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DEPARTMENT OF DEFENSE
STANDARD PRACTICE

ROTORCRAFT STRUCTURAL INTEGRITY PROGRAM (RSIP)

AMSC N/A

FSC 1520

FOREWORD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Comments, suggestions, or questions on this document should be addressed to Commander, U.S. Army Aviation and Missile Command, ATTN: AMSRD-AMR-SE-TD-ST, Redstone Arsenal, AL 35898-5000 or emailed to joseph.m.casamatta.civ@mail.mil. Since contact information can change, you may want to verify the currency of the document and address information using the ASSIST Online database at https://assist.dla.mil/.

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1. SCOPE

This standard practice describes the U.S. Army Rotorcraft Structural Integrity Program (RSIP), which defines the requirements necessary to substantiate and maintain structural integrity in U.S. Army rotorcraft.

1.1 Application. This standard practice applies to rotorcraft structure, as defined in section 3.31, regardless of rotorcraft type, until the rotorcraft is retired, declared excess, or de-milled. For the purposes of this standard practice, the term *rotorcraft* includes conventional helicopters, tilt rotors, tilt wing, co-axial, and compound helicopters. *Rotorcraft structure* includes fuselage, tailboom or tailcone, empennage, wings, stabilizers, stabilators, sponsons, landing gear structural components, interfaces and provisions, as well as rotors and rotor components, rotating and non-rotating rotor control mechanism components, propellers, proprotors, and any transmission and drive-systems components that experience flight-maneuver loads, control-surface induced loads, or loads imparted by fuselage, tailboom or tailcone, empennage, or flight-control mounts.

1.2 Purpose. This standard practice provides direction to government personnel and contractors engaged in the development, production, modification, acquisition, or sustainment of U.S. Army rotorcraft structures.

1.2.1 Goal and objectives. The goal of RSIP is to ensure that structural integrity is maintained at desired levels of reliability. RSIP enables improvement in rotorcraft performance, availability, and life-cycle cost. The objectives of RSIP are to

a. define the structural integrity requirements associated with meeting the rotorcraft system specification;

b. establish, evaluate, substantiate, and certify the structural integrity of rotorcraft structures;

c. acquire, evaluate, and apply usage and maintenance data to ensure the continued structural integrity of operational rotorcraft;

d. provide quantitative information for decisions on inspection, rotorcraft modification priorities, risk management, and related operational and support issues;

e. provide a basis to improve structural criteria and methods of design, evaluation, and substantiation for future rotorcraft systems and modifications.

1.2.2 Primary tasks. The RSIP consists of the following five interrelated functional requirements, which are considered necessary and sufficient to meet the RSIP goal and objectives:

a. Task I (Design Information). Task I is development of criteria which will be applied during design to ensure that the RSIP goal will be met.

b. Task II (Design Analysis and Developmental Testing). Task II includes the detailed characterization of the design usage and operational environment, the development of the design through testing of materials, components, and assemblies, and the analysis of the rotorcraft design.

c. Task III (Full-Scale Testing). Task III consists of flight and laboratory tests of the rotorcraft structure to verify that the design meets structural integrity requirements.

d. Task IV (Fielding with Instructions for Continued Airworthiness (ICA)). Task IV consists of the analyses that substantiate a statement of airworthiness qualification based on the results of Tasks I through III, as well as development of the processes and procedures required to manage fleet structural integrity.

e. Task V (Fleet Management). Task V executes the processes and procedures required to manage fleet structural integrity developed under Task IV. This task will involve revisiting elements of earlier tasks in cases of modifications or changes that potentially impact structural integrity, such as field incidents or changes in service use, configuration, or performance.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this standard practice. This section does not include documents cited in other sections of this standard practice or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this standard practice, whether or not they are listed.

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. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

DEPARTMENT OF DEFENSE SPECIFICATIONS

JSSG-2006 - *Aircraft Structures*

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

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-810 - *Environmental Engineering Considerations and Laboratory Tests*

MIL-STD-882	-	*System Safety*
MIL-STD-1289	-	*Airborne Stores, Ground Fit and Compatibility Requirements*
MIL-STD-1290	-	*Light Fixed and Rotary Wing Aircraft Crash Resistance*
MIL-STD-1530	-	*Aircraft Structural Integrity Program (ASIP)*
MIL-STD-1568	-	*Materials and Processes for Corrosion Prevention and Control in Aerospace Weapons Systems*
MIL-STD-8591	-	*Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase)*

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

DEPARTMENT OF DEFENSE HANDBOOKS

MIL-HDBK-310	-	*Global Climatic Data for Developing Military Products*
MIL-HDBK-516	-	*Airworthiness Certification Criteria*
MIL-HDBK-1823	-	*Nondestructive Evaluation System Reliability Assessment*
MIL-HDBK-6870	-	*Nondestructive Inspection Program Requirements for Aircraft and Missile Materials and Parts*

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

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. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

Department of Defense (DoD)

DoD Instruction	-	*Operation of the Defense Acquisition*

Number 5000.02 *System*

(Copies of this document are available online at http://www.esd.whs.mil/Directives/issuances/dodi/.)

DFARS - *Defense Federal Acquisition Regulation Supplement (DFARS) and Procedures, Guidance and Information (PGI)*

(Copies of these documents are available online at http://www.acq.osd.mil/dpap/dars/dfarspgi/current/index.html.)

Federal Aviation Administration

AC 29-2C - *Certification of Transport Category Rotorcraft*

(Copies of these documents are available online at https://www.faa.gov.)

Joint Aeronautical Commanders Group (JACG)

JACG Aviation Critical Safety Item Management Handbook

(Copies of this document are available online at http://www.dla.mil/ *or when using a DoD-issued Common Access Card* at https://remote2.amrdec.army.mil/csiviewer/doclib.aspx.)

Office of DoD Corrosion Policy and Oversight

DoD Corrosion Prevention and Control Planning Guidebook

(Copies of this document are available online at www.corrdefense.org.)

U.S. Air Force, U.S. Navy, and U.S Army Technical Manuals

TO 33B-1-1 / NAVAIR 01-1A-16-1 / TM 1-1500-335-23 - *Nondestructive Inspection Methods, Basic Theory*

TO 33B-1-2 / NAVAIR 01-1A-16-2 / TM 1-1500-366-23 - *Nondestructive Inspection General Procedures and Process Controls*

(Copies of these documents are available online at https://www.logsa.army.mil, select publications, select ETMs, search for publication number TM 1-1500-335-23 or TM 1-1500-366-23, note that TM 1-1500-366-23 is distribution C and requires a login)

U.S. Air Force Technical Reports

WL-TR-94-4052/3/4/5/6 (Accession Numbers ADA311686/87/88/89/90)	-	*Damage Tolerant Design Handbook (5 Volumes)*

(Copies of these documents are available online at http://www.dtic.mil/dtic.)

U.S. Army

AR 70-62	-	*Airworthiness of Aircraft Systems*
AR 700-142	-	*Type Classification, Materiel Release, Fielding, and Transfer*
DA PAM 700-142	-	*Instructions for Materiel Release, Fielding, and Transfer*

(Copies of these documents are available online at http://www.apd.army.mil.)

U.S. Army Aviation Applied Technology Directorate

RDECOM TR 12-D-12	-	*Full Spectrum Crashworthiness Criteria for Rotorcraft*
USAAVSCOM TR 89-D-22A through E	-	*Aircraft Crash Survival Design Guide, Volumes 1 through 5*

(Copies of this document is available online at http://www.dtic.mil.)

U.S. Army Aviation Engineering Directorate

ADS-13-HDBK	-	*Air Vehicle Materials and Processes*
ADS-27-SP	-	*Requirements for Rotorcraft Vibration Specifications, Modeling and Testing*
ADS-51-HDBK	-	*Rotorcraft and Aircraft Qualification (RAQ) Handbook*
ADS-79-HDBK	-	*Condition Based Maintenance System for US Army Aircraft*

(Copies of these documents are available online at https://www.amrdec.army.mil/amrdec/rdmr-se/tdmd/StandardAero.htm.)

U.S. Navy

SECNAVINST 4140.2 *[also designated as: AFI 20-106, DA PAM 95-9, DLAI 3200.4, and DCMA INST CSI (AV)]*	-	*Management of Aviation Critical Safety Items*

(Copies of these documents are available online at https://doni.documentservices.dla.mil.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

Aerospace Industries Association (AIA)

NAS410	-	*NAS Certification and Qualification of Nondestructive Test Personnel*

(Copies of this document are available online at http://www.aia-aerospace.org or from the Aerospace Industries Association, 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928)

American Society for Quality (ASQ)

ANSI/ISO/ASQ 3534-1	-	*Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

(Copies of these documents are available online at http://www.asq.org or from the American Society for Quality, P.O. Box 3005, Milwaukee, WI 53201-3005)

Battelle Memorial Institute

Metallic Materials Properties Development and Standardization (MMPDS), [developed from MIL-HDBK-5].

(Copies of this document are available online at https://www.mmpds.org or from Battelle, 505 King Avenue, Columbus, Ohio 43201.)

Center for Information and Numerical Data Analysis and Synthesis (CINDAS)

Aerospace Structural Metals Handbook (6 Volumes)

Structural Alloys Handbook (3 Volumes)

(Copies of these documents are available from CINDAS, https://cindasdata.com.)

SAE International, formerly Society of Automotive Engineers.

Composite Materials Handbook 17 (CMH-17),
[developed from MIL-HDBK-17].

(Copies of these documents are available online at http://www.sae.org or from SAE International, 400 Commonwealth Drive, Warrendale, PA, 15096.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, 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 Airworthiness. The property of an air system configuration to safely attain, sustain, and complete flight in accordance with approved usage limits.

NOTE: For the purposes of this standard practice, *air system configuration* is considered rotorcraft.

3.2 Aviation critical safety item. A part, an assembly, installation equipment, launch equipment, recovery equipment, or support equipment for an aircraft or aviation weapon system if the part, assembly, or equipment contains a characteristic any failure, malfunction, or absence of which could cause a catastrophic or critical failure resulting in the loss of or serious damage to the aircraft or weapon system, an unacceptable risk of personal injury or loss of life, or an uncommanded engine shutdown that jeopardizes safety.

NOTE: For the purpose of the standard practice, the terms aviation critical safety item, critical safety item, and flight safety part are synonymous. Additionally, aircraft or aviation weapon system is considered rotorcraft.

3.3 Confidence. The proportion of cases that the one-sided or two-sided interval estimation would contain or bound the true value of a population parameter of interest (in a long series of repeated random samples under identical conditions). See also ANSI/ISO/ASQ 3534-1.

3.4 Corrosion. Deterioration of a material or its properties due to the reaction of that material with its chemical environment.

3.5 Critical characteristic. Any feature throughout the life cycle of a critical safety item, such as dimension, tolerance, finish, material or assembly, manufacturing or inspection process, operation, field maintenance, or depot overhaul requirement, that if nonconforming, missing, or degraded may cause the failure or malfunction of the critical safety item.

3.6 Damage. Any anomaly induced during manufacture, maintenance, or service usage, that degrades, or has the potential to degrade, the performance of the affected structure.

> NOTE: For the purpose of this standard practice, the concept of damage includes "fatigue, environmental effects, intrinsic and discrete flaws, or accidental damage that may occur during manufacture or operation" as described, for example, in Code of Federal Regulations, Title 14, Part 29, sections 29.571(e)(4) and 29.573(c)(3).

> NOTE: For example, *anomalies* include imperfections, discontinuities, flaws, defects, cracks, disbonds, unbonds, delaminations, porosities, fiber waviness, corrosion, wear, thermal degradation, contact with foreign object debris, and degraded material properties due to processing or environmental exposure. Also for example, *maintenance* includes removal, installation, and handling.

3.7 Damage tolerance. The capability of a structure to continue performing its intended function with specified probability and confidence, without repair within the designated retirement or inspection intervals, in the presence of damage less than or equal to specified threshold levels. Stiffness, structural stability, dynamic behavior, load transfer, and functional performance characteristics remain within the design criteria. Residual strength maintains limit load capability.

> NOTE: Damage tolerance of the rotorcraft structure may be enabled by fail-safety of the sub-elements or slow damage growth. Fail-safety may be achieved by introducing dependent (active) or independent (passive) multiple load paths.

3.8 Design loads spectra. The spectra of structural loads used for design that the rotorcraft is expected to encounter throughout the design service life.

3.9 Design service life. The number of years, flight hours, flight cycles, or landings established at design, during which the rotorcraft is expected to maintain its structural integrity when flown to the design usage and maintained as required.

3.10 Design usage. Characterization of operational modes (regimes, mission profiles, and operational environment) and frequencies of application which specify design constraints to meet user requirements.

3.11 Design usage environment spectra. The spectra of environments used for design that the rotorcraft is expected to encounter throughout the design service life.

3.12 Durability. The capability of a structure to resist damage initiation or growth and maintain structural integrity for a prescribed period of time.

3.13 Engineering tolerance. Specified outer limits of acceptability with respect to some characteristic usually prescribed by an engineer.

3.14 Enhanced safe life. The capability of a structure to continue performing its intended function with specified probability and confidence, without repair and without initiating new damage or beginning growth out of existing damage within a designated retirement interval, in the presence of existing damage less than or equal to specified threshold levels. Stiffness, structural stability, dynamic behavior, load transfer, and functional performance characteristics remain within the design criteria. Residual strength maintains ultimate load capability.

3.15 Failure. The inability of an item to perform its intended function.

3.16 Fail Safe. A damage tolerance design concept in which structure retains its required residual strength for a period of unrepaired usage after load path failure or partial failure, up to the design service life.

3.17 Inspectability. Ability to reliably detect damage using inspection procedures that meet the minimum probability of detection requirements.

3.18 Inspection interval. The maximum authorized period (typically measured by flight hours, calendar time, landings or other service usage metrics) between recurring inspections or examinations.

3.19 Limit load. The maximum and most critical load, or combination of loads, experienced during authorized usage (for example, flight, ground, and maintenance) within the design service life.

3.20 Manufacturing stability. Condition in which materials, processes, joining methods, and structural concepts have matured to where consistent and repeatable quality, and predictable costs have been achieved to meet system production requirements. Also, process parameters and methods are understood, and robust and documented approaches for control of these factors, such as specifications, exist.

3.21 Multiple-element damage. A source of widespread fatigue damage characterized by the simultaneous presence of fatigue cracks in adjacent structural elements.

3.22 Multiple-site damage. A source of widespread fatigue damage characterized by the simultaneous presence of fatigue cracks in the same structural element.

3.23 Nondestructive inspection. An inspection process or technique designed to reveal the damage at or beneath the external surface of a part or material without adversely affecting the material or part being inspected.

3.24 Primary structure. Structure which is intended to carry primary design loads or is necessary to maintain certified levels of structural integrity for the rotorcraft.

NOTE: For the purpose of this standard practice, *primary design loads* encompass operational loads, including static and oscillatory loads and applicable factors of safety as specified for the rotorcraft.

NOTE: For the purpose of this standard practice, safety of flight structure is a subset of primary structure.

3.25 Principal structural element. Structural element that contributes significantly to the carrying of flight, ground, or pressurization loads and the fatigue failure of which could result in catastrophic failure of the rotorcraft.

NOTE: For the purpose of this standard practice, *flight, ground, or pressurization loads* are encompassed by operational loads.

NOTE: For the purpose of this standard practice, all Principal Structural Elements (PSEs) are included as a subset of safety of flight structure.

3.26 Probability of detection. The fraction of damage of specified size expected to be found, given their existence.

NOTE: When specifying Probability of Detection (POD), an associated confidence (such as 95%) should also be specified.

3.27 Producibility. Ability to economically manufacture, fabricate, assemble, and inspect materials, parts, components, and structures that achieve required performance, quality, and production rate.

3.28 Reliability. The probability that an item can perform its intended function for a specified interval under stated conditions.

NOTE: Reliability is used in this standard practice to describe the proportion of rotorcraft structure in the fleet which is expected to safely sustain the required load cycles for the required duration.

NOTE: When specifying reliability or any other form of probability, an associated confidence (such as 95%) should also be specified.

3.29 Retirement interval. The maximum authorized period since new or reworked to remove detectable or suspected fatigue damage (typically measured by flight hours, calendar time, landings or other service usage metrics) at which removal from service is required.

3.30 Risk analysis. An evaluation of a potential hazard severity and probability of occurrence.

NOTE: For rotorcraft structural applications, the *potential hazards* include the inability of a structure to continue performing its intended function with the potential to cause injury or death to personnel, damage to or loss of the rotorcraft, or reduction of mission readiness/availability.

3.31 Rotorcraft structure. Components that provide the strength, stiffness, and mechanical stability required for reacting, carrying, or transmitting loads or motions.

3.32 Safe life. The capability of a structure to continue performing its intended function with specified probability and confidence, without repair and without initiating damage within a designated retirement interval. Stiffness, structural stability, dynamic behavior, load transfer, and functional performance characteristics remain within the design criteria. Residual strength maintains ultimate load capability.

3.33 Safety of flight structure. Structure whose failure could cause loss of the aircraft, or cause severe injury or death, or impair a safety critical function, or cause inadvertent store release. The consequences could occur either immediately upon failure or subsequently if the failure remains undetected.

NOTE: For the purpose of this standard practice, *the aircraft* is considered *the rotorcraft*.

NOTE: For the purpose of this standard practice, safety of flight structure includes the subset of primary structure whose failure (detected or undetected) would result in immediate or subsequent loss of the rotorcraft.

NOTE: For the purpose of this standard practice, safety of flight structure includes, but is not necessarily limited to, all structural aviation critical safety items and PSEs.

3.34 Secondary structure. Structure which is not intended to carry primary design loads and is not necessary to maintain certified levels of structural integrity for the rotorcraft.

NOTE: For the purpose of this standard practice, *primary design loads* encompass operational loads, including static and oscillatory loads as specified for the rotorcraft. For detailed guidance, see sections 6.4.2 and 6.4.3.

3.35 Structural integrity. A condition in which a structure is capable of performing its intended function.

NOTE: For this standard practice, rotorcraft structural integrity represents the capability to sustain the required loads spectra for the required duration at specified extremes of operational environment. Structural integrity incorporates specified levels of strength, rigidity, stability, durability, and tolerance to damage (as in enhanced safe life or damage tolerance).

NOTE: Benefits and goals of ensuring structural integrity include providing the desired levels of airworthiness, structural safety, performance, durability, and supportability.

3.36 Structural usage monitoring. Techniques and procedures by which selected aspects of service history can be determined.

NOTE: For the purpose of this standard practice, structural usage monitoring implies monitoring the operational use of the rotorcraft to support structural integrity activities such as component inspection, retirement intervals, usage spectrum updates, loads spectra updates, and usage environment spectra updates.

3.37 Supportability. Condition in which thermal, environmental, and mechanical deterioration of structures have been identified and in which acceptable quality and cost-effective preventive methods and in-service repair methods are either available or can be developed in a timely manner.

3.38 Survivability. The capability of a system to avoid (susceptibility) or withstand (vulnerability) environmental effects, operational threats, and hostile threats.

3.39 Ultimate load. A load which is derived by multiplying the limit load by the specified ultimate factor of safety, or which may be directly specified for load cases where a limit load is not specified.

3.40 Vulnerability. The characteristics of a system that cause it to suffer a definite degradation (loss or reduction of capability to perform the designated mission) as a result of having been subjected to environmental effects, operational threats, and hostile threats.

NOTE: For the purpose of this standard practice, vulnerability is considered a subset of survivability.

3.41 Widespread fatigue damage. Fatigue-related damage in multiple structural locations that are of sufficient size and density such that the rotorcraft structure will no longer meet its residual strength requirements.

NOTE: For the purpose of this standard practice, widespread fatigue damage may be caused by multiple-element damage or multiple-site damage.

