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# AERONAUTICAL DESIGN STANDARD

## HANDBOOK

## AIRWORTHINESS QUALIFICATION AND VERIFICATION GUIDANCE FOR ELECTRO-OPTICAL AND SENSOR SYSTEMS

**AMSC N/A**

# AERONAUTICAL DESIGN STANDARD

# AIRWORTHINESS QUALIFICATION AND VERIFICATION GUIDANCE FOR ELECTRO-OPTICAL AND SENSOR SYSTEMS

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**Decision:**

| **General Type** | **Decision (√)** | **Certification** |
|---|---|---|
| Specification | | Performance |
| | | Detail |
| Standard | | Interface Standard |
| | | Standard Practice |
| | | Design Standard |
| | | Test Method Standard |
| | | Process Standard |
| Handbook | √ | Handbook (non-mandatory use) |
| Alternative Action | | |

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# AIRWORTHINESS QUALIFICATION AND VERIFICATION GUIDANCE FOR ELECTRO-OPTICAL AND SENSOR SYSTEMS

1.0 SCOPE. This document establishes the guidance for airworthiness qualification and discusses the methods of verification for Electro-Optical (EO) and Sensor Systems (SS), mission sensor group, and any other targeting/pilotage systems installed on U.S. Army aircraft. It also establishes the guidance for ancillary equipment, including displays, lasers and targeting systems. The sensors and system-related EO equipment are collectively referred to as a "sensor system" in this document. A combination of analyses and testing is used to verify the design, installation and operation of the sensor system and to support airworthiness qualification.

## 2.0 APPLICABLE DOCUMENTS.

2.1 General. This section lists references that are cited in this document.

2.2 Government Documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards and handbooks form a part of this document to the extent specified herein. It is recommended that the latest versions be used unless otherwise stated within the specification.

| | |
|---|---|
| AMCP 706-203 | Engineering Design Handbook, Helicopter Engineering Part III, Qualification Assurance |
| JSSG-2010-5 | Joint Services Crew Systems Aircraft Lighting Handbook |
| JSSG-2010-7 | Crash Protection Handbook |
| JSSG-2010-11 | Emergency Egress Handbook |
| MIL-E-7016 | Electrical Load and Power Source Capacity Aircraft, Analyses for |
| MIL-L-85762 | Aviator's Night Vision Imaging System (ANVIS) |
| MIL-STD-461 | Electromagnetic Interference Characteristics Requirements for Equipment Subsystem and System |

MIL-STD-464 Electromagnetic Environmental Effects Requirements for Systems

MIL-STD-704 Aircraft Electrical Power Characteristics

MIL-STD-810 Environmental Test Methods and Engineering Guidelines

MIL-STD-882 System Safety Program Requirements

MIL-STD-1472 Human Engineering

MIL-STD-1787 Aircraft Display Symbology

MIL-STD-2525 Common Warfighting Symbology

MIL-STD-3009 Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible

MIL-HDBK-781 Handbook for Reliability Test Methods, Plans and Environments for Engineering, Development, Qualification and Production

MIL-HDBK-87213 Electronically/Optically Generated Airborne Displays

2.2.2 Other Government documents, drawings, and publications. The following documents, drawings, and publications form a part of this document to the extent specified herein.

ADS-37A-PRF Electromagnetic Environmental Effects, Performance and Verification Requirements

ADS-62-SP Data and Test Requirements for Airworthiness Release for Helicopter Sensor Data and Testing Requirements

2.2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein.

International Society of Allied Weight Engineers

SAWE RP7 Weight and Balance Control Data (for Airplanes and Helicopters) Society of Allied Weight Engineers Recommended Practice 7

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

## 3.0 ACRONYMS

| | |
|---|---|
| ADS | Aeronautical Design Standard |
| A&FC | Airworthiness and Flight Characteristics Test |
| ALC | Automatic Light Control |
| AMCP | Army Material Command Pamphlet |
| ANVIS | Aviator's Night Vision Imaging System |
| ATD/C | Aided Target Detection/Classification |
| ATT | Auto Target Tracking |
| AWR | Airworthiness Release |
| CDRL | Contract Data Requirements List |
| CFE | Contractor Furnished Equipment |
| DoDISS | Department of Defense Index of Specifications and Standards |
| $E^3$ | Electromagnetic Environmental Effects |
| EMC | Electromagnetic Compatibility |
| EMI | Electromagnetic Interference |
| EMV | Electromagnetic Vulnerability |
| EOCCM | Electro-Optical Counter-Counter Measure |
| FC | Foot Candle |
| FL | Foot Lambert |
| FLIR | Forward Looking Infrared |
| FOR | Field-Of-Regard |
| FOV | Field-Of-View |
| FOVIS | Field-Of-Vision |
| GFE | Government Furnished Equipment |
| HFE | Human Factors Engineering |
| HTS | Head Tracking System |
| IGE | In Ground Effect |
| IITV | Image Intensified Television |
| IR | InfraRed |
| MRC | Minimum Resolvable Contrast |
| MRT | Minimum Resolvable Temperature |
| MTF | Modulation Transfer Function |
| NOE | Nap of the Earth |
| NVIS | Night Vision Imaging System |
| NVG | Night Vision Goggle |
| OGE | Out of Ground Effect |
| PAE | Preliminary Airworthiness Evaluation |
| RAM | Reliability, Availability, and Maintability |
| SAE | Society of Automotive Engineers |
| SAQ | Statement of Airworthiness Qualification |
| SAWE | Society of Allied Weight Engineers |
| SIL | Software Integration Lab |
| TAS | Target Acquisition System |

TEMP Test & Evaluation Master Plan

# 4.0 GENERAL REQUIREMENTS.

## 4.1 Airworthiness Qualification.

4.1.1 Airworthiness Qualification Process. The airworthiness qualification process generally includes:

a. Engineering analyses, modeling and simulations

b. Formal inspections, design reviews and safety assessments

c. Component and subsystem qualification tests

d. Contractor surveys

e. Formal contractor demonstrations

f. Government testing, to include

(1) A Preliminary Airworthiness Evaluation (PAE)

The objectives of a Preliminary Airworthiness Evaluation (PAE) should consist of the following:

(a) Assess the handling qualities of any aircrafts to facilitate an airworthiness evaluation.

