HIGHLY ACCELERATED LIFE TESTING
AND
HIGHLY ACCELERATED STRESS SCREENING METHODOLOGY

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1 REPORTING REQUIREMENT

The Under Secretary of Defense for Acquisition, Technology, and Logistics (USD(AT&L)) submits this report in response to the National Defense Authorization Act for Fiscal Year 2016, House Report 114-102, pages 188–189, which requested the USD(AT&L), in consultation with the acquisition executives of each Service, to assess the value, feasibility, and cost of greater utilization of highly accelerated life testing (HALT) and highly accelerated stress screening (HASS) methodology to shorten design and development timelines, reduce system and component testing and life cycle costs, and enhance reliability of critical military system components and subcomponents. This report addresses the findings of the assessment, including a description of plans regarding the use of such methodology in ongoing or future defense programs, along with any recommendations to improve the Department's efforts.

2 HALT/HASS TESTING

2.1 Background

The purpose of reliability engineering is to influence system design in order to increase mission capability, decrease logistics burden, and decrease life cycle cost of the product. Properly planned, this early action reduces cost and schedule risks by preventing or identifying reliability deficiencies early in development. Reliability engineering includes a set of design and test activities that start early during the Materiel Solution Analysis phase and continue through the Operations and Support phase. Accelerated test methods such as HALT and HASS are well-recognized industry reliability test and screening methods.

The most common application of accelerated testing such as HALT and HASS occurs with electronic equipment. HALT is used during development to determine the operating and destruct limits. HASS is used during production to screen components to detect latent flaws. Although general guidelines exist for implementing HALT and HASS, tailoring is needed on each item and application. HALT and HASS are focused on detecting and eliminating failure modes at the component and subcomponent level, so that corrective actions can be implemented before the start of system-level testing.

A comprehensive test and evaluation (T&E) program includes practices such as HALT and HASS to discover and mitigate failure modes throughout the development and production process. Although general guidelines exist for implementing HALT and HASS, tailoring is needed on each item and application. HALT and HASS are focused on detecting and eliminating failure modes at the component and subcomponent level, so that corrective action can be taken.

2.2 Applicability

2.2.1 HALT

HALT is an activity implemented along with design verification tests, which are planned and conducted during the design and development process. HALT is not a compliance test and does not replace qualification testing requirements. HALT, which is part of an overall comprehensive T&E program, will quickly reveal failure modes that would (could) occur during the life of the product under normal operating conditions.

HALT is a form of accelerated testing used to determine whether the item (e.g., components, subcomponents) can withstand environmental stresses. Early in the design and development processes, HALT is conducted in a specialized environmental chamber to expose items to a full range of operating conditions. During HALT, environmental stresses are controlled and incrementally applied until they eventually reach a level beyond that which is expected during operational use. Stresses applied during HALT are typically temperature and/or vibration; however, other stresses, such as electrical or mechanical, are also considered. HALT, utilizing combinations of these stresses, is recommended to emulate real-world conditions.

Exposing items to environmental stresses forces failures in order to understand operational margins and identify weaknesses in the design that need corrective actions. If the item (component or subcomponent) survives HALT, it passes the test. Any deficiencies identified during HALT are inspected and analyzed to guide refinement of the design and elimination of the cause(s) of failure.

Reliability growth testing (RGT) is conducted in parallel with HALT to provide engineering confirmation and feedback. Information captured from previous testing and analysis is used to ensure that any areas of concern are properly instrumented and tracked for future tests. Corrective actions are taken to mitigate the reliability deficiencies that arise during testing. Examples of corrective actions include engineering redesign of mechanical components, software recoding, and adjustments to training practices.

After the corrective actions are in place, accelerated tests can also be used to quickly verify the corrective actions. Dynamic modeling and simulation (M&S), finite element stress and heat transfer analysis, and component fatigue analysis toolsets are some of the methods utilized to predict failure mechanisms and support reliability assessments of the proposed design and any subsequent design revisions.

2.2.2 HASS

HASS is discovery testing as compared to compliance testing. HASS identifies inferior/ defective items by exposing the production item to accelerated stresses to identify defects early, before a large number of items with similar flaws are produced. HASS is implemented to ensure the reliability of production line products. HASS is one of several screening approaches used by the Department of Defense (DoD)/industry to provide the opportunity to substantially improve fielded product reliability and reduce overall cost of ownership.

HASS uses accelerated stresses (beyond the product specifications) on production items to identify latent and intermittent defects that are a result of a problem in the manufacturing process. The stresses applied during HASS are based on operational and destructive stress limits established during HALT. HASS is usually not recommended unless a comprehensive HALT has been performed.

3 DoD Assessment

The DoD assessment of HALT in subsection 3.1 and HASS in subsection 3.2 was made in consultation with the acquisition executive of each Service. The Service inputs are included in section 4 of this report. Subsections 3.1 and 3.2 provide an assessment of the value, feasibility, and cost of greater utilization of HALT/HASS to shorten design and development timelines, reduce system and component testing and life cycle costs, and enhance reliability of critical military system components and subcomponents.

3.1 HALT

Value: HALT is an effective tool that is part of a comprehensive T&E program. The value of HALT is the early discovery of failure modes and failure mechanisms and the mitigation of those failures during the development process.