3.42 Yield load. A load which is derived by multiplying the limit load by the specified yield factor.

3.43 List of acronyms.

AC	Advisory Circular
ADS	Aeronautical Design Standard
ANSI	American National Standards Institute
AR	Army Regulation
ASIP	Aircraft Structural Integrity Program
ASQ	American Society for Quality
ASTM	American Society for Testing and Materials
CBM	Condition Based Maintenance
CFR	Code of Federal Regulations
CMH	Composite Materials Handbook
COV	Coefficient of Variation
CPC	Corrosion Prevention and Control
CPCP	Corrosion Prevention and Control Plan
CPCT	Corrosion Prevention and Control Team
CSI	Critical Safety Item
DA	Department of the Army
DFARS	Defense Federal Acquisition Regulation Supplement
DoD	Department of Defense
FMECA	Failure Modes, Effects, and Criticality Analysis
ICA	Instructions for Continued Airworthiness
ISO	International Organization for Standardization
JACG	Joint Aeronautical Commanders Group
JSSG	Joint Service Specification Guide
MAA	Military Airworthiness Authority
MMPDS	Metallic Materials Properties Development and Standardization
NAS	National Aerospace Standard
NDI	Nondestructive Inspection
NDIT	Nondestructive Inspection Team
PEO	Program Executive Officer
POD	Probability of Detection
PSE	Principal Structural Element
RDECOM	(U.S. Army) Research, Development and Engineering Command
RP	Recommended Practice
RSIP	Rotorcraft Structural Integrity Program
SAE	Society of Automotive Engineers
SAWE	Society of Allied Weight Engineers
SB	Structures Bulletin
SSOR	Strength Summary and Operating Restrictions
TM	Technical Manual
TO	Technical Order
TR	Technical Report
U.S.	United States (of America)
USAF	United States Air Force

4. GENERAL REQUIREMENTS

4.1 Rotorcraft development programs. The RSIP shall comply with this standard practice, and the procuring government agency[1] shall

a. task air vehicle design prime contractor(s) to develop an initial RSIP Master Plan at initial contract award (such as during the Technology Maturation and Risk Reduction phase for a milestone A entry, as defined and established by DOD Instruction 5000.02) that identifies the tasks to achieve structural integrity and determine structural performance, durability, supportability, and life cycle costs for the rotorcraft structure, based on the five, interrelated RSIP tasks and their corresponding detailed requirements summarized in table I (see section 6.4.4 Development of the RSIP Master Plan for guidance related to the level of detail and encouraged collaboration),

b. obtain Program Executive Officer (PEO) and Military Airworthiness Authority (MAA) approval of the initial RSIP Master Plan prior to the Systems Requirement Review, and obtain PEO and MAA approval of any changes to the RSIP Master Plan prior to technical reviews associated with program decision milestones,

c. reference this standard practice (tailored, as required, see section 6.5) and the RSIP Master Plan, as well as other RSIP task elements and substantiating documents and data consistent with tailored application of this standard practice, in all program-unique specifications and statements of work related to rotorcraft structure to ensure that contracts are consistent with RSIP,

d. task air vehicle design prime contractor(s) to update the RSIP Master Plan during the Engineering and Manufacturing Development, Production & Deployment, and Operations & Sustainment phases of the program (as defined and established by DOD Instruction 5000.02) to document changes in the RSIP with approval by the PEO and MAA in accordance with item b, above (see section 6.4.4 Development of the RSIP Master Plan for guidance related to the level of detail and encouraged collaboration), and

e. execute the RSIP during the Sustainment Activity to maintain structural integrity during operations of the rotorcraft.

4.2 Rotorcraft modification programs. The RSIP shall comply with this standard practice, and the procuring government agency shall

a. task air vehicle design prime contractor(s) to develop a tailored RSIP Master Plan prior to the start of detailed design of modified structure (see section 6.4.4 Development of the RSIP Master Plan for guidance related to the level of detail and encouraged collaboration), and

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[1] The *procuring government agency* is the command, agency, or office assigned responsibility for the system under development or being acquired. For acquisition programs managed by the U.S. Army, the *procuring government agency* is the *materiel developer*.

b. obtain PEO and MAA approval of the tailored plan for rotorcraft that are to be modified, fly new missions, or whose operation will extend past the rotorcraft's certified service life. An approved tailored plan is required before modifications are executed, regular flights begin under the new mission, or commencing operations beyond the previously certified service life. For rotorcraft modification programs managed by the United States Air Force (USAF), an Aircraft Structural Integrity Program (ASIP) per MIL-STD-1530 requirements and related USAF policy directives and instructions is expected to replace the RSIP.

4.3 Legacy and commercial rotorcraft programs. Pending establishment of a modification program, this standard practice is not intended for application to unmodified legacy and commercial rotorcraft. Legacy and commercial rotorcraft should follow existing Instructions for Continued Airworthiness (ICA) as approved by cognizant authorities. Legacy and commercial rotorcraft programs shall use MIL-HDBK-516 as a guide to airworthiness certification. Legacy U.S. Army rotorcraft programs shall also use ADS-51-HDBK as a guide to qualification of rotorcraft structure. See section 4.2 for modified legacy and commercial rotorcraft programs.

TABLE I. Rotorcraft structural integrity program tasks.

TASK I DESIGN INFORMATION	TASK II DESIGN ANALYSES & DEVELOPMENTAL TESTING	TASK III FULL-SCALE TESTING	TASK IV FIELDING WITH ICA	TASK V FLEET MANAGEMENT
5.1.1 RSIP Master Plan	5.2.1 Material and structural allowables development	5.3.1 Static tests	5.4.1 Updated structural analyses	5.5.1 Implement operational limitations
5.1.2 Design service life, design component retirement intervals, and design usage	5.2.2 Loads analysis	5.3.2 Damage tolerance tests	5.4.2 Strength Summary & Operating Restrictions	5.5.2 Implement structural integrity sustainment plan
5.1.3 Structural design criteria	5.2.3 Design loads spectra	5.3.3 Safe life tests	5.4.3 Structural integrity sustainment plan	5.5.3 Implement aviation critical safety item surveillance process
5.1.4 Aviation Critical Safety Item Management Plan	5.2.4 Design usage environment spectra	5.3.4 Enhanced safe life tests	5.4.4 Aviation critical safety item surveillance process development	5.5.4 Implement mechanical endurance surveillance process for fielded aircraft
5.1.5 Fatigue and fracture methodologies	5.2.5 Threat assessment	5.3.5 Design service life tests	5.4.5 Mechanical endurance surveillance process development for fielded aircraft	5.5.5 Update structural integrity sustainment plan, as required
5.1.6 Corrosion prevention and control	5.2.6 Static structural analysis	5.3.6 Component endurance bench tests	5.4.6 Technical manuals	
5.1.7 Nondestructive Inspection Plan	5.2.7 Damage tolerance analysis	5.3.8 Drop tests		
5.1.8 Condition Based Maintenance Management Plan	5.2.8 Safe life analysis	5.3.9 First flight verification ground tests		
5.1.9 Selection of materials, processes, joining methods, and structural concepts	5.2.9 Enhanced safe life analysis	5.3.10 Structural flight tests		
	5.2.10 Design service life analysis	5.3.11 Environment tests		
	5.2.11 Mechanical endurance assessment	5.3.12 Dynamic flight tests		
	5.2.12 Corrosion assessment	5.3.13 Mechanical endurance surveillance		
	5.2.13 Aeroelastic and aeroservoelastic analysis	5.3.14 Interpretation and evaluation of test results		
	5.2.14 Vibration analysis			
	5.2.15 Mass properties analysis			
	5.2.16 Survivability analysis			
	5.2.17 Design development tests			
	5.2.18 Aviation critical safety item and critical characteristic determination/classification			
	5.2.19 Develop structural usage monitoring algorithms			
	5.2.20 Initial risk analysis			

5. DETAILED REQUIREMENTS

5.1 Design information (Task I). The design information task is development of criteria which will be applied during design to ensure that the RSIP goal will be met. Theoretical, experimental, and operational expertise is applied using trade studies to develop criteria for materials selection, structural design, configuration (including, but not limited to gross weight, center of gravity, rotor speed, external stores, flight control systems, rotor blade airfoil, and rotor track and balance) and planned usage characteristics to meet specified operational, performance, and sustainment requirements throughout the rotorcraft's life cycle.

5.1.1 Rotorcraft Structural Integrity Program Master Plan. The purpose of the Rotorcraft Structural Integrity Program (RSIP) Master Plan is to define and document the specific approach to accomplish the various RSIP tasks throughout the life-cycle of each rotorcraft. The plan shall depict the time-phased scheduling and integration of all required RSIP tasks for design development, analysis, testing, fielding, and fleet management. The plan shall document responsibilities for each element of the plan. The plan shall also include discussion of any tailoring, unique features, exceptions to this standard practice and the associated rationale including risk assessments, and any problems anticipated in the execution of the plan. Prerequisites to each item in the plan shall be documented, including the necessary technical reviews and Government approvals for each item. For cases of an RSIP Master Plan proposing to tailor this standard practice by substituting analysis in place of any section 5.3 full-scale testing for verification of requirements, the air vehicle design prime contractor shall document the basis and limits of validity for each analysis. In such cases, the air vehicle design prime contractor(s) shall provide supporting validation data and analysis to the MAA prior to seeking approval of the plan in accordance with section 4.

5.1.2 Design service life, design component retirement intervals, and design usage. The minimum design service life, minimum design component retirement intervals, design usage, and required reliability and confidence will be provided by the Government as part of the rotorcraft system specification. When not explicitly specified, the required reliability and confidence shall be derived in coordination with the Government and documented in the RSIP Master Plan. Structural reliability shall be maintained throughout the rotorcraft design service life and each component retirement interval. The specified or derived reliability and confidence documented in the RSIP Master Plan shall establish a development baseline for risk analyses and hazard assessments prior to fielding. The design usage shall represent the usage, mission profiles, and operational environment in accordance with the rotorcraft system specification, including usage-environment design criteria derived from climatic data in MIL-HDBK-310. The approach to characterizing design usage shall incorporate relevant aspects of the RSIP Master Plan related to load monitoring, component tracking, and any logistical constraints.

5.1.3 Structural design criteria. Detailed structural design criteria for the rotorcraft shall be established in accordance with the requirements of the rotorcraft system specification. These shall include design criteria for the structural design envelope, loads, strength, deformation, durability, fatigue, fracture, tolerances, mass properties, dynamics, and survivability. The structural design criteria for airborne stores, suspension equipment, and associated rotorcraft-store interfaces shall be in accordance with MIL-STD-8591. The structural design criteria shall be coordinated with the Government to identify and approve any requirement for special inspection, repair, or replacement likely to result from application of the criteria.

5.1.3.1 Structural design envelope definition. A structural design envelope shall be defined which encompasses all rotorcraft performance capability in accordance with the rotorcraft system specification. For the purpose of defining the structural design envelope, performance capability shall include characterization by selected combinations of parameters such as gross weight, center of gravity, load factor, airspeed, control input rate, rotorcraft angular rate and attitude, sideslip angle, and density altitude.

5.1.3.2 Loads criteria. Criteria shall be established such that all critical limit load conditions are developed. These limit loads are the loads which can result from authorized use of the rotorcraft within the structural design envelope and in accordance with the rotorcraft system specification, to include system failures from which recovery is expected. Yield loads for the rotorcraft shall be obtained by multiplying limit loads by the specified yield factor. Ultimate loads for the rotorcraft shall be obtained by multiplying the limit loads by the specified ultimate factor of safety.

5.1.3.3 Strength criteria. Criteria shall be established to ensure that the rotorcraft structure has the static strength required to maintain structural integrity within the structural design envelope and in accordance with the rotorcraft system specification. The strength requirements shall consider the type of structure (such as primary or secondary structure, single load path or multiple load path structure, safety of flight structure); usage environment, load conditions, and factors of safety; and any associated material allowable considerations such as the required basis (A-basis or B- basis) and environmental effects for each case. Sufficient static strength shall be provided in the rotorcraft structure such that no detrimental deformation or damage occurs at yield loads and that no structural failure occurs at ultimate loads.

5.1.3.4 Deformation criteria. Criteria shall be established to ensure that the rotorcraft structure has the deformation characteristics required to maintain structural integrity within the structural design envelope and in accordance with the rotorcraft system specification. Criteria shall include any limits of acceptable deformation at limit loads or yield loads. Cumulative effects of elastic, thermal, aeroelastic, or aeroservoelastic deformations, which result from authorized usage of the rotorcraft, shall not interfere with the mechanical operation of the rotorcraft or adversely affect the rotorcraft aerodynamic characteristics. Adverse impacts to structural loads due to the deformation criteria shall be incorporated into the loads criteria. Criteria shall include any panel or web elastic buckling criteria necessary to maintain validity of subsequent structural analysis and testing assumptions. Special consideration shall be given to buckling criteria for sandwich structure, panels and webs in a diagonal tension field, laminated panels and webs, or panels and webs with cutouts. Any deformation resulting from damage that is within damage tolerance thresholds shall be shown to not impact the structural integrity of the rotorcraft.

5.1.3.5 Durability, fatigue, and fracture criteria. Criteria shall be established to ensure application of the service lives, retirement intervals, and inspection plans for rotorcraft structure, including all PSEs, required to maintain structural integrity within the structural design envelope in accordance with the design usage. Durability, fatigue, and fracture criteria includes criteria related to fatigue lives (safe life, enhanced safe life, or service life), as well as criteria related to durability and damage tolerance. Criteria necessary to implement planned repair concepts and in-service maintenance shall also be identified. Criteria shall be established to ensure the rotorcraft structure can achieve the design service life when exposed to threats related to damage, including fatigue, environmental effects, intrinsic and discrete anomalies (such as flaws or defects), impact or other accidental damage, and hostile threats. For damage tolerant substantiated safety of flight structure, criteria shall define damage tolerance analysis limits of validity in relation to the onset of widespread fatigue damage, whether due to multiple-element damage or multiple-site damage.

5.1.3.6 Engineering tolerance criteria. Criteria shall be established such that engineering tolerances used for design, manufacturing, usage, and serviceability parameters remain within the limits of validity established by analyses and tests related to this standard practice. All structure shall be designed to specified dimensions or to 105 percent more material than the least material condition, whichever would result in a lower margin. However, for safety of flight structure, the criteria shall maintain validity of analysis and test data for any combination of parameters from the maximum to minimum tolerance values. Criteria shall incorporate engineering tolerance ranges that constrain any changes in structural integrity, such as structural capability, load magnitude, or load path. Along with dimensional and material related properties and treatments such as hardness or surface treatment coverage, engineering tolerance criteria shall account for normal wear, thermal and environmental effects, and degradation, and how these relate to the strength, stiffness, fit, and function of the structure. Engineering tolerance criteria shall also account for variances in envelope parameters, such as track and balance or rotor smoothing, airspeed, torque, rotor speed, or load factor indications and limits. Engineering tolerance criteria shall ensure that loads developed in accordance with the section 5.1.3.2 loads criteria remain valid for all configurations in accordance with the requirements of the rotorcraft system specification.

5.1.3.7 Mass properties criteria. Criteria shall be established to ensure the rotorcraft can accommodate aerodynamic, center of gravity, and inertia changes in accordance with the rotorcraft system specification. These changes may result from fuel usage, store expenditure, asymmetric fuel and store loading, fuel migration at high angles of attack and roll rates, rotorcraft re-configuration, and aerial refueling. Criteria shall represent mass properties enveloped by critical loading conditions which can result from usage of the rotorcraft within the structural design envelope and in accordance with the rotorcraft system specification, to include system failures from which recovery is expected.

5.1.3.8 Dynamics criteria. Criteria shall be established to ensure the rotorcraft, in all configurations, including external store carriage, is free from aeroelastic or aeroservoelastic instabilities for all combinations of rotor speed, altitude, and speed within the approved flight envelope by the required airspeed margin of safety. Criteria shall be established such that the rotorcraft structure can withstand the aeroacoustic loads and vibrations due to aerodynamic and mechanical excitations throughout the design service life. The criteria shall ensure that safe flight limitations account for retreating blade stall and advancing blade compressibility. Specifically, criteria shall establish the basis for the implementation of gross weight, density altitude, and airspeed limitations to avoid introducing deleterious oscillatory loads[2] due to retreating blade stall or advancing blade compressibility in sustained steady-state maneuvers such as level flight or other specified steady-state conditions, such as those producing a load factor less than 1.25g. Considerations regarding tolerances for track and balance of rotor blades or rotor smoothing from section 5.1.3.6 shall also be included in the dynamics criteria to ensure that fuselage vibrations remain within limits established by the rotorcraft system specification or by ADS-27-SP, whichever is less. Criteria shall be established to avoid deleterious oscillatory loads due to air resonance or ground resonance.

5.1.3.9 Survivability criteria. Criteria shall be established to meet specified survivability requirements, including crashworthiness and vulnerability requirements. RDECOM TR 12-D-12, MIL-STD-1290, and USAAVSCOM TR 89-D-22A through E may be used as guides.

5.1.4 Aviation Critical Safety Item Management Plan. An Aviation Critical Safety Item (CSI) Management Plan shall be developed to define the means for compliance with Section 2319 of title 10, U.S. Code, and Defense Federal Acquisition Regulation Supplement (DFARS) 209.270. The Aviation CSI Management Plan shall document the procuring government agency's plan to identify items that meet the criteria for designation as an aviation CSI; establish qualification requirements in accordance with procedures established by the design control activity (MAA); qualify and identify aviation critical safety item suppliers and products; and implement heightened surveillance by the designated quality assurance representative. JACG Aviation Critical Safety Item Management Handbook and SECNAVINST 4140.2 (DA Pam 95-9) may be used for guidance.

5.1.5 Fatigue and fracture methodologies. Fatigue and fracture methodologies (including safe life, enhanced safe life, durability, and damage tolerance methodologies) shall be developed to establish service life, retirement intervals, inspection intervals, inspection procedures, and associated probabilities of detection. Establishment (or subsequent revision) of fatigue and fracture methodologies shall require design control activity (MAA) review and approval. The methodologies shall define probabilistic or deterministic methods for assessing component and system reliability and confidence associated with fatigue and fracture related retirement intervals, service lives, and inspection intervals. The methodologies shall explain relationships between fatigue and fracture tests and substantiations from Tasks II, III, and IV. The methodologies shall explain how structural flight test data in conjunction with the design usage spectrum will be used to determine retirement intervals, service lives, and inspection intervals. Methodologies for assessing service lives of safety of flight structure shall address the potential for widespread fatigue damage, whether due to multiple-element damage or multiple-site damage. The methodologies shall require inflight measurement of fatigue loads, stresses, or strains for all safety of flight structure in all critical regimes of the design usage from section 5.1.2, including any government approved modifications to the design usage in accordance with section 5.2.3. The methodologies shall explain how inflight measurements from the flight load survey in section 5.3.10.1 will be used to validate, modify, supplement, or replace loads analysis in section 5.2.2 used in the design loads spectra in section 5.2.3. As applicable, the methodologies shall describe how fatigue tests (coupon and full scale, with or without damage prior to testing,

[2] See section 6.4.12.2 for guidance related to recognizing *deleterious oscillatory loads*.

including details related to use of runouts[3] and the targeted range of cycles to support application of the fatigue curve) and crack-growth tests (coupon and full scale) determine the fatigue and fracture characteristics of all assessed structural load-carrying components. The required tests shall sufficiently demonstrate required fatigue and fracture characteristics. The methodologies shall specify the number of test articles (or other aspects of each methodology) which are necessary to achieve the required reliability and confidence in accordance with section 5.1.2. The methodologies shall completely describe authorized analysis techniques, including cumulative damage calculations, rainflow or other approved cycle counting methods, approved crack growth analysis retardation/acceleration models, assumption quantification, damage sensitivities, mean stress or stress ratio, manufacturing processes, surface treatments, residual stress, stress concentrations, load-binning effects, multi-axial loading, and fracture modes.

5.1.5.1 Safe life methodology. The safe life methodology shall either identify or define how to identify safe life substantiated structure. The methodology shall ensure that safe life substantiated safety of flight structure will not initiate damage, within the specified probability and confidence within its retirement interval, when subjected to operational loads of the specified design usage, including oscillatory loads. The methodology shall establish acceptable means[4] for verifying that stiffness, structural stability, dynamic behavior, load transfer, and functional performance characteristics remain within the design criteria, and that residual strength maintains ultimate load capability. The methodology shall incorporate use of inflight measurements in conjunction with the design usage spectrum as required in section 5.1.5. In accordance with section 5.1.5, the methodology shall describe the use of fatigue testing (coupon and full scale) to determine the fatigue characteristics for all critical, primary[5], structural load-carrying components to be assessed using safe life. The methodology shall describe techniques used to derive curve shapes (in terms of cycles to damage initiation versus strength or strain) for fatigue analysis or for interpretation of full-scale tests. It shall also describe how fatigue tests (coupon and full scale) determine fatigue characteristics of all assessed structural load-carrying components, including operating boundaries or working endurance limit. The methodology shall discuss methods used to determine distributions and associated coefficients of variation (COVs) for significant variables used in reliability assessments, such as strength, loads, and usage. The methodology shall describe fatigue analysis methods that meet the requirements of section 5.1.5, and describe how to ensure required residual strength and stiffness at component retirement.

5.1.5.2 Enhanced safe life methodology. The enhanced safe life methodology[6] shall either identify or define how to identify enhanced safe life substantiated structure. The methodology shall ensure that enhanced safe life substantiated safety of flight structure will not initiate new damage or begin growth out of existing damage that is within specified threshold levels, within the specified probability and confidence within its retirement interval, when subjected to operational loads of the specified design usage, including oscillatory loads. For existing damage within specified threshold levels, the methodology shall establish acceptable means for verifying that stiffness, structural stability, dynamic behavior, load transfer, and

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[3] See section 6.4.19 for guidance related to testing to failure.

[4] Note that section 6.4.10 provides guidance related to acceptable means in relation to fatigue damage initiation.

[5] Note that section 6.4.3 provides guidance related to including secondary structure in analysis and testing.

[6] Parallels between safe life and enhanced safe life result in many common elements between sections 5.1.5.1 and 5.1.5.2. However, the differences are very important. To avoid confusion, see guidance in section 6.4.9 and table II.

functional performance characteristics remain within the design criteria, and that residual strength maintains ultimate load capability. The methodology shall incorporate use of inflight measurements in conjunction with the design usage spectrum as required in section 5.1.5. The methodology shall incorporate specific existing damage threshold levels[7] required to maintain the stiffness and residual strength capability until retirement or reliable detection and repair of existing damage[8] within a specified confidence (using laboratory experiments or benchmarked data for visual inspections or using MIL-HDBK-1823 as a guide for any cases requiring use of NDI). The methodology shall include an impact damage threshold assessment in accordance with the material and structural allowables development of section 5.2.1, the threat assessment of section 5.2.5, and the guidance of sections 6.4.13 and 6.4.16. The methodology shall explain how to locate, identify, and size the probable locations, types, and sizes of damage used for each safety of flight structure damage threshold. The methodology shall require existing damage to be evaluated (via analysis and testing) at critical locations, sizes, and orientations, with consideration for the probability of damage during maintenance or service usage and for the probability of undetected damage during manufacturing. In accordance with section 5.1.5, the methodology shall describe the use of fatigue testing (coupon and full scale, with or without damage) to determine the fatigue characteristics for all critical, primary[9], structural load-carrying components to be assessed using enhanced safe life. The methodology shall describe techniques to derive curve shapes (in terms of cycles to damage initiation versus strength or strain) for fatigue analysis or for interpretation of full-scale tests. It shall also describe how fatigue tests (coupon and full scale, with or without damage) determine fatigue characteristics of all assessed structural load-carrying components, including operating boundaries or working endurance limit. The methodology shall discuss methods used to determine distributions and associated COVs for significant variables used in reliability assessments, such as strength, loads, and usage. The methodology shall describe fatigue analysis methods that meet the requirements of section 5.1.5, and describe how to ensure required residual strength and stiffness at component retirement, considering damage threshold levels.

