AEROSPACE REPORT NO.
TOR-2009(8591)-11

Design Assurance Guide

4 June 2009

Joseph A. Aguilar
Vehicle Concepts Department
Architecture and Design Subdivision

Prepared for:

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

Contract No. FA8802-09-C-0001

Authorized by: Space Systems Group

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

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Approved by:

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Abstract

A large percentage of failures and anomalies that occur in the implementation phase of space programs are attributed to errors or escapes originating in the design process. Across the aerospace industry there are seminal but separate/independent efforts underway to develop approaches to discover, prevent, and correct engineering process errors or escapes earlier in the life cycle where these problems are less expensive or even possible to correct. A sufficient, foundational set of design assurance requirements and processes that are analogous to product quality assurance do not exist for engineering design assurance. In the manner of the quality management system defined in AS9100 (Revision C), it is believed necessary to adapt these process concepts earlier in the design and development process [1].

The cross-discipline, multi-company Design Assurance Topic Team developed a definition of design assurance, identified key design assurance enterprise attributes and program elements, and formulated a risk-based design assurance process flow, which can serve as a roadmap for aerospace programs' design assurance activities.

Acknowledgements

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

Tina Wang—Boeing Space and Intelligence Systems

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Chris Kelly—Northrop Grumman Aerospace Systems

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Alan Exley—Raytheon Space and Airborne Systems

A special thank you for co-leading this team and efforts to ensure completeness and quality of this document goes to:

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> *During the past several years, National Security Space (NSS) assets have been subject to an unacceptable increase in the number of preventable on-orbit anomalies. The reversal of this trend and the reestablishment of acceptably high levels of mission success have been identified as the highest priority for the NSS acquisition community… Recent authoritative studies such as the Tom Young Report have stated unequivocally that in order to achieve mission success it is necessary to re-invigorate and apply with renewed rigor, i.e., in a formal and disciplined manner, the principles and practices of mission assurance in all phases of NSS space programs.* – *Aerospace Mission Assurance Guide*[2]

1. Introduction

This Design Assurance Guide (DAG)[*] describes a process for performing the design assurance (DA) activities and processes independent of any of the constraints of any specific organizational structure. The Guide is intended for use by any organization involved in the acquisition of a space system. The DA process is applied at the enterprise and program levels using enterprise and program resources.

The information in the appendices supports the DAG and is referred to in the Guide. A listing of the material contained in the supporting appendices is as follows:

- Appendix A: Failures and Design Assurance
- Appendix B: Acquisition Life Cycle and Design Assurance
- Appendix C: Design Assurance Enterprise Attributes/Capability Checklist
- Appendix D: Spider/Radar Diagram Examples
- Appendix E: Design Assurance Program Elements
- Appendix F: Frequently Asked Questions
- Appendix G: Useful References
- Appendix H: Glossary

The intent of what is being discussed is not to create a new DA process that has to be integrated into existing processes. Rather, a process is being described that makes use of existing processes that are already being used in the industry.

1.1 Purpose and Objective

The purpose of the DAG is to reduce or eliminate the escapes or omissions, linked to design, and to ensure design integrity and robustness while maintaining efficiency. Recent Aerospace studies strongly suggest that the dominant root cause for 40% of recent on-orbit failures are design issues [3].

[*] Design Assurance Guide and Guide are interchangeable terms.

Additionally, design issues have significantly increased over the last 10 years [3]. See Appendix A, Failures and Design Assurance, for additional information.

The objective of the DAG is to provide a DA process that uncovers undiscovered or unidentified design risks so these design risks can be prevented or the cause corrected as early in the design cycle as possible. See Appendix B, Acquisition Life Cycle and Design Assurance, for additional information. The DAG presents a two-level approach to DA: One, an assessment of the enterprise-level infrastructure supporting design, and two, an independent assessment of the program design activity.

1.2 Definition

Design assurance is a formal, systematic process that augments the design effort and increases the probability of product design conformance to requirements and mission needs. The activity associated with design assurance has, as its objective, a truly independent assessment of the overall process for development of engineering drawings/models/analyses and specifications necessary to physically and to functionally describe the intended product, as well as all engineering documentation required to support the procurement, manufacture, test, delivery, use, and maintenance of the product.

1.3 Further Explanation

DA is a mission assurance function applied to design activities throughout the program life cycle, similar to product assurance or quality assurance activities which more typically apply to the manufacturing, integration, test, and logistics phases of a program life cycle. DA takes into account the user’s mission needs, which are translated into requirements, standards, and design documentation. Design engineering performs the initial review of requirements and lays out the building blocks of the design and should consider areas such as reliability, maintainability, producability, testability, etc. Systems engineering performs additional elements of design (e.g., interface controls, requirements allocation and flow-down, systems analyses, etc.). Product engineering verifies that the final product is produced and tested using the appropriate practices and processes.

In order to be unbiased, DA activities need to be performed by experts that are largely independent of the day-to-day design and systems engineering efforts to increase the likelihood that the design meets or exceeds customer expectations in function and performance. Having experts that are truly independent (having no organizational affiliation or program involvement) of the program may not be possible. What is important is that they provide unbiased and uncompromised assessments free from any conflicts of interest with the program, such as an independent reporting path. Subject matter experts supporting the independent DA assessment may come from the systems engineering organization or other disciplines associated with the design.

1.4 Why Use Design Assurance

DA is comprised of independent assessments used to identify possible design escapes as early as possible in the design life cycle and is a tool for determining the adequacy and efficacy of engineering design processes and products. DA increases the likelihood that the design meets or exceeds customer expectations in function and performance. While DA incorporates an independent element into the program, DA is meant to provide the program additional assistance and not be a hindrance.

The reach back and experiences of the DA team are greater than those available to any single program. The DA team will work with the program to make use of those resources to ensure program success.

1.5 How to Use the Guide

The DA process has been developed so it is general enough to work within the unique environment and culture of a given contractor, federally-funded research and development center, or government agency.

Most organizations are likely already using many facets of DA that are the subject of this Guide. This Guide is a framework that describes the DA process and DA tools and outlines what is considered to be the must do's for DA activities.

1.6 Design Assurance Topic Team

The DA Topic Team (Topic Team), listed in Table 1, studied the current best practices and literature on DA and developed the DA process in the Guide.

Table 1. Design Assurance Topic Team

Company	Role	Name	Phone	E-mail
NGAS	Chair	Ty Smith	310-813-1696	ty.smith@ngc.com
NGAS	Member	Chris Kelly	310-813-8655	chris.kelly@ngc.com
Aerospace	Co-chair	Joseph Aguilar	310-336-2179	joseph.a.aguilar@aero.org
Aerospace	Member	Daniel Nigg	310-336-2205	daniel.a.nigg@aero.org
Ball Aerospace	Member	Dave Pinkley	303-939-4498	dpinkley@ball.com
Boeing	Member	Tina Wang	310-364-5360	christine.l.wang@boeing.com
LMCO	Member	Ken Shuey	408-743-2487	ken.shuey@lmco.com
LMCO	Member	Bob Torczyner	408-756-7844	bob.torczyner@lmco.com
Raytheon	Member	Alan Exley	310-647-4016	alan_d_exley@raytheon.com

NGAS = Northrop Grumman Aerospace Systems; LMCO = Lockeed Martin Corporation.

2. Design Assurance Framework

The DA framework, Figure 2.1, shows how DA integrates into a representative enterprise functions/program environment infrastructure.

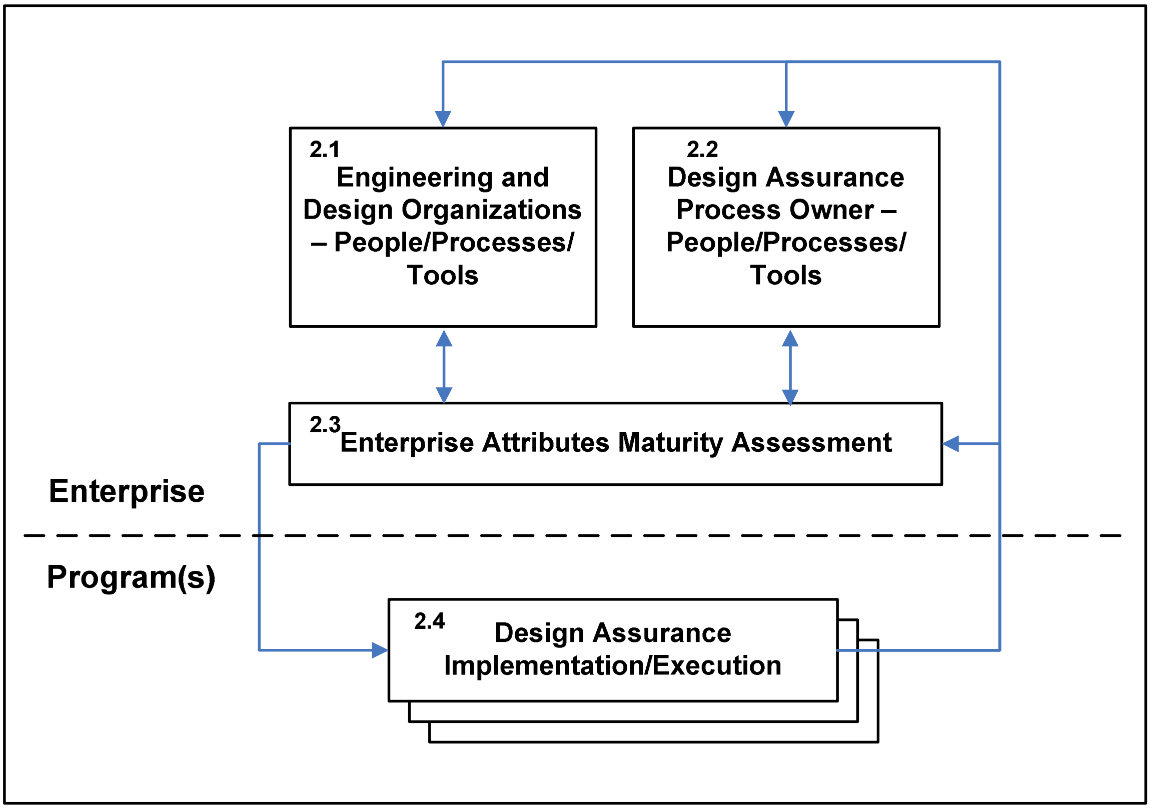

2.1 Engineering and Design Organizations – People/Processes/ Tools
2.2 Design Assurance Process Owner – People/Processes/ Tools
2.3 Enterprise Attributes Maturity Assessment
Enterprise
Program(s)
2.4 Design Assurance Implementation/Execution

Figure 1. Design assurance framework.

The DA framework combines the core responsibility and accountability of the engineering and design organizations for people, processes, and tools with the program responsibility and accountability for execution to meet customer design requirements. The DA team must have the technical expertise appropriate to review design-related processes and products. The key point of Figure 1 is that the DA process is independent from engineering design organizations and programs, both of whom are responsible for providing DA enterprise attributes. These enterprise attributes enable execution of the DA process on each program. It is acknowledged that customers' needs influence both the enterprise and program process and activities.

2.1 Engineering and Design Related Roles

The engineering (e.g. systems engineering) and design-related roles include the enabling functions with respect to people, processes, and tools to support the DA process. These include:

- Create and maintain the command media that defines the design process

- Identify and maintain the design and analysis tools
- Provide trained and knowledgeable design process performers
- Provide subject matter experts to support the DA assessments
- Incorporate lessons learned to continuously improve design guidance documents and training
- Ensure functional discipline to core processes
- Develop best practices and leverage best practices from other organizations

2.2 Design Assurance Process Owner

Mission assurance (e.g., quality, mission excellence, mission success, reliability, etc.) is the DA Process Owner. The DA Process Owner should be a technical organization that is independent of the design organization. The mission assurance organization ensures the DA process, described in Section 3, is implemented. A DA technical team will be assembled that will have the responsibility for carrying out the DA activities. The DA Process Owner responsibilities include:

- Assembling the DA team and provide the personnel to chair or conduct the independent DA assessments. The DA team shall be a cross-functional team comprised of subject matter experts representing the applicable technical disciplines (e.g. subject matter experts may come from other organizations besides the DA/mission assurance organization).
- Defining the DA process and create/maintain the DA command media.
- Assuring that DA processes are well defined, conformant, and that there exists a knowledgeable and competent source of resources to perform the design and development process.
- Evaluating the effectiveness of DA enterprise attributes infrastructure within the Engineering and Design Functional Organizations independent of the program.
- Evaluating the process based on the DA enterprise attributes relevant to the specific program under evaluation.
- Selecting DA activity lead and ensure completion.
- Incorporating DA process lessons learned.

