

TECHNICAL REPORT RD-TM-00-01

SYSTEM RELIABILITY FOR PRECISION MISSILERY

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January 2000



U.S. ARMY AVIATION AND MISSILE COMMAND
Redstone Arsenal, Alabama 35898-5000

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REPORT DOCUMENTATION PAGE			Form Approved OMB No. 074-0188	
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1. AGENCY USE ONLY		2. REPORT DATE January 2000		3. REPORT TYPE AND DATES COVERED Final
4. TITLE AND SUBTITLE System Reliability for Precision Missilery			5. FUNDING NUMBERS	
6. AUTHOR(S) Mike H. Danesh				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Commander, U. S. Army Aviation and Missile Command Aviation and Missile Research, Development and Engineering Center ATTN: AMSAM-RD-TM Redstone Arsenal, AL 35898			8. PERFORMING ORGANIZATION REPORT NUMBER TR-RD-TM-00-01	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE A	
13. ABSTRACT (<i>Maximum 200 Words</i>) This presents a top-level summary for a series of papers that will provide details on the development of a complex missile system. This series is based upon a systematic approach that should provide insight into the integration of scientific, engineering, and mathematical technologies necessary for development of a robust missile system. The thrust of these papers will be focused on reliability while keeping in mind the ever present constraints for cost, schedule, and political implications.				
14. SUBJECT TERMS			15. NUMBER OF PAGES	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UNLIMITED	

ACKNOWLEDGEMENTS

I dedicate this paper to Mr. Vernon Chance, Dr. Daniel Willard, and Dr. Herb T. David for their profound guidance and encouragement to solidify its foundation.

Also, I extend my gratitude to Ms. Paula Lasch for her outstanding effort in the preparation of this paper.

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I. INTRODUCTION

This presents a top-level summary for a series of papers that will provide details on the development of a complex missile system. This series is based upon a systematic approach that should provide insight into the integration of scientific, engineering, and mathematical technologies necessary for development of a robust missile system. The thrust of these papers will be focused on reliability while keeping in mind the ever present constraints for cost, schedule, and political implications.

A simple definition of missile reliability is as follows:

Does the missile accomplish its mission when called upon?

To answer this question, one has to plan and conduct a wide spectrum of reliability and other activities that may span a decade and encompass the following areas:

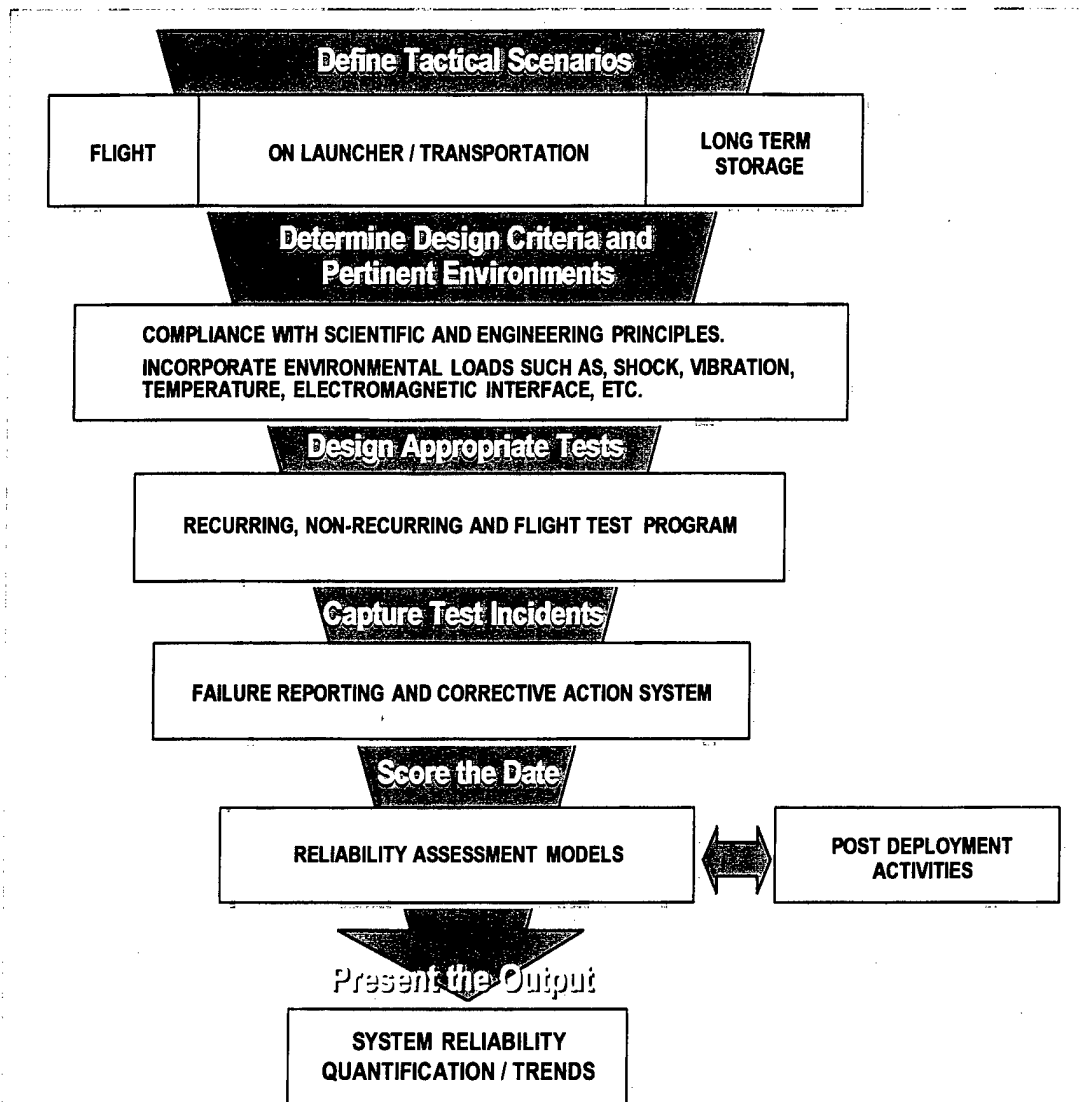
- A. Realistic Tactical Scenarios**
- B. Design Criteria**
- C. Testing**
- D. System Maturity Assessment**
- E. Manufacturing and Quality System**
- F. Post-Deployment Activities.**

