g suit control.** Verify by ________.

VERIFICATION RATIONALE (4.6.6.3.1)

To assure compliance of the steady state suit pressurization schedule.

VERIFICATION GUIDANCE

Simulator tests shall verify that "pressure onset" and "slope(s)" are selectable from the specified location. Simulator tests shall verify that (for any selected "pressure onset" value) when the simulated aircraft vertical acceleration is at or below the "pressure onset" value, suit pressure does not exceed the "pressure onset" specified tolerances. Simulator tests shall verify that (for any selected "pressure onset" or "slope" value) the steady-state suit pressure is within the specified tolerance of the theoretical. The theoretical value, for any simulated vertical aircraft acceleration g, is:

Suit Pressure (psi) = 0, if g = PRESSURE ONSET

Suit Pressure (psi) = (SLOPE) X [G - (PRESSURE ONSET)]
otherwise, (subject to the maximum pressure limit)

VERIFICATION LESSONS LEARNED

3.6.6.3.2 **Anti-g suit inflation/deflation rates.** The anti-g suit shall respond to a full range commanded step change in pressurization by reaching 63 percent of its final value within ___(a)___ seconds for inflation and ___(b)___ seconds for exhaust.

REQUIREMENT RATIONALE (3.6.6.3.2)

This paragraph specifies the minimum dynamic response characteristics of the simulated anti-g suit system.

REQUIREMENT GUIDANCE

a. Specify the effective time constant for the inflation rate.

b. Specify the effective time constant for the deflation rate.

REQUIREMENT LESSONS LEARNED

An effective time constant of 1.2 seconds for inflation and 0.65 seconds for deflation have been found satisfactory in the past. Enhancements (such as a sub-atmospheric sink) may be required to obtain this deflation rate.

4.6.6.3.2 Anti-g suit inflation/deflation rates. Verify by __________.

VERIFICATION RATIONALE (4.6.6.3.2)

To assure compliance of the dynamic suit pressurization schedule.

VERIFICATION GUIDANCE

Apply a square wave with a period of at least ten times the larger of the two specified time constants and an amplitude which corresponds to a full-range pressure change to the anti-g suit system input. Monitor the command input signal and the output of a pressure transducer placed in the anti-g suit air line on a multi-channel strip chart recorder. Verify that the suit pressure reaches 63 percent of its final value within the specified times for both inflation and deflation.

VERIFICATION LESSONS LEARNED

3.7 **Visual system.** A __(a)__ visual system shall be provided to generate out-the-window visual scenes for __(b)__. The visual system shall be capable of __(c)__ operations within the __(d)__ aircraft flight envelope. The visual system shall include a visual environment or data base, an image generator, a display system, and all other hardware and software necessary to provide the visual cues required to train __(e)__, and maintain and control the visual system. These tasks are defined further in 3.7.1 and subparagraphs. The visual system shall be designed to process and display data bases which contain the information required to train the above listed tasks. The visual system shall provide sufficient field-of-view, image quality, and positional accuracy to train the above listed tasks. The system shall be capable of simulating various atmospheric and weather effects, and shall provide __(f)__. Transport delay and unwanted visual artifacts shall not impair training for the above listed tasks.

REQUIREMENT RATIONALE (3.7)

This paragraph provides a top-level statement of the visual system requirements. Like much of the image generation section of this specification, it is oriented toward a computer image generation system. It defines the tasks to be trained, which should be determined via interaction with the user. This paragraph also defines which crew members need to see the visual display, and it defines the components of the visual system.

REQUIREMENT GUIDANCE

a. Fill in the blank with monochrome, two-color, or full color. Low cost visual systems are not all capable of full color operation.

b. List the crew members who must use the visual display. This typically includes the pilot and copilot, and may include the navigator, engineer, instructor, etc.

c. Fill in the blank with night-only, dusk/night, or day/dusk/night, depending upon the user's needs.

d. Fill in the aircraft being simulated. If the full flight envelope of the aircraft is to be simulated, say so.

e. List the training tasks to be supported by the visual system. These can include taxi, take-off, and landing, aerial refueling, low-level flight, etc.

f. List other visual system requirements here, including texture, special effects (weapons effects, threats), etc.

If the capability to create, update, and manually enhance the visual data base is required, it should be mentioned here to scope the overall visual system effort.

REQUIREMENT LESSONS LEARNED

It is important that the top-level system specification be derived from user requirements. Over-specification can dramatically increase visual system acquisition and life-cycle costs. It may be possible to achieve considerable cost-savings if a calligraphic system or a low-cost graphics system can satisfy the training requirements. Do not overspecify the number of people who need to see the visual display, since this will determine the display type, the number of display units, and the exit pupil of the display system. Color can add significantly to the cost, but it does enhance the acceptability of the system to the user, and can contribute to the overall training effectiveness for some tasks.

Since there are a number of visual systems now commercially available that cover a large spectrum of capabilities, this document has been written to address the highest complexity visual simulation approach using full color, day/dusk/night raster scan systems. When developing a specification to meet a requirement for lower-fidelity or night-only systems, it will be necessary to remove many of the detailed requirements contained herein as part of the tailoring process. The guidance and lessons learned sections should help in this process.

4.7 **Visual system**. The performance of the visual system, including the visual data base, visual image generator, and visual display subsystem, shall be verified.

VERIFICATION RATIONALE (4.7)

Verification of the visual system is required to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses, demonstrations, and tests should be the primary means of verifying visual system performance.

VERIFICATION LESSONS LEARNED

All aspects of the image generator must be tested, both separately and in an integrated mode, to insure that the system meets all requirements. For example, the data base should be tested separately for content and area of coverage, and the image generator should be tested separately with static test patterns to verify capacity. The data base should also be tested with the image generator in real-time to verify real-time access and dynamic processing capacity. The required verification activity will be discussed in more detail in the following sections.

3.7.1 **Training tasks and visual cues**. The visual system shall be designed to provide high-fidelity simulation with appropriate scene content and visual cues to support training task requirements throughout the complete mission profile and within the full __________ flight envelope.

REQUIREMENT RATIONALE (3.7.1)

The training tasks and their associated required visual cues will be used to determine the image generator, data base, and display system requirements. The entire visual system design will be based on the requirements of this paragraph and its subparagraphs. A subparagraph should be inserted after 3.7.1 for each visual training task to provide details about the visual cues required.

REQUIREMENT GUIDANCE

a. Fill in the blank with the aircraft being simulated.

Requirements for correlation between the visual imagery and other sensors, such as radar and infrared, should also be added here.

REQUIREMENT LESSONS LEARNED

The aircraft being simulated is stated so that any peculiarities of aircraft dynamics that might determine visual system performance can be considered.

4.7.1 Training tasks and visual cues. Analyses, demonstrations, and tests shall be conducted to verify that the visual system is capable of supplying the visual cues required to support the specified training tasks.

VERIFICATION RATIONALE (4.7.1)

Verification of the ability to provide required visual cues is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering tests and analyses should be the primary means of verifying the visual system's ability to provide training for the required tasks.

VERIFICATION LESSONS LEARNED

Tests may be objective from the standpoint of determining whether a specific cue has been simulated, but frequently the task of determining how well the simulation has been implemented is subjective in nature. A period of time may be set aside to "fly" the visual system through the data base to exercise the various data base and image generator features.

3.7.1.1 **Taxi, takeoff, and landing.** The visual system shall generate and display the visual cues required for taxi, takeoff, approach, landing, and other airfield and ramp operations. Real-world airfield models shall be provided for ___(a)___. The capability to include ___(b)___ relocatable generic airfields shall be provided. The generic airfields shall be located anywhere in the world with any desired runway heading and elevation. A minimum of ___(c)___ mile radius of the area surrounding the airfield shall be provided as part of the gaming area. This area shall provide the necessary terrain and cultural definition, including buildings and lights, to support the takeoff and landing tasks. The immediate airfield area shall provide the runways, taxiways, and ramp areas with appropriate surface markings, markers, signs, and lights; appropriate buildings including hangars, control towers, and other structures; other aircraft; and ground vehicles. Lights shall be simulated with their appropriate flashing and directional characteristics. In addition, a model for a companion ___(d)___ aircraft shall be provided for formation taxi and takeoff. The simulation of ownship landing and taxi light effects shall include ___(e)___.

REQUIREMENT RATIONALE (3.7.1.1)

This paragraph discusses the requirements and cues for the taxi, takeoff, and landing task.

REQUIREMENT GUIDANCE

a. Specify the real-world airbase models required, if applicable.

b. Specify the number of generic airbase models required.

c. Specify the radius of the area to be modelled around each airfield.

d. Specify the type of aircraft to be modelled for formation training tasks, if required.

e. Specify the fidelity required for the landing/taxi light effects, including size and shape of light pattern, steering, and fog effects.

REQUIREMENT LESSONS LEARNED

It is beneficial to avoid modelling real-world airfields if possible, due the subjective problems encountered in accepting such a model. If real-world airfields are required, the number should be minimized, since the hand modelling and tuning process can be costly. Ground rules should be established to guide the development and subjective evaluation of any real-world data base areas. Generic airfields can be used to supplement or replace real-world airfields. A few generic models can be developed which contain desired variations but provide the required cues, and these can be relocated to any desired geographic location.

4.7.1.1 Taxi, takeoff, and landing. The ability of the system to support taxi, takeoff, and landing training shall be verified.

VERIFICATION RATIONALE (4.7.1.1)

Verification of this task is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses, demonstrations, and tests should be the primary means to verify visual system support of the taxi, takeoff, and landing task. Much of the verification of this requirement can be accomplished by detailed data base content tests, assuming that the real-time operation of the system has been verified. Data base content verification can include airfield models, content, and area of coverage. Real-time demonstration can include the companion aircraft simulation, light characteristics, and landing/taxi light effects (which include steerable illumination and visibility effects). In addition, analysis may be used where appropriate (for example, to determine landing light lobe pattern).

VERIFICATION LESSONS LEARNED

3.7.1.2 **Aerial refueling**. The visual system shall provide the visual cues required to train the aerial refueling task. Rendezvous, approach, precontact, contact, operation within the refueling envelope, disconnect, and emergency maneuvers shall be simulated. The visual system shall accurately depict the __________ tanker aircraft and moveable refueling boom, along with sky and clouds and receiver relative motion. The tanker, boom, and all other cues shall appear in the proper perspective and position. Curved surfaces and other appropriate detail on the tanker shall appear proper with respect to cockpit references as well as to each other. All tanker lights, including director lights, and tanker illumination effects shall be properly portrayed in accordance with range, visibility, and function. The boom shall automatically connect once the receiver aircraft has maneuvered into and stabilized in the contact position, and shall maintain the connection as long as the receiver remains within the contact envelope, or until normal disconnect occurs. The capability shall be provided to allow the instructor to initiate an automated demonstration of boom envelope limits.

REQUIREMENT RATIONALE (3.7.1.2)

This paragraph discusses the requirements and cues for the aerial refueling task.

REQUIREMENT GUIDANCE

Specify the tanker aircraft which shall be portrayed in the aerial refueling scenario (typically KC-10, KC-135, etc). A probe and drogue system is available typically for refueling smaller aircraft. The cues are obviously different from a boom type system.

If the specification is aimed toward a full color system, it is a good idea to add a requirement for texture in the aerial refueling scene, since it can help provide cues for small degrees of relative motion.

It may also be beneficial to require that the boom connect at random times once the receiver achieves contact position, in order to simulate the effects that would be encountered in the real aircraft if the receiver stabilizes near the edge of the boom envelope.

REQUIREMENT LESSONS LEARNED

- Do not overspecify aerial refueling requirements. Specify only those tankers which will be needed. Also, the user may prefer manual control for a boom limit demo, and may also require the ability to take manual control of tanker flight path. These needs must be translated into the specification. Finally, remember that the field-of-view requirements for aerial refueling often conflict with the requirements for other, perhaps more essential training tasks. This may force tradeoffs in the overall field-of-view and field-of-view positioning.

4.7.1.2 **Aerial refueling.** The ability of the system to support aerial refueling training shall be verified.

VERIFICATION RATIONALE (4.7.1.2)

Verification of this task is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means to verify visual system support of the aerial refueling task. Data base content demonstration can verify the presence of all required tanker and boom model geometry and light details. Real-time demonstration combined with analysis can verify the proper tanker and boom dynamics and response to instructor/operator control inputs.

VERIFICATION LESSONS LEARNED

3.7.1.3 **Low level flight.** The visual system shall provide the required cues to train low level flight, and shall support descent to low level, low level flight ___(a)___, and withdrawal from low level. The purpose of the low level flight capability shall be ___(b)___. The terrain model to support low level flight shall correlate with ___(c)___. Cultural features to be portrayed include ___(d)___. Texture is required to provide the necessary altitude and velocity cues.

REQUIREMENT RATIONALE (3.7.1.3)

This paragraph discusses the requirements and cues for low level flight. Many of the same capabilities are required for terrain following, terrain avoidance, low level navigation, etc.

REQUIREMENT GUIDANCE

a. If low level flight with a companion aircraft is required, so state; otherwise, delete reference.

b. Define the purpose of low level flight (typically confidence building, train low level navigation, etc).

c. Specify sensors (typically: radar, infrared, etc) that are required to correlate with visual.

d. Specify what cultural features are important to the task. (Typically: vertical obstructions, powerlines, lines of communications threats, targets, etc).

REQUIREMENT LESSONS LEARNED

The requirements of this paragraph can be a significant cost driver, since they may result in an intensive data base generation effort over a potentially large geographic area. Determine what correlation is required, and define the specifics (what features, what tolerance, etc). Also, do not specify data base features which have no relevance to the training task. If low level flight is a high priority training task, a full color day/dusk/night system will likely be required to provide the needed texture cues and overall environment density.

4.7.1.3 **Low level flight**. The ability of the system to support low level flight training shall be verified.

VERIFICATION RATIONALE (4.7.1.3)

Verification of this task is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means to verify visual system support of the low level flight task. Data base content demonstration can verify the presence of the terrain/culture models and texture. Real-time demonstration can verify the companion aircraft capability if required, and can also verify that the visual system is capable of retrieving and displaying the appropriate sections of the data base at real-time rates and at the proper levels of detail. Analysis and real-time demonstration can be used to verify that the data base is properly correlated with other data bases (radar, sensor, etc).

VERIFICATION LESSONS LEARNED

If there is a requirement to display one or more aircraft concurrently with the low altitude data base, be sure to require such a demonstration. Such a scenario may be the acid test of the image generator's ability to process large amounts of data while balancing the load for an acceptable portrayal of high detail aircraft and terrain.

3.7.1.4 **Air-to-air combat**. The visual system shall provide the required cues to train the air-to-air combat task. These cues shall include ___________.

REQUIREMENT RATIONALE (3.7.1.4)

This paragraph specifies the requirements and cues for the air-to-air combat training task.

REQUIREMENT GUIDANCE

Fill in the cues required for air-to-air combat, based on training requirements and user needs.

REQUIREMENT LESSONS LEARNED

4.7.1.4 **Air-to-air combat**. The ability of the system to support air-to-air combat training shall be verified.

VERIFICATION RATIONALE (4.7.1.4)

Verification of this task is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means to verify visual system support of the air-to-air combat task. Data base content demonstration can verify the presence of required moving model details. Real-time demonstration combined with analysis can verify the proper moving model portrayal and response to instructor/operator control inputs.

VERIFICATION LESSONS LEARNED

3.7.1.5 **Air-to-ground weapons delivery.** The visual system shall provide the required cues to train the air-to-ground weapons delivery task. These cues shall include ___________.

REQUIREMENT RATIONALE (3.7.1.5)

This paragraph specifies the requirements and cues for the air-to-ground weapons delivery training task.

REQUIREMENT GUIDANCE

Fill in the cues required for air-to-ground weapons delivery, based on training requirements and user needs. Assure cues are inclusive set for all weapon types to be delivered.

REQUIREMENT LESSONS LEARNED

4.7.1.5 **Air-to-ground weapons delivery.** The ability of the system to support air-to-ground weapons delivery training shall be verified.

VERIFICATION RATIONALE (4.7.1.5)

Verification of this task is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means to verify visual system support of the air-to-ground weapons delivery task. Data base content demonstration can verify the presence of required model details. Real-time demonstration combined with analysis can verify the proper special effects portrayal and response to instructor/operator control inputs.

VERIFICATION LESSONS LEARNED

3.7.2 **Image generation.** The image generator shall process the visual environment data to generate the display scene for the appropriate viewpoint. The displayed scene shall be computed using the ownship position and attitude within the simulated environment. The result of this transformation shall be a video signal which is fed directly to the display system. The visual scenes created by the image generator shall have the characteristics discussed in the following subparagraphs.

REQUIREMENT RATIONALE (3.7.2)

This paragraph specifies top-level requirements for the image generator. It defines the basic input (environment data base and position/attitude data) and the output (video signal) for the image generation subsystem.

REQUIREMENT GUIDANCE

This is a required introductory paragraph for all image generators.

REQUIREMENT LESSONS LEARNED

4.7.2 **Image generation.** The ability of the image generator to process the data base and present imagery on the display subsystem at real-time rates shall be verified.

VERIFICATION RATIONALE (4.7.2)

Verification of image generator capabilities and capacities is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses, demonstrations, and tests will be the primary means to verify visual system real-time performance. These general requirements will be addressed more specifically in the following subparagraphs.

VERIFICATION LESSONS LEARNED

Be certain that all capabilities that will be used concurrently in actual simulator use are tested concurrently. Some image generator functions may perform well in stand-alone tests, but may fail or cause degraded imagery in integrated real-time operation.

3.7.2.1 **Scene elements.** The visual imagery produced by the image generator shall appear as recognizable real-world scenes. These scenes shall be constructed with the scene elements and characteristics discussed below.

REQUIREMENT RATIONALE (3.7.2.1)

This paragraph provides some basic requirements for the character of the generated image, and introduces the following detailed specifications.

REQUIREMENT GUIDANCE

This is a required introductory paragraph for all image generators.

REQUIREMENT LESSONS LEARNED

4.7.2.1 **Scene elements.** The ability of the image generator to generate visual scenes possessing the characteristics discussed in the following subparagraphs shall be verified.

VERIFICATION RATIONALE (4.7.2.1)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

This is a top-level specification which introduces the detailed image generator tests.

VERIFICATION LESSONS LEARNED

3.7.2.1.1 **Edge/surface capacity**. The image generator shall be capable of computing ___(a)___ edges or ___(b)___ surfaces per frame. A potentially visible edge or surface is one which is within the field-of-view, faces the observer, and would normally be visible unless occulted by some other object.

REQUIREMENT RATIONALE (3.7.2.1.1)

This paragraph specifies the basic processing capability of the image generator in terms of edges or surfaces, depending upon the type of image generator technology to be employed.

REQUIREMENT GUIDANCE

Capacity for a given image generator will be specified either in terms of edges or surfaces, but not both.

a. Specify the minimum number of potentially visible edges required. Since there is no data available to define how many edges are required to provide adequate training for a given training task, typically the number filled in here is chosen to discriminate between the different general classes of systems (calligraphic vs. raster, etc).

b. Specify the minimum number of potentially visible surfaces required. This number should specify a surface capacity comparable to that specified in terms of edge capacity. Generally the number of surfaces should be specified as about half the number of edges.

REQUIREMENT LESSONS LEARNED

For the purposes of this specification, an edge is the boundary between two displayed surfaces, which may have the same or different colors. Edge or surface capacity is specified in terms of processing ability rather than data base storage or content. Since it is not yet well understood exactly what cues are required for training, the traditional approach to specifying processing capacity has been to use a number at or slightly below the capacity of currently available systems. This requirement can be reduced for a dusk/night system.

4.7.2.1.1 **Edge/surface capacity**. A test pattern shall be used to test the system capacity as specified in 3.7.2.1.1. This pattern shall be displayed both statically and dynamically. All edges/surfaces shall be displayed without any distracting visual effects.

VERIFICATION RATIONALE (4.7.2.1.1)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means to verify visual system edge/surface capacity.

VERIFICATION LESSONS LEARNED

By studying the documented design of the image generator, it should be possible to determine the theoretical edge/polygon capacity. Also, a regular, repeated test pattern containing the specified number of edges or polygons is often displayed to test this requirement, since it is difficult, if not impossible, to display a scene at the full image generator capacity using the real data base. The image generator may continuously attempt to adjust the processing load to some percentage of the maximum capacity, so it may be necessary to disable the image generator load management function. Finally, remember that for some designs, channel capacity, as well as system capacity, must be tested.

3.7.2.1.2 Lights--image generation. The image generator shall be capable of generating a minimum of ___(a)___ lights per frame. These shall include ___(b)___. All lights shall vary in brightness as a function of range and visibility. The instructor shall have the capability to control ___(c)___.

REQUIREMENT RATIONALE (3.7.2.1.2)

Lights are a necessary part of a night image.

REQUIREMENT GUIDANCE

a. Specify the total number of lights to be displayed per frame. This is important for some systems which are intended primarily for night training and which therefore rely on light capacity to provide most of the cues.

b. Specify the types of lights to be simulated. These can include normal lights for representing runway lights and general cultural lighting, and they may also include special purpose lights with special blinking, color, and directional characteristics used to simulate beacons, rotating lights, VASI lights, and obstruction lights.

c. Specify the light controls available to the instructor. These typically include on/off controls for runway strobes and tanker lights, and intensity controls for airfield lights and perhaps general cultural lights.

REQUIREMENT LESSONS LEARNED

The number of lights required is dependent upon the training task and the importance of lights to the task. State-of-the-art image generators can typically produce 4,000 or more lights. Some systems, however, trade edge or polygon processing capacity for light processing capacity. These requirements may need to be specified on a channel basis in addition to the total scene requirements discussed in the paragraph as written. These requirements also may need to be significantly enhanced for a dusk/night system. Finally, special purpose lights require dedicated processing for some system types and thus have limited availability.

4.7.2.1.2 Lights--image generation. A test pattern shall be used to test the system light capacity as specified in 3.7.2.1.2. The pattern shall consist of the required mixture of point, perspective, and special purpose lights. The pattern shall be portrayed statically to allow verification of the number of lights. The pattern shall also be displayed dynamically to demonstrate that all lights exhibit the proper characteristcs. The pattern shall include various directional, blink, and color characteristics for special purpose lights. All lights shall be displayed without any distracting visual effects.

VERIFICATION RATIONALE (4.7.2.1.2)

Verification of this requirement is necessary to insure compliance

VERIFICATION GUIDANCE

Engineering demonstrations and analyses should be the primary means of verifying the light capacity of the image generator.

VERIFICATION LESSONS LEARNED

In practice, it may be advisable to merge the light test pattern with the edge/polygon test pattern for a better overall assessment of the system capacity.

3.7.2.1.3 **Surface shading.** Surface shading or color shall be computed as a function of object structure, illumination angle, range from the eyepoint, and visibility limitations. A minimum of ___________ shall be provided. The capability to selectively apply curved surface shading to simulate curved surfaces shall be provided to be used in the presentation of other aircraft, storage tanks, etc.

REQUIREMENT RATIONALE (3.7.2.1.3)

The purpose of this requirement is to insure that the image generator can properly compute the colors for the flat or curved surfaces which are the building blocks of the visual scene.

REQUIREMENT GUIDANCE

Fill in the blank with the minimum number of shades of grey for a monochrome system, or the number of colors for a color system. Typical values are 256 shades of grey, and at least 256 colors.

REQUIREMENT LESSONS LEARNED

Usually eight bits are allocated to store each color component. Thus, 256 shades of grey are typical for monochrome systems. In color systems, typically eight bits are used for each of the primary colors, resulting in a 24-bit color word and a very large number of possible colors. Be sure to specify that illumination and visibility effects are included in the surface color computation. These effects provide valuable information about the surface orientation and distance from the observer. Curved surface shading is required to mask the polygonal structure of the model which is to be portrayed as curved.

4.7.2.1.3 **Surface shading.** The surface shading capability of the system shall be verified. A test pattern with a palette of the available colors or grey shades shall be displayed. A test data base shall also be used to demonstrate that the shading of representative surfaces is affected by surface orientation relative to the simulated sun, ambient light conditions, range from eyepoint, and visibility conditions. The test data base shall also exhibit the curved surface capability.

VERIFICATION RATIONALE (4.7.2.1.3)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering demonstrations and analyses should be the primary means of verifying the surface shading capability of the image generator.

VERIFICATION LESSONS LEARNED

3.7.2.1.4 Texture--image generation. The image generator shall have the capability to display a minimum of __________ texture patterns simultaneously to provide relative altitude and velocity cues. Texture capability shall be in addition to the edge/surface processing capacity specified herein. Texture patterns shall be assignable to any surface or feature in the visual environment. Texture shall remain stationary with respect to the surface, and shall maintain the proper perspective, occulting, and contrast/color relationships for the surface.

REQUIREMENT RATIONALE (3.7.2.1.4)

The purpose of this requirement is to specify the requirement for texture, which can be employed to provide more realistic imagery and important motion and altitude cues without detracting from the basic edge/surface processing capability of the system.

REQUIREMENT GUIDANCE

Specify the number of texture patterns or types of texture required.

REQUIREMENT LESSONS LEARNED

This requirement is dependent upon the tasks to be trained. The number of patterns or types of texture required depend upon the architecture of the image generator, and some calligraphic or low-cost image generators may not support texture at all. Some image generators may be able to portray each texture type with several different colors, in effect increasing the number of texture types. New techniques are being developed to provide real-time photomapped texture, whereby the contents of any photograph can be mapped onto culture and terrain surfaces. Texture may be applied only to large features near the viewpoint. As a minimum, patterns are needed to portray common natural features such as lakes, forests, grassland, rock, sand, etc. Texture may also be needed for man-made features such as urban areas, industrial areas, farmland, etc. In any event, remember that texture is often a significant cost driver. However, it provides beneficial cues and is a major factor in acceptability of the visual imagery, especially for low level tasks.

4.7.2.1.4 Texture--image generation. The texture capability of the image generator shall be verified. A test pattern shall be used to demonstrate that the specified number of texture patterns or types can be displayed simultaneously. In addition, a test data base shall be provided to demonstrate that texture can be portrayed in addition to the specified edge/polygon and light capacity of the system. The test data base shall be displayed under dynamic conditions to insure that texture patterns exhibit proper color and positional stability, perspective, occulting, and detail emergence effects.

VERIFICATION RATIONALE (4.7.2.1.4)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering demonstrations and analyses should be the primary means of verifying the texturing capability of the image generator.

This paragraph should be eliminated if there is no texture requirement.

VERIFICATION LESSONS LEARNED

3.7.2.1.5 **Cultural features--image generation.** The image generator shall display appropriate culture features as necessary to train the tasks specified herein. There shall be no limitations in the display of cultural features other than the overall image generator edge/surface and light capacity as specified herein.

REQUIREMENT RATIONALE (3.7.2.1.5)

The purpose of this requirement is to ensure that the image generator has adequate capacity to process the cultural features required to train the tasks.

REQUIREMENT GUIDANCE

This paragraph is included primarily to address image generators which impose limitations in the portrayal of culture features in addition to the basic system edge/surface capacity.

REQUIREMENT LESSONS LEARNED

4.7.2.1.5 **Cultural features--image generation.** The ability of the image generator to display culture features shall be verified.

VERIFICATION RATIONALE (4.7.2.1.5)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis should be the primary means of verifying the cultural feature display capability of the image generator.

VERIFICATION LESSONS LEARNED

The purpose of this requirement is to verify that there is no inherent limitation in the image generator design which artificially restricts the number of features which can be portrayed when there is still available edge or polygon capacity.

3.7.2.1.6 **Terrain--image generation.** The image generator shall display the appropriate terrain structure as defined in 3.7.3.1.4 and 3.7.3.2.1. There shall be no limitations in the display of terrain information other than the overall image generator edge/surface capacity specified herein.

REQUIREMENT RATIONALE (3.7.2.1.6)

The purpose of this requirement is to ensure that the image generator has adequate capacity to process the terrain model required to train the tasks.

REQUIREMENT GUIDANCE

This paragraph is included primarily to address image generators which impose limitations in the portrayal of the terrain model in addition to the basic system edge/surface capacity.

REQUIREMENT LESSONS LEARNED

4.7.2.1.6 **Terrain--image generation.** The ability of the image generator to display the terrain model shall be verified.

VERIFICATION RATIONALE (4.7.2.1.6)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis should be the primary means of verifying the terrain processing capability of the image generator.

VERIFICATION LESSONS LEARNED

The purpose of this requirement is to verify that there is no inherent data base structure or image generator design limitation which artificially restricts the terrain portrayal when system edge or polygon capacity is still available.

3.7.2.1.7 **Moving models--image generation.** The image generator shall be able to portray a minimum of __________ moving models simultaneously. The moving models shall be independently controllable and shall include any combination of surface or airborne moving models. The capability to select desired models from the moving model library and insert them into the training scenario shall be provided. Models shall be capable of being controlled by the instructor or following a predefined motion path. The motion path of surface moving models shall conform to the terrain and culture structure defined in the visual environment.

REQUIREMENT RATIONALE (3.7.2.1.7)

The purpose of this paragraph is to ensure that the image generator can control and process the computational load involved when the required number of moving models are displayed simultaneously. It also specifies general requirements for the motion and control of moving models.

REQUIREMENT GUIDANCE

Specify the number of simultaneous moving models required. This will depend upon the training tasks.

If surface moving models are not required, delete the last sentence from the specification paragraph.

Determining occulting priorities for moving models on the surface is a major task when total freedom of movement is allowed; it may be desirable to specify a maximum number of each type of moving model (surface and airborne). If the instructor takes complete control of a surface moving model (direction as well as speed), it is very difficult to have the moving model follow the terrain properly. There is also no simple (or inexpensive) way to keep the instructor from driving the model through trees and other objects. In some cases, moving models may be required to exhibit special effects such as missile impact, etc.

REQUIREMENT LESSONS LEARNED

Do not specify more than the required number of moving models. Moving models can present a significant processing load to the image generator. In some cases, the solution may involve reducing the density of the terrain and culture data base to avoid overload when moving models are brought into the scene. If possible, add exact requirements to the paragraph to describe the desired moving model capability and eliminate any chance of misinterpretation. For example, while the Air Force may consider a refueling tanker with moving boom and boom extension as one moving model, a contractor may consider this as two or three moving models since that number of moving coordinate systems are required to portray the model. Be as specific as possible in the requirement.

4.7.2.1.7 **Moving models--image generation.** The ability of the image generator to portray the specified number of simultaneous moving models shall be demonstrated. This shall include the capability to select a desired model from the library and display it in a dynamic environment which demonstrates the required freedom of movement. All moving models shall exhibit smooth motion and proper level of detail transitions, and shall be free of distracting visual effects.

VERIFICATION RATIONALE (4.7.2.1.7)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis and demonstration should be the primary means of verifying the moving model capability of the image generator.

VERIFICATION LESSONS LEARNED

Be certain that the moving model capability is demonstrated using the maximum number of moving models required. Also be sure that the models being used are the same high-fidelity models which will actually be used in the training scenarios. Finally, if the models are to be portrayed in a dense visual scene (including an airfield or low-level terrain), the demonstration should include a dynamic verification of the capability.

3.7.2.2 **Computed visual range.** The image generator shall have the ability to compute a visual scene from the eyepoint to a range of ___________ nautical miles, regardless of the effects of visibility limitations discussed in 3.7.2.3 and subparagraphs.

REQUIREMENT RATIONALE (3.7.2.2)

The purpose of this paragraph is to specify the maximum range from the eyepoint at which objects shall be visible in the visual scene.

REQUIREMENT GUIDANCE

Specify the maximum computed visible range (typically 15-25 nautical miles).

REQUIREMENT LESSONS LEARNED

Do not overspecify or underspecify this number. A number that is too large requires design of the image generator to accommodate a larger active data base and process a larger load, in effect increasing cost or reducing the overall data base density. A number that is too small will result in the ability to see beyond the "edge of the world" under the proper visibility conditions, and may have detrimental effects with regard to visual correlation with other sensors.

4.7.2.2 Computed visual range. The capability of the system to provide continuous visual imagery from the eyepoint to the maximum computed visual range shall be verified. This shall be accomplished using an operational data base under known position and velocity conditions. With maximum visibility, the distance at which the lowest level of detail transitions into the scene should be determined. This is the observed maximum computed visual range. Transitions should be smooth and should exhibit no distracting effects.

VERIFICATION RATIONALE (4.7.2.2)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis and demonstration should be the primary means of verifying the maximum computed visual range capability of the image generator.

VERIFICATION LESSONS LEARNED

It is necessary to test the maximum computed visual range using a real data base under realistic dynamic conditions to insure that the data base and image generator have been tuned at a system level to control the processing load. This verifies that the system is capable of presenting usable imagery at the maximum visible range.

3.7.2.3 **Atmospheric simulation.** The image generator shall have the capability to provide the following simulated atmospheric conditions.

REQUIREMENT RATIONALE (3.7.2.3)

The purpose of this paragraph is to introduce the requirement for simulated visibility and atmospheric effects.

REQUIREMENT GUIDANCE

This introductory paragraph is required for all image generators.

REQUIREMENT LESSONS LEARNED

3.7.2.3.1 **Ambient light.** The image generator shall provide simulated ambient light levels for ___________, to be controllable by the instructor. Sun illumination angle shall be controllable, and the effects of sun angle shall be portrayed on all features in the visual scene.

REQUIREMENT RATIONALE (3.7.2.3.1)

The purpose of this paragraph is to ensure that the image generator can provide appropriate illumination effects for the required ambient light levels.

REQUIREMENT GUIDANCE

Typically day, dusk, and night.

REQUIREMENT LESSONS LEARNED

If daytime simulation requirements are minimal or non-existent, a less expensive image generator can be used. Elimination of a daytime capability can have significant cost savings.

3.7.2.3.2 **Haze/visibility.** The image generator shall simulate the effects of reduced visibility due to atmospheric conditions. Visibility attenuation shall be computed for all features in the visual scene for all visual tasks. Haze/visibility shall be controllable over a range of ___(a)___ in ___(b)___ increments.

REQUIREMENT RATIONALE (3.7.2.3.2)

The purpose of this paragraph is to ensure that the image generator has the capability to simulate decreased visibility conditions, and to provide for instructor control of this function.

REQUIREMENT GUIDANCE

a. Specify visibility dynamic range (typically 0-25 miles).

b. Specify the resolution of visibility control (may be separate values for several ranges--for example, 1,000-foot increments for 0 to 2 miles and 1-mile increments for 2 to 25 miles).

REQUIREMENT LESSONS LEARNED

3.7.2.3.3 **Clouds.** The image generator shall simulate clouds and overcast conditions. Textured cloud portrayal shall be used to enhance relative motion cues for aerial refueling. Cloud conditions shall include, as a minimum, clear, overcast/smooth, and overcast/rugged (scud). Cloud thickness shall be controllable in ___(a)___ increments over the range of ___(b)___. Cloud ceiling shall be controllable in ___(c)___ foot increments over the range of ___(d)___ and in ___(e)___ increments over the range of ___(f)___.

The instructor shall be able to insert/delete scud cloud effects. The simulated horizon shall be portrayed when the aircraft position is above the defined cloud height.

REQUIREMENT RATIONALE (3.7.2.3.3)

The purpose of this paragraph is to ensure the image generator is capable of simulating the required cloud effects and provides the necessary instructor controls.

REQUIREMENT GUIDANCE

a. Specify cloud thickness resolution (typically: 1,000 feet).

b. Specify cloud thickness range (typically: 1,000-20,000 feet).

c. Specify cloud ceiling resolution for low altitudes (typically: 100 feet).

d. Specify cloud ceiling low range (typically: 0-15,000 feet).

e. Specify cloud ceiling high altitude resolution (typically: 1,000 feet).

f. Specify cloud ceiling high range (typically 15,000 feet to aircraft service ceiling).

REQUIREMENT LESSONS LEARNED

3.7.2.3.4 **Horizon.** The horizon shall be simulated for all ambient light conditions. The day horizon shall be simulated to include atmospheric light dispersions. The night horizon shall consist of a band of illumination which decreases in intensity as it extends upward from the horizon. All features in the scene shall exhibit fading effects, as a function of range, toward a controllable color shade at the horizon.

REQUIREMENT RATIONALE (3.7.2.3.4)

The purpose of this paragraph is to specify the image generator capability to simulate horizon effects.

REQUIREMENT GUIDANCE

This specification is required for all image generators.

REQUIREMENT LESSONS LEARNED

3.7.2.3.5 **Thunderstorm/lightning.** The visual system shall simulate thunderstorm and lightning conditions. The simulation of the thunderstorm conditions shall include the effects of gradual visibility attenuation due to precipitation as a function of range to the storm and intensity of the storm. Lightning associated with the storm condition shall be simulated. The simulation of lightning conditions shall include lightning bolts, and rapid and random intensifying in the out-the-window visual scene at an occurrence rate dependent on storm intensity. Thunderstorm conditions shall include, as a minimum, light, medium, and heavy, with lightning on/off control for all conditions. On/off control of the thunderstorm condition shall be controllable by the instructor. All thunderstorm conditions shall be controllable by the instructor.

REQUIREMENT RATIONALE (3.7.2.3.5)

This paragraph ensures the capability for thunderstorm/lightning simulation.

REQUIREMENT GUIDANCE

This requirement is needed when all-weather training capability is specified.

REQUIREMENT LESSONS LEARNED

4.7.2.3 **Atmospheric simulation.** The capability of the image generator to portray ambient light effects and sun illumination, haze and visibility restrictions, clouds, and a horizon shall be verified. A test data base which contains a mixture of terrain and culture features, moving models, lights, texture, and any other special effects shall be used. The proper effect of ambient light and sun position changes on all visual scene elements shall be demonstrated. The proper effect of haze and reduced visibility on all visual scene elements shall be demonstrated with all specified controls and under all ambient light conditions. Clear, overcast smooth, and overcast rugged (scud) cloud conditions shall be demonstrated with all specified controls and under all ambient light conditions. Horizon band effects shall be demonstrated under all ambient light conditions.

VERIFICATION RATIONALE (4.7.2.3)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis and demonstration should be the primary means of verifying the visibility and atmospheric effects capability of the image generator.

VERIFICATION LESSONS LEARNED

Be sure to verify that all required combinations of these effects work together.

3.7.2.4 **Environment retrieval.** The image generator shall have the capability to retrieve and process the appropriate environment (gaming area) data to be used in creating the visual scene. The system shall retrieve and process that portion of the environment in the immediate vicinity of the ownship position, where immediate vicinity is defined to include all data within the computed visual range, as specified herein, in all directions from the eyepoint. As the ownship moves through the environment, new environment data shall be accessed and shall replace data which has moved out of the immediate vicinity of the viewpoint. This process shall not cause distracting visual effects in the visual scene. Image generator processing capacity shall not be wasted on features which are outside the field-of-view or face away from the viewpoint.

REQUIREMENT RATIONALE (3.7.2.4)

The purpose of this paragraph is to ensure that the image generator can access that portion of the visual environment that is within the current field-of-view, that this access can take place with no distracting effects at real-time rates, and that features which are not visible in the scene are eliminated from further processing as soon as possible.

REQUIREMENT GUIDANCE

This paragraph is required for all image generators.

REQUIREMENT LESSONS LEARNED

4.7.2.4 **Environment retrieval.** The capability of the image generator to retrieve the appropriate areas of the visual data base from mass storage and portray them at the proper levels of detail without any distracting visual effects shall be verified.

VERIFICATION RATIONALE (4.7.2.4)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis and demonstration should be the primary means of verifying the environment retrieval capability of the image generator. Analysis of the design documentation should verify that the system has adequate active data base storage, combined with the appropriate real-time access capability, to display well-behaved imagery for the full dynamic range of translational and rotational rates of the aircraft being simulated. Demonstration at representative rates using the actual data base will provide a final verification.

VERIFICATION LESSONS LEARNED

Be certain that this demonstration is performed using the actual data base and realistic airspeeds and turn rates. Perform the test/demonstration at several altitudes (i.e., very low, very high, and somewhere in between), and set the visibility at or near its maximum. Watch for sudden changes in levels of detail, sudden appearance or disappearance of scene elements, and other distracting effects.

3.7.2.5 **Load management.** The image generator shall be designed to constantly monitor and control its own processing load so that a near-capacity load is maintained. The capability to gracefully degrade the simulated imagery to prevent and recover from overload conditions shall be provided. This shall be accomplished by temporarily reducing the processing load by eliminating scene detail in a structured and non-distracting manner, so that features of minimal importance to the current training task are eliminated or portrayed in lower levels of detail, and features of higher importance are preserved.

