AEROSPACE REPORT NO.
TOR-2010(8591)-18

Mission Assurance Program Framework

June 30, 2010

William D. Bjorndahl

Mission Assurance Subdivision
Systems Engineering Division

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
El Segundo, CA 90245-2808

Contract No. FA8802-09-C-0001

Authorized by: Space Systems Group

Developed in conjunction with Government and Industry contributions as part of the U.S. Space Programs Mission Assurance Improvement Workshop.

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AEROSPACE
Assuring Space Mission Success

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This document has been produced as a collaborative effort of the Mission Assurance Improvement Workshop. The forum was organized to enhance Mission Assurance processes and supporting disciplines through collaboration between industry and government across the US Space Program community utilizing an issues-based approach. The approach is to engage the appropriate subject matter experts to share best practices across the community in order to produce valuable Mission Assurance guidance documentation.

The document was created by multiple authors throughout the government and the aerospace industry. For their content contributions, we thank the following contributing authors for making this collaborative effort possible:

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Executive Summary

The Mission Assurance Program Framework team was one of five teams of the 2009-2010 Mission Assurance Improvement Workshop (MAIW) program. The team met approximately weekly via telephone conference and periodically in person during the ten months of its existence. The goal of the team, which consisted of government and industry partners, was to define core and supporting mission assurance processes for U.S. space programs. The team members were asked to consider and bring forth their separate enterprise processes that were considered necessary for mission assurance whether or not the processes were carried out by the mission assurance organizations within each of the enterprises. This survey resulted in 16 common mission assurance processes which were remarkably and almost universally consistent (when core and supporting processes were considered together) across all organizations. The survey results also provided information regarding which organizations within each enterprise were responsible for carrying out specific mission assurance processes. This information led to the observation that the organizations responsible for specific mission assurance processes can vary between enterprises.

These 16 common mission assurance processes are recommended as an essential set necessary to provide effective mission assurance for U.S. space programs. They are recommended for implementation at prime contractor and supplier levels. Descriptions of each of the processes are given within this document. Recommendations for follow-on activities are provided. Further suggestions regarding modifications of the Mission Assurance Guide were developed and recorded in a separate white paper.

Contents

Tables

Appendixes

1. Introduction

1.1 Background

The origins of the "Mission Assurance Program Framework" project were based on a desire to establish guidance in application of core and supporting processes aimed at ensuring mission success for programs providing space-related products and services. In the absence of a universally-accepted definition, the term "Mission Assurance" means different things to different stakeholders within the U.S. space enterprise. Differences in understanding can result in miscommunications among the stakeholders within and across programs and lead to potential gaps or overlaps in the planned mission assurance process. The project team, comprising subject matter experts from both industry and government agencies, has undertaken the task of identifying the essential set of processes required for effective mission assurance on programs.

As mission assurance is a very broad area, the team first solicited input on key core and supporting processes that support mission success. Responses were tabulated to identify prevalence across the enterprise, and a set of recommended processes were identified and described. Cross-referencing to existing requirements and guidelines documentation was accomplished to identify sources of additional information.

1.2 Existing MA Requirement/Guideline Resources

Mission assurance is the disciplined application of proven scientific, engineering, quality, and program management principles toward the goal of achieving mission success. Given the diversity of these disciplines and associated knowledge systems, it follows that there is no single mission assurance requirements document that covers all of the U.S. space programs enterprise. Several companies and government agencies charged with development, production, procurement, or oversight of space system products or services have created requirements and guideline documents to serve their specific purposes. Two noteworthy government-issued MA resources are tabulated below, and were reviewed by the team:

Document	Scope
TOR-2007(8546)-6018 Rev A, *Mission Assurance Guide*, 1 July 2007	Provide practical guidance to personnel of the Aerospace Corporation, and in general, National Security Space (NSS) program office personnel, who are responsible for executing mission assurance functions.
MDA-QS-001-MAP, *Missile Defense Agency Assurance Provisions (MAP)*, 9 January 2004	A set of safety, quality, and mission assurance requirements for mission and safety critical items in support of MDA-procured systems.

1.3 Definition of Terms Used in This Document

Term/Acronym	Definition
Independent	Tasks or processes performed by an organization or personnel that are technically, managerially, and financially independent of the development organization to achieve unbiased and objective assessments
MAG	Mission Assurance Guide
Mission Assurance (MA)	Disciplined application of proven scientific, engineering, quality, and program management principles toward the goal of achieving mission success[1]
Recommended Processes	Processes considered essential to ensuring mission success for programs providing space-related products and services
Tier 1	A term used to collectively describe prime contractors and other major contractor organizations
Tier 2	A term used to collectively describe subcontractors and other suppliers one layer removed from the end user or acquisition agency
TOR	Technical Operating Report. A class of documents published by The Aerospace Corporation that contain technical information, guidelines, and other specification and standard information
MAIW	Mission Assurance Improvement Workshop

1.4 Anticipated Uses of This Document

The goal of the team was to create a listing of essential mission assurance processes, provide a common objective/description for each, and define an elemental framework for application of these processes within space programs. It is anticipated that all U.S. spacefaring organizations will compare their own policies and procedures to those listed herein, and take action to address gaps that may exist. This document, and associated follow-on work in this area, is intended to establish a uniform set of mission assurance processes and reference framework applicable to the entire US space enterprise.

[1]From 2009 National Space Program Mission Assurance Summit.

2. Core and Supporting Processes

2.1 Definitions

The following definitions were selected to differentiate between core and supporting mission assurance processes:

> **Core MA Processes** – The key drivers to mission success, independent of organizational construct.
>
> **Supporting MA Processes** – Verification processes/activities executed within the performing discipline to verify work product or process integrity prior to completion.