5.1.5.3 Durability and damage tolerance methodologies. The durability and damage tolerance methodologies shall either identify or define how to identify durability and damage tolerance substantiated structure. The methodologies shall ensure that damage tolerant substantiated safety of flight structure will continue performing its intended function with specified probability and confidence within specified retirement or inspection intervals when subjected to operational loads of the specified design usage, including oscillatory loads. While damage remains below the threshold level, the methodologies shall establish acceptable means for verifying that stiffness, structural stability, dynamic behavior, load transfer, and functional performance characteristics remain within the design criteria; and that residual strength

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[7] For the enhanced safe life methodology, multiple damage threshold levels should be considered, including worst-case existing damage that is expected to remain on the structure for its operational life, worst-case detectable existing damage that does not require corrective action (such as repair or replacement), and worst-case detectable existing damage that requires corrective action.

[8] In contrast to the damage tolerance methodology, enhanced safe life damage thresholds do not correspond to detection of fatigue crack initiation or growth out of existing damage. When recurring inspections result from application of an enhanced safe life methodology, the intent of any required recurring inspections is to detect existing damage that requires corrective action to avoid fatigue crack initiation or growth prior to the applicable retirement interval or design service life.

[9] Note that section 6.4.3 provides guidance related to including secondary structure in analysis and testing.

maintains limit load capability. The methodologies shall incorporate use of inflight measurements in conjunction with the design usage spectrum as required in section 5.1.5. The methodologies shall incorporate specific damage threshold levels required to maintain the required stiffness and residual strength until reliable detection and repair within a specified confidence (using MIL-HDBK-1823 as a guide). Due to dependence on safety by inspection, the methodologies shall ensure that NDI meets requirements related to POD and confidence. The methodologies should require NAS410 Level 3 Inspector oversight for implementation of the section 5.1.7 NDI Plan, using TO 33B-1-1 / NAVAIR 01-1A-16-1 / TM 1-1500-335-23 as a guide. The methodologies shall include an impact damage threshold assessment in accordance with the material and structural allowables development of section 5.2.1, the threat assessment of section 5.2.5, and the guidance of sections 6.4.13 and 6.4.16. The methodologies shall explain how to locate, identify, and size damage used for each safety of flight structure damage threshold. The durability methodology shall include assessment of the potential for widespread fatigue damage, whether due to multiple-element damage or multiple-site damage, of safety of flight structure throughout the service life. The durability methodology shall be similar to the methodology of section 5.1.5.1 with the exception that one full-scale design service life test article shall be used for each section of structure tested. In accordance with section 5.1.5, the damage tolerance methodology shall describe how crack-growth tests (coupon and full scale) shall determine fracture-mechanics characteristics for all critical, primary[10], structural load-carrying components to be assessed using damage tolerance. The damage tolerance methodology shall describe techniques to derive crack-propagation-rate curves (such as da/dN versus stress intensity) for fracture-mechanics analysis or for interpretation of full-scale tests. The damage tolerance methodology shall discuss methods used to determine distributions and COVs for reliability assessments, such as crack-propagation-rate (or stress intensity), loads, usage, and damage detection during inspection. The damage tolerance methodology shall describe fracture-mechanics analysis methods that meet the requirements of section 5.1.5, and describe how to ensure required residual strength and stiffness with damage up to specified threshold levels.

5.1.6 Corrosion Prevention and Control. Corrosion Prevention and Control (CPC) shall be established for the rotorcraft structure, and the CPC Plan of section 5.1.6.1 shall define all tasks necessary to implement effective CPC measures throughout the entire lifecycle. The procuring government agency shall establish a CPC Team (CPCT) responsible for establishment and oversight of the execution of the specific controls. The CPCT shall be comprised of representatives from engineering, manufacturing, quality assurance, Nondestructive Inspection (NDI), maintenance, and stakeholders involved in the design, engineering development, production, structural certification, and fleet management of the rotorcraft structure relative to CPC. The CPCT shall evaluate design concepts, material, weight, performance, cost trade studies, relative to CPC early during the rotorcraft's design and provide recommendations to the procuring government agency for consideration. The CPCT shall evaluate selection of materials, processes, joining methods, finish systems, coating systems, and films used in the rotorcraft design. All CPCT members will be cognizant of all key components in finish and coating systems in order to ensure the proper CPC practices are established. CPC guidelines are provided in JSSG-2006, the DoD Corrosion Prevention and Control Planning Guidebook, MIL-STD-1568, and DFARS 207.105 procedures, guidance and information 207.105(b)(13)(ii). The

[10] Note that section 6.4.3 provides guidance related to including secondary structure in analysis and testing.

CPCT shall report unresolved CPC issues to the lead service's Corrosion Control and Prevention Executive and design control activity (MAA) for evaluation.

5.1.6.1 Corrosion Prevention and Control Plan. A Corrosion Prevention and Control Plan (CPCP) that is consistent with the design service life shall be developed by the CPCT and executed by the procuring government agency. The plan shall define all tasks necessary to implement effective CPC measures throughout the entire lifecycle, define the CPC requirements, list applicable specifications and standards, include the process and finish specifications, and address sustainability and logistics considerations. The CPCP shall be prepared in accordance with this standard, DoD Corrosion Prevention and Control Planning Guidebook, MIL-STD-1568, and JSSG-2006.

5.1.6.2 Evaluation of corrosion susceptibility. An evaluation of the susceptibility of the rotorcraft structure to corrosion shall be conducted by the CPCT. The evaluation shall identify locations where the structure might be susceptible to corrosion and the expected type(s) of corrosion (for example, galvanic, exfoliation, uniform, crevice, intergranular, and stress-corrosion cracking) that could occur at these locations. To identify potential corrosion damage locations, the evaluation shall account for the materials, manufacturing processes, corrosion prevention systems (for example, coatings and sealants), preventative maintenance approaches (for example, hangaring, wash cycles, wash fluids), the inspectability of the location, sustained and cyclic stress, and structural fabrication techniques as well as the expected operational environments to which the rotorcraft are subjected. The results of the evaluation shall be used to establish CPC requirements that are incorporated into the CPCP.

5.1.7 Nondestructive Inspection Plan. An NDI Plan shall be developed and executed in accordance with MIL-HDBK-6870. The NDI plan shall establish the NDI requirements for the rotorcraft structure and all tasks necessary to ensure compliance with the durability, fatigue, and fracture criteria of section 5.1.3.5 and the fatigue and fracture methodologies of section 5.1.5. The procuring government agency shall establish an NDI Team (NDIT) with authority and responsibility to evaluate and implement appropriate NDI processes into all phases of the rotorcraft program. The NDIT shall be comprised of representatives from engineering, manufacturing, NDI, quality assurance, maintenance, and stakeholders involved in the design, engineering development, production, structural certification, and fleet management of the rotorcraft structure in cases where RSIP uses NDI to ensure structural integrity of a PSE. The NDIT shall determine reliability of detecting damage at the threshold size established through the analysis and testing for damage tolerance structure and enhanced safe life structure. The NDIT shall establish POD and associated confidence based on damage location, type, and size, using MIL-HDBK-1823 as a guide. To ensure that NDI meets requirements related to POD and confidence essential to safety by inspection, the NDI Plan shall meet the requirements of the durability and damage tolerance methodologies related to NAS410 Level 3 Inspector oversight for all inspections supporting the section 5.1.5.3 durability and damage tolerance methodologies, using TO 33B-1-1 / NAVAIR 01-1A-16-1 / TM 1-1500-335-23 as a guide. The NDI Plan shall be in accordance with TO 33B-1-2 / NAVAIR 01-1A-16-2 / TM 1-1500-366-23 regarding assessing the suitability of NDI procedure application and supplemental instructions. The capability of NDI processes used for production process monitoring and quality control of structural components shall be established to mitigate risk of missing intrinsic anomalies (such as flaws or defects) and other damage consistent with threshold levels defined in the durability, fatigue, and fracture criteria, methodologies, and related requirements. Special emphasis shall be given to PSEs. Capability demonstration of production NDI processes shall be performed as determined by the NDIT. The NDIT shall report unresolved NDI issues to the lead service's design control activity (MAA) for evaluation.

5.1.8 Condition Based Maintenance Management Plan. A Condition Based Maintenance (CBM) Management Plan shall be developed following the guidance in ADS-79-HDBK. The plan shall include details related to any plans to use CBM in a manner which potentially impacts or enhances structural integrity of the rotorcraft. Specifically, any plans for implementation of a structural usage monitoring system for fatigue life management via structural usage monitoring, loads monitoring and estimation, individual component fatigue damage tracking , or usage spectrum updates shall be incorporated into the CBM Management Plan. Similarly, the CBM Management Plan shall incorporate any plans for use of structural health monitoring via integrated NDI.

5.1.9 Selection of materials, processes, joining methods, and structural concepts. Materials, processes, joining methods, and structural concepts shall be selected to result in a structurally efficient rotorcraft design that meets the strength, rigidity, fatigue, damage tolerance, durability, environmental, observability, energy absorption, and other requirements of the applicable specifications. Trade studies may include selection of new materials, processes, joining methods, and structural concepts, such as those with low readiness levels or without service history in certified production rotorcraft applications. However, prior to a commitment to new materials, processes, joining methods, and structural concepts, an evaluation of manufacturing stability, producibility, characterization of mechanical and physical material properties, the predictability of structural performance, and supportability shall be performed with input from the CPCT, NDIT, MAA, and rotorcraft structural integrity experts (such as senior technical personnel with fatigue and fracture expertise). The risk associated with the selection of the new materials, processes, joining methods, or structural concepts shall be estimated and risk mitigation actions defined. Suitability for integration of design details related to durability, fatigue, and fracture criteria shall be a major consideration in the final selection of materials, processes, joining methods, and structural concepts. The detailed rationale for the individual selections and any proposed risk mitigation actions shall be documented at initial contract award (such as during the Technology Maturation and Risk Reduction phase for a milestone A entry, as defined and established by DOD Instruction 5000.02). The structural description, each selection rationale, trade studies, and all supporting data shall become part of the design database during the design of the rotorcraft. Risk mitigation actions shall be defined and implemented in the rotorcraft program based on an estimate of the level of risk associated with the selection of the new materials, processes, joining methods, and structural concepts. The specific actions required will depend on the classification of the structural component, the design concept, and the estimated risk level. The CPCT, NDIT, and rotorcraft structural integrity experts providing technical input to the risk assessment process shall report unresolved risk mitigation actions to the lead service's design control activity (MAA) for evaluation.

5.1.9.1 Manufacturing stability. Repeatability, quality, and maturity of materials, processes, joining methods and structural concepts shall be evaluated, and the variability of structural properties shall be identified. Technology readiness level and manufacturing readiness level shall be identified and assessed in accordance with DoD Instruction 5000.02. MIL-HDBK-896 may be used as a guide for manufacturing readiness. Process parameters and methods shall be established and controlled via specifications, standards, and manufacturing instructions.

5.1.9.2 Producibility. Production feasibility shall be evaluated. Quality control shall be enabled through the identification of appropriate process control measures to be employed during the manufacture of the rotorcraft structure. Selection shall consider inspectability during the manufacturing process.

5.1.9.3 Characterization of mechanical and physical material properties. Suitability and availability of mechanical and physical properties shall be evaluated. Considerations shall include characterization of the set of key properties in the operational environment and in the as-fabricated condition using the selected manufacturing processes and joining methods. Key mechanical properties include but are not limited to strength, elongation, fracture toughness, damage growth rates, fatigue, stress corrosion, and damage initiation and growth thresholds. Key physical properties include but are not limited to density, corrosion resistance, population of intrinsic anomalies (flaws, defects, or any other intrinsic damage during manufacturing), surface reflectivity, thermal stability, coefficient of thermal expansion, fire resistance, fluid resistance, and surface roughness.

5.1.9.4 Predictability of structural performance. Analytical capabilities for predicting full-scale test structural performance shall be evaluated. For new materials, processes, joining methods, or structural concepts, existing subcomponent test data shall be provided which demonstrates that valid analytical or empirical methods are available to predict critical failure modes, damage initiation, and damage growth in the structure.

5.1.9.5 Supportability. Maintainability, inspectability, and repairability shall be evaluated. As a minimum, legacy experience and health/environmental regulations shall be considered. The selection of preventive and repair methods (such as corrosion preventive coatings, mechanically fastened repair, bonded repair, advanced composite repair, field welding and stress relief, grinding, shot peening) shall consider the potential for repeated use on individual rotorcraft. Suitability and accessibility shall be evaluated to enable evaluation of the structure for quality and integrity. This evaluation shall be in coordination with the CPCT and the NDIT.

5.2 Design analysis and developmental testing (Task II). The design analysis and developmental testing task includes the detailed characterization of the design usage and operational environments, the development of the design through testing of materials, components, and assemblies, and the analysis of the rotorcraft design. The design analysis and developmental testing task is intended to (1) determine the design usage and operational environments based on section 5.1.2; (2) perform design analyses and developmental tests based on these environments; and (3) substantiate ability of the rotorcraft design to meet structural integrity requirements prior to section 5.3 full-scale test verification. When necessary to ensure structural integrity in support of section 5.4.1, validation of analysis methods, models, and procedures and verification of software implementation of them shall require approval by the procuring government agency and the service design control activity (MAA). Analysis procedures, test plans, test procedures, and schedules shall be approved by the procuring government agency. This task shall include aspects of the building block approach for testing, using CMH-17 as a guide.

5.2.1 Material and structural allowables development. Material and structural (for example, joints) allowables data that are not certified via Metallic Materials Properties Development and Standardization (MMPDS), Composite Materials Handbook (CMH-17), Damage Tolerant Design Handbook (WL-TR-94-4052/3/4/5/6), Aerospace Structural Metals Handbook, or Structural Alloys Handbook (provided required equivalency testing meets requirements) shall be required to demonstrate material properties that meet the intended usage and operational environment. Considerations include, but are not limited to, sources for existing design allowables, test methods used to develop design allowables, processes used to manufacture test coupons, environmental and operational effects on material properties (including stress corrosion cracking), how test results will be used to develop the design allowables, effects of impact damage and other barely visible damage, and data and analyses to substantiate compliance with applicable design requirements. ADS-13-HDBK, MMPDS, and CMH-17 may be used as guidance. Experimental programs to obtain the data and generate analysis test data shall be formulated and performed for new materials and those existing materials for which there are insufficient data available. Use of a building block approach should be considered, where appropriate, in accordance with CMH-17. The variability in material properties shall be considered when material and structural allowables are established. Development of material and structural allowables shall include fatigue curve shapes and fracture mechanics characteristics, as well as associated COVs required to implement the fatigue and fracture methodologies of section 5.1.5.

5.2.2 Loads analysis. Loads analysis[11] shall determine the magnitude and distribution of static and dynamic loads encountered by rotorcraft structure when operating within the structural design envelope established by the structural design criteria. This analysis consists of a determination of the flight loads, ground and handling loads (including tie-down, air and ground transport, and shipboard interface loads), powerplant loads, control system loads, pressurization loads, acoustic loads, weapons firing effects, and flare and chaff firing effects. When applicable, this analysis shall include the effects of temperature, aeroelasticity, and dynamic response of the rotorcraft structure. Validation of loads analysis tools is required prior to use of the tools to ensure structural integrity per section 5.4.1. Interpolation of normalized historical structural flight test loads for a comparable rotorcraft configuration may be used for this validation as well as any method in accordance with a DoD adopted or MAA approved standard practice. As part of the section 5.4.1 updated structural analyses, loads analysis shall be validated, modified, supplemented, or replaced with section 5.3.10.1 flight loads survey data per the section 5.1.5 methodologies. For analysis of foreign object debris impact loads such as due to shedding ice from the rotors or bird strike, see section 5.2.5. For crash loads analysis (including ditching and

[11] In this standard practice, loads analysis denotes analysis of external or applied loads, including interface loads at joints in single load path components of the rotor and control mechanism. For analysis of the resulting internal loads in rotorcraft structure, see section 5.2.6.

water impact loads), see section 5.2.16.1.

5.2.3 Design loads spectra. The design loads spectra shall fully encompass operational usage and establish the spectrum of loads for each rotorcraft structure load path to support fatigue analysis and component design. The loads shall be in accordance with the design usage of the rotorcraft throughout the design service life. Loads shall be adjusted for reliability and confidence in accordance with the methodologies of section 5.1.5. Loads analysis, and appropriate legacy flight test loads (normalized to maximum steady state oscillatory loads for similar rotorcraft/component configurations) for each load path are applied to the design usage from section 5.1.2. Results from updated contractor efforts, such as analysis of pilot interview data and analysis of validated CBM regime recognition and loads monitoring data, may be used to propose refinements to the design loads spectra and the design usage from section 5.1.2. As part of the section 5.4.1 updated structural analyses, the design loads spectra shall be updated with section 5.3.10.1 flight loads survey data, which validates, modifies, supplements, or replaces loads analysis data per the section 5.1.5 methodologies.

5.2.4 Design usage environment spectra. Design usage environment spectra (natural or induced, such as, temperature, altitude, precipitation, humidity, chemical, abrasive, vibratory, and corrosive) shall be developed to establish such characteristics as the intensity, duration, and frequency of occurrence, of the environment which the rotorcraft structure will experience based on the design service life and usage in accordance with section 5.1.2, including criteria derived from climatic data in MIL-HDBK-310. With appropriate justification and with documentation in the structural design criteria from section 5.1.3, the RSIP Master Plan may incorporate a legacy approach of using environmental extremes or refinements to the design usage from section 5.1.2 may be proposed by the contractor.

5.2.5 Threat assessment. An assessment shall be performed to identify potential damaging threats that the rotorcraft could be exposed to throughout its design service life. Threats considered shall include fatigue, environmental effects (such as erosion, corrosion, hail, and lightning), intrinsic and discrete anomalies (such as flaws or defects), impact or other accidental damage (such as bird strikes, dropped tools, or contact with foreign object debris), operational threats (such as hard landings, weapons effects), and hostile threats.

5.2.6 Static structural analysis. Static structural analysis[12] supported by test data shall be used to substantiate that sufficient static strength is provided to react all design loading conditions without yielding, detrimental deformations and detrimental damage at design limit loads and without structural failure at design ultimate loads. The static structural analysis shall be conducted in accordance with sections 5.1.3, 5.2.1, and 5.2.16.1 and shall substantiate that sufficient static strength exists for operations, maintenance functions, and system failures from which recovery is expected. The static structural analysis shall include the analytical determination of internal loads and margins of safety for critical failure modes, including deformation calculations when deflections or thermal deformations affect the failure mode. Internal loads and margins of safety calculations shall include consideration of structural

[12] In this standard practice, static structural analysis corresponds to internal loads and static strength analysis, which includes detailed stress analysis. For purposes of comparing this standard practice with MIL-STD-1530, the static structural analysis section in this standard practice compares with MIL-STD-1530 stress and strength analysis.

instability. For cases where crash loads drive the lowest margin, a margin shall also be calculated for operational loads (specifically, other than crash[13]). Special factors, such as but not limited to casting factors, bearing factors, fitting factors, control system joint factors shall be used on applicable structure and their origin referenced. Stress analysis methods shall include application of classic structural methods, finite element modeling techniques, or both, as appropriate. In addition to assessing the design for strength, the stress analysis shall be sufficient to support the selection of critical structural components for design development tests, execution of material review actions, and selection of loading conditions used in structural testing. Analysis load cases shall also include structural test representative cases when stress and deflection due to applied test loads and constraints would exceed more realistic analysis representations of operational loads. Static testing in accordance with section 5.3.1 shall validate, correlate, or correct the analysis results and shall verify that the rotorcraft structure meets performance requirements for static loads.

5.2.7 Damage tolerance analysis. Damage tolerance analysis supported by test data shall be used to substantiate that specified rotorcraft structure meets damage tolerance requirements, with consideration of threats identified in the threat assessment per section 5.2.5. When a damage tolerance analysis is conducted on the basis of slow damage growth, the analysis shall establish the critical damage size and the associated growth period during which the element or component maintains required stiffness and residual strength to support limit load. When a damage tolerance analysis is conducted on the basis of multiple load path structure with fail-safe elements, dependent load paths shall each be analyzed for concurrent fatigue damage (considering damage initiation and growth). In either case, damage tolerance analysis shall clearly state any limits of validity due to potential widespread fatigue damage, whether due to multiple-element damage or multiple-site damage. Damage tolerance analysis shall use the durability, fatigue, and fracture criteria, durability and damage tolerance methodologies, design allowables, and design loads spectra, as established in accordance with sections 5.1.3.5, 5.1.5.3, 5.2.1, and 5.2.3, to conduct damage growth, stiffness, and residual strength analyses, with an applicable coupon or building block test basis. When determining damage growth rates, high cyclic loads including those present in steady-state flight conditions shall be considered in both analyses and tests. Truncation[14] of the design loads spectra used for damage tolerance analysis shall require substantiation that the truncated spectra and full design loads spectra produce equivalent damage growth rates in the analysis (after compensating per the methodology for any reduction in damage growth rates due to truncation). Substantiation of equivalent damage growth rates for truncated loads spectra shall be submitted for approval by the procuring government agency and the service design control activity (MAA). Damage tolerance testing in accordance with section 5.3.2 shall validate, correlate, or correct the analysis results and shall verify that inspection intervals ensure structural integrity in the specified damage tolerant structure.