It is important that the individual(s) leading the DA process have experience relevant to the DA activities being performed. They should have been significantly involved in executing design and programs to understand program design constraints of the specific mission. Also, they should understand the breadth and depth of the functional areas such as engineering, quality control, supplier control, and manufacturing.

2.3 Enterprise Attributes Maturity Assessment

DA involves many aspects of a company, both at an enterprise level and a program level. In this document, the enterprise-level capabilities are called DA enterprise attributes. Enterprise attributes are implemented at a higher level and provide the framework within which the program design effort is performed (e.g. they envelope the potential design space for the program under evaluation). Enterprise attributes also include the command media (design standards or similar documentation) that control the design effort and the infrastructure that is needed to create and maintain the integrity of the design products such that they fully describe the intended product and support the manufacture, test, delivery, use, and maintenance of the product.

A crucial step in performing an independent DA risk evaluation is a system level DA process gap analysis in accordance with Appendix C, Design Assurance Enterprise Attributes/Capability Checklist. Appendix C is a listing of the key enterprise attributes independent of any specific design application related to DA and includes definitions, risk levels, and maturity rating descriptions. This appendix can be used as a program resource to ensure coverage of key enterprise attributes to the design, as a knowledge resource, to better understand specific design assessment attributes, and/or a resource for evaluating (or analyzing) how well a company is implementing the DA process at any given point in time. By understanding the aspects detailed in the different maturity ratings, an organization can better understand what specific actions to implement to improve and mitigate design risk.

Maturity levels are described for each enterprise attribute that range from an ideal implementation to a more sporadic implementation of the DA process. As various changes commonly occur on programs, Δ assessments using the DA enterprise attributes maturity assessment should be performed during the life cycle of the program and incorporated into DA program planning, discussed in Section 3.1. As DA processes become more mature, these enterprise attributes can and should evolve as risk analysis and nonconformance and noncompliance trends are fully understood.

It is understood that each contractor, government agency, and federally-funded research and development center will implement DA differently, and it is believed the DA process can add significant value regardless of the specific implementation. By analyzing the enterprise attributes in Appendix C, refining the DA process where appropriate, this DAG can improve the implementation of DA within any organization or program. This includes external suppliers that have design authority (e.g. suppliers that design and manufacture to build to specification).

The following is a list of 22 DA enterprise attributes that are in one of three categories: DA Process, Design Engineering Tools, and DA Supplier Assessment.

- DA Process
  - Dedicated design subject matter experts network
  - Integrated and cross functional design organizational structure with shared responsibilities and accountabilities
  - Workforce capability and maturity
  - Lessons learned and significant risk mitigation actions continuously embedded into command media and design guides
  - Process discipline—Consistency between documented processes and actual practice

  - Robust nonconformance and noncompliance processes
  - Useful engineering conformance and compliance metrics
  - Documented DA definition and process requirements and DA plan
  - Limited tailoring options for processes
  - Realistic cost, schedule, and resource estimates committed in program proposal
  - Defined product tailoring and design reuse
  - Completed and controlled design integration

- Design Engineering Tools
  - Approved and common tools
  - Robust design guides available and accessible
  - Robust configuration and data management system
  - DA requirements assessment to verify and validate
  - Demonstrated technology readiness and manufacturing readiness

- DA Supplier Assessment
  - Effective and integrated supplier program management
  - Controlled acceptance of supplier product/process
  - Robust flow down of requirements to suppliers
  - Early supplier involvement in design
  - Robust process for handling furnished and supplied equipment

The DA Supplier Assessment enterprise attributes apply to suppliers who provide both build-to-print (suppliers do not have design authority) and build-to-specification (suppliers have design authority) products. It is recommended that suppliers with significant design responsibility (e.g., teammates/partners), self-assess for all the DA enterprise attributes using the DA enterprise-attributes capability checklist and DA activities be planned commensurate with risk. This assessment can be reviewed by higher-level customer representatives as required.

This assessment can indicate the strengths and weaknesses of the existing core engineering and design organizations. An overall numeric score can be determined and used as an improvement metric. Associating applicable life-cycle product phases, gates, and/or reviews to each enterprise attribute can help understand and plan when to assess an organization's maturity or capability. The expected goal and weight shown in the DA enterprise attributes/capability checklist can be tailored for programs of different scope (e.g. internal research and development, space vehicle level program, or system program). Goals can be set and to provide further clarity of DA gaps, the results can be documented using a spider/radar diagram. See Appendix D, Spider/Radar Diagram Examples, for additional information. Based on the results of gap analysis, the customer/mission assurance function can review appropriate sub-processes to determine risk posture against the specific risk profile of the program.

2.4 Design Assurance Implementation/Execution

As the DA framework combines the core responsibility and accountability of the engineering and design organizations for people, processes, and tools with the program responsibility and accountability for execution to meet customer design requirements, the effective implementation of

DA process requires a symbiotic partnership between the program and the enterprise organizations. When the system level DA gap analysis reveals preventive and corrective action opportunities, the functional organizations need to take ownership to address the actions that are systemic and affect the enterprise (multiple programs will be affected and future programs will benefit) and the program organizations need to take ownership to address the actions specifically related to their program's execution of the DA processes and tools necessary to achieve the design products required by the customer. Having the functional organizations address the systemic actions will help increase process and tool commonality in the long run. For example, a product alert should be addressed by all the programs for containment and systemic corrective action should be elevated to an appropriate preventive action board and/or corrective action board for review and systemic corrective action implementation.

3. Design Assurance Program Implementation/Execution Process

The DA process the DA team will apply to the program, shown below the dotted line in Figure 1, is explained in greater detail in Figure 2 below. On each program, this is the DA process the DA team will cover. The DA process encompasses the following activities: program planning, independent baseline assessment, activity planning, execution, and monitoring and reporting. The process flow of these activities is shown in Figure 2.

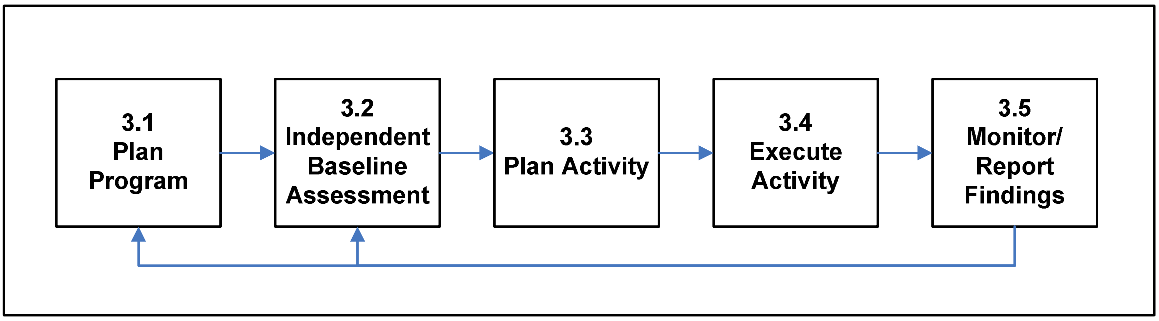

3.1 Plan Program
3.2 Independent Baseline Assessment
3.3 Plan Activity
3.4 Execute Activity
3.5 Monitor/ Report Findings

Figure 2. Design assurance process flow.

The DA process flow will be responsive to customer requirements as described in the plan program sub-process.

3.1 Plan Program

The first step in executing the DA process on a program is to develop the DA program plan. This plan will establish the scope of the DA activities that will be executed independently of the program but commensurate with program planning and identify specific areas of focus for mitigating program risk.

The DA plan program sub-process includes the following key steps: (1) collect all program requirements documentation, (2) review program requirements documentation, and (3) complete program DA plan. Table 2 summarizes the key inputs, process steps and outputs of the DA plan program sub-process.

Table 2. Design Assurance Plan Program Sub-Process

Inputs	Key Steps of Process	Outputs
• Customer and supplier requirements o Contract and subcontracts o Statement of work o Terms and conditions o Specifications and standards o Plans and schedules o Cost o Risk posture • Design assurance program plan template • Design assurance monitoring and reporting feedback • Results of Enterprise Attributes Maturity Assessment	• Collect all program requirements documentation • Review requirements documentation • Complete/update design assurance plan	• Design assurance program plan

DA planning begins as early in the program life cycle as possible. This should include risk reduction and proposal activities. A key component of this step is the establishment of the program's overall risk profile. For instance, a concept development program will likely accept a higher level of design risk than an operational program. This risk profile can then be decomposed to each of the key program elements to establish guidance on what activities the DA team will execute based upon the specific risk the design element embodies. Appendix E, Design Assurance Program Elements, contains a draft list of program elements that can be addressed by DA.

The DA team works closely with program management and integrated product team leads to access relevant design documentation specific to the program development phase and DA activity. Documentation collected includes proposals, program plans, requirements, designs, cost, and schedule information. DA planning should be developed sufficiently.

An important source of data for the DA team is risk, anomaly, and nonconformance data relevant to the enterprise attributes under evaluation. This data could include: watch list items, preventive action board actions and status, discrepancy reports, failure review board data, integration returns, independent review team reports, incidents, and hardware issues. Based on this data the program plan should be updated as needed.

The DA team will review the design documents and analyze anomaly data to assess the risk posture of the design against its baseline risk profile. Findings will be used to provide additional focus to the planned DA activities. These DA focus areas could be a functional element of the design, plans and executability (schedule, cost, staffing), technology maturity, and/or process executability. The DA product at this step in the process is the initial version of the DA plan.

3.2 Independent Baseline Assessment

The second step in executing the DA process on a program is to perform an independent assessment of risk for the program and analyze the DA risk. DA risk identification is the independent activity that examines selected risk elements of the program to identify the associated root causes for the negative findings identified above, begin their documentation, and set the stage for the following DA activities.

The DA independent baseline assessment sub-process includes the following key steps: (1) independent identification of design risks, and (2) initial DA baseline risk analysis. Table 3 summarizes the key inputs, process steps, and outputs of the DA independent baseline assessment sub-process.

Table 3. Design Assurance Independent Baseline Assessment Sub-Process

Inputs	Key Steps of Process	Outputs
• Design assurance program plan • Design assurance monitoring and reporting feedback • Design assurance Enterprise Attributes Maturity Assessment results • Government-industry data exchange program/design alerts • Lessons learned • Best practices • Customer feedback • Material review board/failure review board issues • Corrective action reports • Program risk list • Interviews with program, engineering, mission assurance/quality, etc.	• Independent identification of design risks • Initial design assurance baseline risk analysis (functional, programmatic, quality, cost, schedule, etc.)	• Independent selection of design risks/issues to perform design assurance activities

For programs to have a high potential for success, DA risk identification needs to begin as early as possible and continue throughout the design life cycle with regular reviews and analyses of technical performance measurements, schedule, resource data, life cycle cost information, earned value management data/trends, progress against critical path, technical baseline maturity, safety, operational readiness, and other program information available to the DA team members.

This step of the DA process provides for the independent identification of design risk and the initial DA baseline risk analysis. The DA team will identify program design risks by addressing some of the following:

- Examining the technology readiness level of the program design elements.

- Reviewing program planning for eliminating and mitigation or technology readiness level risks.

- Examining resource allocation including current and proposed staffing profiles, process, design, supplier, operational employment dependencies, etc.

- Reviewing program planning with respect to coverage of key DA enterprise attributes relevant to the program phase and design attribute under evaluation.

- Examining key technical performance metrics against margin requirements.

- Reviewing analysis products and the program incorporation of those products for managing DA risks.

- Monitoring test results throughout the design life cycle especially test failures (e.g. engineering models, failure review boards, etc.).

- Reviewing any other potential design shortfalls against initial requirements allocation as the design matures.

- Analyzing negative trends, reduced margins, schedule slips, funding shortfalls, engineering changes, audit findings, customer feedback, etc.

- Analyzing signification issues that are active or open.

- Reviewing lessons learned database (e.g. *100 Questions for Technical Review* – see Appendix G).

- Review best practices (e.g. failure mode effects and criticality analysis, fault management, systems engineering handbooks and guides – see Appendix G).