For core processes, emphasis is placed on the mission assurance value represented by the process, regardless of who owns or performs the work. This definition would identify, for example, program assessments and independent readiness reviews as important MA processes, and de-emphasize the actual performer as a discriminator. In this manner, we sought to identify key processes, and not just mimic the processes or tasks performed by individual mission assurance organizations.

The definition for supporting processes is intended to describe verification activities accomplished within performing functions or disciplines to check their own work prior to completion and release. Examples include a drawing check function, or a manufacturing planning peer review.

2.2 Survey Approach

To obtain information regarding core and supporting processes in use within the U.S. space enterprise, the team requested this information from a broad spectrum of organizations. Most members of the project team provided process tabulations for their respective organization. In all, the following groups and agencies were contacted:

- Space Quality Improvement Council (SQIC) members – 13 "Tier 1" companies and The Aerospace Corporation
- Space Supplier Council (SSC) members – 25 "Tier 2" companies
- Space and Missile Systems Center (SMC)
- Missile Defense Agency (MDA)
- National Aeronautics and Space Administration (NASA)
- National Reconnaissance Office (NRO)

Replies were received from ten organizations. Processes for an eleventh organization were provided by one of the ten responding organizations, based on prior collaboration between the two organizations. To retain confidentiality, respondents were assigned an alpha-numeric designation, with "I" reserved for industry and "G" reserved for government agencies. The key is held by the project team and the MAIW steering committee.

3. Comparative Matrix of Core and Supporting Processes Across Organizations

In response to the request, organizations provided listings of core and supporting MA processes. These core and supporting processes were then examined to determine their prevalence across the organizations. The processes were then tabulated.

3.1 Review of Respondent Information

To accomplish the tabulation, there were a number of adjustments made in summarizing the information submitted by the respondents. For example, an organization may have mentioned three items associated with supplier quality assurance (e.g., supplier audits, supplier approval, and resolution of supplier issues). Another organization may have just mentioned supplier quality assurance and indeed may accomplish all of the above three activities under that heading. For the purpose of keeping the tabulation to a manageable number of distinct activities, all those activities which appeared to be related to supply-base mission assurance were enveloped within the term "Supplier Quality Assurance." In general, similar activities were listed under the most descriptive and common process name.

3.2 Process Categorization and Ranking

Processes other than those listed in Table 3-1 were provided by the respondents; however, Table 3-1 lists those which exhibited broad recognition across all respondents. Specifically, if the process was mentioned by half of the responding organizations (five in this case), it was included in Table 3-1. For example, cost modeling and earned value management systems (EVMS) were mentioned by only two organizations, and thus were not included. The top 16 items are shown in Table 3-1. The complete response data is included in Appendix A.

To differentiate processes based on organizational categorization (core or supporting), a numerical ranking process was applied. Core processes were rated 5, supporting processes were rated 2, and combinations were rated 4. Summation of these factors across a given process resulted in totals that permitted ranking of the processes, from predominately core to more supporting (or neither).

3.3 Performing Disciplines

Also denoted within Table 3-1 is a color code indicating, if identified, which discipline within the organization had the actual responsibility for accomplishing the activities associated with the process. In this manner, if a process is performed by Quality Assurance, but they report into Mission Assurance, the process is assigned to QA (green) versus MA (blue).

Table 3-1. Core and Supporting Mission Assurance Processes across Responding Organizations

Organization	G1	G2	G3	G4 (1)	I1	I2	I3	I4	I5	I6	I7
Process											
Hardware Quality Assurance	C	C	C	C	C	S	C	C	C	C	C
Design Assurance	C	C	S	C	C	S	C	C	C	C	S
Parts, Materials, and Processes	S	C	C	C	C	S	S (3)	C	C	C	C
System Safety	S	C	C	C	S	S	C	C	S	C	C
Risk Assessment and Management	S	C (2)	C (2)		C	C/S	S	C	C	C	C
Software Assurance	S	C	C	C	C	S	S	C	C	S	S
Integration, Test, and Evaluation	C	S	S	C	C	S	C/S	C	S	C	S
Independent Reviews	C	S	S (3)	C	S	C/S	S	S	C	C	C
Failure Review Board	S	C	S		C	C/S	C	S	C	C	S
Reliability Engineering	S	C	C	C	C	S	S	C	S	S	S
Supplier Quality Assurance	S	C	S	C	C	S	S	C	S	S	C
Requirements Analysis and Validation	C	C	S		C	S	S	C	C	S	S
Configuration Management	S	C	S	C	S	S	S	C	S	S	S
Corrective/Preventative Action Board	S	C	S (3)		S	C/S	S	S	S	C	S
Alerts, Information Bulletins	S	S	S		S	S	S	S	C	C	S
Environmental Compatibility (4)	S	S	C		C	S	C/S	S	S		S

Performing Discipline:

- Mission Assurance
- Quality Assurance
- Systems Engineering
- Parts, Materials, and Processes
- Supply Chain Management
- Engineering/Technical Function
- Program Management
- (clear) Multiple Disciplines, or N/A

Notes:
(1) G4 data compiled by organization G1
(2) Performed by both Mission Assurance and Program Management
(3) Performed by both Engineering and Mission Assurance
(4) Includes EMI/EMC, radiation assessment/analysis, contamination control processes, and others

4. Recommended Process Sets and Groupings

Upon review of the responses, it became clear that all MA processes were interchangeably listed as either core or supporting by different organizations. For example, reliability engineering was almost unanimously considered a core and supporting process.

To create a listing of essential mission assurance processes, it became useful to consider the MA merits of each process in Table 3-1, whether it is categorized as core or supporting by the respondents. What is important is that the process be performed by qualified individuals within the organization. To that end, Table 4-1 identifies 16 recommended mission assurance processes. Consistent with the project charter, these processes are considered essential to ensuring mission success for programs providing space-related products and services.

The tabulation order in Table 4-1 differs from Table 3-1, and is intended to categorize the processes into three groups as follows:

1. **Program Execution:** Includes "mainstream" processes performed throughout program execution.