5.2.8 Safe life analysis. A safe life analysis supported by test data shall be used to substantiate that specified rotorcraft structure meets safe life requirements. The analysis shall include a comparison of predicted stress to operational boundaries (or working endurance limit), with separate indication of stress levels for transient maneuvers and sustained steady state

[13] See also guidance of section 6.4.15.
[14] In this standard practice, *truncation* denotes reducing or eliminating low-amplitude cycles in a spectrum.

conditions. The analysis shall use the durability, fatigue, and fracture criteria, safe life methodology, design allowables, and design loads spectra, as established in accordance with sections 5.1.3.5, 5.1.5.1, 5.2.1, and 5.2.3, to conduct a stress-life or strain-life damage initiation fatigue assessment. Truncation of the design loads spectra used in the safe life analysis requires substantiation that the truncated spectra and full design loads spectra produce equivalent results (after compensating per the methodology for any reduction in damage growth rates due to truncation). For truncation of any loads above 50% of the operational boundaries (or working endurance limit), substantiation of equivalent results shall be submitted for review and approval by the procuring government agency and the service design control activity (MAA). Safe life testing in accordance with section 5.3.3 shall validate, correlate, or correct the analysis results and shall verify that component retirement intervals ensure structural integrity in the specified safe life structure.

5.2.9 Enhanced safe life analysis. Enhanced safe life analysis supported by test data shall be used to substantiate that specified rotorcraft structure meets enhanced safe life requirements, with consideration of threats identified in the threat assessment per section 5.2.5. The analysis shall evaluate the structure for damage at critical locations, sizes, and orientations, with consideration for the probability of damage during maintenance or service usage and for the probability of undetected damage during manufacturing. The analysis shall include a comparison of predicted stress to operational boundaries (or working endurance limit), with separate indication of stress levels for transient maneuvers and sustained steady state conditions. The analysis shall use the durability, fatigue, and fracture criteria, enhanced safe life methodology, design allowables, and design loads spectra, in accordance with sections 5.1.3.5, 5.1.5.2, 5.2.1, and 5.2.3, to conduct a stress-life or strain-life damage initiation fatigue assessment and to evaluate required stiffness and residual strength to support ultimate load in the presence of damage, including intrinsic anomalies (such as flaws or defects) per section 5.1.9 (see also section 5.2.17) and the threat assessment per section 5.2.5. Truncation of the design loads spectra used in the enhanced safe life analysis requires substantiation that the truncated spectra and full design loads spectra produce equivalent results (after compensating per the methodology for any reduction in damage growth rates due to truncation). For truncation of any loads above 50% of the operational boundaries (or working endurance limit), substantiation of equivalent results shall be submitted for review and approval by the procuring government agency and the service design control activity (MAA). Enhanced safe life testing in accordance with section 5.3.4 shall validate, correlate, or correct the analysis results and shall verify that component retirement intervals ensure structural integrity in the specified enhanced safe life structure.

5.2.10 Design service life analysis. A design service life analysis[15] supported by test data shall be used to substantiate that specified rotorcraft structure meets design service life requirements. The design service life analysis shall also substantiate that the probability of catastrophic fatigue failure is within specified probability and confidence thresholds without establishing replacement times, inspection intervals or other procedures under section 5.4.3. The analysis shall include a comparison of predicted stress to operational boundaries (or working endurance limit), with separate indication of stress levels for transient maneuvers and sustained

[15] For purposes of comparing this standard practice with MIL-STD-1530, the design service life analysis/test sections in this standard practice compare with MIL-STD-1530 durability analysis/test.

steady state conditions. The analysis shall use the durability, fatigue, and fracture criteria, durability methodology, design allowables, and design loads spectra, as established in accordance with sections 5.1.3.5, 5.1.5, 5.2.1, and 5.2.3. Truncation of the design loads spectra used in the design service life analysis requires substantiation that the truncated spectra and full design loads spectra produce equivalent results (after compensating per the methodology for any reduction in damage growth rates due to truncation). For truncation of any loads above 50% of the operational boundaries (or working endurance limit), substantiation of equivalent results for truncated loads spectra shall be submitted for review and approval by the procuring government agency and the service design control activity (MAA). The analysis should consider specified and potential threats identified in section 5.2.5. The analysis shall forecast the onset of widespread fatigue damage, including consideration of initial quality and initial quality variations, chemical and thermal environment, load sequence and environment interaction effects, material property variations, and analytical uncertainties. Design service life testing in accordance with section 5.3.5 shall validate, correlate, or correct the analysis results and shall verify that the design service life ensures structural integrity in the specified rotorcraft structure.

5.2.11 Mechanical endurance assessment. A mechanical endurance assessment shall be conducted to evaluate the ability of the rotorcraft structure to achieve the applicable retirement interval or design service life allowing for wear and degradation of components. The assessment shall identify wear and degradation susceptible components, anticipated wear and degradation severity, types of wear and degradation expected, and the structural integrity consequences associated with wear and degradation damage in each component. The mechanical endurance assessment shall assess the control measures (such as design criteria or maintenance) planned for each wear and degradation susceptible component, as required in accordance with the engineering tolerance criteria of section 5.1.3.6, including consideration of thermal and environmental effects. Special attention should be given to those safety-of-flight and mission-critical rotorcraft structural components where wear and degradation could invalidate loads and structural analyses or otherwise accelerate the time to fatigue crack development, including in adjacent components. Examples of particular areas of concern for wear and degradation include articulated rotor hinge flapping, feathering, or lead-lag joints; flight control mechanism rod ends; and any elastomeric mounts, dampers, or bearings. Component endurance bench testing in accordance with section 5.3.6 and mechanical endurance surveillance in accordance with section 5.3.13 shall combine to validate, correlate, or correct the assessment results and shall verify that specified design criteria, inspections, and the applicable retirement interval or design service life combine to ensure structural integrity in the rotorcraft structure.

5.2.12 Corrosion assessment. A corrosion assessment shall be conducted to evaluate the ability of the rotorcraft structure to achieve the design service life. The assessment shall identify corrosion susceptible locations, anticipated corrosion damage severity, types of corrosion damage expected, and the structural integrity consequences associated with corrosion damage in each location. The corrosion assessment shall assess the corrosion prevention and control measures for each corrosion susceptible location in accordance with section 5.1.6. Special attention should be given to those safety-of-flight and mission-critical rotorcraft structural locations where corrosion damage could accelerate the time to fatigue crack development, the susceptibility to stress corrosion cracking, and the onset of widespread fatigue damage, whether due to multiple-element (fatigue) damage or multiple-site (fatigue) damage.

5.2.13 Aeroelastic and aeroservoelastic analysis. Analysis shall be conducted[16] to determine the susceptibility of the rotorcraft for flutter, divergence, dynamic instability (including aeroelastic and mechanical instability), air resonance, ground resonance, whirl flutter, and other related aeroelastic, aeroservoelastic, or rotor instabilities. The primary objective of the analysis is to evaluate potential aeroelastic, aeroservoelastic, and rotor instabilities (including air resonance, ground resonance, and whirl mode instabilities) and substantiate the capability of the rotorcraft structure to meet the specified aeroelastic airspeed margins, damping requirements, and aeroservoelastic stability margins for all design and operational conditions. Analysis for design failure conditions shall also be conducted.

5.2.13.1 Blade stall and compressibility analysis. A blade stall and compressibility analysis shall be conducted to identify any and all flight conditions within the structural design envelope per section 5.1.3.1 for which the rotor components, and other components in the same load path, are expected to experience an increase in vibratory loads due to the onset of rotor retreating blade stall or advancing blade compressibility. Because retreating blade stall is directly related to airspeed, rotor speed and rotorcraft gross weight the rotorcraft airspeed limitations shall be defined for the authorized range of gross weights, density altitudes, center of gravity locations, and external store configurations such that deleterious oscillatory loads[17] due to retreating blade stall and advancing blade compressibility are avoided in sustained steady state maneuvers such as level flight or other specified steady-state conditions, such as those producing a load factor less than 1.25g. The maximum steady state oscillatory loads shall be such that the probability that damage will accrue in any rotorcraft structure during these conditions is below the threshold corresponding to required reliability and confidence in accordance with in section 5.1.2. Parametric rotor load models, comprehensive rotor analysis based on wind tunnel testing, or comprehensive rotor analysis coupled with a computational fluid dynamics analysis may be used as appropriate, however, the accuracy of any predictive analysis shall be validated or corrected with comparisons to wind tunnel testing of the rotor or normalized legacy flight test data for similar configurations.

5.2.14 Vibration analysis. A vibration analysis shall be conducted to predict the resultant environment in terms of vibration levels in various areas of the rotorcraft such as the fuselage, tailboom or tailcone, empennage, rotors, crew compartment, cargo areas, engine mounts, and equipment bays. The vibration analyses shall show that the structure in each of these areas is resistant to cracking due to vibratory loads throughout the design service life in accordance with ADS-27-SP. In addition, the analyses shall assess modal responses and show that the vibration levels are in accordance with the rotorcraft system specification regarding occupied areas (for crew proficiency and health) and equipment installations (for equipment life, performance, and maintenance).

5.2.14.1 Sonic fatigue analysis. A sonic fatigue analysis shall be conducted to ensure the rotorcraft structure is resistant to sonic fatigue cracking throughout the design service life. The analysis shall define the intensity of the aeroacoustic environment from potentially critical sources and shall determine the dynamic response.

[16] See ADS-51-HDBK for guidance related to evaluating and avoiding potential aeroelastic, aeroservoelastic, and rotor instabilities in rotorcraft.
[17] See section 6.4.12.2 for guidance related to recognizing *deleterious oscillatory loads*.

5.2.15 Mass properties analysis. A mass properties analysis shall be conducted to substantiate the rotorcraft structural weight and balance requirements are achieved in accordance with section 5.1.3.7 mass properties criteria. This analysis shall be based on estimates of the rotorcraft's design, construction, and usage. In addition, a Mass Properties Control and Management Plan shall be established and implemented throughout the life of the rotorcraft. Detailed guidance may be found in the Society of Allied Weight Engineers Recommended Practice Number 7 (SAWE RP No. 7).

5.2.16 Survivability analysis. A survivability analysis shall be conducted to ensure the rotorcraft structure can maintain required performance in an operational environment.

5.2.16.1 Crashworthiness analysis. A crashworthiness analysis shall be conducted based on crashworthiness criteria in accordance with section 5.1.3.9. The crashworthiness analysis shall include crash loads analysis to be used in the static structural analysis from section 5.2.6 (including analysis of ditching and water impact loads). Analyses of cabin occupied volume, crew stations, crew seats, landing gears and retention of high mass items such as the rotors, engines and transmissions shall be conducted to substantiate the crashworthiness capability.

5.2.16.2 Vulnerability analysis. A vulnerability analysis shall be conducted to verify that the rotorcraft structure can maintain required performance after exposure to the specified and potential threats identified in section 5.2.5.

5.2.16.3 Weapons effects analysis. A weapons effects analysis shall be conducted to ensure the rotorcraft structure can withstand the loads due to weapons captive-carriage/jettison loads and firing effects such as launch and hangfire loads, recoil, thermal transients, blast effects, exhaust products/debris, and any lack of weapon clearances in accordance with MIL-STD-1289. Consideration of exhaust products/debris shall include the potential for impact damage to the rotorcraft structure and rotor system oscillatory loads due to potential ingestion of the weapons exhaust plume by the engine.

5.2.17 Design development tests. Design development tests shall be conducted to establish design allowables related to selected materials, processes, joining methods, and structural concepts; develop, validate, and correct analysis methods and procedures; obtain early evaluation of allowable stress levels, material selection, joining methods, and the effect of the design usage environment spectra of section 5.2.4; establish aeroelastic and loads characteristics through wind tunnel tests; obtain early evaluation of the corrosion resistance, strength, durability, fatigue, and damage tolerance capabilities of Safety of Flight structural components and assemblies subjected to damage in accordance with the section 5.2.5 threat assessment and associated damage thresholds; and provide any other test data necessary for design or risk-reduction prior to full-scale testing. Examples of design development test specimens are coupons; elements such as splices, joints, and fittings; subcomponents such as skin and stringer panels, frames, beams, skin panels, and sandwich panels; and components such as blades, control system components, structural operating mechanisms. Examples of establishing design allowables include establishment of life improvement factors or knock-down factors for selected processes, establishment of high resistance to stress corrosion cracking for selected materials in the operational environment, and establishment of structural element elastic buckling allowables for panels with penetrations, sandwich structure, laminated composite panels, or panels with bonded stiffeners (see also guidance in section 6.4.16). Sequencing of the design development tests should follow the building block approach, using AC 29-2C and CMH-17 as a guide. The test plans shall include rationale for selection of tests and impact if not conducted, description of test articles, test procedures, test loads and test duration, test data capture requirements, NDI, structural health monitoring, and test cost and schedule. Consideration shall be given to factors such as specimen complexity, load orientation and frequency, duration, environmental conditions, sample size for required reliability and confidence, and consistency with known test standards or data sets to ensure that the test objectives are achieved. The test program shall include sufficient testing to characterize the effects of material, processing, and manufacturing variability, and the resultant impacts to mechanical properties. Tests shall be performed to determine critical sizes, locations and effects of manufacturing and in-service damage and evaluate confidence in production NDI, field NDI, and structural health monitoring capabilities to detect and monitor damage. Repair development and verification shall also be part of the test program. The following subsections provide important details related to specific types of design development tests. However, these topics do not represent an exhaustive list of the various types of materials, processes, joining methods, structural concepts, or design development tests related to RSIP.

5.2.17.1 <u>Design development tests of composite structures</u>. A building block approach shall be used for design development testing of structural designs that incorporate bonded joints or assemblies or are manufactured from composite materials, or both, using AC 29-2C and CMH-17 as a guide. For example, testing shall generate bearing-bypass design allowables, bearing design allowables and crippling design allowables. The building block test program shall include sufficient testing to characterize the effects of material, processing, and manufacturing variability, and the resultant impacts to mechanical properties. Testing shall incorporate the design loads and environment to determine all potential failure modes, effects of repeated loading and environmental exposure on failure modes, and condition compensated allowables that account for effects of repeated loading and environmental exposure that are representative of design usage as required by full-scale static test methods selected from section 5.3.1.1. Building block tests shall also be performed to determine critical sizes, locations and effects of manufacturing and in-service damage and evaluate confidence in production NDI, field NDI, and structural health monitoring capabilities to detect and monitor damage. Repair development and verification shall also be a part of the building block test program. Appropriately sized sub-components and components shall be tested to both fatigue loads and design ultimate load, while strain measurements shall be obtained and compared to analysis predictions using the material allowables associated with the test conditions for all critical locations, including effects of repeated loading and environmental exposure that are representative of design usage. If acceptable analysis correlation is not obtained, additional analysis method development and testing shall be performed until satisfactory analysis correlation is achieved. For any tests in the building block test program, any changes in failure modes between ambient-air test conditions and test article conditions that account for effects of repeated loading and environmental exposure shall be accounted for in full-scale structural tests (specifically any tests per sections 5.3.1, 5.3.2, 5.3.3, 5.3.4, or 5.3.5 that would be potentially impacted by the failure modes) unless the testing is performed in the design environment (including temperature and moisture).

5.2.17.2 Durability tests. Durability tests shall be conducted to evaluate the ability of the structure to resist damage initiation and propagation for the design service life. Damage sources shall be in accordance with the section 5.2.5 threat assessment. Durability tests shall include thermal cycling to characterize effects on mechanical properties for structure vulnerable to thermal cycling (including, as examples, application of structural adhesives or composites with operational temperatures ranging near glass transition, or application of elastomeric components with extremely hot or cold operating temperatures). Regarding hostile threats, resultant damage from a variety of shot angles, round orientations, over pressure of enclosed volumes, and hydrodynamic ram effects on surrounding support structure should be evaluated for impact on structural integrity. Testing shall account for the operational environment or conditions where the potentially damaging threat is expected to be encountered. Testing shall be performed on coupons and representative structural elements and shall be accomplished by repeatedly subjecting test articles to identified threats, as well as application of the design loads spectra from section 5.2.3. The duration of durability tests shall be sufficient to determine an initial estimate of the onset of widespread fatigue damage and to establish the distribution of intrinsic anomalies (such as flaws or defects). Testing shall also be used to establish damage threshold levels for a damage tolerant or enhanced safe life structure.

5.2.17.3 Corrosion tests. Corrosion testing shall be conducted to evaluate the effectiveness of the corrosion protection system to meet design service life requirements for the defined service environments and for the materials and processes, structural designs, and joining methods utilized in the structural design. Comparative tests shall be conducted on representative structure (including fasteners and full material stack-ups) and similar legacy rotorcraft (or other aircraft) protection systems to evaluate corrosion protection system alternatives. The test results shall be used to establish CPC requirements in the CPCP.

5.2.18 Aviation critical safety item and critical characteristic determination/classification. The cognizant military service design control activity (that is, the MAA and engineering support activity) is responsible for criticality determinations. Prime contractors, original equipment manufacturers, or other parties may provide recommendations regarding criticality determinations but the cognizant design control activity is responsible for the official determination. Failure consequence is the primary factor in determining an item's criticality. A Failure Modes, Effects, and Criticality Analysis (FMECA) should be conducted to identify failure modes and consequences. JACG Aviation Critical Safety Item Management Handbook and SECNAVINST 4140.2 (DA Pam 95-9) may be used for guidance.

5.2.19 Develop structural usage monitoring algorithms. Structural usage monitoring algorithms shall be developed to enable CBM regime recognition and loads monitoring and estimation in accordance with the guidance of ADS-79-HDBK, appendices A, B, and C. The algorithms shall subsequently be validated using flight testing, as discussed in section 5.3.10.3 and section 5.4.3.5. The algorithms shall be designed to monitor usage and loads in accordance with the CBM Management Plan such that the design component retirement intervals and associated levels of reliability for structural components are maintained.

5.2.20 Initial risk analysis. An initial risk analysis shall be performed to identify risks associated with achieving and maintaining structural integrity. This analysis shall consider, at a minimum, rotorcraft structural life assessments based on durability, fatigue, and fracture criteria, damage tolerance analysis, safe life analysis, enhanced safe life analysis, design service life analysis, and testing planned for implementation in section 5.3 subsections. The initial risk analysis shall be in accordance with MIL-STD-882 with appropriate modifications to adhere to the applicable rotorcraft System Safety Management Plan, such as definition of the consequence categories, hazard probability, and associated levels of risk. The initial risk analysis shall be reassessed and updated based on full-scale test results, updated design analysis, or upon implementation or update of the structural integrity maintenance plan. In cases where the minimum design service life, minimum design component retirement intervals, or required reliability (section 5.1.2) are not met by the design, the risk is above the development baseline by definition. In such cases, alternatives shall be implemented to (1) seek approval to change the rotorcraft system specification for life or reliability, or both; (2) consider design changes to achieve the rotorcraft system specification requirement; or (3) seek risk acceptance in accordance with the rotorcraft System Safety Management Plan and applicable regulations and policies for the procuring government agency.

5.3 Full-scale testing (Task III). The full-scale testing task consists of flight and laboratory tests of the rotorcraft structure to verify that the design meets structural integrity requirements. Test plans, instrumentation, procedures, and schedules shall be approved by the procuring government agency. Test results shall be used to validate, correlate, or correct analytical design data and to verify requirements are achieved.

5.3.1 Static tests. The static tests shall validate, correlate, or correct the static structural analysis results in section 5.2.6 and shall verify that the rotorcraft structure meets performance requirements for static loads, including design limit and ultimate loads. The static test program shall be conducted on an instrumented rotorcraft using applied test loads and constraints that represent and envelope all critical loading conditions. For cases where crash loads represent the critical loading condition, a set of loads shall also be derived for operational loads (specifically, other than crash[18]) and tested to ultimate loads prior to testing cases with crash loads. Based on the results of design development tests in section 5.2.17, thermal environment effects shall be simulated in addition to the load application. When practical, static testing shall continue[19] at increased load levels required to establish a strength margin beyond current design ultimate loads for future vehicle growth, but only after first demonstrating the required performance. The static test program shall include static test article(s) representing all primary structure, including fuselage, tailboom or tailcone, empennage, wings, stabilizers, stabilators, sponsons, landing gear, interfaces and provisions, as well as rotor components, rotating and non-rotating rotor control mechanism components, propellers, proprotors, and any transmission and drive-systems components that experience flight-maneuver loads, control-surface induced loads, or loads imparted by fuselage, tailboom or tailcone, empennage, or flight-control mounts. The static test program shall validate or correct predicted load paths, stresses, and strains and identify any structural design details requiring redesign to alleviate and prevent future structural safety or maintenance difficulties. Any unique static test requirements for metallic structure, composite

[18] See also guidance of section 6.4.15.
[19] See section 6.4.19 for guidance related to testing to failure.

fiber-dominated stable structure (linear response), composite post-buckled structure (non-linear response with mixed fiber and resin modes) and thick composite structure (resin dominated modes) shall be determined and performed. If it is shown (for minor modifications) that the rotorcraft structure and its loading are essentially the same as that of a previous rotorcraft structure which was verified by full-scale tests, full-scale static tests may also be waived by the procuring government agency. However, major changes result from changes in configuration, such as major repairs, extensive reworks and refurbishments, and component modifications which alter the structural load paths, or which represent significant changes in structural concept. Major changes may also result from changes rotorcraft usage or performance, as characterized by design usage, structural design envelope, loads analysis, design loads spectra, and design usage environment spectra (per sections 5.1.2, 5.1.3.1, and 5.2.2 through 5.2.4). Major changes shall generally require a static ultimate load test of the affected rotorcraft structure. See section 5.3.7 for common structural test requirements applicable to this section.

