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MIL-HDBK-515 (USAF)
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DEPARTMENT OF DEFENSE HANDBOOK

WEAPON SYSTEM INTEGRITY GUIDE (WSIG)

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FOREWORD

1. This handbook is approved for use by the Department of the Air Force and is available for use by all Departments and Agencies of the Department of Defense (DoD).

2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

3. This document provides guidance on how to integrate the existing integrity processes within systems engineering. This is accomplished through three basic thrusts:

a. To integrate the efforts called out in the various integrity processes, namely: the Aircraft Structural Integrity Program (ASIP), the Engine Structural Integrity Program (ENSIP), the Mechanical Equipment and Subsystems Integrity Program (MECSIP), and the Avionics/Electronics Integrity Process (AVIP).

b. To synergistically integrate or coordinate specific integrity process efforts/tasks with related efforts in various other systems engineering disciplines (see table 1).

c. To place increased emphasis on the sustainment portion of the life cycle.

4. The integrity processes outlined for design and manufacturing along with sound repeatable maintenance practices, resulting from accurate training systems and technical orders, are critical to the achievement, fielding, and sustainment of systems which meet the war fighter's needs from delivery to retirement.

5. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: ASC/ENOI, Bldg 560, 2530 Loop Road West, Wright-Patterson AFB OH 45433-7101 by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, by letter, or by e-mail to: Engineering.Standards@wpafb.af.mil.

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1. SCOPE

1.1 Scope.

This document provides guidance on how to integrate the existing integrity processes within systems engineering, resulting in a more efficient and cohesive approach to engineering. In order to accomplish this, the Weapon System Integrity Guide (WSIG) contains three basic thrusts:

a. To integrate the efforts called out in the various integrity processes, namely: the Aircraft Structural Integrity Program (ASIP), the Engine Structural Integrity Program (ENSIP), the Mechanical Equipment and Subsystems Integrity Program (MECSIP), and the Avionics/Electronics Integrity Process (AVIP);

b. To synergistically integrate or coordinate specific integrity process efforts/tasks with related efforts in various other systems engineering disciplines; and

c. To place increased emphasis on the sustainment portion of the life cycle.

This handbook does not supersede the integrity process documents referenced. This handbook is for guidance only and cannot be cited as a requirement.

1.2 Applicability.

Application of the WSIG to the design, production, and sustainment of systems is virtually unlimited. It applies to all elements of the weapon system (e.g., airframe, subsystems, avionics, engines, support, and training equipment) in all phases of life. Weapon system integrity applies to more than just new developments: it applies to system modifications (MODS), commercial off-the-shelf (COTS) equipment, use of form, fit, and functional interface (F^3I) (interchangeable), changes in use, service life extension, and all of the corresponding changes in sustainment needed to maintain the integrity of performance. Each integrity process document referenced herein details specific activities to be accomplished during the various phases within a program. This guide integrates the integrity processes within systems engineering and provides a single contractual reference.

Each of the integrity process documents, as well as other referenced documents, provide more detailed guidance for application of pertinent integrity efforts in the design and sustainment process. The application of guidance must be tailored to the equipment in question and the function provided. The WSIG integrates these practices and policies into a cohesive approach that fills in the gaps, reduces overlap, and addresses sustainment of integrity of the system/item throughout its lifetime.

1.3 Introduction.

Weapon system integrity is an overarching set of tools and processes which enables the integration of sound engineering practices at the systems level: the impetus being the sustainment of safety, suitability, and effectiveness for the life of the system. This includes the ability to return systems to specification level performance after repair/overhaul activities. Weapon system integrity is an integral process through which operational safety, suitability, and effectiveness (OSS&E) and airworthiness are implemented.

Integrity provides the guidance through which design margins are initially established and subsequently sustained via the use or modification of: inspection, repair/overhaul, and/or replacement intervals (based on the life used and/or margin remaining), or through

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redundancy/reconfigurability so as to mitigate the loss of a function performed by an individual item. Maintenance actions taken to repair or replace defects/items must provide performance and life consistent with, or exceeding, the original manufacturers' specifications (unless those specifications or required life have changed). This necessitates a process that can ensure the correctness and completeness of Technical Orders (TO), engineering dispositions, and training at all levels.

Applying integrity to structures, avionics, or engines is relatively straightforward: ASIP, AVIP, or ENSIP respectively. However, when you have a system that crosses integrity disciplines, such as flight controls, subsystems, or cockpit, one needs to apply multiple integrity processes in an integrated manner. As an example, when integrity is applied to a flight control system, MECSIP must be applied to the mechanical elements, such as the actuators, AVIP to the electronics, such as the sensors and processors, and quality assurance provisions to the software that is executed within the processors. In expanding this concept to the aircraft level, weapon system integrity establishes the guidelines and processes necessary to synergistically apply the integrity concept across all appropriate elements of the aircraft. The specific integrity processes that must be implemented will vary with the specific application; i.e. the applicable processes for an avionics upgrade to an existing platform will certainly differ from a new start program. Weapon system integrity helps to ensure the proper integrity processes are applied, whether a program is in development, undergoing a modification, or in a sustainment phase.

Weapon system integrity establishes overall guidance for an aircraft level integrity process. It does not replace the existing integrity processes but points to them for the detailed implementation related to a specific application. This methodology is shown on figure 1.