- Reviewing results of DA enterprise attributes assessment

- Evaluating risks from quality, functional, programmatic, cost/schedule aspect.

- Interviewing key business and functional leaders and asking them what concerns them about the program (e.g. if not enough resources, what on the work breakdown structure is not getting done).

The aspects of DA that are applied at a program level are called DA program elements in this document. Appendix E is a listing of the DA program elements which can be used as a tool during the design process.

3.3 Plan Activity

The third step in executing the DA process on a program is to develop a DA activity plan. Different than the DA program plan (or program quality plan), the DA activity plan includes the what, when, who, and how the DA team will address the risks found. The activity plan will identify what specific design risks and issues will be addressed, how they will be addressed, who will be addressing them, and when they will be addressed. The DA plan does not need to be a separate plan and may be included as an element of a broader mission assurance plan.

The DA plan activity sub-process includes the following key step: (1) develop the plan for executing the DA activity. Table 4 summarizes the key inputs, process steps and outputs of the DA plan activity sub-process.

Table 4. Design Assurance Plan Activity Sub-Process

Inputs	Key Steps of Process	Outputs
• Independent selection of design risks/issues to perform design assurance activities	• Develop the plan for executing the design assurance activity	• Design assurance activity plan

The DA activity plan may include the following for each risk or issue that will be assessed:

- System level and lower level design reviews. If these reviews are already occurring on the program, duplication is not necessary; however, specific issues in those reviews may require more scrutiny based upon previous DA findings.
- Detailed description of the actions to be taken on the designated design area and their relationship to program activities and milestones.
- Identify appropriate experts required to perform the activity.
- Schedule of the activities which includes mitigation of specific DA risks.
- Risk burn down could be accomplished by both reduction in likelihood and changing the impact or consequence of the risk occurring.
- Decision points will be established based on the finding from the activities.
- Additional resources required including program and/or functional support.

The level of detail in the DA activity plan can be scoped down commensurate with program need. In the previous step selected risk elements of the program were identified. The risks identified will be technical, process, or executability risks. Appendix E, Design Assurance Program Elements, is a guide that can be used to identify risk. Assuming that the risks have been identified as low, medium, or high risk levels, the actions in Table 5 can be used as guidance to address the programmatic risks.

Table 5. Actions for Low, Medium, and High Risks

	Technical Risks	Process Risks	Executability Risks
Low	• Capture the technical parameters on a watch list doing the following: o Document the specific issue for each parameter o Identify the responsible design owner o Determine when the process will be executed o Determine the re-visit criteria that could include schedule or events	• Capture the process metrics on a watch list doing the following: o Document the specific issue for each process o Identify the responsible process owner o Determine when the process will be executed o Determine the re-visit criteria that could include schedule or events	• Work with specific program integrate product teams to determine executability risks against the contractual requirements baseline doing the following: o Place areas with tight margins on watch list o Document the specific issue o Identify the responsible design owner o Determine the re-visit criteria that could include earned value added performance deviations and or cost/schedule re-baselines
Medium	• Perform an independent assessment of the design doing the following: o Review the specific design artifacts o Conduct interviews o Participate in technical working groups o Participate in technical reviews • Follow design threads top down, bottoms up, and cross integrated product teams. For tops down and bottoms up, utilize information on process and process flow, budgets allocations, and common source reuse. For cross integrated product teams (at common level of design) use similarity of designs and components, and shared assembly processes.	• Perform a process compliance assessment doing the following: o Gather and review the current process documentation and all relevant process waivers for the program o Notify the process owner and process users that a process assessment will be performed. o Work with the process owner and process users, schedule the assessment o Request specific objective evidence from process users that will be used to evaluate process compliance o Review the objective evidence to process compliance o Capture any findings and necessary corrective actions o Work with the process owner and the program to reach closure on findings and corrective actions	• Work with specific integrated product teams to compare the program technical requirements baseline against baseline costing including work breakdown structure mapping, basis of estimates, labor spreads, and capital requirements doing the following: o Participate in program costing reviews • Assess integrated product teams in formulating executability risks include the risk to mission success at the current apportionment and level of funding and the de-scope(s) that would be required to execute within current budgets

Table 6. Actions for Low, Medium, and High Risks

	Technical Risks	Process Risks	Executability Risks
High	• Perform an independent design analysis doing the following: ○ Execute a program accepted design process	• Perform a process compliance assessment doing the following: ○ Gather and review the current process documentation and all relevant process waivers for the program ○ Notify the process owner and process users that a process assessment will be performed. ○ Work with the process owner and process users, schedule the assessment ○ Request specific objective evidence from process users that will be used to evaluate process compliance ○ Review the objective evidence to process compliance ○ Capture any findings and necessary corrective actions ○ Work with the process owner and the program to reach closure on findings and corrective actions	• Perform an independent assessment of the design doing the following: ○ Review the program technical requirements baseline against baseline costing including; work breakdown structure mapping, basis of estimates, labor spreads, and capital requirements ○ Participate with the program by conducting integrated product team interviews and participation in program costing reviews ○ Assess specific executability risks and present to program. This should include the risk to mission success at the current apportionment and level of funding and de-scope(s) that would be required to execute within current budgets.

The actions in Table 3.3.2 can be used as guidance to address the programmatic risks.

Organizations should use their own risk-management process to quantify risks to add in decision making and risk mitigation resource allocation. As an example the *Risk Management Guide for DOD Acquisitions* [4] and *ISO 17666: Space Systems – Risk Management, 1st Ed.* [5] could be used (see Appendix G).

The following is an example of an activity in the DA activity plan. During the DA risk process it was identified that the program's qualification by similarity process was not robust. The activity plan would review multiple qualification by similarity packages. This review would generate risk findings that the DA team communicates to the program and functional groups. The DA team stays engaged with the program and functional organization to help plan an activity to burn down risk. DA success is increased as DA becomes active team player/partner in planning activity to burn down risk. If the program chooses to do nothing about the risk, the DA team and process owner would escalate the findings.

3.4 Execute Activity

The fourth step in executing the DA process on a program is to perform the DA activity.

The DA execute activity sub-process includes the following key steps: (1) execute the DA activity plan, and (2) subject matter experts work with functional and program personnel. Table 7 summarizes the key inputs, process steps, and outputs of the DA execute activity sub-process.

Table 7. Design Assurance Execute Activity Sub-Process

Inputs	Key Steps of Process	Outputs
• Design assurance activity plan	• Execute the design assurance activity plan • Subject matter experts work with functional and program personnel	• Design assurance results and findings, including new risks, issues, actions, lessons learned, etc. • Revise design assurance plan as needed

DA activities will vary based upon the program's risk profile and classes of risks on each program. The following provides a general guideline for the different risk levels on technical, process, or executability categories of risk. Note that the majority of DA activities are not related to specific program defined reviews. The DA execution activity may be divided into two categories: (1) design assessment tasks and (2) process compliance tasks.

Design assessment tasks are those that address the risks identified in the plan. Those risks may be cost, schedule, or technical in nature. First, collect and review the related design materials. The subject matter experts should engage and interact with program design working groups. Informal discussions with design engineers, participation in the various risk boards, and attending formal design reviews are means to engage with those working groups.

A 'thread' approach is key to identifying many issues and risks quickly. This approach is based upon a thread both vertically and horizontally within the program structure. Vertical threads include, but are not limited to, following a potential problem that may have been caused by a previously performed process (usually at a higher architecture level), budget allocations, or common source reuse. Horizontal threads include following potential problems by looking at similarities between unit designs, common sub-assembly designs, shared assembly processes, and requirement allocations. Many potential problems may be uncovered in this fashion and may be instantly resolved by communicating with the effected design team(s).

If, in the course of investigation, a thread identifies a new potential risk or issue that may have significant effect on program execution; the DA team may initiate an independent assessment (i.e., a technical evaluation) of the design process. This risk or issue would be elevated to the appropriate levels and would be done in coordination with program management.

Process compliance tasks are those that address the engineering process risks identified in the program plan. The first step is to communicate to the process owner and users that a process assessment is to be performed. Next, process documentation is collected and reviewed. Objective evidence is assessed for compliance to the process documentation.

Any findings, corrective actions, lessons learned, etc., are collected for the last step of the process.

3.5 Monitor/Report Findings

The fifth, and final, step in executing the DA process on a program is to monitor and report the findings from the DA activities. At the conclusion of each DA activity, the results and corrective actions, if any, will be documented and communicated to the program and functional organizations as appropriate. For any activities identified as a risk, they will be monitored by the DA team until they are removed.

The DA monitor/report findings sub-process includes the following key steps: (1) watch the DA results and findings identified as areas of risk, (2) report the results and findings, and (3) escalate findings to senior management. Table 8 summarizes the key inputs, process steps, and outputs of the DA monitor/report findings sub-process.

Table 8. Design Assurance Monitor/Report Findings Sub-Process

Inputs	Key Steps of Process	Outputs
• Design assurance results and findings, including new risks, issues, actions, etc.	• Watch results and findings identified as risk areas • Report results and findings • Escalate findings	• Design assurance report to programs, engineering, process owners, mission assurance • Risks to risk management process • Watch list items to program mission assurance and design assurance process owner • Lessons learned to affected process owner • Feedback to design assurance program plan

Results and findings discovered from the previous step must be monitored to assure they are properly resolved. The program must decide whether or not it will act on the DA team output, however, the DA team has a responsibility to verify and validate how each of the findings were acted upon. If the DA team feels that a particular result that has significant risk has not been acted on properly, the findings can be elevated within the organization.

Activity results could include a summary of the actions taken, the design teams participating, and/or the design processes involved. Specific actions or corrections will be documented. This may include reporting of design changes instituted as part of the DA activity or recommended design changes. For recommended DA actions, the report will include the responsible integrated product team on the program and the recommended actions with a due date commensurate with program milestones.

The report is maintained by program mission assurance and any new risks which have been identified in the DA process are to be inserted into the program risk list for monitoring and tracking. The DA team will also communicate all the findings and corrective actions (completed and pending) to the appropriate functional engineering and mission assurance organizations for their specific actions and for incorporation into their respective lessons-learned databases.

4. Conclusions

This DAG provides a process for performing DA that uncovers design risks as early in the design cycle as possible. The Guide can be used by any organization involved in the acquisition of a space system. The Topic Team developed this Guide specifically to develop a definition of DA, identify key DA enterprise attributes and program elements, and formulate a risk-based DA process flow. From the beginning of this activity, it was clear that the scope of the Guide was going to be focused on developing a process for performing DA and that many other aspects of DA would need to be addressed by others at a later date. As such this Guide does not cover all areas of DA and those areas that are covered can be developed in further detail. It is the hope of the Topic Team that this content can be used as a starting point for the aerospace community and will lead to further DA development.

During the development of the DAG, substantial comments and feedback have been provided and incorporated. Appendix F captures some of the questions that were posed to the Topic Team, along with responses to those questions. A number of useful references have been identified that can be used to support DA activities, and are captured in Appendix G. Finally, Appendix H is a glossary for some of the key terms used in the DAG.

Appendix A. Failures and Design Assurance

Recent Aerospace studies strongly suggest design issues account for 40% of all failures, far exceeding other failure causes, which shows there are escapes with current design practices [3].

A 1997 Aerospace study shows design issues accounted for a much smaller number of on-orbit failures [6]. The data in Figure A-1 shows design assurance anomalies accounting for 19% of the on-orbit failures.