5.3.1.1 Static tests of composite structures. Subject to approval by the procuring government agency, one of the following methods shall be applied to the static tests of structural designs that incorporate bonded joints or assemblies, are manufactured from composite materials, or both. With approval of the MAA and with application of correlated analytical methods from section 5.2.17.1, the static test program may combine two or more of these methods to account for effects of temperature and humidity separately.

5.3.1.1.1 Test at design environment to design loads. Precondition the test article for effects of repeated loading and environmental exposure that are representative of design usage including the worst case combination of environmental effects (for example, temperature and moisture), and test under these environmental conditions to design limit and ultimate loads.

5.3.1.1.2 Test at room temperature with ambient air to design loads. Test at room temperature with ambient air to design limit and ultimate loads and obtain strain measurements at all critical locations. As an alternative, conduct the static test after application of repeated loads that are representative of design usage. In either case, the strains measured at design ultimate load in the critical locations shall be compared to analysis predictions using the material allowables associated with the test article conditions and the correlated analysis methods and procedures validated by design development tests per section 5.2.17.1 (to account for effects of repeated loading and environmental exposure that are representative of design usage). The comparisons between test measurements and analysis predictions shall be used in the interpretation and evaluation of test results per section 5.3.14. Because correction of analytical design data would not prove sufficient for application of this method, analysis used in this method shall be updated per section 5.4.1 to maintain correlation and valid application without extrapolation. For application of this method, the procuring government agency shall ensure that correlated analytical tools used in interpretation of the test results remain available to the procuring government agency for adaptation of test results or application of similar test procedures to future modification of the rotorcraft design.

5.3.1.1.3 Test at room temperature with ambient air to loads in excess of design loads. Test at room temperature with ambient air to loads in excess of design limit and ultimate loads. As an alternative, the static test may use a preconditioned test article based on prior application of repeated loads that are representative of design usage. In either case, the factors applied to the design loads shall be based on the most critical condition compensated allowables compared to the static test article conditions (to account for effects of repeated loading and environmental exposure which are representative of design usage). Selection of this method shall require risk mitigation actions considering the potential for test article failure prior to completing all required test load conditions.

5.3.2 Damage tolerance tests. The damage tolerance tests shall validate, correlate, or correct the damage tolerance analysis results from section 5.2.7 and shall verify that inspection intervals ensure structural integrity in the specified damage tolerant structure in accordance with section 5.1.5.3. Testing shall be performed on specified rotorcraft structural elements (full scale) whose structural integrity depends on establishing inspection intervals. This testing shall be accomplished by repeatedly subjecting the structure to flight-by-flight applications of the design loads spectra from section 5.2.3 while validating and correcting the section 5.2.7 predicted damage growth rate and predicted flight hours between damage detectability and the critical damage threshold related to residual limit strength capability. Truncation of the design loads spectra for damage tolerance testing shall require that test evidence of the truncated spectra and full design loads spectra producing equivalent results (after compensating per the methodology for any reduction in damage growth rates due to truncation) be submitted for approval by the procuring government agency and the service design control activity (MAA). Determination of the test spectrum shall also consider inclusion of marker bands to facilitate subsequent application of quantitative fractography in accordance with section 5.3.7.4. Thermal and other environmental effects per sections 5.2.1 or 5.2.17 shall be accounted for in the test. The number of test articles shall be in accordance with section 5.1.5 as necessary to achieve the required reliability and confidence in accordance with sections 5.1.2 and 5.1.5.3. Test load levels shall be in accordance with the applicable methodology of section 5.1.5. See section 5.3.7 for common structural test requirements applicable to this section.

5.3.3 Safe life tests. The safe life tests shall validate, correlate, or correct the safe life analysis results from section 5.2.8 and shall verify that retirement intervals ensure structural integrity in the specified safe life structure in accordance with section 5.1.5.1. Specified rotorcraft structural elements (full scale) shall be subjected to steady and oscillatory loads to determine the load levels at which damage would initiate. The load levels and number of cycles to damage initiation shall be plotted to develop the stress-life (S-N) or strain-life (ε-N) curve for that component and failure mode in accordance with section 5.1.5.1. Constant amplitude testing is typically preferred over spectrum testing to maximize ongoing applicability of the test results in the presence of potential future changes in rotorcraft usage. Thermal and other environmental effects per sections 5.2.1 or 5.2.17 shall be accounted for in the test. The number of test articles shall be in accordance with section 5.1.5 as necessary to achieve the required reliability and confidence in accordance with sections 5.1.2 and 5.1.5.1. The results of the safe life tests shall be used with appropriate fatigue curve shapes and COVs, as described or developed in accordance with sections 5.1.5.1, 5.2.1, and 5.2.17 to define fatigue strength. Test load levels shall be in accordance with the applicable methodology of section 5.1.5. See section 5.3.7 for common structural test requirements applicable to this section.

5.3.4 Enhanced safe life tests. The enhanced safe life tests shall validate, correlate, or correct the enhanced safe life analysis results from section 5.2.9 and shall verify that retirement intervals ensure structural integrity in the specified enhanced safe life structure in accordance with section 5.1.5.2. Specified rotorcraft structural elements (full scale) shall be seeded with damage within the specified threshold and subjected to steady and oscillatory loads to determine the load levels at which new damage would initiate or begin growth out of existing damage. The seeded damage shall represent critical locations, sizes, and orientations, with consideration for the probability of damage during maintenance or service usage and for the probability of undetected damage during manufacturing. The load levels and number of cycles to damage initiation or growth out of existing damage shall be plotted to develop the enhanced stress-life (S-N) or enhanced strain-life (ε-N) curve for that component and failure mode in accordance with section 5.1.5.2. Constant amplitude testing is typically preferred over spectrum testing to maximize ongoing applicability of the test results in the presence of potential future changes in rotorcraft usage. Thermal and other environmental effects per sections 5.2.1 or 5.2.17 shall be accounted for in the test. The number of test articles shall be in accordance with section 5.1.5 as necessary to achieve the required reliability and confidence in accordance with sections 5.1.2 and 5.1.5.2. The results of the enhanced safe life tests shall be used with appropriate fatigue curve shapes and COVs, as described or developed in accordance with sections 5.1.5.2, 5.2.1, and 5.2.17 to define fatigue strength. Test load levels shall be in accordance with the applicable methodology of section 5.1.5. See section 5.3.7 for common structural test requirements applicable to this section.

5.3.5 Design service life tests. The design service life tests shall validate, correlate, or correct the design service life analysis results from section 5.2.10 and shall verify that the design service life ensures structural integrity in the specified rotorcraft structure in accordance with the durability methodology of section 5.1.5.3. The test shall be conducted on an instrumented full-scale rotorcraft and shall use a repeated loads application of the design loads spectra from section 5.2.3. Truncation of the design loads spectra for design service life testing shall require that test evidence of the truncated spectra and full design loads spectra producing equivalent results (after compensating per the methodology for any reduction in damage growth rates due to truncation) be submitted for approval by the procuring government agency and the service design control activity (MAA). Thermal and other environment effects per sections 5.2.1 or 5.2.17 shall be accounted for in the test. In accordance with the durability methodology of section 5.1.5.3, one full-scale article shall be tested for each section of structure as necessary to achieve the required reliability and confidence from section 5.1.2, including consideration of the onset of widespread fatigue damage, whether due to multiple-element damage or multiple-site damage. Subsequent to demonstrating design service life, testing shall demonstrate the residual strength capability and characterize the initial quality of rotorcraft structure to support the update of the section 5.2.20 initial risk analyses. Full-scale design service life tests should be used to demonstrate the feasibility of candidate NDI and structural health monitoring systems. Also, for any damage initiation discovered during the test, additional testing may supplement section 5.3.2 damage tolerance tests by obtaining additional data such as damage location and damage growth (after either adjusting the test spectrum or correcting for any remaining test spectrum truncation effects), which validates, correlates, or corrects the damage tolerance analysis from section 5.2.7. See section 5.3.7 for common structural test requirements applicable to this section.

5.3.5.1 Design service life test duration. The minimum design service life test duration shall be twice the design service life per section 5.1.2, unless the test demonstrates that continued testing is not practical due to the onset of widespread fatigue. The procuring government agency shall establish a reduced service life for affected rotorcraft structure in cases where the duration of testing does not demonstrate twice the design service life prior to the onset of widespread fatigue. One lifetime of design service life testing, inspection of all critical structural areas, and an evaluation of test results shall be completed prior to a full production go-ahead decision. Two lifetimes of design service life testing, inspection of all critical structural areas, and an evaluation of test results shall be completed prior to delivery of the first production rotorcraft. In the event the schedule for the production decision and production delivery milestones becomes incompatible with the above schedule requirements, a study shall be conducted to assess the technical risk and cost impacts of changing these milestones. To understand potential structural constraints on plans to extend service life in the future, the test duration should be extended (by up to four lifetimes) to determine the onset of widespread fatigue damage. In addition, the extended test duration should also provide sufficient data to validate or correct analysis of repairs and modifications accomplished during testing. The test article and test facilities shall be available for the time required to extend testing and complete an additional two lifetimes of testing to enable the procuring government agency to fund testing beyond two lifetimes as required.

5.3.6 Component endurance bench tests. The component endurance bench tests shall verify that specified design criteria, inspections, and the applicable retirement interval or design service life combine to ensure structural integrity in the rotorcraft structure in accordance with the assessment results from section 5.2.11. Component endurance bench testing shall include all wear and degradation susceptible components, and demonstrate the wear and degradation severity, types of wear and degradation to be expected in the field, and the structural integrity consequences associated with wear and degradation damage in each component. In addition, data from the component endurance bench testing shall be used to assess control measures (such as design criteria or maintenance) in accordance with the engineering tolerance criteria of section 5.1.3.6, including consideration of thermal and environmental effects. See section 5.3.7 for common structural test requirements applicable to this section.

5.3.7 Common structural test requirements. Structural tests including static tests, damage tolerance tests, safe life tests, enhanced safe life tests, design service life tests, and component endurance bench tests shall meet the common structural test requirements of this section in addition to the particular requirements of sections 5.3.1, 5.3.2, 5.3.3, 5.3.4, 5.3.5, and 5.3.6, respectively. Sections 7-6 and 9-2 of ADS-51-HDBK may be used as a guide.

5.3.7.1 Selection of test articles. The test articles shall be Engineering and Manufacturing Development phase (as defined and established by DOD Instruction 5000.02) full-scale test rotorcraft structures, assemblies, or components and shall be representative of the operational configuration (including all significant structural details) and manufacturing processes. It is not required that the static or design service life test articles include systems, but the articles shall include system attach structures and associated details representative of the operational configuration and manufacturing process. If there are significant design, material, or manufacturing changes between the test articles and production rotorcraft structures, assemblies, or components, then corresponding tests of additional articles or selected components and assemblies thereof shall be required.

5.3.7.2 Test accuracy assessment. An assessment of the test accuracy shall be performed to characterize precision and bias in the test results due to potential sources of variability in the test, such as the test method, test method realization, test apparatus, test environment, test specimens, and design of experiments[20]. The assessment shall address differences between structural analyses based on distributed air loads, the full design loads spectra from section 5.2.3, and the structural test loading. The assessment shall address loading differences due to test fixture constraints or stiffness and the load application points and actuators. The accuracy assessment shall address test equipment calibration for load generation and measurement. For damage tolerance tests, safe life tests, enhanced safe life tests, design service life tests, and component endurance bench tests, the assessment shall also address the spectrum truncation approach applied to the test loading.

5.3.7.3 Damage detection and monitoring. Visual inspections, NDI and structural health monitoring (when used) shall be conducted as an integral part of the full-scale structural tests and the damage detection and monitoring plan for implementing these techniques shall be approved by the procuring government agency. For damage tolerance tests, safe life tests, enhanced safe life tests, and design service life tests, the objectives of damage detection and monitoring shall be to provide damage initiation time, location, and growth data necessary to validate relevant criteria, requirements, and inspections, and to minimize the risk of unanticipated catastrophic failure during testing. For component endurance bench tests, the objectives of damage detection and monitoring shall be to provide wear and degradation rate data necessary to validate relevant criteria, retirements, and inspections.

5.3.7.4 Teardown inspection and evaluation. At the end of the full-scale structural tests[21], including any scheduled damage tolerance tests or residual strength tests following a design service life test, a teardown inspection and evaluation program shall be conducted to confirm failure modes resulting from the test and to refine test results related to damage initiation or growth. All parts used for structural testing shall be permanently marked as test specimens to prevent their use as replacement spares on aircraft. The teardown inspection and evaluation shall include careful and deliberate disassembly of the entire structural test article, and close visual inspection of all structural elements shall be performed while the disassembly is performed. NDI of those critical areas identified in the design as well as additional critical structure identified during testing shall be performed. Fractographic examinations[22] shall be conducted to obtain damage growth data to validate or correct damage growth analysis (using quantitative fractography), to determine fatigue damage initiation site(s), to determine any anomalies at the fatigue damage initiation site(s), to provide evidence of failure mode, and to assist in the assessment of the initial quality of the rotorcraft structure (using traditional fractography). A distribution of intrinsic anomalies (such as flaws or defects) shall be derived from the damage discovered during testing and the teardown inspection and evaluation. Prior to teardown,

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[20] This section applies terms *precision*, *bias*, and related terminology in accordance with ASTM E 177 and ASTM E 456.
[21] See section 6.4.19 for guidance related to testing to failure.
[22] See *Fractography* (volume 12 of the *ASM Handbook*) for guidance and other information related to fractography.

consideration should be given to evaluation of the effectiveness of the anticipated NDI methods planned for application to fielded rotorcraft. The structural test article parts to include pieces subjected to fractographic examination shall be retained after teardown inspection and evaluation to enable future examination.

5.3.8 Drop Tests. Drop test articles shall demonstrate compliance with the rotorcraft system configuration and shall be used to validate or correct loads used in structural substantiation (analyses and tests).

5.3.8.1 Landing gear drop tests. Drop tests of the landing gear and critical backup structure shall be used to demonstrate compliance with the rotorcraft system specification. Normal load factor and the reserve energy absorption capacity of the landing gear shall be demonstrated. Tests shall be conducted to verify the dynamic load characteristics over a representative range of rotorcraft weights, angles of attack, and sinking speeds, as applicable to the landing gear type. For wheel-type landing gear, landing gear drop tests shall include sufficient wheel spin-up to simulate critical wheel contact velocities. See section 5.3.9.7 for landing gear drop test requirements to be completed prior to first flight. Landing gear drop test demonstration of crash condition capability including any frangible features such as shear pins and energy absorbing structure shall be completed prior to fielding.

5.3.8.2 Rotorcraft drop tests. A Rotorcraft drop test program, designed to demonstrate the ability of the air vehicle primary structure to withstand the design range of sink rates, pitch and roll attitudes, gross weight, and centers-of-gravity under defined field and gear/tire/oleo service conditions shall be performed on a production representative test article, such as a reconfigured static test article in accordance with section 5.3.1. Simulation of rotor lift under varying conditions with wheels locked and additionally with wheel speeds sufficient to simulate the effects of wheel contact velocities shall be accounted for. Drop test measurements shall be made on the rotorcraft drop test article that will verify that sink rates and the reactive loads throughout the rotorcraft meet structural integrity requirements. The vertical, drag, and side forces acting on the ground shall also be measured. Instrumentation methods and accuracies shall be reflected in the test plans and results. External protrusions (representing geometry, stiffness, and inertial properties for items such as antenna, tail bumpers, and external stores) shall be installed to verify that specified clearances and interface loads will be maintained as required for subsystem performance during landing impacts. The test article shall include representative mass, centers-of-gravity, orientation, hydrodynamic effects (including representation of hydrodynamic ram loading on structures adjacent to fuel cells), and structural interfaces and provisions for large mass items such as engines, gearboxes, fuel tanks, rotors, *etc*. When engagement would be applicable to the test scenario, the test article shall include (or simulate the effects of, when approved by the MAA) any crash protection systems in the configuration that attenuate structural loads or otherwise affect structural performance. The test requirements, test conditions and limitations for the drop test program shall be clearly documented.

5.3.9 First flight verification ground tests. The following verification tests and associated interpretation and evaluation of test results (in accordance with section 5.3.14) shall be conducted prior to first flight. These tests, interpretations, and evaluations are in addition to required test plan approvals and Task I and II analyses as specified in the RSIP master plan (in accordance with section 5.1.1).

5.3.9.1 Mass properties tests. Mass properties tests shall be conducted to validate or correct the rotorcraft weight and balance predictions and verify that mass properties are within limits for all design conditions per the structural design criteria and structural flight test plan(s). Analysis shall demonstrate that the gross weights and center of gravity ranges during take-off and landing, power on and power off (including engine failure), of the prototype flight test rotorcraft are such that it can safely operate within the specified envelope.

5.3.9.2 Functional proof tests. Functional proof tests shall be conducted to design limit load to demonstrate the functionality of safety of flight structure, flight controls, mechanisms, and components whose correct operation is necessary for safe flight. In addition to other functional requirements, these tests shall demonstrate that the deformation requirements have been achieved.

5.3.9.3 Strength proof tests. Strength proof tests of rotorcraft safety of flight structure shall be conducted prior to first flight when either (1) the required strength has not been verified by the full-scale static test article or (2) flight restrictions to ensure that component loads do not exceed the previously verified strength would limit envelope expansion testing to less than the structural design envelope defined in section 5.1.3.1. Strength proof test loads shall be as specified, but not more than 95% of analytical yield strength and not less than 110% of limit loads within the authorized flight and ground operations envelope for the planned flight and ground test activity to support safety of flight via establishment of appropriate peak structural flight test limitations for structural instrumentation monitoring.

5.3.9.4 Flight control surface rigidity and free-play tests. Flight control surface rigidity and free-play tests shall be conducted to validate or correct the flutter analysis as well as to ensure safe free-play limits. These tests shall be conducted prior to ground vibration tests for both design failure and normal conditions. Flight control surface mass balances used to prevent aeroelastic instability shall be designated as safety of flight structure, and stiffness tests of the mass balance attachments shall be conducted. In addition, the mass and inertia of the control surfaces shall be measured in support of the flutter analysis and to validate or correct the mass property analysis.

5.3.9.5 Ground vibration tests. Prior to first flight of any rotorcraft, ground vibration tests shall be performed on the first rotorcraft to fly (including installed components such as avionics and crew seats), and on any rotorcraft to be used for the aeroelastic flight testing if the first rotorcraft is not used for those tests. These tests shall be conducted to validate or correct analysis predictions of the natural frequencies, mode shapes, and structural damping of the rotorcraft. Natural frequency and forced response mode shape data shall also be obtained for a range of amplitudes and frequencies at various positions in the rotorcraft to identify modes important for rotor induced vibration. Test results shall be correlated against the structural model used in all aeroelastic analyses. Evaluation of the rotorcraft supporting system shall be performed to ensure rigid body modes of the rotorcraft do not interfere with the capture of rotorcraft elastic modes. To allow for any necessary changes in the structural models, component ground vibrations tests shall be conducted prior to rotorcraft assembly and in advance of full-scale rotorcraft tests.

5.3.9.6 Aeroservoelastic and ground resonance tests. Aeroservoelastic ground tests to include open-loop transfer (frequency response) tests and closed-loop coupling (structural resonance) tests shall be conducted to correlate and validate or correct the aeroservoelastic analysis results related to control of flutter, divergence, dynamic instability (including aeroelastic and mechanical instability), air resonance, ground resonance, whirl flutter, and other related aeroelastic, aeroservoelastic, or rotor instabilities. Ground testing related to ground resonance and mechanical stability shall be completed prior to first flight. Ground resonance testing shall verify that the rotorcraft is free of any mechanical instabilities. Ground resonance testing shall include tests conducted with the landing gear and at least one main rotor lag damper in degraded (unserviced) conditions.

5.3.9.7 Landing gear drop tests (prior to first flight). In partial completion of section 5.3.8.1, drop tests of the landing gear and critical backup structure to design limit sink speed conditions shall be performed prior to first flight to demonstrate sufficient design load/stroke characteristics to support flight testing.

5.3.9.8 Safe life or enhanced safe life tests (prior to first flight). In partial completion of section 5.3.3 or section 5.3.4 test requirements, safe life or enhanced safe life tests shall be conducted (with at least two specimens of all fatigue critical components) in order to demonstrate sufficient strength to support the flight test duration and safety of flight via establishment of appropriate oscillatory structural flight test limitations for structural instrumentation monitoring.