As time permits, and with the participation of experts from a given field, a series of papers will be generated that will provide additional information and intricate mechanics in each of these areas.

II. OBJECTIVES

There are no panaceas for reliability. Each program poses its own unique requirements and challenges that demand discipline and intelligent management. In the following section, each area will be discussed in some detail with incorporation of associated subelements for completeness.

A simplified diagram for reliability process is depicted below:



III. OVERALL ARCHITECTURE

This section will expand on the six distinct topics that were stated in the introduction.

Although the subjects are unique, overlap and interrelation provide the continuum links for a comprehensive integrated process.

A. Realistic Tactical Scenarios

A missile system will be exposed to various environments during its designed life.

There are three distinct modes that are critical for consideration. **Flight Mission** has the highest stresses due to the broad and severe spectrum of mechanical, electromagnetic, and other phenomenon that are encountered. **On Launcher/Transportation** and **Long Term Storage** complete the environments for tactical missions. These environments include shock, vibration, thermal, humidity, salt, fog, rain, sand, nuclear, biological, chemical, etc.

The test program must duplicate the tactical loads as closely as possible. A well designed and tested canister should protect the missile from many of these environmental elements.

B. Design Criteria

A simple rule of thumb for a reliable design is to ensure that all performance capabilities are greater than the spectrum of all induced loads. The magnitudes of these differences are described in terms of margins and safety factors. Operational and long term storage requirements must be defined and uniformly flowed into functional hardware and software design parameters.

The applicable design points for electrical systems are parameters such as antenna gain, digital processor capability, probability of detection, management of internal and external noise, signal-processing efficiency, amplifier output power, etc. Some of the other aspects could be tensile strength or torsion for structural integrity, propellant/propellant bond line strength and strain capabilities, thermal batteries hermeticity, and software throughput. Built-In Test and Built-In Test Equipment (BIT/BITE) should be considered to the maximum extent possible.

The key for a successful design is a robust balanced aggregate of all design activities within the given constraints.

Establishment of the reliability requirement as an early part of the design process is a must. A possible approach is experience from predecessor or similar systems. Trade-off can be made between demonstrated reliability and advancement in technologies, for the establishment of realistic reliability requirements. Reliability allocation, prediction, and a detailed flow diagram for the system and subsystems with a hierarchical approach extending down to the circuit card or complex component levels are important. Designers could use this effort to identify redundancies, and other considerations.

Other critical areas are establishment of policies for selection of parts and materials, derating activities, proven soldering techniques, and corrosion prevention. These areas of engineering and science must be thought out to the extent that will ensure also the survival of the missile for the harsh environments due to the long term storage and on launcher/transportation.

Circuit simulation tools should provide valuable information to avoid "sneak paths" and insight to the impact of temperature and humidity induced by the long term storage. Design verification activities are necessary to provide an in-depth evaluation for complex functions, such as overall timing, electronic counter measures, etc.

Failure modes and effect, and physics of failure will complement other design objectives. This effort will provide important data for trade-off analysis for the cost of BIT/BITE, reliability, and maintainability as well.

Safety engineering requirements should be documented, and must be complied with.