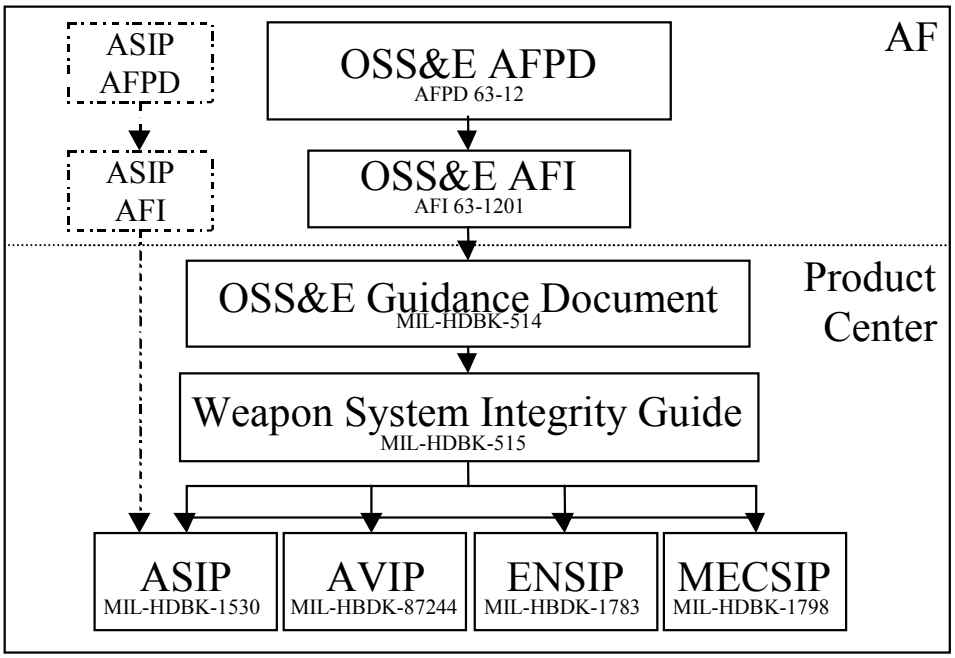

FIGURE 1. OSS&E weapon system integrity link.

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1.4 Responsibilities.

Responsibilities for accomplishment of weapon system integrity are consistent with the responsibilities paragraphs provided in ASIP documents, AFPD 63-10 and AFI 63-1001 and similarly through the implementation of OSS&E as called forth in AFPD 63-12, AFI 63-1201 and AFMCI 63-1201. The system program director (SPD) is responsible for implementation of weapon system integrity on the program. Chief engineers are responsible for all technical aspects of weapon system integrity. In general, the chief engineers should ensure that:

a. Planning addresses responsibilities throughout the life cycle.

b. Scheduling (PERT/CPM or the like which explains the linkages between tasks) addresses when tasks/activities are to be accomplished.

c. Identification and description of activities, including appropriate completion criteria, such that decisions are made based on sufficient information and the understanding of how performance will be delivered and sustained for the life of the system.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed below are not necessarily all of the documents referenced herein, but are the ones needed in order to understand the information provided by this handbook.

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.

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-882	Standard Practice for System Safety
MIL-STD-1629	Procedures for Performing a Failure Mode Effects and Criticality Analysis (Cancelled)

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-514	Operational Safety, Suitability, & Effectiveness Guidance Document for the Air System Product Line
MIL-HDBK-965	Acquisition Practices for Parts Management (Cancelled)
MIL-HDBK-1530 (USAF)	Aircraft Structural Integrity Program, General Guidelines For
MIL-HDBK-1783	Engine Structural Integrity Program (ENSIP)
MIL-HDBK-1798	Mechanical Equipment and Subsystems Integrity Program
MIL-HDBK-87244 (USAF)	Avionics/Electronics Integrity

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(Copies of these documents are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094 or online at http://astimage.daps.dla.mil/quicksearch/ or www.dodssp.daps.mil.)

2.2.2 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.

AIR FORCE PUBLICATIONS

DIRECTIVES

AFPD 62-4	Standards of Airworthiness for Passenger Carrying Commercial Derivative Transport Aircraft
AFPD 62-5	Standards of Airworthiness for Commercial Derivative Hybrid Aircraft
AFPD 62-6	USAF Aircraft Airworthiness Certification
AFPD 63-10	Aircraft Structural Integrity
AFPD 63-12	Assurance of Operational Safety, Suitability, & Effectiveness

INSTRUCTIONS

AFI 63-1001	Aircraft Structural Integrity
AFI 63-1201	Assurance of Operational Safety, Suitability, & Effectiveness
AFMCI 63-1201	Assurance of Operational Safety, Suitability, & Effectiveness

(Copies of AF publications are available to Department of Defense activities online at http://afpubs.hq.af.mil or e-mail afpdc-service@pentagon.af.mil.)

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. DEFINITIONS

3.1 Acronyms used in this handbook:

The acronyms used in this handbook are defined as follows:

a. ASIP Aircraft Structural Integrity Program

b. AVIP Avionics/Electronics Integrity Process

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c.	CCL	Criticality Control Logic
d.	COTS	Commercial Off-The-Shelf
e.	DADT	Durability and Damage Tolerance
f.	DLT	Durability Life Test
g.	DMR	Diminishing Manufacturing Resources
h.	DR	Deficiency Reports
i.	ECD	Environmental Criteria Document
j.	ENSIP	Engine Structural Integrity Program
k.	ESS	Environmental Stress Screens
l.	FMEA	Failure Modes Effects Analysis
m.	FMECA	Failure Modes Effects and Criticality Analysis
n.	F^3I	Form, Fit, and Functional Interface
o.	FRACAS	Failure Reporting and Corrective Actions System
p.	IAIS	Improved Avionics Intermediate Shop
q.	JRMET	Joint Reliability Maintainability Evaluation Team
r.	LO	Low Observables
s.	MCO	Maintenance Concept of Operations
t.	MECSIP	Mechanical Systems Structural Integrity Program
u.	MNS	Mission Needs Statement
v.	MODS	Modifications
w.	MTBM	Mean Time Between Maintenance
x.	OEM	Original Equipment Manufacturer
y.	ORD	Operational Requirements Document
z.	OSS&E	Operational Safety, Suitability and Effectiveness
aa.	QA	Quality Assurance
bb.	QC	Quality Control
cc.	R&M	Reliability & Maintainability
dd.	SM	Single Manager
ee.	SPD	System Program Director
ff.	SSHA	Subsystem Safety Hazard Analysis
gg.	TCTO	Time Compliance Technical Order
hh.	TO	Technical Orders

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4. WEAPON SYSTEM INTEGRITY PROCESS

Weapon system integrity provides a disciplined and integrated approach to achieve the objectives of the Operational Safety, Suitability, and Effectiveness (OSS&E) directives.