5.3.9.9 Rotor whirl tests (prior to first flight). Rotor whirl tests shall be conducted for stress and motion, over-speed, and specified endurance to support safety of flight. For each rotor design incorporated into the rotorcraft, test articles, as a minimum, shall include the rotor hub, rotor blades, rotor controls, a drive shaft interface to the whirl stand, and instrumentation corresponding to the flight test article. Test articles shall be the same configuration as the flight test article. The primary goal of conducting the rotor whirl tests prior to flight is to provide initial validation or correction of stress distributions in the rotor system over the range of stress and motion testing and during over-speed conditions. The secondary goal is to safely demonstrate that initial flight test inspections are appropriate for the wear, durability, and endurance characteristics of the rotor system, especially for unanticipated damage or damage growth mechanisms in the dynamic system.

5.3.9.10 Component endurance bench tests (prior to first flight). In partial completion of section 5.3.6 test requirements, component endurance bench tests shall be conducted in order to demonstrate that wear and degradation inspection procedures and intervals are sufficient to support the flight test duration, environment, and safety of flight. Component endurance bench tests should be coordinated with section 5.3.9.9 rotor whirl tests, and rotor whirl testing in accordance with section 5.3.9.9 may be substituted in place of first flight requirements in this section for any safety of flight structure, mechanisms, and components with sufficient inspection procedures and intervals demonstrated by rotor whirl testing.

5.3.9.11 Subsystem tests (prior to first flight). For subsystems that are not rotorcraft structure[23] but could impact structural integrity as a result of malfunction (such as by violating structural design criteria), verification that the subsystem meets functional requirements in a relevant environment, including specified tests, shall be completed prior to first flight to ensure that the subsystems pose no impacts to structural integrity during flight testing.

5.3.10 Structural flight tests. Structural flight tests shall be used to verify that the rotorcraft structure meets requirements. Structural flight test conditions shall be flown in accordance with a flight maneuver standards guide which provides procedures and parameter tolerances intended to ensure reliable and repeatable data for each type of structural flight test. Envelope expansion flight testing shall be conducted with structural instrumentation in support of the flight loads survey and prior to other structural or non-structural flight testing. Sections 7-6, 9-1, 9-2, and 9-4 of ADS-51-HDBK may be used as a guide. The following structural flight tests shall be conducted in coordination with structural flight tests required for envelope expansion.

5.3.10.1 Flight loads survey. A flight loads survey shall be conducted to obtain mean and oscillatory load data (which includes stress, strain, and load data) for each flight condition in the design usage spectrum, including test configurations and conditions necessary to validate the section 5.1.3.6 engineering tolerance criteria. Data from the flight loads survey shall be used to validate, modify, supplement or replace loads analysis per the methodologies of section 5.1.5. Loads data collected in the flight loads survey shall include coverage of each safety of flight structural load path. To minimize technical and schedule risks, backup gages shall also be incorporated into the test. Loads instrumentation and calibration used in the flight load survey shall correspond to identical instrumentation and calibration used in the full-scale safe life, enhanced-safe life and damage tolerance testing. Mean and oscillatory load levels shall be measured for each gross weight, center of gravity, airspeed, and altitude condition necessary to substantiate design usage within the structural design envelope in accordance with sections 5.1.2 and 5.1.3.1. Sufficient replications of critical conditions shall be performed in order to characterize load variability for the rotorcraft and substantiate the required confidence in loads to be used in the damage tolerance substantiation (section 5.4.3.1) and the fatigue substantiation (section 5.4.3.2). The procuring government agency may approve of using validated loads analysis methods to interpolate loads trends between test conditions and thereby inform opportunities for increased replications in more critical conditions while deferring maneuvers identified as less critical by validated analysis.

5.3.10.2 Structural demonstration. A structural demonstration test program shall be conducted with structural instrumentation necessary to substantiate the airworthiness of the rotorcraft and to provide a formal demonstration of compliance with the structural requirements of the rotorcraft system specification. The objectives of the structural demonstration test program shall be to (1) demonstrate the safe operation of the rotorcraft to the maximum attainable operating limits consistent with the structural design envelope (section 5.1.3.1); (2) verify that loads used in the structural analyses and tests are not exceeded during operation of the rotorcraft at the structural design limits of the flight envelope; and (3) establish the allowable

[23] For subsystems that are not rotorcraft structure, section 6.4.20 provides guidance related to subsystem tests that will be required prior to first flight.

flight envelope at the critical conditions for strength, rigidity, and operation in cases where the loads used in the structural analyses and tests are exceeded within the structural design envelope.

5.3.10.3 Structural usage monitoring system validation. Structural usage monitoring system validation testing shall be performed in coordination with the flight loads survey and structural demonstration testing. Validation efforts shall incorporate comparison of structural loads measured during validation testing and the resulting fatigue damage fractions to those assessed by the structural usage monitoring system. Usage algorithms, sensors, and other elements of the structural usage monitoring system should be validated following guidance contained in ADS-79-HDBK, appendix B.

5.3.11 Environment tests. Full-scale component, assembly, and system-level environment testing shall be conducted to identify potential environment induced structural problems in the field. Environmental testing shall identify any structural problems caused by corrosion; sand and rain (such as bearing wear, improper drainage, or erosion of rotor blades, wings, empennage, or landing gear); icing (such as expansion of trapped fluids); and sea state and high winds during tie-down and mooring. In addition, environment testing shall characterize environmental effects unique to the design, such as composite structure moisture absorption and desorption rates, thermal cycling of adhesives and composites, and rotor blade snow and ice loads. Fluid sources, trapped fluid locations, and improper drain paths shall be determined. Test conditions and methods shall envelop the design usage environment spectra from section 5.2.4, using MIL-HDBK-310 and MIL-STD-810 as a guide. The test results shall be used to determine field implications and corrective actions such as to establish a basis for operating restrictions and design modifications such as additional CPC requirements in the CPCP.

5.3.12 Dynamic flight tests. The following dynamic flight tests shall be conducted.

5.3.12.1 Aeroelastic flight tests. Tests shall be conducted to verify the rotorcraft structure is free from aeroelastic instabilities and has satisfactory damping throughout the operational flight envelope. Test rotorcraft shall have sufficient instrumentation installed and acceptable methods of inflight excitation shall be used to determine the frequency and amount of damping of the primary modes of interest at each flight test condition.

5.3.12.2 Aeroacoustic flight tests. The aeroacoustic environments shall be measured on a full-scale rotorcraft to validate or correct the acoustic loads/environment used in the sonic fatigue analysis. Measurements of sound pressure levels shall be made of those areas determined to be sonic-fatigue critical. Sufficient instrumentation shall be in place for both flight and ground operations which produce the significant aeroacoustic loads.

5.3.12.3 Vibration flight tests. Flight vibration tests shall be conducted to validate or correct analysis of the vibration environment. Measurements shall be made at a sufficient number of locations and at sufficient sampling rates to define the vibration characteristics of the rotorcraft structure with the test results being the basis for equipment environmental requirements (including vibration of avionics, engines, and crew seats). In addition, the test results shall be used to demonstrate that vibration control measures (including rotor track and balance procedures) prevent excitation of vibrations that exceed specifications or cause deleterious oscillatory loads[24] in rotorcraft structure. Finally, the test results shall be used to demonstrate that the vibration control measures provide for reliable performance of personnel and equipment throughout the design service life.

5.3.13 Mechanical endurance surveillance. The mechanical endurance surveillance shall validate, correlate, or correct the assessment results from section 5.2.11 and shall verify operational availability of the rotorcraft based on wear and degradation impacts. Mechanical endurance surveillance shall be conducted on structural flight test aircraft, with continuation on high time aircraft after fielding in accordance with sections 5.4.5 and 5.5.4. Mechanical endurance surveillance includes assessment of any necessary changes to the specified design criteria, inspections, and the applicable retirement interval or design service life, as necessary to ensure structural integrity in wear and degradation susceptible rotorcraft structure. Mechanical endurance surveillance shall incorporate inspection of all wear and degradation susceptible areas of rotorcraft structure. During structural flight testing, mechanical endurance surveillance shall include monitoring changes in loads for repeatable conditions to directly assess any impact of wear and degradation on loads. After fielding, unexpected wear and degradation noted as a result of mechanical endurance surveillance of high time aircraft may require additional component endurance bench testing or structural flight testing to determine load impacts. Mechanical endurance surveillance shall demonstrate any operational availability impacts due to wear and degradation severity, types of wear and degradation expected in the field, and the structural integrity consequences associated with wear and degradation damage in each component. In addition, data from the component endurance bench testing shall be used to assess control measures (such as design criteria or maintenance) in accordance with the engineering tolerance criteria of section 5.1.3.6, including consideration of thermal and environmental effects. Mechanical endurance surveillance should represent planned operational usage with accelerated flying hours. With cost and schedule risk acceptance by the procuring government agency related to operational availability requirements, the mechanical endurance surveillance may also be conducted as lead the fleet testing on a limited number of rotorcraft after fielding the system (such as low rate initial production or first unit equipped rotorcraft).

5.3.14 Interpretation and evaluation of test results. Each structural problem that occurs during the tests performed in accordance with this standard practice shall be analyzed to determine the root cause, corrective actions, field implications, and estimated costs. Examples of structural problems include but are not limited to inadequate static strength to meet yield load and ultimate load requirements, inadequate fatigue strength to meet specified retirement intervals, onset of widespread fatigue damage prior completion of design service life testing necessary to substantiate the specified design service life, and components failing to maintain required stiffness. RSIP impacts due to any analytical shortfalls (measured loads, stresses, strains, and vibrations, which differ from predictions) which are identified during testing shall also be analyzed and documented to identify the necessary updates to previously completed RSIP analyses and plans. The results of these evaluations shall define corrective actions required to demonstrate that the strength, rigidity, damage tolerance, enhanced safe life, safe life, and durability design requirements are met and the associated risk reduction is achieved. Structural modifications or changes derived from the results of the full-scale tests to meet the specified strength, rigidity, enhanced safe life, damage tolerance, and durability design requirements shall

[24] See section 6.4.12.2 for guidance related to recognizing *deleterious oscillatory loads*.

be substantiated by subsequent tests of components, assemblies, or full-scale article, as appropriate. Risk analysis from section 5.2.20 shall be updated as required. In any case where the risk is assessed as higher than the development baseline (corresponding to required reliability and confidence in accordance with in section 5.1.2), either rotorcraft system specification change, design change, risk acceptance, or some combination of the three will be required (with baseline risk determined based on the system specification at fielding).

5.4 Fielding with instructions for continued airworthiness (Task IV). The fielding with instructions for continued airworthiness task consists of the analyses that substantiate a statement of airworthiness qualification based on the results of the design information task, the design analysis and developmental testing task, and the full-scale testing task (Tasks I through III), as well as the development of the processes and procedures required to manage fleet structural integrity (including operating instructions, limitations, and maintenance instructions necessary to maintain structural integrity, such as retirement intervals and inspection intervals, methods, and procedures). For rotorcraft acquisition programs managed by the U.S. Army, rotorcraft airworthiness and materiel release regulations include AR 70-62 and AR 700-142, with applicable guidance and procedures provided in DA PAM 700-142.

5.4.1 Updated structural analyses. The structural description from section 5.1.9 and the drawings, models, and analyses from section 5.2 and subsections shall be updated and revised based on the interpretation and evaluation of corresponding test results from section 5.3.14, including incorporation of updates necessary due to any associated rotorcraft system specification changes or design changes. Production drawings/models and associated lists shall document the final design and configuration for all safety of flight structure and all aviation CSIs. The scope of updates shall include any analyses (or portions of analyses) necessary to substantiate the strength summary and operating restrictions, the structural integrity sustainment plan, aviation CSI surveillance, or the technical manuals.

5.4.2 Strength summary and operating restrictions. The Strength Summary and Operating Restrictions (SSOR) report shall summarize the results of updated analyses, test results, and other structural data, providing rapid visibility of the important structural characteristics, limitations, and capabilities in terms of operational parameters such as speed, acceleration, altitude, center-of-gravity location, and gross weight. The summary shall include brief descriptions of each major structural assembly, indicating structural arrangements; materials; critical design conditions; fatigue, durability, and damage tolerance critical areas; and minimum margins of safety. Appropriate references to drawings/models, detail analyses, test reports, and other back-up documentation shall be provided. The rotorcraft Operator's Manual shall incorporate operating restrictions identified in the SSOR document. In cases where the design has not been verified to meet the specified structural design envelope (section 5.1.3.1), the SSOR shall document the rationale and basis for rotorcraft system specification changes or, as appropriate, for recommending future modification programs to achieve the rotorcraft system specification.

5.4.3 Structural integrity sustainment plan. The intent during the design of the rotorcraft is to achieve robust rotorcraft structure that will require little, if any, maintenance for corrosion, fatigue damage initiation or growth, stress corrosion cracking, or damage to composites, such as delaminations, within the design service life, assuming that the rotorcraft is operated in accordance with the design usage. However, full-scale testing performed in accordance with section 5.3 and the updated structural analyses performed in accordance with section 5.4.1 may identify critical areas that would require additional analysis and in-service inspections and perhaps production or in-service modifications to maintain the validity of all criteria in section 5.1.3. Inspections in the structural integrity sustainment plan shall be in accordance with the NDI Plan of section 5.1.7, and the NDIT shall verify that the inspections prescribed in the structural integrity sustainment plan meet structural integrity requirements related to inspection POD and confidence. The structural integrity sustainment plan shall define the "when, where, and how" of these inspections, maintenance actions, repairs and modifications as well as the recurring structural maintenance instructions. Guidance related to application of CBM structural health monitoring systems as part of the structural integrity sustainment plan can be found in Appendices A and C of ADS-79-HDBK. The structural integrity sustainment plan shall be implemented into the rotorcraft Maintenance and NDI Manuals, as well as instructions for depot maintenance of the rotorcraft.

5.4.3.1 Damage tolerance substantiation of inspection intervals and procedures. The damage tolerance substantiation of inspection intervals and procedures shall use an approved damage tolerance methodology, design usage, the CPCP, design loads spectra, the NDI plan, damage growth parameters and COVs developed in accordance with sections 5.1.2, 5.1.3.5, 5.1.5, 5.1.6, 5.1.7, 5.2.1, and 5.2.3. Substantiation shall incorporate analyses and structural test data in accordance with sections 5.2.7 (damage tolerance analysis), 5.3.2 (damage tolerance tests), and 5.3.10 (structural flight tests) to establish the specified reliability and confidence that structural integrity would not be compromised due to damage prior to detection and repair during the design service life or retirement interval. Inspections shall be set such that damage shall be detected and repaired before the minimum required stiffness or residual strength is reached. When necessary to ensure structural integrity, the structure shall be restored through repair or replacement to ultimate load capability. To ensure that NDI meets requirements related to POD and confidence essential to safety by inspection, the structural integrity sustainment plan shall meet the requirements of the durability and damage tolerance methodologies and NDI plan related to NAS410 Level 3 Inspector oversight for inspections supporting the section 5.1.5.3 durability and damage tolerance methodologies and the section 5.1.7 NDI plan. The structural integrity sustainment plan shall use TO 33B-1-1 / NAVAIR 01-1A-16-1 / TM 1-1500-335-23 as a guide. Inspection procedure development and approval shall be in accordance with TO 33B-1-2 / NAVAIR 01-1A-16-2 / TM 1-1500-366-23.

5.4.3.2 Fatigue substantiation of component retirement intervals and rotorcraft design service life. The fatigue substantiation of component retirement intervals shall use an approved fatigue life methodology, design usage, fatigue curve shapes, COVs and design loads spectra developed in accordance with sections 5.1.2, 5.1.3.5, 5.1.5, 5.2.1, and 5.2.3. Safe life substantiations shall incorporate analyses and structural test data in accordance with sections 5.2.8 (safe life analysis), 5.3.3 (safe life tests), and 5.3.10 (structural flight tests). The safe life substantiations shall establish that the specified proportion of components would not initiate damage within design retirement intervals when subjected to the design loads spectra, with the specified level of confidence. Enhanced safe life substantiations shall incorporate analyses and structural test data in accordance with sections 5.2.9 (enhanced safe life analysis), 5.3.4

(enhanced safe life tests), and 5.3.10 (structural flight tests). The enhanced safe life substantiations shall establish that the specified proportion of components would not initiate damage, or begin growth out of existing damage for specified threshold levels, within design retirement intervals when subjected to the design loads spectra, with the specified level of confidence. The fatigue substantiation shall also verify that the design service life precludes initiation of widespread fatigue damage, whether due to multiple-element damage or multiple-site damage, by incorporating analyses, full-scale test data and flight test data in accordance with sections 5.2.10, 5.3.5, and 5.3.10. This will ensure that the design service life remains within the limits of validity for the section 5.4.3.1 damage tolerance substantiation of inspection intervals and procedures.

5.4.3.3 Mechanical endurance substantiation. The mechanical endurance substantiation shall establish that specified design criteria, inspections for wear and degradation, and the applicable retirement interval or design service life combine to ensure structural integrity of all wear and degradation susceptible areas of rotorcraft structure. The mechanical endurance substantiation shall incorporate design usage, engineering tolerance criteria, design loads spectra, and applicable endurance assessments, test data, and surveillance data from sections 5.1.2, 5.1.3.6, 5.2.3, 5.2.11, 5.3.6, 5.3.9.9, 5.3.9.10, and 5.3.13 (with updates, as required, based on surveillance data from 5.5.4). The mechanical endurance substantiation shall establish control measures (such as design criteria or maintenance) for each wear and degradation susceptible component, as required in accordance with the engineering tolerance criteria of section 5.1.3.6, including consideration of thermal and environmental effects. In accordance with section 5.3.13, the mechanical endurance substantiation shall document any operational availability impacts related to wear or degradation based on mechanical endurance surveillance.

5.4.3.4 Structural substantiation of damage repair limits and processes. Allowable damage limits and associated growth rates shall be established to develop repair concepts for structural components and assemblies. Structural analyses and testing shall be used to establish repair designs as well as to identify post-repair inspection requirements and any operational restrictions. Repair procedures shall specify materials (including material specification), processes, tools, equipment, facilities, and training necessary to complete the repairs. Repair materials, processes, methods, and concepts shall be selected in accordance with section 5.1.9 with associated design allowables developed in accordance with sections 5.2.1 and 5.2.17.

5.4.3.5 Updated structural usage monitoring algorithms. The algorithms developed for structural usage monitoring in accordance with section 5.2.19 shall be validated and updated using structural flight test data (section 5.3.10.3). Additional information regarding the development and validation of structural usage monitoring algorithms can be found in Appendices A, B, and C of ADS-79-HDBK. The known maneuvers, regimes, or load conditions executed during structural flight testing shall be compared to the maneuvers, regimes, or load conditions predicted by the structural usage monitoring algorithms. Recommended levels of accuracy for structural usage monitoring systems can be found in Appendix B of ADS-79-HDBK. If changes are made to the algorithms as a result of the review of structural flight test data (or similarly, if the algorithms are trained by such flight test data), additional testing shall be performed to validate algorithms.

5.4.3.6 Rotorcraft tracking system development. A system to perform individual rotorcraft tracking and fleet trending shall be developed to obtain usage data that is used to adjust maintenance intervals. All fielded rotorcraft shall have systems that record sufficient flight hours, loads, and usage parameters that can be used to determine the usage and loading history for the rotorcraft structure in accordance with the CBM Management Plan developed in section 5.1.8. The systems shall have sufficient capacity and reliability to maintain the specified reliability and confidence for the safety of flight structure. The systems shall include serialization of interchangeable/replaceable rotorcraft structural components, as required. The rotorcraft tracking system shall be ready to acquire data at the beginning of initial flight operations. If an instrumentation system (with sensors) is part of the rotorcraft tracking system, the instrumentation system shall be incorporated into full-scale testing in accordance with section 5.3 (and subsections). Data systems should follow the guidance of ADS-79-HDBK.

5.4.3.7 Component tracking system development. A system to perform component tracking shall be developed to provide data to support continued airworthiness. All fielded rotorcraft shall have systems that record sufficient flight hours, loads, and usage parameters that can be used to determine the usage and loading history for each serialized component to allow for individual component fatigue damage tracking in accordance with the CBM Management plan developed in section 5.1.8. The systems shall have sufficient capacity and reliability to maintain the specified reliability and confidence for each component.

5.4.3.8 Develop criteria for updating structural integrity sustainment plan. Criteria shall be developed for assessing the significance of potential future modifications or changes that impact structural integrity and invalidate the structural integrity sustainment plan of section 5.4.3. Candidate changes include mitigation of field incidents, changes in service use, changes in configuration, changes in performance, and unexpected trends established by structural health monitoring data or by inspection findings. Specific criteria related to configuration changes should include criteria related to engine upgrade programs, changes in rotor or rotor blades, changes in gross weight, changes in rotorcraft trim due to external stores or center of gravity, and changes in the flight control system in a manner that affects loads. Specific criteria related to performance changes may include enabling greater airspeed, altitude, load factor, or changes to other parameters defining the structural design envelope in accordance with section 5.1.3.1.

5.4.4 Aviation critical safety item surveillance process development. In support of the CSI management plan in section 5.1.4 and related quality assurance activities, a surveillance process shall be developed to assure that aviation CSIs from approved sources retain required capabilities. The contractor's quality management plan is subject to government review and approval. JACG Aviation Critical Safety Item Management Handbook and SECNAVINST 4140.2 (DA Pam 95-9) may be used for guidance.

