Reliability, Availability, and Maintainability (RAM) Determining the Long-Term Success of CBRNe Equipment: A Tester's Prospective

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Background

What is RAM?

Reliability, Availability, and Maintainability (RAM) are, in and of themselves, important factors to consider when one is looking to determine the long-term suitability of a program, system, or system component. Each provides an important facet in the overall operational cost for a program and should be determined prior to acquisition and production. As such, performing developmental testing that addresses these factors is extremely important to overall mission success.

One assumes that the design of a RAM test solely addresses the gathering of data to support the determination of a system's reliability, availability, or maintainability. When designed properly, however, RAM testing can provide additional information as well. In fact, one could utilize RAM testing to address the following:

- Integration – How well does a component work within a set of systems to address overall mission requirements?
- Human Factors Engineering – How well can the user operate the system? What limitations exist within the operational environment?
- Training Procedures – Is training adequate such that a user in the field will be able to operate the system in question? What changes need to be made to the system or the training of the system to address system limitations?
- Replacement Costs – Which system accessory items should be considered consumable? Is it worth replacing various parts rather than attempting a repair? How long will a consumable item last before replacement is needed?
- Corrective/Preventative Maintenance (CM/PM) Actions – Does the vendor accurately address all corrective/preventative maintenance for a system? What is the user-level required for various CM/PM events? What are the common repair actions for a particular system? How long will a particular item last before CM is required? Has the vendor identified all possible catastrophic failures that may occur for a system?
- Logistical Information – What spares does one require to have onsite for system repair? How many? How much space will be required to address the system and its CM/PM?
- Manpower and Personnel Integration (MANPRINT) – How many users will be required to ensure that a system is readily available for use when needed? What will be needed to address system transport to the field?
- Safety – Are their any hazards that need to be considered when operating the system? Can mitigation strategies be developed to mitigate and risks associated with the use of the system?

Thus, RAM is intrinsic to the entire program – not merely a separate event or step to be addressed during developmental testing.

Why is RAM important?

RAM has significant impact on operational availability. In turn, maintaining the operational availability of a system has a direct impact on the cost of that system. The various parameters of RAM and their impact can be summarized as follows:

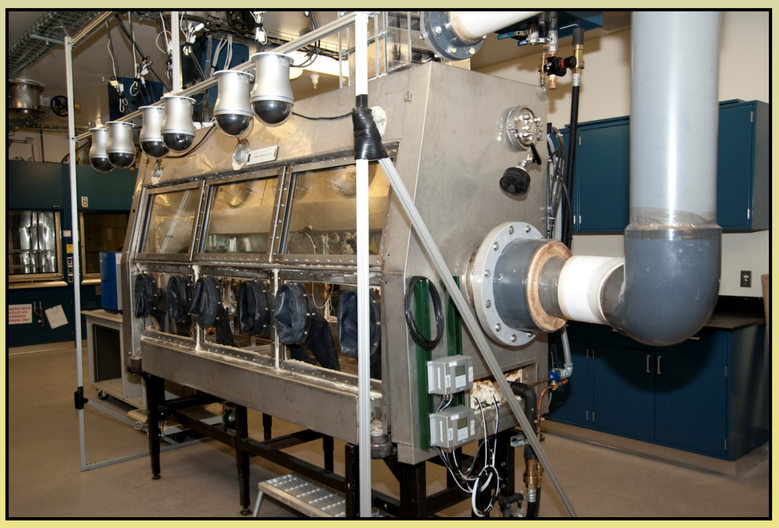
Reliability	Maintainability	Impact On Operational Availability
Increase	No Change	Increase
Decrease	No Change	Decrease
No Change	Increase	Decrease
No Change	Decrease	Increase

A study performed in 2008 by the Defense Science Board Task Force on Developmental Test and Evaluation found that the dramatic increase in the number of systems not meeting suitability requirements during Initial Operational Test and Evaluation (IOT&E) was primarily due to various RAM deficiencies. To ignore RAM is to ignore the potential detrimental cost associated with acquiring and fielding a system.