REQUIREMENT RATIONALE (3.7.2.5)

The purpose of this paragraph is to ensure that the image generator and data base are designed to anticipate and avoid overload conditions, while at the same time maintaining an image generator load near full capacity.

REQUIREMENT GUIDANCE

This specification is required for all image generators.

REQUIREMENT LESSONS LEARNED

4.7.2.5 **Load management.** The capability of the image generator to accommodate overloads, recover gracefully from overloads, and maintain a near-capacity processing load shall be verified.

VERIFICATION RATIONALE (4.7.2.5)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis and demonstration should be the primary means of verifying the load management capability of the image generator.

VERIFICATION LESSONS LEARNED

This demonstration should be performed over a variety of data base areas extending from very sparse to very dense areas. Some new image generators have the capability to provide loading information continuously or for short intervals, and this can be a great help in determining how well the image generator and data base are tuned to provide optimum scene content.

3.7.2.6 Concentration of scene detail. The image generator shall be designed such that it concentrates scene detail in the immediate vicinity of the viewpoint or where training requirements dictate. This shall be accomplished as appropriate to the training task without creating distracting visual effects. Transitions from one level of detail to another shall be gradual and shall exhibit no distracting effects.

REQUIREMENT RATIONALE (3.7.2.6)

This paragraph ensures that the image generator devotes a high percentage of its resources to the enhancement of the detail of the near scene with decreasing detail in proportion to the distance from the eyepoint. The paragraph also prohibits distracting visual effects related to level of detail transitions.

REQUIREMENT GUIDANCE

This specification is required for all image generators.

REQUIREMENT LESSONS LEARNED

Two exceptions to the requirement that detail be concentrated near the eyepoint are the air-to-air and air-to-ground scenario, where detail at some distance from the eyepoint is also required.

4.7.2.6 Concentration of scene detail. The capability of the image generator to concentrate image detail near the ownship position, or where training requirements dictate, shall be verified.

VERIFICATION RATIONALE (4.7.2.6)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the image generator ability to control scene detail. Verification shall consist of analysis of design documentation and demonstrations using the actual training data base to study the smooth emergence of scene detail as features progress from far portrayal to near portrayal.

VERIFICATION LESSONS LEARNED

During demonstration of this capability, watch to see that important features are displayed at their highest resolution where required. Also, if there are limitations on texture capability, surfaces in the near field should be textured at the expense of those at long ranges from the eyepoint. Finally, detail and texture emergence should be a smooth progression with no distracting visual effects.

3.7.2.7 **Dynamic priority.** The image generator shall eliminate features or parts of features that are occulted by other features in the line of sight. This does not apply to translucency. The proper occulting relationships shall be provided for static and moving features for all flight paths and viewing angles in the simulated environment.

REQUIREMENT RATIONALE (3.7.2.7)

The purpose of this paragraph is to ensure that the image generator is designed to accommodate the computations required to determine the proper priority relationships (which objects are visible and which are hidden by other objects) for all elements of the visual scene.

REQUIREMENT GUIDANCE

This specification is required for all image generators.

REQUIREMENT LESSONS LEARNED

In the past, a specification of this type was usually accompanied by a number of occulting levels. It is better to state the requirement in terms of function so that all possibilities are covered.

4.7.2.7 **Dynamic priority.** The capability of the image generator to properly compute and display the occulting relationships for scenes of the complexity provided by the visual data base shall be demonstrated.

VERIFICATION RATIONALE (4.7.2.7)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the dynamic priority capability of the image generator. Verification shall consist of analysis of design documentation and demonstrations using the actual training data base and test data bases to determine that the dynamic priority capabilities of the system have no practical limit.

VERIFICATION LESSONS LEARNED

In the past, most specifications were written with a specific number of occulting levels. Due to the unpredictable complexity of data bases which are generated automatically from Defense Mapping Agency data, this was not always a safe method. It is better to require a design which essentially has no limit on the number of occulting relationships. A test data base with a large number of features with known complexity, in a straight line, could be used to help quantify the occulting capability. Also, the real training data base should be used to test this capability in areas of high density (typically in rough terrain at low altitudes to force calculation of a number of priority relationships along the horizon).

3.7.2.8 Anti-aliasing computation. The image generator shall compute the contributions of scene edges/polygons to each displayed picture element (pixel) on a subelement basis to reduce quantization effects. A minimum of 4 X 4 (16) subpixels shall be computed for each pixel.

REQUIREMENT RATIONALE (3.7.2.8)

This paragraph specifies a minimum "edge smoothing" capability for the image generator.

REQUIREMENT GUIDANCE

Some type of anti-aliasing processing is required for all image generators. This specification as worded is intended for full color, day/dusk/night raster image generators. The anti-aliasing requirement may need to be reduced for calligraphic systems.

REQUIREMENT LESSONS LEARNED

4.7.2.8 **Anti-aliasing computation.** The capability of the image generator to provide effective anti-aliasing techniques shall be verified.

VERIFICATION RATIONALE (4.7.2.8)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the anti-aliasing capability of the image generator.

VERIFICATION LESSONS LEARNED

The best way to observe aliasing effects is to use a relatively high-contrast scene with many visible edges or face boundaries at different orientations. The scene should also have a number of features or lights whose size or width approaches pixel size. Contrast may be improved for this demonstration with visibility set to a high value (20 or more miles). Roll inputs with position freeze should result in noticeable crawling along edges if effective anti-aliasing has not been applied. In addition, pitching up or down may cause small features to temporarily disappear between scanlines and give a blinking effect in the absence of adequate anti-aliasing.

3.7.2.9 **Distracting visual effects.** The image generator shall be designed so as to minimize the occurrence of distracting visual effects. Distracting visual effects shall be limited to ___(a)___ occurrences per one hour training period, and shall have a maximum duration of ___(b)___ seconds. Distracting visual effects include, but are not necessarily limited to, breakup, dropout, streaking, flashing, noise, and/or discontinuities of any part of the visual image; staircasing, quantization, scintillation, and any other spatial aliasing effects; abrupt changes in image detail; apparent movement of objects in the scene due to detail transitions; repetitive or periodic motion of the visual scene not computed in the host simulator flight system; mach bands or lines separating different colors on curved shaded surfaces, and abrupt shifts in color, texture or ambient brightness of a display window or subset.

REQUIREMENT RATIONALE (3.7.2.9)

The purpose of this paragraph is to attempt to define and restrict distracting visual effects in a quantitative manner. In the past, distracting visual effects have been one of the prime complaints lodged against image generators.

REQUIREMENT GUIDANCE

a. Specify the number of detectable distracting effects per hour (typically: 3-10).

b. Specify the maximum duration of each distracting effect (typically: 1-5).

REQUIREMENT LESSONS LEARNED

Distracting visual effects have been present in various degrees in all image generators. When present, they can provide negative training by drawing the student's attention away from the task at hand, or in some cases, by drawing his/her attention to the object of his/her search. In the past, the observance and acceptability of these effects was almost totally subjective. It is necessary to limit the number and duration of distracting visual effects to ensure delivery of a visual system that is usable for training.

4.7.2.9 **Distracting visual effects.** The ability of the image generator to provide continuous dynamic visual scenes over long duration training sessions with a minimum of distracting visual effects shall be verified.

VERIFICATION RATIONALE (4.7.2.9)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the ability of the image generator to provide imagery free of distracting visual effects.

VERIFICATION LESSONS LEARNED

Until the past several years, distracting visual effects were accepted as a necessary evil when dealing with computer image generators. Recently however, the technology has evolved to the point where it is reasonable to expect an image free (or practically free) of these effects. The demonstration consists of a period of subjective evaluation, at least several hours in length and covering all data base areas and flight profiles, which could be expected in a training situation. It may be desirable to video tape this demonstration so that results can be reviewed and verified later. It is likely that some effects will be noted which could be considered distracting. Some subjective interpretation is required to determine if such effects really affect training or if they are objectionable.

3.7.2.10 **Transport delay**. Visual system transport delay shall be defined as the interval from the time that ownship position and attitude data are available at the input of the image generator until the time that the display of the first field of the new image computed from that information is complete. Transport delay shall not exceed __________ milliseconds during normal processing.

REQUIREMENT RATIONALE (3.7.2.10)

The purpose of this paragraph is to insure that the image generator can compute the image and present it to the pilot rapidly and in the proper timeframe with respect to other simulator cues. Excessive transport delay or synchronization problems with motion can cause nausea and disorientation.

REQUIREMENT GUIDANCE

Specify the maximum allowable transport delay (typically: 100–150).

REQUIREMENT LESSONS LEARNED

Although 150 milliseconds is generally thought of as an upper limit, time variations of 100 milliseconds between aircraft and simulator performance are detectable by experienced pilots. Excessive transport delays can contribute to pilot induced oscillations. In some past systems, programmable transport delays were required to ensure that motion cues were presented prior to visual system cues, in order to avoid perceptual problems. Some systems may run at one speed for normal processing and extend the frame time (thus increasing the transport delay) for a short time under overload conditions. This is an acceptable approach as long as the extended frame time still falls within the overall transport delay specification. Finally, remember that there are cue correlation issues which must be considered when specifying transport delay.

4.7.2.10 **Transport delay**. The ability of the image generator to operate within the specified limits for transport delay shall be verified.

VERIFICATION RATIONALE (4.7.2.10)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the ability of the image generator to operate with the specified transport delay.

VERIFICATION LESSONS LEARNED

Transport delay can be difficult to measure. If possible, it is best to come to agreement with the contractor on an approach to this problem. A measurement system should be set up using strip charts, storage oscilloscope, or some other recording device

3.7.2.11 Update rate. The image generator shall compute a new scene from the visual environment using a new position and attitude update at least __________ times per second to assure a smooth dynamic response to all ownship and moving model manuevers.

REQUIREMENT RATIONALE (3.7.2.11)

In order to provide a smoothly moving picture with no objectionable stepping, the update rate needs to be specified.

REQUIREMENT GUIDANCE

Specify computed eyepoint update rate (typically: 30 or 60).

The requirement for 60 Hz operation can be a significant cost driver since in most systems twice the edge/surface processing capacity is available at 30 Hz.

REQUIREMENT LESSONS LEARNED

Failure to update the eyepoint at least 30 times per second will result in visible quantized movement (stepping) and flicker in the visual scene. Aircraft performance and training requirements should be carefully examined when this value is being chosen. For highly interactive tasks such as aerial refueling or air-to-air combat, an update rate of 60 is desirable.

4.7.2.11 Update rate. The ability of the image generator to use positional updates to compute imagery at the specified rate shall be verified.

VERIFICATION RATIONALE (4.7.2.11)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the visual system update rate.

VERIFICATION LESSONS LEARNED

3.7.2.12 **Dynamic response.** The image generator shall have the capability to provide imagery consistent with all velocities and accelerations within the performance envelope of the __________ aircraft, for all normal and emergency maneuvers. The image generator shall be capable of simulating the motion of other moving models with the proper translational and rotational rates. There shall be no visual system restrictions on the relative position and attitude between the ownship and any other static or moving object in the environment.

REQUIREMENT RATIONALE (3.7.2.12)

The purpose of this paragraph is to ensure that the image generator can react to eyepoint changes due to ownship dynamics with appropriate speed.

REQUIREMENT GUIDANCE

Specify the type of aircraft being simulated (ownship).

REQUIREMENT LESSONS LEARNED

4.7.2.12 **Dynamic response.** The ability of the image generator to properly react to all translational and rotational motion within the performance envelope of the ownship or specified moving models shall be verified.

VERIFICATION RATIONALE (4.7.2.12)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations should be the primary means of verifying the visual system dynamic response.

VERIFICATION LESSONS LEARNED

During demonstration of this capability, watch for any signs of scene breakup or quantized movement due to abrupt or high translational and/or rotational rates.

3.7.2.13 **Special effects.** The system shall simulate all special effects required to support the training tasks, including __________.

REQUIREMENT RATIONALE (3.7.2.13)

This paragraph specifies those visual effects which do not fall into categories specified elsewhere. The need to include these effects and the fidelity to which they are modelled are determined by analysis of training requirements.

REQUIREMENT GUIDANCE

Examine the list of sample special effects below. Include only those which are essential. A separate subparagraph is required to specify each special effect selected. Include the motion required for special effects if it is over the number of moving models displayed.

a. Weapons effects (missile launch, missile track, tracers, muzzle flash, etc).

b. Target hit/damage indication.

c. Smoke (to portray position or wind direction).

d. Illumination flares.

REQUIREMENT LESSONS LEARNED

While some of the special effects listed above are fairly common, the ability to simulate others may be limited, or may cause a considerable cost impact. Effects such as target hit indication and scoring may require complex aero models. The need for each effect must be weighed against cost and the fidelity with which it can be provided.

4.7.2.13 **Special effects.** The ability of the image generator to portray all specified special effects shall be verified.

VERIFICATION RATIONALE (4.7.2.13)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses shall be used in the review of design documentation to determine that the image generator has been designed to provide the required special effects. Demonstrations shall be used to observe and evaluate the effectiveness and adequacy of each specified effect.

VERIFICATION LESSONS LEARNED

As special effects are evaluated, be certain that the image generator can accommodate them concurrently with a realistic processing load. If the design is not carefully thought out, these effects can require image generator resources which make them incompatible with other requirements. For example, in a dense air-to-ground environment, numerous simultaneous weapons effects may be incompatible with target damage indication (smoke, etc). As always, do not get in the mode of stand-alone image generator tests which exercise only one requirement at a time.

3.7.2.14 Simulator compatibility. The image generator shall respond to all control commands from the host simulator, including initialization, repositioning, freeze, and ___________.

REQUIREMENT RATIONALE (3.7.2.14)

The purpose of this paragraph is to ensure that control of the visual system through the host simulator is possible.

REQUIREMENT GUIDANCE

Specify any other applicable control commands. For example, record-playback capability.

REQUIREMENT LESSONS LEARNED

4.7.2.14 Simulator compatibility. Visual system compatibility with the host simulator shall be verified.

VERIFICATION RATIONALE (4.7.2.14)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations shall be the primary means of verifying the simulator compatibility of the visual system. Analysis of the visual system interface documentation shall be combined with demonstrations of all appropriate controls.

VERIFICATION LESSONS LEARNED

Be sure to verify all interface capabilities, including such items as crash override, record-playback capability, etc.

3.7.2.15 **Positional range and accuracy.** The image generator shall generate an image that is positioned within the following tolerances when presented on the cockpit displays. The tolerances are with respect to the inputs provided to the image generator. Simulated angular position shall be within ___(a)___ degrees. Simulated altitude shall be within ___(b)___ inches. Simulated horizontal position shall be within ___(c)___ inches. Moving model position shall be presented within ___(d)___ inches horizontally and ___(e)___ inches vertically. Moving model attitude shall be within ___(f)___ degrees. In addition, the data base coordinate system and image generator processing shall be designed to support world-wide flight.

REQUIREMENT RATIONALE (3.7.2.15)

This requirement is necessary to ensure that the visual system portrays the visual environment and other moving models with the proper position and attitude relative to the ownship viewpoint, and that the system design supports training over the required range of operation.

REQUIREMENT GUIDANCE

Typical values are:

a. +/- 0.2 degrees.

b. +/- 0.5 inches.

c. +/- 1.0 inches.

d. +/- 1.0 inches.

e. +/- 0.5 inches.

f. +/- 0.2 degrees.

The requirement for world-wide flight may not be applicable for all systems, and in such cases should be deleted.

REQUIREMENT LESSONS LEARNED

Many past visual systems were designed to support training over relatively small areas, and thus used a flat-earth coordinate system which made no attempt to simulate the curvature of the earth. Since many users now require a mission rehearsal capability over large area data bases, and since the visual scene is expected to correlate with radar and other sensors, most systems will require a coordinate system which matches that of the other simulations.

4.7.2.15 **Positional range and accuracy.** The ability of the visual system to portray simulated ownship and moving model position within the specified tolerances shall be verified. In addition, the capability to represent ownship and moving model position in a world-wide coordinate system shall be verified.

VERIFICATION RATIONALE (4.7.2.15)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations shall be the primary means of verifying the simulated position properties of the visual system. Analyses shall determine the dynamic range and accuracy designed into the visual system. Demonstration using specific visually significant test cases shall also be used.

VERIFICATION LESSONS LEARNED

Some systems with world-wide flight capability use two separate coordinate systems to properly portray the polar areas. If this is the case, be certain to test areas where the two coordinate systems overlap to assure that a smooth transition capability has been provided.

3.7.2.16 **Crash detection and display.** The image generator shall detect collision of the ownship aircraft with ____(a)____. When a crash is detected, the image generator shall provide a crash indication to the air vehicle system. When the air vehicle system indicates a crash condition, the visual system shall rapidly ____(b)____.

REQUIREMENT RATIONALE (3.7.2.16)

This paragraph is used to specify the visual system crash detection capabilities, and to specify how the visual system will display a crash condition. If crash detection were not specified, the ownship aircraft could fly right through a terrain or cultural feature and the image generator would continue to provide a picture.

REQUIREMENT GUIDANCE

a. Specify the features in the visual environment which shall be "crash detectable". This can range from all features in the visual environment, including moving features, to a specified subset of features, as determined from the training requirements.

b. Specify how the visual system displays a crash (typically: "fade to a red color" or "fog the visual scene").

REQUIREMENT LESSONS LEARNED

Before specifying that crash detection be completely performed by the image generator, consider the option of doing some types of crash detection in other simulator subsystems. For example, the host computer can sometimes perform crash detection for moving objects, since it is computing their motion path.

4.7.2.16 **Crash detection and display.** The ability of the image generator to detect collision with any object in the visual environment, and to signal a crash to the host computer shall be verified. The ability of the image generator to display a crash condition on command from the host system shall be verified.

VERIFICATION RATIONALE (4.7.2.16)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and tests shall be the primary means of verifying the crash detection and display capability of the visual system.

VERIFICATION LESSONS LEARNED

Crash detection should be tested in several ways. First, the ownship should be positioned over the runway at an altitude less than the length of a wing. Then with the simulator in position freeze, the ownship should be rolled 90 degrees right. This should cause a crash condition from the right wing. The same maneuver can be repeated to the left. If the altitude is low enough, the aircraft can be pitched up, and the tail should cause a crash. The second category of test should by done dynamically, with a qualified pilot "flying" the system. Ownship collision should be tested at random with all types of visual environment features, including terrain and culture objects and moving models. In addition, special crash indicators, such as taxiing off the runway and landing too hard, should be tested as required.

3.7.3 **Visual environment.** A visual environment shall be developed and shall be processed by the image generator to produce the required real-time visual imagery. The visual environment shall be provided for __________. The environment shall also include libraries of models to support the required training tasks.

REQUIREMENT RATIONALE (3.7.3)

This paragraph defines the top-level data base requirements.

REQUIREMENT GUIDANCE

Fill in the blank with the geographic boundaries of the real-world area to be simulated, or specify the size and nature of a generic environment that will satisfy training needs.

REQUIREMENT LESSONS LEARNED

The decision must be made at this point whether to pursue a real-world data base or to employ a generic area which provides the required training features but is not representative of any real-world area. These two approaches could also be combined. There are several issues to be considered. Real-world data bases must be derived from a data source which ideally would be available in a standard format over large geographic areas. An example of such data is the Digital Landmass System (DLMS) produced by Defense Mapping Agency (DMA). Historically however, the use of this data has been fraught with problems, including numerous types of errors in the data, mismatches between adjacent areas of data, difficulties in merging other data with DMA data, and the relatively low resolution of the data. In addition, the process of transforming the data into a format compatible with a real-time image generator is a very complex, time-consuming problem, especially when it must be done for a data base area covering hundreds or thousands of square miles. Finally, we have experienced numerous subjective acceptance problems when aircrews are asked to evaluate a model of a real-world area, and are disappointed that their favorite details along the airfield approach are not portrayed to their satisfaction.

While it may be possible to devote less effort to come up with a generic environment tailored to a user's needs, the ability to provide navigational charts for the generic area and correlate this area with other sensors has not yet been demonstrated. Ultimately, this is a decision that requires very careful analysis of training requirements and intimate involvement of the user.

4.7.3 **Visual environment.** Analyses, demonstrations, and tests shall be performed to verify the ability of the visual environment (data base) to support the specified training tasks.

VERIFICATION RATIONALE (4.7.3)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses, demonstrations, and tests will be the primary means to verify the content and adequacy of the visual system data base. These general requirements will be addressed more specifically in the following subparagraphs.

VERIFICATION LESSONS LEARNED

A good way to partially fulfill this verification requirement is to set aside a period of time to "fly" the visual system around all parts of the visual data base to verify the presence of the required content and the absence of any anomalies.

3.7.3.1 **Visual data base libraries.** A set of libraries shall be provided to support data base generation and realtime display of the visual imagery. These libraries shall include specific models of important features, portrayed in multiple levels of detail where necessary. The following libraries shall be included.

REQUIREMENT RATIONALE (3.7.3.1)

This paragraph is a top-level requirement to develop libraries of models for commonly used features which may be referenced repeatedly in order to save data base development and enhancement effort.

REQUIREMENT GUIDANCE

Most current visual requirements include the capability to simulate other moving models or some type of generic features. This is often accomplished with the use of libraries. If no such requirement exists, this paragraph and its subparagraphs can be deleted.

REQUIREMENT LESSONS LEARNED

3.7.3.1.1 **Moving model library.** This library shall contain models for __________. The specific requirements for each of these models is defined as follows.

REQUIREMENT RATIONALE (3.7.3.1.1)

This paragraph is used to specify what moving models will be developed for later display in a real-time environment.

REQUIREMENT GUIDANCE

Fill in the blank with the required moving models, including friendly and aggressor aircraft and ground moving models. A separate subparagraph is to specify the details to be portrayed on each model.

REQUIREMENT LESSONS LEARNED

3.7.3.1.1.1 **Companion aircraft.** A model shall be provided to represent a companion ____(a)____ aircraft. Details to be portrayed shall include ____(b)____. Lights to be portrayed shall include ____(c)____.

REQUIREMENT RATIONALE (3.7.3.1.1.1)

This paragraph specifies the modelling of the companion aircraft.

REQUIREMENT GUIDANCE

a. Specify the type of aircraft to be modelled.

b. Include details of the aircraft which must be portrayed. For example, antennas, propeller arcs, or any other features that may normally be used to maintain a formation position could be specified. This normally requires user involvement.

c. List lights that need to be simulated, including rotating beacons, formation lights, etc.

REQUIREMENT LESSONS LEARNED

3.7.3.1.1.2 **Tanker aircraft.** A model shall be provided to portray the ____(a)____ tanker aircraft. Details to be portrayed shall include ____(b)____. Lights to be portrayed shall include ____(c)____.

REQUIREMENT RATIONALE (3.7.3.1.1.2)

This paragraph defines the tanker models to be provided, along with the required details.

REQUIREMENT GUIDANCE

a. Fill in the types of tanker models to be provided (typically, KC-10 and/or KC-135).

b. Fill in the tanker details to be modelled. These typically include the center line belly stripe; main landing gear doors on the fuselage; outline of wing flaps, ailerons, elevators, and rudder; boom and ruddervators; tanker UHF antenna; white refueling reference stripe; boom operator's window; drains, stains, oil markings, and other textural cues; rivets (shown as lines); and surface features such as bands, stiffeners, etc.

c. Fill in the tanker lights to be modelled. These typically include director lights, rotating beacons, navigation lights, underbody illumination lights, nacelle illumination lights, underwing illumination lights, and boom nozzle lights.

REQUIREMENT LESSONS LEARNED

3.7.3.1.2 **Mission model library.** This library shall be developed to support the portrayal of ___(a)___ to be used in a particular training mission or session. The features in this library may be static, or they may have associated dynamic effects, including missile launch, artillery fire, or portrayal of damage as a result of ownship attack. This library shall contain at least ___(b)___ models.

REQUIREMENT RATIONALE (3.7.3.1.2)

This paragraph defines the requirement to provide a library of models which can be inserted into the visual environment during a mission build process to tailor threats and targets to training needs.

REQUIREMENT GUIDANCE

a. Fill in the blank with the types of models to be provided.

b. Specify a minimum number of models, depending on mission requirements.

REQUIREMENT LESSONS LEARNED

3.7.3.1.3 **General model library.** This library shall be developed to support the portrayal of required three-dimensional features. Models shall be developed for features important to the training tasks and stored in the library for automated or manual insertion into the visual environment at proper or desired locations.

REQUIREMENT RATIONALE (3.7.3.1.3)

This paragraph requires the development of a library of general purpose models to represent standard cultural features in the visual environment. Use of such a library can reduce environment generation effort and storage. Include the types of features necessary.

REQUIREMENT GUIDANCE

This paragraph is required only when a general model library supports the documented training requirements.

REQUIREMENT LESSONS LEARNED

3.7.3.1.4 **Airfield model library.** Models shall be provided for ___(a)___ ___(b)___ airfields. These airfields shall be placed ___(c)___. Each airfield model shall include a high-fidelity portrayal of the immediate airfield area, along with the surrounding terrain and culture within a ___(d)___ mile radius. Seasonal effects shall be modelled, including ___(e)___. The airfields shall contain the following details, as appropriate.

REQUIREMENT RATIONALE (3.7.3.1.4)

This paragraph specifies the top-level requirements for the development of airfield areas, which may be real-world or generic.

REQUIREMENT GUIDANCE

a. Specify the number of airfields to be modelled in the visual environment.

b. Specify real-world or generic airfields.

c. Specify the locations for real-world airfields, or the method of placement and orientation for generic airfields.

d. Specify the radius of the surrounding area to be modelled (typically, 15-25 miles).

e. Specify seasonal effects, for example, a snow covered runway. If no seasonal effects are necessary, delete the requirement.

REQUIREMENT LESSONS LEARNED

3.7.3.1.4.1 **Airfield area structures and markings.** The airfield shall contain detailed models for the runways, taxiways, and ramps, including texture and surface markings. Airbase buildings, including control tower and hangers, shall be provided. The area surrounding the airfield shall contain appropriate terrain and landmarks, including towns, roads, bridges, trees, lakes, rivers, etc. Texture shall be employed in the airfield areas and especially along the approach path to provide the required motion cues. Surface markings shall be provided, including ___________.

REQUIREMENT RATIONALE (3.7.3.1.4.1)

This paragraph states the requirements for the content of the airfield areas.

REQUIREMENT GUIDANCE

List the surface markings appropriate to the airfields being modelled. These typically include threshold, centerline, landing zone, and touchdown zone markings; edge/side-stripe markings; runway midpoint and overrun or relocated threshold markings; stabilized shouldermarkings, runway remaining markers; runway identifier numerals and letters, and runway tire rubber buildup.

Texture is an expensive option and should not be required if it is not needed.

REQUIREMENT LESSONS LEARNED

3.7.3.1.4.2 **Airfield lights.** Airfield lights shall be modelled as appropriate, and shall include special purpose lights for the rotating beacon, VASI lights, and approach strobe lights. Lighting effects shall be provided for runway remaining markers. Runway definition lights shall include __________. In addition, general cultural lighting shall be provided in the area surrounding the airfield for night cues.

REQUIREMENT RATIONALE (3.7.3.1.4.2)

The modelling of lights in the airfield areas is needed for realism.

REQUIREMENT GUIDANCE

List all appropriate runway definition lighting. This typically includes threshold, approach, touchdown zone, and edge lights; centerline and overrun lights; runway end identification lights (REILS); taxiway and ramp lighting; and runway remaining marker lighting effects.

REQUIREMENT LESSONS LEARNED

4.7.3.1 **Visual system data base libraries.** The required content of the specified visual data base libraries shall be verified.

VERIFICATION RATIONALE (4.7.3.1)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations shall be the primary means of verifying the visual data base libraries. Design review documentation shall be reviewed and used as a guide to verify the content of each library through extensive verification using the visual system.

VERIFICATION LESSONS LEARNED

The specified content of each library should be verified. A test data base should be created to include at least one occurrence of each model from each of the libraries. Each model then must be examined to see that it exists in the required levels of detail and has the required content in terms of objects, surfaces and lights.

3.7.3.2 **Low-altitude data base.** The low altitude data base shall be developed for ____(a)____ using ____(b)____.

REQUIREMENT RATIONALE (3.7.3.2)

This paragraph defines the area of coverage requirement for the low altitude environment.

REQUIREMENT GUIDANCE

a. List the geographic area of coverage for a real-world low altitude data base, or an area (size) for a generic area.

b. List the required source data (for example DMA digital data) for a real-world data base. Leave blank for a generic area.

REQUIREMENT LESSONS LEARNED

4.7.3.2 **Low altitude data base.** The character and area of coverage for the low altitude data base shall be verified.

VERIFICATION RATIONALE (4.7.3.2)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis of design documentation shall be used to determine that the required data base area has been produced, and that the specified source material has been used. Demonstrations shall be used to verify the area of coverage, and to correlate source data to the delivered data base.

VERIFICATION LESSONS LEARNED

A good way to test area of coverage is to manually position the simulator or visual system to randomly selected locations to see that a useable data base is present as required. Continuous flight should be used over randomly selected routes to verify the continuity of the data base. Demonstration of correlation of the data base content to the source material (if real-world) should also be provided. If a generic data base was required, it may be necessary to verify the adequacy of generic navigational maps/charts to use with the data base.

3.7.3.2.1 **Terrain model.** The terrain shall be modelled in multiple levels of detail as appropriate to the training task. The terrain model shall be designed and constructed such that no distracting visual effects occur in the real-time imagery at the level-of-detail transition boundaries. There shall be no perceptible regular or artificial visible effects due to the structure of the terrain model. As a goal, the terrain model shall be adaptable to the terrain roughness, such that edge/polygon density is higher in areas of rough terrain and lower in areas of flat terrain.

REQUIREMENT RATIONALE (3.7.3.2.1)

This paragraph states the basic requirements for the terrain model.

REQUIREMENT GUIDANCE

It may be advantageous to specify terrain accuracy by range, and leave the determination of the number of levels of detail to the contractor. Otherwise, there is the risk of specifying densities which exceed the data base or image generator capacities.

REQUIREMENT LESSONS LEARNED

4.7.3.2.1 **Terrain model.** The terrain model shall be verified with respect to requirements for smooth and continuous high fidelity portrayal of terrain from the near scene to the far scene.

VERIFICATION RATIONALE (4.7.3.2.1)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis and demonstrations shall be used to verify that there is no regular structure in the terrain model, that detail emerges smoothly during "flight", and that the portrayal is adequate for rough terrain as well as for smooth and rolling terrain.

VERIFICATION LESSONS LEARNED

3.7.3.2.2 **Culture features (data base).** The data base shall portray all culture features required to support the training tasks. Culture features shall be portrayed as two-dimensional or as three-dimensional objects in the data base. ___(a)___ shall be portrayed in either two or three dimensions. ___(b)___ shall be portrayed in three dimensions up to a density of at least ___(c)___ features per square nautical miles. Culture features shall be modelled in multiple levels of detail to allow for a recognizable presentation and display at appropriate ranges without overloading the image generator.

REQUIREMENT RATIONALE (3.7.3.2.2)

This paragraph specifies the fidelity of portrayal for cultural features.

REQUIREMENT GUIDANCE

a. Specify features which can be portrayed in either two or three dimensions (typically grassland, forests in some cases, lakes, etc).

b. Specify features which must be portrayed in three dimensions, including towers, smokestacks, and any other features which provide important visual height cues.

c. Specify the maximum density required for specific mission applications.

REQUIREMENT LESSONS LEARNED

Do not overspecify the features which require three-dimensional portrayal. For most real-time processing approaches, the problem of creating a three-dimensional model for an irregular three-dimensional shape is difficult, if not impossible, to do correctly. The ability to display regularly shaped three-dimensional features may also be limited, but the specification as written here is an attempt to scope the contractor's modelling effort.

4.7.3.2.2 **Culture features--data base.** The culture content of the data base shall be verified.

VERIFICATION RATIONALE (4.7.3.2.2)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Analysis of the data base generation design documentation shall be examined to determine the data base content with respect to culture feature representation. Demonstrations shall be used to determine that specified features have been portrayed with the proper fidelity.

VERIFICATION LESSONS LEARNED

Random inspection of data base areas using the image generator or an off-line scene generation capability (if available) should be done to determine that the specified features or classes of features are present and are portrayed adequately for training purposes. Keep in mind that features required for their training value should have the highest probability of surviving the data base generation process. Features low in training value may not be present in all cases.

3.7.3.2.3 **Texture (data base).** All terrain surfaces shall be portrayed as textured in the low altitude data base. In addition, all mission-relevant culture features shall be portrayed as textured, including ____________.

REQUIREMENT RATIONALE (3.7.3.2.3)

The purpose of this paragraph is to ensure that texture attributes are assigned to appropriate data base features, so that texture can be portrayed in real-time.

REQUIREMENT GUIDANCE

Specify the culture feature categories which should be portrayed as textured. These include, for example, forests, urban areas, lakes, industrial areas, etc.

REQUIREMENT LESSONS LEARNED

4.7.3.2.3 Texture--data base. The presence of texture descriptors for all specified terrain and culture objects in the data base shall be verified.

VERIFICATION RATIONALE (4.7.3.2.3)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis of design documentation shall establish that the data base can accommodate required texture descriptors, and that they are in fact present in the delivered data base. Demonstrations shall be used to verify that the texture information is present as specified and that it contributes positively to the visual imagery.

VERIFICATION LESSONS LEARNED

3.7.3.2.4 **Lights (data base).** Lights shall be placed in the low-altitude data base to simulate traffic, residential areas, industrial areas, etc, in order to support appropriate dusk and night training conditions. General cultural lights shall be associated with appropriate cultural features. Cultural features which are considered vertical obstructions shall have associated obstruction lights.

REQUIREMENT RATIONALE (3.7.3.2.4)

The purpose of this paragraph is to ensure that appropriate and necessary lights are included in the data base.

REQUIREMENT GUIDANCE

This specification is needed for any systems which have a low altitude night training requirement.

REQUIREMENT LESSONS LEARNED

4.7.3.2.4 **Lights--data base.** The presence of specified obstruction, traffic, and general cultural lights in the data base shall be verified.

VERIFICATION RATIONALE (4.7.3.2.4)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analysis of data base generation system and data base design documentation should be used to verify the capability to insert and portray specified light types in the low altitude data base. Demonstrations should be used to show that all light types exist, and that they are portrayed with appropriate characteristics.

VERIFICATION LESSONS LEARNED

3.7.3.2.5 **Accuracy.** For real-world environments, the terrain model shall portray the terrain to within ___(a)___ of the actual source data elevations at a visual range of ___(b)___. Prominent terrain features, including peaks, ridges, and valleys, shall be preserved. Cultural features shall be portrayed within ___(c)___ of their source data locations at a visual range of ___(d)___.

REQUIREMENT RATIONALE (3.7.3.2.5)

The purpose of this paragraph is to ensure that real-world data bases provide an accurate portrayal of the environment. Use this paragraph only for real-world data bases.

REQUIREMENT GUIDANCE

a. Specify the maximum allowable terrain model deviation from the source data elevation points. This should be specified for each level of detail, and is dependent upon training requirements. Typical range is 30-2,000 feet.

b. Specify the visual range associated with ___(a)___. The ranges would normally match visual system level of detail ranges.

c. Specify maximum allowable deviation for culture feature position. This depends on training requirements.

d. Specify the visual range associated with ___(c)___.

REQUIREMENT LESSONS LEARNED

4.7.3.2.5 Accuracy. The ability of the data base to support the specified accuracy requirements shall be verified.

VERIFICATION RATIONALE (4.7.3.2.5)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses should be used to determine the ability of the data base and the data base generation system to support the accuracy requirement. Analysis may also be used to verify several test terrain elevation points and cultural features to show that they are represented in the delivered data base to the required accuracy. Demonstrations using the image generator may also be used to verify positional accuracy.

VERIFICATION LESSONS LEARNED

3.7.3.3 **Data base generation/modification.** The capability to generate new data base areas and update existing areas shall be provided. Update capabilities shall include the ability to create, add, delete, move, or modify library models or any data base features.

REQUIREMENT RATIONALE (3.7.3.3)

This paragraph is to ensure that the user has the capability to create new data base areas and update/revise existing areas, if this capability is required.

REQUIREMENT GUIDANCE

This requirement is used only when the user needs the capability to add to or change the delivered data base.

REQUIREMENT LESSONS LEARNED

Expand this paragraph to explain specifically what generation or modification features are required. Remember that the user will have to provide for a staff of skilled personnel to use this capability. Also, specify where the capability is to be provided.

4.7.3.3 **Data base generation/modification.** The ability to generate new visual data base areas and update existing areas, as required, shall be verified.

VERIFICATION RATIONALE (4.7.3.3)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Engineering analyses and demonstrations shall be the primary means of verifying the data base generation/modification capability.

VERIFICATION LESSONS LEARNED

To demonstrate the data base generation capability, a new data base area of a mutually agreeable size should be generated. The area should be chosen by the Air Force at the time of the demonstration. Be sure to have each required data base modification capability demonstrated with each applicable type of feature.

3.7.4 **Visual display system.** A visual display system shall be provided. It shall be mounted on the simulator cockpit/motion platform with a display structure that is capable of withstanding all g-forces within the range of the motion system without damage to any visual system components. Neither the display components nor any support or mounting structure shall penetrate or interfere with the full-scale accurate representations of the cockpit, windscreens, structural framework, glareshields, panels, or head-up display.

REQUIREMENT RATIONALE (3.7.4)

This paragraph provides the top-level requirement for the visual display subsystem.

REQUIREMENT GUIDANCE

Include any unique top-level display requirements such as quantity of displays, type of display restrictions, etc. This requirement simply establishes the need for a display system, and should not address any specific parameters. While the interference of display components with cockpit structure, windshield, glareshield, etc. should be limited as much as possible, it may at times require a compromise to secure the best training value. In such cases, the issue should be addressed at a mock-up review, and should be resolved as a function of all training requirements.

REQUIREMENT LESSONS LEARNED

4.7.4 **Visual display system.** Tests shall be conducted to verify the performance of the visual display system.

VERIFICATION RATIONALE (4.7.4)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

All aspects of the visual display system must be tested. This should usually be done in an integrated mode with an image generator. All test patterns should be generated by the image generator. The display subsystem should be set up once and all tests performed without readjustment. Measurements should be made from the pilot's eyepoint. The required verification activity will be discussed in more detail in the following sections.

VERIFICATION LESSONS LEARNED

3.7.4.1 **Field of view.** The display system shall present a minimum instantaneous field of view of ___(a)___. Instantaneous field of view is that seen from the design eyepoint. The total field of view shall be no less than ___(b)___. Total field of view includes any area that can be seen by moving the eyepoint around within the exit pupil. The horizontal and vertical fields of view shall be optimized for the nominal eyepoint. The loss of display field-of-view due to any gaps between display windows shall be minimized, and shall be limited to a minimum instantaneous gap angle of ___(c)___ or less. The position of the horizontal and vertical fields of view shall be adjusted to cover the areas of interest shown in figure 1.

REQUIREMENT RATIONALE (3.7.4.1)

The display field of view requirement is probably the single most important parameter affecting simulator visual system design. The aircraft being simulated, the positions of crew members using the display, and the tasks being trained must all be considered to determine the required field of view. In addition to the field of view, it is also usually necessary to specify the placement or positioning of the field of view to provide optimum training.

REQUIREMENT GUIDANCE

a. Fill in the blank with the minimum instantaneous field of view. A "typical" maximum instantaneous field of view for a single display channel may be on the order of 58 X 36 degrees.

b. Fill in the blank with the minimum total field of view for the window. This number can be the same as ___(a)___ if the entire window is visible.

c. A typical allowable gap angle is 5 degrees. This will vary considerably from system to system. For example, mirror/beamsplitters can be butted edgewise together to achieve extremely narrow gap angles. Mosaicked pancake windows, dome displays, and some multiple-projector rear or front projection displays have little or no gap angle. Specify the largest gap angle that can be tolerated so that the greatest number of display types can be proposed.

REQUIREMENT LESSONS LEARNED

It may be helpful to include a diagram to graphically show the required field of view and its placement. Figure 1 is provided as an example in which the aircraft field of view and the required visual system field of view are overlaid on the same plot.