Feasibility: The most common application of HALT occurs with electronics; HALT is also applicable on mechanical, pneumatic, hydraulic, and optic systems. HALT is applicable across commodities, such as electronics, missiles, aircraft, vehicles, and software. Determining the level (component/subcomponent) at which HALT should be implemented is a critical part of the test planning phase. In limited instances, HALT can be applied at the system level. For example, HALT can be a part of combat vehicle durability testing and aircraft durability testing. HALT should generally be conducted in parallel with RGT to improve design and reduce risk. One of the key challenges for a HALT program is to conduct HALT early enough in the schedule to allow sufficient time for design iterations. Implementing HALT can help expose failure modes in the increasing complexity of today's new technology, which makes it difficult to predict failure modes and mechanisms.

Cost of greater utilization: The cost of fixing errors increases as the system matures. Earlier identification of problems helps to avoid costly corrective actions and schedule delays late in development. Trade studies may be needed during the development phase to ensure a positive return on investment for implementing design changes to correct failure modes and failure mechanisms discovered during HALT (for development). HALT needs to be included as part of the Engineering and Manufacturing Development (EMD) request for proposal (RFP) so that the activities are part of the overall cost.

Shorten design and development timelines: HALT will not necessarily shorten design and development timelines. Using HALT will identify design weakness during development so that corrective actions can be implemented early to avoid costly corrective actions and schedule delays late in development. Using HALT as well as other accelerated or conventional growth test methods will improve reliability.

Reduce system and component testing: HALT will not reduce the need for system and component testing, but HALT can reduce the time to execute the testing by reducing or eliminating some failure modes from occurring during those tests. Using HALT will identify design weakness early in development. Conducting HALT in parallel with other RGT provides engineering confirmation and feedback during development. Information captured from previous HALT and analysis is used to ensure that any areas of concern are properly instrumented and tracked for future tests.

Reduce life cycle costs: HALT alone will not directly reduce life cycle costs. Correcting failure modes earlier during HALT instead of during system testing is cheaper and will reduce research and development costs. Using HALT will make the product more robust before moving to system-level testing. To maximize results, HALT should be applied early. HALT is best suited and most economically implemented to make design changes at the component or subcomponent level in which the failure modes and failure mechanisms are directly traceable.

Enhance reliability of critical military system components and subcomponents: As HALT is conducted with RGT, interim reliability goals are demonstrated through developmental test results. The design matures and reliability is tracked as the system moves through EMD and progresses toward a low-rate initial production (LRIP) decision. Systems with comprehensive reliability growth programs are more likely to meet their development goals than systems without such programs.

3.2 HASS

Value: HASS is an effective tool that is part of a comprehensive T&E program. The value of HASS is the early identification of latent or intermittent failures of production items before a significant number of the items have been produced.

Feasibility: HASS is most commonly performed at the component and subcomponent levels. Although currently the most common application of HASS occurs with electronic equipment, HASS is also applicable on mechanical, pneumatic, hydraulic, and optic systems. Determining the level (component/subcomponent) at which HASS should be implemented is a critical part of the test planning phase. Implementing HASS can help expose failure modes in the increasing complexity of today's new technology, which makes it difficult to predict failure modes and mechanisms.

Cost of greater utilization: The cost of fixing errors increases as the components are produced. The earlier a problem is identified in production, the easier it is to avoid costly corrective actions and schedule delays late in production. Trade studies may be needed during the production/ remanufacturing phase to ensure that a positive return on investment would be achieved via remanufacturing to address the failure modes discovered during HASS. HASS needs to be included as part of the Production and Deployment RFP.

Shorten design and development timelines: HASS will not shorten design and development timelines. HASS is used in production.

Reduce system and component testing: HASS will not reduce system and component testing because HASS is used on production items.

Reduce life cycle costs: HASS is best suited and most economically implemented at the component or subcomponent level in which the failure mode is directly traceable to the effects of the environment.

Enhance reliability of critical military system components and subcomponents: HASS is used in production.

4 HALT/HASS METHODOLOGY AT THE MILITARY DEPARTMENTS

4.1 Department of the Army

4.1.1 Plans and Policies

The Army has long acknowledged that HALT/HASS and similar reliability engineering activities are critical to substantially improving the reliability of acquisition systems. Beginning in December 2007, the Assistant Secretary of the Army (Acquisition, Logistics, and Technology) instituted policy for the use of key reliability best practices in acquisition programs.

The list of best practices emphasizes the use of design for reliability (DfR) tools—which includes HALT/HASS as well as other accelerated test methods, physics-based probabilistic analysis, and M&S—in conjunction with reliability program management tools such as a closed-loop failure reporting, analysis, and corrective action system (FRACAS) as the basis of a holistic approach to reliability growth. In the years since, the Army reiterated its policy to use reliability engineering best practices, broadened the policy applicability to all systems, and elevated the guidance to a regulation (Army Regulation (AR) 702-19) in March 2015.