Most of the individual integrity efforts, regardless of the program in question, occur throughout the life cycle, building on knowledge gained during the previous phase(s). The activities necessary to accomplish systems integrity can be grouped into nine basic groups: Planning and Coordination, Design Criteria, Characterizing the Environment, Characterizing Materials, Characterizing Production and Quality, Identification and Tracking of Critical Items, Analysis, Tests and Demonstrations, and Life Management. These are addressed in table 1 and subsequent paragraphs in more detail.

Synergy is provided through those responsible for systems integrity. The “weapon system integrity engineer” acts to promote the coordination of integrity efforts and results. The development of design to environments is provided as an example (see figure 2).

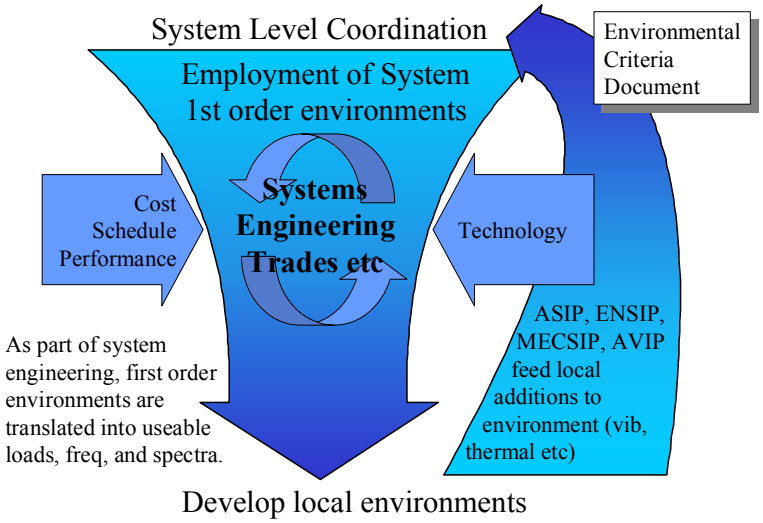

FIGURE 2. Design to environment loop.

The development, acquisition, and sustainment of systems differ dramatically depending on the attributes of the system and acquisition in question. New developments, modifications, modernization, F^3I, service life extensions, technology insertion, COTS, etc. are all considerations in the application of systems integrity. Yet the approach remains the same. Systems integrity and sound engineering practices in general are associated with the accumulation of knowledge sufficient to ensure a complete understanding of the ramifications of decisions made during the design, development, manufacture, and sustainment of hardware/software in order to ensure OSS&E. This gathering of data varies depending on the level and quality of data currently available; the technological maturity of the design under

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consideration, production process controllability, quality control; degree of systems integration; risk associated with wrong decisions; and the effort required to gain that data still needed. Depending on the scope of the effort involved, different elements within a system will start and end this information gathering and decision process at different times within a program. For this reason, system integrity, in terms of the tasks delineated, cannot be completely tied to milestones for all systems or subsystems within any given program. Rather, the appropriateness of efforts and schedules must both support OSS&E as well as other program requirements while acknowledging the scope of the tailored effort (acknowledging information yet to be gleaned, as well as the timeliness and inter-relatedness of said efforts).

The weapon systems integrity process follows the generic flow shown on figure 3. This process begins with requirements and desires as laid out in the Mission Needs Statement (MNS), and Operational Requirements Document (ORD), followed shortly thereafter by the Maintenance Concept of Operations (MCO). These documents are used to develop an understanding of the environment the system will be operated and maintained in as well as the performance characteristics sought. Table I provides a more in depth understanding of the efforts that are required to accomplish this process.

The efforts delineated in table 1 are basic in nature and should in no way be viewed as all-inclusive. For simplicity, these basic efforts have been coalesced into nine basic groups: each of which is discussed briefly in the following paragraphs (see 4.1 through 4.9), spread across the five phases of development and sustainment. The thought process involved with review of table 1 should result in one of three results:

a. The effort has been satisfied via currently available information.

Example: Under “Characterizing the environment” efforts “First order information, Usage, basing, Second order information, Installed locations, Usage updated, Environmental spectra defined” should already be known (depending on the extent of the modification) for an existing fielded system. Detailed environmental and usage information should therefore be reviewed only to identify shortfalls if they exist rather than to determine the design to environment. Again, depending on the extent of the modification, the design to environment should be based on the information gathered through the original design and subsequent fielded experience with that design, including appropriate deficiency reports (DR) and failure reporting and corrective actions system (FRACAS) results etc.