Do not overspecify the field of view. For example, in a recent refueling simulator procurement, the user imposed an unrealistic horizontal field of view requirement of 90 degrees. In that particular case, all the training value was contained in 75 degrees. Most of the content was contained in the 60-65 degrees, and could be presented in a single window display at reasonable resolution and cost. A similar refueling trainer, the B-52 aerial refueling part-task trainer, has been successfully using less than 50 degrees horizontal field of view. It does not make sense to double or triple the cost and complexity of the visual system to see wingtips when 75 percent of the wing is already visible. Field of view also significantly affects brightness and resolution of the display on a per-channel basis. Both of these parameters fall off approximately inversely proportionally to the area of the field of view.

The placement of the field of view with respect to the cockpit is very important. For example, a typical field of view might be 36 degrees high and 58 degrees wide. A simulator which is used primarily for take-off and landing training would need the vertical field of view offset downward to give a better view of the runway and airfield (perhaps +10 degrees and -26 degrees). On the other hand, a refueling trainer needs a greater upward field of view (such as +25 degrees and -15 degrees).

4.7.4.1 **Field of view.** A theodolite shall be set up at the pilot's eyepoint. If possible, total field of view measurements shall be made without cockpit obstruction. The theodolite may be moved within the specified head motion envelope; however, special precautions must be observed to maintain alignment. All other measurements shall be made from the pilot's eyepoint without moving the theodolite. For each of the specified angular requirements, the measured angle shall meet or exceed the specified requirement.

Where field of view has been specified in terms of a field of view plot, a sufficient number of points shall be measured to assure compliance with the specification.

VERIFICATION RATIONALE (4.7.4.1)

Field of view is an important display parameter which should be objectively tested to assure compliance.

VERIFICATION GUIDANCE

All instantaneous fields of view measurements should be made with the center of the theodolite located at the design eyepoint. Total field of view measurements should allow for head movement, and include the field of view hidden by windows, optical barriers, etc.

VERIFICATION LESSONS LEARNED

It is usually difficult to make field of view measurements with the pilot seat in place. If convenient, the seat should be removed. Location of the exact pilot eyepoint is critical to achieving an accurate measurement in many types of displays. Reference points on the cockpit or display can be used to align the theodolite. Three points are usually sufficient; one on the floor, one near the front of the display, and one near the side are often the best choices.

The theodolite should be chosen to have the ability to focus at short distances (3 feet is good). This capability aids in setting up alignment points. Many transits which are typically used for surveying are not easy to use for field of view measurements due to their large size or long focus distance capability.

3.7.4.2 **Brightness.** The minimum highlight brightness of the maximum intensity area of the window test pattern shall be ___(a)___ foot-lamberts. Brightness uniformity shall be within ± ___(b)___ percent of the center of the screen highlight brightness. The brightness variation from any display edge to an adjacent display edge shall not vary more than ___(c)___ percent.

REQUIREMENT RATIONALE (3.7.4.2)

It is important to try to achieve the highest brightness available because the eye can see better detail for any given resolution and contrast ratio at a higher brightness.

REQUIREMENT GUIDANCE

a. Although 6 foot-Lamberts (fL) is a good number to shoot for, it is often unattainable on commercially available systems. For example, a typical highlight brightness in a dome system may only be 0.5 fL. The background raster on a pancake window typically has a peak highlight of 1.5 to 2.0 fL. Each display system has inherent limitations imposed primarily by physics and the state of the art.

b. Fill in the blank with a percentage. The worst-case specification should not exceed ±50 percent. Most visual displays have an inherent brightness falloff away from the center. Often electronic corrections are made in an attempt to make a uniform picture. A ±20 percent brightness uniformity is very good.

c. Fill in the blank with a percentage. Today's state-of-the-art and practical considerations will support a ±20 percent variation. The center brightness of each display is usually adjustable, and matching can be done with a photometer. The worst-case specification should not exceed ±50 percent. Edge brightness mismatch is the easiest for the eye to detect because the brightness changes occur abruptly.

REQUIREMENT LESSONS LEARNED

The eye's logarithmic brightness response permits substantial brightness variation without becoming objectionable. A 2:1 brightness variation across an area is required to ensure detection. Edge matching becomes easier to detect because the brightness change occurs sharply. In some cases it may be better to allow center-to-center window tolerances to deteriorate somewhat if an improvement in edge-to-edge matching could be achieved. This is an important consideration in an air-to-air combat simulator (for example) where the pilot may track an aircraft traveling from one window to another.

Absolute peak brightness is easy to over-specify. Brightness claims may at times be exaggerated, and these exaggerations tend to find their way into specifications. It is better to specify a somewhat smaller peak brightness, and have a number which more accurately represents the day-to-day operating level of the system.

4.7.4.2 **Brightness.** Brightness shall be measured by setting up a calibrated precision spot photometer, such as the Pritchard photometer (Photo Research model 1980 or equivalent) at the pilot's eye position. A uniform flat white field surrounding a 9 or 10 step linear grey scale chart shall be displayed. The uniform field should cover the entire field of view. The photometer shall be used to measure the brightness of the peak white in the center, and of the flat field of random locations throughout the field of view.

When measuring area brightness, an aperture which covers at least 10 raster lines shall be used. The center brightness shall meet or exceed the specified brightness. The worst case high and low brightness readings shall be used to determine brightness uniformity. A similar procedure shall be used to determine the performance parameters for multiple window displays.

VERIFICATION RATIONALE (4.7.4.2)

There is no way to subjectively evaluate picture brightness or uniformity. An objective test is required to assure compliance.

VERIFICATION GUIDANCE

When selecting the reference brightness, the center of the display should be used. This may or may not be 0 degrees azimuth and elevation. For brightness uniformity measurements, all numbers should be referenced to the center brightness. For example, if the center brightness is 5.0 fL, and the worse case variation is 3.0 fL, the brightness variation is (5.0 - 3.0)/5.0 X 100 percent, or 40 percent. Usually the number of brightness points which are measured can be minimized. The display can be examined by eye and the bright and dim display areas measured. Typically, the corners are the dimmest areas.

VERIFICATION LESSONS LEARNED

When setting up the photometer, the center of the lens should be set up at the eyepoint. The tripod should be set up so that the pivot point rotates around the center of the lens. Although an ideal position can seldom be achieved, a good compromise can be achieved without significantly affecting measurement results.

Do not measure brightness at the very edge of the display. Usually 3 to 5 degrees is a close as measurements should be made to the edge.

3.7.4.3 **Resolution/modulation transfer function.** When viewed from the display nominal eyepoint, the horizontal and vertical resolution shall meet or exceed the data listed in table VI:

TABLE VI. Display image resolution.

Resolution	Modulation near the center of each display within a circle equal to picture height	Modulation outside a circle equal to picture height
(a)	(b)	(c)
(a)	(b)	(c)
(a)	(b)	(c)
(a)	(b)	(c)

REQUIREMENT RATIONALE (3.7.4.3)

The resolution and modulation transfer function determines to a large extent how much detail is visible and how sharp the picture appears. Resolution is a primary specification and will often drive the selection of both the display system and the image generator.

REQUIREMENT GUIDANCE

a, b, and c. The best way to ensure that adequate resolution and modulation transfer is obtained is to specify a matrix of resolutions/modulations. The approach shown in the specification is typical of the format; however, the actual numbers will vary widely between systems. Resolution will typically degrade as a function of angle off-axis. Specify a resolution near the center and near the corner to define the system. For example:

Resolution element size	Modulation near the center of each display within a circle equal to picture height	Five degrees from any corner of each display and outside equal to picture height
2 arc min	10%	---
5 arc min	15%	10%
10 arc min	25%	20%
20 arc min	75%	60%

REQUIREMENT LESSONS LEARNED

Specification of limiting resolution is not sufficient. Limiting resolution is a number which is often given in manufacturers' specifications and usually has little meaning. Limiting resolution is obtained subjectively by looking at a resolution test chart on the display. Typically, limiting resolution represents an element size which has 5 percent to 10 percent modulation. By specifying resolution and modulation and measuring it objectively, the limiting resolution problem is eliminated.

Specification of the modulation transfer function more accurately defines the system's resolution capabilities. The greater the area under the MTF curve, the sharper and clearer the picture. In figure 2a, systems 1 and 2 have the same limiting resolution; however, system 1 will have the best picture because of its significantly higher modulation for the lower and middle frequency components of the picture.

Resolution and modulation should be specified as system parameters. It is not enough to specify only the display or only the image generator. The system MTF curve is approximately the product of the MTF curves of each stage of the system. For example, figure 2b shows the system MTF for image generator A, video distribution B, display C, and optics D. Note that in order to obtain a limiting resolution at 5 percent modulation, each element must have a modulation significantly better than 5 percent.

Resolution and modulation requirements can be roughly determined. First, pick the smallest item that needs to be detected, and determine its detection range. For example, a UHF antenna on a refueling tanker needs to be detected at 50 feet. Compute the resolution element size using geometry and attach a realistic modulation. 10 percent modulation is barely perceptible, 25 percent modulation is easy to see, 50 percent modulation and better is sharp and clear. Modulations are always specified for white on black or black on white. If a dark grey object needs to be detected on a light grey background, the modulation specification at the object's resolution element size needs to be exaggerated.

Some visual systems may include an area of interest (AOI). This is a special high resolution target area which is somehow inset into a larger, lower resolution background area. An area of interest may be fixed in position, or it may move around within the field of view as a function of target position, head movement, or even eye movement. Due to its special high resolution characteristics, the AOI resolution must be specified separately.

4.7.4.3 Resolution/modulation transfer function. For systems using camera model or pure optical systems, resolution test charts having horizontal and vertical bar charts corresponding to the specified resolutions shall be substituted for the model. For computer generated image systems, the resolution pattern shall be computer generated.

Resolution and MTF shall be measured using a scanning slit photometer or similar technique except for display systems using shadow mask CRTs. A scanning slit photometer (Photo Research Model 1980B with slit and angle scanning attachment or equivalent) shall be set up at the pilot's eye position. The slit aperture shall have a width no greater than 1/2 the smallest resolution element size to be measured. A black and white reference test pattern shall be set up or displayed in the specified location within the field of view. The difference in brightness between the black and white areas shall represent 100% modulation for that test area within the field of view. A horizontal resolution test chart of the specified resolution shall be substituted for the reference test pattern. The slit shall be set up to scan perpendicular to the resolution test pattern. The difference between the brightness of the black and white resolution elements expressed as a percentage of the 100% reference is the modulation. The modulations so determined must equal or exceed those specified. For vertical resolutions, the scanning slit photometer and test patterns must be rotated 90 degrees.

VERIFICATION RATIONALE (4.7.4.3)

An objective test is required to assure compliance with the resolution specification.

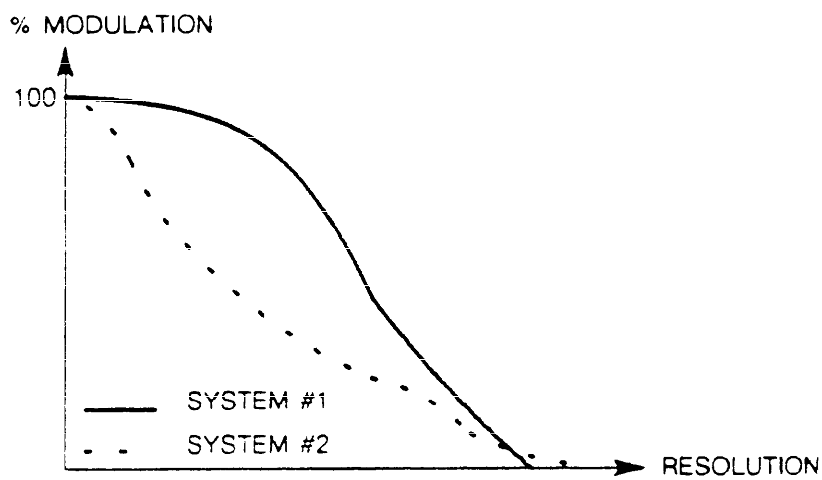
VERIFICATION GUIDANCE

Other methods may be proposed by the contractor to assure compliance with the resolution specification. The scanning slit photometer provides an accurate way to test the display in most cases. Any proposed test must be repeatable and reliably indicate the modulation that the pilot sees.

VERIFICATION LESSONS LEARNED

When using the scanning slit photometer on collimated systems such as WIDE or DUOVIEW, beware of collimation errors interfering with the measurement. Unfortunately, the entrance pupil on the photometer is significantly wider than the eye's; collimation errors will degrade the measured resolution. Since absolute brightness measurements are not required when measuring MTF, it is possible to make a small aperture (1/4 inch to 1/2 inch in diameter) and place it over the photometer's lens. This minimizes the collimation errors and will permit accurate MTF measurements to be made on systems with large collimation errors.

It may or may not be practical to use the scanning slit photometer with a shadow mask CRT because the tiny triad dots cause interference patterns with the smallest resolution test patterns. The height of the slit needs to cover several lines of the raster in order to minimize these errors.



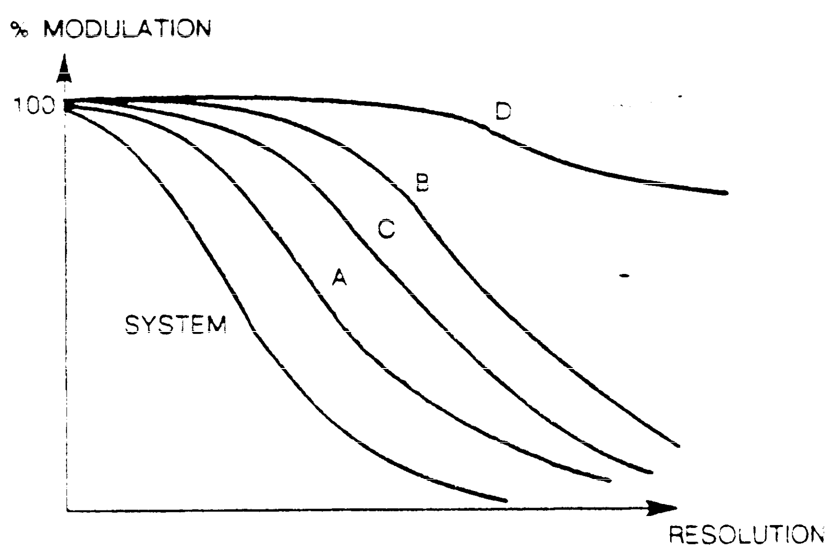


FIGURE 2. System modulation transfer function (MTF).

3.7.4.4 Contrast ratio. Contrast shall be defined as:

C = (W - B) / B

where:

C = contrast

W = peak white brightness (measured in fL)

B = black brightness (measured in fL)

Across the entire field of view of each display, contrast shall be no less than ___(a)___ for angular separation of ___(b)___. Contrast shall be maintained in each display individually when all other displays are displaying a typical daylight scene.

REQUIREMENT RATIONALE (3.7.4.4)

The contrast ratio is an important display parameter which describes the ratio of the brightest white to the blackest black. It works in conjunction with brightness and resolution characteristics to determine the quality of the displayed image.

REQUIREMENT GUIDANCE

a. Fill in the blank with a contrast ratio of 30:1 where practical. A contrast ratio of 30:1 combined with decent resolution and brightness characteristics will yield an excellent displayed image. Beware that many visual systems will not support such a high contrast. A good working knowledge of contrast ratios of candidate systems of acceptable quality will be helpful.

b. Unless otherwise determined, use an angular separation of 2 degrees.

REQUIREMENT LESSONS LEARNED

There are several common definitions of contrast ratio, and different results will be obtained using different definitions. Let W be the peak white brightness under test conditions, let B be the minimum black brightness, and let C represent contrast. Assume for example that W = 6 fL and B = 0.5 fL. Optics companies would compute C = W/B, with a result of 12:1. Terminal manufacturers would compute C = (W+B)/B, with a result of 13:1. The Air Force would compute C = (W-B)/B, with a result of 11:1. The standard Air Force definition accurately describes system performance because it degrades contrast for poor black level. A good dark black level enables light details to be distinguished and provides a sharper looking display.

The test conditions are extremely critical for contrast. For example, contrast can be significantly affected by simply changing the size of the target window used. See the verification section for a description of this problem.

On systems where more than one display unit is used or on wide field-of-view visual systems, make sure contrast is specified for normal daylight operation. All the displays, except the one under test, should be operating at typical daylight scene levels. Reflections, halations, and diffused light can significantly change a contrast measurement. Conditions should be specified in the requirements portion of the specification.

4.7.4.4 **Contrast.** A standard window pattern consisting of a white block inside a black background shall be displayed. The white area shall be approximately half the dimensions of the background (i.e., for a 36 degree by 48 degree field-of-view, the white block should be about 18 degrees by 25 degrees). A calibrated Pritchard photometer (Photo Research model 1980 or equivalent) with a 15-minute aperture shall be placed at the pilot's eyepoint. The white area and black area shall both be measured in ft-lamberts at points approximately 1/2 the specified separation distance from the white/black transition. With this data recorded, contrast (C) shall be:

C = (white (fL) - black (fL))/black (fL)

VERIFICATION RATIONALE (4.7.4.4)

Verification of contrast is required to assure compliance.

VERIFICATION GUIDANCE

The test conditions are extremely critical for contrast. Contrast can be significantly affected by changing the size of the target window used. Light from the test pattern can bounce off of reflective surfaces and degrade the contrast ratio. Typically the larger the test pattern, the poorer the measured contrast. When testing, ensure that the test pattern size is as stated in the requirement.

The white test pattern brightness should be set up to be the same as the peak highlight brightness of the system. System brightness or contrast adjustments should not be readjusted for this test.

VERIFICATION LESSONS LEARNED

A problem may be encountered when measuring contrast near a black-to-white transition with a photometer. The photometer's measurement area is in the center of the field of view as indicated by a dark spot. Ideally, the photometer measures only this area and ignores the area outside the spot. Internal reflections within the photometer's optics may cause a slightly high reading of the black area if the white area is also within the photometer's total field-of-view. The higher the visual system's contrast, the more likely it is that this effect will become noticeable. Judgment must be exercised when making the black brightness measurement. As the specification requires, it is necessary to measure the contrast near a black-to-white transition to include effects of the display's optics. On the other hand, the measurement should not be degraded by the measuring device.

Always measure contrast from the pilot's eyepoint. Measurement of CRT or display projector contrast is not an accurate measurement of the visual display contrast

3.7.4.5 **Collimation quality**. For a collimated display, the image presented to the nominal eyepoint shall be displayed at or near infinity. Collimation errors, as measured within the exit pupil, shall not exceed ___(a)___ diopters divergent from the display or ___(b)___ diopters convergent from the display. Dipvergence shall not exceed ___(c)___ milliradians. Rays converging toward the nominal eyepoint shall be minimized at the expense of rays diverging toward the nominal eyepoint. For real image displays such as domes, the minimum distance from the pilot's eyepoint to the image surface shall be greater than or equal to ___(d)___ feet.

REQUIREMENT RATIONALE (3.7.4.5)

Collimation quality is a measure of the apparent range of the display. A perfectly collimated display would present the scene at infinity. It is impossible to achieve perfect collimation. Poor collimation can result in pilot fatigue, headaches, or nausea. It is important to specify collimation in order to avoid these effects. Collimation varies through the display, so it must be specified and measured at various points.

REQUIREMENT GUIDANCE

a. A typical divergence display requirement is −0.1 diopters.

b. A display convergence of +0.02 diopters is usually acceptable.

c. Only a small amount of dipvergence can be tolerated by the eye. A typical display specification is 5 milliradians.

d. Twelve (12) feet is a typical minimum eye relief for a real image display, although a dome radius of 10 feet has been used successfully.

The last sentence of the requirement is applicable only to real image displays.

REQUIREMENT LESSONS LEARNED

Definitions for collimation are often confused because different literature presents the information from different points of view. The Air Force definitions are stated in terms of the direction the light rays go. Refer to figure 3. An object which appears closer than infinity has rays which diverge toward the observer. The divergence is expressed in diopters as $D=1/f$, where f is the focal length in meters. In a perfectly collimated display, the object would appear in front of the viewer at infinity, with a collimation of 0.0 diopters. The eye can accommodate displays which are divergent because divergent rays occur in a natural real scene, and the eye muscles can focus on the image without strain.

Optical systems can create rays converging toward the observer. Converging rays do not occur in nature. These rays intersect behind the observer and are expressed as a positive diopter. +0.02 diopter convergent rays indicate an object with a focal distance 50 meters behind the observer. The eye cannot tolerate convergent rays, so specifications should be written to minimize convergent rays at the expense of divergent rays.

Dipvergence is measured in milliradians and represents a difference in apparent elevation angle between the rays entering each eye. Dipvergence does not occur naturally and cannot be tolerated by the eye.

A HUD display presents special problems for collimation. Normally, the ideal condition is to have the display collimated at infinity. Unfortunately, HUDs are factory aligned and typically collimated to distances of 200 to 300 feet. If the display was collimated at infinity and the HUD at 200 feet, the target would appear to move with respect to the HUD reticle as the pilot moves his head. Since HUDs are prealigned, it is often easier in practice to collimate the display to the same distance as the HUD in the area observed through the HUD.

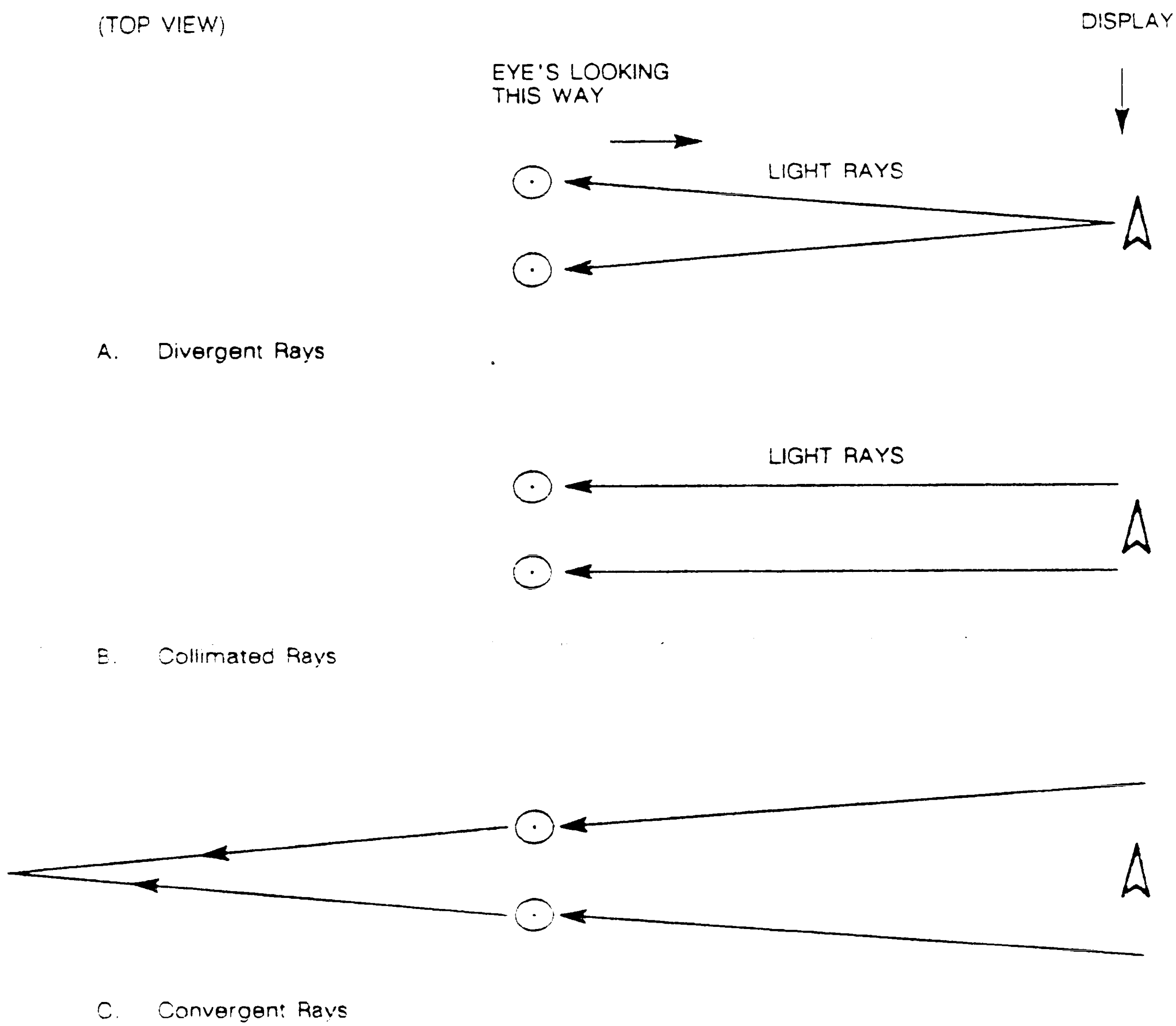


FIGURE 3. Collimation.

4.7.4.5 **Collimation quality**. For collimated displays, a dot pattern consisting of a minimum of 10 rows by 10 columns of equally spaced dots shall be generated by the visual system and fed into the display. Collimation quality shall be measured using a standard parallel telescope consisting of two parallel collimated and calibrated monoculars separated by an interocular distance of 70 mm. One of the monoculars shall have a reticle calibrated in diopters. The test shall be conducted by measuring collimation with the telescope placed at the pilot's eye point. A sufficient number of dots shall be measured to ensure compliance throughout the field-of-view. Lateral deviations observed through the parallel telescope shall represent convergence/divergence errors. Vertical deviations represent dipvergence.

For real-image displays, the distance from the pilot's design eyepoint to the screen shall be measured at a sufficient number of positions to ensure compliance with the specification. It is also possible to verify this requirement through analysis.

VERIFICATION RATIONALE (4.7.4.5)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Measure the collimation in the center of the display and near the corners. Additional points should also be taken near the edges and at random positions throughout the field-of-view. Ten points are usually sufficient to verify the requirement.

VERIFICATION LESSONS LEARNED

Collimation tests sometimes reveal optical misalignments. For example, if the top of the display is primarily convergent and the bottom is primarily divergent, it may be possible to readjust the CRT or optics position to equalize the collimation errors.

In all cases, convergence and divergence errors should be minimized at the expense of divergence errors.

Foreign simulator manufacturers often use parallel telescopes with an interocular spacing of 67 mm. Although this introduces some measurement error, it is insignificant for practical purposes. Alignment of any parallel telescope should be verified prior to use by measuring the collimation of a distant real object. Minor miscalibration of the telescope can significantly affect the measurement.

3.7.4.6 Viewing volume. The exit pupil shall be a minimum of a __________ inch diameter sphere centered at the nominal eyepoint position. A larger exit pupil is desirable. All visual display specifications shall be met from any point within the exit pupil volume.

REQUIREMENT RATIONALE (3.7.4.6)

The exit pupil defines the area around the pilot eyepoint wherein all of the visual specifications must be met. Since pilots are often required to move their heads around during the course of a flight, the exit pupil must include the normal range of head movement.

REQUIREMENT GUIDANCE

It is also acceptable to specify the exit pupil in terms of "zones". If this is done, the distortion parameters must be specified for each zone.

Some types of displays do not have a symmetrical exit pupil, and therefore it will not be a sphere. In these cases, the vertical and lateral head/eye movement should be specified independently.

A 12" diameter sphere is usually sufficient for fighter aircraft applications where the pilot's movement is restrained. It is often desirable to have a larger exit pupil on a wide-body aircraft; however 12" remains a typical specification.

REQUIREMENT LESSONS LEARNED

In some cases it is desirable to have a single display to be used by multiple crew members. For these cases, an extremely large exit pupil is required. Systems that can provide an extremely large exit pupil without degrading picture quality are now commercially available.

4.7.4.6 Viewing volume. The design eyepoint at the center of the exit pupil shall be identified. The display shall be observed from the pilot's eyepoint and from all positions within the specified exit pupil. No excessive gap angles, geometric distortion, or other degrading optical effects shall be observable.

VERIFICATION RATIONALE (4.7.4.6)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

All of the objective tests should pass when they are conducted anywhere within the exit pupil. Usually all tests are run from the pilot's eyepoint. The exit pupil test tends to be subjective to identify potential problem areas. Once a potential problem has been identified, any of the objective tests can be rerun anywhere within the exit pupil.

VERIFICATION LESSONS LEARNED

It is a good idea to subjectively check the alignment of the design eyepoint with respect to the simulator pilot's eye position during this test. The seat should be adjustable so that the pilot's eyepoint can be centered on the simulator's design eyepoint.

3.7.4.7 Geometric distortion. The total geometric distortion for each display shall not exceed ___(a)___ of the total picture height within a circle of diameter equal to the picture height, and shall not exceed ___(b)___ percent of the total picture height outside a circle of diameter equal to the total picture height. Alignment of the displays shall be such that the maximum distortion anywhere within the field-of-view shall be less than ___(c)___ of the picture height.

REQUIREMENT RATIONALE (3.7.4.7)

The purpose of this paragraph is to bound the distortion allowed due to geometric positioning errors.

REQUIREMENT GUIDANCE

The amount of geometric distortion which can be tolerated varies depending upon training requirements and sometimes the field-of-view. The numbers suggested below tend to be on the high side. Do not specify distortions greater than these numbers:

a. ±2 percent.

b. ±3 percent.

c. ±4 percent.

REQUIREMENT LESSONS LEARNED

Geometric distortion occurs in visual systems due to non-linearities in displays and optics. The geometric distortion is defined as an error in geometric position expressed as a percentage of picture height. For displays, error and height are measured in degrees.

Always reference geometric distortion to picture height. On the F-16 visual, the distortion was referenced to the angle away from center, with the intent of minimizing distortion in the HUD area. As it turns out, a literal interpretation permits zero distortion in the center of the picture, which is impossible to achieve. In cases like the HUD, it is best to specify a separate tolerance for that particular area. For example, "Geometric distortion in the area covered by the HUD shall not exceed 0.5 percent."

4.7.4.7 Geometric distortion. A dot pattern consisting of a minimum of 10 rows by 10 columns of equal angularly spaced dots shall be generated by the image generator and fed into the display. A theodolite shall be placed at the pilot's eyepoint and the angular position of the dots in the display shall be measured. Deviations of the actual position from the theoretical dot position expressed as a percentage of the total angular picture height represents the geometric distortion. A sufficient number of points shall be chosen to ensure compliance throughout the field-of-view. Note: A standard dot pattern may be used if the theoretical angular position of each dot is calculated.

VERIFICATION RATIONALE (4.7.4.7)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Do not require too many dots in the test pattern. Closely spaced dots are difficult to identify during test and do not alter the results of the test. Usually only about 10 selected points are needed to assure compliance. Points should be selected near the center, the edge, and the corners. Other points should be selected as necessary.

VERIFICATION LESSONS LEARNED

If standard dot patterns are used, the theoretical angular positions should be substantiated by analysis.

3.7.4.8 **Color convergence**. For each display, within a circle of diameter equal to the picture height, the three primary colors shall be converged to an accuracy of ___(a)___. Outside the circle, the convergence shall be to an accuracy of ___(b)___.

REQUIREMENT RATIONALE (3.7.4.8)

Most color displays are created by combining the three primary colors of red, green, and blue. The accuracy with which these colors are registered needs to be specified to prevent loss of resolution and objectionable color fringing.

REQUIREMENT GUIDANCE

For visual systems, it is best to specify color convergence errors in terms of angular error. It is easier to compare systems, and measurements can be easily made from the pilot eye position with a theodolite or parallel telescope.

a. Fill in the blank with the convergence requirement for the center of the display. A maximum of 6 arc minutes color divergence is typical for a reasonable quality display over a 36 X 58 degree field-of-view.

b. Fill in the blank with the convergence requirement for the corner of the display. A maximum of 9 arc minutes color divergence is typical for a reasonable quality display over a 36 X 58 degree field-of-view.

The color convergence errors should be slightly less than the maximum resolution. For example, if a 4 arc minute per element resolution is required, a 3 arc minute color convergence error would be compatible. It would not make sense to allow a convergence error of 6 arc minutes because the color mismatch would wash out the resolution capability of the system.

REQUIREMENT LESSONS LEARNED

Convergence errors have been rapidly decreasing as the state of the art advances with the newer color systems. Digital convergence techniques now being used have proved to be excellent.

4.7.4.8 **Color convergence**. A dot pattern consisting of a minimum of 10 rows by 10 columns of dots shall be displayed. A theodolite shall be set up at the pilot's eye position. The convergence accuracy shall be determined by measuring the angular displacement of the three primary color dots. A sufficient number of dots shall be measured in each of the specified areas to ensure compliance throughout the field-of-view.

VERIFICATION RATIONALE (4.7.4.8)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Sometimes it is easier to use the parallel telescope to accomplish color convergence tests. If the telescope is accurately calibrated, this is very acceptable.

VERIFICATION LESSONS LEARNED

It is often hard to see dots through optical measurement instruments with large magnification factors. Green is typically the easiest color to see and should usually be used as the reference color. The best approach is to turn off the red and blue components. The measuring instrument can be centered on the green dot. The green dots can be turned off and the red and blue dots turned on in turn. For each color, the new position can be determined.

3.7.4.9 **Video signal-to-noise ratio.** The signal-to-noise ratio as measured at the output of the final amplifier of the video display device shall be greater than __________.

REQUIREMENT RATIONALE (3.7.4.9)

The signal-to-noise ratio of the video signal determines how "snowy" the image appears. A poor signal-to-noise ratio results in a picture which is distracting to watch.

REQUIREMENT GUIDANCE

Fill in the blank with 39 or 50 dB, if practical.

REQUIREMENT LESSONS LEARNED

Specify the video signal-to-noise ratio as close to the final display element as possible. For example, on a display which uses a CRT display, the signal-to-noise ratio should be measured on the modulated cathode.

Measurement techniques are extremely important as they can significantly affect the resulting reading. For repeatable measurements, the tangential method has been proven fairly successful. This technique is described in the verification section of this document. The definition used for signal-to-noise ratio is:

$$S/N = 20 \log \frac{(\text{P-P video signal}) \text{ dB}}{(\text{RMS noise})}$$

Confusion sometimes arises in determining the peak-to-peak (P-P) video signal for night scenes. The P-P video signal remains the same for all brightness levels and represents the difference between the mean voltage level for the peak white and the mean voltage level for peak black. On systems using composite video, the sync and pedestal are never included as part of the P-P signal.

Often the signal-to-noise ratio may be expressed as a negative number. This is not a good practice for specifications; however, it is often seen in literature. The difference occurs because the numerator and denominator in the S/N equation are flipped.

4.7.4.9 Video signal-to-noise ratio. A wide band oscilloscope (Tektronix 2400 series or equivalent) shall be used to measure video signal-to-noise ratio using the tangential method. The signal shall be connected to both channels of the two channel scope with alternate sweep used. For each noise measurement, the identical position shall be aligned on both traces. With both channels identically calibrated, the voltage offset shall be adjusted until the dark band between the two noise traces just disappears. After the signal has been removed from the input, the separation between the two noise-free traces shall represent twice the RMS noise. The peak-to-peak video signal shall equal the difference between the peak white and peak black levels. Pedestal and sync levels shall not be considered as part of the signal level for S/N purposes. Signal-to-noise shall be defined as:

S/N = 20 log (base 10) ([peak-to-peak video]/[RMS noise])

VERIFICATION RATIONALE (4.7.4.9)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Other video signal-to-noise ratio testing techniques are acceptable, but usually require special purpose test equipment. If the above recommended technique is used, the bandwidth of the oscilloscope must exceed the maximum bandwidth of the display subsystem.

VERIFICATION LESSONS LEARNED

When video signal-to-noise measurements are made on the General Electric light valve or other similar devices, it is only practical to measure it at the input of the projector. The GE light valve modulates the sweep waveforms to create the picture; video as such does not exist past the first few input stages. Beware of probe capacitance when measuring S/N on the cathode or grid of a CRT. These high impedance points can sometimes cause the probe to act as a filter which results in an unrealistically good S/N ratio.

3.7.4.10 Sweep signal-to-noise ratio. The signal-to-noise ratio as measured at the final output of the deflection amplifiers shall be greater than __________.

REQUIREMENT RATIONALE (3.7.4.10)

The sweep signal-to-noise ratio determines how stable light points appear in the picture, and how jittery the raster lines appear. A poor signal-to-noise ratio results in a picture which is distracting to watch.

REQUIREMENT GUIDANCE

Fill in the blank. An 80-dB S/N is usually required.

REQUIREMENT LESSONS LEARNED

Refer to the lessons learned section for video signal-to-noise ratio (3.7.5.9). The problems encountered are the same. The primary difference is that the drive signal is typically a current waveform. The current can either be measured using a high frequency oscilloscope current probe or measured as a voltage waveform across the deflection feedback resistor. Assure that the frequency response of the measuring probe is at least equal to the highest frequency response of the deflection amplifier. A ten-to-one frequency response ratio is acceptable.

4.7.4.10 **Sweep signal-to-noise ratio.** The sweep signal-to-noise ratio shall be measured using the tangential method as described previously in "video signal-to-noise ratio." The sweep signals shall be measured with a high frequency current probe on the yoke, or with a voltage probe across the deflection feedback resistor. The peak-to-peak signal shall represent the voltage or current differences for the left/right or top/bottom deflection sweep. The sweep signal-to-noise ratio shall be defined as:

S/N = 20 log (base 10) ([peak-to-peak sweep]/[RMS noise])

VERIFICATION RATIONALE (4.7.4.10)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Other sweep signal-to-noise ratio testing techniques are acceptable, but usually require special purpose test equipment. If the above recommended testing technique is used, the bandwidth of the oscilloscope must exceed the maximum bandwidth of the deflection system.

VERIFICATION LESSONS LEARNED

Beware of probe capacitance if it is necessary to measure the sweep waveform at a high impedance point. Usually feedback resistors are low impedance points and do not cause problems. If a current probe is used, ensure that the frequency response of the probe exceeds the bandwidth of the deflection amplifier.

3.7.4.11 **Blemishes.** No defects in CRT screen or display object surface, envelope, display optical package, or projection screens shall be larger than ___(a)___. There shall be no more than ___(b)___ defects larger than ___(c)___ anywhere within the active picture area.

REQUIREMENT RATIONALE (3.7.4.11)

This requirement is needed to bound or eliminate small area defects in the display system.

REQUIREMENT GUIDANCE

a. A typical maximum blemish size is 0.1 degrees.

b. and c. Typically no more than five defects larger than 0.05 degrees should appear anywhere within the active picture area.

REQUIREMENT LESSONS LEARNED

Blemishes are often created during the manufacturing or handling of CRTs and optical packages. Blemishes are sometimes distracting to the pilot because they remain stationary as the surrounding scene moves. Blemishes which occur at infinity are the most objectionable because the eye is also focused on the collimated display. A CRT phosphor defect is an example. Defects which occur in the optical package may not be objectionable because the eye looks past the defect just as one would look through a screen door. Some judgment must be exercised when deciding if a defect is objectionable and whether it will significantly affect training.

4.7.4.11 **Blemishes.** A flat white field of medium to high intensity shall be displayed. A theodolite shall be placed at the pilot's eye position. The size of each blemish shall be measured in arc-minutes. Each blemish shall be logged onto a blemish map showing relative size and position. The number and size of blemishes shall not exceed those specified.

VERIFICATION RATIONALE (4.7.4.11)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Blemishes can take many forms. Only those which are noticeable or which could affect training should be considered. For example, a slight color variation in a pancake window would not affect training and should not be counted as a blemish. A dark spot which obstructs a portion of the picture would certainly need to be measured.

VERIFICATION LESSONS LEARNED

3.7.4.12 **Image continuity.** Where multiple display units or multiple images sources such as projectors are used with no gaps between channels, the images shall match across the boundary. Accuracy of the image continuity shall be equal to or better than __________ anywhere along the joint, edge, or seam.

REQUIREMENT RATIONALE (3.7.4.12)

On visual systems which require more than one display unit, edge ~~mis~~registration becomes a problem. It is possible to meet distortion specifications for each individual display, but if the errors are in different directions, the resulting display may be unacceptable.

REQUIREMENT GUIDANCE

The image continuity requirement will vary depending upon the training task. A typical requirement for image continuity is 0.5 degrees.

REQUIREMENT LESSONS LEARNED

Visual systems with wide gap angles are more tolerant of image discontinuities. Simulators which require tracking of targets such as air-to-ground weapon air-to-air combat tasks require excellent continuity.