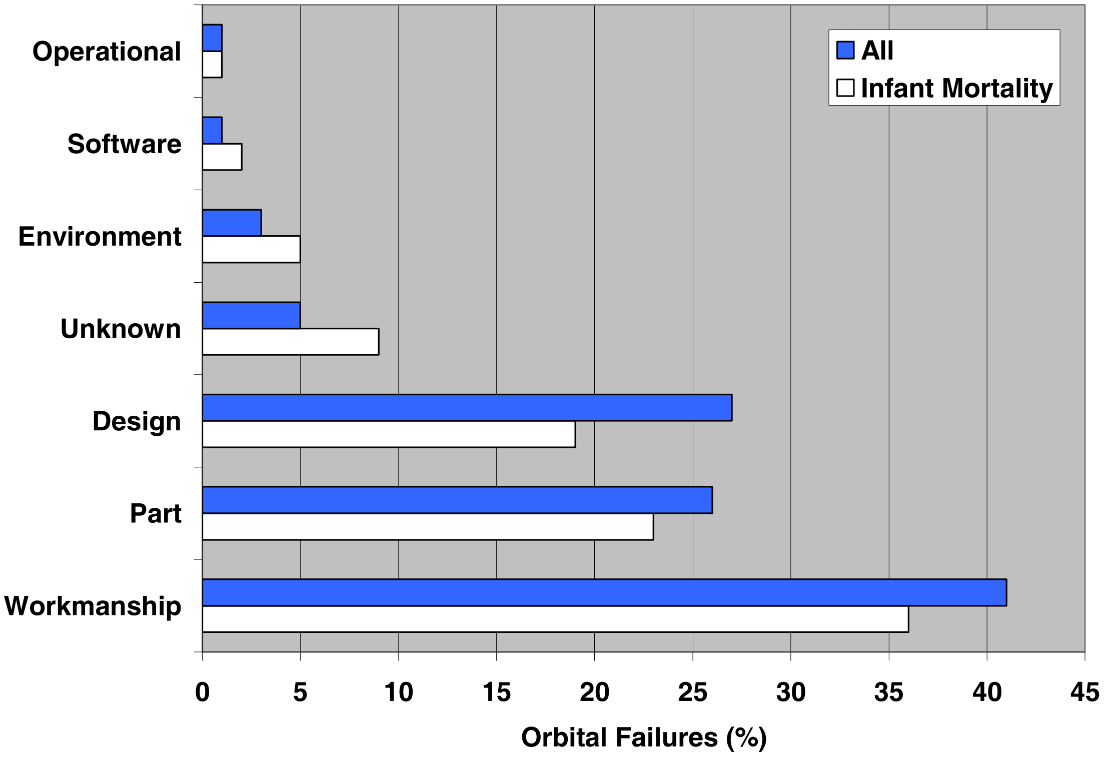


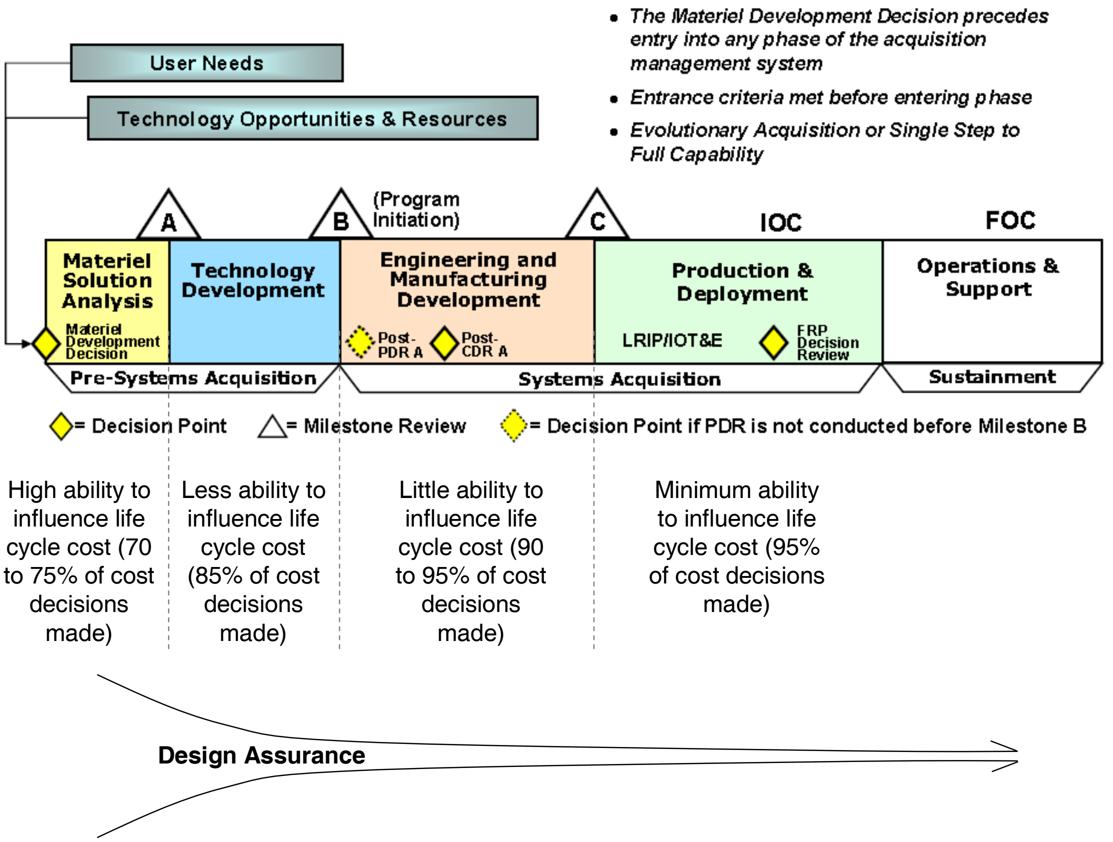
Figure A-1. Past (1997) on-orbit failure causes.

The data in Figure A-1 show that on-orbit failures due to design issues have significantly increased over the last 10 years when compared to recent studies.

Infant mortality shows that the problem manifested itself early in failure, within the first 90 days. Examples of infant mortality design issues include deployment failure due to critical clearance, inappropriate part usage allowed due to design allowance failure, unit failure due to lack of design analysis, and inadequate testing.

Appendix B. Acquisition Life Cycle and Design Assurance

About three-quarters of the total system life cycle costs are based on decisions made before Milestone A [7]. This means the decisions made in the pre-Milestone A period are critical to avoiding or minimizing cost and schedule overruns later in the program. Design assurance is predominantly performed in pre-systems acquisition, or done before Milestone B, and consequently has a critical impact on the system life-cycle cost. Figure B-1 shows how design assurance relates to the Defense Acquisition System [6].



• The Materiel Development Decision precedes entry into any phase of the acquisition management system
• Entrance criteria met before entering phase
• Evolutionary Acquisition or Single Step to Full Capability
User Needs
Technology Opportunities & Resources
A
B
(Program Initiation)
C
IOC
FOC
Materiel Solution Analysis
Materiel Development Decision
Technology Development
Engineering and Manufacturing Development
Post-PDR A
Post-CDR A
Production & Deployment
LRIP/IOT&E
FRP Decision Review
Operations & Support
Pre-Systems Acquisition
Systems Acquisition
Sustainment
= Decision Point
= Milestone Review
= Decision Point if PDR is not conducted before Milestone B
High ability to influence life cycle cost (70 to 75% of cost decisions made)
Less ability to influence life cycle cost (85% of cost decisions made)
Little ability to influence life cycle cost (90 to 95% of cost decisions made)
Minimum ability to influence life cycle cost (95% of cost decisions made)
Design Assurance

Figure B-1. Design assurance and the defense acquisition management system [8].

Appendix C. Design Assurance Enterprise Attributes/Capability Checklist

This appendix lists the design assurance enterprise attributes identified by the team as being a key to the implementation of design assurance at an enterprise level. This appendix can be used as a program resource to ensure coverage of key enterprise attributes to the design, as a knowledge resource, to better understand specific design assessment attributes, and/or a resource for evaluating (or analyzing) how well a company is implementing the design assurance process at any given point in time. By understanding the aspects detailed in the different maturity ratings, an organization can better understand what specific actions to implement to improve and mitigate design risk. Maturity levels are described for each attribute that range from an ideal implementation to a more sporadic implementation of the design assurance process. As various changes commonly occur on programs, Δ assessments using the design assurance capability checklist should be performed during the development life cycle to account for additional design assurance risk areas. As design assurance processes become more mature, these enterprise attributes can and should evolve as risk analysis and nonconformance and noncompliance trends are fully understood.

Similar to the Capability Maturity Model® Integration definition of maturity level, "a maturity level consists of related specific and generic practices for a predefined set of process areas that improve the organization's overall performance. The maturity level of an organization provides a way to predict an organization's performance in a given discipline or set of disciplines. A maturity level is a defined evolutionary plateau for organizational process improvement. Each maturity level matures an important subset of the organization's processes, preparing it to move to the next maturity level. The maturity levels are measured by the achievement of the specific and generic goals associated with each predefined set of process areas." [9]

Generic goals for each of the five maturing levels are described in Table C-1. Note that each level creates a foundation for ongoing process improvement. Rather than uniquely define these maturity levels for design assurance, the maturity levels as defined in the *Capability Maturity Model® Integration: Guidelines for Process Integration and Product Improvement*, Second Edition, were adopted in part. These generic goals shall be supplemented with the specific goals listed in the description of maturity levels for the design assurance enterprise attributes.

Table C-1. Generic Maturity Level Descriptions

Maturity Level 1	Maturity Level 1: Initial At maturity level 1, processes are usually ad hoc and chaotic. The organization usually does not provide a stable environment to support the processes. Success in these organizations depends on the competence and heroics of the people in the organization and not on the use of proven processes. In spite of this chaos, maturity level 1 organizations often produce products and services that work; however, they frequently exceed their budgets and do not meet their schedule. Maturity level 1 organizations are characterized by a tendency to over commit, abandonment of processes in a time of crisis, and an inability to repeat their successes.
Maturity Level 2	Maturity Level 2: Managed At maturity level 2, the projects of the organization have ensured that processes are planned and executed in accordance with policy; the projects employ skilled people who have adequate resources to product controlled outputs; involve relevant stakeholders; are monitored, controlled, and reviewed; and are evaluated for adherence to their process descriptions. The process discipline reflected by maturity level 2 helps to ensure that existing practices are retained during times of stress. At maturity level 2, status of the work products and the delivery of services are visible to management at defined points. Commitments are established among relevant stakeholders and are revised as needed. Work products are appropriately controlled. The work products and services satisfy their specified process descriptions, standards, and procedures.
Maturity Level 3	Maturity Level 3: Defined At maturity level 3, processes are well characterized and understood and are described in standards, procedures, tools and methods. The organization’s set of standard processes, which is the basis for maturity level 3 is established and improved over time. These standard processes are used to establish consistency across the organization. Projects establish their defined processes by tailoring the organization's set of standard processes according to tailoring guidelines. At maturity level 3, processes are managed more proactively using an understanding of the interrelationships of the process activities and detailed measures of the process, its work products, and its services.
Maturity Level 4	Maturity Level 4: Quantitatively Managed At maturity level 4, the organization and projects establish quantitative objectives for quality and process performance and use them as criteria in managing processes. Quantitative objectives are based on criteria in managing processes. Quantitative objectives are based on the needs of the customer, end users, organization, and process implementers.
Maturity Level 5	Maturity Level 5: Optimizing At maturity level 5, an organization continually improves its processes based on a quantitative understanding of the common causes of variation inherent in processes. Maturity level 5 focuses on continually improving process performance through incremental and innovative process and technological improvements. Qualitative process improvement objectives for the organization are established, continually revised to reflect changing business objectives, and used as criteria in managing process improvement. The effects of deployed process improvements are measured and evaluated against the quantitative process improvement objectives. Both the defined processes and the organization's set of standard processes are targets of measureable improvement activities.

The following 25 pages are a collection of 22 design assurance enterprise attributes. These enterprise attributes have been separated into one of three categories: Design Assurance Process, Design Engineering Tools, and Design Assurance Supplier Assessment. This list is not necessarily exhaustive and may be evolved to add and/or delete enterprise attributes as deemed appropriate by any organization. The risk impact is discussed and score, goals, and weighting columns are left to the Guide user to tailor to their specific needs. Some of the more common terms used in the design assurance enterprise attributes have been abbreviated and are:

• DA:	Design assurance
• DE:	Design engineering
• IPT:	Integrated product team
• RAA:	Responsibility, accountability, authority
• SME:	Subject matter expert
• SE:	System Engineering

Design Assurance Process – 1

Dedicated design subject matter experts network		Applicable Phases of Project /Life Cycle Gate/Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: A network of subject matter experts (SME) that is used to support DA reviews, provide input to lessons learned, and support development and modification of design guides. This network is maintained through a certification process or other formal means.						
Risk Impact: SMEs are a key component of the DA process. Lack of identified SMEs presents a high risk to success of the effort.						
Maturity Level 1	No SMEs have been officially identified.					
Maturity Level 2	There are SMEs, but their use varies by organization.					
Maturity Level 3	There is a network of SMEs, but there is not a centralized, accessible listing, or they are kept by several organizations.					
Maturity Level 4	A network that identifies subject matter experts exists, is readily accessible, and is utilized. However, there is no certification process.					
Maturity Level 5	A network that identifies subject matter experts exists, is readily accessible, and is utilized. These experts have been certified through a standard process and are recognized for their expertise. The SMEs have responsibility to share their knowledge in a way that it can be effectively leveraged throughout an organization.					

