Response to Mr. Grimm (DUSA-TE) Tasker on Reliability Initiatives

Scope

The purpose of this white paper is to serve as an official AMSAA response to Mr. Grimm's (DUSA-TE) tasker regarding the reliability initiatives that programs, to include system contractors, should take between Milestones A and B (i.e. during the Technology Development (TD) phase of the acquisition cycle).

Background

On 4 February 2011, AEC Reliability and Maintainability (RAM) Directorate and AMSAA Reliability Branch briefed Mr. Grimm on the status of ATEC/AMSAA Center for Reliability Growth (CRG) efforts and other reliability initiatives.

As a result of the briefing, Mr Grimm recommended that AEC/AMSAA examine what reliability initiatives contractors should be doing between Milestones A and B, and additionally, provide example language for Test and Evaluation Strategies.

Findings

A successful and efficient system-level reliability initiative requires a strong Design for Reliability (DFR) effort early on. It is imperative to incorporate DFR into the earlier phases of the acquisition process in order to identify and eliminate failure modes prior to initiating the system level reliability growth program. Historically, many programs have been unable to achieve the required initial reliability because the systems have far too many failure modes, sometimes well into the hundreds. Up front DFR ensures that failure modes are not only identified, but also reduced to a manageable number. Without DFR efforts, the reliability growth potential may be too low to achieve the requirement through the test-fix-test process.

DoD worked closely with both industry and the Government Electronic and Information Technology Association (GEIA) to develop a new standard (STD) number 0009, "Reliability Program Standard for Systems Design, Development, and Manufacturing." GEIA-STD-0009 is a key source of information which outlines the essential reliability processes that must be performed to design, build, and field reliable systems. Additionally, AMSAA prepared a technical report, "Design for Reliability" which provides details on the application of the DFR process topics identified in GEIA-STD-0009 and expands upon the steps required to ensure a robust design. At the core of both documents is a reliability engineering and growth process that is fully integrated with systems engineering.

In order to support the objective of surfacing and correcting a high percentage of failure modes prior to system testing, the following reliability initiatives are recommended to be conducted between Milestone A and Milestone B:

- Understand customer/user requirements and constraints
- Estimate operational and environmental life-cycle loads and stresses
- Develop Reliability Program Plan or RAM Case Plan that discusses the requirements and reliability design strategy for achieving them
- Initiate a RAM Case Report that documents all assessments of progress and supporting data
- Develop and employ engineering- and physics-based models to identify potential failure mechanisms (e.g., conduct Finite Element Analysis (FEA)/ Thermal, Vibration and Shock Analyses)
- Conduct component- and subsystem-level Highly Accelerated Life Testing (HALT)/ Accelerated Life Testing (ALT)/ Highly Accelerated Stress Screening (HASS) to surface failures early
- Perform component level and subsystem testing to surface failures
- Identify failure modes that could potentially be induced by user or maintainer error
- Develop Reliability Growth Program/Curve and use this to assess the extent of early design activities needed to achieve the required initial reliability level, as well as to assess the adequacy of planned reliability test hours and corrective action periods to support the growth plan

- Ensure reliability activities are integrated with design and testing activities - actively participate in test strategy planning to ensure that sufficient reliability test hours and corrective action periods are scheduled and resourced to support the growth plan
- Perform Failure Modes and Effects Criticality Analysis (FMECA)
- Perform Fault Tree Analysis (FTA)/Reliability Block Diagrams
- Conduct routine reliability assessments, interchanges and technical reviews and use the resulting assessments to adjust the RAM Case plan and level of planned reliability design effort as needed
- Develop reliability training plan for management and design/system engineering personnel

Additional reliability initiatives which may be considered for this period are:

- Implement a Failure Reporting and Corrective Action System (FRACAS) process
- Initiate and maintain a database of corrective actions implemented
- Establish and document lessons learned in terms of reliability
- Initiate development of DA Form 7492 (Test Incident Report)

Sample Reliability Language for the Test and Evaluation Strategy (TES)

The TES is developed prior to Milestone A and describes the test and evaluation events and activities expected during the acquisition of a program. The TES transitions into the draft Test and Evaluation Master Plan (TEMP) at Milestone B. Its format resembles that of the TEMP. The italicized text represents broad guidance for preparing the TES. The regular text represents an example of how that guidance may be tailored to a generic system.

SUSTAINMENT TEST AND EVALUATION. (Note: Some TES documents might have separate sections for each program phase - Technology Development (TD), EMD, Production and Deployment (P&D).)

Discuss test and evaluation approaches to be used to surface failure modes during early program phases prior to system testing, and discuss the approach to evaluate reliability thresholds and to track progress against the system's reliability growth curve after system testing starts, to include test configuration, data collection and scoring. The reliability growth curve developed during the TD phase will be an initial draft providing a general description of the scope of the reliability testing effort based on rough-order-of-magnitude estimates of reliability test hours from scheduled test events. This growth curve should be integrated with the contractor's DFR efforts to enhance the system's probability of achieving the initial MTBF. If the achievement of the initial MTBF for the reliability growth curve is considered high risk, the TES may include statements such as:

- *A Reliability Improvement Program to increase the level of design-for-reliability efforts prior to system testing will be considered.*
- *Alternate growth curves may be considered based on the actual initial MTBF achieved by the system.*
- *If necessary, tradeoffs may be performed assessing reliability versus cost and schedule.*
- *Based on the inability to achieve the initial MTBF, the reliability requirement may be reassessed.*

Sustainment Test and Evaluation (TD Phase - Reliability portion)
The program will employ the Reliability, Availability, Maintainability and Testability (RAM&T) Case Management approach to (1) understand the customer/user's requirements, (2) develop designs that meet/exceed RAM&T requirements, and (3) seamlessly transition the design into EMD. Substantiating the reliability requirements with sound component/subsystem data-based assessments and establishing a design architecture that facilitates quick access and 'plug and play' component replacement for rapid maintainability is of paramount importance during the TD phase. The body of evidence that provides progressive assurance of RAM requirements verification will be provided in the RAM&T Case Management Report prior to PDR, CDR and subsequent development milestones. A life cycle reliability growth program that includes the application of Design for Reliability best practices to the extent required to achieve reliability requirements will be outlined in the TD phase and detailed for implementation in the EMD and PD phases.

Sustainment Test and Evaluation (EMD Phase - Reliability portion)
The EMD program will continue to employ the RAM&T Case Management approach to (1) mature designs that meet/exceed RAM&T requirements, and (2) produce reliable, maintainable and testable systems/products, and (3) monitor and assess user RAM&T requirements compliance. Reliability Enhancement Testing will be leveraged at the component and subsystem level to verify robustness of design to the operational and environmental limits and beyond. Demonstration of RAM&T requirements will begin during EMD and culminate in PD. Reliability growth and evaluation will leverage all tests that expose failure modes and eliminate/mitigate them through verified corrective actions. At least x prototypes [Note: the value "x" is used as a placeholder and actual values for x will be based on agreement between the PM and the T&E community] per Contractor will undergo dedicated RAM&T testing for requirements compliance assessment during PQT, against operational conditions in accordance with the OMS/MP and scored with the system Failure Definition/Scoring Criteria (FD/SC). The life cycle reliability growth program will be finalized for implementation in the EMD phase.

Sustainment Test and Evaluation (PD Phase - Reliability portion)
The PD phase will provide the final verification of RAM&T requirements by the FRP Decision. At least x prototypes will undergo dedicated RAM&T testing during PVT, in accordance with the OMS/MP and scored with the FD/SC, to determine the reliability of production representative articles, verify failure modes exposed during EMD have been mitigated, and verify that the system is ready for Initial Operational Test (IOT). IOT will provide the confirmation that RAM&T requirements have been attained through demonstration with high statistical confidence. If the RAM&T requirements are validated in an operational test environment, then operational availability requirements will be verified by analysis using the System of Systems Analysis Tool that simulates the administrative logistics delay time.

Reliability Growth Planning

Provide a short overview of the planned reliability growth program, to include notional values for the reliability growth curve (e.g., initial MTBF, target MTBF, growth potential, etc.) based on the system reliability requirements. The reliability growth program should also include rough-order-of-magnitude estimates of reliability test hours from scheduled test events. This growth curve should be integrated with the contractor's DFR efforts to enhance the system's probability of achieving the initial MTBF. The reliability growth curve provided in the TES is considered preliminary and may be updated in the TEMP. The purpose of the reliability growth curve is to initiate the planning of the reliability growth program. It is recommended that the allotted testing time for a reliability testing event should be at least 3 times the estimated MTBF for that event. This provides a high probability of uncovering at least 1 correctable failure during the testing event.

This section provides a basic example of TES/TEMP input for system-level Reliability Growth planning.

Table 1 below identifies the test type, Soldier involvement, and duration of test events that are being considered. While the timeframe, total number of test events, and their exact duration will be finalized later in the Milestone B TEMP, the details in Table 1 are driven by SYSTEM's 214 hour Mean Time Between Operational Mission Failure (MTBOMF) requirement and represent a close approximation to what is needed in a typical RG program.

	Test Event	Test Type	Soldier Operators	Test Length (Hours)	Cumulative Test Hours
1	DT1	DT	No	809	809
2	DT2	DT	No	1,165	1,974
3	LUT	OT	Yes	1,977	3,155
4	DT3	DT	No	3,155	7,006
5	IOT	OT	Yes	916	8,022

Table 1. SYSTEM's Reliability Growth Test (RGT) Events and Hours.

In each test event listed, Test Incident Reports (TIR) and Corrective Action Reports will be documented in standard Army formats and incorporated into the Army Test Incident Reporting System (ATIRS) in accordance with Section 10-10 of AR 73-1. Each TIR will be officially scored via the SYSTEM's RAM Scoring Conference per the user's FD/SC. Each of the Operational Tests shown in Table 1 will be executed in accordance with the user's Operational Mode Summary / Mission Profile (OMS/MP). The DT events will mirror OMS/MP conditions as much as possible.
Figure 1 illustrates the tentative RG planning curve for SYSTEM, which includes four test phases, four Corrective Action Periods (CAPs), and an IOT. The lengths of the test phases are based on the durations shown in Table 1 and are estimated to uncover about 3 correctable failure modes per CAP. The CAPs represent scheduled downtime between test phases whereby design changes are made to mitigate reliability deficiencies observed during the testing. These corrective actions may consist of a variety of different efforts including (but not limited to): hardware design changes; software reprogramming/ debugging; modifying training regiments; addressing human/operator error; etc.

The two primary goals for this RG program include: (1) demonstrating the 214 hour MTBOMF requirement during the IOT with at least 80% statistical confidence and; (2) demonstrating the AAE reliability test threshold of 150 hours, i.e., 70% of the 214 hour requirement with at least 50% statistical confidence. The estimated initial reliability goal is 173 hours MTBOMF. The development goals associated with this RG program include addressing 95% of the initial failure intensity via the corrective action effort and mitigating associated correctable failure modes with 80% effectiveness (on average). The MTBF growth potential is 721 hours.

[Note: Reliability Growth Planning Curve below was developed using the PM2 model. The general rule of thumb is to reliability growth planning is to keep the goal below 80 percent of the growth potential, because rate of growth is significantly lower for the final 20 percent of the growth potential For this program, the idealized growth curve achieves approximately 70 percent of the growth potential at IOT.]

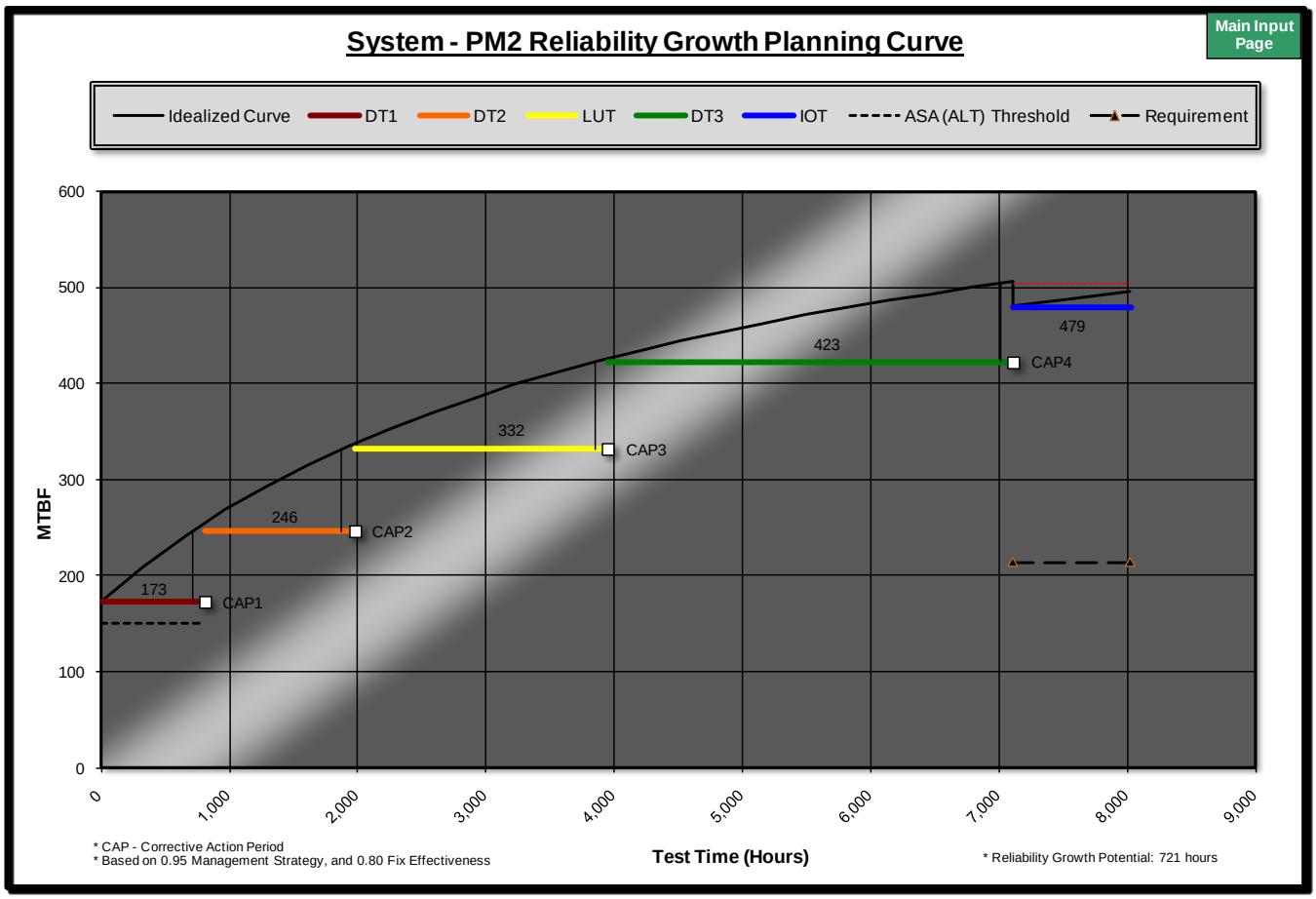

Figure 1. SYSTEM's Reliability Growth Planning Curve.

The Producer and Consumer risk for demonstrating the ASA(ALT) required reliability threshold are 0.20 and 0.50, respectively. This means that there is an 80 percent chance that the system will successfully demonstrate the 173 hour MTBOMF threshold with at least 50 percent statistical confidence in the initial DT event. Likewise, the Producer and Consumer risk for demonstrating the 214 hour MTBOMF requirement during the IOT is 0.30 and 0.20, respectively. Further mitigation of the producer risk during the IOT would require either increased design margin in the SYSTEM, or greater test exposure to increase the maximum allowable number of failures. Finally, while the tentative RG program above is based on SYSTEM's reliability Key System Attribute, it is subject to modification and may be updated/finalized in the Milestone B TEMP.

[Note: Producer and Consumer risks are based on the example Reliability Growth Curve provided above. Producer and Consumer risks for IOT typically range from 20 to 30 percent.]

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