2. **Risk, Oversight, and Assurance:** Includes "oversight" processes intended to enable successful program execution.

3. **Triage, Information, and Lessons Learned:** Represent knowledge sharing and information feedback activities intended to promote organizational learning throughout an enterprise.

Table 4-1. Recommended Mission Assurance Processes (tabulated by process group)

No.	Recommended Mission Assurance Process	Process Group
1	Requirements Analysis and Validation	1. Program Execution
2	Design Assurance	
3	Parts, Materials and Processes	
4	Environmental Compatibility	
5	Reliability Engineering	
6	System Safety	
7	Configuration/Change Management	
8	Integration, Test and Evaluation	
9	Risk Assessment and Management	2. Risk, Oversight, and Assurance
10	Independent Reviews	
11	Hardware Quality Assurance	
12	Software Assurance	
13	Supplier Quality Assurance	
14	Failure Review Board	3. Triage, Information and Lessons Learned
15	Corrective/Preventative Action Board	
16	Alerts, Information Bulletins	

Moreover, each of the 16 recommended mission assurance processes are both monitored and implemented. Monitoring or reviewing of contractors'/suppliers'/partners' (CSP) mission assurance process activities can be performed by a customer's technical representatives or delegates in order to assess compliance with requirements and to provide insight into CSP consistency with their own imposed requirements/processes. This is an independent risk assessment and control function and ideally draws upon the broader experience base and more unbiased perspective of technical representatives whose responsibilities do not include budgetary and financial commitments. Implementing organizations at contractors, suppliers, and partners perform MA processes activities using their own organization's processes and procedures or command media. The focus within the implementing organizations is on defining and performing the MA processes with the goal of delivering compliant, high integrity space products to the customer.

Table 4-2 provides additional information for each of the 16 processes, in the form of a process objective and a brief description.

Table 4-2. Recommended Mission Assurance Processes

No.	Process	Description
1	Requirements Analysis and Validation	**Objective:** Ensure that (a) a complete and optimal set of requirements is established based on analysis of mission needs and that (b) a 1:1 association exists between a requirement and its source and derived requirements, its implementation, its verification method and verification results. **Description:** The Requirements Analysis and Validation process begins early in the life cycle of a program with analysis continuing in an iterative fashion during all program acquisition phases. The validation of requirements is primarily accomplished through modeling, simulation, and test to ensure that the requirements, if met, will result in a system that meets the user's expectations and needs. Mission assurance activities supporting requirements analysis are: • Independent evaluation of requirements traceability • Independent mission effectiveness assessment • Cost and schedule elements evaluation • Mission analysis validation • Evaluation of models and simulations used to analyze requirements
2	Design Assurance	**Objective:** Ensure the sufficiency of the conceptual, preliminary and the detailed design to perform its intended function through all operating conditions and throughout its design life. **Description:** The design assurance process is a set of activities which are performed to improve the probability that space, launch, and ground systems will meet the intended requirements through all operating conditions and throughout the design life. Design assurance activities are concerned not only with the independent assessment of the design processes from a "design" engineering perspective (e.g., trade studies, modeling, analysis, design failure modes and effects analysis (DFMEA), and change control) but also evaluate, through the product qualification, manufacturing and test phases, whether or not the design intentions are being achieved. It also encompasses failure and anomaly investigations to the extent that lessons

<table>
<tr><th>No.</th><th>Process</th><th>Description</th></tr>
<tr><td></td><td></td><td>learned are captured and communicated so that necessary improvements can be incorporated into future space programs.</td></tr>
<tr><td>3</td><td>Parts, Materials, and Processes</td><td>Objective: Ensure that parts, materials, and processes used in deliverable products and ground equipment will function and perform in accordance with the requirements of their intended application.

Description: The Parts, Materials, and Processes (PMP) function includes oversight of electrical and mechanical parts and components as well as specific materials and the processes used in the manufacturing of deliverable hardware. It also includes definition of expectations for attributes such as derating and performance as well as review of non-standard or non-compliant items.

PMP activities include:
Verification of all subcontractor’s performance to assure that delivered products satisfy contractually flowed down requirements
Regularly scheduled PMP meetings to resolve issues
Verification of worst-case circuit analysis
Validation of piece part failure rates
Verification of degradation limits of critical parameters for worse case design</td></tr>
<tr><td>4</td><td>Environmental Compatibility</td><td>Objective: Ensure that products are designed to withstand all environmental conditions encountered in service by 1) defining environmental requirements, 2) considering these requirements in system design and implementation, 3) supporting environmental testing and evaluation, and 4) supporting post launch environmental response evaluation.

Description: The Environmental compatibility process is either a specific application of systems engineering, Mission Assurance or specialized design engineering processes to ensure all environmental requirements are defined and flowed to the appropriate levels, and that appropriate analysis and test methods are employed to verify the design will withstand the environments encountered in service with robust margins. It begins during the feasibility study phase of a pre-project, continues through launch, and occasionally continues during the mission. The key tasks are to establish and implement, early in the development phase, the design and test recommendations and requirements that lead to robust, cost effective hardware designs that can be adequately environmentally tested and are delivered on time

Applicable environments include:
Contamination, outgassing
EMI/EMC/Magnetics
Loads and acceleration
Pressure, vacuum, and venting</td></tr>
</table>