Design Assurance Process – 2

Integrated and cross functional design organizational structure with clearly defined RAAs and overall shared responsibilities and accountabilities for product throughout program life cycle		Applicable Phases of Project /Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Design groups on a program consist of team members from cross functional organizations such as engineering (design, stress, etc.), manufacturing, tooling, materials and processing, supplier management, quality, customer or mission assurance. Team members are appropriately represented and share responsibility and accountability for overall product cost, schedule, performance, and delivery.						
Risk Impact: Having cross functional representation mitigates design for manufacturing, assembly, and test issues and allows earlier preventive action.						
Maturity Level 1	Design is done in series: Design hands off to stress, to manufacturing, etc					
Maturity Level 2	Design is done concurrently (in parallel) but no shared responsibility and accountability between the functions.					
Maturity Level 3	Design organization is organized as an integrated product team (IPT) but engineering holds all responsibility and accountability for the product, and therefore holds all decision making power. Customers are included in reviews only as required by contract.					
Maturity Level 4	Design organization is organized as an IPT (on paper) but realistically operates only as an integrated product team late in the program when design and development are near complete. Customer review occurs at final design. Prior to this, IPT is engineering centric.					
Maturity Level 5	IPT operates as such throughout the program and product life cycle with shared RAA for product design, cost, schedule etc. and decisions are made as a team with customer review as needed.					

Design Assurance Process – 3

Workforce capability and maturity		Applicable Phases of Project /Life Cycle/Gate/ Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Personnel supporting the DE, SE, etc., tasks have sufficient training to excel at their respective duties. This includes the designers, analysts, systems engineers, quality engineers and DA personnel as well as support functions that give inputs to design. These functions include manufacturing, test, assembly, integration as well as materials and processes, quality, etc.						
Risk Impact: All people need to be trained and have a training plan that is actively managed. RAA agreements between the different DE and DA roles must be clearly defined. Clear RAAs for design interfaces (physical part, process, tool) need to be fleshed out and agreed to by affected organizations and executed by functional organizations and programs as required.						
Maturity Level 1	Adequacy of training specific to job functions is in question. Only training required for enterprise is tracked.					
Maturity Level 2	All personnel are adequately trained in their specific duties. Little or no training specific to the DA process.					
Maturity Level 3	All personnel are adequately trained in their specific duties. DE training and certification is timely (e.g., performer awareness, DA training, DE/DA training, SE requirements training). Only the personnel directly supporting DA are trained regarding the DA process.					
Maturity Level 4	All personnel are adequately trained in their specific duties. Some personnel are trained regarding the DA process sufficiently to support in multiple DA tasks as required.					
Maturity Level 5	All personnel are adequately trained in their specific duties. In addition, all personnel are trained regarding the DA process sufficiently to support in multiple DA tasks as required.					

Design Assurance Process – 4

Lessons learned and significant risk mitigation actions continuously embedded into command media and design guides.		Applicable Phases of Project/Life Cycle/Gate/ Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: The lessons learned process is "closed loop." Not only is the data gathered and disseminated by a database (or other means), the lessons learned are incorporated into the design guides and other command media so that they become part of the way of doing business. Training regarding the lessons learned is included in actively managed training plans.						
Risk Impact: Incorporating lessons learned into design guides or other command media is the most effective way to ensure that the information is used by the personnel performing the DE tasks.						
Maturity Level 1	Only minimal thought is given to lessons learned when creating or updating command media such as design guides.					
Maturity Level 2	Lessons learned are considered when updating the command media (such as design guides). The frequency of updates is not consistent.					
Maturity Level 3	There is a formal process in place to incorporate lessons learned into command media (such as design guides). This process may not be performed consistently. Training and/or notification regarding this documentation of lessons learned is not consistently flowed to users.					
Maturity Level 4	There is a formal process in place to incorporate lessons learned into command media (such as design guides). This process is performed whenever a design guide or other command media is updated. Training and/or notification regarding changes to documentation is not consistently flowed to those affected.					
Maturity Level 5	There is a formal and regular process in place to incorporate lessons learned into command media (such as design guides). This process is performed frequently to ensure that the lessons-learned information is included in a timely fashion. The process includes flow down of new and revised command media to all affected. People are aware of all process changes prior to release by training and/or notification.					

Design Assurance Process – 5

Process discipline - Actual practice consistent with approved, documented processes		Applicable Phases of Project/Life Cycle/Gate/ Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: The processes used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These processes are readily accessible, and in a form that is utilized by the personnel. This includes, but is not limited to the DA process.						
Risk Impact: Having a documented set of processes within an organization/program is the key to process commonality across a broader organization where feasible. When employees know the processes they are responsible for and have documented the best practice of the process, they not only follow the process with more discipline but they also will likely improve the process documents as warranted.						
Maturity Level 1	Processes exist, but they may or may not be approved, accessible, utilized, or updated in a consistent manner. Variation exists across functions and interfacing engineering groups.					
Maturity Level 2	Some processes used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. Approval is not always consistent for all design related processes, process discipline varies or these processes may not be readily accessible. Processes may be evaluated and updated as required to support changes. Noncompliance to process e.g. design review entrance and exit criteria, results in travelled work/risk. Travelled risk is recognized but not managed as part of the risk process.					
Maturity Level 3	All processes used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These processes are readily accessible, but may be too cumbersome to use by some personnel (i.e., perceived as restrictive by programs) and hence, limited implementation. Process deviations are continually used without documented processes evaluated and updated as required to support changes and refinements in the operations. Travelled risk due to process noncompliance is adequately managed within the overall risk management process (e.g. open issues from design reviews).					
Maturity Level 4	All processes used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These processes are readily accessible, but may not be utilized consistently by all personnel. Processes are continually evaluated and updated as required to support changes and refinements in the operations. Process compliance is the norm, so travelled risk due to process noncompliance is minimized.					
Maturity Level 5	All processes used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These processes are readily accessible, and in a form that is utilized by all personnel. Processes are continually evaluated and updated as required to support changes and refinements in the operations. Culture of openness allows anyone in the organization to bring up process noncompliances that jeopardize quality of design deliverables.					

Design Assurance Process – 6

Robust nonconformance and noncompliance processes—Integrity of the problem identification, containment actions, root cause(s) determination, systemic corrective actions, and corrective and preventive action verification of effectiveness		Applicable Phases of Project/Life Cycle/Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Evaluation of the effectiveness of the corrective action processes employed in the DE effort. Includes metrics to measure the effectiveness. Allows feedback to improve the corrective action process. Also includes robust and timely technical alert process that ensures all programs are aware of technical issues that may affect their program and containment across all programs is timely and thorough.						
Risk Impact: Many engineering problems result in changes to engineering processes. There needs to be a process, (e.g., plan, do, check, act or define, measure, analyze, improve, control) to verify that the revised/new process was effective in solving the problems. If problems recur, this indicates either a breakdown in corrective action or an incorrect root cause. For significant technical issues, an alert process must be in place to ensure that other programs and organizations are made aware of the issue and action is taken to mitigate recurrence.						
Maturity Level 1	Engineering problems are mostly addressed with containment actions and no effort towards root cause analysis and needed corrective action. Very little focus on process. Focus is on fixing the product and moving it down the manufacturing line.					
Maturity Level 2	As a result of engineering issues, systemic fixes involving process changes are identified but inconsistently executed. Technical issues are discussed but there is no formal process to alert and track impact across other programs or organizations. Repeat issues occur on other programs.					
Maturity Level 3	As a result of engineering issues, corrective action involving process changes or development are worked by the responsible organization/program, implemented, but only seem to be executed on the near term program. Process changes are not institutionalized across programs and/or products.					
Maturity Level 4	As a result of engineering issues, corrective action involving process changes or development are worked as an integrated team by the functions and programs that share the RAA. The corrective action is implemented but only seem to be executed on the near term programs and does not adequately capture new programs. Process changes are not institutionalized across programs and/or products.					
Maturity Level 5	When process changes are implemented to fix an engineering problem, follow up is done to verify that the process change was effectively implemented and no recurrence of problems is evident. If engineering noncompliance and nonconformance continues to indicate that the process is not fixed, additional process corrections are made. These processes are institutionalized across programs and products as applicable, and a system is in place to ensure new programs embrace the process changes.					

Design Assurance Process – 7

Useful engineering conformance and compliance metrics		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Standard metrics that are developed to measure the conformance of the DE effort to the DA requirements, as well as the performance of the DA process itself. Examples include number open actions during reviews, number of gate liens, number of years experience of key program leadership; number of missed milestones (budget to actual CPI),first time quality of design releases, specification releases etc., number of engineering changes after build phase has begun. Metrics shall be in place to ensure internal and external customers' needs are being met.						
Risk Impact: If we don't measure conformance and performance, how do we know if DE is working and what needs to be modified?						
Maturity Level 1	Metrics are not indicative of true health of the program/product. Achievable metrics are chosen rather than predictive, helpful metrics.					
Maturity Level 2	Metrics are fairly indicative of problems but are not reviewed more than a few times a year. Metrics are refined to distinguish in-phase and out-of-phase design escapes. Metrics drive some root-cause-and-corrective action activity but corrective-action implementation is inconsistent and not systemic.					
Maturity Level 3	Metrics are fairly indicative of program/functional health and are reviewed and trended regularly for possible systemic improvement opportunities. Mission critical metrics are kept up-to-date and available for constant attention. Resources are not consistently applied to corrective action and missed opportunities exist.					
Maturity Level 4	Metrics are fairly indicative of program/functional health and senior management actively supports resource requirements needed for corrective action. Timely corrective actions are instituted based on the metrics and the customer related metrics. Metrics themselves are not regularly evaluated for possible changes when nonconformance and noncompliance shift.					
Maturity Level 5	Set of metrics indicate the true health of the program, the organizations, and has adequate runway to allow preventive actions. Preventive actions as well as corrective actions are supported by leadership with resources. Metrics are actively and effectively analyzed to improve processes, improve functional discipline and decrease nonconformance and noncompliance. Metrics themselves are adjusted to focus on processes indicated by trend analysis and risk analysis.					

Design Assurance Process – 8

Documented DA definition and process requirements DA plan (There should be a standardized template that can be tailored for programs). This may be incorporated into a more broadly defined mission assurance or quality plan.		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: This is the formal documentation that defines DA and provides the process requirements to accomplish the independent DA tasks. This should include the definition of how DA relates to mission assurance, quality assurance, and product assurance. RAA of each related organization shall be defined with giver/receiver requirements. This can be documented in a formal DA plan that defines how a specific program will implement the DA process. The plan should be a documented plan of actions: who, what, when, how, where does DA happen? The plan should be tied with the risk management plan, and updated as the program matures.						
Risk Impact: This sets the framework in which DA is performed. Even without a formal program plan, independent design activities can be performed and provide benefit.						
Maturity Level 1	Many are confused regarding the definition of DA, and the DA processes may or may not be included in several different processes.					
Maturity Level 2	The definition of DA is only understood by the personnel involved in DA. There are several formal processes that establish the activities, attributes, and application of DA; ownership of these processes may be divided among several organizations.					
Maturity Level 3	The definition of DA is understood by many personnel involved in the DE activities, but the interrelationships with the other “Assurance” activities may or may-not be defined. There are several formal processes that establish the activities, attributes, and application of DA; ownership of these processes may be divided among several organizations.					
Maturity Level 4	The definition of DA is understood by most personnel involved in the DE activities, the interrelationships with the other “Assurance” activities are defined, but confusion exists regarding the interrelationships. A single formal process establishes the independent activities, attributes, and application of DA.					
Maturity Level 5	The definition of DA is understood by all personnel involved in the DE activities, and the interrelationships with the other “assurance” activities are defined and understood. A single, formal process establishes the independent activities, attributes, and application of DA.					