C. Testing

The tactical environments must be thoroughly planned and conducted in a comprehensive test program. Therefore, activities such as power spectral densities for mechanical and electrical dynamics for the system and subsystems must be enveloped accordingly. Adequate margins should be applied to the test levels, in order to overcome any new challenges that the system may encounter in the field.

The test equipment should include parameters that address all functional aspects of hardware and software design. These parameters should be traceable to appropriate design points.

Powerful simulation programs such as Hardware-in-the-Loop (HWIL) can provide valuable data for other system performance capabilities. The output of this critical effort can immensely enhance the data that is generated from each flight mission.

A comprehensive failure reporting and corrective action system has to be in place to accurately capture all test incidents. The center of this system is a detailed database that must be developed. Subsets of this database will add value by tracking and monitoring complex components of the system, i.e. traveling wave tube, focal plane array, safe and arm device, oscillators, gyros, etc. **Root cause identification and elimination for all test incidents must have high priority.**

A byproduct of test activities, such as modification of design, is a contribution to developing Environmental Stress Screening (ESS).

D. System Maturity Assessment

Statistics provides viable models allowing utilization of data for system reliability assessment. With the evolving world of technologies, new mathematical approaches are being evaluated. Use of tools from uncertainty management is being investigated as well. With contributions from experts around the country, the Belief Domain may find its own special place.

Due to limited flight missions all data (discrete, continuous, similar system data, and others) must be considered as input to the models. The variety of data could present issues regarding their level of contribution to the system reliability requirement. A possible solution for application of various data has been documented as "system test relevance". This concept provides a logical vehicle that correlates any type of test to an actual tactical scenario. In order to minimize bias, a team of experts must develop the relevance matrices for submission to the independent evaluators.

Statistical tools are invaluable. If the missile system program has been planned and executed based upon a solid foundation, then the probability of generating pure and unbiased data for any model will be vastly improved.

E. Manufacturing and Quality System

Repeatability is the basis for any successful production process. **This requires that steady state be achieved for design changes, configuration management, and quality system.**

Change is an inherent attribute for any process. Design changes can occur due to improvements of design, parts obsolescence or other reasons. Configuration management provides baseline documentation to control the accuracy and stability of activities associated with a manufacturing process. Detailed quality and configuration management programs need to be established as an early part of the design activity. This system will be used to document and assure proper execution of plans, policies, and other activities required to produce a robust product.

ESS is an important part of a quality program. It consists of vibration, thermal, and other stresses that are incorporated to eliminate infant mortalities as efficiently as possible. It is a process that should be considered at the lowest levels possible and optimized throughout the duration of the production program. Since ESS often shares personnel and equipment with overall system and subsystem testing, the development of this process and test should be carefully coordinated.

Statistical process control is highly recommended for any application, including design, testing, incoming inspection, etc. Continuous process improvement is an essential ingredient to improve the quality of the product.

Independent process reviews of selected activities have been shown to be of proven value. As a result, it is suggested that independent reviews be scheduled at regular intervals.

Quality engineering is a well established discipline and should be strictly adhered to in order to ensure a reliable missile system.

F. Post-Deployment Activities

Following successful production of a missile, the deployment era will become as significant as the development phase. A comprehensive program has to be planned and executed that generates critical status indicators for the missile population. This information determines the level of readiness and short/long term actions that are necessary for implementation.

This data could be the result of a well balanced periodic destructive and nondestructive test program. Missile systems are designed for long service life. Since some of the components may have a shorter designed life than required, all the missiles have to be retrieved from the field in order to replace the limited life components. This recertification will provide a valuable window of opportunity for a thorough system test, and incorporation of any other improvements. Provisions should be in place to track each missile as built down to the lowest levels possible by serial number/manufacture data.

Operations research provides effective tools such as "goal programming" to optimize the cost, reliability and other constraints that impact the management of a fielded missile system.

Logistics support must be involved from a systems development throughout its life cycle to ensure the systems maintainability, reliability and growth. Logistics support becomes critical when a system is fully deployed to assure that the system maintains pace with advances in technology, and sustained using concurrent engineering and innovative logistics methods.

A well planned and executed field surveillance program will result in a high level of tactical availability during the system's life cycle.

IV. CONCLUSION

There is no doubt that the inherent system reliability is ultimately determined by assessment of all data that will emanate from development and deployment of a system, coupled with the countering of various tactical threats for the duration of its life cycle.

The critical factor in addressing any system reliability is the management of the large pool of variables that can range in number from hundreds to thousands. Each variable or combination, if not properly accounted for and addressed, could result in a mission failure and degraded system reliability. **As a dedicated team, we have the responsibility to use the latest tools and technologies to present our best analyses and recommendations (associated with pre and post-deployment) to the decision makers to field an exceptional missile system.**

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