Further, the Army developed tools to aid the Army acquisition community in applying reliability engineering best practices, including HALT/HASS, to acquisition programs. These tools include the following:

- A DfR handbook (Army Materiel Systems Analysis Activity (AMSAA) TR-2011-24).
- Reliability scorecards to check progress and assess risk.
- Sample contract language to obtain DfR activities, including HALT/HASS.
- Training modules on DfR methods, including physics-of-failure (PoF) and HALT/HASS methods, provided through the Army's Center for Reliability Growth.

AR 702-19, “Reliability, Availability, and Maintainability,” dated April 28, 2015:

- AR 702-19 sets forth policies for planning and managing Army materiel systems’ reliability, availability, and maintainability (RAM) during development, procurement, deployment, and sustainment. It applies to all combat or mission-essential developmental, nondevelopmental, commercial items adapted for military use, and product-improved hardware and software systems. Materiel systems also include but are not limited to stand-alone or embedded automatic data processing equipment hardware and software, support and ancillary equipment comprising the total materiel system, and multi-Service materiel systems when the Army is lead Service.

- With regard to RAM engineering and design, AR 702-19 states that HALT and/or M&S shall be planned and funded prior to prototype fabrication to support the establishment of profiles for environmental stress screening (ESS). The ESS planning and profiles will be developed prior to production for all Army acquisitions that include electronic, electrical, or electromechanical hardware.

- AR 702-19 defines ESS as the removal of latent part and manufacturing process defects through application of environmental stimuli prior to fielding the equipment. ESS and HALT will be used to ensure that reliable, available, and maintainable systems are produced and deployed that will be devoid of latent part and manufacturing process defects.

Department of the Army Pamphlet (DA PAM) 70-3, “Army Acquisition Procedures,” dated March 11, 2014:

- DA PAM 70-3 provides Army acquisition procedures for all aspects of the materiel acquisition process. In addition to covering Army implementation of the DoD 5000-series acquisition guidance, the pamphlet provides Army unique procedures used in the materiel acquisition process. It is designed to provide guidance in enough detail to facilitate the exercise of discretion and prudent business judgment; to structure a tailored, responsive, and innovative acquisition; and to give materiel developers (MATDEVs) the flexibility to manage their program and accept reasonable risks. Tailoring should result from discussions between the MATDEV, the combat developer, and the Milestone Decision Authority (MDA).

- With regard to the relationship of contracts with reliability and maintainability (R&M) management, DA PAM 70-3 states that solicitations and contracts should provide the MATDEV with visibility into system development plans and progress so as to ensure that systems are designed to meet R&M requirements, that R&M performance can be effectively tested, and that compliance with requirements can be evaluated. When establishing system specifications for contracting purposes, the MATDEV may establish separate requirements for critical functions or for subsystems that are high risk, are safety critical, or have a high repair/replacement cost. In design contracts, the MATDEV should encourage early investment in robust design, PoF, M&S, manufacturing, and quality, as these activities can have a positive impact on end-product reliability. In production contracts, the MATDEV should encourage the use of statistical process controls and other variability reduction techniques. This will have general payoff in reliability enhancement but should be of special concern in processes, operations, parameters, and characteristics that are critical, special, or major.

- The MATDEV should coordinate with the contractor to ensure that appropriate consideration is given to the following factors in program planning:
  - Failure modes, effects, and criticality analysis (FMECA).
  - A test, analyze, and fix process.
  - Use of integrated product teams to independently assess and monitor the growth process.
  - System-level testing to confirm achievement of interim and final R&M requirements.
  - A closed-loop FRACAS.
  - Accelerated growth testing – testing at stress conditions higher than normal to precipitate failures at a faster rate.
- With regard to R&M engineering and design, DA PAM 70-3 specifies that design maturity is an objective in each development program. For early design maturity, MATDEVs should encourage use of the following:
  - Computer-aided R&M design (for example, vibration/thermal analysis and failure mechanism analysis), optimization, and simulation programs when feasible.
  - Component-level R&M testing (hardware and software) well before integration into system prototypes, early system-level R&M testing, and accelerated life testing. The MATDEV should fund for test items (components through systems) and operating time throughout the acquisition process.

To assist the acquisition community, AMSAA published a technical report in August 2011 dealing with the DfR process (TR-2011-24).

- The DfR process blends aspects of statistics, probability and reliability theory, and engineering analysis throughout a product life cycle to evaluate, predict, and verify the application of robust design. Through application of DfR practices, the demand for highly reliable systems can be met while ensuring that the latest methods for the assessment of robust design and reliability risk management are properly addressed.
- TR-2011-24 discusses, in brief, the mathematic and engineering approaches involved in the DfR process. It is designed to provide the next level of detail following the current Government Electronics and Information Technology Association Standard GEIA-STD-0009, “Reliability Program Standard for Systems Design, Development, and Manufacturing,” which covers the “what to do” of design and building inherently reliable systems. Although not directly intended to be a step-by-step guide, the details introduce the stepped approach to analyzing materiel from conceptual design through production.

Incorporation of the applicable design processes will help guarantee a robust final design while limiting design life cycle time and cost.

- Specific HALT/HASS aspects of TR-2011-24 are the following:

  - Early in the design processes, HALT is utilized to expose early prototypes and existing components to the full range of expected operating conditions, within a controlled environment. Any deficiencies identified during HALT are inspected using a PoF approach or are addressed directly in the refinement of the conceptual design. At this phase, PoF computer-aided design (CAD) practices including dynamic M&S, finite element stress and heat transfer analysis, and component fatigue analysis toolsets are utilized to predict failure mechanisms and conduct reliability assessments on the proposed design and any subsequent design revisions.