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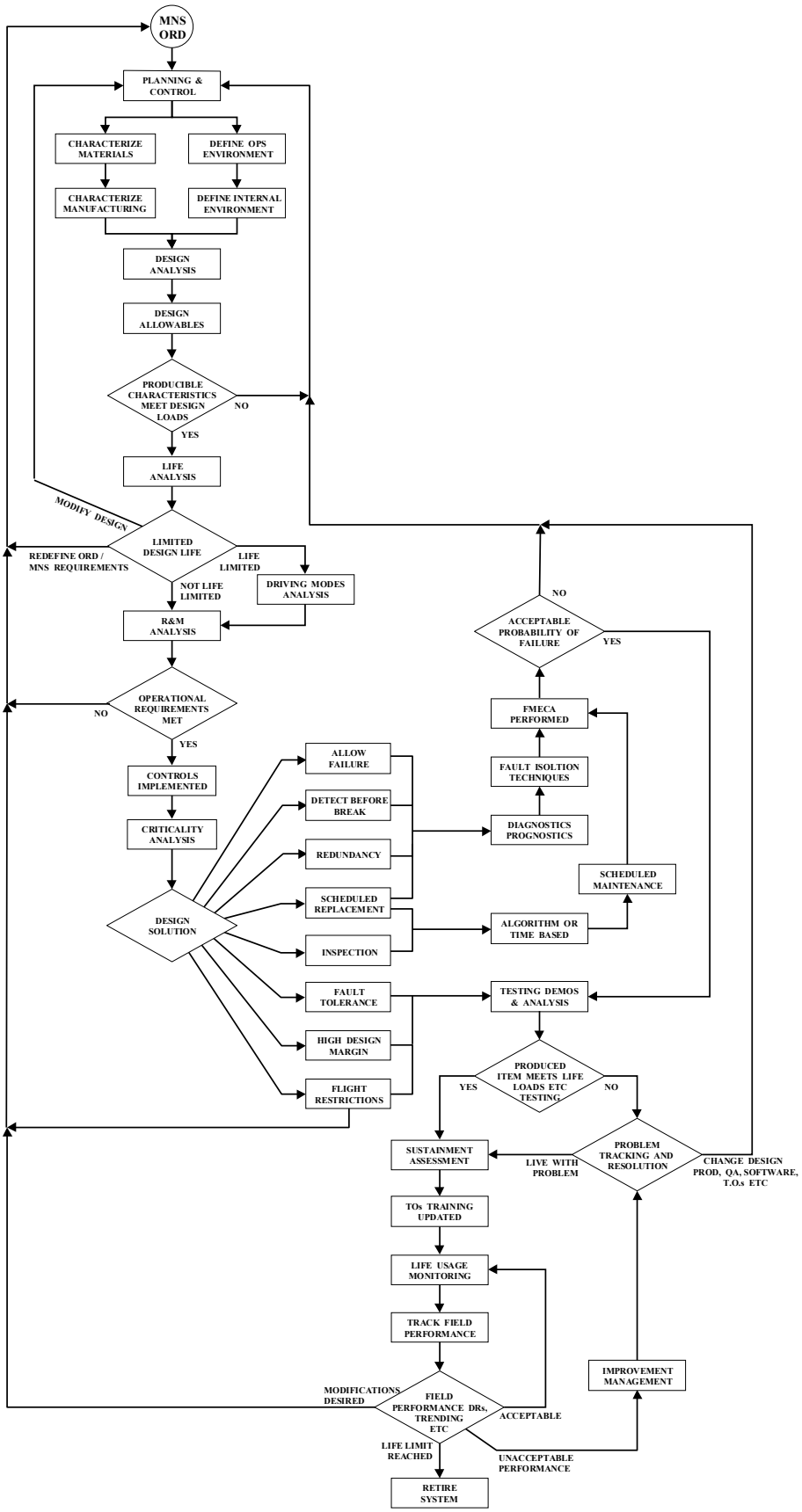

FIGURE 3. Weapon system integrity process flow.

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TABLE I Weapon system integrity process life cycle.

	Design Info & Preliminary Planning	Design Analyses & Development Tests	System/Subsystem/Component Test & Analysis	Ground & Flight Test	Production & Sustainment
Planning & coordination 4.1	Master plan & schedule established - Config mgt plan established - Test planning established Corrosion prevention & control plan defined DADT/DLT plan established Software plan established Development methodology Operation/support concept Development training plan Timed system replacement/ overhaul plan identified	Master plan updated Corrosion prevention & control implemented Timed system replacement overhaul plan implemented	Master plan updated DLT DADT plan updated Reliability growth management defined Software capability/training reviewed	Master plan updated Reliability growth management established	Master plan updated
Design criteria 4.2	Design criteria established - Design service life - Safety, mission reliability - Software reqs analysis	Design criteria updated for - Allowables - Battle damage	Design criteria updated for - Test results	Design criteria updated for - Survey results	Design criteria updated for - Lessons Learned
Characterizing the environment 4.3	Environment characterized - First order information - Usage - Basing	Environment characterized - Second order information -- Installed locations - Usage updated	Environment spectra defined Installed locations - Transmissibility surveys - Thermal/vibration	Environment surveys conducted	Environment monitored for accumulated stress - Life limited items - Airframe, engines - Subsystems
Characterizing materials 4.4	Critical characteristics identified	Properties identified Critical characteristics defined Variability established Quality control capabilities updated	Materials selected Joining method selected	Manufacturing plan implemented Process control levels verified Quality control levels verified Deviation & waiver tracking system established	Effective Service Life Established for life limited items (wiring, adhesives, etc.)
Characterizing production & quality 4.5	Manufacturing plan initiated Baseline manufacturing processes identified Quality control capabilities identified Software tools developed - Tool selection analysis - Demonstration	Mfg plan updated Process characteristics defined Variability established Quality control capabilities updated	Mfg plan implemented Manufacturing process control levels established - Tolerance sensitivity quality control established for critical parameters		Mfg Plan implemented Repair process controlled - Screening - QC monitoring

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TABLE I. Weapon system integrity process life cycle. – Continued

	Design Info & Preliminary Planning	Design Analyses & Development Tests	System/Subsystem/Component Test & Analysis	Ground & Flight Test	Production & Sustainment
Identification & tracking of critical items 4.6	Hardware/software classified per criticality - Hardware/software control implemented	Hardware/software classified per criticality - Hardware/software control implemented	Hardware/software control established Serialized component tracking defined	Hardware/software control program updated Serialized component tracking implemented Critical component TOs available	Hardware/software control program updated
Analysis 4.7	Integrity analysis conducted - Sizing/strength - Durability/damage tolerance Reliability & maintainability established - Predictions, allocations Functional FMECA conducted Software reqs analyzed - Software allocation process - Software interface analysis	Integrity analysis conducted - Sizing/strength - Durability/damage tolerance Reliability & maintainability established - Predictions, allocations Functional FMECA conducted Software reqs analyzed - Software allocation process - Software interface analysis	Reliability & maintainability updated - Predictions, allocations update - Maintenance task analysis TO development initiated FMECA updated FRACAS implemented Detailed software analysis and error reduction conducted - Software sizing and refinement	Reliability & maintainability updated - Predictions, allocations FMECA updated FRACAS updated JRMET Repairability/inspectability analyzed TO validation Software code analysis/error reduction completed Software error analysis/tracking completed	Estimated stress compared to actual - Update life estimates - TO changes - Lead the fleet eval service life extension -TOs, MODS, usage FRACAS updated
Tests & demonstrations 4.8	Design development completed Software prototyped	Design development completed Software prototyped	Integrity tests completed - Functional - Strength - DLT - Damage tolerance - Environmental Software tool/compiler demos Software simulation/modeling	Flight test completed Ground tests completed - Iron bird - Simulators - Avionics system integration - Strength LO durability completed Software development testing completed	
Life management 4.9	Installed inspection and maintenance capability identified	Installed inspection and maintenance capability identified	Life limited items updated	Tracking initiated Life limited items updated	Tracking system in place - Accumulated stress - Life remaining estimates - Deviation/waiver tracking field/depot - Repairs/removals - Inspections - Overhauls - TO changes maintained - Lead the fleet implemented - Software transitioned to support

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b. The effort must be undertaken to gather the appropriate information.

Example: Under “Characterizing production and quality” efforts “Baseline manufacturing processes identified, Quality control capabilities Identified, Manufacturing plan updated, Process characteristics defined, Variability established, Quality control capabilities updated, Manufacturing quality control levels established, Tolerance sensitivity” etc. must be accomplished to gather the information needed for a structural modification which employs a different process from that currently used. The process must be understood in sufficient detail to derive the controllability of defect size, location, and frequency. This information is necessary for design and sustainment (development of TOs repair procedures, etc.). While this “different process” may be used for other items, its usage for this item must be understood. Information may be gleaned from other sources, such as the processes inherent controllability, but this only provides a starting point. The controllability of the process may vary based on the unique characteristics of the item being manufactured. Likewise, given this “new” process and its controls, quality control must ascertain their ability to detect defects, and the frequency of said defects, which exceed allowable limits.

c. This effort is not relevant for the design under consideration.

Example: Under “Characterizing production and quality” efforts “Software tools developed, Tool selection analysis, Demonstration” would be irrelevant for a modified wing spar provided the change does not effect flight characteristics and consequently requires no associated software changes or additions.

This approach to systems integrity and OSS&E is preferred over “simply” choosing those efforts that apply as it ensures that no stones are left unturned. In other words, efforts are met through knowledge: either that knowledge is already possessed, must be gained through some activity, or the activity being evaluated is irrelevant. This course of action ensures that all efforts are evaluated for applicability.

Systems integrity plays a crucial role in the development of OSS&E’s planning and execution.

4.1 Planning and coordination.

Planning and coordination provide the backbone for the logical integration of the integrity processes. The entire process of determining what is known and what is yet to be gathered and proven (as well as how it will be proven) must be detailed in these plans. Planning must address the inter-relationships that exist between tasks such that the data gathered is done so in the most effective and efficient manner. A definition of the criteria and processes for both acceptable timed replacement and overhaul, for safety and system elements, is essential in planning. Planning must consider the design of the system, characteristics to be achieved, and the process associated with coordinating tasks, hardware, and software to achieve system requirements, as well as the means by which risks or problems are identified and resolved. Exit/success criteria associated with tasks and their management must be included in the Master Plan and Master Schedule. The Master Plan and Master Schedule are living documents that must be updated periodically: updates are a key to a successful program. If the Master Plan and Master Schedule can accurately describe not only the tasks and achievements (exit criterion), but their relationships as well, then lower level planning may not be required.

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4.2 Design criteria.

Design criteria are developed for the system level and lower level systems/items consistent with their use, criticality, and driving failure mechanisms as detailed in the ASIP, ENSIP, MECSIP, and AVIP documents.

Design criteria addresses all stress inducing sources/elements which produce design driving failure mechanisms expected to occur during any or all of: manufacture, repair, transportation, handling, storage, and field operations (life time). Applicability of damage tolerance and durability design criteria should be determined through criticality control logic (CCL).

“Allowables” account for defects and anomalies in manufacture, assembly, and maintenance. In essence, “allowables” provide manufacturing, quality assurance, maintenance, and TOs with the acceptable level of imperfection that will not impact the service life of the system as fielded under anticipated use.

Survey and test results are used to update analysis tools and design criteria as appropriate. Survey/test results, combined with field experience, may eventually become lessons learned in application for future efforts.

4.3 Characterizing the environment.

The environments to be characterized are those in which the system and its elements are to be used, manufactured, stored, transported, maintained, and repaired. These environments generate stresses in equipment, which directly affect performance, life, and reliability. In order to assess the impacts of these environmental stresses, they must first be broken down into their elemental stresses, those stresses affecting life and design. As the design progresses, the installed location environments must be refined to include those stresses imparted by virtue of the item’s location (including transmissibility) and operation within the system so that a complete map of the environment is available for design purposes. This “map” is sometimes referred to as the Environmental Criteria Document (ECD). The ECD becomes the guiding influence for design, test, and initial assessments of future modifications and enhancements. Installed locations affect not only stress, but maintenance as well. In turn, integrity will be directly affected by the ease with which the installed equipment can be maintained and/or inspected.

Characterizing the environment does not end with the fielding of the system. The actual environments must be measured to determine if the assumptions made in design hold in operational usage.

4.4 Characterizing materials.

The characterization of materials is a basic first step in design, but materials characterization goes far beyond the ability to handle shear, bending, torsion, etc. Materials exhibit different characteristics under different conditions: material transition curves associated with temperature, chemical reactions, galvanic corrosion, and fluid absorption are just a few such examples. Different methods of joining materials together whether they're the same material or not (chip on a board, bonding adhesives, panel to a spar, etc.), provide an additional area which must be identified and addressed through the integrity processes. The characteristics and variability of these joining methods must be considered in design decisions (see 4.5).

Software quality assurance by its very nature does not deal with materials, it never the less has a materials characterization analogy. The “materials” for software involve

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assessing the characteristics of the languages and compilers being considered. Decisions regarding the quality and consistency are equally important to software as hardware.

4.5 Characterizing production and quality.

Integrity assumes material characteristics degrade over the life of the system. This degradation is driven by usage, environment, materials, and the potential existence of flaws in manufactured items. The size of any potential assumed flaws is reflected in the integrity analysis. Characterization of the manufacturing process ties process control levels to key characteristics required to achieve performance for life and quality assurance provisions. Manufacturing variability must be assessed to understand, quantify, and control the likelihood that flaws (larger than those allowed) will be introduced as part of the manufacturing or repair/overhaul process and enter field service. True quality of the end product exists when the manufactured item consistently provides characteristics that meet or exceed the levels required by the design. This must be accomplished in a cost-effective manner, generally meaning that the system is incapable of ensuring 100% of all items produced will meet design requirements in all areas. The ability to detect such a flaw then becomes one of the main thrusts of quality assurance (QA). Design and manufacturing must work in unison to minimize the presence of flaws in general, but especially in locations that are hard for QA or maintenance to measure or inspect. QA ensures design defect levels and sizes are met on a consistent basis through the use of the following methods:

a. Inspections

b. Stress screens of all types (environmental stress screens (ESS), etc.) are designed to precipitate defects in a cost-effective manner.

c. Sampling procedures with associated testing.

d. Proof testing (limited application and does not address certain aspects of failure such as stress corrosion cracking, etc.).

The integrity of the design process must therefore ensure that achievable quality levels and variability are consistent with design constraints (allowables).

Key characteristics (or critical points) provide linkage between manufacturing, quality control, process control, and design. Critical points must be delineated in drawings with identified safety margins to compensate for variability.

Like manufacturing variability, the integrity of software is directly impacted by the software tools used and the consistency/correctness in coding that results from their use.

4.6 Identification and tracking of critical items.

The identification of critical functions and components occurs through various analytical tools: mission reliability analysis, FMECA, functional hazard analysis, subsystem safety hazard analysis (SSHA), and criticality control logic (CCL). Guidance for determination of criticality is well developed in both FMECAs and SSHAs. Design response to criticality is directed through damage tolerance, durability, manufacturing, and quality controls and documented in both FMECAs and SSHAs. The process of identifying critical items is as follows:

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a. Functions provided by the system in question are assessed in terms of their respective importance: safety critical, mission critical, durability critical, non-critical.

b. Critical functions are further broken down into their constituent items (hardware and software).

c. Critical safety item: A part, assembly, installation or production system with one or more critical safety characteristics that, if missing or not conforming to the design data, quality requirements, or overhaul and maintenance documentation would result in an unsafe condition. Unsafe conditions relate to hazard severity categories I and II of MIL-STD-882 and include conditions which would cause loss or serious damage to the end item or major components, loss of control, or serious injury or death to personnel.

d. Critical safety characteristic: Any feature, such as tolerance, finish, material composition, treatment, manufacturing, assembly, process control levels, overhaul, repair or inspection process of a product, which if nonconforming or missing, could cause the failure or malfunction of the critical safety item.

e. Mission critical item: Failure of a single item can cause loss of a function required for any mission.

f. Durability critical item: Failure may result in a major economic and/or availability impact to the system requiring costly downtime, maintenance, and/or repair/replacement which if not performed would significantly degrade performance or operational readiness.

The greater the part/item criticality, the greater the controls established and enforced during manufacture and sustainment. For example, safety critical items are tracked throughout production and in the field. Inspections, repair procedures, etc. are determined through integrity analysis and must be detailed in TOs.

4.7 Analysis.

The lifecycle of a system is described in the integrity processes through a series of five phases. Within this lifecycle, items are removed for failure (corrective maintenance), removed for life reasons (life-limited items, scheduled maintenance, timed replacement), or may undergo inspections or preventive maintenance. The accumulation of stress and subsequent removal of items based on that information is largely relegated to those items or components which have well defined wear out curves: a direct result of the understanding of the environment and manufacturing/parts procurement variability, also known as integrity analysis. As can be seen on figure 4, service life is defined to take advantage of the most supportable (affordable) portion of the component life.

Systems integrity uses the analysis from appropriate integrity processes to assess the overall life providing a direct impact to the fielded reliability of the systems. When technology cannot provide an economically feasible design that meets all of the other performance requirements (as determined through integrity analysis), life management or corrective maintenance is the only result possible. The impact of the maintenance practice to be employed is reflected in reliability analysis.

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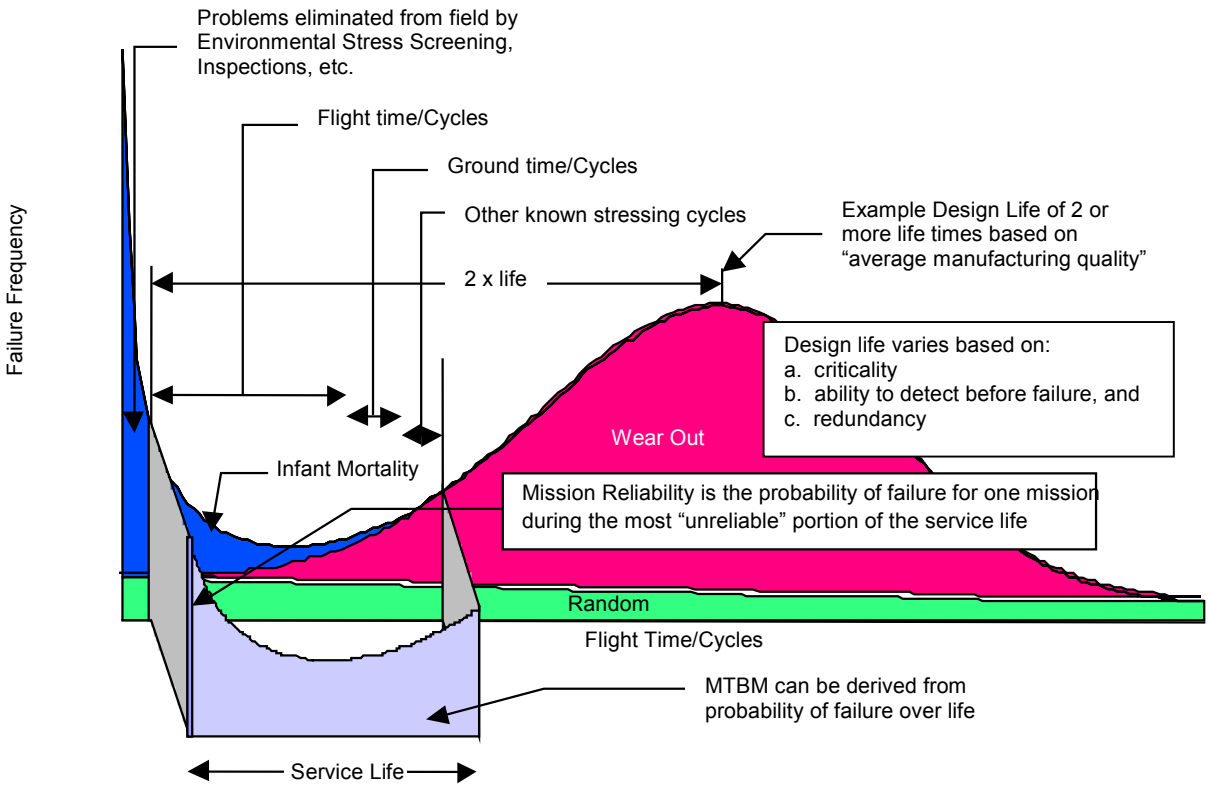