Design Assurance Process – 9

Limited tailoring options for processes		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: The DA process should allow for some process tailoring of the DA plan to account for different products (i.e. military versus. commercial versus. scientific programs). Tailoring should be limited and controlled by a formal process or organization.						
Risk Impact: The less the tailoring of options, the less variability, cost, need for resources. Program to establish tailoring where it makes business sense.						
Maturity Level 1	No tailoring guidelines exist. Every program is treated like a new opportunity with no attention placed on commonality. Organizations/programs do not have approval to deviate from command media without deviation approval, but processes vary significantly dependent on who is working the various programs. Risks involved with tailored processes is not well defined or understood by enterprise or program.					
Maturity Level 2	Process tailoring guidelines exist but are not followed with discipline in all organizations. Inconsistent approvals for processes that are tailored when different than command media.					
Maturity Level 3	Tailoring guidelines exist but are not followed with discipline in all organizations. Conscious design effort to be common with past programs where possible and leverage existing design related processes. May or may not be a consistent tailoring approval process. Risks involved with tailored processes not well defined or understood by Program.					
Maturity Level 4	Tailoring guidelines exist and are followed by the majority of organizations. Conscious design effort to be common with past programs where possible and leverage existing design related processes. Development of new processes where needed are done with the intent of repeatability and reuse by future programs. A consistent tailoring approval process exists.					
Maturity Level 5	Clear guidelines are set with regard to tailoring options; programs and product groups have tailored business streams identified (i.e., baseline, government options, program/customer options for processes). Programs work together to maximize commonality where it makes enterprise business sense and supports the long-range business plan. Process tailoring is reviewed with discipline and only approved when tailored process meets overall business-case criteria. Risks involved with tailored processes are well understood by enterprise and program and risk-mitigating actions are in place.					

Design Assurance Process – 10

Realistic cost, schedule and resource estimates committed in program proposal		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Proper consideration is given to design activities during proposal development. Commitment to provide resources commensurate with schedule occurs throughout program.						
Risk Impact: Without adequate resources to meet schedule, the risk of problems escalate. Problems drive cost and domino-effect onto schedule.						
Maturity Level 1	Program proposal team is not part of program execution team. Resources committed by program are not aligned with program execution team strategy. New processes and tools committed for program do not allow for proper training and experience level necessary to meet program schedule. No upfront training or conversion of heritage design products prior to program start.					
Maturity Level 2	Program proposal team is not part of program execution team. Resources committed by program are not aligned with program execution team strategy. New processes and tools committed for program do not allow for proper training and experience level necessary to be turn key for program start. Risk list identified for program does not include new process and tools and lack of trained resources however, internal watch list includes issues as potential risks. Some resources committed to convert heritage design products into usable formats for new tools slated for use on program.					
Maturity Level 3	Program proposal team must get approval from program execution team prior to final submittal. Functional organizations provide limited early training for new design tools and processes slated for program, however not adequate for turn-key program start. Program risk list identified includes new process and tools and lack of trained resources. Baseline management plan is in place but not disciplined in execution due to frequent program leadership changes.					
Maturity Level 4	Program proposal team must get approval from program execution team prior to final submittal. Functional organizations provide early training for new design tools and processes slated for program. Some resources committed to convert heritage design products into usable formats for new tools slated for use on program. Cost and schedule slips are not absorbed and are accumulated throughout program (no program "slush" fund). Program risk process is not controlled at the detailed level and issues escalate quickly. Baseline management discipline is rigorous and most changes are adequately negotiated.					
Maturity Level 5	Program proposal team must get approval from program execution team prior to final submittal. Functional organizations provide early training for new design tools and processes slated for program. Some resources committed to convert heritage design products into usable formats for new tools slated for use on program. Cost and schedule slips are adequately re-budgeted and resource allocations increased using program slush fund. Program risk process is detailed and controlled at that level; issues get identified early when before they escalate into significant program impact items. Any changes to baseline is managed rigorously with negotiations for commensurate additional cost, resources, schedule, etc.					

Design Assurance Process – 11

Defined product tailoring and design reuse		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: In an effort to be cost effective, product groups have identified product variability options— i.e., Tailored Business Stream (TBS) 1, TBS 2, TBS 3 where TBS 1 represents common product design that can be used across programs; TBS 2 represents common product design that can be used across a subset of programs (more tailored); TBS 3 represents common product design that requires unique design. The DA process should include guidance on controlling product variability dependent on customer requirements and leverage common design where possible.						
Risk Impact: The less the tailoring of products, the less variability, cost, need for resources. Program to utilize common products where it makes business sense.						
Maturity Level 1	No tailoring guidelines exist. Every design is treated like a new design with no attention placed on commonality. No common parts databases approved, standard fastener/commodities list, etc. Product designs do not follow a disciplined approach to vet existing designs prior to designing all new designs—vary dependent on who is working the various programs.					
Maturity Level 2	Tailoring guidelines exist but are not followed with discipline in all organizations. Some product tailoring guidelines, common parts library, standard fasteners list etc., exist but commonality is difficult to verify due to non-nimble processes and related product data management systems. Inconsistent approvals for processes that are tailored when different than command media.					
Maturity Level 3	Tailoring guidelines exist but are not followed with discipline in all organizations. Specific hardware and software design elements are analyzed to determine if off the shelf components or existing designs will satisfy the design and interface criteria. Conscious design effort to be common with past programs where possible and leverage existing products and processes.					
Maturity Level 4	Tailoring guidelines exist, shared across the organizations that share design interfaces and are followed by the majority of organizations. Conscious design effort to be common with past programs where possible and leverage existing products and processes.					
Maturity Level 5	Clear guidelines are set with regard to product tailoring options and product groups have common products identified (i.e., baseline, government options, program/customer options for both products). Programs work together to maximize commonality where it makes enterprise business sense and supports the long-range business plan. Product and process tailoring related to products is reviewed with discipline and only approved when tailored product/process meets overall business case criteria.					

Design Assurance Process – 12

Complete and controlled design integration		Applicable Phases of Project/Life Cycle/ Gate/Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Design integration is adequately addressed, and "ownership" of the integrated design is specifically identified at the appropriate levels. This includes integration between IPTs, subsystems, payload/spacecraft, spacecraft/ground, hardware/software, team mates, suppliers, etc.						
Risk Impact: The more complex the interfaces, the more important the design integration activity becomes.						
Maturity Level 1	Design integration is fractured; neither side of the interface assumes ownership of the integration activities. There may be some Interface Control Documents (ICDs), but they are not adequately controlled nor maintained. There is no owner identified for the integrated design.					
Maturity Level 2	Some areas may employ adequate design integration, but it is not consistent across-the-board. Integration internal to one company or IPT may be good, but the integration between companies and IPTs is not consistent. Use and control of ICDs are inconsistent. There is no owner identified for the integrated design.					
Maturity Level 3	Design integration activities are performed by all associated groups, and ICDs are developed for the interfaces between groups. Most of the ICDs are defined and controlled, but ownership of the integrated design is not clearly established. Integration RAA is given to design integration person who doesn't reside in either interface product group.					
Maturity Level 4	Design integration activities are performed by all associated groups, and ICDs are developed for the interfaces between groups. All of the ICDs are defined and controlled, but some overlap in ownership of the integrated design may still exist. Integration IPTs have the RAA for the interface and are positioned to specifically focus on the integration issues between interfacing product IPTs. Integration IPT members primarily include engineers affected by the interface.					
Maturity Level 5	Design integration activities are performed by all associated groups, and ICDs are developed for the interfaces between groups. All of the ICDs are defined and controlled, and ownership of the integrated design is specifically identified. Integration IPTs are structured similar to the overall product build plan and all functions affected by the interface are included as needed.					

Design Engineering Tools – 1

Approved tools - includes computer aided design tools, dimensional management tools, digital mock up, virtual manufacturing simulation, analysis tools such as Failure Modes, Effects, and Criticality Analysis (FMECA), design to cost, Design for Manufacturability, Assembly, Test (DFMAT), and robust design margin analysis		Applicable Phases of Project/Life Cycle/Gate/Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: The tools used by personnel supporting DE tasks are approved utilizing a formal process and/or by a designated organization. There is a clear understanding of which tools (analyses, models etc) and processes should be used by all personnel, by each program. This includes, but is not limited to, the tools used to perform the DA process.						
Risk Impact: Having a common set of design and analysis tools within an organization/program is key to success.						
Maturity Level 1	Standard tools exist, but they may or may not be approved, utilized, or updated in a consistent manner. Tools such as DFMAT, FMECA, digital mockup etc. have not been integrated into the designers standard work processes.					
Maturity Level 2	Most tools used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. Approval may not be consistent, or exceptions may not be noted. The tools are continually evaluated and updated as required. Most designers are familiar with the design and analysis tools available. Within product groups, there are defined criteria of when tools are required (e.g., worse case analysis, FMECA)					
Maturity Level 3	All tools used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These tools are readily accessible, but may be too cumbersome to use by some personnel. The tools are continually evaluated and updated as required. Given appropriate schedule, these tools are effectively used as needed.					
Maturity Level 4	All tools used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These tools may not be utilized consistently by all personnel, but exceptions are noted. Tools are continually evaluated and updated, as required, to support changes and refinements in the operations. Designers are trained to use the available analysis and design tools. Results of the tools are incorporated into the standard work processes and reviews.					
Maturity Level 5	All tools used by personnel supporting DE tasks are approved utilizing a formal process or by a designated organization. These tools are utilized by all personnel. The tools are continually evaluated and updated as required. Tools used by internal and external organizations (includes suppliers and partners) shall be the same or have an approved protocol to ensure accurate translation or transformation (digital product definition tools, computer aided design tools, analysis tools, etc.) All functions that interface with design are trained to understand the available analysis and design tools. Results of the tools are incorporated into the standard work processes and reviews.					

Design Engineering Tools – 2

Robust design guides available (easily accessible)		Applicable Phases of Project/Life Cycle/ Gate/Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Design guides are readily available to the people performing DE tasks. These design guides provide sufficient detail to cover the complexity level in the different areas of design.						
Risk Impact: Having current design guides with lesson-learned captured, accessible to design engineers is key.						
Maturity Level 1	Design guides are usually ad hoc and chaotic. The organization usually does not provide a stable environment to support the generation or maintenance of design guides.					
Maturity Level 2	Some pockets of good design guides exist in limited number of organizations. This is more a function of local subject matter experts or their management than strong functional support or robust processes for documented design lessons.					
Maturity Level 3	Design guides have been developed and maintained for many product groups within the local organization but are not shared outside the local organization to other interfacing functions. Design guides include descriptions of standards, process descriptions, procedures, etc.					
Maturity Level 4	Design guides are reviewed and updated to include additional lessons learned when time and resources permit. Design guides include process descriptions, product details, product design best practices, etc. Some product groups are more thorough than others. Design guides are accessible by all functions, not just DE and meet the needs of the customer, end users, interfacing functions.					
Maturity Level 5	All product groups have current design guides. Design guides are regularly updated to incorporate lessons learned and customer needs. Design guides are readily accessible (user friendly wiki or electronic format) to all functions.					

Design Engineering Tools – 3

Robust configuration and data management system		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: System ensuring engineering data - models, design guides, drawings, test, and analysis models—is controlled to provide robust configuration and data management to all organizations affected.						
Risk Impact: Having robust configuration of engineering data ensures efficient and early design integration and mitigates late discovery of issues.						
Maturity Level 1	Configuration management of drawings, engineering changes, and engineering models is not well defined. Engineering changes can be made without incorporation into the existing drawing or 3D engineering model. Engineering drawings not organized in sync with the manufacturing process (i.e., drawing tree doesn't match build tree). 3D models not released in native computer aided design formats and process to ensure released design data configuration matches native computer-aided design files is manual process.					
Maturity Level 2	Product Data Management (PDM) system manages all associated design products and manually ensures changes are synchronized across affected design products; design products include standardization guidance e.g., standard drawing notes, standard formats, identification of key characteristics or critical to quality requirements, standard specifications, reference to applicable standards and specifications.					
Maturity Level 3	PDM system manages all associated-design products and electronically ensures changes are synchronized across affected design products. Product data management system provides configuration control of current and historical data. Design products have standardized templates, notes, formats, etc. to ensure maximum commonality and ease of use.					
Maturity Level 4	PDM system provides robust linkages/integration between all different data types that span beyond design organization's products (loads, analysis, computer aided design and manufacturing, support, tooling). Users of PDM have notification of part changes automatically provided to them. Single source of product data is used to eliminate data replication and ensure linkage between each of the pieces of product definition data.					
Maturity Level 5	Configuration management of design products and other organizations' work products that affect design (e.g., drawings, engineering models and data, software) are well defined and process documents are adequately detailed and followed. Engineering changes are controlled and engineering data is accessible by all. Engineering digital product definition is considered authority data across all organizations and strict processes ensure digital data is an accurate representation of engineering parts.					