  - As the iterative design process progresses, early prototype quality testing is employed to validate design changes and assumptions as well as the results derived from HALT and PoF analysis. Using the iterative DfR process provides benefits in reduction of early-on physical testing and traditional test-fix-test cycles, while ensuring that the reliability level of the preliminary design review design candidate is equal to or exceeds the minimum level identified by reliability growth modeling. Estimation of the design candidate's initial reliability can be done through a combination of M&S along with lower level testing. Milestone B requirements are typically met at this point, and the design process moves to the complete system prototype phase.

  - Post-Milestone B, complete system prototypes experience exhaustive testing to capture both hardware and software reliability metrics. RGT is conducted in parallel with HALT, accelerated life testing, and environmental testing to provide engineering confirmation and feedback data for mathematical modeling. Information captured from previous PoF and HALT analysis is leveraged during test to ensure that any areas of concern are properly instrumented and tracked. Training strategies are also investigated for comprehension and effectiveness.

  - As LRIP begins, HASS, ESS, or the like is implemented to ensure production-line reliability. LRIP assets enter operational test and evaluation for verification that final designs meet operational reliability requirements. Engineering rework, software recoding, and training practice corrective actions are identified for any failure modes that are identified through HASS, ESS, or operational testing. PoF and HALT techniques are employed to expedite the time between any potential failures and corrective actions. They also help to reduce the length and complexity of any necessary follow-on T&E. This reduces time between LRIP and a move to full-rate production and fielding.

  - HALT is a method aimed at discovering and then improving weak links in the product in the design phase. HALT is performed to precipitate and detect latent defects/weaknesses in early design stages that may, or may not, be uncovered in conventional qualification methods to improve reliability. By simulating the item with stresses beyond what it would normally see in field use, HALT compresses the test time required and quickly reveals weaknesses that would cause field failures. Moreover, HALT stresses the item to failure in order to assess design robustness.

- Chapter 7 deals exclusively with HALT by addressing the following areas: approach, failure analysis, corrective action verification, database management, test processes, and test procedures.

- Chapter 8 deals with HASS, which is treated as a quality control activity used to maintain reliability during the production process.

  - HASS is a compressed form of HALT applied to the product to induce, detect, and fix weaknesses and flaws occurring during production. The screening uses the highest possible stresses determined in HALT, well beyond the qualification levels, in order to gain time compression.

  - HASS may use the cross-over-effect technique by applying stresses that do not occur in the field to uncover flaws that might show up in the field due to other stresses. The screens must be of acceptable fatigue damage accumulation or lifetime degradation. HALT is utilized to improve the design reliability by removing design weakness. The stress profiles for HASS can then be extracted from HALT. Therefore, HASS is generally not possible unless a comprehensive HALT has been performed as, without HALT, fundamental design limitations may restrict the acceptable stress levels to a great degree and could prevent the large accelerations that are possible with a very robust product.

  - With the proper application of HALT, the design will have several, if not many, of the required lifetimes built into it and so an inconsequential portion of the life would be removed during the HASS analysis. The goal is to determine how much life is left in the system after HASS and not how much has been removed. Because the screening has to be performed on every part, proof of safety to ship the product after repeated HASS as well as effectiveness is essential.

  - HASS can be performed at many levels within a system. When dealing with components, HASS may be carried out on components that are not mature, are susceptible to damage, or experience new operating conditions. HASS can also be utilized for subassemblies such as power supplies, hard drives, servo motors, communication radios, and engines. Assemblies and complete systems can also benefit from HASS such as avionics assemblies and unmanned ground and aerial vehicle systems. Another immense advantage of HASS is the ability to provide a cost-effective approach to induce multi-axis vibration conditions on the product. This can be a reasonable alternative to single-axis electrodynamic shakers.

  - Chapter 8 deals exclusively with HASS by addressing the following areas: approach, precipitation, detection, failure analysis, corrective action verification, and database management.

4.1.2 Current Use

HALT is performed to precipitate and detect latent defects/weaknesses in early design stages to improve reliability. By exposing the item to stresses beyond what it would normally see in field use, HALT compresses the test time required to surface eventual field failure modes. HALT can be performed in days whereas a traditional life test using field stresses may take years.

HALT is not intended to demonstrate that the product will function properly at a specified stress level (i.e., it is not a reliability demonstration test). It is intended to quickly determine weaknesses during the design stage so that they can be eliminated when it is cost-effective to do so.

When performed properly, HALT addresses system reliability in two ways: (1) it improves the system's resistance to irregular events (i.e., lowers the system's failure rate during its "useful" life period) and (2) it lengthens the system's useful life (uncovers components of the system that wear out first so that they can be improved.) For this to happen, the maximum stress boundaries must be explored.

HALT is not prescriptive. A plan can be generated; however, because HALT is a discovery test, flexibility is required. If the test is performed and no failures are uncovered, the test is worthless. Failure is expected and addressing the failures is required for the test to be successful.