FIGURE 4. Integrity, reliability, and quality relationship.

4.8 Tests and demonstrations.

Tests are aimed at filling in the gaps of documented knowledge; validating analyses; increasing the understanding of the variability associated with manufacturing and control; providing information regarding the behavior of materials under stress; verifying the manufactured design meets requirements and can maintain that level of performance and safety for life. Through various phases of the integrity processes, these tests become more representative of the stress to be accumulated during the service life. Results of these tests, in terms of failures that occur, are analyzed and folded back into the design, manufacturing process controls, parts procurement, and quality assurance, as appropriate.

4.9 Life management.

The purpose of life management is to ensure safe, sustainable, and reliable original equipment manufacturer (OEM) specification level performance that is readily maintainable throughout life. When technology and materials are incapable of providing a solution that meets all requirements, or when a system is kept in use beyond the

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intended design service life, compensating provisions must be implemented. While life management is required for all systems, the extent to which it will affect the field varies.

With aging aircraft, performance and health is an essential ingredient in field maintenance, programmed depot maintenance, and overhaul processes. The performance and health of items must be monitored and compared to the timed replacement/overhaul plan and the initial design criteria. Of greatest importance, the performance and health must be continually assessed to ensure the safety of the aircrew, maintenance crew, and especially for unmanned aircraft the inhabitants of those areas to be over flown.

Economic life, as with criticality, is another life management consideration. Simply put, the economic life of a system is reached when it becomes cheaper to replace the unit than to continue maintaining it. In a sense, durable critical items are those which must be economically maintainable, that is, repair or replacement of the item is more economically feasible then developing a new system. This requires a well-defined wear out curve before economic decisions can be justified. It therefore follows that cost effective life management must also address issues such as diminishing manufacturing resources and technology refresh cycles.

In general, there are several points that must be considered during life management:

a. Monitoring aging aircraft to ensure OSS&E compliance.

b. The gathering of stress related environmental data.

c. The gathering of maintenance and repair/overhaul data to ensure OEM specification compliance through maintenance and repair/overhaul actions.

d. Integrity analysis to determine the life used, tied to appropriate response(s) (TOs). Diminishing manufacturing resources and technology refresh.

Diminishing manufacturing resources (DMR) have become a fact of life: fewer sources are available and components are dropped, as they become economically infeasible. The use of commercial equipment in military environments requires the implementation of the integrity processes. As with COTS, the use of commercial parts in place of MIL STD parts requires similar scrutiny. To ensure the long-term integrity of the system, not only design but parts procurement as well should require engineering concurrence to maintain continued design specification performance.

Technology refresh programs (in effect a modification) occur for various reasons: everything from reducing maintenance and cost burdens to increasing capabilities and availability. Technology refresh applications package new technology in existing systems (also a modification). Consistent with OSS&E, modifications require the same integrity efforts that would be imparted on a new system.

4.9.1 Tracking.

Configuration management is a major constituent within life management as well as OSS&E. The ability to track individual items during use plays a direct role in the fidelity of life management. Moreover, it provides the additional flexibility needed to accomplish trend analysis (useful in updating life estimates), identification/elimination of “bad actors”, and the understanding needed to allow the field use of “less than specification compliant items” where advantageous.

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4.9.1.1 Tracking defective product use.

Optimal use of programmatic assets often results in the use of “less than specification compliant” or “defective” items (generally handled through waiver, deviation, material review boards) to maintain testing schedules, deliveries, etc. Defective in this sense means “not within specification limits”. The presence of these defects may be related to life (determined through integrity analysis) possibly affecting scheduled maintenance, removal, or inspection intervals. Life management and in turn TOs for such items must be adjusted accordingly. The criticality of the function provided by the item(s) and the degree to which individual item(s) can be tracked is fundamental in determining whether a “defective” item should be considered for use.

4.9.1.2 Maintenance tracking.

Maintenance tracking supports inspection and repair of all equipment at all levels of maintenance. The TO and data system must ensure that sufficient information is gathered, preferably on a noninterference basis, to verify that actions have been appropriately executed. Changes to TOs must consider the impacts to integrity. The TO system must ensure error free software. This implies control of configurations of both systems supported and TO content. TO logic changes and manual fault isolation procedures must be evaluated against FMECA and SSHA to ensure consistency of design, manufacturing, and maintenance. This also necessitates that the TO content be controlled at all points from development through implementation, with updates during field service (similar to software control procedures).