Design Engineering Tools – 4

DA Requirements Assessment—DA will review system engineering processes for requirements and leverage Capability Maturity Model Integration activity related to requirements management. DA will ensure feedback loop regarding effectiveness of requirements management with program risk assessment and plan.	Note: There are existing frameworks for requirements flow down and assessment that can be used to support DA activities (i.e. Capability Maturity Model Integration, International Council on Systems Engineering, etc). Rather than developing another framework with respect to requirements management and development, DA will leverage the existing frameworks. This section describes attributes that are considered important to the DA process and should be used if an existing requirements framework is not being used.				
Risk Impact: Requirements definition, allocation, decomposition and flow down can have an extreme effect on the downstream program processes. Getting the requirements right helps the downstream users avoid undue rework.					
Depot requirements identified	Applicable Phases of Project Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Requirements for "after delivery" use are identified and incorporated into the design specifications early in the design phase.					
Requirements allocation and decomposition	Applicable Phases of Project Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: DA would assess the allocation and decomposition of the requirements at various phases of the program.					
Requirements definition/phases	Applicable Phases of Project Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: DA would assess the definition of the requirements at the various phases of a program and would ensure that the requirements are at the proper level of maturity to enter the next program phase. This would include an assessment of adequate requirements derivation.					

Design Engineering Tools – DA Requirements Assessment continued

Requirements traceability verifiable	Applicable Phases of Project Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Do the requirements have proper “parent/child” relationships? Can the traceability of the requirements between various levels of specifications be verified?					
Flow through of requirements from customer to suppliers	Applicable Phases of Project Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Are the requirements properly flowed to the suppliers, partners and any other outside entity supporting the program?					
Robust requirements contract flow thru process/robust contract flow through process	Applicable Phases of Project Life Cycle/Gate /Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Requirements flow down can be traced from customer, to supplier, to sub-tier suppliers					

Design Engineering Tools – 5

Technology Readiness Level and Manufacturing Readiness Level (MRL) are utilized to determine maturity and readiness for implementation and execution on a program.		Applicable Phases of Project/Life Cycle/ Gate /Review	Score	Goal	Weight	Comments / Objective Evidence
Definition: TRL (Technology Readiness Level) is a measure of the degree to which proposed critical technologies meet program objectives. It is a measure to assess the maturity of evolving technologies (materials, components, devices, etc.) prior to incorporating that technology into a system or subsystem. MRL (Manufacturing Readiness Level) is a measure used to assess the manufacturing maturity and risk of a given technology, weapon system or subsystem, and to guide risk mitigation efforts.						
Risk Impact: Failure to include TRL/MRL as part of a design process leads to greater risks to an enterprise/program. Additionally, attempts to transition emerging technologies at lesser degrees of maturity leads to increased overall program risk.						
Maturity Level 1	TRL/MRL processes are not in place or used.					
Maturity Level 2	TRL/MRL processes have been defined but are not utilized routinely or effectively.					
Maturity Level 3	TRL/MRL processes are well characterized and understood and are described in standards, procedures, tools and methods.					
Maturity Level 4	Organization and projects establish quantitative objectives for TRL/MRL process performance and use them as criteria in managing processes. Programs limit concurrent development of new technology on new programs to technologies with TRL ≥ 6.					
Maturity Level 5	Organization continually improves its TRL/MRL processes based on a quantitative understanding of the common causes of variation inherent in processes. Programs limit the overall number of concurrent development of new technologies (with TRL ≥ 6) to a manageable few.					

Design Assurance Supplier Assessment

The level of DA activity related to suppliers will be directly related to the amount of supplier related issues which should be reviewed as an overall input to the DA process. If engineering-design metrics indicate that there are no significant areas needing improvement, DA activities related to this section can be minimized. Note that this section of enterprise attributes applies to suppliers who provide both build-to-print (suppliers do not have design authority) and build-to-specification (suppliers have design authority) products. It is recommended that suppliers with significant design responsibility (e.g., teammates/partners) self-assess for all the DA enterprise attributes using the DA enterprise attributes capability checklist and DA activities be planned commensurate with risk. This assessment can be reviewed by higher-level customer representatives as required.

Design Assurance Supplier Assessment – 1

Supplier program management		Applicable Phases of Project/Life Cycle/ Gate/Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Management of all supplier related activity performed to support a program.						
Risk Impact: Ability of supplier to manage cost, schedule, and technical aspects of product must be evaluated prior to program start. Supplier program management weaknesses will cause domino effect to all downstream build/test activity.						
Maturity Level 1	Supplier program management capability is not assessed prior to contract award and processes don't require assessment after contract award except in extreme cases. RAA of supplier program management tasks are not well defined and spread haphazardly through several organizations in a nonintegrated manner.					
Maturity Level 2	Supplier program management capability is not assessed during pre-award phase but review is performed after award. Actions taken as a result of the supplier program management capability assessment are rarely followed through by both the company and the supplier. Actions are not contractual obligations.					
Maturity Level 3	Supplier program management capability is not assessed during pre-award phase but there is a detailed assessment performed to ensure all risks related to supplier's capability are accounted for and managed. Completion of actions related to risks is contractually flowed to supplier.					
Maturity Level 4	Supplier program management capability is an integral part of the pre-award phase however only a limited number of resultant actions are acted upon by organizations with supplier related RAAs. Process is in command media but not implemented across all applicable products and processes due to unclear RAAs within the organizations performing supplier related activities, lack of common process, training, process discipline and integrated approach.					
Maturity Level 5	Supplier program management capability is an integral part of the pre-award phase. Suppliers must have demonstrated minimum capabilities in order to be considered in the bid process. Company RAA's for supplier related activities clearly defined for all organizations affected with integrated plan for success. Processes documented that detail RAAs; people have been trained and are consistently following processes. RAA for supplier development with regard to program management has been defined and assessment results are channeled into specific action plans that are executed with oversight and leadership of the responsible organization. Process is in place with clear organizational RAA to ensure supplier's continued capability and compliance to program management best practices.					

Design Assurance Supplier Assessment – 2

Acceptance of supplier product/process		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Processes designed to ensure that products with product or process defects do not get passed on. “Accept No Defect, Pass No Defect.”						
Risk Impact: Lack of robust qualification, verification/inspection of suppliers for processes, products cause travelled risk. Test failures that happen late in the program may have been mitigated with earlier inspection/verification and robust qualification processes.						
Maturity Level 1	Minimal assessment of suppliers capabilities are performed prior to determining make/buy decisions. Verification of supplier's products is primarily done using source inspection. Inconsistent documentation of conformance. Supplier’s Build to Specification (BTS) product designs are not required to be reviewed and approved by customer organization.					
Maturity Level 2	Verification of supplier's products includes review of supplier's inspection records. Oversight of supplier's product acceptance is enforced as part of the supplier's overall quality system. Supplier’s BTS product designs are required to be reviewed and approved by customer organization.					
Maturity Level 3	Verification of supplier's products includes early process capability with respect to digital manufacturing and inspection techniques, process control, and quality system. Suppliers’ capabilities are assessed prior to making any make/buy decisions but deficiencies are not followed up with mandatory improvement plan. Supplier’s BTS product designs are reviewed and approved by the customer organization at incremental design reviews. Supplier's first article inspection per AS9102 records are reviewed for verification of product conformance.					
Maturity Level 4	Verification of suppliers' product conformance includes first article inspection review, supplier's inspection records, product and process qualifications, and capability approvals. Processes defining requirements for these reviews, qualifications, and capability approvals are well-defined and appropriately implemented. Processes for flow down of specification changes that affect suppliers who manufacture and design BTS hardware are documented and robustly implemented.					
Maturity Level 5	Suppliers’ capabilities are assessed prior to making any make/buy decisions and deficiencies are address by supplier improvement plan that is rigorously enforced. Verification of suppliers' product conformance and process compliance has been ongoing with successful results. Supplier has earned delegation of authority for inspection of hardware and limited material review board authority. Continued product and process assessments indicate continued delegation as low risk. Program schedules include review and approval tasks for BTS products and address critical chain path to minimize schedule risk to downstream tasks.					

Design Assurance Supplier Assessment – 3

Flow down of requirements to suppliers		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Flow down of requirements to suppliers includes advance notification of engineering changes (e.g., engineering specifications, materials, and processes specifications) as well as changes to supplemental requirements (e.g., inspection, testing, shipping, handling, packaging issues).						
Risk Impact: Inadequate (not clear, too many layers to get to real requirement) flow down of requirements to suppliers increases risk of noncompliant and nonconforming product.						
Maturity Level 1	Suppliers are given drawings and specifications needed to build hardware. However, process to ensure suppliers get revisions to drawings and specifications in a timely manner is inconsistent. Requirements are not delivered as scheduled and late requirements in turn feed incomplete designs.					
Maturity Level 2	Suppliers are given drawings and specifications needed to build hardware. However, process to ensure suppliers get revisions to drawings and specifications in a timely manner is unwieldy with no specific change documentation (must review whole document and compare to previous revisions). Requirements definition is not delivered as scheduled; “To Be Required” and “To Be Determined” are still included in requirements documents beyond schedule. Interface requirements between customer organization and supplier are not incrementally managed within the detailed program schedule.					
Maturity Level 3	Suppliers are given design products (e.g., drawings and specifications needed to build hardware). Suppliers’ design data contractually requested as part of the deliverable are received but not reviewed in a timely manner. Issues found in supplier data occur much later than possible due to lag in review of product data compared to product acceptance. Requirements affecting suppliers who design and manufacture build-to-specification hardware are shared but not consistently in a timely fashion.					
Maturity Level 4	Suppliers are given adequate initial design data products. Changes to design products and supplemental products are flowed to supplier in a timely manner. Review of supplier submitted data is timely.					
Maturity Level 5	Suppliers have controlled access to latest specifications and drawing revisions and notifications of change are distributed prior to changes being required to be implemented. Specifications are void of “To Be Required” and “To Be Determined” at required gates/reviews. Requirements are properly referenced and flowed at the right product level (i.e., detail, assembly, installation, system, etc). Review of supplier-submitted data is timely and tracked in project schedule.					

Design Assurance Supplier Assessment – 4

Supplier involvement in design		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Suppliers involved in the manufacture of Build-to-Print (BTP – no design authority) hardware shall be consulted early in the design process to ensure that their manufacturing capabilities and capacities can adequately support the design. Suppliers involved in design and manufacture of Build-to-Specification (BTS – supplier has design authority) hardware are assessed for DA capability and control.						
Risk Impact: No involvement of supplier during design phase reduces opportunities for design trades with respect to manufacturability, testability, assembly. Possible cost and schedule reductions are not leveraged.						
Maturity Level 1	Suppliers are not part of the design review process. Designers are not aware of suppliers on bid.					
Maturity Level 2	Suppliers are not part of the design review process. Designers are aware of suppliers bidding for the work but because suppliers haven't been chosen, no coordination is done between suppliers and design organizations.					
Maturity Level 3	Suppliers are inconsistently involved in BTP final design reviews. For BTS hardware, only final design reviews are attended by customer's engineering organization for review and approval.					
Maturity Level 4	Suppliers are part of the final design reviews but only inconsistently involved in the preliminary design reviews. For BTS hardware, significant supplier deliverables and incremental design reviews are attended by customer's engineering organization for review and approval.					
Maturity Level 5	BTP suppliers are an integral part of the integrated product team responsible for the design of the hardware. Suppliers are involved in reviews throughout the product life cycle and successfully give inputs to improve manufacturability, assembly and test. BTS suppliers include customer organizations as an integral part of the integrated product team and customer organization is permitted to review and approve design and design changes.					