HALT is most effective when performed in the design stages. It is complementary to other forms of M&S such as finite element analysis, fatigue analysis, and PoF analysis. It is an excellent test for stressing interconnects, which are difficult to model using other means and are a common source of failure. It can and should be performed at the lowest subassemblies up to intermediate subsystems. However, because of the nature of the equipment, the heavier the subsystem, the more difficult it becomes to input the required energy to effectively stress the components.

HASS is a method to rapidly expose and improve manufacturing flaws that would cause field failures. It is complementary to HALT (uses the same equipment and knowledge learned from HALT) and replaces traditional ESS. The intent of both HASS and ESS is to prevent poorly produced products from being fielded (products that would fail short of their desired life). The main advantage of HASS is that it can be done in a fraction of the time that it would take to perform ESS because much higher stresses are being applied. The main disadvantage is that it requires specialized equipment (just like HALT) and can be applied only on fairly small and light systems as mentioned in the previous paragraph.

4.1.3 Path Forward

The Army strongly endorses a holistic approach to improving system reliability that includes, but is not limited to, HALT/HASS. HALT and HASS are powerful and useful methods to stress a component to failure in order to quickly find weaknesses in the design. Surfacing failure modes and correcting them are central to improving system reliability. When HALT and HASS are used, it should be in conjunction with other reliability engineering activities, such as engineering analysis, M&S, and accelerated test methods, as part of a comprehensive DfR effort.

As outlined above, the Army's recognition of using HALT/HASS as a valuable tool for reliability improvement, as appropriate, is well documented in policy and practice. The Army encourages, or prescribes, HALT/HASS as a best practice and funded contract direction when it is appropriate to do so. The Army continues to find opportunities to use HALT/HASS smartly via its continuous emphasis on reliability improvement during program and design reviews and actively advocates for the inclusion of HALT/HASS into acquisition contracts when it makes sense to do so. The Army is currently developing a new best practices pamphlet that will accompany AR 702-19 and describe the various methods for succeeding in the application of DfR to various types of programs. To ensure that this is an enduring emphasis, this pamphlet will address the successful application of HALT/HASS.

4.2 Department of the Navy (Navy/Marine Corps)

4.2.1 Plans and Policies

The Department of the Navy (DON) recognizes the importance of system and component reliability in improving system operational effectiveness and suitability and reducing overall system operating and sustainment costs. The Navy and systems command (SYSCOM) chief engineers also acknowledge that HALT and HASS are two of many commonly used and well-accepted practices used by vendors developing reliable Navy and Marine Corps capabilities and solutions. The vendor selects the combination of methods it uses to achieve its contract specification, which includes standard R&M engineering activities integrated with real-time and accelerated test methods, physics-based probabilistic analysis, and M&S—in conjunction with a closed-loop FRACAS.

The current Secretary of the Navy Instruction (SECNAVINST) 5000.2E, "Department of the Navy Implementation and Operation of the Defense Acquisition System and the Joint Capabilities Integration and Development System," specifically identifies the program manager (PM) as the authority responsible for ensuring Joint Capabilities Integration and Development System requirements such as the sustainment key performance parameter (KPP), which consists of three interconnected factors: availability, reliability, and ownership cost.

- SECNAVINST 5000.2E provides for review of critical program metrics such as reliability in periodic "Gate Reviews" that align with specific program milestones such as Capability Development Document (CDD) approval, RFP approval, and Milestone B. These Gate Reviews continue during the EMD phase to provide the program MDA with visibility into the PM's decision processes and to provide PM support for programmatic decisions and business case analyses within program cost/schedule/performance tradespace.

- Specifically, the Gate 4 review approves the formal system design specification (SDS) for Acquisition Category (ACAT) I, IA, and selected ACAT II programs and authorizes a program to proceed to Gate 5 (RFP) and then Milestone B/source selection. An SDS is produced upon successful completion of a system requirements review and shall be used to develop the technical performance specifications of the formal EMD phase RFP. Gate 4 review will ensure the following:

  - The SDS reflects the design parameters necessary to provide and satisfy the CDD KPPs, key system attributes, and other attributes.
  - The system is designed for producibility, operability, interoperability, reliability and maintainability.
  - DON critical design criteria are defined in areas that are applicable.
  - Configuration Steering Board changes are addressed.
  - Program health is reviewed for satisfactory cost, schedule, risks, and budget adequacy, and areas of concern are discussed and resolved.

- The SDS should normally have significant industry input at the prime contractor and subcontractor levels. This input may be achieved via the use of a draft RFP and a draft SDS when authorized by the MDA in the acquisition strategy. Reliability-focused items in the SDS would include the following:
  - Basic functional requirements.
  - The family of system specifications including tailorable and non-tailorable specifications, interface requirements, and detailed design standards.
  - Government oversight that delineates the key responsibilities and engagement points for ensuring effective prosecution of design and construction activities.
  - Division of responsibilities document that addresses lead activities (both Government and industry) for various aspects of design and manufacturing.
  - Major processes that will be employed to ensure successful implementation of the SDS (e.g., integrated master schedule, manufacturing and assembly plan, work breakdown structure, commitment tracking system, earned value management).
  - Threshold attribute values for operability, producibility, reliability, and maintainability.