No.	Process	Description
		• Radiation • Shock, vibration, and acoustics • Thermal • Micro-meteoroid and space debris • Other natural space environments such as atomic oxygen and extreme ultraviolet (EUV) effects
5	Reliability Engineering	**Objective:** Ensure that design risks are balanced with program requirements and constraints through comprehensive reliability analyses and closed-loop problem failure reporting and closure. **Description:** Reliability Engineering is the process that provides independent insight, planning, and validation for reliability, end-of-life capability, and environmental capability of deliverable hardware design through concurrent analyses, reviews, and test assessments. Activities include performing a structured set of reliability analyses as an integral part of the design process for the purpose of assessing product reliability and to highlight any potential problems for timely resolution. These analyses include, but are not limited to • Reliability prediction and allocation • Failure mode and effects • Probabilistic risk assessment • Part-level electrical, mechanical, and thermal stress analysis • Worst-case analyses • Fault-tree analysis • Limited life analysis • Critical item assessment analysis • Trend analysis A closed-loop failure analysis and corrective action system is also a key element of the reliability program. The effectiveness of these measures is determined and supported by design analyses, design reviews, hardware tests, and failure data evaluation.
6	System Safety	**Objective:** Ensure the identification and control of potential hazards to personnel, equipment, and facilities and address them to achieve acceptable levels of risk. **Description:** The System Safety process develops, coordinates, and deploys system safety policies, standards, procedures, plans and practices and assists/assesses programs in effective application. Significant activities include the following: • Provide safety requirements checklists for program

No.	Process	Description
		tailoring consistent with mission requirements and determination of compliance position • Perform hazard analyses and risk assessments, create preliminary hazard analysis (PHA), Safety requirements/criteria analysis (SRCA), Subsystem hazard analysis (SSHA), System hazard analysis (SHA), and operating and support hazard analysis (O&SHA) • Monitor safety-critical activities • Investigate and formally report mishaps and safety-related failures • Provide input to the Safety Data Package such as the Missile System Pre-launch Safety Package (MSPSP), Safety Analysis Reports (SAR), etc. System Safety interfaces with the Environmental, Health and Safety (EHS) department on issues relating to compliance with the Occupational Safety and Health Administration (OSHA); the Environmental Protection Agency (EPA); and other federal, state, and local regulations.
7	Configuration/Change Management	**Objective:** Establish and maintain consistency and accurate knowledge of a product's performance, functional, and physical attributes with its requirements, design, and operational information throughout its life. **Description:** Configuration management (CM) is a process which implements efficient application of configuration management principles and practices to the identified context and environment. Change management is the practice of effective communication of potential or actual changes affecting a program. Communication of potential or actual changes combined with effective analytical tools and processes allow the program team to evaluate and make informed decisions regarding technical performance, cost, and schedule impacts. The activities that are performed within the configuration and change management processes are as follows: • Configuration Management Planning • Configuration Identification • Change Control including Program Changes • Configuration Status Accounting • Configuration Verification The program CM operating plan normally includes or references the following topics: • General product definition and scope • Description of CM activities and procedures for each major CM function • CM organization, roles, responsibilities, and resources

No.	Process	Description
		• Programmatic and functional interfaces • Product data management tools and systems • Recording (logging) management of change control activities including analysis products and ensuring interface accountabilities • Deliverables, milestones, and schedules • Subcontract flow down
8	Integration, Test, and Evaluation	**Objective:** Ensure that for each level of assembly, the functional performance, design, construction, and interface requirements are properly executed. **Description:** Integration, test, and evaluation (IT&E) is a broad process whose purpose is to (1) integrate components, subassemblies, assemblies, and subsystems, (2) verify that the hardware and software meet program/project requirements and (3) provide documentation on the performance and overall compliance. From a systems or responsible engineering perspective, the focus is on ensuring that the elements are physically and functionally compatible and on verifying end item requirements satisfaction (e.g., functionality, performance, design/construction, interfaces, and environment). The emphasis for mission assurance extends to verifying compliance to assembly and test processes standards as well as ensuring that robust design margins have been retained, results have been properly documented, and configuration control has been maintained. Other relevant aspects of IT&E include the development of ground support equipment (mechanical and electrical) and the integration of software products, if applicable. As each article is manufactured, quality, performance, and functionality are measured to ensure process and requirements compliance. At higher levels of assembly, (subsystem and system) test, demonstration, simulation, and analysis are used in appropriate combination to provide discernable evidence of compliance. Some of the key Mission Assurance activities for IT&E include: • Evaluating the contract mechanisms defining the scope and tasks to assure contract includes information required to plan, execute, and evaluate comprehensive integration and test program • Independently evaluating that adequate resources are allocated for a robust test program – assess test standards compared to historical test programs, cost, and mission success trends. • Evaluating that evidence provided of completion satisfies the requirements and specification baseline • Assessing system concept and new technology that may impact testing or simulation • Identifying integration, and test feasibility – issues with

No.	Process	Description
		the proposed test, integration and verification plans and procedures, including, required ground support equipment, special test equipment, and unique interface requirements • Understanding prior test history to optimize the test program and avoid over-testing potential flight hardware • Evaluating the appropriateness and risk of verification by any method other than testing • Evaluating risk associated with deviations from assembly and test (e.g., environmental) test standards and other applicable standards or best practices • Evaluating overall test program against "test like you fly" principle • Assessing the degree to which requirements are objectively verifiable and correct or addressing unverifiable requirements • Evaluating analysis, simulation, inspection, and test results to determine readiness to proceed to subsequent test or program activities. • Assessing readiness of test, such as build article configuration status and sufficiency of plans and tests.
9	Risk Assessment and Management	**Objective:** Identify and mitigate events and situations that are possible, but not yet realized, and that carry adverse consequences for a program or mission. **Description:** The risk assessment and management process is a comprehensive process that identifies the risk, risk owner, background information, probability of occurrence and associated consequences, mitigation tasks, performance indicators, and closure criteria. The process is also applicable to various types of suppliers including component suppliers, service suppliers, and subcontracts and is usually focused on identifying and mitigating technical, schedule or financial risks. All program individuals are responsible for risk identification. However risk management may have key areas of responsibility. For instance: Program Risk Management: • Ensure all risks are identified, mitigation plans established, and funding, schedule, and resources are adequate to mitigate • Capture technical, cost, and schedule risks • Monitor and track risks until they are either accepted or retired Besides the formal program risk management process, many organizations have an independent, less formal risk identification and management process that frequently is executed by the Mission Assurance or similar organization.