(b) Assess the software performance, utility, and functionality of the Sensor System.

(c) Verify system specification compliance.

(d) Provide a safety confirmation recommendation.

(e) Accomplish interoperability test.

(f) The PAE will include an evaluation of human factors engineering to include cockpit integration.

(2) an Airworthiness and Flight Characteristics Test (A&FC)

(3) Government operational testing (OT), if required by the approved Test & Evaluation

Master Plan (TEMP)

4.1.2 Statement of Airworthiness Qualification. A statement of airworthiness qualification is a final document establishing full qualification status and airworthiness release that is issued in conjunction with the Airworthiness Qualification Substantiation Report. This statement is based on the final results of engineering function and performance tests conducted on the aircraft and its systems and subsystems.

4.2 Verification. The verification is conducted to ensure that all subsystems and components conform to the System Specification. All applicable requirements, specifications, and deviation considered will be imposed. Any deviation from the specification that does impact AWR will be coordinated with the customer.

4.2.1 Methods of Verification. Analyses, simulations, inspections, and/or testing of the sensor system will verify its compliance with specifications and will support airworthiness qualification. Airworthiness qualification testing will be integrated with contractor and other Government testing to include the following.

a. Engineering Analysis. Verification by analysis may include, but is not limited to, the following activities: simulation, modeling, engineering evaluation and analysis, component properties analysis and similarity arguments. Tools such as NVTherm, $I^2$TV model, and other modeling tools and techniques to analyze its imaging systems may be used.

b. Component/Subsystem Laboratory Testing. Subsystems and components can be verified by their similarity to previously verified or qualified items, but should be subject to Government approval.

c. Other Methods of Verification. System-Level Laboratory Testing and Surveys are other methods of verification.

d. Flight Testing and Formal test. Testing is verification through systematic exercising of the item under predetermined and appropriate conditions. Instrumentation should be allowed for the collection, analysis and evaluation of the performance parameter.

e. Demonstrations. Demonstrations are verification by the operation of the item in performing its designed functions under a specific set of conditions. The item may be instrumented, and data may be collected.

f. Inspection. Verification by inspection includes visual inspection and measurement of a condition or state.

Inspection determines the conformance to requirements without the use of special laboratory equipment or procedures.

4.3 System Safety. Pertinent data from all designs, analyses, simulations and testing should be utilized in a safety assessment of the sensor system and its integration into the aircraft. Safety-critical components and operations should be identified, and documentation should be provided to show that the associated risks have been controlled and/or reduced to acceptable levels. Since eliminating all system hazards is impractical, the evaluation and classification of hazards is critical. All component and subsystem tests should be planned and conducted in accordance with MIL-STD-882.

4.4 Reliability, Availability and Maintainability (RAM). A combination of substantiation, verification and demonstration should be performed to verify the reliability of new and modified sensor components and systems. MIL-HDBK-781 should be used for guidance.

## 5.0 DETAILED REQUIREMENTS.

5.1 Engineering Analyses. Engineering analyses may be used to predict system performance prior to actual testing. The analyses should incorporate as many realistic, operational conditions as possible. Analyses should be carefully documented to assure that all possible hazards have been addressed without omission or generalization. Analyses should show the same or greater level of acceptability as would be demonstrated by testing to requirements specified. Analyses should be specific and all calculations, formulae, tables, etc., included. Conclusions should be specific and logically derived from the presented data. Analyses should be provided for the end-to-end Minimum Resolvable Temperature (MRT), Minimum Resolvable Contrast (MRC), and Light Level versus Resolution to achieve the required performance, which will be in the specification.

5.1.1 Modeling and Simulation. Models and simulations should be used throughout the development process. Thermal imaging models may be used to assess image quality, target detection, classification, recognition, and identification capabilities.

5.1.2 Wire Strike. As part of the design process, an analysis of the sensor system design and mounting to the aircraft should be performed to assess wirestrike probabilities. In the event of a wirestrike occurring an aircraft safety assessment should be done.

5.1.3 Electrical Loads Analysis. An electrical loads analysis should be conducted. The analysis should be in accordance with MIL-E-7016. This analysis may take the form of an update to an existing or baseline electrical loads analysis. Per MIL-E-7016, the analysis should demonstrate the impact of the new system on all aircraft operating modes.

5.1.4 Crash Load Analysis. As part of the design process, crash load analysis should be performed, focusing on the effects and contributions of the sensor system components. The analyses and/or simulations should be available to the Government for inspection. Realistic tests may be required for qualification.

5.1.6 Weight and Balance. A system of weight control and reporting in accordance with SAWE RP7 should be established for the sensor system added to the aircraft. Should a weight and balance analysis be performed to include data from a pre-modification weighing and a weighing with A & B-kits installed. The analysis should reconcile the estimated weight of the modification based on individual component weights and locations with the actual as-weighed differences between pre- and post-modification. Other maintenance activities occurring between the weightings should be accurately recorded in the aircraft weight and balance file so that they can be separated from the Kit weight and center of gravity determinations. Actual weight and balance reports should be submitted.