- The SDS will not direct prime contractors and subcontractors to implement specific techniques or capabilities such as HALT/HASS to meet an element of the specification, unless that technique or capability is agreed upon by all parties. In normal practice, a data item description listed in the contract data requirements list (CDRL), which is part of the RFP, will direct the vendor to describe how it will achieve capabilities and specifications identified in the SDS. To achieve the desired system reliability as described in the CDD, a vendor may identify tools such as HALT/HASS in its statement of work (SOW) as the vendor competes for a contract award. PMs and their team will assess the proposed reliability growth program as part of source selection.

The DON’s R&M Engineering Executive, following the example set by Office of the Director of Operational Test and Evaluation staff, established the Integrated Reliability Software Suite, which consists of ReliaSoft’s Synthesis Master Suite of R&M engineering and management tools, as the Navy standard reliability toolset available for all DON acquisition programs to ensure consistency of process and standard implementation across the DON acquisition enterprise.

Each SYSCOM has an R&M Engineering Lead and a community of practice within its systems engineering group that supports PMs. They ensure consistent implementation of tools, dissemination of best practices and lessons learned, and professional development across the acquisition programs and their engineering competency. They coordinate with the DON R&M Engineering Executive to maintain enterprise alignment.

4.2.2 Current Use

DON SYSCOMs (Naval Air Systems Command, Naval Sea Systems Command, Space and Naval Warfare Systems Command, and Marine Corps Systems Command) are the engineering experts that support PMs as they develop and field their systems. Fielding systems that meet stated reliability requirements starts in the requirements generation phase and is implemented in the RFP/SOW language. Although each SYSCOM has minor differences in implementation, the approach and results are the same for ships; submarines; aircraft; command, control, communications, computers, and intelligence systems; or armored vehicles.

The fundamental Navy approach to designing and assessing reliability is a combination of mandated requirements and activities implemented by the contractor using the methods it knows best to deliver a product that is affordable and meets requirements. However, this does not mean that the Government accepts vendor process and results without engagement or oversight. The development and implementation of RGT are a collaborative effort between the vendor and Government organizations, with a test readiness review conducted before starting test to review existing data and establish expectations. The vendor is almost always provided with the flexibility to conduct a HALT/HASS type test in place of a traditional reliability development growth test (RDGT) when required. Figure 1 is a redacted sample of a Reliability SOW. The acronym CAST refers to the contractor’s proprietary accelerated life cycle testing process.

HALT/HASS is not a ubiquitous solution. For example, system size, complexity, or environmental concerns may drive the contractor/Government team to choose a traditional RDGT over HALT/HASS. Contractors have also expressed concern that using HALT/HASS could drive the system beyond design limits and then to have failures, potentially driving extensive redesign that was not warranted.

The final exercise in developing and assessing system reliability is operational testing. Representatives from the Navy’s independent DON Operational Test Agencies (Commander, Operational Test and Evaluation Force and Marine Corps Operational Test and Evaluation Activity) are critical members of each acquisition program’s T&E Working Integrated Product Team and work to ensure that the system reliability data being generated through all techniques are adequate to forecast true system performance in an operational environment. They then conduct an independent assessment of system reliability during dedicated operational testing events, and these data are fed back to the SYSCOM and program offices, allowing them to assess developmental efforts and refine processes.

3.9.4 Reliability, Maintainability, and Built-in-Test Testing

3.9.4.1 Reliability Development Growth Test

For each RDGT, prior to testing, the Contractor shall conduct a test readiness review that ensures assets and facilities are available.

For each RDGT, the Contractor shall submit a RDGT Test Plan for approval. When authorized the plan becomes the basis for contractual compliance. The Government will observe the reliability growth testing.

Upon completion of each RDGT, the Contractor shall submit a final test report. (CDRL xxxx Reliability Development Growth Test Plan) (xxxx Reliability Development Growth Test Plans)

3.9.4.1.1 Environmental Control Unit

The Contractor shall subject the Environmental Control Unit (ECU) to reliability growth testing that identifies high failure items and BIT failures. The Contractor shall conduct either a classical Reliability Development Growth Test (RDGT) in accordance with the latest Contractor Reliability Development Test Plan or an accelerated test as described in the Contractor Combined Accelerated Stress Test (CAST) Program for all Avionics and Airframe Electronic Controllers (xxxx STL 00A0060)

3.9.4.1.2 Processor WRA

The Contractor shall subject the processor to reliability growth testing that identifies high failure items and BIT failures. Prior to the processor obsolescence redesign, the Contractor shall implement on the processor shop replaceable assemblies the CAST Program for all Avionics and Airframe Electronic Controllers (xxxx STL 00A0060), excluding Accelerated Mission Testing. The testing may be conducted in a phased approach where the first phase of testing is conducted to the specification limits and the second phase of testing defines the operational limits. After the processor obsolescence redesign, the Contractor shall implement the Accelerated Mission Testing portion of the CAST Program for all Avionics and Airframe Electronic Controllers (xxxx STL 00A0060) on the production representative processor WRA.

3.9.4.1.3 Infrared Receiver

The Contractor shall identify any infrared receiver Shop Replaceable Assembly (SRAs) or circuit card assemblies that would benefit from RDGT or CAST. The Contractor shall provide a list of any infrared receiver SRAs or circuit card assemblies recommended for testing, the rationale behind the selection of the item, and an estimated cost for the testing.