No.	Process	Description
		This additional risk process provides the following: • Independent path for risk reporting • Independently identify risks to program • Monitor program risk resolution • Big Picture of risk in mitigation and cumulative "residual" risk • Focus is on all risk with cost and schedule imposing constraints • Collecting and integration of risks from the Mission Assurance Disciplines • MA risks are integrated into the program risk list as appropriate • Captures early program decisions that contribute to overall risk posture, e.g., accepted single point failures Risk management is used as a communication tool to ensure common understanding of a program's current project risk posture. The risk management process is managed and monitored separately from issue tracking.
10	Independent Reviews	**Objective:** Ensure independent assessment and identification of remaining program risks through the examination of work products, processes, and program milestone events. Independent technical reviews validate processes, techniques, and results. **Description:** The independent review process evaluates the technical, schedule, quality, and programmatic details of the design of a product. An independent review is a disciplined review for evaluating progress, assessing risks, surfacing potential problems, identifying issues, and communicating decisions. The results are presented to the program and appropriate levels of management, and archived for subsequent review. Action items are frequently assigned as the result of independent reviews with the intent of further addressing and mitigating high risk areas. Independent reviews may be problem- or issue-focused or driven by program milestones such as a System Readiness Review or a Pre-Ship Independent Readiness Review. These reviews are performed by an organization or personnel that are technically, managerially, and financially independent of the development organization to achieve unbiased and objective assessments.
11	Hardware Quality Assurance	**Objective:** Ensure that hardware products used in deliverable products and ground support equipment meet the highest level of quality for their intended application. **Description:** The Hardware QA process includes quality procedures and quality work instructions specific to the program as the primary means of defining quality controls. All

No.	Process	Description

		standards for acceptable workmanship are included in process documents and training material. The Hardware QA function can be principally subdivided into Program Hardware Quality Assurance, Material Quality and Supplier Quality Assurance. Supplier QA is described separately as process 13. Program Hardware Quality Assurance responsibilities generally include oversight or participation in:
		• Requirement verification; contract through flow-down
		• Process verification; capability, readiness, Process FMEAs, certification and compliance
		• Metrology of measurement and test equipment
		• Personnel qualification and certification for key manufacturing processes
		• Product verification; compliance, non-conformance handling
		  – Inspection verifications necessary to ensure product compliance including,
		    ▪ Receiving, in-process, and final inspections of products
		    ▪ Verification of test set-ups and test output data
		    ▪ Verification of critical features and key characteristics
		    ▪ Material receiving and dimensional /attribute verification
		    ▪ Prohibited materials screening
		    ▪ Inspection and documentation of the first article built
		    ▪ Non-Destructive Inspection/Testing
		• Product Pedigree;
		  – Photograph circuit card assemblies and critical installations and interfaces
		  – As-Built data package review and verification
		• Product Preservation;
		  – Packaging, handling, preservation, transportation and shipping of products (pre-ship through receipt at customer)
		  – Cleanliness, contamination, and corrosion control
		• Environment Controls
		  – Surveillance of laboratories and manufacturing areas for environmental controls including temperature, humidity, and cleanliness requirements specific to products in manufacture
		  – Audit ESD controls and compliance

No.	Process	Description
		• Verify adequate environmental controls prior to manufacture
12	Software Assurance	**Objective:** Ensure delivered software meets all functional, performance, and interface requirements, including the required dependability, reliability, maintainability, availability, security, supportability, and usability. **Description:** The Software Quality Assurance (SQA) process provides objective participation in all phases for all types of software development and purchase efforts. The SQA participation includes providing process and product oversight for: • All software that resides on hardware • All software that directly controls or processes data from hardware • All software that resides on ground support equipment and is used to test hardware • All developmental software used to test and evaluate delivered software • All safety-critical software • All program subcontracts and customer-furnished software in support of any of the above items. SQA also maintains oversight to ensure that the software architecture is sufficiently extensible and computer resources have sufficient margins. Software is defined as computer instructions or data, programs, routines, databases, firmware, and symbolic languages that control the functioning of hardware and direct its operations. Software is anything that can be stored or executed electronically. Firmware is defined as software contained in ROM, EPROM, FPGAs, flash memory, or other programmable devices. Software Assurance can be further subdivided into Software Reliability and Software Safety as described below: **Software Reliability** The software reliability function assures built-in reliability and maturity of the software for its intended application and measures reliability growth. Built-in reliability is ensured through the Capability Mature Model Integrated software development (CMMI-DEV) process which emphasizes detailed peer reviews, thorough testing, and defect management. Software reliability growth is measured through the lifecycle using statistical measures to assess the current state of the software and to recommend adjustments to the development and test programs to ensure reliability growth. **Software Safety** The software safety function identifies critical software

No.	Process	Description
		elements that represent hazards to both the mission system and development personnel. Once safety-critical software functions are identified by performing appropriate hazard analyses, design safety features and procedures are implemented to mitigate risk to acceptable levels. Software safety typically includes: • Identification of safety critical functions • Identification of the system and subsystem hazards/risks • Determine the effects of risk occurrence • Analyze the risk to determine all contributing factors (hardware, software, human error, and combinations) • Categorize the risk in terms of severity and likelihood of occurrence • Determine mitigation requirements for each hazard commensurate with the identified risks • Determine test requirements to prove the successful implementation • Determine and communicate any residual safety risks. • Determine software product is sufficiently robust to gracefully degrade (i.e., doesn't cause catastrophic loss of system) in the presence of anomalous events
13	Supplier Quality Assurance	**Objective:** Ensure that supplied products used in deliverable products and ground support equipment meet the highest level of quality for their intended application. **Description:** Supplier Quality Assurance (SQA) processes include the assessment of supplier capabilities, compliance to processes and flow-down requirements and the verification of products and services. Development and maintenance of an approved and qualified supply base can reduce the risks associated with receipt of supplied products. Supplier Quality Assurance processes include: • Pre-contract on-site surveys to assure the supplier can – Produce correctly, on time, the first time – Prevent defect outflow • Periodic (e.g., quarterly) supplier performance assessments/resurveys • Analyze data and perform objective, supplier-quality ratings • Issue and closure of Supplier Corrective Action Requests (SCARs) • Counterfeit materials avoidance specifically requirements flow-down, compliance verification, and suspect parts, alert coordination with other functions • On-site (supplier location) inspections of in-process and final products