4.9.2 Lead the fleet.

Progress in electronics and data compression now allow for the tracking of stressing events on virtually all life limited items (on systems with this capability). But even with this capability, there is a defensible need for lead-the-fleet programs. Lead the fleet does more than assess the “average” wear or fatigue associated with “general” use of life-limited items: it provides a substantial buffer. With each system having its own unique signature of use, the need for generalizing can be overcome. However, lead the fleet provides a buffer, a time to react, between the highly used lead-the-fleet systems and the rest of the fleet (as exposed to the future operational environment). Highly characterized systems with refined analysis and well understood environmental stress generally could not justify the expense of lead the fleet, but less well understood usage might find it beneficial. Lead the fleet is not limited to flying alone. It may be achieved in a laboratory through stress via actuated movements, deflections, loads, etc. that reflect fielded experience. In the long run this may prove to be more cost effective than a fielded effort.

4.9.3 Force management and sustainment.

An element of force management is the rotation of aircraft within the fleet to ensure that life usage is, more or less, evenly distributed. Aircraft used in areas of harsh environments or high stress exercises/mission profiles can be rotated to locations with less harsh or stressful conditions to ensure their life in years, as well as stress cycles, etc. are not compromised. The concept of rotating aircraft to “spread out the stress” based on usage provides for significantly easier management with limited data requirements. Conversely, limited data collection requires greater “margins” to account for the unknowns which must be “assumed” to occur. This has direct impacts on determining the amount of life remaining and extending life. In some limited situations,

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such as those associated with phasing out an operational system, the time and cost associated with performing an analysis to extend life may prove to be neither cost effective or operationally desirable.

Software support for fielded systems, like hardware, must maintain configuration control, including diagnostics and appropriate links to TOs. Software is often called upon to enhance the capability of existing systems. These changes can have direct impacts on the effects of failures as they propagate through systems and must be evaluated through FMECAs and other appropriate analyses to fully understand the effects.

4.10 Application of integrity processes.

Each integrity process has its own unique system focus. Many systems have elements that fall under more than one of the integrity processes. The question then becomes, which integrity process applies? In fact, all the integrity processes apply. The contractor reviews the appropriate integrity processes and determines which tasks, practices, or tools are appropriate (based on the characteristics of the items being developed or used) and which are most effective in providing a system which will meet specification performance throughout the intended service life.

Integrity processes are applied to all air vehicles and elements/components thereof, ground equipment, and COTS, as well as modifications to the use and manufacture of existing equipment/systems (which should be addressed through life management plans). There are no exceptions to the process: only differences in the amount of information possessed and the amount needed (see 4). The amount of resources committed to integrity depends on the lack of information.

4.10.1 Application to new systems.

Weapon system integrity is applied as outlined in this guide to all new systems.

4.10.2 Application to modifications.

Application of CCL and generation of FMECAs must ensure that modifications do not increase the probability of loss of a critical function or alter the propagation of failures such that safety or mission reliability is reduced. All other areas mentioned herein apply to modifications. In this light it should be understood that form, fit, and functionally interchangeable (F^3I) items, as with any other modification, require the appropriate level of integrity to ensure the replacement system meets all of the considerations of the pre-existing system. This requires an understanding of the effects of failure in addition to operating and environmental restrictions. Different designs, while meeting the F^3I definition, may have drastically different effects based on internal failures or the propagation of external failures.

4.10.3 Application to COTS and modified use.

There is little difference between modified use and COTS. Modified use implies a component will be used in a different environment than it was originally designed for. Likewise, COTS is often considered for employment in environments that differ from the original design. In effect, the design life based on integrity analysis for the current or design to environment must be compared with the new usage environment.

The ramifications of COTS and modified use can result in, but are not limited to the following:

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a. Changes in maintenance: removal and replacement of life-limited items (generally not available at the end of life), increasing failure rates, increased inspections, or additional scheduled maintenance.

b. Changes in usage: reduced load limits, reduced usage environment.

c. Modifications to the COTS or modified use equipment: thus reducing the benefits achieved through economy of scale etc.

An example of COTS modified for use is the Improved Avionics Intermediate Shop (IAIS) which employs a "ruggedized" COTS PXI computer, power supply, and disc drives. "Ruggedized" in this example entailed encapsulating the computer in an isomer shockproof chassis.

4.10.4 Extending the service life of existing systems.

Extending the life of an item requires additional considerations from integrity processes. An obvious question that applies to all life-limited items, is how much life remains? Subsequently, because the components must now endure higher levels of accumulated stress, life management and integrity analysis must be reviewed to determine if any new limited life items have been added by virtue of extending the life. If any new items are added, systems engineering must determine, along with the integrity processes, how best to handle these new life-limited items. The ramifications of extending service life can result in, but are not limited to the following:

a. Change in overhaul requirements and processes.

b. Reduced load limits (reduced usage environment).

c. Removal and replacement of life limited items (generally not available at the end of life).

d. Increasing failure rates, increased inspections, additional scheduled maintenance etc. all associated with lower levels of availability and increased cost.

e. Changes in timed replacement frequency.

f. Additional inspections to assess remaining life.

5. SUMMARY

Weapon system integrity, as a process, exists not only during development and production but in sustainment as well. It is the primary means through which OSS&E is achieved within systems engineering. While points of entry into the process will depend on the level of information already available, the utility of the process is fully recognized only when the entire process is followed.

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6. NOTES

6.1 Intended use.

This handbook provides guidance on how to integrate the existing integrity processes within systems engineering. This is accomplished through three basic thrusts:

a. Integrating the efforts called out in the various integrity processes, namely: ASIP, ENSIP, MECSIP, and AVIP.

b. Synergistically integrating or coordinating specific integrity process efforts/tasks with related efforts in various other systems engineering disciplines (see table 1).

c. Placing increased emphasis on the sustainment portion of the life cycle.

6.2 Subject term (key word) listing.

Analysis

Critical Items

Design Criteria

Environment

Life Management

Production

Quality

Sustainment

Systems Engineering

CONCLUDING MATERIAL

Custodian:

Air Force – 11

Preparing Activity:

Air Force - 11

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