5.4.5 Mechanical endurance surveillance process development for fielded aircraft. The process for conducting mechanical endurance surveillance of high time fielded aircraft shall be in accordance with section 5.3.13.

5.4.6 Technical manuals. The rotorcraft technical manuals shall support RSIP by documenting structural operational limitations and restrictions, maintenance requirements, *etc.*, based on the SSOR and structural integrity sustainment plan. Technical manuals supporting RSIP include the operators manual, the parts manual, repair manuals, and NDI manuals.

5.5 Fleet management (Task V). The fleet management task executes the processes and procedures required to manage fleet structural integrity developed under fielding with instructions for continued airworthiness (Task IV). This task will involve revisiting elements of earlier tasks in cases of modifications or changes that potentially impact structural integrity, such as field incidents or changes in service use, configuration, or performance.

5.5.1 Implement operational limitations. All Operational limitations, to include those specified in the section 5.4.2 SSOR document, shall be incorporated into the rotorcraft's Operator's Manual.

5.5.2 Implement structural integrity sustainment plan. The structural integrity sustainment plan developed in section 5.4.3, including service lives, retirement intervals, and inspection intervals and procedures, shall be implemented via maintenance manuals, logbooks, the CBM structural usage monitoring system, and the CBM structural health monitoring system. To ensure that NDI meets requirements related to POD and confidence essential to safety by inspection, implementation of the structural integrity sustainment plan shall meet requirements related to NAS410 Level 3 Inspector oversight of section 5.4.3.1 inspections in accordance with the durability and damage tolerance methodologies (5.1.5.3), the NDI Plan (5.1.7), and the structural integrity sustainment plan (5.4.3). TO 33B-1-1 / NAVAIR 01-1A-16-1 / TM 1-1500-335-23 may be used as a guide for implementation of the structural integrity sustainment plan. Structural usage monitoring shall be used to periodically monitor usage for comparison against the design usage spectrum. Individual rotorcraft tracking and fleet trending shall be used to adjust the inspection, modification, overhaul, and replacement times based on the actual, measured usage of the individual rotorcraft. Component tracking shall be used to perform individual component fatigue damage tracking.

5.5.3 Implement aviation critical safety item surveillance process. Quality assurance shall be used at each source in accordance with SECNAVINST 4140.2 (DA Pam 95-9) to assure proper implementation of CSI requirements as outlined in sections 5.1.4 and 5.4.4, with first article testing, production lot testing, and product verification audits incorporated into the contract(s). JACG Aviation Critical Safety Item Management Handbook and SECNAVINST 4140.2 (DA Pam 95-9) may be used for guidance.

5.5.4 Implement mechanical endurance surveillance process for fielded aircraft. The process for conducting mechanical endurance surveillance of high time fielded aircraft shall be implemented in accordance with sections 5.3.13 and 5.4.5.

5.5.5 Update structural integrity sustainment plan, as required. Modifications or changes to the rotorcraft that impact structural integrity may be related to field incidents or changes in service use, configuration (such as limitations related to gross weight, center of gravity, rotor speed, external stores, flight control systems, rotor blade airfoil, or rotor track and balance), or performance (such as, enabling greater airspeed, altitude, or load factor). Modifications or changes to the rotorcraft that impact structural integrity shall require (1) review of the RSIP-related criteria, methodologies, analyses, and tests to determine necessary updates in accordance with the RSIP master plan; and (2) update of the SSOR, structural integrity sustainment plan, and RSIP-related technical manuals in accordance with the requirements of sections 5.4.3.8, 5.4.6, and 5.5.2. In addition to structural integrity impacts, system safety hazards related to structural integrity may also become apparent due to field incidents or changes in usage, configuration, or performance. The procuring government agency shall implement its System Safety Management Plan for hazards during the period prior to implementing an updated structural integrity sustainment plan or when changes in the plan do not mitigate structural integrity related risks to the baseline established by the RSIP Master Plan in accordance with section 5.3.14. In accordance with section 4.2 requirements for rotorcraft modification programs, a new RSIP Master Plan may be required for acquisition programs related to modifications or changes that expand rotorcraft capabilities.

6. NOTES

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

6.1 Intended use. This standard practice provides a foundation to establish and conduct an RSIP during development and fielding of military-unique rotorcraft. Although federal aviation regulations contained in the Code of Federal Regulations Title 14 (14 CFR) ensure application of appropriate means for continued airworthiness and airworthiness-related structural integrity for commercial rotorcraft, service regulations govern military rotorcraft programs. Execution of military-unique rotorcraft programs depends on specification compliance and oversight from design control activities (airworthiness authorities) in each service to establish means of ensuring continued airworthiness and airworthiness-related structural integrity. Specification and application of this standard practice during development of military-unique rotorcraft ensures conformity to airworthiness-related service regulations from a structural integrity standpoint. Contractual documents may contain tailored requirements for each program, based on the content herein.

6.2 Acquisition requirements. Acquisition documents should specify the title, number, and date of this standard.

6.3 Data requirements. Long-term operation and maintenance of military rotorcraft and equipment is directly dependent on the availability of structural data used for rotorcraft development. During execution of an RSIP, the RSIP tasks generate key items of structural data, which are used to establish, assess, and support continued airworthiness, including inspections, maintenance activities, repairs, modification tasks, and replacement actions for the life of the rotorcraft structure. Contractual provisions will ensure these data are available to the procuring government agency, the service design control activity (MAA), and to relevant contractors and subcontractors throughout the operational life of the system. The following list provides a general guide to the necessary data. The procuring government agency may tailor this list based on system operational requirements, the support concept and strategy, the requirements contained in this standard practice, and applicable structural-integrity related specification guidance.

a. RSIP Master Plan (See 5.1.1)

b. Design service life, design component retirement intervals, and design usage (See 5.1.2)

c. Structural design criteria (See 5.1.3)

d. Aviation CSI Management Plan (See 5.1.4)

e. Fatigue and fracture methodologies (See 5.1.5)

f. CPC Plan (See 5.1.6.1)

g. Evaluation of corrosion susceptibility (See 5.1.6.2)

h. NDI Plan (See 5.1.7)

i. CBM Management Plan (See 5.1.8)

j. Selection rationale for materials, processes, joining methods, and structural concepts (See 5.1.9)

k. Structural description report (see 5.1.9 and 5.4.1)

l. Material and process specifications (See 5.1.6.1, 5.1.9, 5.2.1, 5.2.17, 5.4.1, 5.4.2, and 5.4.3.4)

m. Material and structural allowables data (See 5.2.1 and 5.4.1)

n. Loads analysis (See 5.2.2 and 5.4.1)

o. Design loads spectra (See 5.2.3 and 5.4.1)

p. Design usage environment spectra (See 5.2.4 and 5.4.1)

q. Threat assessment (See 5.2.5 and 5.4.1)

r. Static structural analysis (See 5.2.6 and 5.4.1)

s. Developmental design drawings/models and associated lists (See 5.2.6, 5.4.1, and 5.4.2)

t. Mathematical model finite element structural report (See 5.2.6 and 5.4.1)

u. Mathematical model finite element analysis report (See 5.2.6 and 5.4.1)

v. Damage tolerance analysis (See 5.2.7 and 5.4.1)

w. Safe life analysis (See 5.2.8 and 5.4.1)

x. Enhanced safe life analysis (See 5.2.9 and 5.4.1)

y. Design service life analysis (See 5.2.10 and 5.4.1)

z. Mechanical endurance assessment (See 5.2.11 and 5.4.1)

aa. Corrosion assessment (See 5.2.12 and 5.4.1)

bb. Aeroelastic and aeroservoelastic analysis (See 5.2.13 and 5.4.1)

cc. Blade stall and compressibility analysis (See 5.2.13.1 and 5.4.1)

dd. Vibration and sonic fatigue analyses (See 5.2.14 and 5.4.1)

ee. Mass properties analysis (See 5.2.15 and 5.4.1)

ff. Mass properties control and management plan (See 5.2.15)

gg. Survivability, crashworthiness, vulnerability, and weapons effects analyses (See 5.2.16 and 5.4.1)

hh. Design development test plans, reports, data, interpretations, and evaluations (See 5.2.17 and 5.3.14)

ii. FMECA reports and CSI-related recommendations (See 5.2.18 and 5.4.1)

jj. Structural usage monitoring algorithms (See 5.2.19 and 5.4.3.5)

kk. System safety management plan (See 5.2.20)

ll. Risk analyses (See 5.2.20 and 5.3.14, see also 5.1.1, 5.1.9, and 5.3.5)

mm. Static test plans, reports, data, interpretations, and evaluations (See 5.3.1 and 5.3.14)

nn. Damage tolerance test plans, reports, data, interpretations, and evaluations (See 5.3.2 and 5.3.14)

oo. Safe life test plans, reports, data, interpretations, and evaluations (See 5.3.3 and 5.3.14)

pp. Enhanced safe life test plans, reports, data, interpretations, and evaluations (See 5.3.4 and 5.3.14) qq. Design service life test plans, reports, data, interpretations, and evaluations (See 5.3.5 and 5.3.14)

rr. Component endurance bench test plans, reports, data, interpretations, and evaluations (See 5.3.6 and 5.3.14)

ss. Drop test plans, reports, data, interpretations, and evaluations (See 5.3.8 and 5.3.14)

tt. First flight verification ground test plans, reports, data, interpretations, and evaluations (See 5.3.9 and 5.3.14)

uu. Flight maneuver standards guide (See 5.3.10)

vv. Envelope expansion flight test plans, reports, data, interpretations, and evaluations (See 5.3.10 and 5.3.14)

ww. Structural flight loads survey test plans, reports, data, interpretations, and evaluations (See 5.3.10.1 and 5.3.14)

xx. Structural demonstration test plans, reports, data, interpretations, and evaluations (See 5.3.10.2 and 5.3.14)

yy. Structural usage monitoring system validation test plans, reports, data, interpretations, and evaluations (See 5.3.10.3, 5.3.14, and 5.4.3.5)

zz. Environment test plans, reports, data, interpretations, and evaluations (See 5.3.11 and 5.3.14)

aaa. Aeroelastic flight test plans, reports, data, interpretations, and evaluations (See 5.3.12.1 and 5.3.14)

bbb. Aeroacoustic flight test plans, reports, data, interpretations, and evaluations (See 5.3.12.2 and 5.3.14)

ccc. Vibration flight test plans, reports, data, interpretations, and evaluations (See 5.3.12.3 and 5.3.14)

ddd. Mechanical endurance surveillance test plans, reports, data, interpretations, and evaluations (See 5.3.13 and 5.3.14)

eee. Production drawings/models and associated lists (See 5.4.1 and 5.4.2)

fff. SSOR report (See 5.4.2)

ggg. Structural integrity sustainment plan (See 5.4.3 and 5.5.5) hhh. Damage tolerance substantiation report (See 5.4.3.1)

iii. Fatigue substantiation report (See 5.4.3.2)

jjj. Mechanical endurance substantiation report (See 5.4.3.3)

kkk. Structural substantiation of damage repair limits and processes (See 5.4.3.4)

lll. Rotorcraft Tracking System Plan and reports (see 5.4.3.6 and 5.5.2)

mmm. Component Tracking System Plan and reports (See 5.4.3.7 and 5.5.2)

nnn. Structural-Integrity-Sustainment-Plan update criteria report (See 5.4.3.8)

ooo. CSI Surveillance Process Plan and Quality Management Plan and reports (See 5.4.4 and 5.5.3)

ppp. Operator's manual (See 5.4.6 and 5.5.1)

qqq. Maintenance manuals (See 5.4.6 and 5.5.2)

rrr. NDI manual (see 5.4.6)

6.4 Explanatory notes.

6.4.1 Transmission and drive components. See JSSG-2009 Appendix K and ADS-50-PRF for guidance and aeronautical design standardization related to analysis and testing of transmission internal rotating components and drive system components that are not subjected to flight maneuver loads, control surface induced loads, or loads imparted by fuselage, tailboom or tailcone, empennage, or flight control mounts.

6.4.2 Categories of structural elements. Rotorcraft structure is comprised of primary and secondary structure (see definitions 3.24 and 3.34). These mutually exclusive categories of structural elements are established during design synthesis. One should not confuse terms *primary structure* and *secondary structure* with primary and secondary load paths in a multiple load path structure. Secondary structure may react local aerodynamic and inertial loads (such as in support of ancillary equipment) or protect against heat transfer or moisture intrusion. However, secondary structure should not contribute significantly to the overall lift, drag, download, control, or load-carrying capability of the rotorcraft. To protect primary structure, design of the secondary structure and the interfaces between primary and secondary structure should minimize beneficial or detrimental load transfer between primary and secondary structure. The intended function of secondary structure must not be necessary for safe flight and should not be necessary for meeting mission requirements. On the other hand, primary structure contributes significantly to the overall lift, drag, download, control, or load-carrying capability of the rotorcraft. Primary structure includes safety of flight structure (see definition 3.33). Loss of function of safety of flight structure could result in loss of the rotorcraft. Safety of flight structure includes all PSEs (see definition 3.25). Fatigue failure of a PSE could result in catastrophic failure of the rotorcraft. Figure 1 shows the relationship between these categories of structural elements. Per U.S. Code Title 10 section 2319(g), aviation CSIs are military aviation items warranting special contractual and quality considerations. Ideally and by definition, the cognizant military-service design control activity (MAA) should classify and manage all safety of flight structural elements as aviation CSIs (see definition 3.2) with corresponding definition of critical characteristics (see definition 3.5). However, to ensure timely execution of RSIP-related analyses or testing required in this standard practice for safety of flight structure or PSEs, execution of the RSIP-related analyses and testing should be based on definitions 3.25 and 3.33 rather than aviation CSI determinations (see section 5.2.18). In other words, contractor input based on definitions 3.25 and 3.33 should inform aviation CSI determinations rather than depend upon them.

6.4.3 Analysis and testing of secondary structure. Although primary structure, safety of flight structure, and PSEs are the proper focus of structural analyses in accordance with sections 5.2.6 through 5.2.10, each analysis may also include secondary structure when there is an economic benefit or for secondary structure which has the potential to become foreign object debris that could damage the engine, rotors, empennage, wings, stabilizers, or stabilators. In such cases, each analysis should clearly identify any secondary structure analyzed, along with the rationale for inclusion. Similar considerations may warrant testing of secondary structure. In such cases, each test plan should clearly identify any secondary structure included in the test, along with the rationale for inclusion.

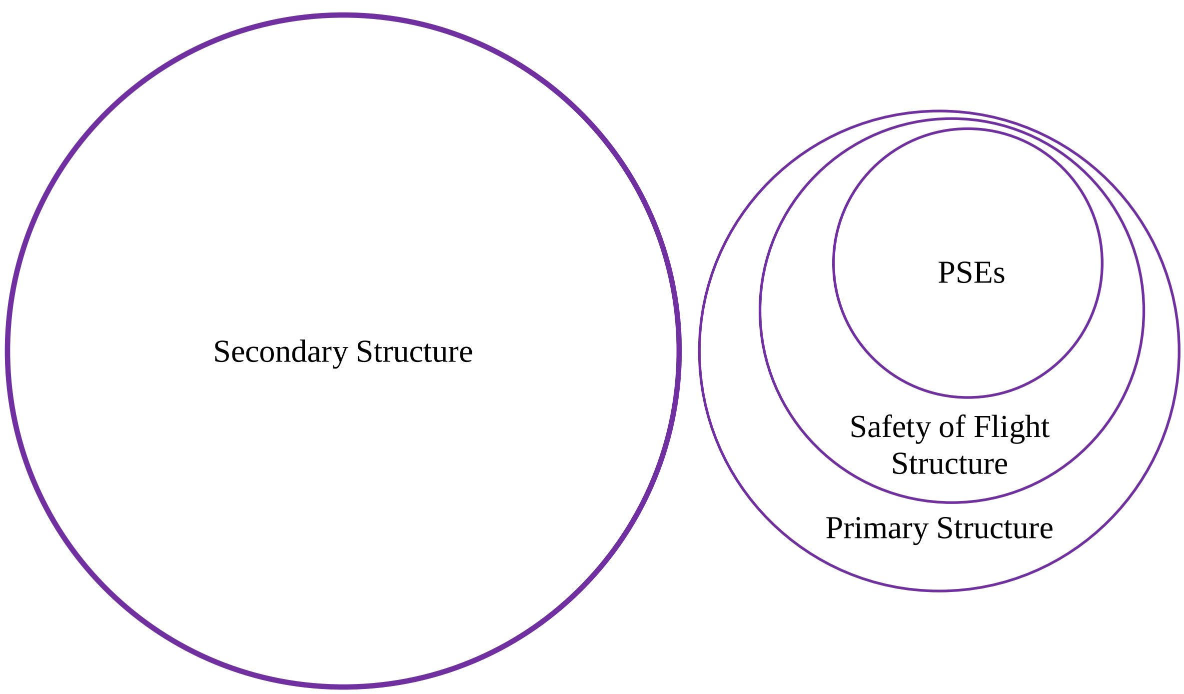

FIGURE 1: Relationship between RSIP categories of structural elements.

6.4.4 Development of the RSIP Master Plan. This standard practice intends that the procuring government agency will work closely with the air vehicle design prime contractor(s) to develop an initial RSIP Master Plan and obtain appropriate government approvals in accordance with sections 4.1 and 5.1.1. After appropriate coordination with representatives of the procuring government agency, the PEO, and the MAA; the air vehicle design prime contractor(s) should deliver the initial RSIP Master Plan and any subsequent changes in accordance with section 6.3 item a for formal review and approval in accordance with section 4.1 item b. The level of detail in the initial RSIP Master Plan should be sufficient to confirm methods of verification (analysis, test, etc.), to demonstrate inclusion and coordination of necessary RSIP task elements within the RSIP Master Plan, and to provide for coordination between the RSIP Master Plan and other rotorcraft program plans and schedules. As RSIP matures with the design, subsequent revisions to the RSIP Master Plan should complete the level of detail necessary to support design reviews (Preliminary Design Review and Critical Design Review) associated with program milestones per DOD Instruction 5000.02. The procuring government agency should follow a similar process with a similar level of coordination, documentation, review, and approval for subsequent rotorcraft modification programs in accordance with section 4.2.

6.4.5 PEO designee (for RSIP approval). The PEO may designate a representative to act in place of the PEO regarding coordination, concurrence, and approvals per sections 4.1, 4.2, 6.4.4, and 6.5. However, lead service regulations, policies, and instructions may limit the extent of the designation. For rotorcraft acquisition programs managed by the U.S. Army, the designated representative for RSIP approval is the U.S. Army Program Manager unless otherwise specified.

6.4.6 RSIP Technical Advisor. The MAA should designate an RSIP Technical Advisor as a representative to act in place of the MAA regarding coordination, concurrence, and approvals per sections 4.1, 4.2, 5.1.1, 5.2.2, 5.2.7, 5.2.8, 5.2.9, 5.2.10, 5.3.2, 5.3.5, 6.4.4, and 6.5, as well as regarding receipt of reports related to unresolved issues or risk mitigation actions per sections 5.1.6, 5.1.7, and 5.1.9. However, lead service regulations, policies, and instructions may limit the extent of the designation. The RSIP Technical Advisor designation would not include representation regarding aviation CSIs referenced in sections 5.1.4, 5.2.18, 5.4.1 and 6.4.2.

6.4.7 Substituting analysis in place of full-scale testing. An RSIP Master Plan may tailor this standard practice in accordance with sections 5.1.1 and 6.5. For cases where the RSIP Master Plan proposes substituting analysis in place of any section 5.3 full-scale testing for verification of requirements, the air vehicle design prime contractor should[25] validate application of the analysis methods to the rotorcraft design via interpolation of existing full-scale test data from representative designs. In such cases, analysis proposed for substitution should include factors to account for variation in the data at the specified confidence.

6.4.8 Detailed guidance related to structural design criteria. ADS-51-HDBK and ADS-29 contain detailed guidance related to rotorcraft structural design criteria per section 5.1.3. In addition, a rotorcraft structures specification guide is under development for future use in specifying rotorcraft structural designs. Loads criteria should consider authorized flight loads (including special cases such as external lift, aerial refueling, and deployment), ground loads

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[25] See section 5.1.1 for requirements related to this guidance.

(including blade fold and tie-down), transport loads (including hoist, tie-down for ground/ship/air transportation), maintenance loads (including hand-holds and steps/platforms), as well as common and unavoidable mishap loads such as jam, abuse, or tool drops. Loads should incorporate propulsion and mission equipment installation and operation loads via superposition.

6.4.9 Application of fatigue and fracture methodologies. The rotorcraft system specification should identify which types of analysis and testing is applicable to each PSE. Various types of structural fatigue and fracture analyses in accordance with sections 5.2.7 through 5.2.10 and testing in accordance with sections 5.3.2 through 5.3.5 are available. Table II provides guidance related to application of damage tolerance, safe life, and enhanced safe life methodologies to rotorcraft structures.

6.4.9.1 Damage tolerant fail safe structures. Fail safe concepts are related to damage tolerance in accordance with definition 3.16. Fail-safe designs result from material selection, sizing to reduced stress levels, and multiple load path structural arrangements, the combination of which maintains the required strength in the presence of a crack or damage. Multiple load path structure is either dependent (active) or independent (passive).