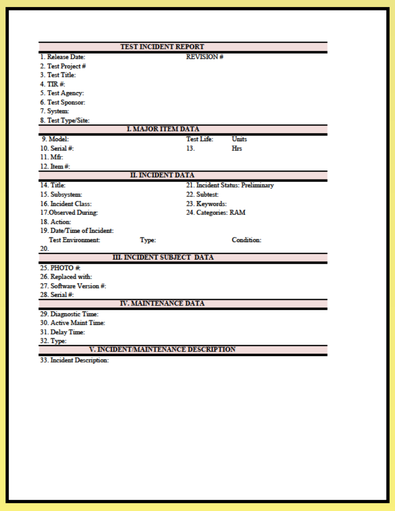
Understanding RAM Terminology

The following are definitions for common terms associated with RAM testing. (Source: *DOD Guide for Achieving Reliability, Availability, and Maintainability*):

- Reliability – Reliability is the probability (likelihood) of an item to perform a required function under stated conditions (usually environmental in nature) for a specified period of time.
- Availability – Availability is a measure of the degree to which an item is in an operational state and can be utilized for an operational mission when the mission occurs at an unknown point in time. It is a function of the following:
    - How often failures occur.
    - What corrective maintenance is required.
    - How often preventative maintenance is performed.
    - How quickly failures can be isolated, identified, and repaired.
    - How quickly preventative maintenance can be performed.
    - Delays associated with logistical support that may result in down time.
- Maintainability – Maintainability is the ability of an item to be repaired or restored to an operational level of performance. Maintainability is usually defined in terms of a user-level, which is based on the anticipated personnel skills or training level required.
- Failure – An event that occurs which results in a system that is impaired or non-functional. Failures are usually determined in accordance with their impact on mission success. Various levels of failures are determined with respect to their outcome on the overall success of the mission. Failures are typically defined as follows:
    - CRITICAL – Failure that results in loss of mission completion or unsuccessful mission result.
    - MAJOR – Failure which greatly impairs the success of the mission, however the mission is still able to be completed.
    - MINOR – Failure which disrupts the mission, but can be quickly repaired such that the mission can be successfully completed with little to no impact.
    - INFORMATION – Failures that do not effect/impact mission performance, but must either be addressed or noted offline.
- Failure Rate – Failure rate is a parameter used to describe the likelihood of a system to encounter a failure during operation. It is determined by calculating the total number of failures within a population, divided by the total operational time of the population. The higher the failure rate, the less reliable a system will be. As a result, additional cost will be spent to maintain and repair the system for use.
- "Mean Time Between…" (MTB…) - Reflects the average time anticipated between reliability events. These terms are used to address both repairable and non-repairable items. Some examples are as follows:
    - …Failure" (MTBF) – The average time that a system is expected to be operational before encountering a failure
    - …Repair" (MTBR) - May be used in place of MTBF to denote a failure that requires an anticipated repair.
    - …Critical Failure" (MTBCF) - The average time between failures that cause a loss of a systems function.
- Readiness – Readiness refers to the state of preparedness of a system to meet a mission based on providing an adequate level of trained personnel, material availability, supplies and spares, condition of any supporting systems, etc. This parameter can be determined via proper RAM planning and testing.
- Total Cost of Ownership (TCO) – Sometimes interchanged with the term "Life Cycle Cost" (LCC), TCO is an attempt to determine the total cost of a system – from initial design and development, to operational use, and finally disposal. By integrating RAM aspects early on in the design and development of a system, one can reduce the overall long-term cost associated with the operation of the system. It is the long-term operation of a system that requires the greatest portion of funding within the TCO.
- Logistics Footprint – the logistics footprint defines the number of personnel (MANPRINT) and material needed for a system in a given theater of operations. The need for users to be readily mobile, and items to be readily and easily transportable, requires one to employ mitigation strategies that reduce the logistic footprint of a system to the greatest extent possible. RAM testing allows one to determine not only the logistic footprint of a system, but also develop possible mitigation strategies to reduce the size of the footprint.
- Commercial-Off-The-Shelf (COTS) – Items that are commercially and readily available for purchase and use. COTS items are advantageous because they provide material solutions that may be obtained from multiple sources and cost savings via warranties, but users should be fully aware of the disadvantages of relying on COTS equipment without performing proper RAM testing. Manufacturer limitations, especially in regards to environmental conditions, should be fully investigated prior to investment. RAM data, if available from the manufacturer, tends to relate to failures associated with the manufacturing processes of their systems and engineering design analyses via production control, as opposed to actual operational testing within a theater of operations at various environmental conditions.



