AEROSPACE REPORT NO.
TOR-2012(8960)-6

Mission Assurance Approach within a Mission Class Development vs Production Programs

June 30, 2012

Christine L. Stevens
Engineering and Integration Division
Space Systems Group

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
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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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The document was created by multiple authors throughout the government and the aerospace industry. We thank the following contributing authors for making this collaborative effort possible:

Marvin Ramierz (The Boeing Company)
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1. Introduction/Background/Overview

Mission Assurance (MA) is defined as "the disciplined application of general systems engineering, quality and management principles towards the goal of achieving mission success, and toward this goal, provides confidence in its achievement."[1] Decisions on the MA approach and its implementation can directly influence mission success as well as the business (cost/schedule) performance of an acquisition program. In general, the stakeholders are aligned so that substantial and timely MA content in a development program will ultimately provide return on the investment in both the mission success and business domains.

While National Security Space programs do not approach the unit numbers typically associated with a "production line," the existence of multiple vehicles motivates the community to seek unit cost reductions beyond the first article. For the purposes of this document, a production program is defined as a program where the stakeholders expect a significant reduction in non-recurring engineering (NRE) and recurring costs on articles built subsequent to the first article. Examples of production programs are provided below:

- A follow-on program, where a substantial portion of the development has been achieved on a different contract.
- A program utilizing an existing product line, but with a different payload layout and antenna design, which is typical of most commercial programs.
- A program with a significant number of units following the development vehicle.

Almost any follow-on program has an element of work that can be considered "production" or "routine" where an optimized or tailored MA approach can be utilized that will achieve cost/schedule savings. However, there is also high likelihood that some content on the follow-on will have changed from the baseline and a broader MA approach that is similar to, if not greater than, the prior program will be required. The objective of this document is to assist stakeholders, both government and industry, in the identification of the scope of work in each camp and address guidelines for how to develop the optimized or tailored MA approach to yield cost/schedule savings without a loss of quality or MA.

This 2012 Mission Assurance Improvement Workshop (MAIW) product is intended to build upon previous MAIW products, specifically, the Mission Assurance Framework to provide such guidance. The MAIW team responsible for this product includes senior members from both government and industry. We do not intend to duplicate previous work defining the MA Framework or the specific processes therein, but rather to address the transition from development to production.

This document serves as a complement to the previous MAIW product on the use of heritage hardware and software. The Use of Heritage Hardware and Software technical operating report (TOR) provides guidance for assessing the use of components of a set design developed to meet requirements other than those on the program in question. This document addresses the situation where the requirements are mainly set and the design of various components may change or evolve.

[1] The Mission Assurance Guide, TOR-2007(8546)-6018

2. Background

The transition of MA practices, when moving from development to production, is more complex than identification of MA activities to discard or scale back, or those to add or augment. Fundamental to successful production is the overt assessment and decision that a program state has been achieved that will support production and deviation from the MA processes implemented, hopefully successfully, on the development program. In short, there is a need for some type of activity/review where the stakeholders verify/confirm that the system is ready for production. Ideally, this type of activity would be conducted prior to the end of the development program, provided schedule and funding are available. It is the intent of this document to provide an outline for the conduct of such a review which we term a "Unit Equivalency Review" or UER.

The UER could be accomplished either on the development program as a final product or as a requirement on any proposal for follow-on activities. One of the main tenets of the UER is to add "producibility" to the review cycle in the early stages of the program. There are numerous case studies showing that successful production programs focus on production issues early in the program, even before the first development vehicle or units are built.

When a program moves from development into production, there are opportunities to make risk-based decisions regarding the reduction of certain MA activities with an expectation of cost savings. We intend to identify such opportunities and provide guidance for making such decisions. In order to achieve those savings, one must consider the factors that influence cost/schedule and manage expectations accordingly. There are three broad categories of activities on National Security Space programs for consideration: contractor activities, government activities, and the interactions between the two. This document does not address those activities conducted solely by the government. It is noteworthy that robust and disciplined risk management remains essential on production programs as the realization of risks induces unplanned/unscheduled engagement from all parties.

A key theme that emerged over the course of this MAIW activity is the danger that results to Mission Assurance from attempts to dictate a uniform level of reduction across an entire program. Such a "peanut butter spread" approach of some percentage reduction across the entire enterprise has been observed to have a sub-optimization effect as certain non-negotiables such as those activities in support of safety-related requirements are impacted. Similarly, reductions in unit level tests and screening during production have resulted in increased program cost as defects are found late in the integration and test phase. The approach taken by the team in the development of this document is to guide the stakeholders through thoughtful consideration of MA activities to ensure a right-sized and balanced approach on production programs.

It is the consensus of the team that "first article" development is not typically characteristic of the first item off a production line. More of the manufacturing and assembling of a "first article" may be done in house than later bid in production. More hands-on engagement and support from engineering/design staff may occur along with hand-crafted or selected (cherry picked) parts. As a result there may be a need to adjust, possibly increasing, certain MA processes in production as the ready availability of technical engineering expertise reduces and work done by technicians increases.

Contractual commitments of 1–2 vehicles give the impression that production is possible, but in reality each instantiation is like a new start. There appears to be little motivation for the contractor to expend limited resources during a 1–2 vehicle development program to ensure manufacturability or vetting out of manufacturing process procedures and documentation. As program personnel staffing shifts from the development team to the production team, there is more reliance on documentation and less on skilled engineers being readily available.

Examples of changes observed in the production vice the development environment that may impact MA activities are listed below:

- Parts obsolescence
- Root Cause Corrective Action (RCCA) activities for factory and on-orbit anomalies requiring design/process changes–this can occur during development programs, but the number of occurrences is usually much higher in production programs as the development articles are fielded and full operations reveal deficiencies or improvement opportunities.
- Suppliers changing location, equipment, people, processes, or design since the development program or between block builds
- Reduction or change in System Engineering staff reviewing unit and system level test.
- Suppliers lose key personnel with detailed knowledge of the design of the units and systems.
- The supplier/prime contractor implements changes into the product line to improve productivity in the middle of the production program.
- Change of suppliers or outsourcing an item previously built in-house

As a result of these general observations, expected cost savings may not be realized on follow-on production programs.

A useful metric already available for use in assessing the readiness for production is the Manufacturing Readiness Levels (MRLs). MRL Level 8 is defined[2] as that state where a system, component or items is in advanced development and is ready for Low Rate Initial Production (LRIP). At this level, engineering and design changes should decrease significantly from the numbers previously experienced on the program. Another discriminator is that manufacturing processes and procedures have been proven and are under control. Again, the limited numbers comprising National Security Space systems challenge the community to determine a program's readiness for production. The UER is presented as a recommended process to inform that determination.

[2] Manufacturing Readiness Level (MRL) Deskbook, Version 2.0, May 2011, OSD Manufacturing Technology Program

3. Purpose & Scope

This document is intended for use during the acquisition of a follow-on program, a program to complete or replenish a constellation, and possibly during a single multi-buy program/contract should sufficient confidence be gained during the execution to anticipate a follow-on. Additionally, this document would be useful to acquisition teams seeking to initiate a program that would be postured for a smooth transition from development to production.

This document is focused on the actual vehicle to be produced and does not address items such as factory infrastructure or test equipment.

As mentioned above, this 2012 MAIW product is intended to build upon previous MAIW products, specifically, the Mission Assurance Framework to provide such guidance. This document does not seek to replace or augment existing specification and standards currently in use, but rather provide guidance in tailoring those same documents based upon an informed understanding of the readiness of a program to move into production.

3.1 Use of this Document by the Government and Industry

This document is intended as a guidance document to help stakeholders that are engaged early in the acquisition process identify and implement an acceptable, best value, MA approach on recurring Class A and B programs. The document includes guidance on handling of specific issues, assessments, or trades that need to be completed to support determination of an effective MA approach.

Issues to be addressed include:

(a) issues impacting transition from first article development to recurring production

(b) guidance on relevant facts and data to support MA approach decision making

(c) considerations on decision making in the absence of complete data

4. Assessment and Plan for Production Programs

4.1 Introduction

The issues that the National Security Space Programs face as they transition from development to production phases are considerably different than those seen in other industries such as general aviation, especially from a Mission Assurance perspective. The goal of this chapter is to identify the problems that typically arise and provide processes and guidelines to minimize the risks to the program.

Typically, the production (or Follow-On) programs are expected to be comprised mostly of recurring costs with little or no non-recurring engineering (NRE) (see Figure 4-1). The current Mission Assurance Guide (MAG) does not provide guidance on Mission Assurance of Phase D for Follow-On programs. The assumptions for Phase D at the time of Follow-On buy approval is that no significant changes have occurred and no changes are required for the “production” units. While it is feasible this can occur, and has on commercial programs, such as Iridium, it occurs rarely on government programs. If the development program had a specific focus on Design for Manufacturing and Test (DFMAT) during Phase B and C, this may be feasible. However, there can be design changes to units or subsystems in the “production” phase which can create issues that were not anticipated. Another concern is product and process variability that occur during production programs, especially as personnel change on the manufacturing floor. This chapter is intended to highlight such issues so that an assessment can be made to determine if they are properly adjudicated in the Mission Assurance approach during all phases of the production program.

The authors recognize that current Defense Acquisition Management processes are defined in DODI 5000.02 with Space-Related Revisions contained in Directive-Type Memorandum (DTM) 09-025– Space Systems Acquisition Policy (SSAP). For the purposes of establishing terminology for the identification of program phases, and to maintain consistency with The Mission Assurance Guide, TOR-2007(8546)-6018, we reference the previous National Security Space (NSS) Acquisition Policy 03-01.

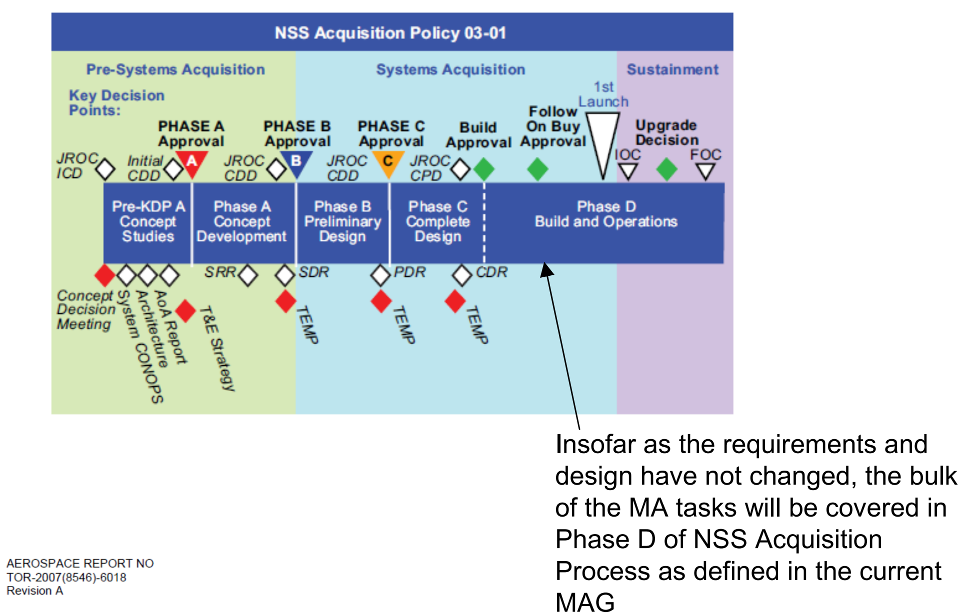

Figure 4-1. NSS 03-01 Phases for Space Acquisition.