No.	Process	Description
		• Certification of special processes by third party such as NADCAP e.g., heat treatment, prohibited material testing, Non-destructive Test (NDT)
14	Failure Review Board	**Objective:** Assure that failure root causes are identified and corrective and preventive actions are implemented. **Description:** Failure Review Board is a closed-loop system for recording and analyzing anomalies, determining root causes, determining appropriate correction actions, tracking actions to closure and reporting failure status throughout the project life cycle. The Failure Review Board process includes representatives from appropriate organizations (e.g., engineering, quality assurance, test operations) with the level of expertise, responsibility and authority to perform root cause analyses and implement corrective actions to prevent recurrence of the failure. Failure analysis and review tasks include: • Recording and analyzing anomalies • Determining root cause • Performing independent review of non-repeatable and unknown cause type failures • Assessing risk to the project or program • Performing corrective actions and risk mitigations
15	Corrective/Preventative Action Board	**Objective:** Assure that systemic issues or defects are identified and appropriate corrective and preventive actions are implemented. **Description:** A group consisting of representatives from appropriate organizations (e.g., engineering, quality assurance, test operations, supply chain) with the level of responsibility and authority to review anomaly and incident data and trends from a variety of sources to identify areas for focused improvement activities and to ensure that corrective actions are achieving the desired end state. The perspective is of a broader nature than that of Failure Review Boards which focus more narrowly on individual anomalies or failures.
16	Alerts, Information Bulletins	**Objective:** Disseminate information of a critical nature or universal application to appropriate stakeholders to prevent additional adverse conditions or share lessons experienced by a different organization. **Description:** Alerts inform affected or potentially affected entities of identified risks to Mission Assurance. In addition to providing information about the risk, these alerts may also assign and track actions to mitigate the risk. Some sources of alerts are: • Incidents in hardware or software processing areas • Failure Review Boards • Material review activities • Corrective Action Boards

No.	Process	Description
		• Government/Industry Data Exchange Program (GIDEP) or other industry alert systems • Suspect/known counterfeit parts

It is recommended that all US spacefaring organizations compare their own policies and procedures to this tabulation, and take action to address gaps that may exist.

4.1 Correlation to Existing Requirements and Guidelines Documentation

The recommended processes and descriptions above serve as a top-level tabulation. Within the body of existing requirements and guidelines documentation there resides additional detailed information of value. Each of the processes above has been correlated to these documents as a means to identify sources of additional information (requirements, guidelines, best practices, etc.).

In many cases, organizations have their own guidance documents or internal "command media" for these essential processes. These internal process documents are often excellent references equivalent to, and sometimes more detailed than, the publicly available references available from public domain sources identified to date in Table 4-3 below. Some references (noted with an asterisk [*]) are products from prior-year's MAIW topic teams.

Table 4-3. Open Reference Material for Recommended Mission Assurance Processes

No.	Process	Correlated Reference
1	Requirements Analysis and Validation	ANSI/EIA 632, *Process for Engineering a System*, 1 Sept 2003 SMC Standard SMC-S-001, *Systems Engineering Requirements and Products*, 13 June 2008 TOR-2004 (3901)-3242, *General Guideline for Space Vehicle Verification Plan Development and Execution*, 15 March 2004 TOR-2006(8506)-4494, *Space Vehicle Systems Engineering Handbook*, 30 November 2005 *TOR-2008 (8506)-8377, *Guidelines for Space Vehicles Late Changes Verification Management*, 30 June 2008 NASA NPR 7123.1A, *NASA Systems Engineering Processes and Requirements w/Change 1 (11/04/09)*, 26 March 2007
2	Design Assurance	MIL-STD-1521C, *Technical Reviews and Audits for Systems, Equipment and Computers*, October 2004 (draft) MIL-STD-499C, *(DRAFT) Aerospace Report Number: TOR-2005(8583)-3, Systems Engineering*, 15 April 2005 TOR-2006(8506)-4494, *Space Vehicle Systems Engineering Handbook*, 30 November 2005 *ATR-2009(9369)-1, *Critical Clearances in Space Vehicles*, 31 October 2008 *TOR-2009(8591)-11, *Design Assurance Guide*, 4 June 2009