4.7.4.12 **Image continuity**. A small pattern or target shall be displayed along an edge between two adjacent displays. A theodolite set up at the pilot's eye position shall be used to determine the maximum mismatch between the two images. The error shall not exceed the specified amount.

VERIFICATION RATIONALE (4.7.4.12)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

The mismatch error is a combination of horizontal and vertical offset between the test image as it crosses the window or display boundaries. Although not mathematically exact, it is usually sufficient to consider the error to be the square root of the sum of the squares of the horizontal and vertical errors.

VERIFICATION LESSONS LEARNED

Watch the target as it crosses the window boundaries at several points. The eye is pretty good at detecting mismatches. Measurements can be minimized by spot checking those areas that appear to have the worst error.

3.7.4.13 **Swimming**. No swimming of the visual image shall be observable as the observer's eyepoint is moved within the exit pupil.

REQUIREMENT RATIONALE (3.7.4.13)

Swimming occurs in the visual display system when small optical errors cause the images to appear to wave as the observer moves his head.

REQUIREMENT GUIDANCE

This paragraph is required to maintain display quality.

REQUIREMENT LESSONS LEARNED

4.7.4.13 **Swimming**. Swimming shall be verified by inspection.

VERIFICATION RATIONALE (4.7.4.13)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

When checking for display swimming, the observer should move across the exit pupil from various directions. Side-to-side head motion and top-to-bottom observation should be made.

VERIFICATION LESSONS LEARNED

Any display system using optical elements is subject to some swimming. Judgment must be exercised when determining if any image swimming is objectionable or will degrade training.

3.7.4.14 **Spurious images.** There shall be no objectionable spurious images or reflections apparent to the viewer. Spurious images include light leaks, mirror imperfections, optical or CRT imperfections, reflections on the glare shield or windscreen, or reflections from opposing displays.

REQUIREMENT RATIONALE (3.7.4.14)

Spurious images often appear as reflections of diminished brightness. These images can be distracting especially if they move through the field of view.

REQUIREMENT GUIDANCE

This paragraph is required to limit the spurious images in the display system.

REQUIREMENT LESSONS LEARNED

In addition to reflection within the display itself, control panel lamps sometimes reflect into the display and produce objectionable images. It is best to look for spurious images with all panel lamps at full brightness, and with high brightness and high contrast images in the display. This process makes it easy to identify the spurious images; however, judgment must be used to determine if they are objectionable. For example, "full lamps" is unrealistic for night scenes, or for situations where the pilot would be wearing night vision goggles.

4.7.4.14 **Spurious images.** Each of the specified spurious images shall be determined by inspection. To ensure a valid test, instrument panel lights shall be set to maximum. A small bright object shall be moved dynamically through the field of view against a dark background. Spurious images may appear as dimmer images travelling in the same or opposite directions from the target image.

VERIFICATION RATIONALE (4.7.4.14)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Spurious image requirements need to be included in any simulator which contains optical elements or wind screens.

VERIFICATION LESSONS LEARNED

When looking for spurious images, look for different colored reflections in side windows, etc. as well as reflections in the primary display windows. Sometimes the spurious images appear at apparent ranges other than infinity. This type of image is not usually distracting when the pilot is concentrating on the display, but may be objectionable when he is looking at the cockpit panel and catches the reflection out of the corner of his eye. Judgment must be exercised when evaluating the spurious images. Most display systems contain some spurious images. Some reflections from wind screens occur naturally as a function of panel layout, as they do in the real aircraft cockpit. If spurious images are found, it is sometimes possible to decrease the brightness of cockpit lamps or switch lights to minimize the problem.

3.7.4.15 **Grey scale.** The display system shall be capable of presenting a ___(a)___-step linear grey scale. With this ___(a)___-step grey scale input, the displayed brightness difference between any two adjacent steps shall be within ___(b)___ of the total brightness difference between black and white.

REQUIREMENT RATIONALE (3.7.4.15)

The grey scale requirement is needed to assure that there is a linear relationship between the displayed brightness and the desired grey shade. A linear function insures a good grey scale rendition by preventing compressed blacks or smashed whites.

REQUIREMENT GUIDANCE

a. A 10-step linear grey scale is typical.

b. For most applications, the blank can be filled with "11 percent ±5 percent" of the total brightness difference between black and white.

REQUIREMENT LESSONS LEARNED

4.7.4.15 **Grey scale.** A ___(a)___-step linear grey scale test pattern shall be placed onto the display such that the entire pattern is visible from the pilot's eye position. For camera model or optical systems, this pattern shall be generated by substituting a ___(a)___-step linear reflectance grey scale test chart in place of the model aircraft. For computer generated image systems, the grey scale shall be generated by the computer. Each of the grey step levels shall be measured in the display with a Pritchard Photometer (Photo Research model 1980 or equivalent) placed at the pilot's eye position. The grey scale steps in ft-lamberts shall be ___(b)___ of the total brightness difference between black and white.

VERIFICATION RATIONALE (4.7.4.15)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

The exact number of grey steps is not critical. The intent is to assure that the video generator/display provide a linear brightness response.

a. Insert the same number of steps as stated in the requirement. 10 grey steps are typical.

b. 11 percent ±5 percent if a 10-step pattern is used.

VERIFICATION LESSONS LEARNED

To avoid the brightness non-uniformity from interfering with the grey scale test, it is sometimes wise to measure the brightness in the center of the screen. The test pattern can then be moved to bring the proper grey scale level into the center.

3.7.4.16 **Display refresh rate.** The display of the visual scene shall be refreshed at least __________ times per second to insure constant brightness and flicker-free presentation.

REQUIREMENT RATIONALE (3.7.4.16)

The refresh rate needs to be specified in order to provide a smoothly moving picture with no objectionable flashing.

REQUIREMENT GUIDANCE

Specify a refresh rate (typically 30 for a 2:1 interlace scan).

REQUIREMENT LESSONS LEARNED

A 30-per-second refresh rate with 2:1 interlace is typical for raster display systems with standard CRT phosphor and average brightness. However, a dim picture or a high persistence display may be subjectively acceptable with a lower refresh rate.

4.7.4.16 **Display refresh rate.** The specified display refresh rate shall be verified.

VERIFICATION RATIONALE (4.7.4.16)

Verification of display refresh rate is required to assure compliance.

VERIFICATION GUIDANCE

An engineering demonstration shall be the primary means of verifying the display refresh rate.

VERIFICATION LESSONS LEARNED

3.7.4.17 **Shrouding and access.** The cockpit displays shall be enclosed in a lightproof shroud to permit operation in a lighted facility. The shrouding shall prevent loss of air conditioned ambient air provided by the simulator cockpit air conditioning unit in the event that wind screens are removed to improve optical effects. Maintenance access shall be provided for display equipment mounted on the simulator. All shrouding shall be designed for rapid removal and replacement to facilitate maintenance on the visual displays and other portions of the simulator.

REQUIREMENT RATIONALE (3.7.4.17)

A light-tight area is needed so that room lighting does not adversely affect the visual display.

REQUIREMENT GUIDANCE

Include this requirement for any display system which includes optical elements. Dome-type display systems do not require shrouding in the conventional sense.

REQUIREMENT LESSONS LEARNED

Beware of shrouding which makes maintenance difficult.

4.7.4.17 **Shrouding and access.** Verify by demonstration.

VERIFICATION RATIONALE (4.7.4.17)

A shrouding and access demonstration is required to assure compliance.

VERIFICATION GUIDANCE

An acceptable demonstration should include a check for light leaks and a check to insure that maintenance items can be accessed.

VERIFICATION LESSONS LEARNED

The easiest way to check for light leaks is to dim all cockpit controls and displays and to turn the room lighting to maximum. Sometimes the shrouding limits access to some display or cockpit electronics, etc. In these cases, the shrouding should be inspected to ensure that it can be removed for access in a reasonable amount of time.

3.7.4.18 **Maintenance of the visual display.** Modularized construction techniques and maintenance test points shall be incorporated into the design of the display system. Recommended cleaning procedures for all optical elements in the display system shall be established, and a dustproof enclosure shall be provided to prolong the useful life of the visual display system.

REQUIREMENT RATIONALE (3.7.4.18)

The location of display subsystems can make maintenance difficult. This requirement is needed to ensure that the system can be aligned and maintained easily. Cleaning procedures have a significant effect on the useful life of large optical elements such as mirrors and beamsplitters. Optical coatings also need to be protected, so the contractor should always be required to recommend cleaning procedures.

REQUIREMENT GUIDANCE

This requirement can be tailored for specific display configurations. For example, in the case of multiple-window displays, it may be wise to require the ability to remove display electronics for each window separately with out disturbing the alignment of the other units.

REQUIREMENT LESSONS LEARNED

Display optics are often difficult to clean, and frequent cleaning can lead to premature degradation. It is sometimes helpful to use filtered air entering the enclosed area which houses the optics. A slight positive pressure prevents dirty air from contaminating the optics.

4.7.4.18 **Maintenance of the visual system display.** Verify by inspection.

VERIFICATION RATIONALE (4.7.4.18)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Usually an inspection is adequate to verify requirement. Ease of maintenance should be addressed in design reviews prior to fabrication to insure compliance.

VERIFICATION LESSONS LEARNED

3.7.4.19 **Repeater monitor.** A repeater monitor shall be provided, and shall be capable of displaying any selected video channel from the visual system. The repeater monitor need not be the same size as the actual display units, but must have adequate resolution and brightness to be used as a troubleshooting and/or instructor aid. If practical, the repeater shall be movable to other areas within the simulator facility.

REQUIREMENT RATIONALE (3.7.4.19)

If the visual display system contains more than one window, it is usually adequate to require only one repeater with the capability to switch to each different video channel from the monitor location.

REQUIREMENT GUIDANCE

TBD.

REQUIREMENT LESSONS LEARNED

4.7.4.19 **Repeater monitor.** Verify by inspection.

VERIFICATION RATIONALE (4.7.4.19)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

Testing of the repeater monitor need not be as rigorous as testing of the display. Typically, an inspection of the monitor with a typical picture is sufficient to verify the requirement.

VERIFICATION LESSONS LEARNED

3.7.4.20 **Remote alignment control.** The primary visual display alignment controls shall be easily accessible for maintenance. It shall be possible to view the displayed scene either directly or indirectly (for example, reflected from mirror) during alignment. If multiple display units are used, a remote alignment box shall be provided so that any display can be aligned while viewing the display from the pilot's eye position. A jack (or multiple jacks if necessary) shall be provided in the cockpit so that the remote alignment box can be removed and stored when not in use.

REQUIREMENT RATIONALE (3.7.4.20)

A remote alignment box makes visual display alignment much easier and results in a higher quality display.

REQUIREMENT GUIDANCE

This paragraph is required for all display systems.

REQUIREMENT LESSONS LEARNED

Typically, this capability provides for adjustment of color convergence, color balance, and geometric edge matching between adjacent displays.

4.7.4.20 **Remote alignment control.** Verify by demonstration.

VERIFICATION RATIONALE (4.7.4.20)

Verification of this requirement is necessary to insure compliance.

VERIFICATION GUIDANCE

The complexity of the remote alignment box is dependent upon the type of display. For example, a color display will typically include convergence controls. A calligraphic beam generation CRT approach will require controls for alignment of the various colored light points. For multiple window displays, geometric matching functions are usually necessary.

When possible, it is a good idea to demonstrate this alignment capability prior to final acceptance testing. Avoid misaligning the display simply to demonstrate the alignment box. Usually, the functions of the box have been adequately demonstrated at periodic program reviews.

VERIFICATION LESSONS LEARNED

3.8 **Electronic combat simulation.** The electronic combat (EC) simulation shall consist of the simulation of equipment functions and the associated environment.

REQUIREMENT RATIONALE (3.8)

This is an introductory paragraph.

REQUIREMENT GUIDANCE

The general scope of this section is stated as including both equipment and environment requirements.

REQUIREMENT LESSONS LEARNED

4.8 **Electronic combat simulation.** Tests, demonstrations, inspections, and analyses shall be conducted to verify the EC simulation.

VERIFICATION RATIONALE (4.8)

This is an introductory paragraph.

VERIFICATION GUIDANCE

Detailed verifications are included in other paragraphs.

VERIFICATION LESSONS LEARNED

3.8.1 **Electronic combat equipment simulation.** The following EC equipment suite shall be simulated in accordance with design criteria: __________. All equipment shall interact as it does in the weapon system.

REQUIREMENT RATIONALE (3.8.1)

The characteristics of the specific EC requirements installed in the weapon system must be accurately simulated for realistic training since EC equipment tends to be different even within certain categories, such as radar warning receivers.

REQUIREMENT GUIDANCE

List the specific equipment to be simulated. A separate subparagraph should be written for each EC function. Simulation requirements should be tailored to the specific training requirement and characteristics of the equipment. The required quality of the audio and video signals should be addressed. Simulation unique requirements may be required for chaff and flare designs, such as the capability to reload during a mission. The characteristics of associated digital signal processors and display processors should be examined to determine whether specific characteristics and certain processing loads need to be specifically addressed. It may be necessary for certain requirements to be placed in the ECE in order to assure certain training requirements are met. Consult Defensive Avionics Mil-Prime, MIL-A-87247, as a source of in-depth background information on generic offensive system requirements.

REQUIREMENT LESSONS LEARNED

Both functional simulation and stimulation of processors has been successfully utilized. Recent trends have been to stimulate complex EC processors especially when the OFPs are still under development and/or are expected to undergo considerable change, which is not unusual for EC equipment.

4.8.1 **Electronic combat equipment simulation.** Inspection shall be conducted to verify the presence of all required equipment. Tests shall be conducted to verify that the equipment operates correctly when integrated.

VERIFICATION RATIONALE (4.8.1)

To assure compliance.

VERIFICATION GUIDANCE

A separate paragraph should be written for each set of EC equipment. Tests should verify the normal operation of the equipment throughout all modes and in conjunction with specific JARMs. Abnormal operation as well as integrated EC equipment interactions should also be tested.

VERIFICATION LESSONS LEARNED

Special tests should be conducted to verify that EC equipment interactions (with each other and with non-EC equipment) are simulated in accordance with designation. Often there is interference among EC equipment that is observable and sometimes results in operational interactions. Interference on the weapon system may be a result of dirty signals, locations of antennas out of specification (or even within specification) performance, etc. Whatever the cause, this type of anomaly should be verified in the simulation.

3.8.2 Electronic combat environment (ECE)

3.8.2.1 Jammer, artillery, radar, missile (JARM) systems

3.8.2.1.1 JARM library. A JARM library shall be provided which includes all the JARMS to be simulated. This library shall include at least the following JARMs: ____(a)____. Each JARM in the library shall include all characteristics needed to meet the requirements of the specification. As a minimum this shall include____(b)____. The capability shall be provided to expand the library as new JARMs are defined.

REQUIREMENT RATIONALE (3.8.2.1.1)

The scope of the JARM modelling needs to be defined.

REQUIREMENT GUIDANCE

a. All the JARMs (red, blue, grey) should be listed. This, along with other requirements, provides a complete definition of the task needed to build the JARM library and also helps to define the worst-case signal environment to be simulated. The list is normally defined by the using command based on the training missions they expect to develop.

b. Normally the JARM library includes frequency, pulse repetition interval (PRI), stagger, jitter, scan pattern, antenna pattern, pulse length, and detection range. Additional information is often included which aids in the generation of missions. This may include networking information of some JARMs or JARM clusters.

REQUIREMENT LESSONS LEARNED

4.8.2 Electronic combat environment

4.8.2.1 Jammer, artillery, radar, missile systems

4.8.2.1.1 JARM library. Inspections shall be conducted to verify the presence of all required JARMs and accuracy of JARM data in the library.

VERIFICATION RATIONALE (4.8.2.1.1)

To assure compliance.

VERIFICATION GUIDANCE

The entire JARM library should be inspected to assure that each JARM in the library is correctly described on an individual basis. The accuracy and utility of other data (networking, clusters, etc) should also be verified. This can normally be performed by user personnel and/or other knowledgeable personnel, e.g., AFEWC.

VERIFICATION LESSONS LEARNED

3.8.2.1.2 JARM simulation. JARM simulation shall consist of the observable characteristics of each JARM, including the signal structure (frequency, PRI, pulse length) and the dynamics (modes, tactics, networking) in accordance with design criteria.

REQUIREMENT RATIONALE (3.8.2.1.2)

The extent of the JARM simulation needs to be defined.

REQUIREMENT GUIDANCE

The extent of JARM simulation can vary widely from very simple to very complex. The more complex simulations include extensive automatic interaction with the ownship aircraft. This section should be tailored to user requirements. The need for additional paragraphs will vary depending on the complexity of the simulation.

REQUIREMENT LESSONS LEARNED

4.8.2.1.2 JARM simulation. Tests shall be conducted to verify the correct simulation of all JARMs in the library.

VERIFICATION RATIONALE (4.8.2.1.2)

To assure compliance.

VERIFICATION GUIDANCE

The accuracy of the simulation of each JARM must be verified. Normally this can be performed by user personnel or other qualified personnel, e.g., AFEWC, and can often be done in parallel with other verifications on a non-interference basis.

VERIFICATION LESSONS LEARNED

Even though this is very time consuming, it must be done so that problems are identified before more complex integrated EC environment testing is attempted.

3.8.2.1.3 JARM platforms/JARM sites. JARM sites shall have fixed locations. JARM platforms shall be assigned to any moving targets as specified by 3.2.1.5.1. There shall be no other limit on the distribution of JARM sites and platforms. The capability to relocate JARM sites during a mission shall be provided. The capability to alter the EC environment by inserting or deleting any JARM shall be provided.

REQUIREMENT RATIONALE (3.8.2.1.3)

Moving JARMs, either airborne or on the ground, are needed in the EC environment. The instructor needs some limited controls to insert, move, and delete JARMs, depending on the training mission progression.

REQUIREMENT GUIDANCE

The number of moving platforms required are specified later and should be based on the types of mission to be trained and the length of missions. The number of platforms to be permitted by the instructor is dependent on the task loading of the instructor and the types of missions.

REQUIREMENT LESSONS LEARNED

4.8.2.1.3 **JARM platforms/JARM sites.** Tests shall be conducted to verify the dynamics of JARM platforms and the control of JARM sites.

VERIFICATION RATIONALE (4.8.2.1.3)

To assure compliance.

VERIFICATION GUIDANCE

The tests may be conducted in conjunction with other tests. More specific verifications may be defined depending on specific requirements.

VERIFICATION LESSONS LEARNED

3.8.2.1.4 **JARM countermeasure evaluator and tactics.** A countermeasures evaluator shall be developed for each JARM which shall evaluate the effects of ownship actions against the JARM. JARM tactics shall be simulated (mode changes, frequency changes, etc) based on the dynamic interaction with the ownship both for the individual JARM and in collaboration with other networked JARMs.

REQUIREMENT RATIONALE (3.8.2.1.4)

A dynamically interactive environment simulation is required to provide satisfactory training in most ATDs. Often this is the only method through which the aircrew can receive such training in dense environments.

REQUIREMENT GUIDANCE

The complexity of the required evaluators and tactics should be spelled out. Care must be taken not to include classified data or to inappropriately reference it.

REQUIREMENT LESSONS LEARNED

4.8.2.1.4 **JARM countermeasures evaluation and tactics.** Inspections and tests shall be conducted to verify the correct tactics are simulated for each JARM and that the effects of ownship actions are correctly interpreted and acted upon.

VERIFICATION RATIONALE (4.8.2.1.4)

To assure compliance.

VERIFICATION GUIDANCE

Tests should be conducted to assure that the correct tactics are employed by each JARM.

VERIFICATION LESSONS LEARNED

3.8.2.1.5 JARM weapons. JARM weapons shall include those weapons associated with specific JARMs. The weapon simulation shall be correlated with the electronic signal environment (search, track, lock-on, guidance, etc) and shall correlate with other functional subsystem simulations (visual, radar). Weapons dynamics shall be in accordance with design criteria. A lethality algorithm shall be provided for each terminal encounter. Ownship damage shall be simulated based on hit/miss criteria and indications of damage shall be in the form of malfunctions and/or a kill.

REQUIREMENT RATIONALE (3.8.2.1.5)

The simulation of weapons associated with some JARMs is an integral part of the EC environment.

REQUIREMENT GUIDANCE

Even though JARM weapons are not part of the EC environment, they are most closely associated with the EC environment and therefore included here. The weapon simulation must be correlated with other subsystems. All types of JARM weapons associated with specific JARMS are to be included, such as projectiles and missiles.

REQUIREMENT LESSONS LEARNED

4.8.2.1.5 JARM weapons. Tests shall be conducted to verify the weapons dynamics are correct. Inspections shall be performed to verify the basic algorithms for lethality. Integrated performance of all weapons effects shall be tested as part of the missions.

VERIFICATION RATIONALE (4.8.2.1.5)

To assure compliance.

VERIFICATION GUIDANCE

Both inspections and tests may be used to verify that all these requirements are met. Testing of each weapon and weapon effect should be conducted, as well as integrated testing.

VERIFICATION LESSONS LEARNED

3.8.2.1.6 JARM editing. The capability to create or modify JARMs and associated data shall be provided to the user. Air Force support personnel shall be able to perform this editing at the computer support center using skills covered by the __________ course.

REQUIREMENT RATIONALE (3.8.2.1.6)

The need to update and create JARMs representing new weapon systems is essential in keeping the electronic combat environment up-to-date.

REQUIREMENT GUIDANCE

Provisions for inputting intelligence data into the JARM libraries should be explicitly described and should include useful, flexible editors for the system. Fill in the name of the training course that users and support personnel receive at the contractor's facility.

REQUIREMENT LESSONS LEARNED

4.8.2.1.6 **Jarm editing.** Tests shall be conducted to verify JARM editing.

VERIFICATION RATIONALE (4.8.2.1.6)

To assure compliance.

VERIFICATION GUIDANCE

Both inspections and tests should be conducted at the computer support center by Air Force personnel.

VERIFICATION LESSONS LEARNED

3.8.2.2 **Mission electronic combat environment.** The mission electronic combat environment (MECE) is a set of JARMs that make up the entire electronic environment which may interact with the EC equipment during any mission. The MECE for any mission shall consist of at least ___(a)___ JARMs and ___(b)___ JARM signals. The capability to simulate any set of JARMs identified in the JARM library within these constraints shall be provided. The MECE is an integral part of a preprogrammed training exercise.

REQUIREMENT RATIONALE (3.8.2.2)

The size of the EC environment to be simulated needs to be scoped.

REQUIREMENT GUIDANCE

a. Insert the number of JARMs required in a mission. This may vary from about a hundred to over a thousand.

b. Insert the number of JARM signals required in a mission. An average of 2 or 3 signals per JARM is usually adequate for large environments. The number of JARMs and JARM signals should be based on the training requirements for the aircrew and equipment characteristics. The task loading of the EC responsible aircrew member should be closely analyzed since overstating the environment requirements can be expensive.

REQUIREMENT LESSONS LEARNED

4.8.2.2 **Mission electronic combat environment.** Tests shall be conducted to verify the limits of the MECE

VERIFICATION RATIONALE (4.8.2.2)

To assure compliance.

VERIFICATION GUIDANCE

Specific tests should be conducted to verify the limits of each MECE parameter. The mission can normally be used to complete the testing.

VERIFICATION LESSONS LEARNED

3.8.2.3 Instantaneous electronic combat environment. The instantaneous electronic combat environment (IECE) is a set of JARMs that can interact with the EC equipment at any point in space. The IECE shall consist of at least ___(a)___ JARMs and ___(b)___ JARM signals. The entire content of the IECE shall be updated at least every ___(c)___ seconds. The IECE shall be selected from the MECE based on range and importance of the JARMs. The capability for the instructor to modify the IECE shall be provided. There shall be no limit in the distribution of JARMs around the ownship. At least ___(d)___ JARMs in the IECE shall exhibit tactics. At least ___(e)___ JARM weapons shall be capable of being in flight simultaneously.

REQUIREMENT RATIONALE (3.8.2.3)

The environment instantaneously available to the ownship needs to be specified since it is a major performance driver.

REQUIREMENT GUIDANCE

a. Insert the number of JARMs. This can vary from a small number (about 20) to a large number (more than a hundred).

b. Insert the number of JARM signals. See 3.8.2.2 guidance.

c. Insert the update rate which may range from 1 to 5 seconds.

An analysis should be performed to determine how often the IECE must be updated based on potentially changing content. This analysis is a function of ownship speed, mission type, planned signal environments, and signal characteristics (primarily detection range). The IECE selection algorithm should be based on range and importance, which is a function of potential JARM lethality, detection range, and mission type.

d. Insert the number of JARMs which must concurrently simulate tactics. The entire IECE is often specified since the complexity of a selection algorithm for only a portion of the IECE may require as much computation time as the entire IECE.

e. Insert the number of simultaneous JARM weapons required to be in flight. It is normally just one, but there may be cases when more are required.

REQUIREMENT LESSONS LEARNED

4.8.2.3 **Instanteous electronic combat environment.** Specific tests shall be conducted to verify the limits of each IECE parameter.

VERIFICATION RATIONALE (4.8.2.3)

To assure compliance.

VERIFICATION GUIDANCE

Tests should be developed which explicitly verify the IECE parameters. Since this is an important set of requirements, time should be spent in the development and test under known conditions.

VERIFICATION LESSONS LEARNED

3.8.2.3.1 **JARM occulting.** For each JARM in the IECE, the occulting status shall be updated at least every __________ seconds.

REQUIREMENT RATIONALE (3.8.2.3.1)

The terrain masking (occulting) status can be very dynamic at low and medium altitudes and must be recomputed.

REQUIREMENT GUIDANCE

Insert a time, typically 1 or 2 seconds. The rate is a function of mission type, flight profiles (high, medium, low altitudes, and the types of JARMs to be encountered). For high speed, low altitude flight paths in a hostile environment a 1 second update rate is normal.

REQUIREMENT LESSONS LEARNED

4.8.2.3.1 **JARM occulting.** Tests shall be conducted to verify the correctness of the JARM occult function.

VERIFICATION RATIONALE (4.8.2.3.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests should include known conditions.

VERIFICATION LESSONS LEARNED

3.9 **Digital radar landmass subsystem.** A digital radar landmass simulator (DRLMS) system shall simulate the characterictistics and capabilities of the __________.

REQUIREMENT RATIONALE (3.9)

The exact type and configuration of a radar system may vary from aircraft to aircraft of a given model. This requirement is to insure that the radar system simulated is of the exact type and configuration desired.

REQUIREMENT GUIDANCE

The requirement should precisely state radar system designation and level of modification.

REQUIREMENT LESSONS LEARNED

4.9 Digital radar landmass subsystem. Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of the radar subsystem.

VERIFICATION RATIONALE (4.9)

To insure that the system has been correctly simulated.

VERIFICATION GUIDANCE

Inspection of design criteria should be an adequate means of verifying the basic design concept. Radar subsystem performance shall be tested, demonstrated, and analyzed as required.

VERIFICATION LESSONS LEARNED

3.9.1 **General DRLMS requirements**

3.9.1.1 **DRLMS system accuracy.** The DRLMS system shall be designed to satisfy the accuracies specified in the following paragraphs. These required accuracies are functions of range scales and modes and are defined at the display with respect to the appropriate level of the Defense Mapping Agency's (DMA) digital data base (DDB). These required accuracies include transformations, storage, processing, and display of the DMA data.

REQUIREMENT RATIONALE (3.9.1.1)

Accuracy is defined as the ability of the DRLMS to generate a simulated radar image from transformed DMA data without errors that would detract from the training objective. Accuracy requirements are necessary to establish the level of performance to which the DRLMS will be designed.

REQUIREMENT GUIDANCE

Accuracy should be defined with respect to planimetric horizontal position, planimetric height, and terrain elevation. From an operator perception viewpoint, geographic positional accuracy is closely related to the ratio of displayed ground distance (range) to radar indicator size and to observable display deviations. For example, a ten-mile range selection (60,760 feet) on a ten-inch diameter indicator would provide a ratio of 6,076 feet per inch. If it is decided that a display location deviation of 1/64 of an inch is acceptable, then for the ten mile range selection, an error of 95 feet (6,076 per inch times 1/64 inch) would be acceptable. However, the accuracy values selected should also be consistent with the performance of the actual radar system in terms of such parameters as pulse length, PRF, display errors, and the like. In general, this approach should be used for each range scale and operational mode of the radar system being simulated.

From an operational viewpoint, it is desirable that the DRLMS accuracy be related to the actual radar system's portrayal of the earth's surface. However, a DRLMS operates on a digital data base created from DMA data, not the earth's surface. Therefore, DRLMS accuracy should be defined at the simulated radar display with respect to the DMA data base.

REQUIREMENT LESSONS LEARNED

The general approach for determining accuracy was successfully demonstrated on the C-130, KC-135, and B-52 programs. The accuracy values selected closely matched the performance of the actual radar systems and no degradation to the simulated image was detected. Using-command crew members were selected to evaluate DRLMS performance and were unable to attribute system deficiencies to accuracy.

4.9.1 **General DRLMS requirements**

4.9.1.1 **DRLMS system accuracy.** DRLMS system accuracy shall be quantitatively measured.

VERIFICATION RATIONALE (4.9.1.1)

To insure that the required level of performance has been achieved.

VERIFICATION GUIDANCE

Accuracy of the displayed image is dependent upon the entire process of transforming, storing, retrieving, and manipulating the data. Therefore, accuracy should be measured as close to the final display as possible and should not be relative to the DMA input data. An automated verification approach should be specified due to the excessive time required to manually accomplish tests, and to insure that an adequate number of test cases are considered for statistical significance.

VERIFICATION LESSONS LEARNED

3.9.1.1.1 **Terrain elevation accuracy.** Terrain elevation accuracy requirements are defined as a function of a terrain roughness index which is defined below. Terrain elevation accuracies are specified as ___________.

REQUIREMENT RATIONALE (3.9.1.1.1)

The terrain elevation accuracy requirement defines how closely the DRLMS system should be able to represent the terrain surface as compared to the source representation in the DMA digital terrain elevation data (DTED) file. Elevation accuracy is significant for purposes of overall image fidelity, terrain pattern recognition, and for simulated terrain avoidance/terrain following flight simulation.

REQUIREMENT GUIDANCE

The on-line DRLMS terrain data base is a representation of the earth's surface based upon the digital terrain file. Terrain vertical accuracy indicates how closely terrain elevation values measured near the indicator match DMA elevation values. The process of "transforming" the DMA data to an on-line format tends to become more complex, as does the on-line data structure, as the vertical accuracy requirement becomes more stringent. The present requirement philosophy is to define the vertical accuracy in a statistical manner as a function of the displayed radar range. The assumptions made are: the terrain representation over flat areas should be more accurate than that over rough areas and the greater the range displayed, the less accurate the data need be.

Table VII illustrates how terrain elevation accuracy can be specified. Terrain elevation accuracy requirements may be defined as a function of a terrain roughness index, as well as range setting or target scale. The maximum allowable mean error (μ), standard deviation of error values (σ) and error (δ max) apply to any block of data of n by n elevation values.

REQUIREMENT LESSONS LEARNED

Contractors have attempted to meet the required accuracies by the use of both complex algorithms for approximating the terrain surface and iterative processes for bringing the approximation within the statistical limits. Mean and standard deviation requirements are usually met; however, the absolute error is frequently exceeded. Although the accuracies have not always been satisfied, the resulting simulated terrain imagery has been of good quality and has provided meaningful training. However, it is not precisely known how image quality varies as a function of terrain elevation accuracy and whether a relaxation or alternate specification approach could still provide the required level of fidelity. Terrain elevation accuracy is an area that requires additional research and development effort.

TABLE VII. Terrain elevation accuracy example.

RANGE SELECTION (NM)	5	10	20	30	40	50	75	100	125	150	200
TERRAIN ELEVATION ACCURACY (FT) / μ /	α	α	α	2 α	2 α	2 α	2 α	4 α	4 α	4 α	4 α
σ	β	β	β	2 β	2 β	2 β	2 β	4 β	4 β	4 β	4 β
/ δ max /	γ	γ	γ	2 γ	2 γ	2 γ	2 γ	4 γ	4 γ	4 γ	4 γ

TERMS: / μ / = Absolute value of maximum allowable mean terrain elevation error.

σ = Standard deviation of terrain elevation error values.

/ δ max / = Absolute value of maximum allowable terrain elevation error.

The following is an example of how terrain roughness (R) has been defined on previous programs.

$$R = \frac{1}{(n-2)^2} \sum_{i=2}^{n-1} \sum_{j=2}^{n-1} \frac{\left| 2e_{i,j} - (e_{i,j+1} + e_{i,j-1}) \right| K + \left| 2e_{i,j} - (e_{i+1,j} + e_{i-1,j}) \right|}{4}$$

n	=	number of elevation elements in latitude or longitude
R	=	terrain roughness index (nondimensional)
$e_{i,j}$	=	element of an nxn terrain elevation matrix the element spacing of which are function of level and zone
$e_{1,1}$	=	elevation of southwest corner of the matrix (meters)
$e_{n,1}$	=	elevation of northwest corner of the matrix (meters)
$e_{1,n}$	=	elevation of southeast corner of the matrix (meters)
$e_{n,n}$	=	elevation of northeast corner of the matrix (meters)
K	=	$\frac{\text{COS (latitude of the nth row)} + \text{COS(latitude of the 1st row)}}{(2)\ (Z)}$ -1

α	=	$\frac{R+4}{10}$	$R<6$ $R\geq6$		1 for Zone I
β	=	$\frac{10R-8}{68}$	$R<6$ $R\geq6$	Z =	1/2 for Zone II 1/3 for Zone III
γ	=	4	all R		1/4 for Zone IV 1/6 for Zone V

The mean error, standard deviation of error values, and absolute error are defined as:

$$\mu = \frac{1}{N} \sum_{i=1}^{N} \delta_i$$

δ	=	measured elevation value--DMA elevation value
N	=	total number of DMA defined elevation values within the selected block of data ($[n]^2$)

The precision of δ is the precision of elevation as defined by DMA in the DMA DDB.

$$\sigma = \left[\frac{\sum_{i=1}^{N} (\delta i - \mu)^2}{N - 1} \right]^{1/2}$$

δ max = maximum allowable δ

4.9.1.1.1 **Terrain elevation accuracy.** Terrain elevation accuracy shall be verified by ________.

VERIFICATION RATIONALE (4.9.1.1.1)

To insure specification compliance for each range scale and display mode and to insure that verification includes a wide variety of terrain roughness.

VERIFICATION GUIDANCE

Engineering tests on the DRLMS should be the primary means of verifying terrain elevation accuracy. The contractor developed test procedures should consider the statistical nature of process measurements and the methodology should be automated in nature. Contractor demonstrations and analyses may be used to supplement the verification process.

VERIFICATION LESSONS LEARNED

Geographic area selection for terrain accuracy testing is critical. A geographical area in which a transition from flat to mountainous terrain tends to drive accuracy abnormally high at the transition edge. Consideration should be given to the necessity of selecting this type of area for testing.

3.9.1.1.2 **Planimetry elevation accuracy.** Planimetry elevation accuracies apply to all DMA-defined feature elevation. Planimetry elevation accuracies are specified as ________.

REQUIREMENT RATIONALE (3.9.1.1.2)

The planimetry elevation requirement defines how closely the DRLMS system should be able to represent the height of planimetry features compared to the source representation in the DMA digital feature analysis data (DFAD). Planimetry elevation accuracy is important when the training scenario involves low altitude flight and vertical obstructions and cultural shadows are considerations.

REQUIREMENT GUIDANCE

All DMA planimetry features are assigned an elevation value, which is defined as the height of a feature above the ground. For certain applications, such as high altitude navigation, there may be no need to require planimetry elevation. However, at low altitudes, it is necessary to consider the effects of planimetry elevation for the computation of vertical obstruction clearance and shadow. Criteria for selecting planimetry elevation accuracy have not been determined; but it would seem reasonable to associate tighter accuracies to the shorter range selections and to consider the accuracy of aircraft altitude measuring equipment such as the radar altimeter and terrain avoidance/terrain following equipment. Table VIII illustrates how planimetry elevation accuracy has been specified on previous DRLMS systems.

TABLE VIII. Planimetry elevation accuracy example.

SELECTION (NM)	3.1	6.2	12.5	60	75	100	150	200
PLANIMETRY ELEVATION ACCURACY (FT)	±25	±25	±25	±50	±50	±100	±100	±100

REQUIREMENT LESSONS LEARNED

The requirements specified on previous programs have created no design problems for DRLMS contractors and system performance has been easily verified. Evaluation of the simulated imagery and overall DRLMS performance with regard to low level flight indicates no problems associated with planimetry elevation accuracy.

4.9.1.1.2 **Planimetry elevation accuracy.** Planimetry elevation accuracy shall be verified by ________.

VERIFICATION RATIONALE (4.9.1.1.2)

To insure specification compliance for each range scale and display mode.

VERIFICATION GUIDANCE

Engineering tests on the DRLMS should be the primary means of verifying planimetry elevation accuracy. Accuracy testing may be manually accomplished since the actual process is relatively simple and quick.

VERIFICATION LESSONS LEARNED

3.9.1.1.3 **Planimetry location accuracy.** Planimetry location accuracies are defined in two ways, an absolute value and a relative value. The absolute planimetry location accuracies apply to vertices and line segments not deleted or replaced by a process of the transformation program (common to both the radar and DMA DDBs). The relative planimetry location accuracies apply to feature vertices with respect to all other intrafeature vertices which have not been deleted or replaced by a process of the transformation program. The absolute and relative planimetry location accuracy requirements in no way compromise the feature fidelity and system resolution requirements. Planimetry location accuracies are specified as ____________.

REQUIREMENT RATIONALE (3.9.1.1.3)

The planimetry location accuracy requirement defines how closely the DRLMS system should be able to position planimetric features for display as compared to their position in the DMA digital feature analysis data (DFAD) file. Location accuracy is significant for purposes of overall image fidelity and when the training scenario requires the identification and use of representations for purposes such as avionics system position update and simulated weapon delivery.

REQUIREMENT GUIDANCE

The on-line DRLMS planimetry data base is a representation of everything (natural and man-made) that sits on the earth's surface (including water and soil) and is based upon the DMA DFA file.

Planimetry location accuracy should be quantitatively specified as a function of radar range, mode selection, and radar characteristics. Absolute accuracy values are estimates based upon perceptibility of position with respect to such indicator/system references as crosshair and range marker width, and indicator size. Relative accuracy values are estimates based upon radar characteristics such as pulse length and display resolution, and upon the requirements to retain the general shape or relative geometry of features defined in the DMA DFA file.

Figures 4a and 4b further illustrate the concept of absolute and relative planimetry location accuracy. Table IX illustrates how planimetry location accuracy has been specified on previous programs.

TABLE IX. **Planimetry location accuracy example.**

SELECTION (NM)	3.1	6.2	12.5	60	75	100	150	200
Planimetry Location Accuracy (Absolute and Relative in feet)	±25	±25	±25	±50	±50	±100	±100	±100

REQUIREMENT LESSONS LEARNED

In general, the planimetry location accuracy requirements have closely paralleled the resolution of the actual radar system. However, before assigning accuracy values based strictly upon aircraft performance, it should be pointed out that planimetry location accuracy has a significant impact on DRLMS complexity and the speed at which the DRLMS computational system must operate. Contractors have attempted to meet the required accuracies by the use of complex and high speed data retrieval and processing systems. In many cases, 100 percent compliance with planimetry location accuracies would result in prohibitively costly systems. As a result, the accuracies are not always satisfied. Errors that have been encountered have resulted in no perceptible degradation to the simulated imagery, nor have they degraded the quality of training. However, it is not precisely known how image quality varies as a function of planimetry location accuracy and whether a relaxation of the accuracy values would still provide the required level of fidelity. Planimetry location accuracy is an area that requires additional research and development effort.

4.9.1.1.3 **Planimetry location accuracy.** Planimetry location accuracy shall be verified by __________.

VERIFICATION RATIONALE (4.9.1.1.3)

To insure specification compliance for each range scale and display mode, and for a wide variety of feature types.