Absent the ideal situation of frozen requirements and design, unchanged bills of materials, and no changes driven by on-orbit observations, we recommend revisiting, as needed, the MA tasks as defined in previous MAIW topics. The Mission Assurance Guide, TOR-2007(8546)-6018, should be a reference document for National Security Space (NSS) Production Program Mission Assurance (MA) implementation, in conjunction with this document, to determine how to adjudicate issues that occur in production programs. In addition, Mission Assurance Guidelines for A-D Mission Risk Classes, TOR-2011(8591)-21, should be referenced for Mission Assurance process implementation across the mission risk classes (A, B, C, or D). The Mission Assurance Guidelines for A-D Mission Risk Classes leverage the processes defined in Mission Assurance Program Framework, TOR-2010(8591)-18, for their support in achieving mission success.

4.2 Introduction to the Unit Equivalency Review

When the procuring agencies and system providers are contemplating a follow-on procurement, the issues that typically arise, and can be predicted based on lessons learned, should be adjudicated as early as possible. Each Follow-On program should review the predecessor program (whether it was a development program or previous block purchase) to determine which artifacts of Phases A-D, as defined in Mission Assurance Guide, TOR-2007(8546)-6018, are still applicable, and which artifacts are missing. If the prior program was a Class C program, but the Follow-On program is redefined as a Class A program, a substantial amount of NRE in Phases A-C should be expected. However, if the Follow-On program requirements are the same as the prior program, Phase A-D can be tailored to minimize the NRE while still addressing the remaining risks.

The Unit Equivalency Review (UER) is a process which provides the procuring agency, the prime contractor, and suppliers with the knowledge (facts and data) to determine which reviews and qualification tests will be required for the production program. The expected output of the UER is a clear understanding and consensus by all stakeholders (customer, prime, and vendors) what reviews are required, how they should be tailored, and a clear statement of work (SOW) can be written to the prime and suppliers. If the suppliers and prime contractors know how the units are built and qualified, this should not be a burdensome review. The UER needs to occur before the program baseline and unit purchase orders are placed and is intended to protect all stakeholders from misinformation leading to poor decisions, future rebaselining, and contractual disputes.

For the purpose of this document, it is assumed that software changes during production will originate, be implemented, and tested by an existing sustainment functional that includes a validation/verification test bed. It is recognized that certain hardware changes may impact software/firmware so the UER attendees must include personnel capable of identifying such changes so that program activities can be planned so that the two communities are brought together in a timely fashion to avoid unanticipated cost/schedule growth.

A key area to evaluate is the program’s ability to transition to the production phase and whether Design for Manufacturing, Assembly, and Test (DFMAT) was considered during the design of the units and spacecraft. An assessment should also be made of the ability of both the staff and processes to perform the expected increase of work in process (WIP). A review of outstanding programmatic issues to meet the required production rate and planning to address those issues is also recommended.

The UER is required to engage all level of procurement, including the prime contractor, suppliers, and if necessary, sub-tier suppliers. Ideally, one UER meeting with all key stakeholders attending should identify any changes since the last time the unit was produced for the program. In addition, it is highly recommended to explicitly identify and record the Subject Matter Experts (SMEs) by name, company, and relevant contact information, to help resolve production issues and anomalies expediently.

To illustrate the possible differences of the Mission Assurance approach of the production (or Follow-On) program, refer to Figure 4-2A, which shows the typical approach for a development program.

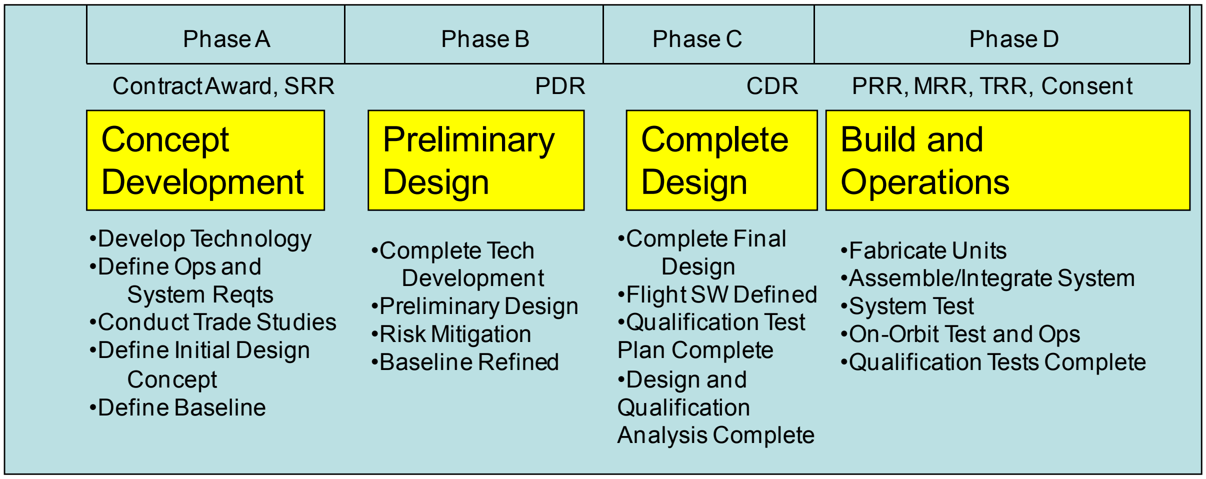

Figure 4-2A Mission Assurance Approach for Class A Development Program

The NRE to create these artifacts is substantial for the development program. If the previous development program was a Class C program, the required NRE in Phases A-D was most likely not completed, or at a lower standard than required for a Class A program. Another possibility is the prior program was meant to prove a new technology, but producibility was not a high priority. In these cases, the Class A Follow-On program may require more NRE than was accomplished during the predecessor Class C Development program.

However, if the Follow-On program is the same mission classification as the prior program and the system provider can leverage a significant portion of the prior programs NRE, a significant cost reduction should be achievable (refer to Figure 4-2.B.) without increasing technical risk. Here, Phase A has been redefined as Equivalency Review, where the key stakeholders assess the system level requirements and production capabilities of the contractors and subtier suppliers to verify that a substantial portion of the NRE that occurred on prior programs is still relevant to the new program. A UER is held for each unit to determine what level of NRE, if any, is required. For those units that require no changes, the long lead parts can be procured to minimize the critical path schedule. For units that require redesign, the tailoring of the NRE will be determined at the UER so that a realistic program baseline can be established which minimizes the cost and schedule risks while maintaining the technical and qualification requirements of the program. If changes are required beyond the unit level, a subsystem delta Critical Design Review (CDR) may be required to verify that the technical risks are adjudicated.

The aggregation of all unit equivalency assessments will provide stakeholders the overall picture of the entire program's readiness for production and help inform program planning decisions regarding MA activities.

4.2.1 Initial Phase of the Production Program

4.2.1.1 Unit Equivalency Review (UER) (Follow-On Phase A)

The purpose of the Unit Equivalency Review is to determine the state of requirements satisfaction at all levels of the program and determine which reviews and artifacts are required to ensure all units, subsystems, software/firmware and the overall system will continue to meet all performance and qualification requirements. As mentioned previously, the existence of sustainment resources performing maintenance on software and associated databases may be leveraged as part of the UER process.

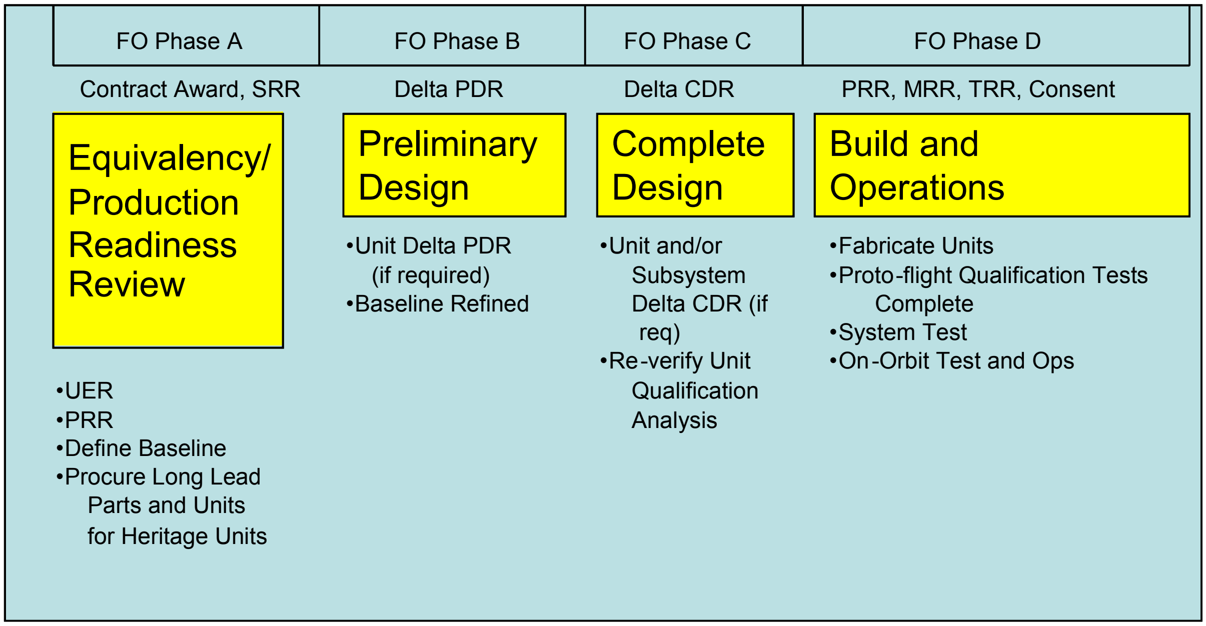

Figure 4-2B. Mission Assurance Approach for a Class A Follow-On Program

The UER meetings should be held at the start of the program, before unit procurement. The purpose of the UER is to determine what level of Preliminary Design Review (PDR), CDR, Qualification Review, and Manufacturing Readiness Review/Production Readiness Review (MRR/PRR) is required at later stages of the program. All known changes of unit design, manufacturing processes, materials, manufacturing location of parts and assembly, and alternate parts are reviewed by senior system and unit engineers and the units then classified as “No Change,” “Insignificantly Changed,” “Significantly Changed,” or “New.”

No Change–The unit has no design changes, is manufactured in the same facility, and no standard process change has occurred. If a unit meets this definition, but a significant gap between production runs has occurred, an MRR and first unit protoqual level test may be prudent as well as a Qualification Review for the facility and processes.

Insignificantly Changed–Form, fit, and function have not changed. Most units that fall in this category will do so due to parts obsolescence issues where a drop-in replacement is available. The review for this type of unit may be an impact assessment to the worst-case circuit analysis (WCCA), thermal analysis, and reliability calculation. The unit may require a change to the drawing and AD/AB to add the alternate part. Processes changes and/or manufacturing facility change may also fall into this category. Unit level PDR or CDR is not required, but a Qualification Review and an MRR is usually required. For process or facility change, steps must be taken to qualify or otherwise gain confidence in the new process or facility. It is also recommended that a review of the original First Article Inspection (FAI) be conducted to determine if a delta FAI is required.

Significantly Changed–Form, fit, or function has changed, requiring a review of the qualification of the unit and verification of the impacts to analysis and unit/system level test plan. A new application-specific integrated circuit (ASIC) with new printed wiring board (PWB) layout within a unit would be an example of a significant change. A delta PDR may not be required, but a delta CDR, Qualification Review, and MRR will need to be conducted.

New–the unit has never been used in the development system or it is a new application of the unit in the production system. Generally, all Mission Assurance Guidelines for Development Programs should be followed, and full PDR, CDR, Qualification Review, and MRR will need to be conducted.

4.2.1.2 Production Readiness Review (PRR) or Manufacturing Readiness Review (MRR) (Follow-On Phase A/D)

Early in the production program, a PRR or MRR should be conducted to verify that any issues that were brought up in the UER have been addressed for manufacturability. The government accounting office (GAO) study titled Defense Acquisition, Assessments of Selected Weapons has demonstrated the common characteristic of successful production programs was early, multiple, and well supported focus on production issues throughout the program from development through production.[3] The reference to the study is GAP-12-400SP, March 2012. The PRR should be conducted in phase A to identify any gaps in the production program, such as a defined test architecture, facilities, special test and integration equipment, tooling, etc. The GAO reports successful programs held multiple meetings through all phases, in parallel with the design phases, and the outcome was a mature production process during first article production. Unsuccessful programs would conduct one PRR meeting shortly before first article production began; consequently, no effective changes would be incorporated in time.

The MRR is usually held just prior to production of units and is intended to verify all of the engineering, equipment, personnel, and facilities are ready for production.

4.2.1.3 Preliminary Design Review/Critical Design Review (PDR/CDR) (Follow-on Phase B, C)

If there are any new units or significantly changed units in the production program, a subsystem/system PDR/CDR should be conducted to verify that there were no unintended consequences introduced by the design change. This is in addition to the unit level PDR/CDR. For example, a unit hardware change may affect how the existing Flight software will respond to an anomaly. A risk assessment needs to be made with senior software engineers to determine what types of regression or verification and validation tests are required to be run even if Flight software is reused without changes. These design reviews can be delta Design Reviews; focused on the specific design changes relative to the prior development program's design.

4.2.1.4 Qualification Review (Follow-on Phase C)

The Qualification Review, for purposes of this document, includes changes to requirements, hardware design, software, parts, manufacturing facilities, manufacturing instructions, standard site processes, vendors, and workforce. On development programs, the time from qualification to delivery of the system is short enough to usually preclude these issues. Production programs, which may occur years later and span decades, need to verify the unit design and production processes are equivalent to the prior qualification unit and the analyses used for qualification are still relevant.

4.2.2 Unit Manufacturing Phase

During unit level manufacturing, new issues that were not discovered during the prior design reviews may arise. Usually, these are reported as production or test non-conformances. The industry standard Parts, Materials and Processes Configuration Board (PMPCB), Material Review Board (MRB), and Failure Review Board (FRB) should be just as effective in production as in development programs.

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[3] The reference to the study is GAP-12-400SP, March 2012.

However, as production ramps up and multiple systems are being built simultaneously, the impact of such issues to production costs can be greater due to the increased Work In Process (WIP). The programs need to determine if there is reach back or reach forward concerns that typically do not exist when the plan is to produce only one unit or system at a time. Consequently, the Mission Assurance organization and processes may need to be tailored to adjudicate any issues quickly.

Key stakeholders may desire, or require, a reduction in production costs. Critical path units should be identified first and their unit failure history reviewed, because the cost savings in schedule can be substantial. If all past anomalies have occurred during in-process testing or in initial ambient testing and no vehicle level test anomalies have occurred, a reduction in Thermal Vacuum (TVAC) testing duration should be considered. Other risk considerations such as the impact to remove and replacing the units should also factor into the decision of reducing unit level testing requirements.

Another area for potential unit cost reduction is to increase in-process testing (at the subassembly level, for example) if too many components are failing at unit level or system level testing. By increasing the lower level testing or screening, costs may be avoided should components fail later in the integration and test phase.

4.2.3 Vehicle Level Test Phase

In addition to workmanship issues being uncovered during vehicle level testing, vehicle level interface issues can be uncovered. It may be the first time a redesigned unit is integrated into the vehicle, so attention should be paid to anomalies that could be caused by interface issues with other units. These types of anomalies are expected during development programs, but are unexpected during subsequent builds. As redesigned hardware or software is integrated with the rest of the vehicle, it is important that the test team be aware of the changes so appropriate regression testing is planned to ensure identification of interface design problems.

In summary, the vehicle level test program should clearly delineate the test program for vehicles in production and those in development. The aim is to reduce the NRE and risk when transitioning to the production phase and reduce non-value added recurring tests, while ensuring mission success. Figure 4.2-3 illustrates how a system level test program architecture can minimize the NRE as the program transitions from development to production.

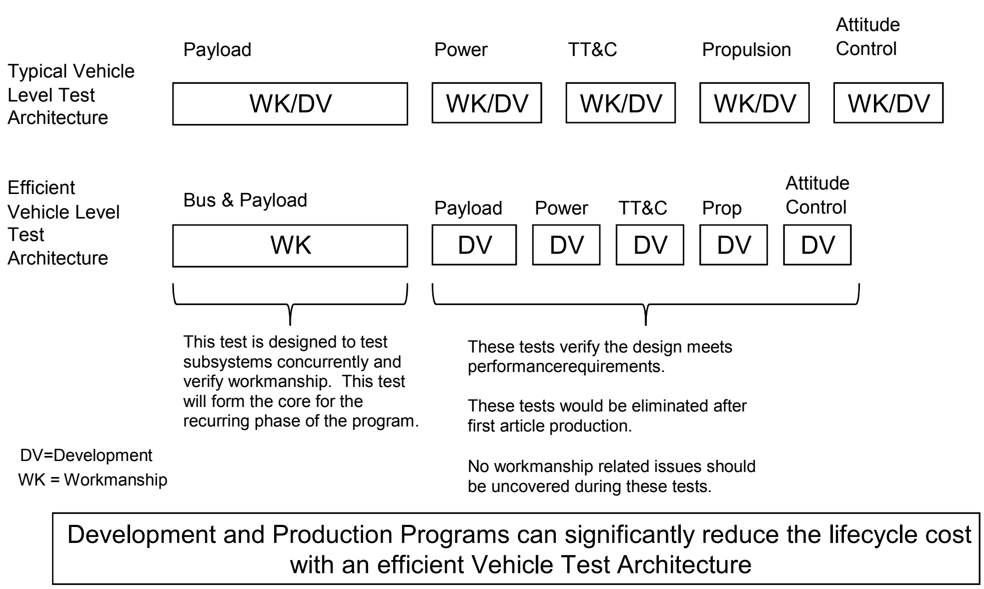

Figure 4.2-3. Vehicle level test program architecture.

4.2.4 End-to-End System Changes

As the ground equipment needs to be replaced, subtle changes can occur that affect the performance and function of the overall deployed system (a satellite and associated ground control system, for example). This can also occur when the interface is redesigned to address new threats from adversaries (anti-jamming or enhanced encryption). Such changes should be thoroughly reviewed in the UER to determine the appropriate level of MA activities associated with these changes consistent with both the program risk posture and other programmatic constraints.

4.2.5 ConOps Changes

During the production life cycle of a program, changes to shipping, launch vehicles, and mission design can create new requirements. The issue for production programs is that new requirements may not be recognized or flowed down appropriately because the requirements management infrastructure in the program office may no longer exist or otherwise be significantly reduced. During the UER, the customer should review the requirements flowed to the prime contractor to verify that Concept of Operations (ConOps) changes are explicitly stated and enveloped by the existing requirements.

4.3 Organizations and Continuity of Resources

The organizational structure for a production program is derived from the structure of its parent development program. Development specific functions are tailored out of the organizational structure to the extent practicable based on production needs and the target cost of the program. As a program transitions from development to production, there is a reduced need for engineering resources associated with requirements development, design development, and requirements verification and validation. It is assumed that development program requirements have been fully established, verified and validated, however specific engineering expertise may need to be retained based on new production program requirements, parts or materials obsolescence, process changes or support to anomaly investigations. New production program requirements and parts or materials obsolescence issues require a comprehensive impact assessment on all potentially affected interfaces to minimize implementation risk. These issues represent a significant production program challenge since the full assessment of these issues may be impacted by the lack of available engineering resources with the specific domain and/or development program expertise. Access to potential engineering resources needs to be established early in the production program to successfully address these production program issues.

Development program documentation may need to be revised for production program use to properly address production program needs. Program planning shifts from development tasks to production and supply chain and production management become key areas for program focus. Early in the production program, systems engineering tasks focus on production unique requirements and validation. Proof of design will have been completed and necessary performance margins established during the development program. Requirements associated with design performance will remain and will serve as the basis for design verification during production. There will be a reduction in Systems Engineering staff associated with analysis of test results and in support of anomaly investigations associated with first item production, however; the need for engineering resources will remain throughout the production program to resolve production phase anomalies.

A significant challenge for production programs is the loss of key personnel with specific product knowledge. Programs need to ensure that there is adequate transfer of product knowledge to ensure successful production program execution. To meet this need, development programs anticipating production follow-on contracts should implement a plan to ensure that specific product knowledge is maintained, perhaps within the prime contractor's functional organization or a supplier's. Associated development program documentation such as:

- trade study results;
- design analyses;
- engineering build documentation;
- and anomaly investigations

should be maintained from the development program to support the evaluation of new production program requirements, parts or materials obsolescence, process changes or support to anomaly investigations during the production program. This need applies to all levels of suppliers and failure to address it represents a risk to the maintenance of a qualified industrial base should there be a significant gap between development and production contracts.

4.4 Manufacturing

4.4.1 Manufacturing Assurance

Manufacturing processes for production programs should have been developed to be successfully repeatable during the development program. The focus of Manufacturing Assurance for production programs is to assure that the manufacturing processes are implemented in a successfully repeatable manner. Corrective Actions from issues addressed by Corrective Action Boards and Lessons Learned are assessed for manufacturing impacts and implemented for subsequent production builds. Manufacturing impacts from new production program requirements, parts or materials obsolescence, and process changes need to be assessed per Manufacturing Assurance processes applicable to the development program phase. Manufacturing Assurance processes for production programs are tailored to be consistent with production program needs based on criteria for the post design phases and production program impacts from new production program requirements, parts or materials obsolescence, and process changes as described above.

4.4.2 Facilities

Development programs with the potential for production follow-on should create a facility plan which addresses requirements for production facilities and establishes how the program will provide production facilities. When development facilities are planned for production use, their use needs to be coordinated and scheduled based upon demands of the enterprise. If other facilities are planned for production use, they need to be identified and scheduled, and assessed to ensure qualification to execute in accordance with program requirements.

4.5 Other Considerations

4.5.1 Issues Impacting Transition from First Article Development to Recurring Production

Multiple issues can impact production programs during the transition phase following first article development. While issues associated with the transition from development to production may exist, issues associated with second article production leading into production may be more challenging. The following key areas are provided as examples of potential issues during the transition phase.

A key concern for production programs is parts or component obsolescence. Development programs with the potential for production follow-on should have processes in place to assess designs for potential parts or component obsolescence and address the impacts to production. In cases where a development end item contains obsolete parts or components, or potential obsolescence is identified during production, an opportunity exists for pre-production risk reduction studies and potential further development, to establish options or solutions for production. A full awareness of industrial base issues should also be maintained to ensure that parts, components, subsystems and supplier expertise are available to meet production needs.

An additional concern for production programs is attrition within the supply chain. Suppliers may exit the space business, change locations, equipment, people, processes, or designs subsequent to product development program or between block builds. Programs should assess and address supply chain stability during development. Strategic relationships with suppliers may need to be assessed. The potential exists for supply chain instability to affect development phase trade study results.

4.5.2 Assessing the Results of Development Mission Assurance (MA) Execution

Production programs should also assess how well MA processes were executed during development to identify potential risks. Potential concerns involve hardware/software designs with use-as-is assessments from development phase anomalies, one-time-use requirement waivers, unverified failures and open liens. Development programs with the potential for production should have a process in place to ensure that production programs can easily identify, assess, and address these concerns.

4.5.3 Relevant Facts and Data to Consider for Mission Assurance (MA) Approach Decision Making

Development programs should consider the following key areas when establishing the MA approach for each program phase. Other areas may also exist based on program unique implementations and output from UERs conducted.

1. Technical and quality issues that may impact program risk and ultimately mission success
2. The program's mission class (development and production may be different)
3. Design maturity
4. Development program anomalies, use-as-is assessments, unverified failures
5. Requirements and design changes
6. Available budget and schedule
7. Available trained and skilled personnel resources with end-item domain expertise

The applicability of development phase MA processes within the production phase is typically based on the amount of change to be considered by the production program. Production programs with no- or minimal- change may be able to execute with minimal risk using MA processes applicable to the post design phases. Any change should, however, be assessed for impact to end-item qualification. In cases where item qualification has been impacted, MA processes applicable to concept development, preliminary and final design phases should be implemented. A hybrid approach associated with production programs with some development content is the most typical implementation for production programs.

4.5.4 Repeatability

A significant product of development programs with the potential of production follow-on is the establishment of mature and successfully repeatable processes which have minimized the need for specific domain or end-item subject matter expertise. While it is assumed that a suitably qualified workforce will continue to be required for process execution consistent with technical domain requirements, the availability of personnel with specific end-item expertise is an acknowledged challenge. Specific skills required to successfully and consistently implement company command media and associated processes are expected to be maintained and available for production programs. Training should be established to ensure that a qualified workforce is maintained to address personnel attrition. Mature end-item descriptive documentation should also be available to facilitate program end-item unique training for new personnel. There also may be a lapse of time between development and production, and key personnel may move to other job assignments. Development programs should implement a transition plan to enable a seamless transition from development to production. Production program staffing plans should be created during the development phase which addresses development to production transitions.

4.6 Decision Making in the Absence of Complete Data

Production programs may need to make decisions without full access to desired data or subject matter experts. These decisions will need to fully address impacts to program risk. The risk to program execution is directly related to the quality of program documentation and the availability of subject matter experts to address production issues. It is critical that production programs faithfully execute their MA processes to ensure that when decisions are made without the full benefit of program data or the assistance of subject matter experts, the risk to program mission success is well understood and minimized. When a decision is needed for a high risk situation, the situation may justify the need to recreate missing data or consult subject matter experts familiar with the topic that are part of or available to provide support to the production team.

Key personnel for the production phase should be identified during development to facilitate knowledge transfer and ensure production program mission success. Key personnel should ensure that end-item documentation is mature and that program processes are repeatable. In addition to Concept of Operations (CONOPS), requirements, design and verification documentation, a typical list of documentation would include design review data packages, trade study documentation, product discrepancy reports, full component data packages, and component, subsystem and end-item handbooks. Additionally, key personnel should ensure that new program personnel are trained and have full awareness of existing program documentation to ensure that their expertise can be applied effectively during production to minimize program attrition risks.

5. Mission Assurance Tailoring Considerations and Recommendations

Several areas have been identified as candidates for tailoring of MA. The selection of these specific areas was based upon the typical cost drivers on space programs. The following sections provide guidance and considerations for tailoring MA activities in each of these areas.

5.1 Test and Evaluation

Once a program transitions to production, the purpose of the test and evaluation is verifying workmanship. However, unless there is a concerted effort among all stakeholders (customer, prime, and suppliers) to remove the design verification tests, it is common to continue testing the production units using the test procedures used during the development cycle. The barriers to altering the test and evaluation program usually include: a lack of clarity differentiating between design and workmanship testing, limited NRE funding to make the changes, absence of capital funds available to purchase more efficient test equipment, and fear of change (especially if stakeholders are new to the program). The result is a longer than necessary production cycle leading to cost and schedule increases.

A reduction in vehicle level test can significantly reduce costs. Typically, during development programs, tests designed to verify design are included in the test program. Since vehicle level test is on the critical path of the program schedule, the purpose of each test should be reviewed to determine if it is to prove design or workmanship. Tests that verify design after the first article has been built, and the design successfully established, should be examined to determine the added value for the program and any resulting risk associated with elimination. Also, vehicle level tests that only exercise features within one unit should be reviewed to determine their value if they have already been executed during unit level testing. Ideally, vehicle level tests should test the workmanship at the vehicle level (interfaces between units) and in a Test Like You Fly (TLYF) mode (subsystems tested simultaneously), rather than sequential subsystem and unit level tests. If the production test program can be defined and designed based upon the results of the development test program, it will reduce the lifecycle cost of the program and provide data to ensure removing design related tests is the correct decision. Similarly, thoughtful planning of the development test program, with an eye towards the production test program can result in efficiencies during production. Figure 4.2-3 illustrates how a system level test program architecture can minimize the NRE as the program transitions from development to production.

The main goal for production vehicle level test program is to verify the workmanship of spacecraft integration and the interfaces between units (for example: structural, thermal, electrical, and RF interfaces). The development program will have verified that the design meets performance requirements, with margin to allow for manufacturing variability, to ensure the contractual requirements will be satisfied; therefore, rerunning these tests will not be value added (for example: stressing cases for the power subsystem, gain and phase margins for Attitude Control system (ACS) and payload, Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC), sine vibration, etc.).

A common practice unique to the space industry is focusing test programs on unit and subsystem level testing. In other industries, there is more reliance on in-process control and system level testing, resulting in faster cycle times and increased productivity. While the space programs have low production runs which make it uneconomical to utilize automated machinery, production efficiency can be improved if the stakeholders focus on production and testing methods to reduce the critical path schedule of production articles as illustrated in Figure 4-2.3 “Spacecraft Level Test Program Architecture.” In addition, for units on the critical path, there may be enough evidence to show that in process testing has screened out all workmanship issues and a convincing case could be made that the risks have been mitigated before unit level test. We specifically mention units on the critical path because Return on Investment (ROI) calculations are more compelling when justifying the cost for the trade study to alter the screening methods for the unit, which can be substantial.

5.2 Prime Contractor Quality Assurance

Tailoring the Quality Assurance activity at the prime contractor is a slightly different exercise than tailoring the subcontractor quality effort which will be discussed separately. During the development phase the prime contractor quality team is focused on working through all of the issues that come with a new design, including new hardware, new processes, new procedures and new tooling/ground support equipment (GSE). As problems discovered during the development phase are resolved the expectation is that drawings are changed, and processes are improved and updated so that when the production phase arrives there is a well defined baseline from which to start. In the absence of these expectations being met, it will be difficult to identify areas for tailoring as there will be little evidence of the starting baseline. Recommended reviews and assessments to inform tailoring decisions are provided below. As discussed previously, all tailoring decisions should be made in the balance of an understanding of the resulting risks.

A good starting point is a review of all the assembly and test non-conformances generated during the development phase to look for patterns or trends, to verify that preventative/corrective actions have been implemented and to determine if there are areas that will require extra attention during production. Verify that all drawings and procedures have been updated (redlines incorporated) and interview the key members of the production and test teams for any lessons learned that may have not been formally documented. Reviewing the institution's internal audit records can also be helpful as they should reveal where there may be process problems or facilities issues that could require special attention. Also a review of the controls for prevention of counterfeit parts, prohibited materials and obsolete materials should be performed.

A next step could be to work with the program team as the assembly and test plans are developed. For the production phase these plans should be very detailed and should be well thought out in order to assure that Assembly, Integration and Test (AI&T) is performed in the most efficient manner possible. This extra detail on the production side will also allow for the deployment of Quality Assurance (QA) resources to be extremely well coordinated and cost-effective.

A key consideration is how the inspections are performed and by whom. One very effective QA Tailoring option is the use of Peer Inspectors. These are typically production technicians from the Manufacturing, Assembly, or Test groups who have received some extra training from the QA group or other qualified sources to act as Peer Inspectors for routine assembly operations such as the proper torque to fasteners or the mating of connectors. The QA team can be relieved of a significant amount of low risk inspection work through the use of Peer Inspectors and this can "free them up" to concentrate on higher risk activities. For this approach to be effective work cannot just be moved from one group to another (QA to Production), the amount of work performed by QA should be reduced which will lead to a reduction in the number of inspectors needed on the program. Those inspections for certain operations that have been evaluated as low risk can be considered as candidates to be performed by technicians already on the production floor who have been trained as Peer Inspectors. Any potential for increased risk can be mitigated by having QA perform audits of Peer Inspected activities.

An additional risk mitigation that can be used to support a more streamlined inspection approach is to perform "walk downs" at strategic points in the AI&T process. These independent reviews are typically performed prior to key program milestones, such as prior to item delivery to the next level of integration, to minimize risk to the program's critical path. These walk downs should be performed by independent Subject Matter Experts (SMEs) and should be specific to a particular aspect or subsystem of the vehicle. For example, a walk down of the thermal control subsystem would be headed by an independent thermal engineer accompanied by the project thermal engineer and representatives from Quality and Production Control. The team could start with a quick review of the design followed by an audit of the production documentation to verify proper materials and processes were followed and that the "as built" matches the "as designed." The final step would be an actual walk down of the vehicle where the SME can examine the fit of the thermal blankets, the thermal finishes on the exposed structure or boxes and inspect any special or unique attributes like the placement of thermal straps or isolators. Throughout the process, action items should be documented and tracked to closure. Such walk downs may be performed on any subsystem or unique aspect of the vehicle such as Telecom, Cable Harness, propulsion, or deployable mechanisms.

In the end, tailoring the QA effort is a risk management activity. In order to be successful, the proper amount of research must be done to assure that adequate QA resources are deployed on all operations that are identified as having high risk. The thoughtful use of Peer Inspectors can then be used on low risk operations to significantly reduce the amount of actual QA coverage required, therefore reducing QA costs, but still providing that all important "second set of eyes" that has been proven to reduce errors. Additional mitigation can be achieved through the strategic use of audits and walk downs that provide important checks and balances and further reduce the risk.

5.3 Subcontractor Management and Quality Assurance

5.3.1 Tailoring Subcontractor Management

On most large space programs a significant amount of the required hardware is purchased through subcontracts and delivered to the prime for final integration and testing. These subcontracts therefore represent a significant percentage of the inherent risk and total budget for the program. Aggressive, proactive management of these subcontracts during the production phase can therefore yield significant savings while maintaining the program risk posture.

During the development phase, subcontractors are chosen and relationships between the prime and the subcontractors are established. During this time, quality system surveys and technical evaluations are performed to assure the supplier has the institutional infrastructure to do the required work. Because this is a development program, many of these contracts may be for new designs or significantly altered heritage hardware. In these cases the subcontract will likely proceed with the standard set of formal reviews Systems Readiness Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Manufacturing Readiness Review (MRR), and Test Readiness Review (TRR) and a significant amount of insight/oversight to assure requirement compliance and program performance. As with the prime contractor, it is ideal that consideration of production during development result in subcontractor tasks to ensure the final product is properly documented, all analysis is complete and approved and that a firm foundation for production has been laid. During the UER process, verification of production conditions at subcontractors and performance of deployed systems can form the basis to adjust for appropriate production level activities based on objective data such as Test Readiness Level (TRLs) and Manufacturing Readiness Level (MRLs).

When the production program starts, all major subcontractors should be included in the UER process, evaluated and risk rated based on their performance during the development program. The ratings should include verification of the original survey data (any location, staff, company strategic direction, and/or systems changes) in addition to information about:

- cost and schedule performance;
- hardware requirement compliance;
- problems encountered during fabrication/test;

- lessons learned;
- and effectiveness of preventative/corrective actions.

This information, in combination with the results of the Unit Equivalency Reviews (UER) including any identified required contractual modifications, should be the basis for MA tailoring. Clearly, any subcontractor identified as higher risk during this evaluation would not be a good candidate for tailoring, in fact, they may warrant increase scrutiny during the initial production phase.

Potential opportunities for subcontractor management related MA tailoring are provided below:

- Reduce the number of formal reviews based on UER results.
- Reduce the number of required Subcontract Data Requirements List (SDRLs) (Re-use the design analysis from the development effort provided no design changes or operational environment changes, cut back on EIDP).
- Reduce program reporting requirements (Fewer Program Management Reviews (PMRs), fewer face-to-face meetings, and fewer monthly deliverables).
- Reduce number of mandatory inspections points during fabrication (see supplier quality section).
- Reduce participation in the Material Review Board (limit to UAI on interface performance and reliability, non-standard repair. All major test failures).
- Modify test requirements (thermal cycle instead of thermal vacuum, no EMI/EMC once the design has been verified).

Each of these tailoring opportunities must be examined on a case-by-case basis for individual components and subcontractors. Questions regarding the stability of the design, maturity of processes, workforce stability and special considerations of the individual component should be addressed. Any decision to reduce or increase MA involvement at a subcontractor involves an element of risk which should be fully documented in the risk management system with- and mitigation- strategies identified.

5.3.2 Tailoring Subcontractor Quality Assurance:

In many ways, the tailoring effort in this area mirrors what was done for subcontractor management. During the development phase of the subcontract supplier quality involvement could be considerable. With new designs often times come new processes and these increase the challenges for the Supplier Quality team. If managed properly, with the goal of being able to take the hardware to a successful production phase, this increased Quality involvement should be seen as an investment that will yield dividends in the Production phase in the form of reduced need for Quality oversight.

When the production contract begins, the Subcontractor Quality Assurance group should again start with an evaluation and risk assessment. This should be done in conjunction with the subcontractor management evaluation effort. The focus here is of course more specific with the emphasis being placed on the attributes that most affect the hardware quality. This assessment should include an evaluation of:

- The hardware design for manufacturability and inspectability.
- Configuration control of all required processes.
- The adequacy of the employee training and certification program.
- Lessons learned from previous efforts.

- Controls in place for counterfeit parts, prohibited materials, and obsolete materials.

Other items that significantly influence hardware quality are the required tooling and ground support equipment (GSE), they should be investigated to see if they are:

- Adequately documented and under configuration control?
- Properly and regularly maintained?
- Is the metrology system robust and reliable?

Finally, the number and severity of non-conformances linked to workmanship issues should be reviewed and analyzed for trends; the thoroughness of root cause investigations and preventative/corrective actions should also be assessed. The subcontractor may produce historical metrics and trending data that can be very helpful when performing these evaluations. Unfortunately, small companies often times do not generate detailed metrics which makes the evaluation more challenging and obviously more subjective.

If there has been a substantial break in production since the last time hardware component was fabricated, consideration should be given to the conduct of a "First Article Inspection" (AS9102) to help assess whether the supplier can still perform to the expected level. After the risk assessment is completed, informed decisions regarding the extent to which MA activities may be tailored can be made. Obvious tailoring targets in this area primarily involve adjusting the amount and types of inspections performed. The goal is to reduce the amount of interference and delays caused by mandatory inspection points (MIPs) by replacing some subset of them with process monitoring and audits. MIPs typically require the subcontractor to work the hardware up to the point where an inspection is required and then waiting for the customer to perform the inspection. Efficiencies may be gained by performing audits and monitoring processes on a non-interference basis while maintaining the insight of the prime into the quality of work being performed on the hardware.

MIPS are only required at the most critical points like the close out of an electronics box or the final interface verification of a tight tolerance structural component. Processes that can be covered with audits included Printed Wiring Assembly (soldering), staking, potting, conformal coating, mechanical assembly, crimping, and structural panel layup. These types of audits can be scheduled with the supplier by simply identifying when, on the schedule, a certain process will be performed and arranging for the appropriate Quality Representative to be there at that time. Timing for either a MIP or audit may be determined by reviewing the supplier's history and understanding the complexity of the hardware they are building as well as past performance. Should the tailored MA activities reveal deficiencies or concerns, more detailed inspections will be warranted.

5.4 Reviews and Oversight

Mission Assurance reviews and oversight for production programs should be tailored consistent with the results from the Equivalency Review and risk assessment for the program. The program assessment that was accomplished during the Equivalency Review will establish the level of PDR, CDR, and MRR/PRR, etc., that will be required for No Change, Insignificantly Changed, Significantly Changed, and New items at later stages of the program. Programs should evaluate a multitude of areas that impact production program change and risk such as changes to requirements, hardware design, software, parts, manufacturing facilities, manufacturing instructions, site processes, vendors, and workforce. The assessment of these items will serve to establish the need and extent of production program reviews and oversight.

5.4.1 Tailoring of Mission Assurance Reviews

Production program Mission Assurance Reviews focus on assuring that products are designed to meet requirements, can be successfully produced as designed, and that testing is properly planned and executed at the appropriate level. The reviews assure that open technical issues are closed and establish confidence that the products will perform as intended. TOR 2009(8583)-8545, Guidelines for Space Systems Critical Gated Events, can be referenced for common definitions of gated events, objectives, and entrance/exit criteria.

Technical and schedule risks should be well understood prior to production. Customers and contractors should pay particular attention to items that may drive program risk, cost, or schedule. Tailoring recommendations for production phase Mission Assurance reviews are provided in Table 4-1.

Table 4-1. Tailoring Guidelines for Production Phase Program Reviews

Review	Tailoring Guidance
Integrated Baseline Review (IBR)	Ensure that production phase planning has been completed and that any technical and programmatic risks are understood with mitigations identified. The production phase IBR also examines consistency among technical, schedule, cost, resource and management risks, and assesses the program's ability to execute the production baseline. If production phase planning was completed and evaluated as part of the development phase, the production phase IBR should focus on any program changes since the last review, if any.
Program Management Review (PMRs)	PMRs held for items with significant program risk. Other items statused every other month or less frequently per item production risk assessment.
System Readiness Review (SRR)	The production phase SRR may be required only for changes to mission requirements. Ensure that any mission requirement changes since the last review, if any, are understood and have been translated into system requirements and an updated operations concept. Evaluate any requirement changes for impacts to the baseline. Reassess program risks and assess any changes to the baseline for producibility of the proposed design concept. Note that block changes are a typical source of changes to mission requirements. Consider combining the SRR with the SDR if any program changes warrant the assessments.
Software Design Review (SDR)	The production phase SDR may be required only for changes to mission requirements. Ensure that impacts to the design approach for any requirement changes to the system design specification baseline since the last review, if any, are understood and have been assessed. Evaluate any changes for impacts to external interface requirements and verification planning. Note that block changes are a typical source of changes to mission requirements. Consider combining the SRR with the SDR if any program changes warrant the assessments.
Preliminary Design Review (PDR)	Production phase PDR may be required only for changes to the development phase design or capability to produce the design. Special attention should be paid to the comprehensive assessment of interface impacts that may result from any design changes.
Critical Design Review (CDR)	Similar tailoring to the PDR. Production phase CDR may be required only for changes to the development phase detailed design or capability to produce the design. Special attention should be paid to the comprehensive assessment of interface impacts that may result from any design changes. Consider combining the CDR with the FQR if any program changes warrant the assessments.
Formal	The Formal Qualification Review, for purposes of this document, includes

Review	Tailoring Guidance
Qualification Review (FQR)	changes to requirements, hardware design, software, parts, manufacturing facilities, manufacturing instructions, standard site processes, vendors, and workforce, if any. On development programs, the time from qualification to delivery of the system is short enough to usually preclude these issues. Production programs, which may occur years later and span decades, need to verify that the unit design and production processes are equivalent to the prior qualification unit and the analyses used for qualification are relevant. Consider combining the FQR with the CDR if any program changes warrant the assessments.
Production Readiness Review/ Manufacturing Readiness Review (PRR/MRR)	Ensure that the necessary production and manufacturing planning has been completed and that issues that were brought up in the Equivalency Review or CDR have been addressed. Determines if the necessary planning, materials, procurements, producibility assessments, quality assurance, documentation, manufacturing, tooling, test, facilities, and lessons learned/best practices have been addressed, and ensures that the program is ready to begin production.
Test Readiness Review (TRR)	The TRR examines the contractor's progress and status for each CI/CSCI to determine whether hardware and software procedures are complete and the contractor is prepared to start testing. The results of any informal testing and changes to the CONOPS are also reviewed. Also assess if items will be stored for any length of time which may necessitate subsequent abbreviated testing.
Program Status Review (PSR)	Demonstrate the system is complete and ready for deployment or delivery to the customer. Provide evidence that the requirements, design, analysis, verification, manufacturing, integration and test, packaging, handling, storage, transportation, and program control and execution activities are complete and acceptable to the customer. Assess if items have been stored for any length of time, which may necessitate subsequent abbreviated testing, and allow for this prior to deployment or delivery. The content for this production phase review should be consistent with the development phase review content, no tailoring is recommended.
Flight Readiness Review (FRR)	The FRR evaluates the space flight worthiness of the integrated flight hardware (space vehicle, upper stage and launch vehicle). It also addresses the readiness of launch and support facilities (ground systems), range and orbital operations, and the readiness and training of the operating personnel. The review includes a safety verification of the integrated system. The content for this production phase review should be consistent with the development phase review content, no tailoring is recommended.
Launch Readiness Review (LRR)	The LRR process provides a summary prelaunch assessment of the readiness status of the total system (space and launch vehicle), the launch facility, range safety and instrumentation, the Air Force Satellite Control Network, the operational mission control station, operations personnel, and other launch or on-orbit support. Launch Decision Authority also verifies the closure of issues and items and determines the readiness status of safety, training, weather, and recovery teams. The content for this production phase review should be consistent with the development phase review content, no tailoring is recommended.

New production program requirements, parts or materials obsolescence, process changes, and unique constellation related items should be addressed per Mission Assurance Independent Reviews processes suitable for phases A, B, and C. Production program reviews should establish that the products have matured to the appropriate Manufacturing Readiness Level (MRL) to sustain production. New or significantly changed items will need to be assessed to ensure that they have achieved MRL 8 for entry into low-rate initial production. Subsequent to initial production, the program should establish that the capability is in place to begin full-rate production (MRL 9). MRL 10 will have been achieved once full-rate production has been demonstrated, and engineering/design changes are minimal and generally limited to quality and cost improvements.

5.4.2 Tailoring of Production Program Oversight

Production phase oversight should be reduced from that typically required of complex development efforts. Stable production designs should enable reduced production risk and in turn reduce the need for oversight of risk mitigation efforts. Value based assessments of program oversight processes against program risks should enable reduced production cost and schedule while maintaining the same level of technical performance. The frequency and content of status meetings should be evaluated along with assessing required participation to validate the value that the meetings bring to the program. The need for Change Control Boards and design reviews should be greatly reduced along with the need for diverse subject matter expert engagement as the expectation is that limited change will occur. When the need arises, the design reviews should be sized and implemented to match the risk of the associated change. Production phase Contract Data Requirement Lists (CDRLs) should be evaluated to establish their need, level of detail, and/or frequency. Assessing production risk against oversight needs, and adjusting accordingly, should provide the customer/contractor team with adequate insight to successfully manage the production program.

6. Roles and Responsibilities

The purpose of this section is to articulate key organizational roles and responsibilities to ensure that a space project successfully transitions from development to production. Several studies have already been performed that document the typical risks and issues that arise when weapon systems transition from development to production (see for example DOD 4245-7M "Transition from Development To Production"[4], NAVSO P-6071 "Best Practices: How to Avoid Surprises In the World's Most Complicated Technical Process The Transition From Development to Production" [5], GAO/NSIAD-85-34 "Why Some Weapon Systems Encounter Production Problems While Others Do Not: Six Case Studies" [6] and GAO-10-439 "Best Practices DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed"[7]). This document focuses on the specific issues with space systems transitioning from development to production. Space systems have some unique risks and issues associated with the transition from development to production and often many of the typical risks and issues associated with weapon system transition from development to production are amplified as space systems make this transition.

This section summarizes the key roles and responsibilities of the major stakeholders in space system acquisition as they relate to a space system's transition from development to production. These stakeholders include the following organizations:

- User
- Government Program Office
- Development System Developer
- Production System Developer
- Technical Direction Agent/Federally Funded Research and Development Center

While all organizations listed above have a role in the process of transitioning a development space system into production, the specific organizations performing lead roles and the organizations performing support roles varies during the system's lifecycle in both development and production.

6.1 User

National security space systems are developed to serve a useful purpose by fulfilling an established operational need. The user community has three primary roles in helping programs successfully transition from development to production:

- Establish stable operational requirements at the beginning of the system development lifecycle for the material solution that is developed to fill a capability gap.
- Plan and establish Doctrine, Organization, Training, Leadership, Personnel, and Facilities (DOT_LPF) to use the system being developed.
- Ensure funding to support operations and support of the production system is secured.

In the context of this document, the role of the user community is unchanged whether a system is in development, in transition to production, or in production.

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[4] See http://www.dtic.mil/whs/directives/corres/pdf/424507m.pdf
[5] See http://www.dau.mil/educdept/mm_dept_resources/guidance/6071.pdf
[6] See http://www.gao.gov/cgi-bin/getrpt?GAO/NSIAD-85-34
[7] See http://www.gao.gov/products/GAO-10-439

6.2 Government Program Office

Within the context of this document, the Government Program Office's primary role is to establish the foundation for a successful transition from development to production by planning and implementing an acquisition approach that supports and enables the transition. For a program that will transition from development to production, seven key functions performed by a Government Program office are:

- Perform acquisition planning that plans for the transition from development to production at program inception
- Provide stable funding throughout the program's lifecycle
- Establish stable requirements for the technical solution being developed to meet the user's needs
- Mandate and conduct effective technical reviews—including a production readiness review—to incrementally evaluate design and development efforts
- Provide a knowledgeable acquisition workforce that is familiar with space systems development
- Provide a stable acquisition workforce to ensure continuity in direction provided to developers
- Perform effective risk management; ensure that the development system retires significant technical risks prior to transitioning the system to production

6.3 Development System Contractor

In the context of a space system that transitions from development to production, the development system contractor should follow all applicable best practices to ensure mission success, with the realization that several traditional space system lifecycle activities will have a significant influence on the successful transition from development to production. The list below highlights the specific considerations that should be given during system development to enable a successful transition to production:

- Cost estimating: develop accurate lifecycle cost estimates.
- Design: retire technical design challenges early.
- Parts and Materials Selection: give consideration to parts obsolescence as parts are selected for use on the development system.
- Process Definition and Control: document and validate/qualify all fabrication and assembly processes so that they can be implemented/repeated on the production system.
- Design for Manufacturability and Producibility: give consideration to manufacturability and producibility as the development system is designed.
- Supplier Management: select and manage a qualified supplier base that is capable of serving both the development system and the production system.
- Workforce: retain key engineer and design personnel during and after the transition to production to support emergent technical issues.

- Risk Management: perform effective risk management; ensure that the development system retires significant technical risks during development, prior to transitioning the system to production.
- Parts and Materials: give consideration to obsolescence during selection of parts and materials for the development system.
- Drawings and Documentation: prepare and maintain accurate drawings and documentation that describe the system being built.
- Technical Review: implement effective technical review procedures to incrementally review the adequacy of the design and implementation.
- Schedule Management: implement management controls to avoid schedule slips to the development system that may result in cascading slips to the production system.
- Cost Management: implement management controls to ensure that the program doesn't become unaffordable before the transition to production occurs.
- Production Readiness Review: provide technical support to the production system's Production Readiness Review prior to the transition from development to production to ensure that all organizational units are prepared for production.
- Unit Equivalency Review: provide technical support to the production system's Unit Equivalency Reviews.

6.4 Production Program Contractor

- Production Readiness Review: conduct a Production Readiness Review to ensure the system (and its associated design, drawings, documentation, procedures, facilities, personnel, and processes) are sufficiently mature to transition to production.
- Unit Equivalency Review: conduct Unit Equivalency Reviews as described in this document.
- Change Assessment: perform a change assessment on every change to the design and implementation that is made by the production system to the baseline established by the development system.
- Design: for system elements that require a new design during production (or a redesign during production), follow the best practices associated with space system design as defined in the Mission Assurance Framework.
- Parts and Materials: continue to monitor obsolescence issues.
- Process Definition and Control: ensure manufacturing, assembly, and integration processes are sufficiently documented to be repeatable during production and are measured and assessed to ensure that they repeated correctly.
- Supplier Management: ensure that suppliers retain key capabilities and personnel to support the system throughout its production lifecycle.
- Schedule Management: implement management controls to avoid schedule slips that may result in cascading slips to the production system.
- Cost Management: implement management controls to ensure that the program doesn't become unaffordable during or after the transition to production occurs
- Retain engineering support to facilitate timely resolution of issues, anomalies, problems, and failures.

6.5 Technical Direction Agent / Federally Funded Research and Development Center

The Technical Direction Agent's, or Federally Funded Research and Development Center's primary role is to provide unbiased technical assistance to enable program success. Key functions performed by a TDA/FFRDC include:

- Provide technical oversight of both development and production efforts.
- Provide unbiased guidance to all other entities involved in system development, including users, government program office, development system developer, and production system developer.
- Ensure lessons learned from other space system development efforts are incorporated into activities of the government program office as well as the development process for both the development system and the production system.
- Provide a knowledgeable and stable technical workforce that can provide sustained support to the program during both development and production development efforts.

In the context of this document, the role of a TDA/FFRDC is unchanged whether a system is in development, in transition to production, or in production, however, it is expected that the level and frequency of reviews, etc., will be tailored.

Appendix A. Definitions

Class A Missions: extremely critical operational systems where all practical measures are taken to ensure mission success. They have the highest cost, are of high complexity, and the longest mission life with tight launch constraints. Contract types for these systems are typically cost plus because of the substantial development risk and resultant oversight activities.

Class A missions are achieved by strict implementation of mission assurance processes devised through proven best practices to achieve mission success over the desired life of the system. All practical measures, to include full incorporation of all specifications/standards contract requirements with little to no tailoring, are taken to achieve mission success for Class A missions. Class A missions are long life, nominally greater than 10 years and represent large national investments for critical applications.

Class B Missions: are defined as critical operational, exploration, and technical demonstrators in which only minor compromises are taken in stringent processes for mission success to achieve a low risk profile. The criteria for minor compromises include allowing controlled single point failures, proto-flight hardware, Level/Grade 2 EEE parts, reduced circuit analysis, etc. Class B missions have high costs, are of high to medium complexity, long mission life, with moderate launch constraints. Contract types for these systems are cost plus if there is any significant technology development, i.e., lower technology readiness level hardware and can be potentially firm fixed price given well-defined requirements.

Class B space vehicles are priority missions whose minor compromises to MA are due to programmatic tradeoffs between minimum risk and lower costs. The majority of specification and standard requirements are flowed down, but minor tailoring is allowed based on achieving a low risk tolerance to mission success. Contactor equivalent processes for Class B missions are sought where possible to ensure the risk profile is maintained without unnecessarily driving cost.

Independent Technical Assessment (ITA): a formal or informal process, or combination of processes, formulated and executed using program, engineering, and laboratory resources to proactively evaluate system performance and independently validate contractor processes, techniques, and results using methods different from, and complementary to, those employed by the contractors. In some cases, ITA can be conducted by separate contractors. More commonly, ITA is performed in the context of the government program office-FFRDC-system engineering and technical assistance (SETA) team, where The Aerospace Corporation performs that FFRDC role for national security space (NSS) systems.

Mission Assurance (MA): the disciplined application of general systems engineering, quality, and management principles towards the goal of achieving mission success, and, toward this goal, provides confidence in its achievement. MA focuses on the detailed engineering of the acquired system and, toward this objective, uses independent technical assessments as a cornerstone throughout the entire concept and requirements definition, design, development, production, test, deployment, and operations phases.

Mission Assurance Approach: the sum of organizations, cultures, incentives, knowledge, policies, procedures, processes, and requirements that assure mission success.

Mission Success: the achievement by an acquired system (or system of systems) to singularly or in combination meet not only specified performance requirements but also the expectations of the users and operators in terms of safety, operability, suitability, and supportability. Mission success is typically evaluated after operational turnover and according to program specific timelines and criteria, such as Key Performance Parameters. Mission success assessments include operational assessments and user community feedback.

Process: a series of tasks, involving the practical application of accepted principles, which are architected and organized in logical sequence to achieve a broad set of objectives. MA processes contribute to mission success in terms of directly attributable positive consequences.

Production Program: a program which utilizes a substantial portion of the mission and design of an existing or prior program. The system requirements are unchanged. Usually designated as a Follow-On or Block Buy after the development program is (nearly) completed. Qualification, or requalification, is at the unit level and the majority of units are unchanged from the development program.

Supporting MA Discipline (SMD): an engineering discipline that is specifically oriented and organized to support MA processes and the entire MA program. Because of practical constraints on resources available to a specific program, such support is often limited to a partial, rather than complete, application of the discipline within the MA program itself.

Mission Assurance Approach: the sum of organizations, cultures, incentives, knowledge, policies, procedures, processes, and requirements that assure mission success.

Heritage: Hardware products or software which had previously undergone qualification and been used in an operational environment.

Appendix B. Reference Documents

TOR-2006(8506)-5749	Mission Assurance Tasks for Software
TOR-2007(8546)-6018	Mission Assurance Guide
TOR-2010(8591)-18	Mission Assurance Program Framework
TOR-2011(8591)-18	Supplier Risk Evaluation and Control
TOR-2011(8591)-21	Mission Assurance Guidelines for A-D Mission Risk Classes
SMCI 63-1201	Assurance of Operational Safety, Suitability, & Effectiveness for Space & Missile Systems
MDA-QS-001-MAP	Missile Defense Agency Assurance Provisions
TOR-2009(8546)-8604 Rev A	Reuse of Hardware and Software Products
TOR-2010(8591)-19	Objective Criteria for Heritage Hardware
GAO-10-439	Best Practices DOD can Achieve Better Outcomes by Standardizing the way Manufacturing Risks are Managed
GAO/NSIAD 85-34	Why some Weapons Systems Encounter Production Problems while others do not: Six Case Studies.
NAVSO P-6071	Best Practices: How to Avoid Surprises in the World's most Complicated Technical Process. The Transition from Development to Production.
DID 4245-7M	Transition from Development to Production
Manufacturing Readiness Level (MRL) Deskbook, Version 2.0	

Appendix C. UER Instructions and Checklist

Introduction and Purpose of the Unit Equivalency Review (UER)

The purpose of the Unit Equivalency Review (UER) is to determine if the unit being built is qualified and the manufacturing site has the ability to produce the unit which meets all contractual requirements (both customer contract requirements, prime's requirements, and supplier's requirements).

The Program Office (Customer and Prime) and Mission Assurance organizations want to understand, as early as possible, if there are any unresolved issues before unit production begins. Given the length of time since the last unit was built for the program, parts may have been become obsolete, vendors may have changed facilities, people with unique critical skills may have been lost, tooling or special test equipment may have been lost, or engineering documentation (standard operating procedures or unit design) may have changed.

A checklist should be developed as an aid to help determine which reviews are required for the program. The value in performing the UER is the sharing of facts and data of the state of the design, qualification, and production capabilities of the organizations producing the units such that the correct decisions are made early in the program as to what reviews are required for each unit with lower probability of workmanship or design escapes.

The expected output of the UER is concurrence of all stakeholders (Program Office, Mission Assurance Organizations, IPTs, and Customer) on what reviews will be required for each unit. The list of possible reviews are: PDR, CDR, QRB, MRR, TRR. The stakeholders can decide to tailor the reviews to address only the changes to the unit, such as a delta CDR or delta QRB.

Given the length of time since the last unit build, all units will go through MRR and TRR (TBV with Program Office). New units are automatically required to go through all reviews, so there is no need to perform a UER for those units (other than identifying the units as new). Units that have been verified to have no changes do not need to perform a UER. Only those units with changes (to be described in detail later) will go through a formal UER (a template is attached).

Instructions for filling out UER Template/Checklist:

The attached template covers all items that control the design, qualification, and production/test of a unit.

The SE assigned to the unit or subsystem will determine if there are any new requirements which need to be flowed down to the unit area, either by customer contract or internal requirements.

The Unit REA will need to determine if there have been (or will be) any revisions to the documents controlling production or if the production environment has been changed since the last unit was built for the program.

The SE and Unit REA cannot assume that he/she would have been notified of a change in making the determination. The expectation is that the engineer will verify that the versions of the documents have not changed, or if they have, to understand what the changes were, since the last time the unit was produced. The engineer will then need to verify that all of the changes were adjudicated per customer and Boeing's requirements. If the changes were not adjudicated per requirements, or that an unresolved risk that requires further review has been identified, the engineer is required to fill out the UER template and bring it to the Program Office ERB (and Product Line ERB if it affects multiple programs). The engineer will make a recommendation as to what reviews should be required given the type of change, and the other key stakeholders will either confirm or amend the list at the ERB.

After the engineer has verified that the documentation has not changed or how it has changed, the engineer will enter a Yes or No in the appropriate column. A brief description of the change should be entered on the template. If "No" is entered on the template, the engineer shall provide a statement as to how that determination was made. Below are some examples of acceptable and unacceptable rationales.

Examples of Acceptable Rationales for "No Changes":

> "I have personal knowledge of the engineering documents (drawings, Bill of Materials (BOM), planning, standard operating procedures) and manufacturing facilities and verified there have been no revisions, SCNs, or pending ECRs for this unit. There are no unresolved Process Anomalies or Industry Alerts associated with this unit."
>
> "I have correspondence with the Vendor's REA (provide full name) who has personal knowledge of the engineering documents (drawings, BOM, planning, standard operating procedures) and manufacturing facilities and he/she verified there have been no revisions, SCNs, or pending ECRs for this unit. There are no Process Anomalies or Industry Alerts associated with this unit. The last time I have visited the manufacturing site was on provide date."
>
> "I have personal knowledge of the engineering documents (drawings, BOM, planning, standard operating procedures) and manufacturing facilities and verified that all changes since the last time the product was produced for the program were properly adjudicated by Boeing's M&P and SME. There are no Process Anomalies or Industry Alerts associated with this unit."

Examples of Unacceptable Rationales for "No Changes":

> "I have not been told of any changes to the unit by the manufacturer."
>
> "As far as I know, the vendor has notified Boeing of all changes per contractual requirements."

In short, the engineer completing the template is putting his/her personal warranty that the template was filled out after performing the due diligence expected by the customer, program office, and IPT. If relying on the vendor's statements to make the determination, please file the evidence of the correspondence (emails or notes during phone conversations) so that it can be retrieved at a later date.

Part Changes (Obsolescence)

Since we already know that there will be parts obsolescence issues, we have defined three classifications to help determine if a UER is required or not.

- Alternate part already on drawing—no change to drawing or QDD required since the last unit build—(document in UER matrix but no UER required for this reason)—list as "Yes" in BOM column, "No" in Engineering column (assuming no other changes in engineering), and state in rationale section the alternate part number(s)

- New part to drawing on Program APL—QDD may need updating (e.g., WCCA, etc)—complete UER package (per template) and bring to ERB—List as “Yes” in BOM and Engineering Documentation Columns
- New part to drawing Not on Program APL—QDD will need updating and QRB will be required, get M&P approval to add to Program APL—complete UER package (per template) and bring to ERB—List as “Yes” in BOM and Engineering Documentation Columns

Unit Equivalency Review Template

Unit Information

Part Name:
Supplier:
Part Number:

- **Prior Part Name/Number**
- **Unit Category** – chose the category that best fits the description of the unit
  - **New Unit** – did not exist in the prior system or extensively redesigned
  - **Significantly changed** – a unit that is not "fit, form and functionally" identical to those produced and qualified on the prior program which incorporates a different design solution from those previously produced, or which employs parts from different suppliers or vendors, or different materials or manufacturing processes, techniques or technologies that require internal redesign to accommodate them
  - **Insignificantly changed** – a unit that is "fit, form and functionally" identical to those ; previously produced but employs parts from different suppliers or vendors, or employs different materials or manufacturing processes, techniques or technologies that are "drop in replacements". If different from qualification unit, proto-flight qualification test or analysis may be required to requalify.
  - **Unchanged** – a unit that is "fit, form and functionally" identical in every way (design, suppliers, materials, processes, etc) identical to those manufactured and qualified.

Unit Requirements

Requirement changes from prior program

- List all contractual requirement changes
- List all internal requirements changes
- List all supplier requirements changes

Design Change Summary

Design Changes Details – include part and material obsolescence changes

- Parts changes
- Material changes
- Manufacturing Process changes
- Impact to qualification status
  - Differences between unit and qualification unit
  - Analysis impact
  - Qualification test

Engineering Change Summary

Required Engineering Changes

- List of analysis requiring updates
- List of BOM changes

- List or drawings and specifications which will be revised
- List expected performance changes
- List expected functional changes
- List tooling changes required to build or test unit
- List test procedures requiring changes
- List of all RDWs on prior units
  - Identify which ones are expected to be resubmitted for Follow-On program
  - Provide rationale for any RDW not being resubmitted
- List of new RDWs planned for unit

Unit Qualification/Planned Reviews

Qualification Approach

- List of Qualification Analysis impacted by change
- List of differences between qualification unit and production unit
- Environmental Test level: qualification levels or protoqual levels

Flight Hardware Test Plan

- List which unit will be protoflight tested (if required)
- Identify test procedure or test plan documents for protoflight and acceptance level testing

Proposed Reviews (to be tailored based on DER information)

- New – PDR, CDR, MRR, TRR, Qualification Review Board (QRB)
- Significantly Changed – delta CDR, MRR, TRR, QRB
- Insignificantly Changed – MRR, TRR, QRB
- No Change – MRR and TRR (if there is a break in production flow)

Appendix D. UER Worked Examples

Unit Information

Unit Name: Reaction Wheel Assembly
Supplier: Acme Aerospace
Part Number: 123

- **Prior Part Name/Number**
- **Unit Category—chose the category that best fits the description of the unit**
  - **New Unit**—did not exist in the prior system or extensively redesigned
  - **Significantly changed**—a unit that is not "fit, form and functionally" identical to those produced and qualified on the prior program which incorporates a different design solution from those previously produced, or which employs parts from different suppliers or vendors, or different materials or manufacturing processes, techniques or technologies that require internal redesign to accommodate them
  - **Insignificantly changed**—a unit that is "fit, form and functionally" identical to those previously produced but employs parts from different suppliers or vendors, or employs different materials or manufacturing processes, techniques or technologies that are "drop in replacements." If different from qualification unit, proto-flight qualification test or analysis may be required to requalify.
  - **Unchanged**—a unit that is "fit, form and functionally" identical in every way (design, suppliers, materials, processes, etc) identical to those manufactured and qualified.

Unit Requirements

Requirement changes from prior program

- List all customer requirement changes
  - New launch vehicle environment
- List all "Big Prime" requirements changes
  - None
- List all "Acme Aerospace" requirements changes
  - Bearing design change due to new launch environment

Design Change Summary

Design Changes Details—include part and material obsolescence changes

- Parts changes
  - New bearing
- Material changes
  - Metal to composite
- Manufacturing Process changes (Acme Aerospace)
  - Assembly procedure to incorporate new bearing design
  - All other manufacturing processes unchanged

- Impact to qualification status
  - Differences between unit and qualification unit
    - New bearing design, new environment
  - Required Analysis
    - Mechanical stress, EMI/EMC, reliability, thermal…
  - Qualification test
    - Unit Qualification Test, Life test

Big Prime Engineering Change Summary

Required Engineering Changes

- List of analysis requiring updates
- List of BOM changes
- List or drawings and specifications which will be revised
- List expected performance changes
- List expected functional changes
- List tooling changes required to build or test unit
- List test procedures requiring changes
- List of all Request for Deviation Waivers (RDWs) on prior units
  - Identify which ones are expected to be resubmitted for Follow-On program
  - Provide rationale for any RDW not being resubmitted
- List of new RDWs planned for unit

Big Prime Process Change Summary

Required Process Changes

- List of procurement changes (material source etc.)
- List of planning changes
- List of manufacturing changes
- List of process/materials changes
- List of analysis requiring updates
- List of technician training/certification changes
- List of test changes
- List expected safety/human factors changes
- List tooling changes required to build or test unit
- List of inspection changes
- Care and handling changes
- Etc.

Acme Aerospace Engineering Change Summary

Required Engineering Changes

- List of analysis requiring updates
- List of BOM changes
- List or drawings and specifications which will be revised
- List expected performance changes
- List expected functional changes
- List tooling changes required to build or test unit
- List test procedures requiring changes
- List of all RDWs on prior units
  - Identify which ones are expected to be resubmitted for Follow-On program
  - Provide rationale for any RDW not being resubmitted
- List of new RDWs planned for unit

Acme Aerospace Process Change Summary

Required Process Changes

- List of procurement changes (material source etc.)
- List of planning changes
- List of manufacturing changes
- List of process/materials changes
- List of analysis requiring updates
- List of test changes
- List of technician training/certification changes
- List expected safety/human factors changes
- List tooling changes required to build or test unit
- List of inspection changes
- Care and handling changes
- Etc.

Unit Qualification/Planned Reviews

Qualification Approach

- List of Qualification Analysis impacted by change
  - Previously identified qualification analyses to be updated
- Environmental Test level: qualification levels or protoqual levels
  - Qualification Unit will be subjected to full qualification levels
    - Life test will follow

Flight Hardware Test Plan

- List which unit will be protoflight tested (if required)
  - No protoflight testing required
- Identify test procedure or test plan documents for protoflight and acceptance level testing

Proposed Reviews (to be tailored based on UER information)

- Significantly Changed—delta CDR, MRR, TRR, QRB, FAI, Supplier Quality/Capabilities Assessment
  - Delta PDR, Delta CDR, MRR, TRR, QRB, FAI

Unit Information

Unit Name: Solar Array Assembly
Supplier: Sunshine Aerospace
Part Number: 1776

- **Prior Part Name/Number**
- **Unit Category—chose the category that best fits the description of the unit**
  - **New Unit—**did not exist in the prior system or extensively redesigned
  - **Significantly changed**—a unit that is not "fit, form and functionally" identical to those produced and qualified on the prior program which incorporates a different design solution from those previously produced, or which employs parts from different suppliers or vendors, or different materials or manufacturing processes, techniques or technologies that require internal redesign to accommodate them
  - **Insignificantly changed**—a unit that is "fit, form and functionally" identical to those ;previously produced but employs parts from different suppliers or vendors, or employs different materials or manufacturing processes, techniques or technologies that are "drop in replacements." If different from qualification unit, proto-flight qualification test or analysis may be required to requalify.
  - **Unchanged** - a unit that is "fit, form and functionally" identical in every way (design, suppliers, materials, processes, etc) identical to those manufactured and qualified.

Unit Requirements

Requirement changes from prior program

- List all customer requirement changes
  - None
- List all "Big Prime" requirements changes
  - None
- List all "Sunshine Aerospace" requirements changes
  - None

Design Change Summary

Design Changes Details—include part and material obsolescence changes

- Parts changes
  - None
- Material changes
  - None
- Manufacturing Process changes (Sunshine Aerospace)
  - None
- Impact to qualification status
- Differences between unit and qualification unit
  - None

- Required Analysis
  - None
- Qualification test
- None

Big Prime Engineering Change Summary

Engineering Changes: None

- List of analysis requiring updates
- List of BOM changes
- List or drawings and specifications which will be revised
- List expected performance changes
- List expected functional changes
- List tooling changes required to build or test unit
- List test procedures requiring changes
- List of all Request for Deviation Waivers (RDWs) on prior units
  - Identify which ones are expected to be resubmitted for Follow-On program
  - Provide rationale for any RDW not being resubmitted
- List of new RDWs planned for unit

Big Prime Process Change Summary

Process Changes:

- List of procurement changes (material source etc.)
- List of planning changes
  - Planning changed to address acceptance test flow vs previous protoqual
- List of manufacturing changes
- List of process/materials changes
- List of analysis requiring updates
- List of technician training/certification changes
- List of test changes
  - Protoqual test changed to acceptance
- List expected safety/human factors changes
- List tooling changes required to build or test unit
- List of inspection changes
- Care and handling changes
- Etc.

Sunshine Aerospace Engineering Change Summary

Engineering Changes: None

- List of analysis requiring updates
- List of BOM changes
- List or drawings and specifications which will be revised
- List expected performance changes
- List expected functional changes
- List tooling changes required to build or test unit
- List test procedures requiring changes
- List of all RDWs on prior units
  - Identify which ones are expected to be resubmitted for Follow-On program
  - Provide rationale for any RDW not being resubmitted
- List of new RDWs planned for unit

Sunshine Aerospace Process Change Summary

Process Changes: None

- List of procurement changes (material source etc.)
- List of planning changes
- List of manufacturing changes
- List of process/materials changes
- List of analysis requiring updates
- List of test changes
- List of technician training/certification changes
- List expected safety/human factors changes
- List tooling changes required to build or test unit
- List of inspection changes
- Care and handling changes
- Etc.

Unit Qualification/Planned Reviews

Qualification Approach

- List of Qualification Analysis impacted by change
  - None
- Environmental Test level: qualification levels or protoqual levels
  - Acceptance test level only (includes acceptance level environmental screening)

Flight Hardware Test Plan

- List which unit will be protoflight tested (if required)
  - None
- Identify test procedure or test plan documents for protoflight and acceptance level testing

Proposed Reviews (to be tailored based on UER information)

- No Change – MRR and TRR (if there is a break in production flow)
  - MRR, TRR