5.1.7 Vibration. The effects of aircraft vibrations and mission maneuvers on electro-optical and sensor system performance should be estimated and minimized during system design and development. The effects should be utilized in the designs of any gimbal elements and stabilization elements in the sensor system. Analysis, that approximates realistic mission maneuvers, should be used to verify the compatibility of the sensor system and the aircraft.

5.1.8 Interlocks. A combination of analyses should be utilized to verify the structural integrity of any interlocks on or in the electro-optical or sensor system.

5.1.9 Armament Effect Analysis. Analysis may be performed to assess sensor performance, target acquisition and designation response to blast effects and debris and weapon rate of fire throughout the coverage of the system. The analysis should address the following:

a. Flash Effects. Flash effects from weapon firing should not degrade the sensor systems.

b. Blast/Impact of Debris Effects. Impacts direct or indirect blast effects should have little or no affect on the performance of the sensor systems.

c. Gunfire Effects. Gunfire effects should have little or no impact on the performance of the sensor systems. Smoke from gunfire should not impact the sensor systems FOVIS, or LOS.

5.1.10 Fire Control Integration. An analysis may be performed to assess fire control function such as sensor-to-weapon handover, boresighting, accuracy, pointing and tracking. Fire control analyses and simulations of the missiles, rockets, and guns should be conducted to evaluate the impacts on electro-optical and sensor systems.

5.1.11 Sensor integration with aircraft displays analysis.

5.1.11.1 Display/Control Optimization Study. Trade-off and simulation studies should be conducted to evaluate and optimize control/display relationships. The man/machine interface between crew station displays and controls is crucial to safe and proper subsystem operation. The contractor should conduct analysis for the integration and function of the controls and displays, and any interconnected avionics components, to demonstrate compliance with the Specification. A Controls and Displays Analysis Report should be prepared. MIL-HDBK-87213 should be used as guidance.

5.1.11.2 Display Lighting. Analysis should be used to demonstrate that the lighting requirements of MIL-STD-3009 may be met. The analysis results should address luminance, chromaticity, and spectral radiance of the display/light sources. The display should be readable in a combined environment consisting of 10,000 fc diffuse illuminance and the specular reflection of a 2000 fL glare source at rated drive conditions. Display/light sources should also be compliant with the requirements specified in MIL-STD-3009 for Type I, Class A, Night Vision Goggles”. MIL-L-85762 should be used as a guidance to establish limits on radiant power of emissions within the sensitivity envelope of Night Vision Imaging System (NVIS). The JSSG-2010-5 may be used as a guide for this task.

5.1.12 Emergency Egress. An emergency egress analysis should be conducted in accordance with JSSG-2010-11.

5.1.13 Electro-Optical Analyses.

5.1.13.1 Pilotage Analysis. The pilotage sensor analysis should consist of the following:

a. End-to-end sensor (FLIR and $I^2$TV models) design and performance analysis derived from detailed modeling of component and subsystem parameters. Analysis should include effects of windows (including anti-ice, and low observable features), optical design and elements (including passive and active [electro-optical counter-counter measures (EOCCM) features], detector/dewar/cooler assembly, sensor processing electronics and displays. Analysis should be for worst case (including thermal effects) and expected value performance at initial system delivery needs to be confirmed.

b. The ability of the Pilotage System to meet the respective budgeted requirements with respect to latency.

c. Pilotage laser hardening. Analysis should identify both critical component design performance and system performance in the normal (passive) and activated state. Analysis should address time lines, levels (and wavelengths of the laser threat) and mechanisms for activation and deactivation in response to the appearance or cessation of the threat. The analysis should include the impact of the EOCCM on the performance of the pilotage function.

5.1.13.2 TAS Analysis. The TAS analysis should include the following:

a. End-to-end imaging sensor design and performance analysis should include effects of windows (including anti-ice, and low observable features), optical elements (including EOCCM features), sensor processing electronics, detector/dewar and cooler assembly (including EOCCM features for the FLIR sensor), CCD camera (including EOCCM features for the TV sensor) and displays. Target acquisition performance in each FOV should be modeled for each sensor for both real time and image storage/recall mode, including effects of zoom for worst case (including thermal effects) and expected value performance. Target tracking should include automated and manual tracking of ground and air targets in and out of clutter. Air targets should range in maneuvers from benign to maximum-g turns at maximum rates as specified in the system specification. Models used in the analysis should be delivered to the Government in a readable format. User instructions and a listing of the values used as inputs to the model should be included with the model.

b. TAS hardware and software timelines should be simulated and ground search functions/task workload analyzed for available modes.

c. Laser rangefinder and designation analysis should be met for modes of operation per the system specification, including laser missile hit probabilities.

d. (Automatic and manual ground) and maneuvering aircraft target tracking analysis for each sensor FOV, including use of zoom, and both single and multi-target tracking capability should be analyzed.

e. Under expected operating conditions, boresight, boresight retention, and stabilization performance analysis should be performed at initial system delivery.

f. Tracking performance in manual/automatic track against ground and aircraft targets under benign and maximum g-turn and maneuvers, as specified in system specification. Performance analysis for automatic tracking should be supported by algorithm simulation and emulation testing against databases selected from data collections obtained from FLIR and TV sensors.

g. System level analysis for target handover to another external system of lased/tracked stationary targets, as well as high speed aided search targets, and the analysis should include complete system error budgets.

5.1.14 System Level Lightning Strike Analysis. Tests or analyses should be performed IAW ADS-37A-PRF. The sensor/fire control should survive the effect of a lightning strike as described in the ADS-37A-PRF document. A lightning strike effects analysis should demonstrate that a lightning strike (direct or indirect) will not create an unsafe condition and prevent the aircraft from landing.