Environmental Stress Test Fixture for Reliability, Availability, and Maintainability Testing, Dugway Proving Ground.



TEST INCIDENT REPORT
1. Release Date: REVISION #
2. Test Project #
3. Test Title:
4. TIR #:
5. Test Agency:
6. Test Sponsor:
7. System:
8. Test Type/Site:
I. MAJOR ITEM DATA
9. Model: Test Life: Units
10. Serial #: 13. Hrs
11. MS:
12. Item #:
II. INCIDENT DATA
14. Title: 21. Incident Status: Preliminary
15. Subsystem: 22. Subtest:
16. Incident Class: 23. Keywords:
17. Observed During: 24. Categories: RAM
18. Action:
19. Date/Time of Incident:
Test Environment: Type: Condition:
20.
III. INCIDENT SUBJECT DATA
25. PHOTO #:
26. Replaced with:
27. Software Version #:
28. Serial #:
IV. MAINTENANCE DATA
29. Diagnostic Time:
30. Active Maint Time:
31. Delay Time:
32. Type:
V. INCIDENT/MAINTENANCE DESCRIPTION
33. Incident Description:

Example of a Test Incident Report (TIR) form for Reliability, Availability, and Maintainability Testing. TIR forms capture all significant testing events, including system failures, configuration updates, and procedural changes. They are typically categorized according to failure level.

RAM Testing

In designing a RAM test, one must first consider the system requirements. In particular, the test requirements must be vetted against the intended operational scenario and environment in which the system will be used. In addition, one must consider any additional data desired. This will dictate the type of RAM test to be selected and the way in which the test will be conducted. While it is true that a variety of properly conducted and documented developmental tests can supplement RAM data, they do not entirely replace the RAM test.

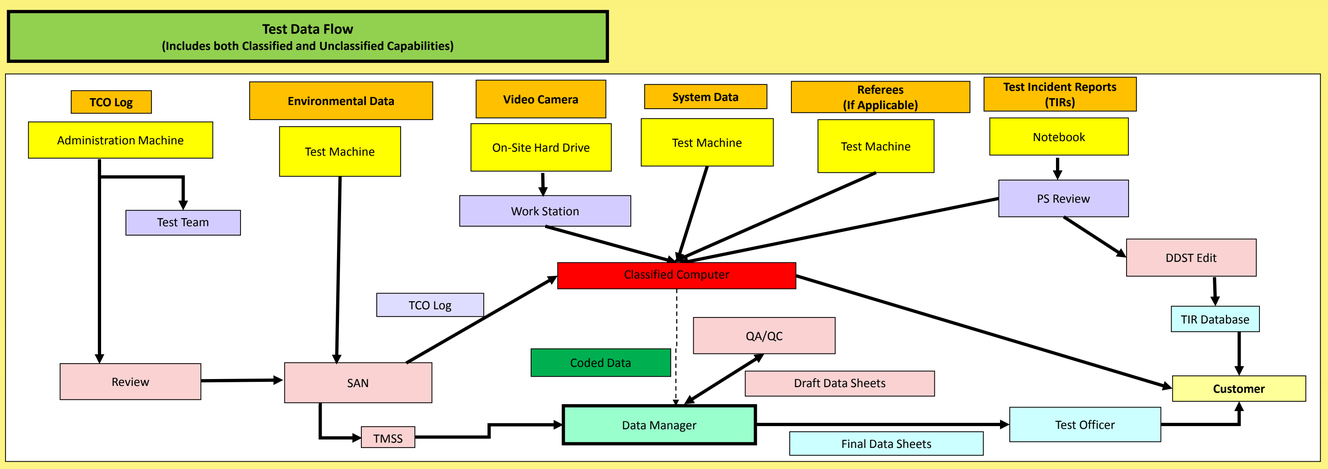
Designing a RAM Test

When designing a RAM test, consider the following:

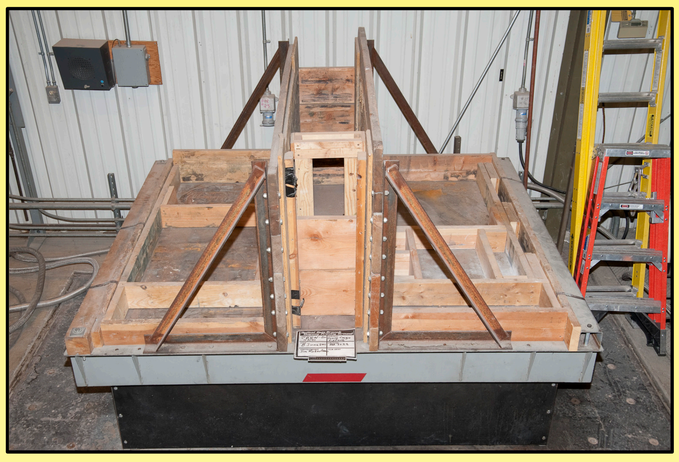
- Design of Experiments (DOE) – Based on a system's operational limitations and the intended operational environment, one can utilize a DOE approach to create a streamlined test matrix that effectively captures the RAM aspects of the system. A DOE effectively utilizes modeling to determine the RAM of the system over the entire range of operational conditions without testing at each and every data point. This effectively reduces the amount of testing required while maintaining the statistical probabilities and confidence levels to meet the system test criteria. In conducting a RAM test in accordance with a DOE, one is able to reduce the cost for test execution while maintaining the integrity of the data.
- Criteria – One must determine, prior to test execution, the criteria by which the RAM will be measured. In particular, special care and consideration must be utilized in determining failures and failure levels for the systems/components under test. In addition, one must consider the corrective maintenance involved and how to determine the functionality of the system/components under test (i.e. What constitutes a functional test/check for the system?).

Understanding RAM Data

What does it mean when one says that a system is "80% reliable with 95% confidence"? Statistical analyses on the data obtained from RAM testing can generate various expectations for system performance. When interpreting a result and confidence level, one should break down the information into two parts. First, begin with the interpretation of the confidence level. The confidence level dictates the range by which the results fall. By indicating a 95% confidence, one is stating that the result is indicative of 95% of the total data obtained. This gives one the "confidence" that the result is valid for the majority of all situations the system will encounter. Next, one must consider the result itself and how it applies to the system. The result provides the likelihood of the system meeting that particular parameter expressed based on the information gathered from a particular sample size within the constraints of the test. Thus, 80% reliable within a certain parameter (e.g. operational time) indicates that that the system will perform its intended function 80% of the time it is in use.



Example of a Data Flow for Reliability, Availability, and Maintainability Testing



Loose Cargo and Secure Cargo Vibration Test Fixtures for Reliability, Availability, and Maintainability Testing, Dugway Proving Ground.

References

[1] "DOD GUIDE FOR ACHIEVING RELIABILITY, AVAILABILITY, AND MAINTAINABILITY", 03 August 2008.
[2]Young, John J. "MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENT DIRECTORS OF THE DEFENSE AGENCIES DEPUTY UNDER SECRETARY OF DEFENSE (A&T)", SUBJECT: Reliability, Availability, and Maintainability Policy, 21 July 2008.
[3]Adolph, Pete; DiPetto, Christopher; and Seglie, Ernest. "DEFENSE SCIENCE BOARD TASK FORCE DEVELOPMENTAL TEST AND EVALUATION STUDY RESULTS", The ITEA Journal of Test and Evaluation 29(3), September 2008.
[4] "DEPARTMENT OF DEFENSE RELIABILITY, AVAILABILITY, MAINTAINABILITY, AND COST RATIONALE REPORT MANUAL", 01 June 2009.