No.	Process	Correlated Reference
		*TOR-2009(8591)-14, *Effective Fault Management Guidelines*, 5 June 2009 *TOR-2009(8546)-8604A, *Reuse of Hardware and Software Products*, 27 January 2010
3	Parts, Materials, and Processes	SMC Standard SMC-S-010, *Parts, Materials, and Processes – Technical Requirements for Space and Launch Vehicles*, 13 June 2008 TOR 2006 (8583)-5235 (MIL-STD-1546), *Parts, Materials and Processes Control Program for Space and Launch Vehicles*, 8 November 2006 TOR 2006 (8583)-5236 (MIL-STD-1547) Rev A, *Electronic Parts, Materials and Processes used in Space Vehicles*, 16 November 2007
4	Environmental Compatibility	SMC Standard SMC-S-016, TR-2004(8583)-1 Rev. A (MIL-STD-1540E), *Test Requirements for Launch, Upper Stage and Space Vehicles*, 6 September 2006 MIL-STD-461F, *Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment*, 10 December 2007 TOR-2005 (8583)-1 Rev A (MIL-STD-1541A), *EMC Requirements for Space Systems*, 1 January 2008 MIL-STD-1542B, *EMC and Grounding Requirements for Space Systems Facilities*, 15 November 1991 DOD-W-8357A, Notice 1, *General Specifications for Space Vehicle Wiring Harness Design and Testing*, 4 September 2002 ASTM E1548-03, *Standard Practice for Preparation of Aerospace Contamination Control Plans, Tailoring and Background*, 12 September 2003 TOR-2004 (8583)-3291 *Criteria for Explosive Systems and Devices Used of Space Vehicles*, 9 August 2004 TOR-2003 (8583)-2894 *Space Systems Structures Design and Test Requirements*, 2 August 2004 *ATR-2009(9369)-1, *Critical Clearances in Space Vehicles*, 31 October 2008
5	Reliability Engineering	TOR-2007 (8583)-6889, *Reliability Program Requirements for Space Systems*, 10 July 2007 MIL-STD-1543B, *Reliability Program Requirements for Space and Launch Vehicles*, 25 October 1988 MIL-STD-1629A, *Procedure for Performing Failure Modes, Effects and Criticality Analysis*, 24 November 1980 SMC Standard SMC-S-013, *Reliability Program for Space Systems*, 13 June 2008 *TOR-2009(8591)-13, *Space Vehicle Failure Modes, Effects, and Criticality (FMECA) Guide*, 15 June 2009 NASA NPR 8705.5, *Probabilistic Risk Assessment (PRA)*

No.	Process	Correlated Reference
		Procedures for NASA Programs and Projects, 12 July 2004
6	System Safety	MIL-STD-882C, *System Safety Program Requirements*, Notice 1, 19 January 1993 NASA NPR 8715.3C, *NASA General Safety Program Requirements (w/Change 4 dated 7/20/09)*, 12 March, 2008
7	Configuration/Change Management	ANSI/EIA 649, *National Consensus Standard for Configuration*, 29 October 2004 ISO 10007, *Guidelines for Configuration Management* SMC Standard SMC-S-002, *Configuration Management*, 13 June 2008
8	Integration, Test, and Evaluation	TOR-2006(8546)-4591, *Space Vehicle Test and Evaluation Handbook*, 6 November 2006 SMC Standard SMC-S-016, TR-2004(8583)-1 Rev. A (MIL-STD-1540E), *Test Requirements for Launch, Upper Stage and Space Vehicles*, 6 September 2006 MIL-HDBK-340A (USAF), *Military Handbook, Test Requirements for Launch, Upper-stage, and Space Vehicles*, 1 April 1999 *ATR-2009(9369)-1, *Critical Clearances in Space Vehicles*, 31 October, 2008 *TOR-2009(8591)-12, *Suggested Checklist to Improve Test Performance in the System Test Equipment Area*, 21 May 2009 *TOR-2009(8591)-15, *Space Vehicle Checklist for Assuring Adherence to "Test-Like-You-Fly" Principles*, 30 June 2009
9	Risk Assessment and Management	ISO 17666, *Space Systems Risk Management*, 1 April 2003 NASA NPR 8705.4, *Risk Classification for NASA Payloads*, 14 June 2004 (revalidated 9 July 2008)
10	Independent Reviews	*TOR-2009(8583)-8545, *Guidelines for Space Systems Critical Gated Events*, 9 May 2008 National Security Space Acquisition Policy 03-01, *Guidance for DoD Space Acquisition Process*, 12 December 2005 SMCI 63-1201 *Assurance of Operational Safety, Suitability and Effectiveness for Space and Missile Systems*, 21 May 2001 SMCI 63-1202 *Space Flight Worthiness*, 2004 SMCI 63-1203 *Independent Readiness Review Team*, 2004 SMCI 63-1204 *SMC Readiness Review Process*, 2004 NASA NPR 8705.6A, *Safety and Mission Assurance Audits, Reviews, and Assessments*, 9 April 2009
11	Hardware Quality Assurance	ISO 9001:2008, *Quality Management Systems, Requirements*, 11 November 2008 SAE AS9100C, *Quality Management Systems - Requirements for Aviation, Space and Defense Organizations*,

No.	Process	Correlated Reference
		15 January 2009 SAE AS9102A, *Aerospace First Article Inspection Requirement*, January 2004 TOR 2005(8583)-3859, *Quality Assurance Requirements for Space and Launch Vehicles*, 1 December 2005 SMC Standard SMC-S-003A, *Quality Systems*
12	Software Assurance	TOR 2004 (3909)-3537B, *Software Development Standard for Space Systems*, 11 March 2005 ISO/IEC STD 15939, *Software Engineering - Software Measurement Process*, 11 July 2002 NASA NPR 7150.2A, *NASA Software Engineering Requirements*, 19 November, 2009
13	Supplier Quality Assurance	ISO 9001, *Quality Management Systems – Requirements* SAE AS9100C, *Quality Management Systems – Requirements for Aviation, Space and Defense Organizations*, 15 January 2009
14	Failure Review Board	S-102-1-4-2009e *ANSI/AIAA Performance-Based Failure Reporting, Analysis & Corrective Action System (FRACAS) Requirements*, 2009 SAE AS9100C, *Quality Management Systems – Requirements for Aviation, Space and Defense Organizations*, 15 January 2009 MIL-STD-1520C *Corrective Action and Dispositioning System for Nonconforming Material*, June 1986 MIL-STD-1543B, *Reliability Program Requirements for Space and Launch Vehicles*, 25 October 1988 MIL-HDBK-2155, *Failure Reporting, Analysis and Corrective Action Taken*, 11 December, 1995 TOR-2007 (8583)-6889, *Reliability Program Requirements for Space Systems*, 10 July, 2007
15	Corrective/Preventative Action Board	SAE AS9100C, *Quality Management Systems – Requirements for Aviation, Space and Defense Organizations*, 15 January 2009
16	Alerts, Information Bulletins	MIL-STD-1556B, *Government/Industry Data Exchange Program (GIDEP) Contractor Participation Requirements*, 24 February 1986

In some instances, the government acquisition organizations have developed and maintain a consolidated set of compliance specifications and standards for their respective acquisitions. These documents contain additional general references relating to the MA Processes and expand on the references cited in Table 4-3.

Space and Missile Systems Center:

- TOR-2008(8583)-8215, SMC Compliance Specifications and Standards, 15 August 2008
- TOR-2008(8583)-8216 (Compact Disc), contains all of the SMC compliance documents that are not restricted by Copyright or license restrictions

National Aeronautics and Space Administration:

- NASA Online Directives Information System, http://nodis3.gsfc.nasa.gov

5. Recommended Next Steps and Future Work

- As stated following Table 4-2, it is recommended that all US spacefaring organizations compare their own policies and procedures to the tabulation of sixteen recommended mission assurance processes, and take action to address gaps that may exist.

- It is recommended that the MAIW consider sponsoring future topic teams to create work products for the four processes that presently do not have open reference requirements or guideline documents. A preliminary gap assessment is as follows:

  - 13 – Supplier Quality Assurance
  - 14 – Failure Review Board
  - 15 – Corrective/Preventative Action Board
  - 16 – Alerts, Information Bulletins

- It is recommended that the MAIW continue the work initiated herein and undertake further evaluation and tailoring of the 16 recommended mission assurance processes for the spectrum of space programs. Two documents exist that establish a four-tiered space mission classification approach where technical and program management attributes are established for the range of US space missions spanning high priority/minimum risk (e.g., high national priority) to low priority/higher risk (e.g., minimum acquisition cost). This classification system was created to correlate mission attributes to allowable risk tolerance, and facilitate a common understanding of many elements of the planned mission assurance process. Universal application of this classification system is lacking, but it is considered of high value to many team members since they are currently executing programs to multiple risk tolerances.

Document	Scope
DoD-HBDK-343, *Design, Construction, and Testing Requirements for One of a Kind Space Equipment,* 1 February 1986	Technical and program requirements for the design, construction, and testing of various classes of space equipment. Defines four payload classes A-D per range described above. Requirements are a composite of those that have been found to be cost effective for one-of-a-kind space programs.
NASA NPR 8705.4, *Risk Classification for NASA Payloads,* 14 June 2004 (revalidated 9 July 2008)	Establishes baseline criteria that define the risk classification level for NASA payloads on human- or nonhuman-rated launch systems or carrier vehicles and the design and test philosophy and the common assurance practices applicable to each level. Utilizes the same Class A-D approach described for DOD-HDBK-343 above.

Appendix A. Summary Tabulation of All Core and Supporting MA Processes

Organization	G1	G2	G3	G4 (1)	I1	I2	I3	I4	I5	I6	I7	Count	Core	Supp	Both	Total
Process																100
Hardware Quality Assurance	C	C	C	C	C	S	C	C	C	C	C	11	10	1	0	52
Design Assurance	C	C	S	C	C	S	C	C	C	C	S	11	8	3	0	46
Parts, Materials, and Processes	S	C	C	C	C	S	S (3)	C	C	C	C	11	8	3	0	46
System Safety	S	C	C	C	S	S	C	C	S	C	C	11	7	4	0	43
Risk Assessment and Management	S	C (2)	C (2)		C	C/S	S	C	C	C	C	10	7	2	1	43
Software Assurance	S	C	C	C	C	S	S	C	C	S	S	11	6	5	0	40
Integration, Test, and Evaluation	C	S	S	C	C	S	C/S	C	S	C	S	11	5	5	1	39
Independent Reviews	C	S	S (3)	C	S	C/S	S	S	C	C	C	11	5	5	1	39
Failure Review Board	S	C	S		C	C/S	C	S	C	C	S	10	5	4	1	37
Reliability Engineering	S	C	C	C	C	S	S	C	S	S	S	11	5	6	0	37
Supplier Quality Assurance	S	C	S	C	C	S	S	C	S	S	C	11	5	6	0	37
Requirements Analysis and Validation	C	C	S		C	S	S	C	C	S	S	10	5	5	0	35
Configuration Management	S	C	S	C	S	S	S	C	S	S	S	11	3	8	0	31
Corrective/Preventative Action Board	S	C	S (3)		S	C/S	S	S	S	C	S	10	2	7	1	28
Alerts, Information Bulletins	S	S	S		S	S	S	S	C	C	S	10	2	8	0	26
Environmental Compatibility (4)	S	S	C		C	S	C/S	S	S		S	9	2	6	1	26
Calibration/Facility Certification		S	S	C	S							4				
Gated Practices		C			S	S					C	4				
Cost Tools and Models, EVMS	S						S				C	3				
Human Factors		S		S				S				3				
Lessons Learned		S	S								S	3				
Program Assurance	C							C			C	3				
Subcontracts Management					S			S		S		3				
Training and Certification				S					S		C	3				
Environmental Health and Safety	S							S				2				
Logistics	S							S				2				
Operations, Maintenance, and Sustainment	C							C				2				
Qualification Review Board						S			C/S			2				
Quality Management Systems					S					S		2				

Performing Discipline:

- Mission Assurance
- Quality Assurance
- Systems Engineering
- Parts, Materials, and Processes
- Supply Chain Management
- Engineering/Technical Function
- Program Management
- (clear) Multiple Disciplines, or N/A

Notes:

(1) G4 data compiled by organization G1
(2) Performed by both Mission Assurance and Program Management
(3) Performed by both Engineering and Mission Assurance
(4) Includes EMI/EMC, radiation assessment/analysis, contamination control processes, and others