5.2 Component Qualification.

5.2.1 Component/Subsystem Laboratory Testing. Laboratory testing validates critical design parameters, fabrication, performance and the integration of flight configuration items. The testing should include operational environments, functions and modes to replicate the complete range of expected operational conditions for the components under test. However, the system specification takes precedent over any requirements within this document.

*5.2.2 Electromagnetic Environmental Effects (E3).*

5.2.2.1 Electromagnetic Interference (EMI). The sensor fire control, electrical, and electronic at the component level, and System LRUs should meet the requirements of MIL-STD-461 (CE 101, CE 102, CS 101, CS 114, CS 115, CS 116, RE 101, RE 102, RS 101 and RS 103 as modified by ADS-37A-PRF).

5.2.2.2 Electromagnetic compatibility (EMC). EO Sensor system per each configuration as installed on the aircraft should meet the requirements of ADS-37A-PRF for electromagnetic capability among all electrical and electronic subsystems internal to the aircraft as well as between the aircraft and supporting systems external to the aircraft such as ground servicing equipment and government supplied equipment. Each system per each configuration as installed on the aircraft should be tested and shown to meet the EMC requirements of ADS-37A-PRF.

5.2.2.3 Electromagnetic Vulnerability (EMV). When installed in the host aircraft, the sensor system should not degrade the existing EMV hardening of the original equipment of the host aircraft.

5.2.3 Environmental. EO Sensor system should be designed in accordance with the requirements of MIL-STD-810 and for operation in a Class 1B environment as defined by MIL-HDBK-5400. The new or modified electro-optical or sensor system should undergo environmental testing, as directed by MIL-STD-810. Some tests may be tailored as necessary and analysis may be performed to verify compliance with the standards. NBC testing may be simulated. The test data, analysis and the results of any simulations should be available for inspection and review. The electro-optical or sensor system should not exhibit damage nor degradation of performance during the environmental testing.

5.2.3.1 Shock. EO Sensor system should meet the requirements of MIL-STD-810, Method 516.5 for functional shock (Procedure 1), crash hazard (Procedure V), and bench handling test (Procedure VI).

5.2.3.2 Crash Loads. EO Sensor system should be analyzed to ensure that it meets the crash load requirements below.

a. External Mounted Equipment. External mounted equipment should meet external crash load restraint requirement IAW MIL-STD-810 and specification.

b. Internally Mounted Equipment. Internally mounted equipment should meet the crash load restraint requirements according to the specification.

5.2.3.3 Acceleration. EO Sensor system should meet the requirements of MIL-STD-810, Method 513.5, Procedures I (Structural Test), and II (Operational Test).

5.2.3.4 Vibration. EO Sensor system should meet the requirements of MIL-STD-810, Method 514.5. Levels for functional and endurance tests should be in accordance with MIL-STD-810. Calculated displacement of all circuit card assemblies should meet the predicted allowable displacement for all helicopters vibration profiles.

5.2.3.5 Continuous vibration. For continuous vibration, EO Sensor system should pass a sine on random non-gunfire vibration test in accordance with MIL-STD-810, Method 514.5, Procedure I, Category 14.

5.2.3.6 Gunfire. For gunfire vibration, EO Sensor system should meet the requirements of MIL-STD-810, Method 519.5.

5.2.3.7 Sand and dust. EO Sensor system should withstand exposure to sand and dust in accordance with MIL-STD-810, Method 510.4 (Procedure I for blowing dust and Procedure II for blowing sand).

5.2.3.8 Fungus. EO Sensor system should meet the requirements of MIL-STD-810, Method 508.5.

5.2.3.9 Salt atmosphere. EO Sensor system should meet the requirements of MIL-STD-810, Method 509.4.

5.2.3.10 Explosive Atmosphere Test (EAT). EO Sensor system should meet the requirements of MIL-STD-810, Method 511.4, for explosive atmosphere. EAT may be approved by analysis, if, the component designs and system controls avoid sparks or arcing relays and high temps or hotspots greater than or equal to 200ºC.

5.2.3.11 Solar radiation. EO Sensor system should meet the requirements of MIL-STD-810, Method 505.4, Procedure 1 – Cycling, for solar radiation.

5.2.3.12 Rain. EO Sensor system should suffer no performance degradation or physical damage when exposed to rain effects in accordance with MIL-STD-810, Method 506.4 (Procedure III– Drip Test).

5.2.3.13 Icing/Freezing Rain. EO Sensor system should meet the requirements of MIL-STD-810, Method 521.2.

5.2.3.14 Temperature, humidity, altitude. EO Sensor system should meet the requirements of MIL-STD-810, Method 520.2 (Procedures I, II, and III).

5.2.3.15 High Temperature Storage. System components should meet the requirements of MIL-STD-810, Method 501.4 (Procedures I and II).

5.2.3.16 Low Temperature Storage. System components should meet the requirements of MIL-STD-810, Method 502.4 (Procedures III).

5.2.4 Component and Subsystem Qualification. Laboratory tests and demonstrations of TAS components and subsystems should include, but not be limited to:

a. Line of Sight Tracking and Stabilization Test. The performance specified herein should be met throughout the full operational envelope, which is listed below:

(1) Slew Rate and Acceleration. The TAS should be capable of moving the LOS in according to the weapons system specification in pitch and yaw, to accommodate scanning in either direction, during flight maneuvers. The TAS should be capable of providing turret accelerations in according with specification in pitch and yaw.

(2) Stabilization. The TAS stabilization should not degrade FLIR or TV stare or gimbal scan performance as defined in the performance specification, when exposed to the non-gunfire or gunfire environments for stare and gimbal scan operation. The stabilization should support the total pointing error as defined in the performance specification, over the entire designation interval.