Figure 1. Navy Redacted Sample of a Reliability SOW

4.2.3 Path Forward

The DON intends to maintain the collaborative effort with its contractors and to continue expanding the use of technology to implement state-of-the-practice techniques to deliver reliable Warfighter systems in a cost-effective manner. Navy Headquarters and SYSCOM reliability engineers will ensure that Navy contracts drive contractors to use the appropriate tools to deliver this capability.

4.3 Department of the Air Force

4.3.1 Plans and Policies

HALT and HASS are unique, accelerated product reliability testing methods focused on finding defects during development, design, and manufacturing of products. The goal is to identify and correct the defects before they become reliability issues in the field.

HALT is a form of accelerated testing, the sole purpose of which is to determine whether the product can withstand the stresses being applied; if the test unit survives, it passes the test; if it does not survive, corrective actions will be taken to improve the product's design to eliminate future causes of failure and therefore improve the product robustness. In general, HALT will not quantify the reliability of the product under normal-use conditions; instead, these tests provide information about the types and severity levels that could be employed to design an accelerated test to assess life characteristics.

ESS involves the removal of latent part and manufacturing process defects through application of environmental stimuli before fielding the equipment. HASS uses the highest possible stresses, frequently well above qualification test levels, to reduce the time required to conduct the screen. HASS cannot be used if HALT has not been applied to the affected items during design. In such cases, "normal" ESS should be used.

HALT supports a robust design approach. HASS screens components to eliminate latent part manufacturing process defects.

DoD Instruction (DoDI) 5000.02, "Operation of the Defense Acquisition System," requires that the PM formulate a comprehensive R&M program using an appropriate strategy to ensure that R&M requirements are achieved. The program will consist of engineering activities including, for example, R&M allocations, block diagrams, and predictions; failure definitions and scoring criteria; FMECA; maintainability and built-in test (BIT) demonstrations; reliability testing at the system and subsystem level; and a FRACAS maintained through design, development, production, and sustainment. To achieve the program's reliability requirements, the PM is required to develop reliability growth curves (RGCs) that will reflect the reliability growth strategy and be employed to plan, illustrate, and report reliability growth.

As part of DoDI 5000.02, it is also required that reliability growth be monitored and reported throughout the acquisition process. PMs will report the status of R&M objectives and/or thresholds as part of the formal design review process and during systems engineering technical reviews or other reviews. RGCs will be employed to report reliability growth status at Defense Acquisition Executive Summary reviews.

DoD policy flows down through Air Force Policy Directives (AFPDs) into Air Force Instructions (AFIs). AFI 63-101/20-101 implements AFPD 63-1/20-1, “Integrated Life Cycle Management.” This instruction establishes the Integrated Life Cycle Management guidelines and procedures for Air Force personnel who develop, review, approve, or manage systems, subsystems, end-items, services, and activities (for the purpose of this report referred to as programs) procured under DoDI 5000.02.

AFI 63-101/20-101 contains and flows down R&M policy. This AFI requires that the PM develop an R&M program using an appropriate strategy to ensure that R&M requirements are achieved. Air Force policy establishes the PM to conduct an analysis of the user’s R&M requirements and flow them into the system specification and appropriate contractual requirements. Air Force policy requires the PM to document the reliability growth strategy, RGCs, and verification methods for R&M requirements.

4.3.2 Current Use

In the Air Force, programs must make an early determination of R&M test requirements in their Test and Evaluation Master Plans to ensure that the cost and schedule impacts are properly considered in the acquisition plans and in contractor proposals.

Air Force programs can minimize the cost of R&M testing by integrating R&M measurement data requirements and test conditions into equipment and system-level environmental and functional tests for the program. These tests then also serve as R&M evaluation tests to provide failure-rate/failure-mode data and removal-rate data to allow for identifying and correcting problems long before the scheduled system R&M demonstration tests.

Typical test planning data may include the following:

- System R&M Demonstration – Summarize the R&M tests and demonstrations to be included in the specification to verify conformance to quantitative R&M thresholds derived from the Initial Capabilities Document.

- R&M Test Sequence – Summarize a preliminary outline of the overall test sequence for the program. Depict the progression of required R&M testing from individual equipment/ subsystem through system performance tests to the system R&M demonstration described above.

- RGT– Summarize the RGTs, including equipment, subsystem, and system-level tests that are part of the reliability program. Address the amount of testing, test schedule, and resources available for achieving the requirements.

HALT is not applicable at the system level for complex systems; its use at a lower level will not reduce the amount of system-level testing required for development and qualification. By detecting and eliminating failure modes at the part, subassembly, or unit level, HALT could reduce the risk of a significant failure mode being discovered during system qualification testing.

Air Force contractors' most common application of HALT and HASS was found to be for electronic equipment. Although general guidelines exist for implementing HALT, it must be tailored for each application. It adds the greatest value to a program—and is most economically implemented—at the part, subassembly, or unit indenture level. On a case-by-case basis, the implementation of HALT at a particular indenture level may reduce the number of thermal cycles required for qualification at that level. However, it will not shorten system-level design and development timelines for complex systems.