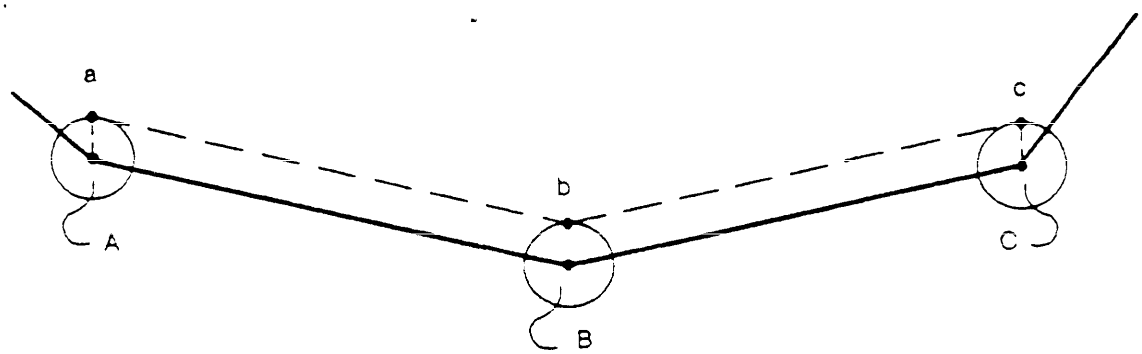
VERIFICATION GUIDANCE

Engineering tests on the DRLMS should be the primary means of verifying planimetry location accuracy. The contractor developed test procedures should consider the statistical nature of process measurements and the methodology should be automated in nature. Contractor demonstrations and analyses may be used to supplement the verification process. All methods of verification should consider the entire life history of a feature including transformation, storage, retrieval, processing, and display.

VERIFICATION LESSONS LEARNED

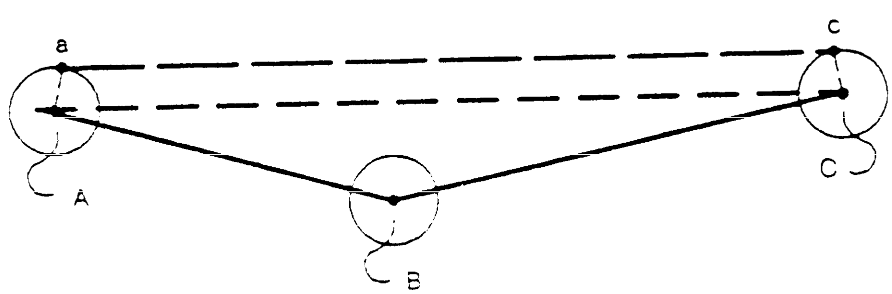
Meaningful test results have been difficult to obtain due to imprecise and slow test methods. Contractor approach to planimetry location accuracy should be carefully reviewed early in a program.

a.



Note: (1) A, B, C are DMA DDB points retained in the radar DDB as a, b, c.
(2) Aa ≤ absolute error
(3) Bb ≤ absolute error
(4) Cc ≤ absolute error
(5) /ab – AB/ ≤ relative error
(6) /bc – BC/ ≤ relative error
(7) /ac – AC/ ≤ relative error

b.



Note: (1) A, C are DMA DDB points retained in the radar DDB as a, c.
(2) B has been dropped by the transformation process
(3) Aa ≤ absolute error
(4) Cc ≤ absolute error
(5) /ac – AC/ ≤ relative error

FIGURE 4. Planimetry location accuracy.

3.9.1.1.4 **Planimetry orientation accuracy.** The true orientation of areal and lineal features is defined by the respective feature coordinates in the DMA DDB. The orientation tolerances are inherent in the accuracy and feature fidelity requirements. Orientation of point features shall be within __________ degrees of the orientation defined in the DMA DDB. Features which are aligned with respect to each other in the DMA DDB (along streets, other thoroughfares, runways, etc) shall appear to be aligned on the display such that cardinal effect can be simulated.

REQUIREMENT RATIONALE (3.9.1.1.4)

The planimetry orientation accuracy requirement defines how closely the DRLMS system should be able to represent the orientation of a point feature as compared to its orientation in the DMA DFA file. The DRLMS uses orientation data to compute the aspect or directivity effects that would be observable on radar. A radar reflector designed to provide a radar return only when the aircraft is aligned with the runway during a landing approach is a good example of the use of orientation in DRLMS processing. Orientation of areal and linear features is inherent by virtue of its representation in the DMA DFA file and therefore does not require orientation accuracy requirements.

REQUIREMENT GUIDANCE

The DMA DFA represents the orientation of point features to the nearest 11.25 degrees. Therefore, the DMA point feature representation of real world features is not highly accurate with respect to orientation. The orientation accuracy for point features will specify how accurately the transformation program and DRLMS must process feature orientation as compared to the DMA representation.

Accuracy values of 22.5 degrees have been successfully used in the past. However, there is no available information that would support either increasing or decreasing this value.

REQUIREMENT LESSONS LEARNED

Although orientation accuracy requirements have been somewhat arbitrary in nature, the results have been satisfactory. Compliance with the requirements is not a problem and tighter accuracies, if desired, can also be easily satisfied. It should be noted, however, that orientation requirements might not be compatible with an orthogonal data base structure.

4.9.1.1.4 **Planimetry orientation accuracy.** Planimetry orientation accuracy shall be verified by __________.

VERIFICATION RATIONALE (4.9.1.1.4)

To insure specification compliance for a variety of different point features.

VERIFICATION GUIDANCE

Engineering tests and analyses on the DRLMS should be the primary means of verifying planimetry orientation accuracy.

VERIFICATION LESSONS LEARNED

Subjective image evaluation has been the primary method of planimetry orientation accuracy verification. The development of a quantitative test should be considered.

3.9.1.2 DRLMS system resolution. The DRLMS shall simulate both the range and azimuth resolution of the actual aircraft radar, (e.g., one half a pulse width for range resolution and one half the power beamwidth in azimuth). Two targets separated by a relatively small distance, which can be "broken out" on the actual radar system shall likewise be "broken out" in the simulated radar system.

REQUIREMENT RATIONALE (3.9.1.2)

Radar resolution is defined as the ability of the radar to differentiate, or separate, two targets in both the range and azimuth (range and range-rate for synthetic aperture radar) directions. Simulation of the radar resolving capabilities is necessary to generate a simulated image that approximates the radar effects of the actual radar.

REQUIREMENT GUIDANCE

Quantitative requirements specifically related to resolution are not currently specified. Rather, the requirement implies that the DRLMS processing and display resolution must be identical to that of the actual radar. Contractor approaches have typically been, therefore, to implement the actual aircraft resolution parameters. However, there is no known relationship between DRLMS image fidelity compared with the radar being simulated and the values for resolution actually implemented in the DRLMS.

REQUIREMENT LESSONS LEARNED

Although actual aircraft parameters for resolution have been implemented in recent DRLMS systems, evaluations by operational crew members have indicated that, from a subjective standpoint, resolution is not realistic. The corrective action, in most cases, has been for the contractor to vary the resolution values until the image appears acceptable. The ability to easily vary resolution is, therefore, a desirable feature in DRLMS system design.

4.9.1.2 DRLMS system resolution. DRLMS system resolution shall be verified in both range and azimuth by __________.

VERIFICATION RATIONALE (4.9.1.2)

To insure specification compliance for each radar and range selection in both the range and azimuth directions.

VERIFICATION GUIDANCE

Engineering tests on the DRLMS should be the means of verifying system resolution. Test methodology should employ the DRLMS test map for system resolution and should be a quick and simple process.

VERIFICATION LESSONS LEARNED

3.9.1.3 **DRLMS processing.** All data within the field-of-view of the radar shall be processed and displayed by the DRLMS. Processing shall in no way contribute toward quantization or discrete time effects which would be perceived by a crew member under any combination of control settings and aircraft/topographic geometry. If any data compression technique (gridding, listing, truncating, etc) is employed in the representation and processing of the data contained in the DMA data base, then said technique shall not degrade the performance of the radar simulation.

REQUIREMENT RATIONALE (3.9.1.3)

Despite specific accuracy resolution, and data density requirements, additional requirements are applicable to the image generation process in order to assure a realistic presentation. Those requirements specifically relate to the digital processing techniques that can cause undesirable effects on the simulated imagery.

REQUIREMENT GUIDANCE

The requirement for the processing and display of all data is intended to eliminate the possibility of "missed" or "dropped" features. The DRLMS system should be capable of generating an image without loss of data provided by the transformation program. In addition, the method of processing the data should not introduce unrealistic effects--concentric rings, stairstep effects, grid, ghost images, block feature representation, etc--into the image, unless those effects are characteristic of the actual radar being emulated.

REQUIREMENT LESSONS LEARNED

Current DRLMS systems have no problem processing all of the data provided by the transformation program. However, with almost every DRLMS system developed, a new image anomaly is discovered. Although software changes may reduce or sometimes eliminate the effects, in many cases problems may still lie in the basic system design. Therefore, without the aid of more definitive DRLMS processing requirements, it is essential to understand and carefully analyze the DRLMS design during each formal design review. Areas that should be closely evaluated include the precision of computations, interpolation techniques, data base structure, etc.

4.9.1.3 **DRLMS processing.** DRLMS processing requirements shall be verified by __________.

VERIFICATION RATIONALE (4.9.1.3)

To insure that no data is lost during processing and that no undesirable effects can be observed.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying processing requirements. Verification of no lost data should be objectively determined by following the test procedure. Image quality can only be determined in a subjective manner, preferably with crew members' assistance.

VERIFICATION LESSONS LEARNED

3.9.1.4 Data base coordinate system. The coordinate system(s) which are either explicit or implicit in the radar data base and real time radar processing shall accommodate simulated missions without perceptible interruption of the radar display and within the accuracies specified herein to the geographic extent defined below: ___________.

REQUIREMENT RATIONALE (3.9.1.4)

Based upon the simulator training objective, the DRLMS will be required to process and display simulated radar video in a continuous, real-time manner. Simulator training objectives may be limited to a single geographic gaming area or may require continuous worldwide coverage. The complexity of a data base coordinate system increases as the area of coverage becomes greater, as the length of the mission increases, and as the data base latitude approaches 90 degrees north or south. Therefore, it is important to specify the limits to which the DRLMS will need to "fly".

REQUIREMENT GUIDANCE

The requirement for data coordinate systems should state the geographic limits for the area of coverage. For example, the requirement might state "unrestricted worldwide flight", "worldwide flight within ±70 degrees latitude", or "unrestricted flight below 50 degrees and within 90-120 degrees west longitude".

REQUIREMENT LESSONS LEARNED

For small geographic areas at low latitudes (less than 50 degrees), data base coordinate systems are relatively easy to implement. However, system development delays and design deficiencies have been encountered on systems with worldwide flight requirements. It is important to carefully evaluate the proposed approach to data base coordinate systems and to insure that the contractor has thoroughly evaluated the problem and is not providing any greater complexity than is required.

4.9.1.4 **Data base coordinate system.** Data base coordinate system requirements shall be verified within the limits of geographic coverage by ___________.

VERIFICATION RATIONALE (4.9.1.4)

To insure that the DRLMS will operate without interruption anywhere within the required area of geographic coverage.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying coordinate requirements. Data base test maps covering the geographic extremes of the required area of coverage should be included as part of the test methodology.

VERIFICATION LESSONS LEARNED

There is a large amount of interdependence between data base management and the data base coordinate system. Consideration should be given to the relationship between the test procedures for these two areas.

3.9.1.5 Correlation with other systems. The following categories of information processed and displayed by the DRLMS shall correlate with the corresponding information contained in the sensory stimuli provided by the following simulated systems: __________.

REQUIREMENT RATIONALE (3.9.1.5)

Operational flight procedures require the utilization of a number of different sensor inputs. The correlation of flight information from a variety of sources that need to be correlated might include radio navigation aids, aircraft navigation equipment, radar, infrared sensor, and visual cues. This requirement is to insure correlation among the various simulated systems.

REQUIREMENT GUIDANCE

State the simulated systems and sources of flight information which should be correlated with the radar. Potential systems are radio navigation aids, aircraft navigation equipment, radar, infrared sensor, and visual cues. Quantitative correlation requirements for parameters such as position, velocity, and altitude have not been defined for previous DRLMS systems. However, for future systems, like inertial navigation and synthetic aperture radar, the need for correlation becomes greater. Consideration should therefore be given to developing quantitative requirements for correlation. In addition, the requirements for a standard topographic reference, such as DMA Level 1 DFAD, should be considered.

REQUIREMENT LESSONS LEARNED

The contractor approach to correlation has consisted primarily of establishing a single set of aircraft "state" information and sharing that information among all simulated systems. From a flight standpoint, performance has been acceptable. Little effort, however, has been devoted to the correlation of data base content among the different image generation systems.

4.9.1.5 Correlation with other systems. DRLMS correlation with other simulator systems shall be verified by __________.

VERIFICATION RATIONALE (4.9.1.5)

To insure that related simulator systems are properly integrated and that each system receives the correct information.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying DRLMS correlation. Test methodology should include quantitative measurement of the correlation requirements although subjective evaluation by crew members may also be required. Integrated simulator operation is required.

VERIFICATION LESSONS LEARNED

3.9.1.6 DRLMS positioning. The capability shall be provided to reset the DRLMS position (aircraft position) or initially position the DRLMS, from any point within the radar data base to any other point within the radar data base, within __________.

REQUIREMENT RATIONALE (3.9.1.6)

For purposes of simulator geographic initialization at the beginning of a mission or position reset during a mission, the DRLMS must be capable of quickly loading its field-of-view memory. This requirement insures that the time required to accomplish a DRLMS position reset is kept to a minimum.

REQUIREMENT GUIDANCE

Depending upon the data density and the field-of-view of coverage, field-of-view memory may be as large as 30-50 megabytes of storage, which may have to be entirely loaded from the gaming area memory. Therefore, it is necessary to consider data transfer design limitations as well as the desire to minimize the time. Previous specifications have required that it should take no greater than two minutes to move the DRLMS anywhere within the data base.

REQUIREMENT LESSONS LEARNED

Current DRLMS design practice permits DRLMS positioning to take place within about 90 seconds. Any time within two minutes is compatible with normal training procedures.

4.9.1.6 DRLMS positioning. The capability to reset DRLMS position anywhere within the data base within the required time shall be verified by __________.

VERIFICATION RATIONALE (4.9.1.6)

To insure that the DRLMS can be repositioned within the required time constraint.

VERIFICATION GUIDANCE

The requirements can be quickly and easily verified with either a simple test or demonstration using only a stopwatch.

VERIFICATION LESSONS LEARNED

3.9.1.7 DRLMS terrain occulting. The DRLMS shall interface with other aircraft systems to provide terrain occulting for the following purposes: __________.

REQUIREMENT RATIONALE (3.9.1.7)

Certain aircraft and ground systems, such as radio navigation aids, communication radios, ground based radar, and missile/artillery tracking systems, are affected by terrain occulting. The DRLMS is the primary source of terrain elevation information necessary to compute the effects of occulting. This requirement insures that terrain occulting information required by other simulated systems is generated by the DRLMS.

REQUIREMENT GUIDANCE

The requirement should be stated in terms of those simulated systems (navigation aids, radios, JARMS) that require terrain occulting. No quantitative requirements or tolerances are assigned to the DRLMS occulting requirement.

REQUIREMENT LESSONS LEARNED

No difficulties have been encountered in the design of the occulting capability nor in subjective evaluation of occulting performance.

4.9.1.7 **DRLMS terrain occulting.** DRLMS capability to compute terrain occulting and provide this information to other simulator systems shall be verified by ________.

VERIFICATION RATIONALE (4.9.1.7)

To insure that all simulator systems requiring terrain occulting status receives the correct information.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying terrain occulting. Tests should be quantitative in nature and should be accomplished while the simulator is operating in an integrated mode of operation. A test map consisting of terrain obstruction and JARM locations might be useful.

VERIFICATION LESSONS LEARNED

3.9.2 **Radar controls and displays.** All controls and displays associated with the radar shall be provided and shall be an exact replica of those on the actual system with the following exceptions: ________. All required radar controls shall be operative and shall permit the required modes and capabilities of the radar to be operated. The interaction among all controls, functions, and displays shall be simulated in accordance with design criteria. The simulated radar indicator shall be capable of the following display characteristics: ________.

REQUIREMENT RATIONALE (3.9.2)

In order to teach aircraft systems operation, flight procedures, and mission rehearsal, simulated systems must appear and operate like the aircraft system to the extent possible. This requirement is to insure a close correlation between the simulated radar's physical appearance and operation, and the actual radar.

REQUIREMENT GUIDANCE

a. State which radar controls and displays need to be provided for appearance and which need to be operational.

b. Specify the radar display/indicator characteristics required by the training objectives.

Due to the lack of any information defining display characteristics as a function of training objectives, the approach usually taken has been to specify duplication of aircraft performance and characteristics.

REQUIREMENT LESSONS LEARNED

This requirement is usually met by using either GFE aircraft hardware or by manufacturing duplicate hardware using aircraft drawings. Although this approach provides realistic appearance, the cost of refurbishment and maintenance of aircraft hardware may be greater than permitting the contractor to approximate the appearance and performance with hardware which is designed and manufactured exclusively for the simulator. Therefore, both long and short term implications of specifying radar controls and displays should be carefully evaluated.

4.9.2 Radar controls and displays. Replication of all required controls and displays, and simulation of system operating modes and capabilities shall be verified by __________.

VERIFICATION RATIONALE (4.9.2)

To insure that system operation is in accordance with the specification and design criteria.

VERIFICATION GUIDANCE

Operational tests and demonstrations based upon aircraft system design documentation and technical order checklists should be the primary means of verifying radar controls and displays requirements. Crew members' assistance is helpful while testing these requirements.

VERIFICATION LESSONS LEARNED

Crew members' evaluation of system performance may conflict with the design criteria. Differences discovered in this manner should be analyzed before submitting to the contractor.

4.9.1.7 **DRLMS terrain occulting.** DRLMS capability to compute terrain occulting and provide this information to other simulator systems shall be verified by __________.

VERIFICATION RATIONALE (4.9.1.7)

To insure that all simulator systems requiring terrain occulting status receives the correct information.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying terrain occulting. Tests should be quantitative in nature and should be accomplished while the simulator is operating in an integrated mode of operation. A test map consisting of terrain obstruction and JARM locations might be useful.

VERIFICATION LESSONS LEARNED

3.9.2 **Radar controls and displays.** All controls and displays associated with the radar shall be provided and shall be an exact replica of those on the actual system with the following exceptions: __________. All required radar controls shall be operative and shall permit the required modes and capabilities of the radar to be operated. The interaction among all controls, functions, and displays shall be simulated in accordance with design criteria. The simulated radar indicator shall be capable of the following display characteristics: __________.

REQUIREMENT RATIONALE (3.9.2)

In order to teach aircraft systems operation, flight procedures, and mission rehearsal, simulated systems must appear and operate like the aircraft system to the extent possible. This requirement is to insure a close correlation between the simulated radar's physical appearance and operation, and the actual radar.

REQUIREMENT GUIDANCE

a. State which radar controls and displays need to be provided for appearance and which need to be operational.

b. Specify the radar display/indicator characteristics required by the training objectives.

Due to the lack of any information defining display characteristics as a function of training objectives, the approach usually taken has been to specify duplication of aircraft performance and characteristics.

REQUIREMENT LESSONS LEARNED

This requirement is usually met by using either GFE aircraft hardware or by manufacturing duplicate hardware using aircraft drawings. Although this approach provides realistic appearance, the cost of refurbishment and maintenance of aircraft hardware may be greater than permitting the contractor to approximate the appearance and performance with hardware which is designed and manufactured exclusively for the simulator. Therefore, both long and short term implications of specifying radar controls and displays should be carefully evaluated.

4.9.2 Radar controls and displays. Replication of all required controls and displays, and simulation of system operating modes and capabilities shall be verified by ___________.

VERIFICATION RATIONALE (4.9.2)

To insure that system operation is in accordance with the specification and design criteria.

VERIFICATION GUIDANCE

Operational tests and demonstrations based upon aircraft system design documentation and technical order checklists should be the primary means of verifying radar controls and displays requirements. Crew members' assistance is helpful while testing these requirements.

VERIFICATION LESSONS LEARNED

Crew members' evaluation of system performance may conflict with the design criteria. Differences discovered in this manner should be analyzed before submitting to the contractor.

3.9.3 Radar system operational capabilities. The following operational capabilities of the radar shall be simulated: ___________. The requirements of each of the following paragraphs shall be met for each radar capability:

a. Modes of operation.

b. Unique characteristics.

c. Malfunctions.

REQUIREMENT RATIONALE (3.9.3)

The radar system being simulated may have more than one operational function. Different capabilities that may require simulation include conventional air-to-ground mapping, high resolution air-to-ground mapping, terrain avoidance/terrain following, air-to-air search, and beacon interrogation. Each of these functions have their own modes of operation, unique characteristics, and typical malfunctions. This requirement is to insure that the operating capabilities required for training are provided and that the desired modes of operation, unique characteristics, and malfunctions are simulated.

REQUIREMENT GUIDANCE

Specify the operational capabilities which shall be simulated. Examples are: conventional air-to-ground mapping, high resolution air-to-ground mapping, terrain avoidance/terrain following, air-to-air search, and beacon interrogation.

In order to specify this requirement, a detailed analysis of the radar design and operational capabilities is required. In addition, it is necessary to obtain an operational insight into the actual use of the system, how it performs, and which characteristics are significant to its performance. This requirement should be stated in terms of which capabilities should actually be simulated by the contractor (conventional air-to-ground mapping, terrain following, beacon interrogation), which modes of operation should be simulated (PPI, off-center sector, spotlight), which unique characteristics should be simulated (required operational techniques, operational procedures not covered by the checklists, operational characteristics not described by the technical orders), and which malfunctions should be simulated. In addition, consider what can be omitted without sacrificing training objectives. For example, if a radar system's 200-mile range capability is rarely used and is of little training significance, then the requirement to simulate the 200-mile range should be questioned if it tends to drive system cost and complexity. It is very helpful to give the contractor photographs of the real radar system imagery to help illustrate the modes of operation, significant display characteristics, and malfunction display manifestations. Each simulated radar system capability should have its own unique requirements and may actually involve physically separate aircraft components.

REQUIREMENT LESSONS LEARNED

The identification of requirements for the simulation of existing radar systems tends to be relatively simple since an abundance of documentation usually exists and the operational capabilities are well known as a result of crew member experience. Crew members are usually happy to describe the performance of their system in great detail. The requirements for new aircraft radar systems are much more difficult to define. It is necessary to obtain basic design information even if preliminary in nature, obtain imagery from test flights if it is available, and to discuss intended system utilization with the using command. In addition, independent (contract) evaluations of system performance viewed from a simulation standpoint may be useful.

4.9.3 **Radar systems operational capabilities.** The modes of operation, unique characteristics, and required malfunctions shall be verified by __________.

VERIFICATION RATIONALE (4.9.3)

To insure that each required capability and mode has been simulated and that unique characteristics and malfunctions are in accordance with design criteria.

VERIFICATION GUIDANCE

Operational tests, analyses, and demonstrations based upon aircraft system design documentation, technical order information, and technical order checklists should be the primary means of verifying system operational capabilities. Although quantitative test procedures are desirable whenever possible, most will likely be subjective in nature. Crew member review of test methodology and assistance during the test process is recommended.

VERIFICATION LESSONS LEARNED

3.9.4 **Radar effects.** Radar effects shall be simulated and shall include those effects associated with the radar sensor and signal processor, the atmospheric environment, and with radar signal interaction with the target/earth's surface. The following specific effects shall be simulated: __________.

REQUIREMENT RATIONALE (3.9.4)

The physics involved with radar image generation give rise to certain effects that cannot be avoided. These effects may either enhance or degrade the radar imagery and may or may not be controllable by the radar designer. For example, the radar range is going to be physically limited by both obstructions, such as mountains and buildings and by the earth's horizon. On the other hand, the designer can influence receiver noise and resolving capabilities.

A DRLMS system is an attempt to model what the real radar is capable of doing--whether good or bad--and is not limited by physical constraints in the same way as the real radar. For example, a real radar cannot image behind mountains. However, a DRLMS will provide an image behind mountains unless it is specifically designed not to. The radar effects requirement is to insure that all effects characteristics of the real radar are provided in the DRLMS.

REQUIREMENT GUIDANCE

Certain radar effects are well defined and have been simulated on previous DRLMS systems. These effects include:

a. Shadow. Terrain shadows and cultural shadows should be computed and displayed. The data contained in the digital data base should be utilized to produce accurate and realistic shadow effects. Realistic transition between the radar line-of-sight (interference and shadow diffraction) regions should be simulated, with emphasis on the simulation of shadows cast by objects narrower (in azimuth direction) than the system beamwidth. There should not be any shadow for objects which cast no shadow in the real world (metal girder structures, nonsolid features, etc).

b. Range and atmospheric attenuation. Range attenuation and atmospheric attenuation should be simulated for all radar returns.

c. Pulse length error. Pulse length error is defined as the distortion in the range direction on the far side of a reflector due to the finite duration of the pulse.

d. Refraction and earth curvature. The use of the 4/3 effective earth's radius approximation is acceptable to meet this requirement.

e. Far shore brightening. Simulation should accommodate the simulated energy pulse passes from water to land, as on the far shore of a lake or river. The radar scope image of the far shore shall be brightened as a function of the far shore aspect angle and the radar reflectivity value to realistically simulate reflections of the radar energy. Aspect dependence should be such that a zero-sloped far shore should result in no far shore brightening. In addition, the far shore brightening simulation should be provided for other than land transition, such as dry lake to land transition.

f. Aspect simulation. The aspect simulation should be a function of both the horizontal aspect angle and the vertical aspect angle. Aspect point effects should be computed for each resolution element. Glitter effects should be simulated.

g. Low level effects. Simulation of returns which are radar significant only for low absolute altitudes should be provided. The radar return energy should be a function of aircraft altitude as well as other radar effects. These returns should blend in with the surrounding area or start to disappear as the aircraft increases in altitude.

h. Antenna pattern simulation. The antenna of the radar should be simulated, including stabilization, gimbal limitations, and tilt. All antenna scan patterns and scan modes should approximate those of the actual radar. Distortions and losses due to the radome should be simulated if perceptible on the radar indicator. The simulated azimuth beam pattern should approximate the actual beam pattern. A means to bypass azimuth beam spread simulation should be provided.

i. Seasonal effects. Snow and rough ice cover which causes scope reversals as defined in AFM 51-40 should be simulated as a function of latitude and time of year (ice cap location as defined in DMA DDB). Seasonal effects could be simulated in real time as a function of multiple parameters such as geographic location, topography elevation, type of topography, time of year, etc. Examples of desired effects are variation in radar return due to soil moisture content, amount of foliage, amount of crop growth, etc.

j. Receiver noise. The receiver dynamic range and transfer characteristics should approximate the actual aircraft system. Noise input to the receiver and noise generated by the receiver should be simulated. The simulation should provide easy access and variable control of the peak power in the noise simulation.

k. Pulse integration. The effects of display pulse integration due to multiple target "hits" should be simulated. Development of this requirement involves an analysis of real radar imagery and discussions with crew members to determine which effects are significant and need to be simulated. In addition, advanced high resolution radar systems will likely have their own unique characteristics which need to be defined.

The requirement should list each of the desired effects. For each effect, a description of the effect's manifestation in the imagery, the extent or limitations to which simulation should be accomplished, and any specific guidance should be provided. Although highly desirable, few quantitative requirements have been developed for radar effects.

REQUIREMENT LESSONS LEARNED

Many DRLMS designers have no idea what an aircraft radar looks like. Therefore, the implementation of radar effects in a DRLMS has not necessarily correlated to the appearance of the "real world" effects. It is, therefore, essential to make the requirement as specific as possible, to critically evaluate the contractor's design approach at each technical review, to provide radar imagery illustrating each of the effects, and to obtain the assistance of using-command crew members throughout the program.

4.9.4 **Radar effects.** Each required radar effect shall be verified by __________.

VERIFICATION RATIONALE (4.9.4)

To insure specification compliance for each each radar effect.

VERIFICATION GUIDANCE

Engineering and operational tests, analyses, and demonstrations should be the primary means of verifying system operational capabilities. Tests maps created for each radar effect should be part of the test methodology as well as portions of the gaming area exhibiting each effect. Test procedures should result in both quantitative and qualitative information. Engineering tests should emphasize the quantitative aspects (e.g., accuracies, resolution, distances, etc) while operational tests should emphasize the qualitative aspects (e.g., image quality, appearance, realism, etc). Crew member evaluation during operational testing is recommended.

VERIFICATION LESSONS LEARNED

Although test maps are useful and should be the primary means for engineering testing, verification using the actual radar data base should not be overlooked.

3.9.5 **Radar landmass digital data base**

3.9.5.1 **DMA digital data base.** The DMA DDB shall be the source data base for the DRLMS. This DDB is defined within the Defense Mapping Agency Product Specification for Digital Landmass System data base, and will be provided by the Government.

REQUIREMENT RATIONALE (3.9.5.1)

Air Force policy requires that all digital cartographic data base requirements be submitted in accordance with Air Force Regulation 96-9 to Air Force Intelligence Service for subsequent coordination with DMA. In most cases, contractor developed source data is not considered an acceptable alternative. This requirement is to insure the utilization of DMA data as the basic source for ground mapping radar simulation. A topographic data base is not required for air-to-air modes.

REQUIREMENT GUIDANCE

This requirement states that DMA data will be the source for the DRLMS and that the definition of the DMA data is contained within the DMA Product Specification. The geographic area of coverage that will be required for simulator data base development needs to be defined early enough in a program to provide the necessary data base delivery lead time. The amount of lead time required will be a function of the amount of the data required, whether the data already exists in DMA's cartographic data base or must be produced, and whether the data requested is a standard DMA product or will require new development. For most DRLMS programs, an acceptable approach is to utilize existing DMA data within the continental United States covering approximately 500,000 square nautical miles. The specific geographic area requested from DMA should be coordinated with the using-command and submitted in accordance with AFR 96-9 approximately six months prior to an anticipated contract award.

REQUIREMENT LESSONS LEARNED

Most contractors with DRLMS development experience have utilized DMA data on previous programs. However, many difficulties have been encountered using the data as a result of errors within the data, misinterpretation of data base specifications, and faulty software design approaches. Specific problems encountered on past programs should be reviewed as part of the specification definition process. Requests to DMA for data should specify the application of ASD/ENETV-developed error correction software.

4.9.5 Radar landmass digital data base

4.9.5.1 DMA digital data base. Tests shall be conducted to verify the performance of the data base.

VERIFICATION RATIONALE (4.9.5.1)

To insure that DMA data is the source for the radar data base.

VERIFICATION GUIDANCE

Analyses of the contractor's basic design in conjunction with inspection of the resulting data base is an adequate means of verifying DMA data base utilization.

VERIFICATION LESSONS LEARNED

3.9.5.2 **Radar digital data base.** The radar DDB shall be produced from the DMA DDB using the digital data base transformation program (DDBTP). The radar DDB storage devices shall be sufficient to store a minimum of ___(a)___ square nautical miles of data. While the aircraft is "flying" in an undefined (by DMA) area of the radar data base, the DRLMS shall provide a display using ___(b)___.

REQUIREMENT RATIONALE (3.9.5.2)

In order to convert the DMA data base format within the appropriate descriptive radar characteristics, the contractor must develop a digital data base transformation program (DDBTP) to accomplish the task. This requirement is to insure that a DDBTP is developed by the contractor, that the DRLMS is capable of storing an adequate amount of the transformed radar data base, and that provisions are included in the contractor's DRLMS design to generate imagery when data is unavailable in a particular area.

REQUIREMENT GUIDANCE

a. The on-line mass storage requirement should be based upon using-command training objectives such as the anticipated length of typical training missions, the maximum range of the radar being simulated, and the required data base density. Typical mass storage requirements have ranged from 400,000 to 600,000 square nautical miles which can easily be accommodated by three 300 megabyte disks, depending upon the data file structure and data compression techniques. Advances in data storage technology will permit larger geographic areas to be stored on-line at equivalent or lower costs in the future.

b. If the DRLMS is "flown" outside the defined gaming area or a block of data is missing, it is desirable that alternative image generation capability be provided; for example, if a large area of water is not specifically defined by the "no-show" appearance of water reflectance returns. If, however, data is missing within a land formation, a simplified form of artificial terrain could be displayed. The artificial terrain might also include a random distribution of artificial cultural objects. However, artificial image generation requirements can increase DRLMS complexity and cost and should be specified only to the level which can be justified for training. If artificial data is to be created by the transformation process, a record must be maintained to insure that the artificial data is replaced when real data becomes available.

REQUIREMENT LESSONS LEARNED

Problems related to the development of the DDBTP are primarily related to the data base described in 3.9.5.1. Since DMA is the recipient and operator of the DDBTP, specification development, proposal evaluation, design reviews, and testing should be closely coordinated with DMA. DMA has provided a high level of support, especially during program testing on previous programs.

No problems have been encountered by contractors in meeting the DRLMS mass storage requirements. The approach taken has been simply to provide an adequate number of data storage devices. Default imagery outside the gaming area has typically been provided by a single default reflectance and terrain elevation value which has met most training requirements, although a more elaborate scheme may be required for future systems.

4.9.5.2 **Radar digital data base.** The requirements for the DDBTP shall be verified. Verification of DDB mass storage requirements and image generation outside the radar data base shall be accomplished by ___________.

VERIFICATION RATIONALE (4.9.5.2)

The intent of radar digital base verification is to insure compliance with and to insure the capability to store the required data base area of coverage. Specific requirements will vary depending on when the transformation process is performed, e.g., support center or Defense Mapping Agency.

VERIFICATION GUIDANCE

Verification of the DDBTP should be accomplished in accordance with specific system requirements. Engineering tests and demonstrations should be the primary means of verifying data base storage capability and default image generation. Test methodology used to verify default image generation should take into account a variety of different topographic situations.

VERIFICATION LESSONS LEARNED

3.9.5.3 DDB densities. The DRLMS system shall be designed to accommodate (transform, store, transfer, process, and display) gaming areas with data densities as defined below:

a. Digital terrain elevation data (DTED): Terrain elevation data density requirements are defined within the DMA Product Specification.

b. Digital feature analysis data (DFAD): Feature analysis data density requirements are defined as follows: ____(a)____. Features may be all point or areal features or any combination of point, lineal, or areal features. The DRLMS system shall handle the following total data mix of DMA feature analysis data base levels: ____(b)____.

REQUIREMENT RATIONALE (3.9.5.3)

The density of the radar data directly impacts the size, speed, and complexity of the DRLMS data storage, retrieval, and processing subsystems. Although the density and feature content of Level 1 data is not adequate for high resolution radar modes, higher resolution data requirements over large geographic areas for conventional, medium resolution, ground mapping radar modes would result in a prohibitively complex and expensive DRLMS system. This requirement gives the contractor sufficient quantitative guidance to design the DRLMS system within limits that will correspond to the capabilities of the radar being simulated and the training requirements of the using command.

REQUIREMENT GUIDANCE

a. For each level of feature analysis, density should be specified as a function of the area of coverage. Figures 5a and 5b are examples of how feature analysis data density can be specified. The requirements would apply to all portions of the DRLMS system (radar data base, data retrieval and processing, etc). Figure 5a indicates that within any 75-nm radius circle in any area covered by Level 1 feature analysis data base, there may be up to 25 square nm of data with density of 40 features/sq nm. This high density data may be in many small pockets or may be in one continuous 25 sq nm region. Similarly, there may be up to 60 sq nm Level 1 data with a density of 35 features/sq nm over any 75-nm radius circle. Any DRLMS which supports a 75-nm range scale should accommodate an average of 7.62 features/sq nm over any 17,671 sq nm areas. This does not mean that the radar DDB (or the DMA DDB) will contain only 79,500 total features, but that for the purpose of scoping the DRLMS, the contractor should assume that the largest continuous area of Level 2 coverage can be circumscribed by a 30-nm radius circle. The actual values of data density finally selected should take into consideration the density of the DMA feature analysis data to be used, anticipated synthetic enhancement which may increase the data density, and the resolution and overall image quality of radar being simulated. Care should be taken not to overspecify this requirement. There is no specific data density requirement for terrain elevation data.

b. State which levels of DMA data are required and how good the coverage must be. ("100 percent coverage of Level 1 feature analysis data and 10 percent coverage of Level 2 data.")

REQUIREMENT LESSONS LEARNED

DRLMS designers have easily met the data density requirements stated for previous DRLMS systems without producing excessively complex systems. Using command crew members have found the resulting imagery has been subjectively acceptable, within the limits of the DMA feature analysis data base content itself. Limitations in the imagery with regard to data density can be directly related to the DMA data and not to the storage/processing capability of the DRLMS systems.

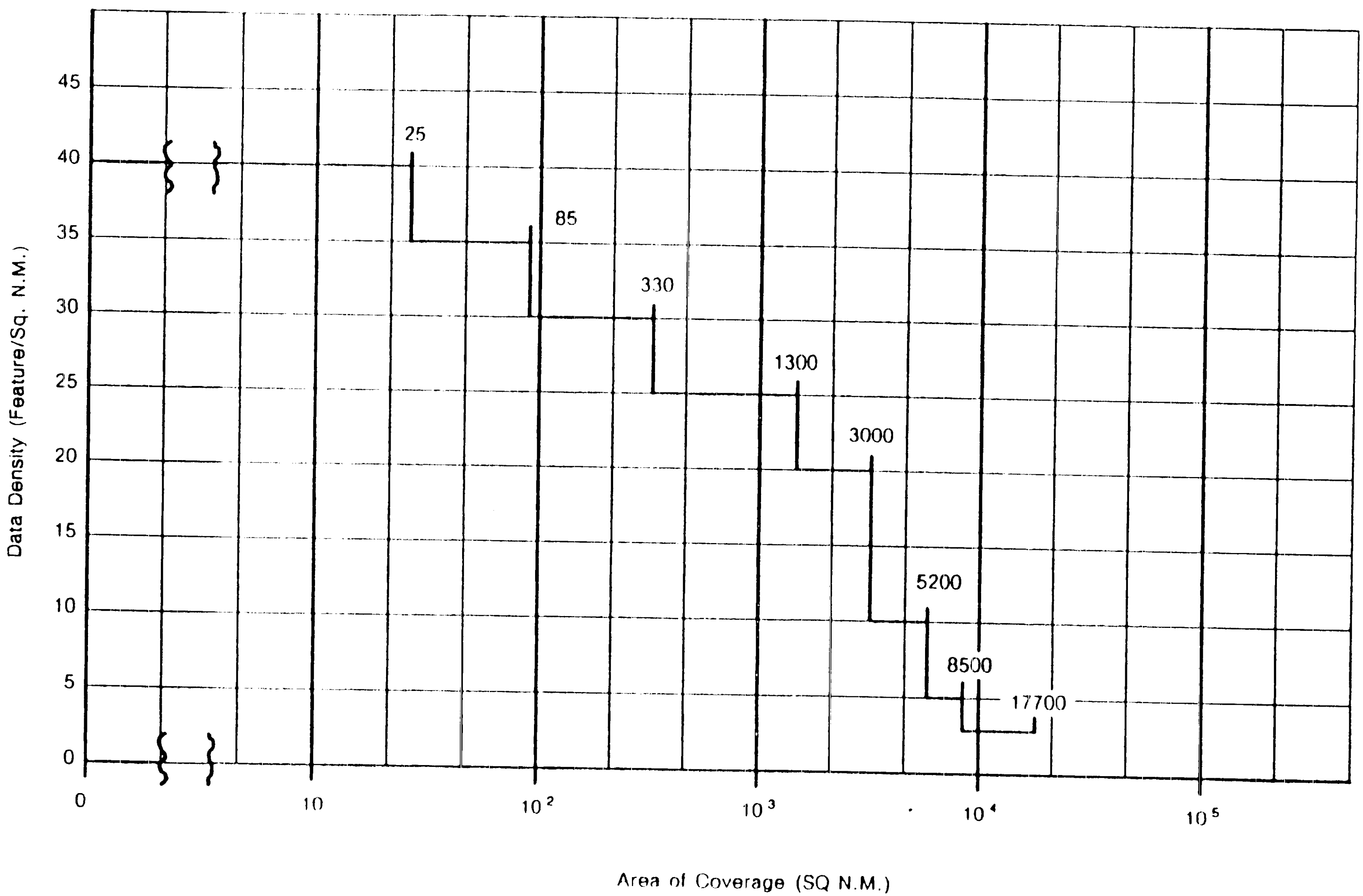


FIGURE 5a. Feature analysis data densities of Level 1 vs. area of coverage.

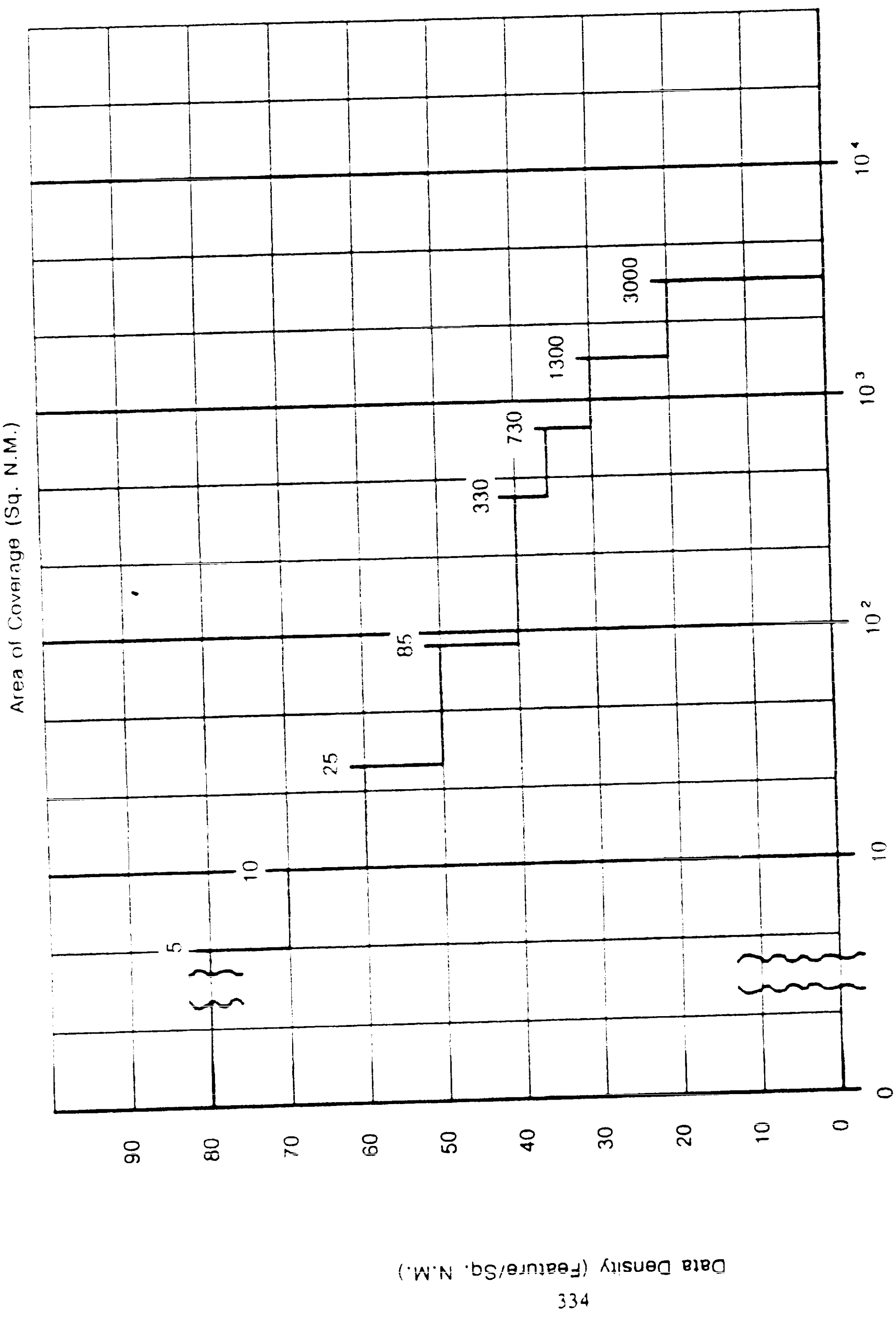


FIGURE 5b. Feature analysis data densities of Level 2 vs. area of coverage.

4.9.5.3 **DDB densities.** Accommodations of the required levels of DMA data shall be verified by __________. DDB density requirements for feature analysis data shall be verified by __________.

VERIFICATION RATIONALE (4.9.5.3)

To insure specification compliance of data base density for each required level of DMA data.

VERIFICATION GUIDANCE

Engineering tests and analyses should be the primary means of verifying data base density requirements. Tests should be quantitative in nature and should utilize test maps generated by either DMA or the contractor. Particular attention should be given to DRLMS system response if the data density requirements are exceeded.

VERIFICATION LESSONS LEARNED

3.9.5.4 **DDB levels.** The DMA terrain elevation data, levels of feature analysis data, and the previously defined densities shall be assigned to the selected radar modes and range selections as follows: __________.

REQUIREMENT RATIONALE (3.9.5.4)

Greater resolution and image detail is generally observed on radar when a small geographic area or a short range is selected. The training device must simulate this effect. This requirement is to insure that the appropriate level of DMA data is applied to each of the radar ranges and display modes.

REQUIREMENT GUIDANCE

The radar modes and ranges should be evaluated from a resolution and image quality standpoint and then correlated with the DMA data. Level 1 data (both terrain elevation and feature analysis) will normally be required for all intermediate and long ranges. Level 2 or High Resolution feature analysis data should be used for short ranges and high resolution modes if Level 1 data will not suffice. Level 1 feature analysis should also be required for the short ranges and high resolution modes if higher resolution data is not available in a particular geographic area. An interim solution, if acceptable to the using command, might be the application of synthetic enhancement to the existing Level 1 data. The need for Level 2 terrain elevation data has not been established; acceptable simulated imagery has been obtained using Level 1 terrain elevation data. Requirements for higher resolution data bases result in high DMA production costs, additional transformation program complexity, greater DRLMS data storage requirements, and increased DRLMS processing complexity.

REQUIREMENT LESSONS LEARNED

For low resolution radar systems (greater than 200 feet), high quality simulated images have been obtained using exclusively Level 1 feature analysis and terrain elevation data. The lack of data base content and detail is only noticed at the shortest ranges (less than 5 miles) and low altitudes (less than 500 feet).

For medium resolution radar systems (100 and 200 feet), high quality imagery has been obtained using Level 2 feature analysis data for the short ranges and Level 1 data in all other areas. The lack of data base content is also noticed at short range and low altitudes.

For high resolution systems (10 to 100 feet), the High Resolution data base should be considered.

4.9.5.4 DDB levels. The required assignment of DMA DDB levels of data to each mode and range selection shall be verified by ________.

VERIFICATION RATIONALE (4.9.5.4)

The intent of data base level verification is to insure that the correct level of DMA data has been used for each required radar mode or range selection.

VERIFICATION GUIDANCE

Engineering tests and analyses should be the primary means of verifying data base level requirements. The methodology should include inspections of the simulated radar image and plots of the data base to insure that the correct level of data is available and has been processed. Plots of the DMA source data should be available for comparison purposes.

VERIFICATION LESSONS LEARNED

3.9.5.5 **Radar reflectivity codes.** There shall be at least ___(a)___ basic radar reflectivity codes into which topography shall be quanitized. The assignment of the reflectivity codes to the data in the DMA DDB shall be accomplished by the transformation program. The dynamic range of basic radar returns shall be at least ___(b)___ dB. The dynamic range of basic radar returns for each reflectivity code shall not be restricted within the ___(b)___ dB range. Once a return level has been assigned to a reflectivity code, it shall be possible to easily modify the return level without changing any other reflectivity code assignment. The ___(a)___ levels shall be used to represent various topography.

REQUIREMENT RATIONALE (3.9.5.5)

The DDBTP must be capable of assigning reflectivity codes to data base features as a function of their physical attribute descriptors such as surface material and feature identification code. The DRLMS must then be capable of assigning a power value to each of the data base features as a function of reflectivity code and the relational geometry between the aircraft and the feature. This requirement is to insure a sufficient number of possible reflectivity code assignments and sufficient range for reflectance power assignments.

REQUIREMENT GUIDANCE

a, b. Sixteen levels of reflectance codes and a dynamic range of 100 dB have been specified on previous DRLMS systems. The use of 32 reflectivity codes has been advocated by several contractors on previous programs to support special situations such as seasonal effects. Additional codes may be required for special effects associated with high resolution radar systems. No studies or evaluations have been completed which might indicate the performance and/or cost benefit of varying these requirements. Compliance with these requirements on previous programs has not been difficult and the results have been subjectively acceptable.

REQUIREMENT LESSONS LEARNED

4.9.5.5 **Radar reflectivity codes.** All required levels of reflectivity codes and their required dynamic range shall be verified by ___________.

VERIFICATION RATIONALE (4.9.5.5)

To insure that the specified number of codes and dynamic range have been provided.

VERIFICATION GUIDANCE

Engineering tests and analyses should be the primary means of verifying reflectivity code requirements. A combination of quantitative and qualitative test methods should be provided. A test map to aid in verification should also be provided.

VERIFICATION LESSONS LEARNED

3.9.5.6 **Object data.** A library of objects shall be provided for insertion into any mission. This library shall include EC threat sites, craters, moving targets, beacons, and expendables. Approximate radar cross sections and codes shall be included.

REQUIREMENT RATIONALE (3.9.5.6)

Radar returns unique to mission specific requirements are required for correlation of the radar with other simulations.

REQUIREMENT GUIDANCE

The types of objects required should be included. Those listed are the ones normally required for most ATDs.

REQUIREMENT LESSONS LEARNED

4.9.5.6 **Object data.** The library of objects shall be verified.

VERIFICATION RATIONALE (4.9.5.6)

To assure compliance.

VERIFICATION GUIDANCE

This is an introductory paragraph.

VERIFICATION LESSONS LEARNED

3.9.5.6.1 Electronic combat ground sites. The capability to insert up to __________ EC ground sites into any mission area shall be provided. Locations shall be correlated with the threat scenario and IECE.

REQUIREMENT RATIONALE (3.9.5.6.1)

EC ground sites which are detected by the radar should be simulated for correlation purposes.

REQUIREMENT GUIDANCE

Insert the number of ground sites potentially viewable by the radar at one time. This number is typically less than the size of the IECE (see 3.2.2.6). The number of cross sections should be sufficient to represent all required JARM sites. Note that one cross section may represent more than one EC ground site.

REQUIREMENT LESSONS LEARNED

4.9.5.6.1 Electronic combat ground sites. Tests shall be conducted to verify that EC ground sites can be inserted into missions and the radar cross sections are correct. At least __________ samples shall be tested as well as test missions. Positions of EC ground sites shall be checked for correlation.

VERIFICATION RATIONALE (4.9.5.6.1)

To assure compliance.

VERIFICATION GUIDANCE

Insert the number of ground sites that must be individually tested. There is no history documented but 10 to 20 samples should be sufficient, as well as testing of the limits.

VERIFICATION LESSONS LEARNED

3.9.5.6.2 **Air targets.** The capability to simulate up to __________ simultaneous moving targets for display on the radar shall be provided. Moving target positions shall be correlated with other ATD functions. This capability also includes nuclear and non-nuclear debris and associated effects.

REQUIREMENT RATIONALE (3.9.5.6.2)

The air-to-air modes of the radar require air target simulation and this must be correlated with other simulations.

REQUIREMENT GUIDANCE

Insert the number of simultaneously moving targets, typically not more than five. Correlation is the primary concern here. The number of moving targets does not have to be the same as those required for other functional simulations since all EC moving targets are not visible to the radar simultaneously. A similar argument holds for the visual.

REQUIREMENT LESSONS LEARNED

4.9.5.6.2 **Air targets.** Tests shall be conducted to verify that all air targets can be simulated and that the positions correlate with other functions.

VERIFICATION RATIONALE (4.9.5.6.2)

To assure compliance.

VERIFICATION GUIDANCE

All air target cross sections and the maximum numbers of simultaneous air targets should be tested.

VERIFICATION LESSONS LEARNED

3.9.5.6.3 **Beacons.** The capability to simulate up to __________ simultaneous beacons for display on the radar shall be provided. These beacon sources shall be airborne or on the ground and shall be capable of being located concurrently with other air targets.

REQUIREMENT RATIONALE (3.9.5.6.3)

Beacon simulation is required for completeness of mission training.

REQUIREMENT GUIDANCE

Insert the number of beacons required, typically five or ten. Beacons may be airborne or located on the ground.

REQUIREMENT LESSONS LEARNED

4.9.5.6.3 **Beacons.** Tests shall be conducted to verify that all types of beacons and beacon codes are correctly simulated.

VERIFICATION RATIONALE (4.9.5.6.3)

To assure compliance.

VERIFICATION GUIDANCE

All airborne and ground beacon types should be tested. All code types and positions of the code should be exercised, not necessarily every code.

VERIFICATION LESSONS LEARNED

3.9.5.6.4 **Expendables.** The capability to simulate expendables which are observable by the radar shall be provided.

REQUIREMENT RATIONALE (3.9.5.6.4)

Expendables, whether jettisoned by ownship or some other aircraft, are observable and should be simulated.

REQUIREMENT GUIDANCE

Any details resulting from specific mission or EC expendable requirement should be included.

REQUIREMENT LESSONS LEARNED

4.9.5.6.4 **Expendables.** Tests shall be conducted to verify the simulation of expendables. These tests shall include each type of expendable and shall include observing the expendable over a period of time.

VERIFICATION RATIONALE (4.9.5.6.4)

To assure compliance.

VERIFICATION GUIDANCE

Tests should be conducted for chaff, flares, etc. and should include each method of normal use. Observing some expendable types (chaff) should show the proper decay.

VERIFICATION LESSONS LEARNED

3.9.6 DRLMS control system and console. The DRLMS shall be provided with a control system and console consisting of hardware and software features to provide complete control and monitoring capabilities for each of the DRLMS modes of operation. Control console hardware shall consist of the following: ___(a)___. The DRLMS control system shall permit the DRLMS to fly within the radar data base while operating in each of the DRLMS modes except for the integrated mode. The following flight control capabilities and parameters shall be provided: ___(b)___. The use of the DRLMS control system and console shall require minimal knowledge of the DRLMS design and minimal technical expertise on the part of the individual operating the system.

REQUIREMENT RATIONALE (3.9.6)

In addition to supplying simulated radar imagery in an integrated training mode, the DRLMS must also be capable of operating as a special purpose computational system for diagnostic and data base update purposes. This requirement is to insure that the DRLMS has a control system and interactive capabilities to accomplish each of its functions.

REQUIREMENT GUIDANCE

a. The operational utilization of the DRLMS control system needs to be evaluated to determine what features and interactive capability will be required. The following types of capabilities should be considered:

(1) Radar display - a display subsystem dedicated to the DRLMS permits the DRLMS to operate and be utilized for both diagnostic and data base update purposes independent of the simulator.

(2) CRT/keyboard terminal - used for interactive and control purposes.

(3) Hardcopy device - used during small area update sessions when hardcopies of CRT plot information are desired.

(4) Special function switches and controls - useful when certain control functions (range selection, receiver gain, antenna tilt) are awkward when operated from the keyboard.

(5) Floppy disk system - useful when small area update information needs to be sent to other DRLMS sites.

(6) Digitizing tablet - useful as an alternate means of accomplishing data base update.

(7) Magnetic tape drive system - useful for processing transformed data from DMA.

b. In the DRLMS independent mode, it is frequently necessary to "fly" the DRLMS within the data base. Since this mode will not be used for training, flight capabilities need not conform to the aircraft capabilities. Therefore, faster than normal climb and descent rates, instantaneous velocity changes, backward flight, motion freeze, etc. are acceptable. Flight control capabilities should include at least speed, altitude, heading, and position reset.

REQUIREMENT LESSONS LEARNED

Control capabilities as required have been met on previous DRLMS systems. However, the control hardware and software have more often been designed to meet the needs of the design engineer than of the using-command operator. Therefore, if a specific approach or method is desired, it should be explicitly stated in the specification.

Mockups of the console and the proposed design approach to control capabilities should be carefully evaluated at each program design review with the assistance of the using command. Conformance to MIL-STD-1472 should also be considered.

4.9.6 DRLMS control system and console. Operations and control capabilities of the DRLMS control system and console shall be verified by __________.

VERIFICATION RATIONALE (4.9.6)

To insure that the DRLMS can be operated in all required modes of operation.

VERIFICATION GUIDANCE

Engineering tests, analyses, and demonstrations should be the primary means of verifying control system operation. Test methodology should permit all modes and capabilities of the DRLMS to be fully exercised. Using command technicians and system evaluation during test procedure review and engineering testing is recommended. Particular emphasis during evaluation should be placed upon the man-machine interface and the overall ease of system use.

VERIFICATION LESSONS LEARNED

Although subjective in nature, ease of use has a different meaning when applied to a system user versus the system designer. Control system requirements verification should be based on the former.

3.9.7 **DRLMS modes of operation**

3.9.7.1 **Independent mode.** Independent mode operation shall permit the DRLMS to operate in a functionally standalone manner independent of the flight simulator. Independent mode operation shall be controlled by the DRLMS control system and console.

REQUIREMENT RATIONALE (3.9.7.1)

Independent mode operation permits the DRLMS to operate in a standalone configuration without aircraft simulator interaction. This requirement is to insure that independent mode operation is provided.

REQUIREMENT GUIDANCE

This requirement should state the type of independence required (usually functional, physical, and/or electrical) and should define the specific purpose for which the independent mode will be used. In addition, the type of DRLMS control should either be stated or referenced. No quantitative requirements are applicable.

REQUIREMENT LESSONS LEARNED

The requirement for an independent mode is easily met and provides an extremely flexible configuration during in-plant testing prior to simulator system integration and for system checkout after deployment.

4.9.7 **DRLMS modes of operations**

4.9.7.1 **Independent mode.** DRLMS operation in the independent mode shall be verified by ___________.

VERIFICATION RATIONALE (4.9.7.1)

To insure that the DRLMS will operate as required in the independent mode.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying the independent mode. Using command technicians and system operator evaluation during independent mode test is recommended.

VERIFICATION LESSONS LEARNED

3.9.7.2 **Integrated mode.** Integrated mode operation shall permit the DRLMS to operate in a fully integrated manner with the flight simulator. Integrated mode operation shall be controlled by the flight simulator. While operating in the integrated mode, the following information shall be displayed at the DRLMS control console: ___________.

REQUIREMENT RATIONALE (3.9.7.2)

Integrated mode operation permits the DRLMS to operate while interfaced with the flight simulator and is the normal mode of operation. This requirement is to insure that integrated mode operation is provided.

REQUIREMENT GUIDANCE

This requirement should state that while in the integrated mode, the DRLMS eyepoint and associated displays/sensory inputs will be exclusively controlled by the flight simulator. In addition, those parameters desired for display at the DRLMS console while operating in the integrated mode should be explicitly stated.

REQUIREMENT LESSONS LEARNED

No significant problems have been encountered with integrated mode operations.

4.9.7.2 **Integrated mode.** DRLMS operation in the integrated mode shall be verified by ___________.

VERIFICATION RATIONALE (4.9.7.2)

To insure that the DRLMS will operate as required in the integrated mode.

VERIFICATION GUIDANCE

Engineering tests, operational tests, and demonstrations should be the primary means of verifying the integrated mode. Using command technicians, system operators, and crew member evaluation during integrated mode test is recommended. Engineering tests should be quantitative in nature. Operational tests may be mission oriented.

VERIFICATION LESSONS LEARNED

3.9.7.3 **Digital data base update mode.** The digital data base update mode shall provide the capability for radar data base modification by the DRLMS control system and update console. The following types of update capabilities shall be provided: ___(a)___.

In addition, the DRLMS shall automatically generate and maintain records of all data base update activities. The following capabilities and specific information shall be provided with the data base management: ___(b)___.

REQUIREMENT RATIONALE (3.9.7.3)

A DRLMS can and should be designed to permit updating to incorporate new topographical and descriptive information.

REQUIREMENT GUIDANCE

a. This requirement should state which types of update capabilities are desired and any specific requirements associated with each update capability. The following is a description of the different types of update capabilities:

(1) Small area update. The small area update capability includes the ability to modify radar DDB descriptors for planimetry features and terrain elevation values. The capability to make temporary radar DDB updates without destroying the permanent radar DDB should be provided. A positive action should be required to enter an update in the permanent file. The DRLMS should be designed to minimize the time required to make updates. An upper limit of two minutes has typically been specified to make a single change on the radar indicator. All updated points/areas should be indistinguishable from non-updated points/areas, in that the method of putting the data in the DDB (original transformation or site update) should not be perceptible on the radar indicator.

(2) Large area updates. Large area updates are required for the following reasons:

(a) User requirements for new targets, aimpoints, routes, etc.

(b) DMA updates due to error correction, better data, etc.

(c) Additions to existing data DDBs and the creation of additional data.

Large area updates should be produced for all levels of both feature analysis and terrain elevation data. Means should be provided to inset a newly transformed large area update into the existing radar DDB. Insertion of a large area update should not result in any distinguishable effects other than the new information contained within the updated area itself.

(3) Mission-unique updates. Mission-unique update provides the capability to temporarily update the radar DDB to its use during a mission and to process this update for video display during a mission without destroying the original data base. Means should be provided for the instructor, between missions, to select either the original or the mission-unique updated data base for video display during the subsequent mission and to delete or permanently incorporate the mission unique as part of the radar DDB.

(4) Data base enhancement. Data base enhancement provides the capability to enhance or generate limited geographic areas in the radar data base. This capability should permit the scene content of an area approximately 5 nm by 5 nm in the radar data base to be upgraded when adequate scene detail is not available in the DMA data base or to generate a data base when DMA data is not available. Data base enhancement is a capability similar to small area update but is intended for more efficient data base generation over a larger geographic area.

b. The data base management capability should permit the using command to maintain configuration management over the radar data base and should be compatible with DMA data base transmittal and operating procedure. Data base management record keeping should not limit or complicate the DRLMS data base update capability and should provide hardcopy data base plot, listings, and reports for all update activities upon operator demand. Data base management should be considered from both a DRLMS and a simulator software support center standpoint.

REQUIREMENT LESSONS LEARNED

Complexity and usability of contractor developed data base update capabilities and management systems are highly dependent upon the radar base format and design approach, and the contractor's interpretation of perceived using-commands' needs and requirements. Although basic requirements for data base update and management have been met on previous systems, significant improvements are still required in the area of "user friendliness", usability, and adequacy from the using command standpoint. Therefore, it is recommended that the using command and DMA play an active part in developing this requirement and in evaluating contractor proposals and preliminary designs.

4.9.7.3 **Digital data base update mode.** Each required data base update capability and the data base management system shall be verified by __________.

VERIFICATION RATIONALE (4.9.7.3)

To insure that each required type of update can be accomplished and that the DRLMS can maintain records of all data update activity.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying the data base update mode. Test procedures should include verification of update capability under a wide variety of different situations including a cross section of different feature types, different levels of DMA data, different geographic areas (especially at geographic/data base extremes/transition points), all data base resolutions, etc. Test methodology should integrate update verification with data base management. Using-command technicians and system operator evaluation during test procedure review and engineering testing is recommended.

VERIFICATION LESSONS LEARNED

3.9.7.4 **DRLMS test map mode.** DRLMS test maps shall be available as both diagnostic and test tools. The term "verification" in this section refers to diagnostic verification. DRLMS test map mode operation shall take place at the control console. Accompanying each test map being displayed on the radar display, the alphanumerics and graphics necessary to identify the test map function and convey all quantitative and descriptive information needed to complete a diagnostic or test evaluation shall be displayed at the control console. Means shall be provided at the console to position the DRLMS to the correct geographic location, altitude, and heading for a desired test situation by entering a test map identification number after the DRLMS has been placed in the test map mode. In addition, means shall be provided to subsequently reposition the DRLMS to a new location, altitude, and/or heading in a similar manner, if required by the purpose of an individual test map. The test maps shall verify the proper operation of the following functions: ___________.

REQUIREMENT RATIONALE (3.9.7.4)

The complexity of DRLMS design and the dependence of image generation upon many different parameters require the capability to display and verify specific radar effects for both diagnostic and test purposes. This requirement insures that a DRLMS test map mode with specific capabilities is provided.

REQUIREMENT GUIDANCE

This requirement should state where the test map mode should be operated, what information should be displayed on each test map, and how the DRLMS should be positioned for test map utilization. It is recommended that contractor proposed test map design be reviewed early in the program and modified as necessary to insure compliance with the intent of this requirement.

The following types of test maps should be considered:

a. Range resolution. Provides for verification of the range resolving capability of the system. The map should permit a determination of the precise resolution being displayed and a direct reference to the required resolution.

b. Azimuth resolution. Provides for verification of the azimuth resolving capability of the system. The map should permit a determination of the precise resolution being displayed and a direct reference to the required resolution.

c. Shadows. Provides for verification of accurate and realistic portrayal of shadows. The map should permit a determination of the precise length of the displayed shadow and direct reference to the correct values of a given set of conditions. Artificial terrain can be provided in lieu of actual terrain for shadow accuracy tests; however, actual terrain should be provided as part of the test map to evaluate realism.

d. Pulse length error. Provides for verification of accurate and realistic portrayal of pulse length error. The map should permit a determination of the precise length of the displayed pulse error and a direct reference to the correct value.

e. Far-shore brightening. Provides for verification of realistic portrayal of far-shore brightening. Artificial terrain can be provided in lieu of actual terrain for verification of far-shore brightening aspect and water-to-land/land-to-land transition; however, actual terrain should be provided as part of the test map to evaluate realism.

f. Aspect. Provides for verification of accurate and realistic aspect effects of both terrain and various planimetric features.

g. Directionality. Provides for verification of the directional characteristic of various types of planimetric features.

h. Low-level effects. Provides for verification of a realistic transition from high to low altitude for low-level effects. The approach should permit a determination of the altitude at which low-level effects become visible.

i. Antenna patterns. Provides for verification of realistic simulation of both the horizontal and vertical antenna patterns.

j. Seasonal effects. Provides for verification of realistic simulation of scope reversal. Topography for at least two different times of year should be provided.

k. Earth curvature. Provides for verification of terrain occulting due to earth curvature. The map should permit a determination of the range at which occulting takes place as a function of the DRLMS absolute altitude. The map should provide a direct reference to the correct occulting range.

l. Reflectance code assignments. Provides for verification of relative reflectance code assignments. The map should permit individual reflectance code assignments to be easily identified.

m. Other special effects. Provides for verification of effects uniquely associated with a specific radar capability such as TA/TF, SAR, or air-to-air.

REQUIREMENT LESSONS LEARNED

Contractor approaches to the test map capability have been acceptable in most cases. Consideration should be given, however, to defining a standard test map format to insure a uniformity of testing for different DRLMS systems and to better insure that the simulation of radar effects meets the performance requirements.

4.9.7.4 **DRLMS test map mode.** Each required DRLMS test map and the associated DRLMS positioning capability shall be verified by __________.

VERIFICATION RATIONALE (4.9.7.4)

To insure that each required test map capability has been provided and that the DRLMS is capable of operating as required in this mode.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying the test map mode. Test procedures emphasis should be placed upon verification of DRLMS operation in the test map mode. Verification of the radar effects demonstrated by the individual test maps should be accomplished in support of the specific radar effect requirement verification. Individual test maps should be analyzed to insure the validity of test results. Using command technician and system operator evaluation during test procedures review and engineering testing is recommended.

VERIFICATION LESSONS LEARNED

3.10 **Avionics systems simulation/stimulation.** The avionics systems shall be simulated or stimulated in accordance with the approved design criteria. The avionics systems shall include the following subsystems: ___________.

REQUIREMENT RATIONALE (3.10)

This requirement defines specific avionics subsystems and functions to be simulated or stimulated.

REQUIREMENT GUIDANCE

List the subsystems and major functions being simulated or stimulated. The subsystem names should be the same as the aircraft names and the specific functions performed should reflect "like functions" in the aircraft.

Typical subsystems and major functions are:

Navigation
Navigation computers
Inertial systems
Celestial systems
Compass and heading systems
Magnetic and gyro heading systems
Long range navigation (LORAN)
Altimeters
Omega
Global positioning system

Communications

- Radios
- Intercom

Mission Avionics

- Weapons
- Weapons Computers
- Stores Management

Radar

- See 3.9

Electronic Combat

- See 3.8

Flight Management

- Flight control computer
- Terrain following
- Terrain avoidance

Controls and Displays

- Display processor
- Multifunction displays
- Integrated keyboards
- Conventional instruments.

REQUIREMENT LESSONS LEARNED

4.10 Avionics systems simulation/stimulation. Inspections shall be performed to verify that all subsystems and equipments are provided.

VERIFICATION RATIONALE (4.10)

To assure compliance.

VERIFICATION GUIDANCE

A top level check to assure that all functions are being simulated or stimulated should be performed. This verification should be initiated at design reviews. Each subsystem and function should be individually tested in accordance with the approved Acceptance Test Procedures.

VERIFICATION LESSONS LEARNED

3.10.1 Avionics architecture. The avionics architecture in the simulator shall be analogous to that of the actual aircraft such that:

a. New avionics subsystems can be added to the simulator's avionics suite in a manner that is consistent with the addition of new avionics to the aircraft avionics suite.

b. Malfunctions of subsystems can be duplicated in accordance with design criteria.

c. Data buses and bus controller characteristics are simulated or stimulated.

REQUIREMENT RATIONALE (3.10.1)

The world of avionics is a dynamic environment and the simulator architecture should be as close to the aircraft architecture as possible to allow for quick incorporation of new systems and the realization of concurrent training between the simulator and the aircraft.

REQUIREMENT GUIDANCE

The design of the simulator avionics suite shall be accomplished with the simulator contractor having a close relationship with the aircraft contractor to assure consistency with the development of new systems and for future updates to existing systems. In cases where concurrency is particularly difficult due to the frequency and magnitude of modifications, the simulator contractor shall develop direct agreements with the individual aircraft contractors. It is important that the avionics architecture be fully understood, especially since multi-bus structures are often encountered. Even though the MIL-STD-1553 bus is a standard, it is implemented in many ways and must be considered in making significant tradeoff decisions regarding stimulation vs. simulation of avionics processors.

REQUIREMENT LESSONS LEARNED

These design techniques will lower the risk factor in the development of new systems and updates to existing systems.

4.10.1 **Avionics architecture.** Tests shall be conducted to verify that all functions are provided.

VERIFICATION RATIONALE (4.9.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests should be developed to verify bus and bus controller characteristics. Malfunctions are normally tested as the result of other requirements. Inspections are normally adequate to verify the growth capability.

VERIFICATION LESSONS LEARNED

3.10.1.1 **Operational flight programs (OFPs).** Avionics functions which include OFPs shall be simulated by __________. Whichever method(s) is (are) used, all aircrew perceptible cues shall be provided. In addition, simulator unique controls (freeze, reset, or others) required by this specification shall be provided.

REQUIREMENT RATIONALE (3.10.1.1)

Avionics systems which contain OFPs require additional controls for the program to work in the simulator environment.

REQUIREMENT GUIDANCE

Identify potential problem areas early in the program so that an unmodified aircraft OFP can be used in the simulator. Conduct a thorough trade study of aircraft processor/OFP simulation, concurrency with the aircraft, training requirements, and the need for simulator-specific controls and instructional controls (freeze, reset, etc). Details of the technical problems associated with Kalman filters and other time history algorithms in OFPs need to be addressed. In addition, the compatibility of standard models (earth models, for example) used in OFPs and other parts of the ATDs should be addressed.

Fill the blank from the following selection:

a. Use of an aircraft OFP directly in the simulator.

b. Use of an aircraft OFP directly in the simulator with minor modifications which can be performed by a trainer simulator support center within two weeks.

c. Automatically translating the OFP to a form suitable for use in the simulator.

d. Functionally simulating the OFP with simulator unique software.

REQUIREMENT LESSONS LEARNED

Simulator contractors are often opting to stimulate certain avionics systems that contain OFPs. Simulating OFPs can result in lengthy times to reset the processor subsequent to a freeze or a command to a specific location. In addition, problems may be encountered due to integrations performed by an OFP. One solution is to include simulator hooks in OFPs to allow simulator controls to be added externally. The time to get an OFP update into the ATD is usually lengthy with the functional simulation approach, depending on the tools available to generate the change and the complexity of the OFP change.

4.10.1.1 **Operational flight program.** Tests shall be conducted to verify the performance of OFPs. Each simulated OFP shall be completely exercised through all modes.

VERIFICATION RATIONALE (4.10.1.1)

To assure compliance.

VERIFICATION GUIDANCE

Most of these tests may be conducted as parts of verification of other requirements. Tests should indicate the modifications of OFPs using the normal simulator support capabilities especially if OFPs are functionally simulated. Tests should also include the exercising of OFPs with simulator unique functions, especially for stimulated OFPs.

VERIFICATION LESSONS LEARNED

3.10.2 **Navigation subsystem simulation.** The __________ navigation subsystem shall be simulated in accordance with the approved design criteria.

REQUIREMENT RATIONALE (3.10.2)

This requirement names the navigation subsystems to be simulated.

REQUIREMENT GUIDANCE

A typical list of navigation subsystems is:

a. Navigation computers - analog and digital

b. Inertial navigation systems

c. Aircraft heading systems

d. Radar altimeter

e. Airspeed indicator

f. Groundspeed indicator (Doppler)

g. Long range navigation (LORAN) system

h. Global positioning system (GPS)

i. Omega

j. Astrocompass systems.

REQUIREMENT LESSONS LEARNED

4.10.2 Navigation subsystem simulation. Tests shall be conducted to verify that the navigation subsystem has been simulated in accordance with the design criteria.

VERIFICATION RATIONALE (4.10.2)

To ensure that the correct systems have been simulated.

VERIFICATION GUIDANCE

Inspection of design documentation and the simulated hardware should be an adequate means of verifying the design concept. Subsystem performance shall be tested, demonstrated, and analyzed as required.

VERIFICATION LESSONS LEARNED

3.10.2.1 Navigation subsystem accuracy

3.10.2.1.1 Absolute accuracy. Navigation subsystems' absolute accuracy is defined as a function of required subsystem model fidelity, the simulated quality of subsystem performance, and the simulator equations of motion state conditions compared to an estimate of actual system performance under the same conditions (position, velocity, altitude, acceleration, and so on). Navigation subsystems' absolute accuracy requirements are: __________.

REQUIREMENT RATIONALE (3.10.2.1.1)

Absolute accuracy requirements are necessary to establish the level of performance as compared to the actual system.

REQUIREMENT GUIDANCE

A means of defining a measure of accuracy in terms of values such as position or velocity that can be used to compare the simulated value to the predicted value will need to be developed. For example, equations of motion position might be used to initialize an INS simulation. Based upon factors such as malfunctions, time between updates, inherent system errors, etc, it could be predicted how well the actual system would be performing. The absolute accuracy measurement would test the simulation's capability to match the actual system performance under the same conditions. The tolerance associated with the absolute accuracy requirement should be based upon the training fidelity requirement (i.e., the greater the fidelity required for training, the tighter the accuracy tolerance). The determination of absolute accuracy requirements will require an in-depth understanding of system design and operational capability. A great deal of information for a mature navigation system should be available from crew member experience

REQUIREMENT LESSONS LEARNED

4.10.2.1 **Navigation subsystem accuracy**

4.10.2.1.1 **Absolute accuracy**. Navigation subsystem absolute accuracy requirements shall be verified by __________.

VERIFICATION RATIONALE (4.10.2.1.1)

To ensure that the simulated system is capable of matching tolerance in a stand alone configuration.

VERIFICATION GUIDANCE

A means of determining the accuracy of the actual aircraft system in terms of position, velocity, altitude, or acceleration values while operating independently will need to be developed. Based upon this information, engineering test procedures will need to be developed that will verify simulated performance accuracy for the same conditions. A verification approach might be based upon a measurement of navigation subsystem parameters e.g., position, velocities, altitude, etc, as a function of time and their comparison with anticipated performance of the actual aircraft system.

VERIFICATION LESSONS LEARNED

3.10.2.1.2 **Relative accuracy**. Navigation subsystem relative accuracy is defined as a function of the required degree of correlation among navigation subsystems. The type of information that is computed and displayed, and the level of performance for each of the navigation subsystems shall correlate with the corresponding information and performance provided by all other simulated subsystems: __________.

REQUIREMENT RATIONALE (3.10.2.1.2)

Relative accuracy requirements are necessary to establish the level of performance as compared to the actual system.

REQUIREMENT GUIDANCE

A set of parameters (e.g., positions, velocities, indicator measurement values, etc) that can be used to compare the simulated performance of the navigation subsystem to another subsystem needs to be developed. The degree of required accuracy or correlation should be a function of the actual aircraft system capability. For example, the degree of correlation between a geographic location determined by a simulated inertial navigation system and the same position displayed on a high resolution digital radar system should be relatively high. However, when considering an analog dead reckoning navigation system and a non-coherent, real-beam radar, the degree of correlation will need to be much less.

REQUIREMENT LESSONS LEARNED

4.10.2.1.2 **Relative accuracy.** Navigational subsystem relative accuracy requirements shall be verified by ___________.

VERIFICATION RATIONALE (4.10.2.1.2)

To insure that the simulated system is capable of matching the performance of the actual system within the specified tolerance while integrated with all related aircraft systems.

VERIFICATION GUIDANCE

A means of determining the accuracy of the actual aircraft system in terms of position, velocity, altitude, or acceleration values while the system is integrating externally generated flight data will need to be developed. Based upon this information, an engineering test procedure will need to be developed that will verify simulated performance accuracy for the same conditions. A verification approach might be accomplished in parallel with absolute accuracy testing. While collecting data for absolute accuracy measurement, the values for common parameters could be compared to determine whether they are within the required tolerances. For example, assuming that simulated errors have been disabled, the navigation computer subsystems should provide aircraft positions to the radar subsystem such that when crosshairs are automatically placed, they will fall precisely on the desired target. Likewise, if multiple sensors are involved, each should designate the same point when provided the same navigation information.

VERIFICATION LESSONS LEARNED

3.10.2.2 **Navigation controls, displays and indicators.** All controls, displays, and indicators associated with each navigation subsystem shall be provided, and shall be exact replications of those on the actual system with the following exceptions: ____(a)____. All required controls shall be functional and shall permit the required modes and capabilities of the navigation subsystem to be operated. The interaction among all controls, functions, displays, and indicators shall be simulated in accordance with the design criteria. Simulated indicators and displays shall ____(b)____.

REQUIREMENT RATIONALE (3.10.2.2)

In order to teach aircraft systems operation, flight procedures, and mission rehearsal, simulated systems must appear and operate like the aircraft system to the greatest extent possible.

REQUIREMENT GUIDANCE

a. This requirement should state which indicators, controls, and displays need to be provided for appearance and which need to be operational.

b. Due to the lack of any information defining display characteristics as a function of training objective, the approach usually taken has been to specify duplication of aircraft performance and characteristics.

REQUIREMENT LESSONS LEARNED

Contractors have been allowed to meet this requirement either by using GFE aircraft hardware or by manufacturing duplicate hardware using aircraft drawings. Although GFE hardware provides realistic appearance, the cost may be greater than if the contractor were permitted to approximate the appearance and performance with hardware designed and manufactured exclusively for the simulator.

4.10.2.2 **Navigation controls, displays, and indicators.** Replications of all required controls, displays, and indicators and simulation of system operating modes and capabilities shall be verified by ________.

VERIFICATION RATIONALE (4.10.2.2)

To insure that system operations is in accordance with the specification and design criteria.

VERIFICATION GUIDANCE

Operational tests and demonstrations based upon aircraft system design documentation and technical order checklists should be the primary means of verifying controls and displays requirements. Crew member assistance is helpful while testing this requirement.

VERIFICATION LESSONS LEARNED

3.10.2.3 **Navigation operational capabilities.** The following operational capabilities of each navigation subsystem shall be simulated. The modes of operation, unique characteristics, and malfunctions shall be simulated as follows: ________.

REQUIREMENT RATIONALE (3.10.2.3)

The aircraft navigation system's operational capabilities may be provided by several independent navigational subsystems or by one multipurpose, integrated system. This requirement ensures that the operating capabilities required for training are provided and that the desired modes of operation, unique characteristics, and malfunctions are simulated.

REQUIREMENT GUIDANCE

In order to write this requirement, a detailed analysis of the design and operational capabilities will be required. In addition, it will be necessary to obtain an operational insight into the system's actual use, how it performs, and what characteristics are significant to its performance. This requirement should be stated in terms of which modes of operation should be simulated, which unique characteristics should be simulated (for example, required operational techniques, operational procedures not covered by the checklists, operational characteristics not described by the technical orders, etc) and which malfunctions should be simulated. Different capabilities that may require simulation include the determination of position, groundspeed, airspeed, and acceleration. In addition, the capabilities should be critically evaluated from an objective standpoint to determine the extent to which the system must actually be simulated. Each simulated navigation system capability should be in its own paragraph since each capability will have its own unique requirements and may actually involve physical aircraft components.

REQUIREMENT LESSONS LEARNED

Requirements for the simulation of existing navigation systems can be derived from the documentation for those systems and from crew member experience. Crew members are usually happy to describe the performance of their system in great detail.

The requirements for new aircraft navigation systems are much more difficult to define. Obtain basic design information, even if preliminary in nature; obtain test flight performance data if available; and discuss utilization with the using command. In addition, independent (contract) evaluation of system performance viewed from a simulation standpoint may be useful.

4.10.2.3 Navigation operational capabilities. The modes of operation, unique characteristics, and required malfunctions shall be verified by __________.

VERIFICATION RATIONALE (4.10.2.3)

To assure that each required capability and mode has been simulated and that unique characteristics and malfunctions are in accordance with design criteria.

VERIFICATION GUIDANCE

Operational tests, analyses, and demonstrations based upon aircraft system design documentation, technical order information, and technical order checklist should be the primary means of verifying system operational capabilities. Although quantitative test procedures are desirable whenever possible, most will likely be subjective in nature. Crew member review of test methodology and assistance during the test process is recommended.

VERIFICATION LESSONS LEARNED

3.10.2.4 Navigation data bases

3.10.2.4.1 Celestial data base. A celestial data base shall be provided for celestial navigation systems or to permit a crew member to practice celestial navigation with a sextant. Celestial simulation of the following bodies shall be provided: ____(a)____. The following errors associated with celestial observations shall be computed: ____(b)____.

REQUIREMENT RATIONALE (3.10.2.4.1)

Training requirements may involve simulation of either astrotracker/astrocompass or manual sextant operation for celestial navigation. In either case, a celestial data base will be required.

REQUIREMENT GUIDANCE

The Naval Observatory publishes an almanac of celestial data that is readily available and contains most of the information necessary for developing a celestial data base for simulation purposes. Based upon the training requirements, the specific celestial bodies will need to be selected for inclusion in the data base.

a. Typical bodies include:

(1) Sun

(2) Moon

(3) Venus

(4) Jupiter

(5) Saturn

(6) Mars

(7) Polaris

(8) Stars 1-57 of the Air Almanac.

b. Errors that may need to be included as part of the simulation processing of the data base include the following:

(1) Moon's parallax in altitude

(2) Atmospheric refraction

(3) Coriolis error

(4) Acceleration error

(5) Rhumb line error

(6) Polaris local hour angle error correctable by Q factor.

In the case of astrocompass or astrotracker, the data base will be processed directly by the system simulation. However, for manual sextant simulation, specify whether celestial observation values will be provided by the visual system or by the instructor.

REQUIREMENT LESSONS LEARNED

Previous programs have had no difficulty generating a celestial data base and the simulation results have been acceptable for training purposes.

4.10.2.4 Navigation data bases

4.10.2.4.1 Celestial data base. The celestial data base content and accuracy shall be verified by ___________.

VERIFICATION RATIONALE (4.10.2.4.1)

To insure that the required celestial bodies and associated errors have been included.

VERIFICATION GUIDANCE

Operational tests and demonstrations of the celestial simulation based upon celestial navigation procedures should be the primary means of verifying the celestial data base. Verification of the celestial data base may be accomplished by manually computing aircraft position using outputs from the simulated celestial navigations equipment. Simulator position based upon celestial data should approximate the actual position when all appropriate celestial error corrections are applied. Crew member review of test methodology and assistance during the test process is recommended.

VERIFICATION LESSONS LEARNED

3.10.2.4.2 Topographic elevation data base. The required navigational subsystems shall access the ___________ data base for topographic elevation.

REQUIREMENT RATIONALE (3.10.2.4.2)

Simulated navigational subsystems such as radar altimeter and ground speed measuring devices require a source of topographic elevation values to accomplish their function. A topographic data base is, therefore, required to meet this need.

REQUIREMENT GUIDANCE

In most cases, topographic elevation values are available from either a DRLMS or visual data base. If the simulation requirement includes radar or visual, then the navigation subsystem should be required to access the available data base. Careful consideration must be given to data base correlation and system integration. For example, training would be difficult if the pilot's radar altimeter values generated by the DRLMS data base conflicted with the pilot's out-the-window scene generated from the visual data base. If no other topographic data base is available (as might be the case for a simplified procedures trainer), then a topographic elevation data base over the area of training interest would need to be developed. Real world versus generic data selection would be a function of training requirements.

REQUIREMENT LESSONS LEARNED

Navigation subsystem simulation approaches have successfully used available data bases. When DMA data have been used as the basic source for all simulation topographic elevation data bases, no significant problems have been encountered in the simulated navigation subsystem. Simulation performance has been acceptable for training purposes.

4.10.2.4.2 Topographic elevation data base. Topographic elevation data base content and accuracy shall be verified by ________.

VERIFICATION RATIONALE (4.10.2.4.2)

To assure that navigation systems can access and process elevation data required for absolute altitude computation purposes.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying accessibility and accuracy of topographic elevation data retrieval and processing for navigation subsystem purposes. Topographic elevation data base testing should be accomplished over a variety of terrain surfaces (e.g., flat, rolling, mountainous, etc) and over a variety of cultural surfaces (e.g., cities, building, forest, etc). Engineering tests should verify that the elevation data retrieved by each navigation subsystem is correct for a given geographic position when compared to data base source. In addition, these tests should also verify that the elevation value processed by each navigation subsystem is the same.

VERIFICATION LESSONS LEARNED

3.10.2.4.3 **Pressure, wind, temperature (PWT) data base.** The navigation subsystem shall access the PWT data bases for environment data. The capability to modify the PWT data bases shall be provided.

REQUIREMENT RATIONALE (3.10.2.4.3)

Navigation subsystem simulation may require environmental information. This information is available from the PWT data base.

REQUIREMENT GUIDANCE

Navigation subsystems that need environmental information should be required to access the PWT data base. Further explanation and discussion of PWT is contained in 3.3.3.

REQUIREMENT LESSONS LEARNED

Simulation results using the PWT data base have been acceptable for training purposes.

4.10.2.4.3 **Pressure, wind, temperature (PWT) data base.** Pressure wind temperature data base content and accuracy shall be verified by ________.

VERIFICATION RATIONALE (4.10.2.4.3)

To assure that navigation systems can access and process pressure, wind, and temperature data required for system simulation.

VERIFICATION GUIDANCE

Engineering tests and demonstrations should be the primary means of verifying accessibility and accuracy of PWT data retrieval and processing for navigation subsystem purposes. PWT data base testing should be accomplished over a wide variety of conditions including flight test and between several different altitudes. Crew member assistance during operational testing should also be helpful.

VERIFICATION LESSONS LEARNED

3.10.2.4.4 Magnetic variation data base. The navigational subsystems shall access the magnetic variation data base. Magnetic variation shall be simulated over ___(a)___. The simulated variation shall match the actual variation to within ___(b)___ degree(s), except for areas within ___(c)___ miles of the magnetic pole. Local magnetic disturbances need not be simulated.

REQUIREMENT RATIONALE (3.10.2.4.4)

Simulated navigation systems such as magnetic reference systems require a source for magnetic variation values. A magnetic variation data base is, therefore, required to meet this need.

REQUIREMENT GUIDANCE

a. The entire simulator gaming area, usually.

b. ±1 degree, usually.

c. 1,000 miles, usually.

The required area of coverage for the magnetic variation data base should match the area of coverage intended for simulator operation. An accuracy tolerance of ±1 degree beyond 1,000 nautical miles from the magnetic poles has been arbitrarily specified in the past. This requirement does not create any design problems. This same accuracy could also be specified closer to the pole. However, due to the convergence of the isogonic lines, the data base would probably become needlessly complex.

REQUIREMENT LESSONS LEARNED

Magnetic variation data bases for previous simulator systems have been acceptable for training purposes.

4.10.2.4.4 **Magnetic variation data base**. Magnetic variation data base content and accuracy shall be verified by ___________.

VERIFICATION RATIONALE (4.10.2.4.4)

To assure that the area of coverage and accuracy of magnetic variation meets the specification requirements.

VERIFICATION GUIDANCE

Engineering tests and demonstrations, and analysis of data base design documentation should be the primary means of verifying area of coverage, data retrieval, accuracy, and processing of magnetic variation data for navigation subsystem purposes. Magnetic variation data base testing should be accomplished over the full extent of the required gaming area with specific attention given near the magnetic poles. Navigation charts depicting magnetic variations may be used to verify the accuracy of the magnetic variation data base.

VERIFICATION LESSONS LEARNED

3.10.3 **Communications subsystem simulation.** All communication equipment included at aircrew members' positions shall be simulated in accordance with design criteria. This shall include all types of radios, data communications, and air traffic control equipments. Realistic interference shall be simulated which is variable in intensity. Background radio traffic shall be simulated as well as mission specific radio traffic. The on-board interphone shall be simulated.

REQUIREMENT RATIONALE (3.10.3)

Communications are essential to satisfactory completion of some missions as well as to realistic task loading. Background non-mission-specific radio traffic is needed for realism.

REQUIREMENT GUIDANCE

Mission-specific communications should be analyzed in detail to assure only that which is essential is specified as "required". Normally, prerecorded messages will suffice for most radio traffic simulation if they are keyed to mission time. The instructor must sometimes be required to act as a radio ground station, controller, or other communication source. Background radio traffic can be prerecorded and synchronized with mission time. Static and other types of interference should have a variable control and be programmable.

REQUIREMENT LESSONS LEARNED

4.10.3 **Communications subsystem simulation.** Verify by __________.

VERIFICATION RATIONALE (4.10.3)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements in accordance with approved methodology.

VERIFICATION LESSONS LEARNED

3.10.4 **Mission avionics subsystem simulation.** The mission avionics subsystem simulation shall be in accordance with aircraft design criteria.

REQUIREMENT RATIONALE (3.10.4)

The mission avionics subsystem simulation is needed to allow training in weapons use.

REQUIREMENT GUIDANCE

Approved Criteria List data should be compared with the aircraft vendor for validation of latest revisions and publication dates relative to the simulator design freeze date.

REQUIREMENT LESSONS LEARNED

4.10.4 **Mission avionics subsystem simulation.** Verify by __________.

VERIFICATION RATIONALE (4.10.4)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.10.4.1 **Weapons control.** The weapons control computer (sometimes called stores management) shall be simulated. All controls and displays shall be provided. The capability to simulate the status, arming, control, and release of all weapons identified below shall be provided. It shall be possible to modify the weapons load for any specific mission.

REQUIREMENT RATIONALE (3.10.4.1)

The aircrew interacts with the weapons load through the weapons computer and such interaction should be simulated.

REQUIREMENT GUIDANCE

Any unique requirements should be stated. Provisions for modifying the weapons load are to allow reflying of certain mission segments and to allow rapid change of mission types in the same training session.

REQUIREMENT LESSONS LEARNED

4.10.4.1 Weapons control. Verify by __________.

VERIFICATION RATIONALE (4.10.4.1)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.10.4.2 Weapons. The following weapons shall be simulated in accordance with design criteria ___(a)___. Weapon operation prior to release/launch and all weapons flight characteristics subsequent to release/launch shall be simulated. Weapons scoring shall be provided against any object in the integrated combat environment simulation and at least ___(b)___ points in the radar data base.

REQUIREMENT RATIONALE (3.10.4.2)

Aircrew members must be trained to interact with the full set of weapons which can be carried by the weapon system.

REQUIREMENT GUIDANCE

a. List the weapons which must be simulated for any possible configuration of the weapon system. Any special requirements should be included. Weapons scoring requirements are stated in 3.5, but the weapons simulation must support the scoring algorithms.

b. Specify the number of points--typically 50 to 100 points.

REQUIREMENT LESSONS LEARNED

4.10.4.2 Weapons. Verify by __________.

VERIFICATION RATIONALE (4.10.4.2)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.10.5 Flight management subsystem simulation. The flight management subsystem shall be simulated in accordance with aircraft design criteria. This shall include simulation of the flight control computers, attitude/motion sensors, and terrain-following flight.

REQUIREMENT RATIONALE (3.10.5)

The behavior of the flight management subsystem must be included in the simulation.

REQUIREMENT GUIDANCE

This section may be deleted if not applicable. References to 3.3 and 3.9 should be included as appropriate.

REQUIREMENT LESSONS LEARNED

4.10.5 **Flight management subsystem simulation.** Verify by __________.

VERIFICATION RATIONALE (4.10.5)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.10.6 **Radar simulation.** The radar shall be simulated in accordance with 3.10.1 and 3.10.1.1 and additional requirements found in 3.9.

REQUIREMENT RATIONALE (3.10.6)

This is included here only for completeness of the avionics subsystem.

REQUIREMENT GUIDANCE

Include 3.10 and 3.10.1.1 as appropriate.

REQUIREMENT LESSONS LEARNED

4.10.6 **Radar simulation.** Verify by __________.

VERIFICATION RATIONALE (4.10.6)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.10.7 **Electronic combat subsystem simulation.** The electronic combat (EC) subsystem shall be simulated in accordance with 3.10.1 and 3.10.1.1 and additional requirements found in 3.8.

REQUIREMENT RATIONALE (3.10.7)

This is included here only for completeness of the avionics subsystem.

REQUIREMENT GUIDANCE

Reference 3.10.1 and 3.10.1.1 as appropriate.

REQUIREMENT LESSONS LEARNED

4.10.7 **Electronic combat subsystem simulation.** Verify by __________.

VERIFICATION RATIONALE (4.10.7)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.10.8 **Avionics controls and displays.** All controls and displays shall be simulated/stimulated in accordance with design criteria. This simulation/stimulation shall include the time delays associated with the use of multifunction displays and display processors as well as symbology and menu sequences associated with the specific avionics application.

REQUIREMENT RATIONALE (3.10.8)

Not only the correctness of the displays and controls are important but also the effects of display processors and required sequencing through menus. All these must be realistically simulated or stimulated.

REQUIREMENT GUIDANCE

Paragraphs 3.10.1 and 3.10.1.1 should be included as appropriate. Care must be taken to blend these requirements with those of other paragraphs such as 3.3, 3.8, and 3.9. Functional requirements are normally found in other paragraphs but controls and displays are included here since they are often included as part of the aircraft avionics.

REQUIREMENT LESSONS LEARNED

4.10.8 **Avionics controls and displays.** Verify by __________.

VERIFICATION RATIONALE (4.10.8)

To assure compliance.

VERIFICATION GUIDANCE

Verify all requirements.

VERIFICATION LESSONS LEARNED

3.11 Trainer support subsystem. The trainer support subsystem (TSS) shall include all hardware and software (computer programs/data) necessary to provide for the modification support of the trainer. All TSS computational hardware shall be subject to the general system requirements for the computational subsystem hardware. The TSS shall be __________.

REQUIREMENT RATIONALE (3.11)

Modification support is necessary to support the trainer throughout its life cycle for changes to mission requirements, implementation of simulation changes due to aircraft ECPs, data base development and modification, etc.

REQUIREMENT GUIDANCE

There are two possibilities for the configuration of the TSS, depending upon the using-command's support concept for the trainer. The first is that of the TSS fully integrated into an operational trainer, making use of the trainer computational resources and other trainer equipment. In this case the blank should be filled in with words to this effect:

(The TSS shall be) "fully integrated into the trainer, utilizing the trainer computational subsystem and other trainer equipment as appropriate."

The second possibility is a stand-alone TSS. In this configuration, computational hardware must be independent of the computational subsystem hardware. This configuration would be used in a multiple-unit acquisition where a remote site is designated to provide modification for all trainers. For this configuration, the blank should contain the following:

(The TSS shall be) "designed as a stand-alone subsystem of the trainer capable of independent operation."

It is important to consolidate modification support requirements only in this section of the specification. Non-modification support requirements should not appear in this section. It is the responsibility of each functional engineer (visual, radar, instructional, etc) to insure that the TSS includes the equipment and software necessary to provide modification support for their respective subsystems. Additional requirements may be needed for a separate processing unit.

REQUIREMENT LESSONS LEARNED

This section replaces the development engineering prototype system (DEPS) found in past specifications. The major problem of the DEPS was that its function was never clearly established. It defined support requirements with no common basis. Requirements for the development (which belong only in the SOW for a truly functional specification), mission support, modification support, maintenance, and test of the trainer were gathered more or less haphazardly into the DEPS section. In this specification, those support functions necessary at each trainer site (in a multi-unit acquisition) are defined in each section of the specification as required. Support requirements which might be located at another site without affecting the current trainer configuration (in other words, modification support) are collected here in this specification.

4.11 **Trainer support subsystem.** Verify by __________.

VERIFICATION RATIONALE (4.11)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted in accordance with an approved Acceptance Test Procedure (ATP) document which will be prepared by the contractor. The ATP shall include step-by-step procedures to verify that all trainer support requirements are satisfied. Specific system level tests will be based on the final support requirements definition.

VERIFICATION LESSONS LEARNED

3.11.1 TSS **mass storage equipment.** Mass storage equipment shall be provided for the TSS which shall be compatible with the secondary mass storage equipment of the computational subsystem. Additional mass storage equipment shall be provided as necessary to provide for the efficient implementation of all modification support activities required for the TSS.

REQUIREMENT RATIONALE (3.11.1)

Mass storage equipment is required to store computer programs and data for modification support activities and to provide a medium which can be used to deliver program updates to the trainer sites.

REQUIREMENT GUIDANCE

No modification of this paragraph is required. As with the computational subsystem requirement, the choice of equipment is left to the contractor.

REQUIREMENT LESSONS LEARNED

4.11.1 TSS **mass storage equipment.** Verify by __________.

VERIFICATION RATIONALE (4.11.1)

To assure compliance.

VERIFICATION GUIDANCE

An objective comparison shall be made between the acquired system(s) with that determined required by analysis of total system requirements and approved at the Critical Design Review.

VERIFICATION LESSONS LEARNED

3.11.2 **Modification support terminals.** __________ support terminals shall be provided to facilitate user interface with all trainer modification support functions requiring the use of TSS computational hardware.

REQUIREMENT RATIONALE (3.11.2)

Support terminals are required to satisfy the support requirements of the trainer.

REQUIREMENT GUIDANCE

This requirement for support terminals will be based on functional requirements levied by the individual subsystems requiring support activities. The types, quantity, and placement of the terminals shall be a function of the need for concurrent modification support activity and all other modification support requirements.

REQUIREMENT LESSONS LEARNED

4.11.2 **Modification support terminals.** Verify by __________.

VERIFICATION RATIONALE (4.11.2)

To assure compliance.

VERIFICATION GUIDANCE

Testing will be predicated on the establishment of the final functional support requirements and on the overall design of the training device. Quantitative tests shall be performed on each terminal provided.

VERIFICATION LESSONS LEARNED

3.11.3 **TSS hardcopy equipment.** Capability shall be provided to produce hardcopy output of all data which is displayable on any peripheral display equipment controlled by the TSS computational hardware.

REQUIREMENT RATIONALE (3.11.3)

Hardcopy equipment is necessary because peripheral display equipment alone is inadequate.

REQUIREMENT GUIDANCE

No modification of this paragraph is required. The selection of hardcopy equipment shall be based on hardcopy throughput requirements, reliability, maintainability, supportability, and life-cycle cost.

REQUIREMENT LESSONS LEARNED

4.11.3 TSS hardcopy equipment. Verify by __________.

VERIFICATION RATIONALE (4.11.3)

To assure compliance.

VERIFICATION GUIDANCE

Hardcopy requirements will be determined by the user needs. Test shall be conducted to verify that required hardcopies can be produced.

VERIFICATION LESSONS LEARNED

3.11.4 **Additional modification support peripheral equipment.** In addition to the modification support peripheral equipment specified previously, any additional modification support peripheral equipment necessary to support the modification of the trainer shall be provided. Included shall be all equipment necessary to support instructional system displays and all digital storage technologies used in the trainer (such as ROM, PROM, FPLAs, etc). The additional equipment shall be configured to operate alone or in conjunction with the TSS computational hardware as necessary and shall also be taken into account for the verification of required spare capacities.

REQUIREMENT RATIONALE (3.11.4)

This paragraph is intended to assure that any and all peripheral equipment necessary for the modification support of the trainer will be provided and included in spare capacity considerations.

REQUIREMENT GUIDANCE

Subsystem-unique modification support peripheral equipment should be identified by the functional engineers responsible for the various subsystems.

REQUIREMENT LESSONS LEARNED

4.11.4 Additional modification support peripheral equipment. Verify by __________.

VERIFICATION RATIONALE (4.11.4)

To assure compliance.

VERIFICATION GUIDANCE

All peripheral equipment required to meet the functional and support requirements shall be tested. The tests and procedures shall be included in the Acceptance Test Procedure document.

VERIFICATION LESSONS LEARNED

3.11.5 **TSS spare memory and growth.** __________ percent spare memory and expansion capability shall be provided to allow for changing modification support requirements over the life-cycle of the trainer. This requirement shall apply separately to each type of memory in each computer configuration in the TSS computational hardware.

REQUIREMENT RATIONALE (3.11.5)

Spare memory and growth capability is necessary for adaptation to changing modification support requirements (due to trainer mission enhancements).

REQUIREMENT GUIDANCE

Specify the amount of spare and expansion memory required. The recommended amount is 100 percent for each blank.

REQUIREMENT LESSONS LEARNED

4.11.5 **TSS spare memory growth.** Verify by __________.

VERIFICATION RATIONALE (4.11.5)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by running the program required by 3.11.8.3 and an objective analysis of the test output.

A means of defining a measure of accuracy in terms of values such as position or velocity that can be used to compare the simulated value to the predicted value will need to be developed. For example, equations of motion position might be used to initialize an INS simulation. Based upon factors such as malfunctions, time between updates, inherent system errors, etc, it could be predicted how well the actual system would be performing. The absolute accuracy measurement would test the simulation's capability to match the actual system performance under the same conditions. The tolerance associated with the absolute accuracy requirement should be based upon the training fidelity requirement (i.e., the greater the fidelity required for training, the tighter the accuracy tolerance). The determination of absolute accuracy requirements will require an in-depth understanding of system design and operational capability. A great deal of information for a mature navigation system should be available from crew member experience

REQUIREMENT LESSONS LEARNED

3.11.6 TSS mass storage spare and growth. Each unit of mass storage equipment which is used in a random-access mode of operation shall have an on-line, spare storage capacity that is at least ___(a)___ percent of its total capacity. Also, the total on-line storage capacity of the mass storage equipment shall be increasable by ___(b)___ percent without increase in interface hardware.

REQUIREMENT RATIONALE (3.11.6)

Spare and growth capacities are necessary for adaptation to changing modification support requirements (due to trainer mission enhancements) and for the efficient operation of the hardware.

REQUIREMENT GUIDANCE

a. Specify the minimum acceptable spare capacity. The recommended value is 50 percent of its allocated capacity.

b. Specify the growth capability required. The recommended value is 100 percent--that is, expansion from one unit to two.

Both of these parameters should correlate closely with the spare requirements of the computational subsystem for primary mass storage. The reason the spare requirement is restricted to random-access mass storage equipment is that it would not make sense to specify spare for a serial-access device such as a magnetic tape drive. All that the contractor would have to do to meet the requirement is supply a longer tape. The requirement for a capability to increase the on-line storage capacity is to insure the interface controller has the capacity to handle additional units without modification or addition of hardware.

REQUIREMENT LESSONS LEARNED

4.11.6 TSS mass storage spare and growth. Verify by __________.

VERIFICATION RATIONALE (4.11.6)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by running programs required under 3.11.8.3 and a design analysis to insure additional units can be added without any redesign.

VERIFICATION LESSONS LEARNED

3.11.7 **TSS I/O expansion.** The total number of I/O channels of the TSS computational hardware, in terms of such peripheral equipment as terminals and mass storage, shall be increasable by ________ percent. The available information transfer capacity shall be increasable by the same percentage.

REQUIREMENT RATIONALE (3.11.7)

Spare capacities are necessary to insure that the system will have the ability to adapt to change.

REQUIREMENT GUIDANCE

The recommended value for this parameter is 50 percent. The contractor is free to provide spare or expansion capacity in whatever combination he desires.

REQUIREMENT LESSONS LEARNED

4.11.7 **TSS I/O expansion.** Verify by __________.

VERIFICATION RATIONALE (4.11.7)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted on all input/output equipment using the delivered diagnostic programs. An analysis of the designs shall insure adequacy of any required expansion capabilities.

VERIFICATION LESSONS LEARNED

3.11.8 **TSS maintenance and test computer programs.** Computer programs/data shall be developed and provided to fully test the operation of the TSS and associated equipment. These programs shall be designed to execute on the deliverable TSS computer configuration(s) and shall be controllable with a single modification support terminal. Hardcopy of the input and output parameters shall be an option at execution time.

REQUIREMENT RATIONALE (3.11.8)

The specified programs are required to assure maintainability and availability of the TSS for modification support activities.

REQUIREMENT GUIDANCE

No modification of this paragraph is required. Specific maintenance and test programs are delineated in the following subparagraphs.

REQUIREMENT LESSONS LEARNED

4.11.8 TSS maintenance and test computer programs. Verify by __________.

VERIFICATION RATIONALE (4.11.8)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify that the complete support system meets all static and dynamic functional requirements necessary to fulfill the defined support concept.

VERIFICATION LESSONS LEARNED

3.11.8.1 TSS computer equipment diagnostic computer programs. A complete set of diagnostic programs shall be provided to isolate equipment failures in the TSS. Except for the portions of test that check whether or not inputs can be received from, and outputs can be transmitted to the equipment in question, all diagnostics shall be fully automatic. This means that once the user has loaded the diagnostic and set up initial conditions, the program will automatically test the TSS equipment and generate error indications (if any) on the terminal and hardcopy device. These programs shall be capable of automatic execution as a total package and as individual diagnostic checks. The diagnostics shall check each computer configuration and its options, and all memory units, peripheral units, and input/output units in the TSS.

REQUIREMENT RATIONALE (3.11.8.1)

Diagnostic programs to isolate hardware failures are necessary to maintain the TSS.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.11.8.1 TSS computer equipment diagnostic computer programs. Verify by __________.

VERIFICATION RATIONALE (4.11.8.1)

To assure compliance.

VERIFICATION GUIDANCE

The complete set of diagnostic programs shall be exercised to verify the capability to isolate failures in the computer equipment for all possible internal operations and computer dependent operations specified. The diagnostics shall be exercised following the prescribed procedures identified in the operations manuals to insure agreement between the program and documentation.

VERIFICATION LESSONS LEARNED

3.11.8.2 **TSS equipment test computer programs.** Computer programs/data shall be provided to check the proper functioning of all remaining TSS equipment and equipment controlled by TSS computational hardware.

REQUIREMENT RATIONALE (3.11.8.2)

This paragraph assures that some level of diagnostic capability shall be provided for all TSS equipment.

REQUIREMENT GUIDANCE

No modification of this paragraph is necessary.

REQUIREMENT LESSONS LEARNED

4.11.8.2 **TSS equipment test computer programs.** Verify by _________.

VERIFICATION RATIONALE (4.11.8.2)

To assure compliance.

VERIFICATION GUIDANCE

All unique and specialized equipment that is included in the support system shall be tested. The programs developed for checking the proper functioning of this equipment shall be tested utilizing the procedures documented in the Acceptance Test Procedures.

VERIFICATION LESSONS LEARNED

3.11.8.3 **Spare memory and mass storage verification computer programs.** Computer programs shall be provided to verify the spare capacities specified for memory and mass storage. These programs shall provide the data from which calculations will be made to verify compliance. The spare memory data shall be obtained from the configuration of modification support activity which produces the maximum memory utilization. Computer vendor operating system built-in functions or utilities may be used if all requirements are satisfied. Optional hardcopy output shall be selectable when exercising each program.

REQUIREMENT RATIONALE (3.11.8.3)

It is desirable to be able to verify spare capacity throughout the life of the ATD.

REQUIREMENT GUIDANCE

No modification of this paragraph is necessary.

REQUIREMENT LESSONS LEARNED

4.11.8.3 **Spare memory and mass storage verification computer programs.** Verify by __________.

VERIFICATION RATIONALE (4.11.8.3)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify that the program provided will accurately determine that the spare capacities can be measured and required hardcopy provided. This includes tests measuring spare memory and spare on-line mass storage.

VERIFICATION LESSONS LEARNED

3.11.9 **Modification support computer programs/data.** Computer programs/data shall be provided to support the modification of the TSS computational system and the interfaced major component subsystems to reflect changes in the simulated air-vehicle or crew stations. Computer vendor-supplied commercial off-the-shelf (unmodified) computer programs shall be provided wherever possible.

REQUIREMENT RATIONALE (3.11.9)

Addition, deletion, or modification of equipment items or systems on airborne digital multiplexed data buses, instrument changes, or other aircraft system modifications which force changes to be made to the trainer interface hardware will also force changes in computational subsystem software.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.11.9 Modification support **computer program/data.** Verify by __________.

VERIFICATION RATIONALE (4.11.9)

To assure compliance.

VERIFICATION GUIDANCE

Test shall be conducted on the adequacy of all vendor-supplied and contractor-developed support programs to meet the functional requirements of the support system.

VERIFICATION LESSONS LEARNED

3.11.9.1 **TSS operating system.** A standard computer vendor operating system (OS) shall be used and provided for each general-purpose digital computer in the TSS computational hardware. The OS must support multi-terminal interactive and batch processing modes of operation. The TSS OS may be the same as that provided for the trainer computational subsystem if all modification support requirements are satisfied. If it is different, then the TSS OS must have the capability to bridge the software between the two systems.

REQUIREMENT RATIONALE (3.11.9.1)

A standard computer vendor operating system has been proven to be necessary for the short and long term supportability of ATDs. It assures hardware and software compatibility over the life-cycle of the trainer if both vendor hardware and software are maintained at their latest revision levels.

REQUIREMENT GUIDANCE

No modification of this paragraph is necessary. It should be noted here that the SOW should require that all commercial software delivered with the trainer should be at the latest available revision level. The contractor may object to this requirement on the grounds that the revision level of software may change during the course of the contract. This is not a valid argument because the commercial software must be maintained at the latest revision levels throughout the life of the simulator. If a revision level changes during the software development phase, the contractor will be demonstrating that the software he develops can readily adapt to changes in the commercial software--that he has put no "hooks" into the OS which are dependent upon a particular subroutine being at a particular memory location.

REQUIREMENT LESSONS LEARNED

In the past, contractors have provided software simply because the specification said they had to provide it. They refused to use it in their development efforts and claimed that the specification did not require they use it.

4.11.9.1 **TSS operating system.** Verify by __________.

VERIFICATION RATIONALE (4.11.9.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests and analysis of the delivered operating system (OS) shall be conducted to insure that it is a standard vendor OS, meet the requirements for supporting multi-terminal interactive and batch processing, is of the latest revision level, and supports all other established support requirements.

VERIFICATION LESSONS LEARNED

3.11.9.2 **Compilers/assemblers.** All compilers and assemblers used in the generation of the CPS shall be provided. The use of compilers and assemblers in the generation of the CPS shall be consistent with the programming language requirements of this specification. In addition, any pre-compilers or sourcecode processors whose output is used as input to the compilers or assemblers shall be provided. Compilers and/or assemblers shall be provided for each type of computer used in the computational system.

REQUIREMENT RATIONALE (3.11.9.2)

Compilers and/or assemblers are required for the modification support of the trainer.

REQUIREMENT GUIDANCE

No modification of this paragraph is necessary.

REQUIREMENT LESSONS LEARNED

4.11.9.2 **Compilers/assemblers.** Verify by __________.

VERIFICATION RATIONALE (4.11.9.2)

To assure compliance.

VERIFICATION GUIDANCE

The verification of availability and adequacy of the compiler/assemblers shall be validated. In performing a system generation of all operational software, testing of significant portions of compilers/assemblers will be accomplished.

VERIFICATION LESSONS LEARNED

3.11.9.3 **Loaders.** All loaders, linking loaders, task builders, and any other computer programs used to establish the operational CPS configuration shall be provided. Standard computer vendor off-the-shelf commercial computer programs shall be used to satisfy this requirement.

REQUIREMENT RATIONALE (3.11.9.3)

These computer programs are required to assure that the operational CPS configuration will be easily modifiable.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.11.9.3 **Loaders.** Verify by ___________.

VERIFICATION RATIONALE (4.11.9.3)

To assure compliance.

VERIFICATION GUIDANCE

The acceptability of the delivered "loaders" will be verified as a result of the system generation required in 3.11.11, followed by the acceptance testing of the total integrated trainer system.

VERIFICATION LESSONS LEARNED

3.11.9.4 **Standard libraries.** All computer vendor standard product libraries for all computer configurations used in the development, support, maintenance, and operation of the CPS shall be provided.

REQUIREMENT RATIONALE (3.11.9.4)

If libraries are required during the development of the CPS, they will also be required for maintenance and support of the CPS.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.11.9.4 **Standard libraries.** Verify by ___________.

VERIFICATION RATIONALE (4.11.9.4)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify the operational programs developed to provide real-time storage and retrieval of on-line computer program items.

VERIFICATION LESSONS LEARNED

3.11.9.5 **Data base management computer programs.** Computer programs/data shall be provided and used to develop and modify data bases which are directly related to hardware which is part of, or controlled by, the computational subsystem. Examples include interface hardware address or configuration tables, mapping tables or data, the visual data base, radar landmass data base, PWT data, and the like.

REQUIREMENT RATIONALE (3.11.9.5)

Support programs will be needed for modifying the operational computer data bases delivered with the trainer.

REQUIREMENT GUIDANCE

Modification of this paragraph may be required. Expand to include details on specific data bases that need to be supported and the types of support required.

REQUIREMENT LESSONS LEARNED

4.11.9.5 **Data base management computer programs.** Verify by ___________.

VERIFICATION RATIONALE (4.11.9.5)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify the data base management program meets the support requirements specified. As part of the test, modifications shall be made to existing data bases to verify the resulting changes are as required and the hardcopy is satisfactory.

VERIFICATION LESSONS LEARNED

3.11.9.6 **Text editors.** Computer programs shall be provided to allow computer program source code to be easily altered or created. The programs shall utilize modification support terminals for user input and output. The programs shall allow the modification of all source-code provided with the trainer (for each type of computer). Standard computer vendor off-the-shelf commercial computer programs may be used to satisfy this requirement.

REQUIREMENT RATIONALE (3.11.9.6)

This requirement assures that the individual programs provided with the trainer will be easily modifiable.

REQUIREMENT GUIDANCE

No modification of this paragraph is necessary.

REQUIREMENT LESSONS LEARNED

4.11.9.6 **Text editors.** Verify by ________.

VERIFICATION RATIONALE (4.11.9.6)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted to verify that the delivered editors provide the required software modification support. If a vendor supplied editor is deemed acceptable, it will be verified that the latest revision level is provided.

VERIFICATION LESSONS LEARNED

3.11.9.7 **Development tools.** All computer program development tools used in the development of the CPS shall execute on the TSS and be provided. Examples of such computer programs are execution flow tracers, emulators, syntax analyzers, and debug computer programs. The programs shall utilize modification support terminals for user input and output.

REQUIREMENT RATIONALE (3.11.9.7)

Computer program development tools used for the development of the CPS have proven to be useful in the modification support of the CPS.

REQUIREMENT GUIDANCE

No modification of this paragraph is required.

REQUIREMENT LESSONS LEARNED

4.11.9.7 **Development tools.** Verify by ________.

VERIFICATION RATIONALE (4.11.9.7)

To assure compliance.

VERIFICATION GUIDANCE

The verification activity will consist primarily of a concentrated effort to ensure that all software used in the development of the trainer is provided.

VERIFICATION LESSONS LEARNED

3.11.9.8 Mass storage copy/comparator software. Software shall be provided which satisfies the following functional requirements between all units (e.g., drives, transports) of similar and dissimilar mass storage in both the primary and secondary mass storage systems (e.g., disc-to-disc, disc-to-tape, tape-to-tape, etc): __________. The programs shall be operable through an operator or support terminal and shall allow the error output to be optionally directed to hardcopy. Commercially available software shall be used if it satisfies all of the above requirements.

REQUIREMENT RATIONALE (3.11.9.8)

This capability is necessary to install software changes from the various support activities distributed on secondary mass storage media.

REQUIREMENT GUIDANCE

The functional requirements list should include the following:

a. Individual and multiple file copy/verification.

b. File concatenation and merge, file-by-file, and by records within files.

c. File-by-file comparison with suppressible error output for multiple errors, for all file types.

REQUIREMENT LESSONS LEARNED

Insure that a full disc comparison system does not require that the disc containing the comparison software be one of the discs involved in the comparison (i.e., compare discs A and B, with the comparison software on disc C).

4.11.9.8 Mass storage copy/comparator software. Verify by __________.

VERIFICATION RATIONALE (4.11.9.8)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall be conducted by taking sample programs and evaluating each of the specified requirements. Sample programs, with and without differences, will be used to validate the correct performance of the software under test.

VERIFICATION LESSONS LEARNED

3.11.10 Computer software tree. Computer programs and required data base shall be provided to generate and maintain a computer software tree (CST). The generation of the CST shall be an automated process. The CPS generation computer programs required in 3.11.22 shall be designed to use the CST as a source data base. The CST shall provide a detailed breakout of all computer software components, and computer software units which contains at least the following items: __________. This data base shall portray the hierarchical structure of the computer software from the top level to the smallest separately compilable unit of code. Each element of the computer software (component, unit, etc) shall be listed as a separate element of the tree. The details of each field for each level of the tree are to be filled in as the software evolves and the applicable data becomes available. As the design progresses and specific computer software units (CSUs) are identified, the time and memory estimates shall be entered in the CSU level elements of the tree. All fields shall be presented in the tree. Any fields not applicable to a specific element of the tree shall be so designated with "N/A". Any field that is applicable but the data not yet available shall be designated with the milestone or date at which the information will be available.

REQUIREMENT RATIONALE (3.11.10)

This capability is required to insure a structured software control system is maintained for software development, tracking, and configuration management. The CST is used throughout the development cycle to assure that the design of the computer software encompasses all development requirements. It will be used as the list of source files for testing purposes. By tying the CST to the source code and using the tree as the control for the system generation, a direct correlation is insured.

REQUIREMENT GUIDANCE

Insert any of the following options for the CST fields:

a. Tree level identifier: A unique identifier shall be assigned to each CSU. This identifier shall provide traceability from that CSU to both higher and lower level units. (A higher level unit is one that calls this unit; a lower level unit is one that this unit calls.)

b. Contractor internal identifier: This identifier shall be reserved for the contractor's use to aid in cross-referencing between his internal system of CSU identification and the methods specified herein.

c. Source file mnemonic name: This is the name of the file on the computer system magnetic media which contains the source code for this CSU.

d. Source file revision level: The source file revision level shall be automatically updated each time a change is made to the source file for this CSU.

e. Source file revision date: This entry shall be automatically updated with the date of the latest revision to the source code for this CSU.

f. Object file mnemonic name: This field is the name of the file on the computer system magnetic media which contains the output from the assembler or compiler.

g. Object file revision level: This entry shall be automatically updated with the revision level of the latest compilation or assembly of the source file; for some languages and/or computer systems, this is not necessarily the same as the source revision level.

h. Object file revision date: This entry shall be automatically updated with the date of the latest compilation or assembly.

i. Load file mnemonic name: This the name of the executable load file on the computer system magnetic media which contains the CSU. Typically, this file will be produced by the linker and may incorporate several object files.

j. Load file revision level: This entry shall be automatically updated with the revision number for the latest version of the executable load file which contains this unit.

k. Load file revision date: This entry shall be automatically updated with the date of the latest load file which contains this CSU.

l. Computer software identification number (CSIN): This number is assigned by the Government.

m. CPU number: The CPU that the CSU is executed in, for multiple CPU systems.

n. Iteration rate: This field shall specify the rate, in Hz, at which this CSU will execute.

o. Scheduling data: This field shall specify (by frame and cycle number or other relevant method) when the CSU executes.

p. Priority: For units which have an execution priority, this field shall contain the operating system software priority assigned to the task to ensure proper scheduling and execution.

q. Support data: Any other data necessary to support the automated assembly/compilation or linking of the CSU.

r. Description: This field shall contain a brief functional description of this unit.

s. Support system: This field shall specify the system or subsystem that this unit supports. For real-time simulation systems or subsystems, this field shall specify the real-world system that this unit simulates (such as engines, aerodynamics, etc).

t. Time estimate: The time estimate field for each level of the tree shall consist of four factors as specified below:

(1) Estimate. This field shall contain the current estimate of execution time for one iteration of this unit.

(2) Metrics: This field shall contain the unit of measurement associated with the estimate in (1), above.

(3) Confidence level/source of estimate: This field shall contain a code specifying the confidence level and/or source of the estimate data in (1), above. As the estimates change over the life cycle of the contract, these estimate codes shall be updated to reflect the level and source of each estimate. These codes shall include at least:

0 = rough guess
1 = estimate based on completion of math model design
2 = based on completion of the flowchart or PDL
3 = based on unit test, coding complete
4 = actual time measurement taken while the CSU is running under typical conditions
5 = revised as a result of qualification test or update

Other codes may be included as appropriate or required.

(4) Date: This field shall specify the date of the estimate given in (1), above. This date may be different from other dates specified herein.

u. Memory estimate: The memory estimate for each level of the CST shall consist of the same four factors as the time estimate. It is intended that this field shall also be updated throughout the life cycle of the software as the estimates change.

v. Documentation reference pointers: This field shall contain the volume numbers and page numbers of the software documentation for this CSU.

w. Development phase and percent completion: This field shall contain the phase of development (preliminary design, detail design, coding, etc) the CSU is currently in and an estimate of the percent of this phase completed.

x. Additional fields shall be provided which shall contain other information as circumstances dictate.

REQUIREMENT LESSONS LEARNED

Be aware of contractors combining separately compilable units of code into larger batch jobs and then reflecting only the batch jobs (which may include any number of separate units) in the software tree. This is especially a problem if documentation is at the separate unit level.

4.11.10 Computational software tree. Verify by __________.

VERIFICATION RATIONALE (4.11.10)

To assure compliance.

VERIFICATION GUIDANCE

This is the control system to be utilized for software development, tracking, and configuration management throughout the development cycle. The verification of compliance will be a continuing activity from initial delivery to utilization as the source data base for the system generation required by 3.11.22.

VERIFICATION LESSONS LEARNED

3.11.11 **CPS generation computer programs.** Computer programs/data shall be provided to perform a "cold-start" or system generation of the total simulator CPS for execution on the computational subsystem. This shall include the automatic compilation/assembly of all source computer programs/data under the control, and in same order, as shown in the CST. The programs shall be designed to require a minimum of user input and shall allow for the optional generation of hardcopy of all terminal output and all listing files generated by the compilers, assemblers, or loaders utilized in the process. A capability shall be included to pause and later resume the system generation without any impact.

REQUIREMENT RATIONALE (3.11.11)

Cold-start is used to establish a baseline CPS configuration and since it can be such a long and tedious process, its automation is desirable. When the CPS undergoes extensive change, a cold-start should be performed. So, these programs do provide a form of modification support.

REQUIREMENT GUIDANCE

No modification of this paragraph is necessary.

REQUIREMENT LESSONS LEARNED

4.11.11 **CPS generation computer programs.** Verify by __________.

VERIFICATION RATIONALE (4.11.11)

To assure compliance and establish a software configuration baseline for the total trainer system.

VERIFICATION GUIDANCE

Tests shall include the complete compilation/assembly of the trainer computer programs/data for execution on the Computational Subsystem. The requirement for minimum operator intervention and optional generation of hardcopy shall evaluated.

VERIFICATION LESSONS LEARNED

3.12 **Practical design considerations.** In addition to the design considerations indicated in paragraph 3, Requirements, the following practical design considerations shall be addressed: experience-based ATD system design considerations, safety, reliability, maintainability, availability for training, accessibility, and life cycle cost.

The ATD shall incorporate standard industry design practices except as modified herein.

REQUIREMENT RATIONALE (3.12)

This paragraph is intended to focus attention on those critical items which industry standards may not adequately cover, but without directing the contractor to specific solutions. In the context of contractor support, which is assumed here, the contractor should be permitted maximum freedom in selecting processes, parts, and assemblies to achieve the required quality and performance at minimum life cycle cost.

REQUIREMENT GUIDANCE

Select those sections of this paragraph which are necessary to achieve the ultimate goal.

REQUIREMENT LESSONS LEARNED

4.12 **Practical design considerations.** Tests, inspections, analyses, and demonstrations shall be conducted as applicable to verify that these requirements have been satisfied.

VERIFICATION RATIONALE (4.12)

To assure compliance.

VERIFICATION GUIDANCE

Verify requirements as indicated.

VERIFICATION LESSONS LEARNED

3.12.1 Air training device system design considerations. Air training device system design considerations shall include facility interface, transportability, power interface, grounding, thermal design, and name plate and product marking.

REQUIREMENT RATIONALE (3.12.1)

These are the major system design considerations in the ATD design.

REQUIREMENT GUIDANCE

This paragraph should be included to indicate those major concerns of the USAF.

REQUIREMENT LESSONS LEARNED

4.12.1 Air training device system design considerations. Tests, inspections, analyses, and demonstrations shall be conducted as applicable, to verify that these requirements have been satisfied.

VERIFICATION RATIONALE (4.12.1)

To assure compliance.

VERIFICATION GUIDANCE

Verify requirements as indicated.

VERIFICATION LESSONS LEARNED

3.12.2 Environmental conditions. The training equipment, including all components, shall be designed for operation within the following ambient air environmental limits:

a. Non-hydraulics: ___(a)___.

b. The hydraulic pump room equipment shall be designed to operate under the following environmental conditions: ___(b)___.

REQUIREMENT RATIONALE (3.12.2)

This requirement indicates the environment for which the ATD should be designed.

REQUIREMENT GUIDANCE

Recommended environmental parameters are:

a. Non-hydraulics.

(1) Temperature: 21 + 5°C. (70 + 9°F).

(2) Relative humidity: 40 to 70 percent (non-condensing).

b. Hydraulic pump room equipment (operational).

(1) Temperature: 15 to 30°C. (60 to 85°F).

(2) Relative humidity: 40 to 70 percent (non-condensing).

REQUIREMENT LESSONS LEARNED

Evaluate the intended site outside environment carefully to determine the expected hydraulic equipment room environment as this impacts the type of heat exchangers used.

4.12.2 Environmental conditions. Verify by __________.

VERIFICATION RATIONALE (4.12.2)

To assure compliance.

VERIFICATION GUIDANCE

Verification may be accomplished by inspection of the contractors design analyses.

VERIFICATION LESSONS LEARNED

3.12.2.1 Thermal design. Adequate thermal design shall be employed to maintain parts within their operating temperature limits under specified operating conditions. The simplest and most efficient thermal design shall be selected. Thermal design provisions shall incorporate a temperature sensing device for thermal protection which will provide visual or aural warning and which will shut off equipment, as applicable, when critical temperature limits are exceeded. Air filters shall be provided for air intakes for fan and blower cooled units when required. Filters, when used, shall be readily removable for cleaning without disassembly of the equipment. Except in commercial off-the-shelf equipment, ventilation and air exhaust openings shall not be located in the top of enclosures or in front panels. Air exhaust shall be so directed that it will not inconvenience operating personnel. Each separate piece of equipment being cooled shall be marked with the high and low operating temperature to which it is designed, the quantity and characteristics of air required to adequately cool the unit, and the resistance to air flow with respect to the air flow rate.

REQUIREMENT RATIONALE (3.12.2.1)

This requirement assures the ATD will function correctly in its intended environment.

REQUIREMENT GUIDANCE

Simple cooling techniques based on conduction, radiation, and free convection which utilize the ambient air as the thermal sink should be used to the maximum extent possible, to minimize life cycle costs.

Forced air cooling shall be used when natural cooling does not provide sufficient cooling or when a significant reduction in overall size and weight can be realized. Induced drafts and ventilation by means of baffles and internal vents should be preferred.

REQUIREMENT LESSONS LEARNED

4.12.2.1 Thermal design. Verify by __________.

VERIFICATION RATIONALE (4.12.2.1)

To assure compliance.

VERIFICATION GUIDANCE

The contractors design analyses should be reviewed as early as possible. Harsh or extraordinary environmental conditions may justify testing to assure compliance for heat exchangers for hydraulic systems.

VERIFICATION LESSONS LEARNED

3.12.2.2 **Detrimental entrained contaminants.** If external cooling air is used, equipment shall be protected from entrained contaminants, including water, by __________.

REQUIREMENT RATIONALE (3.12.2.2)

This requirement assures clean cooling air.

REQUIREMENT GUIDANCE

Select any or all of the following techniques:

a. Avoid direct impingement on internal parts and circuitry by channeling or use of heat exchangers.

b. Use suitable water and contaminant removal devices.

c. Maintain the minimum differential pressure of the heat exchanger(s) or cold plate that still allows adequate cooling.

REQUIREMENT LESSONS LEARNED

4.12.2.2 **Detrimental entrained contaminants.** Verify by __________.

VERIFICATION RATIONALE (4.12.2.2)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.12.2.1).

VERIFICATION LESSONS LEARNED

3.12.3 **Transportability.** The simulator shall be transportable by: ___(a)___. Adequately located and strengthened tie-down points shall be provided. Hoisting or lifting provisions shall be included in the design. Other transportability conditions include: ___(b)___.

REQUIREMENT RATIONALE (3.12.3)

This requirement assures the ATD may be transported to the facility and survive any later moves required.

REQUIREMENT GUIDANCE

a. Indicate means of transport, such as "truck".

b. Indicate other factors which will affect transportability--for example, doorsizes, pallet sizes, maximum weights per unit area, etc.

Include this requirement to assure the ATD is transportable. Also check other portions of the contract to assure this area is adequately covered.

REQUIREMENT LESSONS LEARNED

4.12.3 Transportability. Verify by __________.

VERIFICATION RATIONALE (4.12.3)

To assure compliance.

VERIFICATION GUIDANCE

Inspection of the contractor's design analyses should be adequate.

VERIFICATION LESSONS LEARNED

3.12.4 **Mechanical.** The ATD shall be designed and constructed so that no fixed part shall become loose, and no movable part or permanently set adjustment shall shift its setting or position when subjected to the shock and vibration incident to preparation for shipment, loading, shipping, unloading, and assembly, as well as to training functions and emergency shutdowns. Optical and cathode ray tube systems design, construction, and installation shall be such as to retain alignment and operation within required limits when subject to normal training operation and emergency shutdowns.

REQUIREMENT RATIONALE (3.12.4)

The ATD must be designed to withstand expected mechanical shocks. In addition to the operational environment, the shipping environment must be considered.

REQUIREMENT GUIDANCE

This paragraph should be included when the simulator includes physical motion systems or when the shipping process is a concern.

REQUIREMENT LESSONS LEARNED

4.12.4 Mechanical. Verify by __________.

VERIFICATION RATIONALE (4.12.4)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.12.5)

VERIFICATION LESSONS LEARNED

3.12.5 Workmanship. Workmanship shall be of sufficient quality and assure that manufactured parts are of consistent quality, free of burrs and sharp edges, or other defects that could render the part or equipment unsatisfactory or unsafe for the purpose intended. Parts shall be mounted so that markings are visible. PC boards, except for those contained in commercial off-the-shelf equipment, and other easily misidentified parts shall be keyed to assure insertion in correct slots or positions. Electronic card racks shall have a listing and diagram attached to indicate the position of each card in the rack. Parts shall be cleaned of any material of manufacture or foreign agent which might detract from the intended operation, function, or appearance of the equipment. Fasteners shall be tight. Screw-type fasteners shall show no evidence of cross threading or mutilation and rivet heads shall have their heads tightly seated against their bearing surface.

REQUIREMENT RATIONALE (3.12.5)

This requirement should assure the device is engineered, manufactured, and assembled in ways that will preclude maintenance type problems.

REQUIREMENT GUIDANCE

Include this requirement when organic maintenance is intended. Include relevant portions of this requirement when contract support is intended.

REQUIREMENT LESSONS LEARNED

Ease of reading part identifications, positive PCB slot identification, and keyed PCBs will preclude many incorrect maintenance actions.

4.12.5 Workmanship. Verify by __________.

VERIFICATION RATIONALE (4.12.5)

To assure compliance.

VERIFICATION GUIDANCE

Satisfying this requirement includes analysis of the contractor's quality control program, physical inspection of the assembled ATD, and any necessary steps during manufacture to establish those concepts necessary for contract fulfillment.

VERIFICATION LESSONS LEARNED

3.12.6 Electromagnetic compatibility. The training device shall be electromagnetically compatible with itself, the other equipment in the same facility, and the environment, as applicable. Adequate shielding and circuit separation shall be designed into the training device. Where classified information will be processed, the design shall be in accordance with the guidelines of AFR-100-45, Communications Security Policies, Procedures and Instructions, and __________.

REQUIREMENT RATIONALE (3.12.6)

This requirement assures that electromagnetic emanations do not degrade the ATD performance or compromise security.

REQUIREMENT GUIDANCE

Include this requirement to assure electromagnetic compatibility and when classified information will be used or processed in the ATD. In the blank, fill in the documents from the NSA NACSEM/NACSIM 5100 series appropriate for the equipment involved.

REQUIREMENT LESSONS LEARNED

4.12.6 **Electromagnetic compatibility.** Verify by __________.

VERIFICATION RATIONALE (4.12.6)

To assure compliance.

VERIFICATION GUIDANCE

If classified information is to be processed, or if the facility is to operate in a high RF emission environment such as near a radar transmitter, for example, this requirement will bear close scrutiny during the design process followed by on-site testing.

VERIFICATION LESSONS LEARNED

3.12.7 **Training device electrical system requirements**

3.12.7.1 **Primary power.** The training device manufacturer shall provide the proper National Electrical Manufacturers Association (NEMA) standard equipment for connecting to the Government-furnished branch circuit termination. Transformers and other electrical equipment necessary to distribute and transform power for operation of the mechanical equipment, lighting equipment, and distribution system shall conform to the National Electrical Code and NEMA standards.

REQUIREMENT RATIONALE (3.12.7.1)

Most ATDs will interface with electrical utilities.

REQUIREMENT GUIDANCE

The National Electrical Code and NEMA standards give adequate guidance.

REQUIREMENT LESSONS LEARNED

4.12.7 Training device electrical system requirements

4.12.7.1 Primary power. Verify by __________.

VERIFICATION RATIONALE (4.12.7.1)

To assure compliance.

VERIFICATION GUIDANCE

Test at the power interface; inspect the ATD for standard parts and engineering practices.

VERIFICATION LESSONS LEARNED

3.12.7.2 Main power distribution panel. A main power distribution panel shall be provided and wired in a manner to avoid damage to equipment by actuating switches in an indiscriminate sequence. All power requirements for the training device shall be satisfied from this panel, thereby allowing for a single-point turn-on.

REQUIREMENT RATIONALE (3.12.7.2)

The design of the main power distribution panel can avoid certain problems.

REQUIREMENT GUIDANCE

No tailoring is necessary.

REQUIREMENT LESSONS LEARNED

4.12.7.2 Main power distribution panel. Verify by __________.

VERIFICATION RATIONALE (4.12.7.2)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.12.7.1).

VERIFICATION LESSONS LEARNED

3.12.7.2.1 **Utility power.** Utility power circuits shall be designed to operate from the primary power source and shall be operable while the remainder of the training device power is off. These circuits shall contain the utility lights, utility outlets, and maintenance intercom. Outlets for portable tools and equipment shall be 3-wire grounding type utility duplex receptacles. Utility power circuits shall be protected with ground-fault circuit interrupters.

REQUIREMENT RATIONALE (3.12.7.2.1)

These requirements are needed for safety.

REQUIREMENT GUIDANCE

No tailoring is necessary.

REQUIREMENT LESSONS LEARNED

4.12.7.2.1 **Utility power.** Verify by ___________.

VERIFICATION RATIONALE (4.12.7.2.1)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.12.7 and 4.12.7.1).

VERIFICATION LESSONS LEARNED

3.12.7.3 **Circuit design.** The circuit design shall include a main power switch to shut off all power to the training device units without disconnecting from the power source. An indicator light shall be provided with each power switch required throughout the training device to indicate when power is on.

REQUIREMENT RATIONALE (3.12.7.3)

This requirement is needed for safety and protection of equipment.

REQUIREMENT GUIDANCE

No tailoring is necessary.

REQUIREMENT LESSONS LEARNED

4.12.7.3 **Circuit design.** Verify by __________.

VERIFICATION RATIONALE (4.12.7.3)

To assure compliance.

VERIFICATION GUIDANCE

Test the main power disconnect; inspect for indicator lights.

VERIFICATION LESSONS LEARNED

3.12.7.3.1 **Tolerances for circuit design.** Unbalanced line currents in the system shall not exceed 7.5 percent of the average simultaneously measured line current. The power factor of the total inputs, measured at the primary power source, shall not be less than 85 percent for any mode of operation. The training device shall be protected from permanent damage and alteration of characteristics due to total power failure.

REQUIREMENT RATIONALE (3.12.7.3.1)

This requirement is needed to protect equipment from electrical damage.

REQUIREMENT GUIDANCE

No tailoring is necessary.

REQUIREMENT LESSONS LEARNED

4.12.7.3.1 **Tolerances for circuit design.** Verify by __________.

VERIFICATION RATIONALE (4.12.7.3.1)

To assure compliance.

VERIFICATION GUIDANCE

Test under the various expected "training modes".

VERIFICATION LESSONS LEARNED

3.12.7.3.2 **Overload protection.** __________ shall be provided within the training device for primary circuits and other circuits as necessary for protection of the equipment from damage due to electrical overload. The use of fuses is not permitted except in commercial off-the-shelf equipment. All circuit protection devices shall be readily accessible and replaceable by locating them directly on the front panels of the equipment. All parts that may be subjected to an overload due to circuit malfunctions, poor adjustment, or part failures shall be designed to accommodate such a load. Where parts cannot be designed to accommodate an overload, circuit breakers shall be provided to protect the unit or assembly. The training device shall be designed for protection from overvoltage, undervoltage, and phase power loss for all three phases of line input.

REQUIREMENT RATIONALE (3.12.7.3.2)

This requirement protects the ATD from electrical damage.

REQUIREMENT GUIDANCE

Current state-of-the art is to use circuit breakers for this.

REQUIREMENT LESSONS LEARNED

4.12.7.3.2 Overload protection. Verify by __________.

VERIFICATION RATIONALE (4.12.7.3.2)

To assure compliance.

VERIFICATION GUIDANCE

Examine for NEC/NEMA standard parts, examine original equipment manufacturer's (OEM) data.

VERIFICATION LESSONS LEARNED

3.12.7.3.3 **Power conditioning.** Power conditioning equipment __________ shall be provided to minimize the effects of power disturbances and interruptions on simulator operation.

REQUIREMENT RATIONALE (3.12.7.3.3)

Power conditioning is sometimes needed for the ATD to meet performance requirements.

REQUIREMENT GUIDANCE

Such equipment includes:

Motor generators
Solid state power conditioners
Uninterruptable power sources.

If the simulator system is simple or the power is of high quality, this paragraph is not required.

REQUIREMENT LESSONS LEARNED

4.12.7.3.3 Power conditioning. Verify by __________.

VERIFICATION RATIONALE (4.12.7.3.3)

To assure compliance.

VERIFICATION GUIDANCE

Examine the engineering rationale and design; check for compliance as for 4.12.7.3.2.

VERIFICATION LESSONS LEARNED

3.12.7.4 Grounding and grounding systems. Three separate and isolated reference grounding systems shall be established to control ground-return conducted interference, provide effective shielding, and protect personnel from electric shock hazard. These are:

a. Primary power grounding

b. Signal grounding

c. Chassis grounding.

REQUIREMENT RATIONALE (3.12.7.4)

Contained in the requirement.

REQUIREMENT GUIDANCE

No tailoring is required.

REQUIREMENT LESSONS LEARNED

4.12.7.4 Grounding and grounding systems. Verify by __________.

VERIFICATION RATIONALE (4.12.7.4)

To assure compliance.

VERIFICATION GUIDANCE

Examine ATD grounding plan and associated grounding system drawings.

VERIFICATION LESSONS LEARNED

3.12.7.5 Wire coding/identification. Wire coding and identification shall be as specified herein except that these requirements shall not apply to commercial off-the-shelf equipment.

REQUIREMENT RATIONALE (3.12.7.5)

This is a header paragraph and requires no rationale.

REQUIREMENT GUIDANCE

Include this paragraph when applicable.

REQUIREMENT LESSONS LEARNED

4.12.7.5 Wire coding/identification. Verify by __________.

VERIFICATION RATIONALE (4.12.7.5)

To assure compliance.

VERIFICATION GUIDANCE

Examine wiring in ATD and design documentation.

VERIFICATION LESSONS LEARNED

3.12.7.5.1 **Conductor identification.** To facilitate testing and locating of faults, all conductors which are coded shall follow the same pattern throughout the equipment. The coding selected for a particular circuit shall run continuously through connectors, plugs and receptacles, or interconnecting circuits. When point-to-point wiring is utilized, internal to a chassis or cabinet, non-coded wiring may be used.

REQUIREMENT RATIONALE (3.12.7.5.1)

To facilitate engineering change proposal (ECPs) and logistic support contract changes.

REQUIREMENT GUIDANCE

Include this requirement to preclude conductor identification problems and related problems during efforts to change the contractor for contracted support.

REQUIREMENT LESSONS LEARNED

4.12.7.5.1 **Conductor identification.** Verify by __________.

VERIFICATION RATIONALE (4.12.7.5.1)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.12.7.5).

VERIFICATION LESSONS LEARNED

3.12.7.5.2 **Terminal ends.** The terminal ends of each conductor of a jacketed cable or hookup wire harness shall be marked for positive identification.

REQUIREMENT RATIONALE (3.12.7.5.2)

To facilitate engineering change proposal (ECPs) and logistic support contract changes.

REQUIREMENT GUIDANCE

Include this requirement to preclude conductor identification problems and related problems during efforts to change the contractor for contracted support.

REQUIREMENT LESSONS LEARNED

4.12.7.5.2 **Terminal ends.** Verify by __________.

VERIFICATION RATIONALE (4.12.7.5.2)

To assure compliance.

VERIFICATION GUIDANCE

(See 4.12.7.5).

VERIFICATION LESSONS LEARNED

3.12.8 Nameplates and product marking. Unless otherwise specified herein, nameplates and product marking shall be in accordance with ___(a)___. Control panel markings shall be in accordance with ___(b)___. Abbreviations used in marking equipment shall be in accordance with ___(c)___.

REQUIREMENT RATIONALE (3.12.8)

This requirement assures consistency in drawing standards and product markings and should preclude potential problems when changing contractor for contract support.

REQUIREMENT GUIDANCE

Include this paragraph when organic or contractor support will be used.

a. MIL-STD-130 is typically applied here.

b. MIL-STD-1472 is used here for panel markings.

c. MIL-STD-12 is used for equipment marking.

REQUIREMENT LESSONS LEARNED

4.12.8 Nameplates and product marking. Verify by __________.

VERIFICATION RATIONALE (4.12.8)

To assure compliance.

VERIFICATION GUIDANCE

Inspect documentation and ATD for compliance.

VERIFICATION LESSONS LEARNED

3.12.8.1 **Reference symbol designations.** Reference symbol designations shall be assigned to electrical and electronic component assemblies in accordance with ___(a)___. Mechanical symbols shall be in accordance with ___(b)___. Symbols for electrical and electronic diagrams shall be in accordance with ___(c)___.

REQUIREMENT RATIONALE (3.12.8.1)

This requirement assures consistency in drawing standards and product markings and should preclude potential problems when changing contractor for contract support.

REQUIREMENT GUIDANCE

Include this requirement to assure consistency and standardization of drawing symbols.

a. ANSI Y32.16 is used here.

b. MIL-STD-17 is used here.

c. Use ANSI Y32.2 for these symbols.

REQUIREMENT LESSONS LEARNED

4.12.8.1 **Reference symbol designations.** Verify by ___________.

VERIFICATION RATIONALE (4.12.8.1)

To assure compliance.

VERIFICATION GUIDANCE

(See 3.12.8).

VERIFICATION LESSONS LEARNED

3.12.8.2 Precautionary markings. In all instances where parts, subassemblies, assemblies, and units of ground, air, or space vehicles or equipments are used in the simulation equipment, and these parts, subassemblies, or assemblies are simulated or have been modified in any way for application to the training equipment, such parts, subassemblies, or assemblies shall be durably marked with the following precautionary marking in a plainly visible position (but not visible to the trainee):

WARNING: FOR GROUND TRAINER USE ONLY

If the simulated or modified part is too small to receive the precautionary marking or identification plate, it shall be necessary to affix the precautionary marking or identification plate at the next higher assembly adjacent to the simulated or modified part.

REQUIREMENT RATIONALE (3.12.8.2)

When maintenance personnel raid simulation equipment and use these parts on aircraft, the consequences can be disastrous.

REQUIREMENT GUIDANCE

ALWAYS include this requirement (for safety reasons).

Insert "simulated" or "modified" as applicable.

REQUIREMENT LESSONS LEARNED

4.12.8.2 Precautionary markings. Verify by __________.

VERIFICATION RATIONALE (4.12.8.2)

To assure compliance.

VERIFICATION GUIDANCE

Inspect documentation and ATD for compliance.

VERIFICATION LESSONS LEARNED

3.12.9 Reliability and maintainability

3.12.9.1 Reliability. The reliability requirements for the ATD shall be as follows: __________.

REQUIREMENT RATIONALE (3.12.9.1)

This requirement establishes the minimum acceptable reliability.

REQUIREMENT GUIDANCE

The minimum acceptable quantitative reliability requirement (typically MTBF as defined in MIL-STD-781C) should be derived from the using command's operational reliability requirement (normally MTBM, defined in AFR 800-18). This will require close coordination with the using command to ensure a clear understanding of the requirement. In addition, care should be exercised to ensure consistency in the event it is deemed necessary to specify any related contract requirement, such as availability.

REQUIREMENT LESSONS LEARNED

4.12.9 Reliability and maintainability. Tests, inspections, analyses, and demonstrations shall be conducted to verify the performance of the simulator subsystem.

4.12.9.1 Reliability. The minimum acceptable reliability shall be verified in accordance with the following: __________.

VERIFICATION RATIONALE (4.12.9.1)

To assure compliance.

VERIFICATION GUIDANCE

The scope of test effort shall be consistent with the requirements of this specification.

The government must have a reasonable degree of confidence that reliability requirements have been satisfied before making a production commitment. This is normally accomplished using the procedures of MIL-STD-785B, task 303, as a guide together with an appropriate test plan from MIL-STD-781C. Where possible, the reliability verification test should be integrated with other testing to reduce cost and schedule impact to the program. In addition to citing the specific test plan procedures from MIL-STD-781C, the government should identify the lower test MTBF (usually equal to the minimum acceptable reliability), test duration, life/mission/environmental profile to represent equipment usage in service, equipment to be tested, coordinated logistic support reporting requirements for the LSAR, and data item requirements.

VERIFICATION LESSONS LEARNED

3.12.9.2 **Maintainability.** The maintainability requirement for the ATD shall be as follows: __________.

REQUIREMENT RATIONALE (3.12.9.2)

This paragraph establishes the minimum acceptable maintainability requirement.

REQUIREMENT GUIDANCE

The minimum acceptable quantitative maintainability requirements (typically, mean time to repair and a maximum corrective maintenance time expressed as a percentile of all corrective maintenance times as defined in MIL-STD-471A) should be derived from the using command's operational maintenance manhours per training hour, mean manhours to repair, or other terms defined in AFR 800-18. The required operational maintainability should be developed by, or in close coordination with, the using command to ensure a realistic and defensible requirement. Care should also be exercised to ensure consistency if it should be necessary to specify a related contract requirement such as availability.

REQUIREMENT LESSONS LEARNED

4.12.9.2 Maintainability. The minimum acceptable maintainability shall be verified in accordance with the following: __________.

VERIFICATION RATIONALE (4.12.9.2)

To assure compliance.

VERIFICATION GUIDANCE

Satisfaction of maintainability requirements is normally accomplished using the procedures of MIL-STD-470A, task 301, as a guide together with a contractor developed and government approved test plan in accordance with MIL-STD-471A. Where possible, this test should be integrated with other testing to reduce program costs and schedule impact. In addition to citing the approved test plan procedures, the government should identify the equipment to be tested, test duration, skill levels and type of personnel to be used in the test, maintenance manuals to be used (final, interim or draft documents, etc), coordinated reporting requirements for LSA, and data item requirements.

VERIFICATION LESSONS LEARNED

3.12.9.2.1 Time totalizer. Each major component of the training device that is controlled by a simulator main power panel power switch (e.g., hydraulic system, computers, visual) shall be provided with an elapsed time indicator providing a digital readout (four digit minimum) of the elapsed operating time in hours. Each pump shall have an elapsed time indicator.

REQUIREMENT RATIONALE (3.12.9.2.1)

The time totalizer provides "on time" data which will be useful in evaluating maintenance, whether organic or contract support.

REQUIREMENT GUIDANCE

This paragraph may be tailored by listing the items of equipment, or the circuits, that should have time-totalizing meters.

REQUIREMENT LESSONS LEARNED

4.12.9.2.1 Time totalizer. Verify by __________.

VERIFICATION RATIONALE (4.12.9.2.1)

To assure compliance.

VERIFICATION GUIDANCE

Inspect ATD for compliance.

VERIFICATION LESSONS LEARNED

3.12.10 System safety design. Good commercial practices, in addition to the following design notes (DNs) of AFSC DH 1-6, shall be considered as guidelines in safety designs of training devices:

a. DN 2C2, Man-Machine Safety Design Requirement.

b. DN 2E1, 2, and 3, Introduction, Procedures, and Selection of Safety Analyses.

c. DN 2E4, Resolution of Safety Hazards.

d. DN 4A2, Material Handling Equipment.

e. DN 5D2, Fire Detection.

f. DN 6A1-7, Enviromental Parameters of Man.

g. DN 4E1-2, Electrical/Electronic Equipment.

h. DN 4C1-3, Hydraulic Equipment.

In addition, the training device or any of its components shall be designed to minimize and control health and safety hazards to personnel using or maintaining the equipment, either during operation or while nonoperative. The training device shall conform to the health and safety requirements of Requirement 1 of MIL-STD-454 and MIL-STD-1472. The safety design of the training device shall be adapted to the facility.

REQUIREMENT RATIONALE (3.12.10)

This requirement establishes the control of health and safety hazards.

REQUIREMENT GUIDANCE

Include this requirement for safety reasons.

REQUIREMENT LESSONS LEARNED

4.12.10 System safety design. Tests, inspections, analyses, and demonstrations on the ATD shall be conducted and inspections and analyses of the contractor's documentation shall be performed to verify the performance of the system safety design.

VERIFICATION RATIONALE (4.12.10)

To assure compliance.

VERIFICATION GUIDANCE

Systematically verify the system safety design to assure nothing "falls through the cracks".

VERIFICATION LESSONS LEARNED

3.12.10.1 Hazardous materials. Materials used in the construction of the training device shall not support the propagation of flame. Where the generation of toxic or noxious gases cannot be eliminated, the design effort will be toward control and minimizing this hazard.

REQUIREMENT RATIONALE (3.12.10.1)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.1 **Hazardous materials.** Verify by __________.

VERIFICATION RATIONALE (4.12.10.1)

To assure compliance.

VERIFICATION GUIDANCE

Verify this requirement through inspections and analyses of the contractor's documentation and tests and demonstrations on the ATD itself, as necessary.

VERIFICATION LESSONS LEARNED

3.12.10.2 **Fire detection.** The design shall include a complete fire, smoke detection, and alarm system which operates from facility power. Detectors shall be located in all appropriate contractor-furnished equipment, such as computer cabinets and crew stations. When a contractor-furnished motion system is included in the contract, a minimum of two smoke detectors shall be located beneath the platform. A heat sensor wire shall be installed in the crew station umbilical cable. Means shall be provided to rapidly locate any fire or smoke which is detected. The detection and alarm cables shall be separated from electrical power cables. Detectors shall be installed in accordance with NFPA Standard 72E. The guidance of DN 5D2 of AFSC DH 1-6 shall apply.

REQUIREMENT RATIONALE (3.12.10.2)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.2 Fire detection. Verify by ________.

VERIFICATION RATIONALE (4.12.10.2)

To assure compliance.

VERIFICATION GUIDANCE

Verify this requirement through tests and demonstrations on the ATD where possible and analyses and inspections of the ATD and of the contractor's documentation elsewhere.

VERIFICATION LESSONS LEARNED

3.12.10.2.1 Fire alarm. Means shall be provided to alert all personnel throughout the training device complex that a fire or smoke detection has occurred. The specific aural or visual alarm means and locations to be provided shall be determined through safety analysis, and subject to approval by the procuring activity. The design shall ensure that the specific means provided do not present confusing information when compared with stimuli from other alerting devices such as the facility fire alarm, or the means provided in the cockpit to indicate a simulated crash.

REQUIREMENT RATIONALE (3.12.10.2.1)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.2.1 Fire alarm. Verify by ________.

VERIFICATION RATIONALE (4.12.10.2.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests and demonstrations on the ATD shall verify this requirement.

VERIFICATION LESSONS LEARNED

3.12.10.2.2 **Facility fire control interface.** Interconnections with the facility fire control system shall be provided. Simulator smoke detection signals shall be provided to the facility fire control panel to provide a signal to activate the facility fire warning system in the appropriate facility fire zone where the simulator equipment is located. The simulator emergency power off shall be capable of being activated by a signal from the facility fire control panel originating from activation of a facility fire/smoke detector or sprinkler system.

REQUIREMENT RATIONALE (3.12.10.2.2)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.2.2 **Facililty fire control interface.** Verify by ___________.

VERIFICATION RATIONALE (4.12.10.2.2)

To assure compliance.

VERIFICATION GUIDANCE

Tests and demonstrations shall verify this requirement.

VERIFICATION LESSONS LEARNED

3.12.10.3 **Overheat sensing**. Critical cooling subsystems provided with training device equipment in areas such as visual systems and motion systems shall be equipped with means to automatically deactivate power to the affected subsystem in the event of cooling system failure.

REQUIREMENT RATIONALE (3.12.10.3)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.3 Overheat sensing. Verify by __________.

VERIFICATION RATIONALE (4.12.10.3)

To assure compliance.

VERIFICATION GUIDANCE

Non-destructive tests and demonstrations on the ATD shall verify this requirement.

VERIFICATION LESSONS LEARNED

3.12.10.4 Fire stop sealing. Means shall be provided to seal facility-provided fire stops whenever training device cable runs are installed through the fire stops.

REQUIREMENT RATIONALE (3.12.10.4)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.4 Fire stop sealing. Verify by __________.

VERIFICATION RATIONALE (4.12.10.4)

To assure compliance.

VERIFICATION GUIDANCE

Non-destructive tests and demonstrations shall verify the airtightness of the fire stop.

VERIFICATION LESSONS LEARNED

3.12.10.5 Emergency power off. Emergency power off control shall be provided at multiple locations throughout the training complex and shall be fail-safe. The number and location of these controls shall be subject to procuring activity approval at the mockup/PDR. Emergency power off shall also occur automatically when the fire/smoke detection system is activated. When emergency power off is initiated, all power to the training equipment, including utility power, shall be automatically removed, the motion system shall automatically return to the egress position, the motion system access ramp/stairway shall automatically return to the egress position, emergency lighting interior to the crew station shall automatically activate, and means shall be provided to automatically close air conditioning/ventilation dampers to the cockpit area. Alternate escape provisions shall be provided and be subject to approval by the procuring activity.

REQUIREMENT RATIONALE (3.12.10.5)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.5 Emergency power off. Verify by ________.

VERIFICATION RATIONALE (4.12.10.5)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall verify this requirement where possible: demonstrations shall be used elsewhere.

VERIFICATION LESSONS LEARNED

3.12.10.6 Emergency off switches. All emergency off switches shall consist of red push buttons not less than 1.0 inch in diameter, recessed in black (FED-STD-595, Color 17038) and orange-yellow (FED-STD-595, Color 13538) diagonally striped panels, two inches or larger on a side. The width ratio of orange-yellow to black shall be three to one. The black stripe shall be in one of three widths: 1/16-, 1/8-, and 1/4-inch. The switch button shall not be integrally illuminated. Alternative lighting designs may be used that meet the requirement that the brightness contrast is sufficient to make the control identifiable under all projected illumination conditions. The control characteristics shall fall in the area labelled "clear seeing" of sub note 3(1) DN 2E2, DH 1-3. The nomenclature "EMERGENCY OFF" shall be placed on each panel, consistent with the remainder of the panel nomenclature.

REQUIREMENT RATIONALE (3.12.10.6)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.6 **Emergency off switches.** Verify by __________.

VERIFICATION RATIONALE (4.12.10.6)

To assure compliance.

VERIFICATION GUIDANCE

Inspection shall verify this requirement.

VERIFICATION LESSONS LEARNED

3.12.10.7 **Maintenance/safety intercom.** A single-loop maintenance/safety intercom shall be provided and consist of stations located in and around the training equipment. This intercom shall be independent from other communication systems. Each station shall be capable of transmitting or receiving without the need of other station selection. The system shall be adapted to the facility, and shall provide microphone/headset communication lines. The layout and design of the system shall be approved by the procuring activity. The system shall operate from utility power, with a backup power source for operation during facility power loss. Provisions shall be incorporated to prevent feedback noise and crosstalk from occurring.

REQUIREMENT RATIONALE (3.12.10.7)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.7 **Emergency communications.** Verify by __________.

VERIFICATION RATIONALE (4.12.10.7)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall verify this requirement.

VERIFICATION LESSONS LEARNED

4.12.10.7.1 Maintenance/safety intercom. Verify by __________.

VERIFICATION RATIONALE (4.12.10.7.1)

To assure compliance.

VERIFICATION GUIDANCE

Inspect ATD for compliance.

VERIFICATION LESSONS LEARNED

3.12.10.8 Safety and emergency lighting. When required by facility lighting, low intensity guarded lights shall be provided to illuminate the walkway around the crew station. Crew station interior emergency lighting shall be provided and be activated automatically upon loss of facility power. The system shall also include provisions to turn off the emergency lighting upon deliberate shutdown of facility power. Where batteries are used they shall be rechargeable when power is applied to the ATD.

REQUIREMENT RATIONALE (3.12.10.8)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.8 Safety and emergency lighting. Verify by __________.

VERIFICATION RATIONALE (4.12.10.8)

To assure compliance.

VERIFICATION GUIDANCE

Tests and demonstrations shall verify this requirement.

VERIFICATION LESSONS LEARNED

3.12.10.9 Acoustic noise--user areas

3.12.10.9.1 Hazardous noise levels. The sound level and exposure time in all areas of instructor and student stations, and simulator bay areas, shall be held below the values calculated from the following equation:

$$T = \frac{16}{2^{[(L-80)/4]}}$$

where T = Duration of total daily exposure in hours

L = Noise level in dBA

REQUIREMENT RATIONALE (3.12.10.9.1)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.9 Acoustic noise--user areas

4.12.10.9.1 **Hazardous noise levels.** Verify by __________.

VERIFICATION RATIONALE (4.12.10.9.1)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall verify this requirement.

VERIFICATION LESSONS LEARNED

3.12.10.9.2 Speech interference noise level. The noise level at student and instructor station(s) shall not exceed an articulation index (AI) of 0.7, where the AI is determined by the octave band method. Exception: Where simulated sounds reflecting actual aircraft conditions for the student(s) violate the AI above, the requirements of this paragraph are void for the time period that such simulated sounds are actuated, except that limits in 3.12.10.9.1 shall not be exceeded.

REQUIREMENT RATIONALE (3.12.10.9.2)

(See 3.12.10).

REQUIREMENT GUIDANCE

(See 3.12.10).

REQUIREMENT LESSONS LEARNED

4.12.10.9.2 Speech interference noise level. Verify by __________.

VERIFICATION RATIONALE (4.12.10.9.2)

To assure compliance.

VERIFICATION GUIDANCE

Tests shall verify this requirement.

VERIFICATION LESSONS LEARNED

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