(3) Field-of-Regard (FOR). The TAS clear FOR and Field-of-Vision (FOVIS) should be in according with weapons system specification at the elevation extremes. Total blockage of the FOV should occur within the boundaries in according with specification at the elevation extremes.

b. Automated and manual override gain and level adjustment capability and any additional processing functions to enhance display image quality and target acquisition performance

c. FLIR detector/dewar and cooler assembly acceptance testing including imaging testing

d. Solid state TV/$I^2$TV sensor performance for real time and image storage/recall for each FOV including zoom

e. FLIR sensor performance for each FOV including manual and electronic zoom and polarity reversal

f. Internal autotracker to laser and gyros to autotracker boresight accuracy corrections and stabilization performance including effects of switching sensors, sensor FOVs and changes to the operational environment due to temperature and system vibration

g. Laser designator/rangefinder (LD/RF) performance for the tactical laser including effects of changes to the operational environment due to temperature and system vibration

h. Eye-safe laser ranging performance in both manual staring and wide area gimbal bar scan mode that includes effects of changes to the operational environment due to temperature and system vibration

i. Line-of-sight (LOS) control for manual search, wide area gimbal bar scan, local area gimbal bar scan, manual track and ATT operation including effects due to temperature and system vibration

j. Hardware and software time line evaluations of TAS moding and functions

k. Performance of individual EOCCM Components

5.3 Surveys/Tests. Verification of the adequacy of the Sensor System to perform its assigned mission requires testing which includes all anticipated operating conditions. This testing can be divided into surveys and demonstrations categories.

Test should be conducted using applicable documents IAW this ADS for guidance to substantiate safe and satisfactory sensor subsystem operation over the range of flight and environmental conditions.

a. System-Level Laboratory Testing and Surveys. System testing and surveys verify the fundamental performance requirements of the sensor system and verify it is ready for ground and flight testing.

b. Ground Testing. Ground testing should be conducted on the aircraft using aircraft or ground power as appropriate to validate critical aircraft interfaces to electro-optical, laser, and sensor systems. The objective of this testing is to verify safety of flight critical requirements and to verify the functionality of operational controls and modes. Other items to be verified are cable continuity, data bus integrity, electrical power parameters, power-on checks of the equipment and functional tests of each subsystem. MIL-STD-1425 should be used as guidance. Prior to flight test, all armament and fire control operations should be checked to verify functionality of installed components to include armament control, symbology and target acquisition/designation procedures. Also an Electromagnetic Compatibility Check (EMC) is required. Ground tests should be conducted IAW with this ADS for guidance. These tests should encompass all items requiring verification before the flight tests.

c. Environmental Condition. Operability throughout the range of conditions specified in the aircraft system specification should be verified.

d. Flight Tests. Flight testing by surveys or demonstrations provides data to further evaluate the design and integration of the electro-optical and sensor system. These tests exercise the sensor system at selected points within its performance ranges. Testing should include realistic environments and terrain representative of warfighting mission scenarios to the maximum practical extent. Aircraft operation and manuevers may impart vibrations to the sensing systems, and flight testing should verify these vibrations do not impair functionality.

e. Mini-Weapons Survey Test. A Mini-Weapons Survey Test will be composed of captive flight (non-firing) and live fire tests to verify the functional requirements of the weapons and sights subsystems and the weapons inhibits, limits, and interrupts (WILI’s) previously verified in the hot bench. It should be conducted on a test aircraft with all qualified armament and production representative software and hardware. Preparation for testing included measuring the TAS pointing error, performing software regression testing, measuring the gun transport delay value, bore-sighting all weapons and sights, and performing WILI’s on the hot bench. At least 30 days prior to live fire test, a Firing Readiness Review (FRR) should be prepared with the Government. At least 30 days prior to the FRR, provide to the Government a Safety Assessment Report and other analysis deemed necessary to substantiate it is safe to conduct the live fire tests and to support flight releases.

5.3.1 Aircraft installation checkout Survey. Flight and ground vibration monitoring, conducted during accelerated and unaccelerated flight over the full range of the flight envelope and of the allowable rotor speeds. Provides data to substantiate compliance with vibratory comfort requirements and demonstrate sensor is free from excessive vibrations affecting structural integrity or ability to perform its mission.

5.3.2 Human Factors Engineering. Surveys/ground and flight tests should be used to verify the incorporation of HFE design requirements and criteria in accordance with MIL-STD-1472. Sensor and laser display symbology (whether man-machine interface symbology and switchology) should be demonstrated to comply with MIL-STD-2525 and MIL-STD-1787.

Cockpit Survey. A cockpit survey should be conducted after installation and before first flight to ensure that all LRUs and the information displayed are acceptable and systems integration components of the crew station design are satisfactory.

5.3.3 TAS Survey. The TAS survey should include operating modes, automatic features including prepoint, boresighting, stabilization, image quality and uniformity, manual and auto target tracking, laser rangefinding, laser designation, target location accuracy and handover, sensor FOV switching and focus, target acquisition, exposure time and acquisition timeline assessment for target tracking, engagement or handover, sensor compatibility with displays and EOCCM.
The following should be performed:

a. Survey/Verify TAS functional capabilities. Display of TV/$I^2$TV and FLIR imagery; display of sensor FOVs and sensor switching timelines including electronic zoom FOVs; sensor FOR limits; sector search; fixed forward gimbal cage operation; helmet slaved operation; hand control operation for manual and aided/automatic target acquisition and manual tracking; auto target tracking (including multi-target track capability); internal boresight and boresight retention; laser to gyro boresight algorithm.