As a general practice, the Air Force does not prescribe or direct the use of specific testing methods for reliability growth. Rather, the Air Force and its contractors aim to find opportunities to use the appropriate methods, tools and techniques for reliability improvement during design and development. HALT testing is one important tool in the tool-set of reliability testing, but there are others. Key steps to determine most effective testing methods are discussions of objectives and understanding of product characteristics.

Figure 2 provides a redacted example of Air Force HALT contract language.

Reliability Growth Plan: The contractor's Reliability Growth Plan shall describe the iterative design process, as the design matures to identify actual (via testing) and growth potential (via analysis) sources of failures. The Reliability Growth Plan shall also include the contractor's process for additional future design effort spent on correcting any R&M deficiencies in the product design or manufacturing processes discovered via the R&M modeling and simulation analysis. As part of the R&M program plan, the contractor shall include the following: (a) amount of testing, test schedule and resources available for achieving the specification requirements, (b) reliability growth planning curve as a function of each phase of lab and flight test hours, to grow the reliability to the specification value, (c) use of subsystem or equipment reliability growth testing to identify failure modes and BIT anomalies, which if uncorrected could cause the equipment to exhibit unacceptable levels of reliability performance during operational usage. The contractor shall conduct classical reliability development test or a Highly Accelerated Life Test (HALT) for all newly designed CFE and significantly modified CFE and GFE. The contractor shall make available for Government witness the growth testing, and (d) project and track system reliability growth with a statistical methodology (e.g., Crow AMSAA (NHPP), Crow Extended – Continuous Evaluation, AMSAA Maturity Projection).

Figure 2. Air Force Example of HALT Contract Language

4.3.3 Path Forward

The Air Force and its contractors continue to use design techniques that are best for the application, identify best-fit opportunities to use HALT/HASS for design reliability characterizations, and maintain a strong emphasis on reliability improvement and growth in its acquisition programs.

The Air Force strives to deliver reliable systems that meet sustainment KPPs for the required materiel availability and operational availability levels at an effective cost. Air Force systems engineers continue to acquire weapon systems through contracts and requirements that drive and incentivize contractors to grow and deliver systems at the reliability levels needed by Air Force commands and the Warfighter.

5 Conclusions and Recommendations

A comprehensive T&E program includes stress screening practices such as HALT and HASS to discover and mitigate failure modes throughout the development and production process. HALT and HASS are focused on detecting and eliminating failure modes at the component and subcomponent level, so that corrective action can be taken. HALT is used during development to determine the operating and destruct limits. HASS is used during production to screen components to detect latent flaws. Although general guidelines exist for implementing HALT and HASS, tailoring is needed on each item and application. The most common application of HALT and HASS is performed at the component and subcomponent levels. Determining the level (component/subcomponent) at which HALT and HASS should be implemented is a critical part of the test planning phase.

HALT/HASS methodology has been proven to be an effective tool that is part of a comprehensive T&E program. The value of HALT is the early discovery of failure modes and the mitigation of those failures during the development process, whereas the value of HASS is the early identification of latent or intermittent failures of production items before a significant number of the items have been produced.

Trade studies may be needed during the development phase to ensure a positive return on investment for implementing design changes to correct failure modes discovered during HALT (for development). HALT and HASS are parts of a holistic approach to improving system reliability, which may include conventional and accelerated test methods. HALT is and will continue to be considered, as appropriate, by each Service for its respective programs.

Abbreviations and Acronyms

ACAT	Acquisition Category
AFI	Air Force Instruction
AFPD	Air Force Policy Directive
AMSAA	Army Materiel Systems Analysis Activity
AOAT	Angle-Of-Attack Transmitter
AR	Army Regulation
BIT	built-in test
CAD	computer-aided design
CAST	Combined Accelerated Stress Test
CDD	Capability Development Document
CDRL	contract data requirements list
CFE	contractor-furnished equipment
DA PAM	Department of the Army Pamphlet
DfR	design for reliability
DoD	Department of Defense
DoDI	DoD Instruction
DON	Department of the Navy
ECU	Environmental Control Unit
EMD	Engineering and Manufacturing Development
ERDT	enhanced reliability development test
ESS	environmental stress screening
FMECA	failure modes, effects, and criticality analysis
FPCDV	Flat Panel Color Display Variant
FRACAS	failure reporting, analysis, and corrective action system
GFE	Government-furnished equipment

HALT	highly accelerated life testing
HASS	highly accelerated stress screening
KPP	key performance parameter
LRIP	low-rate initial production
LRU	line-replaceable unit
M&S	modeling and simulation
MATDEV	materiel developer
MDA	Milestone Decision Authority
MTBF	mean time between failures
NHPP	non-homogeneous Poisson process
PM	program manager
PoF	physics of failure
QTP	Qualification Test Procedure
R&M	reliability and maintainability
RAM	reliability, availability, and maintainability
RDGT	reliability development growth test
RDT	reliability development test
RFP	request for proposal
RGC	reliability growth curve
RGT	reliability growth testing
SDS	system design specification
SECNAVINST	Secretary of the Navy Instruction
SOW	statement of work
SRA	Shop Replaceable Assembly
SYSCOM	systems command
T&E	test and evaluation
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics