New Army and DoD Reliability Scorecard

Marguerite H. Shepler
Mechanical Engineer
USAMSAA
392 Hopkins Road
Bldg. 237 (RDAM-LR)
APG, MD 21005-5071
410-278-5124
e-mail: marguerite.shepler@us.army.mil

SUMMARY & CONCLUSIONS

As a part of the Department of Defense (DoD) Reliability Improvement Working Group, the U.S. Army Evaluation Center (AEC) and the U.S. Army Materiel Systems Analysis Activity (AMSAA) developed an Excel-based Reliability Program Scorecard tool to standardize the assessment of a program's path to meeting its reliability requirements.

The Reliability Program Scorecard examines a supplier's use of reliability best practices, as well as the supplier's planned and completed reliability tasks. The Scorecard is important for tracking the achievement of reliability requirements and rating the adequacy of the overall Reliability Program. An early Scorecard may be based solely on a Reliability Program Plan, but as time progresses, the Scorecard will become more accurate if information from technical interchange meetings, a Reliability Case, and results from early reliability tests, are included. The Reliability Case documents the supplier's understanding of the reliability requirements, the plan to achieve the requirements, and a regularly-updated analysis of progress towards meeting the requirements.

There are 40 separate elements among the eight categories in the scorecard. The eight categories are: Reliability Requirements and Planning, Training and Development, Reliability Analysis, Reliability Testing, Supply Chain Management, Failure Tracking and Reporting, Verification and Validation, and Reliability Improvements. Each element within a category can be given a risk rating of high, medium, or low (red, yellow, or green) or not evaluated (gray). The elements are weighted and a normalized overall program risk score and category risk score are produced. This Scorecard is important in tracking the achievement of reliability requirements and rating the adequacy of the overall Reliability Program through a system's life cycle.

INTRODUCTION

In December 2007, the Army Acquisition Executive established a new Reliability, Availability, and Maintainability Policy. The policy was developed in response to data that showed a significant number of Army systems failing to demonstrate established reliability requirements. The policy applies to all programs with a Joint Potential Designator of Joint Requirements Oversight Council, "Interest" in accordance with Chairman of the Joint Chiefs of Staff Instruction 3170.01F dated May 1, 2007. The goal is to cost-effectively increase the reliability of Army systems and encourage use of cost-effective reliability best practices. The policy provides a mechanism to alert key Army leaders when weapon systems are off track with respect to meeting their reliability requirements. One element of this policy is for the U.S. Army

Test and Evaluation Command (ATEC) and AMSAA to review the materiel developer's Reliability Program Plan or Reliability Case and other documentation to determine the risk of a system not achieving its reliability threshold. As a part of the DoD Reliability Improvement Working Group, AEC and AMSAA developed a Reliability Program Scorecard to assess a system's reliability program.

The Reliability Program Scorecard examines a supplier's use of reliability best practices, as well as the supplier's planned and completed reliability tasks. The purpose of the scorecard is to allow for early evaluation of an acquisition program to identify reliability gaps. One benefit of the scorecard is that it ensures that the Program Office and contractors think about reliability very early in the acquisition process and throughout a Program's life cycle. The scorecard was developed based, in part, on reliability assessment approaches developed by the IEEE [2], Raytheon [3] [4], Alion [5], the University of Maryland [6], and others. AMSAA and AEC expanded and refined the individual assessment areas based on several years of evaluation and reliability program experience. Quantitative risk scores are provided for each assessment area as well as for the overall system. This scorecard is important for tracking the achievement of reliability requirements and rating the adequacy of the overall Reliability Program. The scorecard allows for a standard way of assessing programs.

As time progresses and additional programs are evaluated, more data will be gathered which will allow evaluators to compare similar programs. It is the intent that engineers and subject matter experts will conduct site visits in order to fully examine program documents and assess the processes in which suppliers intend to do analysis and testing on their products and systems. With respect to requirement areas that are lacking, engineers can recommend analysis or testing solutions and methods that the contractors could use to ensure that they are meeting the reliability standards. By engaging subject matter experts, the scorecard ratings will become more accurate and each program will have a better chance of achieving success. AMSAA and AEC will be able to re-evaluate and adjust element weighting data on the scorecard to accurately reflect the success of a program according to the scorecard assessment. Scorecard metrics will be collected over time so the Reliability Program Scorecard will become an extremely valuable tool to make an initial reliability projection for a program. One of the ultimate goals is to evolve to a point where the scorecard elements and weights can be adjusted for different system types and/or phases in the Acquisition Lifecycle.

SCORECARD AREAS

The scorecard evaluates eight critical areas. These areas include Reliability Requirements and Planning, Training and Development, Reliability Analysis, Reliability Testing, Supply Chain Management, Failure Tracking and Reporting, Verification and Validation, and Reliability Improvements. Within these eight areas, forty separate elements are reviewed and rated red, yellow, or green, representing a high, medium, or low risk, respectively. An additional rating of gray (representing an element not evaluated) is used for individual elements that are not present and are not a necessary part of the current system's reliability program given the Program's position in the Acquisition Framework. Many of the elements in the scorecard were derived from the list of Reliability Best Practices and categorized using the IEEE P1624 Draft Standard for Organizational Reliability Capability document [2]. Figure 1 shows a snapshot of four of the ten elements within the Reliability Requirements and Planning section of the scorecard.

		High Risk Criteria	Medium Risk Criteria	Low Risk Criteria	H	M	L	NE
Reliability Requirements and Planning	**Design team has a history of producing reliable hardware and software**	Design team has not produced hardware and/or software for previous programs such that history of producing reliable hardware does not exist.	Design team has produced hardware and/or software for a limited number of previous programs and in some cases programs have proven to be reliable.	Design team has produced hardware and/or software for numerous programs and in most cases previous programs have proven to be reliable.				
	History of applying innovative approaches to reliability and high-level and continuous focus on reliability improvement	The developer has little to no experience in developing approaches and/or shows minimal emphasis on finding ways to achieve reliability improvement.	The developer has displayed a moderate level of emphasis on finding ways to improve reliability on previous programs.	The developer has a history of applying innovative approaches and placing a lot of emphasis on achieving high reliability and finding ways to achieve reliability improvement.				
	Reliability activities of the stated reliability program are clearly identified, include timelines/dates and are integral to design and testing activities and consistent with the program's schedule	RAM activity is not incorporated into the program Integrated Master Schedule.	Some of the RAM activity is incorporated into the program Integrated Master Schedule.	A majority of the Reliability/Availability/Maintainability (RAM) activity is incorporated into the program Integrated Master Schedule.				
	Reliability Program identifies progressive assurance (routine evidence) delivery dates for specific products and/or analyses to assure program is on track to achieving requirements.	There is no schedule to track achievements towards meeting reliability requirements or indentification of contract deliverables to show progress.	Deliverables and a general schedule for their delivery is provided to the customer with information needed to determine if the program is on track to meet reliability requirements.	The Reliability Program outlines a detailed schedule with delivery dates for specified products and/or analyses to provide the customer with information to determine if the program is on track to achieving reliability requirements.				

Figure 1 – Selection of Reliability Program Scorecard

An early Scorecard may be based solely on a Reliability Program Plan. As a program matures, information is gathered through the Reliability Case, updates to the Reliability Program Plan, site visits, and involvement in technical reviews. A feedback process will occur allowing all reliability members to understand the perceived risk to that program.

As a part of the feedback process it is important for suppliers and the program office to have an explanation as to why an element received a particular risk level. The scorecard includes two additional columns to provide such information to the supplier and program office. The first column is for the evaluator to include rationale for assessing the element at that risk level. The second column allows the evaluator to include suggestions to improve the reliability program, based on the risk level assigned to the category or element. Many of the ways to improve reliability come from the GEIA Standard 2009, "Standards on Reliability Program Standard for Systems Design, Development, and Manufacturing" [7] and the IEEE P1624 Draft Standard for Organizational Reliability Capability document [2].

Reliability Requirements and Planning

The first category in the scorecard is Reliability Requirements and Planning. There are ten elements within this category which are an important part of understanding the customers' reliability requirements, generating reliability requirements, and planning activities that are necessary to ensure that appropriate reliability requirements are met. Some elements of the Requirements and Planning area are: building and updating a Reliability Case/Reliability Program Plan, showing a history of applying innovative approaches and continuous focus on reliability improvement, and using reliability engineering and management tools like Failure Modes and Effects Criticality Analysis (FMECA) and Reliability Growth. Other elements

include identifying lessons learned from previous programs the contractor has worked on, or from like systems, and evaluating the history of the design team.

There are several activities that define the requirements and planning section. One is to identify and plan for available resources (personnel, testing, equipment, materials, etc.). Another is to create reliability requirements and allocate them to the sub-assemblies or components. Identification of the potential suppliers for the product and their history of reliability capabilities is another activity that is evaluated in the requirements and planning section. Gathering lessons learned from previous programs and documenting them is essential to not repeating history. Once the lessons learned have been documented, the contractor should detail what the current plan is to avoid the pitfalls of predecessors. This should be updated in their Reliability Program Plan/Case.

An integral part of the Reliability Program is to tie the reliability activities to the program's schedule. The activities to be included within a reliability program need to be clearly identified as to when they will occur so that when and if the program schedule shifts the reliability and design team can make adjustments as needed and include these changes within the Reliability Program Plan or Reliability Case.

It is important to determine the reliability analysis, reliability testing, and failure data analysis/tracking needed to ensure the system meets its requirements. These elements should be included in the initial contract with the supplier. Lastly, is the need to identify the logistics for obtaining feedback on results of reliability activities.

Training and Development

Training and Development is the second category in the scorecard. There are four elements that describe the steps necessary to improve the technical and strategic skills and knowledge of people so they can properly execute their responsibility in the design, evaluation and manufacture of a reliable product or system. These elements include having a sufficiently-sized reliability engineering staff tied directly to a design team, developing a training plan for personnel, and monitoring new technologies and industry standards. It is also very important to avoid relying on handbook practices (e.g. MIL-HDBK-217) and avoid viewing reliability as merely Mean Time Between Failure (MTBF).

There are a few activities that help to define the area of training and development. One of these activities is to develop and implement a training plan for both individual contributors and management, including schedule, budget, and identification of training personnel. This could include internal courses, external seminars, college classes, and symposiums. It is important to monitor new developing technologies, modeling and analysis techniques, and trends that impact reliability in order to regularly adjust training.

Reliability Analysis

The Reliability Analysis category includes six separate elements. Among these are conducting thermal and vibration analyses and/or Finite Element Analysis (FEA), characterizing critical loads and stresses, and understanding failure mechanisms and failure sites.

One of the activities of the reliability analysis area is to identify the failure implications of components and products, e.g. create a reliability logic diagram. Some others are to identify potential single points of failure and failure modes, failure mechanisms and their effects, and the criticality of failure modes and mechanisms for a system. Detailed component stress and damage models should be utilized when appropriate. An additional activity for reliability

analysis is to assess adherence to design rules that impact reliability derating, electrical, mechanical, and other guidelines.

Reliability Testing

The fourth category is Reliability Testing. There are four elements within this category which are important in identifying design weaknesses and exploring design limits and environments. Testing is used to demonstrate the reliability of products or systems. Tests may be conducted according to customer requirements or industry standards. Sometimes testing is used to verify existing and frequent occurrence of expected failure modes and mechanisms that were previously identified during analysis.

There are several activities that are key practices in the testing area. First, create detailed reliability test plans that include sample size for tests and the confidence level specifications. Then, perform discovery testing – identifying the design margin and destruct limits for the system. Conduct design verification and reliability testing, including on-going reliability tests, reliability demonstration testing and accelerated testing. The results from reliability tests should be used to change the design in products before production of the system begins.

Supply Chain Management

Supply Chain Management is the fifth category in the scorecard. There are five elements within this category that will aid in determining that sources of components are identified which will satisfy reliability requirements. Also, it is important that a list of components and suppliers is created and managed.

Several activities define the supply chain management section. The first few include creating a list of potential suppliers, selecting a vendor/supplier, and assessing or auditing the supplier. Component qualification is important, which would include the identification and evaluation of key parameters. Another activity would be the review of component monitoring data from suppliers, including process, quality, reliability testing, accelerated test data, and field failure data. Checking to ensure that design specifications include the stated reliability requirements is also an important activity in supply chain management. Another activity that should be present in the Reliability Program Plan is the contingency plan for part obsolescence. In general, the supply chain management section will need to be evaluated as programs progress toward the production phase, which may include on-site visits to contractor facilities and gathering performance history of vendors.

Failure Tracking and Reporting

The Failure Tracking and Reporting category includes three elements that focus on collecting failure data in order to generate corrective actions and reliability improvement activities. These elements include conducting reviews for corrective actions, documenting failed components, and utilizing failure reporting, analysis and corrective action system (FRACAS).
One of the activities for failure tracking and reporting is to conduct statistical analyses of functional test failure data, manufacturing test failure data, reliability test failure data, and field return failure data. It is critical to track the history of the failed components from production through failure and to prepare failure analysis reports identifying failure modes and mechanisms traced to specific materials or processes. Pareto charts and other statistical reports can be prepared based on failure modes and mechanisms. Lastly, the need to determine appropriate corrective actions and analyze data from prognostic monitoring sensors is addressed in the

scorecard. Other activities that should also be included are root-cause analysis and failure confirmation. Time to failure data should be collected and analyzed, and engineering-based reliability predictions should be updated based on information gathered.

Verification and Validation

The seventh area of the scorecard is Verification and Validation. There are four elements within this category that are meant to ensure that planned reliability activities are implemented and validate that outcomes are consistent with other activities. The important things to consider are documenting updates to potential failure modes/mechanisms, modifying reliability analysis methodologies and failure models, modifying testing and procedures based on field failures, and conducting technical design reviews.

Several activities that apply to verification and validation include: conducting internal audits to monitor progress and improve reliability plans and activities; verifying completion of root cause analysis, corrective action and preventing recurrence for appropriate factory test and field return failures; verifying that reliability commitments in supplier agreements have been satisfied; comparing predicted product reliability and failure distributions with actual field reliability and failure distributions; comparing potential failure modes/mechanisms identified in analysis with failure modes/mechanisms from field returns and comparing actual field reliability with reliability requirements.

Reliability Improvements

Reliability Improvements is the final category in the scorecard. There are four elements included in this category that focus on the identification and implementation of product changes based on lessons learned from testing, failures, technical improvements and changing operating conditions. It is especially important to implement corrective actions, determine their effectiveness, and prevent the occurrence of failures in future systems.

Several activities define the improvements area. Two of them are to implement corrective actions identified through failure analysis and to monitor the effectiveness of the corrective actions in improving reliability. Another is to identify and implement changes that will prevent recurrence of identified failure modes and mechanisms in future products. It is also important to identify changes in the product reliability requirements or their lifecycle application conditions that may require subsequent action. An additional activity in reliability improvements is to evaluate developing technologies, modeling, and analysis techniques, and trends that could be used to improve reliability of products. Lastly, document and implement corrective actions that will improve reliability in response to product reliability requirement changes.

SCORING METHODOLOGY

Each of the forty elements in the scorecard should be assigned a risk level of High, Medium, Low, or Not Evaluated (NE). For each element, text is provided in the scorecard to assist the evaluator assigning the risk levels. The determination of an assigned risk level for an element can change based on how far along the program is in the Engineering and Manufacturing Development (EMD) phase. For example, for the, *"Conduct failure modes, effects, and criticality analysis (FMECA), Fault Tree Analysis (FTA); crosswalk to low level testing and a failure mechanism analysis to ensure programmatic coverage,"* element in the Reliability Analysis category:

- For programs early in EMD, you want to see that the reliability program plan or comparable planning documentation addresses FMECA and Fault Tree Analysis (FTA);
- Later, for a low-risk rating, the FMECA and FTA need to be specific contract deliverables and resourced (i.e. dollars, manpower, etc.); and,
- Further in system development, for a low-risk rating, the FMECA and FTA should have been completed, linked to low-level testing and failure mechanism analyses, and used to influence the system design.

Once risk levels and NE inputs have been assigned, the scorecard will provide a summary of the risk assessment (located in separate tab labeled Overall Scorecard Results) which is pictured in Figure 2.

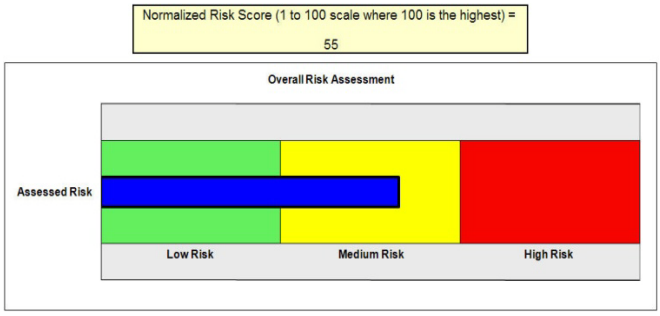

Figure 2 – Overall Program Risk Assessment

The risk assessment score is calculated based on the individual reliability risk ratings assigned to each element (red equates to a risk of 3, yellow equals 2, and green equals 1) All elements that are rated NE are removed from the risk score calculations. The element risk scores are then adjusted by weighting factors (1, 2, and 3) that are locked within the scorecard spreadsheet tool. The overall reliability risk is then normalized to a value between 1 and 100.

The Overall Scorecard Results worksheet also provides a pie chart similar to the one pictured in Figure 3 for the entire scorecard documenting the number of elements that were rated high, medium, low risk or NE. Pie chart results, as shown in Figure 3, and normalized risk score for each category can also be viewed, by clicking on the Category Results tab of the Reliability Program Scorecard tool.

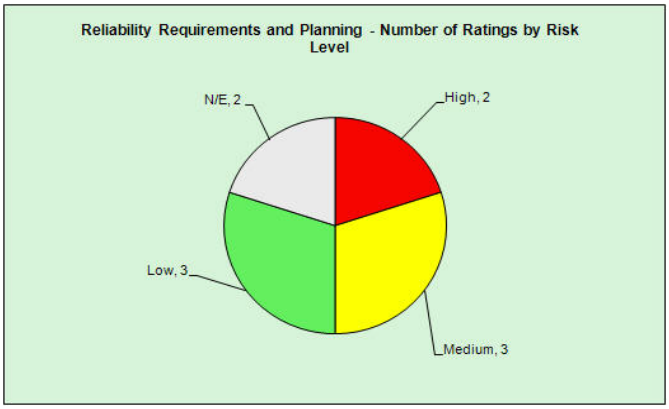

Figure 3 –Example of a Category with Number of Ratings by Risk Level

As more programs are evaluated and data become available, the weights of each element may be refined to produce a final risk assessment score. Programs that are evaluated early and reevaluated as the system progresses into the Production and Deployment phase will help to shape the scorecard. If elements are found to not influence reliability they can be removed or if they influence reliability more than expected a higher weight will be assigned to them. Also this gives the Army and DoD a way to measure Reliability Programs over time, types of programs, and allow for future improvements within the area of reliability based on the metrics collected from the evaluated programs. If the reliability scorecard predicts that a program's Reliability Program is at high risk but the program meets and or exceeds the reliability threshold then the scorecard can be reevaluated to examine the failure. However, if the scorecard produces acceptable results, in that a program with low risk meets or exceeds the reliability threshold, or program with initial high risk, makes changes based on scorecard results and then produces a product that meets or exceeds the reliability threshold, this will validate the scorecard. Over time the hope is that the scorecard can be used to evaluate similar systems side by side and also produce a variety of scorecards for different type systems (e.g., one-shot missile systems) as necessary. This scorecard is important in tracking the achievement of reliability requirements and rating the adequacy of the overall Reliability Program.

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BIOGRAPHIES

Marguerite Shepler is a member of the Electronics Physics of Failure Team at the U.S. Army Materiel Systems Analysis Activity. She earned her bachelor's degree in Mechanical Engineering at Grove City College in Pennsylvania and her master's degree in Operations Research at the Florida Institute of Technology.