6.4.9.2 Limits of validity of damage tolerance analysis. For damage tolerant structure, widespread fatigue damage, whether due to multiple-element damage or multiple-site damage, is a particular concern due to the limits of validity for damage tolerance analysis and testing. After the onset of widespread fatigue damage, damage tolerant structure may no longer maintain the required residual strength after load path failure or partial failure. In accordance with the durability methodology of 5.1.5.3, RSIP uses design service life analysis and testing to address limits of validity of damage tolerance analysis and testing.

TABLE II. Guidance for application of fatigue and fracture methodologies to rotorcraft structure.

Analysis and Testing	Reference Sections	Goal	Design	Damage threshold	Considerations
Damage Tolerance	5.2.7, 5.3.2	Maintain required residual strength	For replacement or repair based on condition at specified inspection interval	Measurable	• When safety by inspection is practical • Slow damage growth structures • Fail safe structures
Safe Life	5.2.8, 5.3.3	Avoid initiation of new (fatigue) damage	For replacement at specified retirement interval	No damage allowed	• Single load path • Replaceable item • Significant high-frequency loading • Low likelihood of damage
Enhanced Safe Life	5.2.9, 5.3.4	Avoid initiation of new (fatigue) damage or (fatigue damage) growth out of existing damage	For replacement at specified retirement interval	Measurable	• Single load path • Replaceable item • Significant high-frequency loading • High likelihood of damage

6.4.10 Fatigue damage initiation. Per Federal Aviation Administration Advisory Circular (AC) 29-2C, fatigue is a degradation process of a structure subject to repeated loads which involves nucleation, coalescence, stable growth, and unstable growth. For the purpose of this standard practice, *initiating damage* as used in definitions 3.14 (*enhanced safe life*) and 3.32 (*safe life*) is comprised of nucleation of microscopic damage and coalescence of possibly multiple instances of microscopic damage into macroscopic damage, which is large enough to be visible if occurring on an accessible surface or edge of part. As such, use of the phrase *damage initiation* (or similar) throughout this standard practice (see sections 5.1.9.4, 5.2.8, 5.2.9, 5.3.3, 5.3.4, 5.4.3, 5.4.3.2, and table II) is consistent with the AC 29-2C paragraph AC 29.571B d(1)(viii) discussion of *crack initiation*. For the purpose of fatigue testing, the contractor should state the crack length used to define crack initiation in each test plan. In the safe life methodology (see section 5.1.5.1), the establishment of acceptable means for verifying that the methodology retains structural design characteristics (such as stiffness and residual ultimate strength) throughout the retirement interval should be consistent with substantiation of the definition of *fatigue damage initiation* (or *crack initiation*) used for fatigue test verification of retirement intervals. ASTM E-1823 defines *crack initiation* as essentially the onset of crack propagation from a preexisting macroscopic crack, which is subsequent to the initial existence of a macroscopic crack marking the *damage initiation* described above. However, the onset of damage propagation is an important concept to capture for application of the enhanced safe life methodology to structures with a measurable threshold of existing damage. To ensure that the definition of enhanced safe life (see definition 3.14) incorporates the ASTM E-1823 concept, the phrase *beginning growth out of existing damage* is used in the same manner as *initiating new damage* (see also similar phrasing in sections 5.3.4 and 5.4.3.2).

6.4.11 Use of loads spectra. Per section 5.1.5, inflight measurements (see section 5.3.10.1) will validate, modify, supplement, or replace loads analysis (see section 5.2.2) used in the design loads spectra (see section 5.2.3), and the fatigue and fracture methodologies will explain the details. Details in the fatigue and fracture methodologies will include loads analysis factors and test methods (such as test point replications) required for the loads spectra to remain in accordance with methods of assessing component and system reliability and confidence. It is necessary to use loads analysis during design analysis and developmental testing (Task II), but structural flight test data (see section 5.3.10) will become available during full-scale testing (Task III). Contractors should consider periodically updating or refining the design loads spectra with flight test data as it becomes available and as part of the updated structural analyses effort (see section 5.4.1, 5.4.3.1, and 5.4.3.2). In support of section 5.2.2, the DoD, the FAA, or a nongovernment standards body should establish a project to develop a standard practice for coordinating use of loads analysis tools with historical flight test data. As a goal, future rotorcraft development programs should use structural flight test data to validate the structural loads analysis rather than replace it. However, current state-of-the-art structural loads analysis appears to have fallen short of that goal at this point. Pending further improvements in loads analysis, the current practice of heavy dependence on binned structural flight test data is likely to continue. As an intermediate step, contractors should consider fatigue methodologies that use flight test data to modify and supplement analytical descriptions of loads-analysis trends. For example, relative changes in measured oscillatory loads may match loads analysis trends better after use of flight test data to anchor the trend at extremes of advance ratio and aerodynamic blade loading (CT/sigma). In addition to placing the loads trend, concentrating flight test data in critical areas would enable better understandings of load variability for use in reliability analysis (establishing a working loads spectra exceedance curve in a fashion similar to the concept of establishing a working fatigue curve).

6.4.12 Fatigue and fracture reliability considerations. For components managed for safety by retirement via safe life (at specified reliability and confidence), RSIP assesses the component contribution to system failure rate and system reliability based on the probability of initiating damage prior to retirement. For components managed for safety by retirement via enhanced safe life (at specified reliability and confidence), RSIP assesses the component contribution to system failure rate and system reliability based on the probability of initiating new damage or beginning growth out of existing damage prior to retirement. For components managed for safety by inspection (damage tolerance) with residual strength (at specified reliability and confidence), RSIP assesses the component (or structural assembly) contribution to system failure rate and system reliability based on the probability of exposure to damage greater than the specified threshold level without detection and repair prior to catastrophic failure. In any case, RSIP should assess reliability for the case of *random fixed* strength, *random independent* loads, and *random fixed* usage distributions and confidence intervals based upon the most recently updated RSIP strength, loads, and usage data. Although sampled at random from the population of components, *random fixed* strength and usage each remain fixed for a particular component over the span of applied load cycles. In contrast, *random independent* loads vary randomly with new values applied in each applied load cycle.

6.4.12.1 Fatigue sensitivity to design details. Fatigue life predictions and associated reliabilities are very sensitive to the influence of stress risers and the estimate of stress concentration factors. Fatigue sensitivity to stress risers is exemplified in the common approximation that a 10% change in stress can change the life prediction[26] by a factor of two (2) for low cycle fatigue. Durable and efficient rotorcraft designs require the designer to avoid introducing unnecessary stress risers.

6.4.12.2 Fatigue sensitivity to high cyclic loads. The rotorcraft load environment during normal operations includes exposure to persistent high-frequency load signals during apparently benign and sustained steady-state flight conditions. For durable, efficient, and low maintenance rotorcraft structure, high cycle fatigue damage resulting from a sustained flight condition (such as level flight) should not be allowed. Depending on materials and associated strength-life or strain-life curve shapes, consideration should be given to performing a reliability-based sensitivity study of the benefits of providing between 15% and 50% separation between high-frequency loads in steady-state flight conditions and the working endurance strength. Pending the outcome of such a sensitivity study, the RSIP should consider *deleterious oscillatory loads* (see sections 5.1.3.8, 5.2.13.1, and 5.3.12.3) as any loads corresponding to substantiating parameters above 50% of the corresponding operating boundary or working endurance limit, as defined in accordance with the applicable safe life, enhanced safe life, or durability methodology from section 5.1.5.

[26] The change in a fatigue life prediction inversely relates to a change in loads after accounting for scatter (average life decreases with increasing loads, and conversely, average life increases with decreasing loads).

6.4.12.3 Recommended efforts to enable safety by inspection. For components managed for safety by inspection (damage tolerance), development and implementation of the NDI Plan is critical to maintaining safety of flight and continued airworthiness. The Plan must ensure that NDI meets requirements related to POD and confidence. For the purpose of preliminary design for damage tolerance, unless otherwise specified, the air vehicle design prime contractor(s) may use USAF Structures Bulletin EN-SB-08-012 as a guide to damage thresholds. However, concurrent with the design development testing of section 5.2.17, an NAS410 Level 3 Inspector should evaluate the detection capabilities for effects of the field environment, equipment, procedures, and personnel to determine requirements to incorporate any demonstration through capability experiments into the testing of section 5.2.17, using MIL-HDBK-1823 as a guide. To minimize risks related to potential NDI optimism during design, the procuring government agency for the rotorcraft should establish a project at initial contract award (such as during the Technology Maturation and Risk Reduction phase for a milestone A entry, as defined and established by DOD Instruction 5000.02) to allow early evaluation of detection capabilities and to establish damage threshold levels for incorporation into the rotorcraft system specification. In this case, specified damage threshold levels would be used during preliminary design in place of guidance derived from USAF Structures Bulletin EN-SB-08-012 as a guide.

6.4.13 Consideration of impact damage. RSIP should incorporate impact damage criteria into the durability, fatigue, and fracture criteria of section 5.1.3.5, including consideration of rotorcraft zoning for areas of potential tool drops, potential impacts from rocks when operating on unimproved surfaces, etc., including the probability of exposure to various impact energy levels for each zone. The threat assessment of section 5.2.5 should also consider potential exposure to various impact energy levels for each zone. RSIP should identify inspection techniques and repair concepts for areas vulnerable to impact damage. Specifically, the NDI plan of section 5.1.7, the design development tests of section 5.2.17, and the structural integrity sustainment plan of section 5.4.3 should each address impact damage in accordance with the threat assessment of section 5.2.5. JSSG 2006 Appendix A provides guidance related to foreign object damage sources, zoning, and inspection requirements. Incorporation of impact energies or energy level cutoff values into the rotorcraft system specification for each zone should consider assessment of structural durability and robustness to the operational environment in accordance with the concept of operations and logistics (such as allowed use of rough airfields or storage outside of hangars, availability requirements, maintenance concepts, and field inspection capabilities).

6.4.14 Structural considerations for engineering tolerance criteria. RSIP establishment of engineering tolerance criteria per section 5.1.3.6 should consider any interactions between tolerances and structural capability or load paths. For example, thickness tolerances allowed for a bulkhead web should include consideration of web buckling. As a second example, gap tolerances for multiple load path structure should consider potential changes in load path where different fasteners, fastener groups, or contacting surfaces react loads as dimensions change within the allowed tolerances. As a third example, elastomeric bearing wear and temperature tolerances should consider potential changes in loads as stiffness and displacements vary for a given operating condition.

6.4.15 Crashworthiness and structural integrity. Although it is possible to distinguish between airworthiness and crashworthiness, survivability requirements motivate criteria for the design of crashworthy features into rotorcraft structure per section 5.1.3.9. As such, structural integrity requires crashworthiness for structural elements to meet their intended purpose. In the absence of user survivability requirements, the procuring government agency should consider emergency landing conditions and other crash-related airworthiness standards provided in 14 CFR (Federal Aviation Regulations), Part 27 or 29 (as applicable) as minimal survivability requirements. As documented in RDECOM TR 12-D-12, MIL-STD-1290, and USAAVSCOM TR 89-D-22A through E, military rotorcraft crashworthiness requirements will often exceed the minimal standards of the Federal Aviation Regulations in order to meet user requirements. Representatives of the user community should be required to concur with any procuring government agency decisions related to the trade space between survivability requirements and criteria derived from 14 CFR, Part 27 or 29 (as applicable), RDECOM TR 12-D-12, MIL-STD-1290, and USAAVSCOM TR 89-D-22A through E. Once the user representatives and procuring government agency agree on the survivability requirements and criteria, RSIP execution ensures that the structure remains capable of performing its intended function. To minimize the impact of any changes in user survivability requirements as the rotorcraft program progresses, the RSIP should not merge section 5.1.3.9 related survivability criteria with section 5.1.3.2 loads criteria. Specifically, other than use of crash loads from section 5.2.16.1 in the static structural analysis, the RSIP should not merge section 5.2.6 static structural analysis with crashworthiness analysis of section 5.2.16.1. Also, crash loads should not be merged with loads analysis of section 5.2.2. Finally, for cases where crash loads result in lower analytical margins than loads per section 5.2.2, separate analytical margins and static test load cases should also be provided for the most critical loads from section 5.2.2.

6.4.16 Establishment of design allowables. RSIP execution should characterize mechanical and physical properties per sections 5.1.9.3, 5.2.1, and 5.2.17 based on methodologies provided in MMPDS and CMH-17. RSIP characterization efforts should include consideration of potential structural integrity impacts due to interactions between fatigue enhancement methods (such as cold working holes or use of interference fit fasteners) and corrosion prevention processes (such as anodization of fatigue critical aluminum structure). For composite structure, many required design allowables may not be available without design development testing per section 5.2.17. For bonded and co-cured structure, design development tests will be required to establish design bond allowables for selected materials and processes. For composite structure, the static strength decreases with increased hole diameter and the fastener bearing allowable will be controlled by hole durability (elongation) as determined from design development tests. Also, for composite structure with the potential for impact damage, design development tests are used to evaluate the influence of impacts up to the damage threshold or defined limit.

6.4.17 Static strength analysis cases requiring yield loads and deformation. When implementing section 5.2.6 requirements to substantiate sufficient static strength, the materiel developer should note that strength substantiations related to certain structural components may not always require the contractor to perform every form of static structural analysis mentioned in section 5.2.6, including analysis of yield load conditions and deformation analysis. To avoid delays in RSIP implementation, the contractor and materiel developer should ensure that an updated structural design criteria report in accordance with section 5.1.3 clearly indicates any such exceptions or special cases for MAA approval prior to performance of the analysis. At minimum, the structural design criteria should require analysis of yield load conditions for PSEs in cases where induced residual stresses due to material yielding or detrimental damage could affect the component's fatigue strength, damage tolerance, or durability. Also, to ensure that beam webs in structural elements will not experience permanent deformation, the structural design criteria should at minimum require analysis of yield load conditions in cases where webs are allowed to buckle below yield load levels. Regarding deformation analysis, the structural design criteria should require deformation analyses for evaluation of selective failure modes (such as, loss of clearance, bearing seizure due to thermal loading, and beam column analyses).

6.4.18 Other weapons effects. Weapons firing should not degrade engine performance or weapons sighting capability.

6.4.19 Testing to failure. In certain cases, full-scale test results may verify that the structure meets performance requirements of the rotorcraft system specification without structural failure of the test article. In such cases, the procuring government agency should consider extending the structural testing to confirm predicted failure modes and consequences in accordance with section 5.2.18. The purpose of extended testing should be to (1) demonstrate the effective application of NDI and structural health monitoring to the structure in accordance with section 5.3.7.4, (2) understand structural constraints on future modification programs, and (3) provide sufficient data to validate analysis methods, models, and procedures. Extended testing may include testing at increased load levels as discussed in section 5.3.1, or at increased cycles as discussed in section 5.3.5.1. Considerations related to extending tests should prioritize safety of flight structures. Without available test articles with relevant failure modes generated during structural tests, challenges related to demonstrating effective applications of structural health monitoring increase. Modification programs may include changes in the structural design envelope per section 5.1.3.1 or changes in the design service life, design component retirement intervals, or design usage per section 5.1.2. Without demonstrating failure modes and consequences via full-scale tests, modification programs will require additional full-scale testing to account for changes in the structural envelope, service life, retirement interval, or usage may require additional testing. More importantly, the necessity of design changes for the modification program may be unclear without either prior testing to failure, or otherwise sufficient testing to validate analysis methods, models, and procedures. When the procuring government agency determines not to test to failure, the agency should consider arranging for storage or continued availability of the test article and test facilities for use in determining the extent of design changes necessary for future modification programs.

6.4.20 Subsystem tests (prior to first flight). For subsystems that are not rotorcraft structure, test requirements are not part of RSIP (for examples, see test requirements in MIL-STD-461, MIL-STD-1798, and ADS-50-PRF). However, test programs should schedule certain subsystem testing to be completed prior to first flight to ensure that the subsystems pose no impacts to structural integrity during flight testing. Examples of subsystems with potential impacts to structural integrity include engines, drivetrains, flight control systems, electrical systems, and hydraulic systems. For the purpose of this guidance, subsystem tests with potential impacts to structural integrity include system integration laboratory testing associated with software verification for each subsystem. Although exemplary rather than exhaustive, the following subsections provide specific supplementary guidance related to seats and fuel tanks.

6.4.20.1 Crew seat tests (prior to first flight). All crew and passenger seats installed in the flight test rotorcraft plus all associated restraints, harnesses, and mounting structure in the rotorcraft should be statically tested to design limit crash loads or have completed dynamic drop tests to design limit crash conditions prior to first flight. In additional, functional tests of mechanical features such as inertia reels, release mechanisms, seat rails, and energy-absorbing structure should also be completed prior to first flight.

6.4.20.2 Fuel tank tests (prior to first flight). All fixed internal tanks, removable internal tanks, and external tanks should be tested to proof pressure, have completed "slosh and vibration" testing and drop testing in accordance with rotorcraft program requirements prior to first flight.

6.4.21 Detailed guidance related to structural demonstration. ADS-51-HDBK and ADS-24 contain detailed historical guidance related to structural demonstration flight testing of rotorcraft per section 5.3.10.2.

6.4.22 Recommended maintenance actions related to damage tolerance substantiation of inspection intervals. The damage tolerance substantiation of inspection intervals and procedures provided in accordance with section 5.4.3.1 should include recommended criteria for determining replacement or repair of each component.

6.4.23 References. This section includes documents recommended for additional information or as examples. See section 2 for documents required in sections 3, 4, and 5.

a. ASTM-E177, *Standard Practice for the Use of Terms Precision and Bias in ASTM Test Methods*. (Copies of this document is available online at http://www.astm.org or from the American Society for Testing and Materials, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania, United States, 19428-2959)

b. ASTM-E456, *Standard Terminology Relating to Quality and Statistics*. (Copies of this document is available online at http://www.astm.org or from the American Society for Testing and Materials, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania, United States, 19428-2959)

c. *Fractography*, Volume 12 of *ASM Handbook* (formerly *Ninth Edition, Metals Handbook*), ASM International, 1987.

d. 14 CFR 29, Code of Federal Regulations, Title 14, Part 29 *Airworthiness Standards: Transport Category Rotorcraft*, also known as Federal Aviation Regulations (FAR) Part 29. (Copies of the FAR are available at https://www.faa.gov)

e. JSSG-2009A, *Air Vehicle Subsystems*, 20 November 2015. (Copies of JSSG documents are available online at http://quicksearch.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094)

f. ADS-50-PRF, *Rotorcraft Propulsion Performance and Qualification Requirements and Guidelines*, 15 April 1996. (Copies of U.S Army Aeronautical Design Standards are available at https://www.amrdec.army.mil/amrdec/rdmr-se/tdmd/StandardAero.htm)

g. ADS-29 (inactive), *Structural Design Criteria for Rotary Wing Aircraft*, September 1986. (Copies of Cancelled or Inactive U.S Army Aeronautical Design Standards are available by following instructions at https://www.amrdec.army.mil/amrdec/rdmr-se/tdmd/StandardAero.htm)

h. ASTM-E1823, *Standard Terminology Relating to Fatigue and Fracture Testing*. (Copies of this document is available online at http://www.astm.org or from the American Society for Testing and Materials, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, Pennsylvania, United States, 19428-2959)

i. USAF Structures Bulletin EN-SB-08-012, *Nondestructive Inspection Capability Guidelines for United States Air Force Aircraft Structures*. (Copies of U.S Air Force Structural Bulletins are available from AFLCMC/EZSS, Bldg. 28, 2145 Monahan Way, Wright-Patterson AFB, OH 45433-7017; 937-904-5476; Engineering.Standards@US.AF.MIL)

j. MIL-STD-461, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*. (Copies of Department of Defense Standards are available online at http://quicksearch.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094)

k. MIL-STD-1798, *Mechanical Equipment and Subsystems Integrity Program*. (Copies of Department of Defense Standards are available online at http://quicksearch.dla.mil or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094)

l. ADS-24 (inactive), *Structural Demonstration*, November 1985. (Copies of Cancelled or Inactive U.S Army Aeronautical Design Standards are available by following instructions at https://www.amrdec.army.mil/amrdec/rdmr-se/tdmd/StandardAero.htm)

6.5 Tailoring guidance for contractual application. To ensure proper application of this standard practice, tailored applications of the requirements in sections 4 or 5 of this standard should require concurrence of the procuring government agency, PEO, service designated user representatives, and the service design control activity (MAA). Tailored applications of this standard practice to joint rotorcraft programs should require concurrence of user representatives and design control activities for each service. For existing contracts, further tailoring of this standard practice (for example during updates of the RSIP) should also require concurrence of contractor designated technical fellows or safety committee representing a structural integrity standpoint.

6.6 Subject term (key word) listing.

airworthiness
blade stall
compressibility
corrosion prevention and control
damage tolerance

developmental test
durability
enhanced safe life
fail safe
fatigue
flight test
full-scale test
helicopter
loads spectrum
nondestructive inspection
principal structural element
proof test
safe life
safety of flight
service life
static test
structural design criteria
structural design envelope
structural test

CONCLUDING MATERIAL

Custodians:
Army – AV
Navy – AS
Air Force – 11

Preparing activity:
Army – AV
(Project 1520-2016-001)

Review activities:
Navy – CG

Industry Associations:
The review team helping to develop this standard practice includes industry representation by more than twenty-five structural integrity experts from four major rotorcraft design prime contractors. The team also includes more than fifteen structural integrity experts from other contractors, companies, or organizations, as well as foreign government representatives.

NOTE: The activities listed above were interested in this document as of the date of this document. Since organizations and responsibilities can change, you should verify the currency of the information above using the ASSIST Online database at https://assist.dla.mil.