b. Survey performance that is dependent on the helicopter being airborne against the system specification requirements. Manual and aided/automatic target acquisition at a hover and on the move with FLIR and TV/$I^2$TV sensors; prepoint, laser designation; laser ranging (tactical laser and eye-safe), auto target tracking (including multitarget track capability); target location and hand-off accuracy; man-in-the-loop target acquisition and engagement timeline capability for operation at a hover and on the move; operational impact of EOCCM protection including manual override. Surveyed performance should address operation in/over low contrast environments; The electro-optical target acquisition sensors should be characterized for end-to-end (at the aircraft display) MRT/MRC in each of the operational sensor FOVs prior to conducting the TAS survey.

c. The TAS survey should conduct an airborne laser designation Total Pointing Error (TPE) survey. A laser spot scoring system should be used. The laser spot scoring system should also be used to measure TAS stabilization, tracking accuracy, boresight, and boresight retention with and without gunfire.

d. Target Acquisition/Designation Subsytem. Turret optical jitter, slew rates, acceleration, position accuracy, gimbal field of regard throughout the specified angular coverage, and Laser characteristics should be determined.

Measurements for tracker qualification should include determination of the capability to track targets in various environmental conditions including clutter, obscurants, target multiplicity, and varying target spacing.

e. Tracking and Laser Designation. The TAS should perform all tracking, sighting, and fire control functions with accuracies consistent with weapon requirements. Laser designation performance should enable laser terminal homing weapons probabilities of hit to be met at ranges and target maneuver conditions. Pulse A-Code and Pulse Repetition Frequency (PRF) coding should meet laser terminal homing weapons requirements. Day and Night zoom available within each of the sensor FOVs. During the zoom mode the display reticle size should be unaffected.

The Laser designator should be capable of continuous operation at its highest required pulse rate without degradation in power output, beam divergence, or boresight retention with a continuous duty cycle. There should be no vignetting, FOV cutoff, or obscurations of the EO sensors. Laser pulse initiation should be synchronized to rotoblade position to minimize obscuration and loss of coded laser pulses.

f. Boresight Subsystem. Operation and accuracy of boresight subsystem with the sensor system should be verified. Boresight tests are performed to ensure that the optical alignment among the various sensor and designator subsystems of the targeting system is within specification requirements and the internal boresighting equipment provides the required boresight accuracy.

g. Target Acquisition/Designation Subsystem Pointing. Target acquisition/designation subsystem day/night pointing throughout the gimbal field of regard and flight envelope should be verified. The minimum set of military targets against which the TAS should perform acquisition functions includes moving and stationary tracked and wheeled vehicles, and rotary and fixed wing aircraft. This test should include boresight retention.

h. Target Acquisition/Designation Subsystem Handover. Target acquisition/designation subsystem handover both air-to-air and ground-to-air should be verified.

5.3.4 Pilotage System Survey. A survey of the pilotage system should be conducted to verify the design. The survey should include:

a. The pilotage System Survey should have image quality, uniformity of sensors (primary and backup), MRT of the thermal sensors. Data should be collected end-to-end, i.e., at the HMD and should be measured across the entire design Field of View (FOV).

b. $I^2$TV performance. The $I^2$TV should not be damaged by exposure to bright lights or to lasers outside the 0.6 – 0.9 micron waveband. The $I^2$TV should be designed to provide imagery that is registered with the FLIR imagery, and is capable of fusion with same. The $I^2$TV should be capable of operation in urban terrain with little/no image saturation due to blooming from cultural lighting. The $I^2$TV should incorporate protection from inadvertent solar disk imaging.

c. Image fused performance. Image fusion should be provided to fuse video from the FLIR sensor and the $I^2$TV sensor into a single optimized video image. The system should provide additive fusion or feature-level fusion of the $I^2$TV and FLIR Imagery, in all FOVs, with the capability to automatically or manually adjust the ratio of fusion of the FLIR and $I^2$TV video. The sensor imagery, FLIR, and $I^2$TV combined with symbology, should interface and be viewable on either, or both crewmembers' displays.

d. The pilotage System Survey should have automatic features to include signal and image processing and the manual overrides.

e. The pilotage System Survey should have sensor compatibility with display (MFD and HMD) to include FOV, flight symbology for visual cues, such as definition of horizon and other system indicators.

f. The pilotage System Survey should have the capability for performing day and night precision maneuvers, and general mission tasks such as NOE and contour flight.

g. The pilotage System Survey should be interface to other aircraft subsystems.

h. Operational impact of EOCCM insertion. All of the sensor equipment should provide the maximum degree of survivability, IAW system specification requirement, in an electronic warfare environment with out sacrificing or degrading the mission requirements on either a temporary or permanent basis. The Sensor should be hardened against electronic countermeasures (in according to the Performance Specification). The Sensor should provide, as a minimum, multiple spectral filters to meet the requirements of the classified Performance Specification. The time to switch between adjacent filter positions in response to an aircraft filter command should not exceed 2.0 seconds. The FLIR should not require refocusing or re-boresighting when the filter position is changed.

i. The pilotage system survey should verify pilotage system functional capabilities and operating modes.

j. Survey performance, that is by specification independent on the aircraft, may be verified on the ground or airborne (horizontal and vertical FOV), field-of-vision, and Field-of-Regard (FOR), pilot and copilot head movement tracking rate and acceleration capability, resistance to image blur and vignetting, and registration error) during ground tests or using the aircraft. Effect of naturally occurring obscurants (rain, fog, and so on), insofar as available, and artificially produced or simulated obscurants (smoke, dust, and so on) should be surveyed.

k. Survey performance that is verified by specification dependent on the helicopter should be airborne (such as support of stationkeeping, hover, and terminal area maneuver) should be verified during ground and flight tests. Vibration and temperature data should be collected to support analysis to be performed to substantiate performance required by the system specification. Effects of natural and artificially produced obscurants should be evaluated. Testing should begin with daylight, visual meteorological conditions (VMC) and progress to nighttime, degraded visibility conditions.

l. Data should be obtained at the lowest accurate level (component bench test, Software Integration Lab (SIL) or aircraft) and surveyed at subsequent levels to verify that integration has not degraded allocated performance.

5.3.4.1 Pilotage Subsystems Testing. Testing of the NVPS or pilotage should be conducted to verify the design. The analysis should include but not be limited to:

a. Image quality, uniformity of sensors (primary and backup), MRT of the thermal sensors Note :( Data should be collected end-to-end and should be measured across the entire design Field of View (FOV). Measurements for $I^2$/TV subsystems include fields of view, noise, automatic light control (ALC) performance, shading characteristics, screen blemishes, signal level, distortion, field-of-view alignment, and MTF.)

b. Automatic features to include signal and image processing and the manual overrides

c. Sensor compatibility with display to include FOV, flight symbology for visual cues, such as definition of horizon and other system indicators

d. Capability for performing day and night precision maneuvers defined in ADS-46 (draft, dated 1 June 1998), and general mission tasks such as NOE and contour flight

e. Interfaces to other aircraft subsystems

f. Pilotage modes including terrain avoidance warnings

g. Operational impact of electro-optical counter-counter measures (EOCCM)

h. Determine the accuracies of helmet-tracked, manually slewed and fixed forward controls

Note: A survey test plan and report should be submitted for government approval per CDRL.

5.3.5 Infrared (IR) Signature Survey. At the system level demonstrates that the IR signature is reduced to acceptable levels. Documents its IR signature for use in countermeasures studies, tradeoffs, and requirements. Three test modes are required to determine the IR signature of a sensor system and the subsequent effectiveness of a countermeasure device against an IR missile threat: (1) ground operation, (2) hovering operation, and (3) a fly-by. Spectral data should be taken at all test conditions with a spectrometer. Current analytical methods utilize the spectral data obtained during the ground/hovering tests to derive the sensor system acquisition range for a particular IR missile. Fly –by testing is conducted with missile simulators as a means of verifying the predictions.

5.3.6 Fire Control Surveys. Ground surveys should be conducted IAW with this ADS for guidance. These tests should encompass all items requiring verification before the flight tests. This should include, but is not limited to, the following:

5.3.6.1 Sensor/Armament/Fire Control Operations. Cockpit procedures utilizing the installed sensor/armament/fire control system should be verified. Sensor /armament/fire control/aircraft control logic interface should be checked. Functional checkout of target acquisition subsystem modes (including symbology) should be conducted.

5.3.6.2 Sensor/Armament/Fire Control Boresight. Boresight procedures and boresight retention should be checked. Particular attention should be paid to the elements of the target acquisition/designation subsystem. Boresight and armament accuracy should be verified. Sensor Turret RMS optical jitter, slew rates, accelerations, positional accuracy with typical in flight wind loads should be verified.

5.3.6.3 Target Acquisition/Designation Subsystem/Weapon Firings. Effects of weapons firing on target acquisition/designation subsystem performance (vibration, smoke, debris). Particular attention should be given to day/night automatic tracking.

5.3.7 System Level EMV Survey. The sensor/fire control should meet the EMV requirements and IAW the ADS-37A-PRF document. The sensor/fire control should performance requirements necessary to complete its mission during exposure to friendly and hostile electromagnetic emitters as defined in the ADS-37A-PRF, table 1, part a and b.

5.3.8 System Level Electrostatic Discharge (ESD) Survey. The sensor/fire control should meet ESD requirement and IAW the ADS-37A-PRF document. The system should preclude damage or upset from ESD due to handling of the equipment by operating or maintenance personnel.

5.3.9 Electromagnetic Compatibility (EMC) Survey. Operation of the sensor/fire control and other subsystems should be verified to determine they do not affect other aircraft subsystems with regard to electromagnetic parameters.

5.3.10 Fire Control Integration Survey. Joint functioning of installed subsystems such as fire control computer, air data sensors, helmet sights, target acquisition/designation subsystem, flexible guns navigational inputs, etc., should be tested. Computer software functioning (accuracy, correctness) should be validated.

5.3.11 Aircraft Flight Performance Survey. The effects of the sensor subsystem installation should be determined on aircraft performance, stability and control throughout the flight envelope of the aircraft, including hover, low speed translation flight, take off and landing, climb, level flight, maneuvering flight, jettisoning, and auto-rotation.

5.4 Software Qualification.

5.4.1 Software Product Evaluation. In-process and final reviews should be prepared for all new and modified software IAW the Software Development Plan (SDP). The Government would like the opportunity to participate in these reviews.

5.4.2 Software Qualification Testing. Review of the Software Test Plans (STPs) and Software Test Descriptions (STD), for conducting all testing to verify compliance with the approved SRS will be required prior to testing. The Software Test Report (STR) will be required for review to determine if all airworthiness criteria have been met. All Software Trouble Reports (STRs) will be supplied with the STR and any corrective actions that have been taken to include Systems Integration Lab/Hot Bench testing results. A laboratory integration testing should be prepared prior to flight test and issue a statement of flight test suitability based on the laboratory results. The suitability statement should identify the pertinent hardware and software configurations/versions in a compatibility matrix as applicable if not part of the Version Description Document (VDD.) A Functional Qualification Testing should be prepared with government witnessing to ensure software Safety of Flight has been met.

5.4.3 Software Safety. The safety analysis of all software should be reported in the Safety Assessment Report.

5.4.4 Failure Modes Analysis. The analysis of software failure modes should be incorporated into the FMEA/FMECA and provided to the government for review.

5.4.5 Identification of Failure Modes. Identify, prior to SRR with update prior to the PDR, any single point software failure that, if it occurred, would be catastrophic or flight critical in nature. The review of the software failures requires a government assessment.

5.4.6 Software Failure Modes Effects Criticality Analysis (SW FMECA). Government review of the methodology used to analyze all critical software to determine the following:

a. Root causes of hardware interface anomalies/failures that may impact software

b. Software impacts of hardware interface anomalies/failures

c. Operational impacts of software response to hardware interface anomalies/failures

5.4.7 Software Documentation. In addition to previous documentation listed, the following software documentation should be provided to ensure software requirements are met and software verification/validation has been achieved:

a. Version Description Documents

b. Computer Resources Integrated Support Document (CRISD)

c. Software User's Manual

d. Software Detailed Design

e. Interface Design Description

f. Interface Control Document

g. Interface Requirements Specification

h. Software Requirements Specification

i. System/segment Design Document

j. Interface Requirements Document

k. System/Segment Specification

l. Source Code

5.4.8 Software Test. All new or modified software should be extensively tested in Software Integration Lab/Hot Bench to verify that armament system functionality and safety has not been inadvertently degraded. This test will include, but not limited to, verification of weapons management functions, no inadvertent launch/firing, and veracity of weapon inhibits, limits and interrupts (WILIs) on the Weapons Software build.

5.5 REQUIREMENTS FOR DEMONSTRATIONS ON SENSOR SYSTEMS. Demonstrations should be conducted on the aircraft under aircraft or ground power as appropriate to validate critical aircraft interfaces to electro-optical, laser, and sensor systems. The objective of this demonstration is to verify safety of flight critical requirements and to verify the functionality of operational controls and modes. Other items to be verified are cable continuity, data bus integrity, electrical power parameters, power-on checks of the equipment and functional tests of each subsystem.

5.5.1 Lighting in Crew Stations Demonstration. The lighting requirements of MIL-STD-3009 should be demonstrated for aviator's night vision imaging system (ANVIS) compatibility during day, night, and all moon phases.

5.5.2 Crew Vision. Vision required for safe flight should be maintained and should be demonstrated to be acceptable during operation with and without night vision goggles or Pilots Night Vision Systems (FLIR and $I^2$TV).

5.5.3 TAS Demonstration. A TAS demonstration should be prepared. Performance parameters affecting Laser missile probability of hit ($P_h$) are collected in a format compatible with the U.S. Army LDWSS. The demonstration includes:

a. Specified operating modes

b. Specified automatic features

c. Stabilization

d. FLIR performance (such as MRT, MTF, noise, etc…) characterization. This will be demonstrated in the laboratory Note:(The performance parameters and procedures should be generated jointly by the Contractor and Government.)

e. MRT/MRC/Light Level versus Resolution Testing. The equipment should undergo MRT, MRC, and light level vs. resolution testing as necessary to establish compliance with mission range, MRT, or MRC requirements. During EMD, these tests should be performed under laboratory conditions, end-to-end from the sensor (including window) through the display. During production, testing will be performed at the IITV or Receiver LRM level. Production test requirements will be established during EMD. The MRT test should be performed using standard four (4) bar target with a 7:1 bar aspect ratio. Single point MRT measurement should be accompanied by point spread function measurements. The MRC test should be performed using the system specification requirements, with approval from the Government. The light level versus resolution test should be performed using U.S. Air Force 1951, tribar resolution targets, black bars on a white background, 95 percent minimum contrast.

f. Image quality and uniformity

g. Tracking includes both manual and autotracking

h. Boresight accuracy and retention

i. Laser ranging (tactical laser and eye-safe laser) and designation (tactical laser)

j. Target location accuracy

k. Target handoff accuracy and cueing

l. Manual and aided/automatic target acquisition function of detection, classification, recognition and identification

m. Sensor FOV, sensor switching time and sensor focus

n. Sensor compatibility with displays

o. Time lines for target acquisition, tracking, engagement or handover

p. Dynamic alignment accuracy

q. Failure modes

r. Operational impact/effectiveness of EOCCM protection

s. Laser Spot Tracker accuracy

5.5.4 Pilotage Demonstration. Compliance with the system specification should be demonstrated. Emphasis should be placed on demonstrating the suitability of the pilotage capability to enable safe NOE pilotage in degraded conditions and at ambient temperature limits. The demonstration includes:

a. Operating modes per the system specification

b. Automatic features per the system specification

c. FLIR performance (such as MRT, MTF, noise, etc…) characterization as measured at the HMD Note:(This will be demonstrated in the laboratory. The performance parameters and procedures should be generated jointly by the Contractor and Government.)

d. Limiting Resolution versus Light Levels as measured at the HMD

e. Sensor compatibility with displays, including flight symbology (for visual cues, such as definition of horizon and other system indicators) and FOV

f. Capability for day and night NOE flight in degraded conditions

g. Interfaces to other subsystems

h. Ability to perform flight tasks to standard for Evaluation with velocity hold and altitude hold on and off

5.5.5 Flight Demonstration. Autotracking accuracy and dynamic capability of the Automatic Target Tracker (ATT) implementation. Performance should include demonstrations using the target database in representative clutter and environmental conditions at ranges, IAW the system specification consistent with operational tactics for engagement by on-board armament. Special attention should be paid to maximum maneuvering helicopter targets flying NOE in heavy clutter. Performance demonstrations should test tracker performance for breaklock, reacquisition, coast, multi-target tracking, target track priority, track file update, tracker output signal rates/jitter for stabilization and line of sight control. Simulated target signal inputs may be used to test performance compliance conditions.

Note: A demonstration test plan and report should be submitted for government approval per CDRL.

## 6.0 NOTES