Design Assurance Supplier Assessment – 5

Furnished and supplied equipment—Customer furnished equipment, government furnished equipment; customer supplied equipment, government supplied equipment		Applicable Phases of Project/Life Cycle/ Gate / Review	Score	Goal	Weight	Comments/ Objective Evidence
Definition: Customer or government furnished or supplied equipment is ready when required.						
Risk Impact: Not having furnished or supplied equipment available when needed may result in delays or potentially greater issues if alternate equipment must be identified and integrated into the system.						
Maturity Level 1	Furnishers of equipment are not part of the design review process. Designers are not working with furnishers or suppliers.					
Maturity Level 2	Furnishers of equipment are not part of the design review process. Designers are aware that equipment will be supplied to the system and have some information on the equipment, but there is no coordination between suppliers and design organizations.					
Maturity Level 3	Designers and furnishers of equipment are inconsistently involved in final design reviews.					
Maturity Level 4	Furnishers of equipment are part of the final design reviews but only inconsistently involved in the preliminary design reviews.					
Maturity Level 5	Furnishers of equipment are an integral part of the integrated product team responsible for the design of the system. They are involved in reviews throughout the product life cycle. They provide inputs to successfully integrate the supplied equipment into the system being fully aware of the entire design over the course of the life cycle.					

Example Using Design Assurance Process – 1

The following is an example of how a design attribute table can be used.

Dedicated design subject matter experts network		Applicable Phases of Project/Life Cycle/Gate/ Review	Score (can give partial credit)	Goal	Weight	Comments/Objective Evidence (assessor must document objective evidence to justify score)
Definition: A network of subject matter experts (SME) that is used to support design assurance reviews, provide input to lessons learned, and support development and modification of design guides. This network is maintained by a certification process or other formal means.						
Risk Impact: SMEs are a key component of the design assurance process. Lack of identified subject matter experts presents a high risk to success of the effort.						
Maturity Level 1	No SMEs have been officially identified.	All gates/phases	0.25 (out of 1)	1	0.3	Not all organizations have identified SMEs. SMEs listed on some organizations' websites but not kept up to date.
Maturity Level 2	There are SMEs, but their use varies by organization.	All gates/phases	0.25 (out of 1)	1	0.3	SMEs are not consistently used due to limited availability and lack of prioritization to help other programs
Maturity Level 3	There is a network of SMEs, but there is not a centralized, accessible listing, or they are kept by several organizations.	All gates/phases	0	1	0.3	No centralized listing for all different SMEs across all organizations
Maturity Level 4	A network that identifies subject matter experts exists, is readily accessible, and is utilized. However, there is no certification process.	All gates/phases	0	3	0.3	No certification process
Maturity Level 5	A network that identifies subject matter experts exists, is readily accessible, and is utilized. These experts have been certified by a standard process and are recognized for their expertise. The SMEs have responsibility to share their knowledge in a way that it can be effectively leveraged throughout an organization.	All gates/phases	0	4	0.3	Not in place

There are 22 design assurance enterprise attributes. Assuming one believes that "Dedicated design subject matter exerts network" should be weighted as 3% of the total design assurance capability score, the most a company/program could score this, if it had demonstrated meeting all aspects of all five maturity levels for this attribute, would be (1 × 0.3) + (1 × 0.3) + (1 × 0.3) + (3 × 0.3) + (4 × 0.3) = 3 points. In this example, the company/program assessed scored a total of 0.15 points out of 3.0 possible. Assigning similar goals/weighting to the other 21 enterprise attributes would result in a total possible score of 100 points. Organizations/companies can choose to select minimum requirements by choosing a minimum required maturity level for each attribute. This could result in total scores that could be ranked, e.g., Platinum (total score 90 to 100 points), Gold (total score 80 to 89 points), Silver (total score 70 to 79 points), Bronze (total score 60 to 69 points), etc.

Appendix D: Spider/Radar Diagram Examples

Figure D-1 is an example of how the design assurance process enterprise attributes can be captured graphically to easily assess the current state of a design assurance process against a future/desired state.

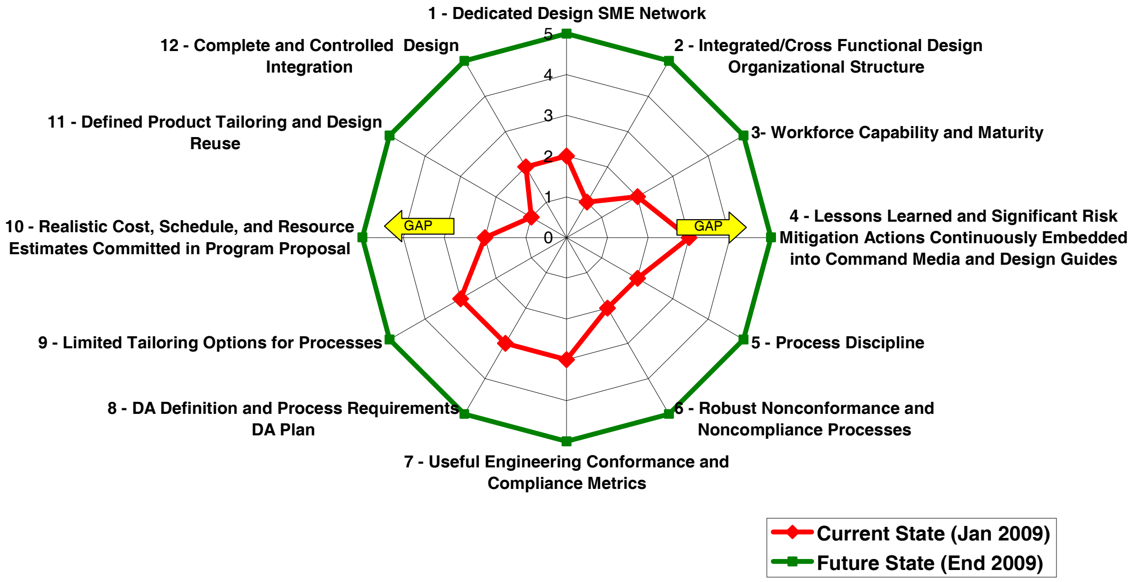


Figure D-1. Spider/Radar diagram, design assurance process enterprise attributes.

The figure illustrates a sample of the design assurance process enterprise attributes from Appendix C with arbitrary ratings shown at an arbitrary current state. The difference between the current state and final state shows the gap the enterprise needs to fill to make a more robust design assurance process. A similar figure for the design engineering tools enterprise attributes and the design assurance supplier assessment enterprise attributes can be generated to show their gaps, as shown in Figure D-2.

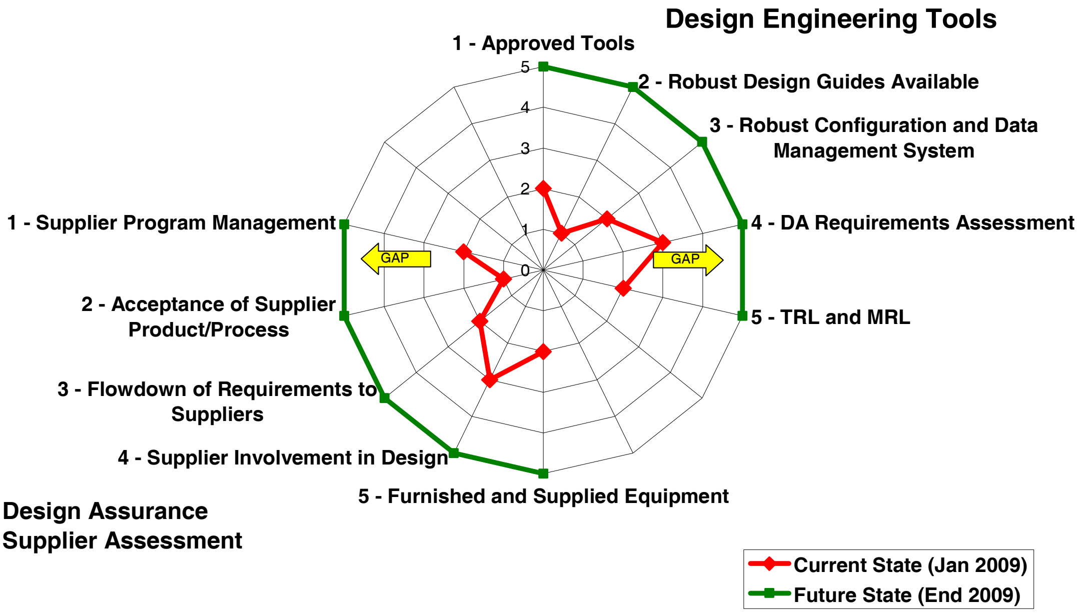


Figure D-2. Spider/Radar diagram, design engineering tools and design assurance supplier assessment enterprise attributes

Prospective users of this Design Assurance Guide must choose the specific enterprise attributes that they wish to evaluate.

Appendix E. Design Assurance Program Elements

Table E-1 contains a sample list of program elements of any design and associated design-assurance activities that can be used in developing specific design assurance tasks. This is intended as a starting point and should be tailored for each program. These program elements include programmatic, technical, executability, and process performance items. This table can be used in determining the type of activities that the design assurance team could perform based upon the determined risk and risk threshold for each program element. For each line item in this Appendix, a task from Table 5 could be identified for any risk level. This enables the design assurance team to provide the appropriate activity to a specific design area based upon the overall program-risk profile.

Table E-1. Program Elements

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Planning				
Design plans				Complete design assurance planning
				Rigorous information/configuration management approach
				Robust margin policy
				No single point failure policy
				Comprehensive reliability analysis approach
				High reliability electrical, electronic, electromechanical parts review/selection approach
				High reliability materials/processes review/selection approach
				Thorough government-industry data exchange program process
				Low risk contamination control approach
				Comprehensive fault-management testing
Production plans				Personnel certification
				Facilities certification
				Support equipment certification
				Production processes certification
				Process specifications
				Use of travelers
				Workmanship standards
				Development of breadboards and engineering models
				Critical hardware spares

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Planning (cont.)				
Subsystem/payload integration plans				Comprehensive performance verification approach
				Comprehensive environmental verification approach
				Thorough hazard identification/control (personnel and hardware)
				Closed-loop anomaly reporting policy
Quality plan				Complete hardware quality assurance planning
				• Approved supplier list
				• Procedure review
				• Inspection (shipping/receiving, in-process)
				• Test witnessing
				• Data audit
				Complete software quality assurance planning
				• Thorough development process review
				• Thorough documentation review
				• Thorough requirements/design traceability review
				• Comprehensive testing
Tooling/manufacturing/ground support				Metrology planning
				Ground support equipment calibration
				Structural proof testing
				Tolerance verification
				Computer aided design/computer aided manufacturing verification
				Manufacturing aids
Requirements				
Functional requirements				Functional verification methods
				Requirements traceability approach
				Functional margin policy
				• Mass
				• Power
				• Throughput
				• Data storage
				• Up/down link
				• Mechanism stroke/torque
				• Attitude control

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Requirements (cont.)				
Functional (cont.)				Factor of safety for structure
Performance requirements				Performance verification methods
Internal/external interface requirements				Interface requirement documentation and control process
Operational requirements				Operation verification methods
Environmental requirements				Through environmental verification methods
				Robust margin policy for levels and durations
				• Thermal vacuum
				• Dynamics
				• Loads
				• Electro-magnetic interference
				• Radiation
				• Micro-meteoroid/orbital debris
				• Threats
				Self-compatibility
				• Jitter
				• Contamination
				• Plume impingement
				• Electromagnetic compatibility
Reliability and lifetime requirements				Thorough reliability verification method
				• Reliability analysis
				• Life-testing
				• Fault management
				• Single point failure policy
				• Redundancy
				• Cross-strapping
				High reliability parts and materials selection
Software requirements				Software verification methods
				Independent documentation review
				Design guidelines
				Coding standards
Requirements traceability				Comprehensive verification matrix
Design				
Trade studies				Probabilistic risk assessment
				System-level fault-tree analysis
				Single point failure analysis

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Design (cont.)				
Trade studies (cont.)				Reliability block diagrams
Parts, materials, and processes				Independent electrical, electronic, electromechanical parts list review per selection criteria
				• Reliability
				• Radiation
				• De-rating
				Independent material and process list review
				• Reliability requirements compliance
				• Qualification
				• Application review
Requirements versus capabilities				Inheritance peer reviews
				Breadboard development
				Margin assessment
				• Performance
				• Environmental
				• Life-time
Design reliability				Single point failure analysis
				Assembly interface failure mode and effects criticality analysis
				Worst case analysis
				Part stress analysis
				Mechanism fault tree analysis
				Life-testing
				Reliability estimate
Maintenance				Maintenance planning
				Maintainability assessment
				• Time to trouble-shoot and repair
				• Critical hardware sparing inventory
				Approach for line replaceable units
Packaging				Stress analysis
				• Thermal
				• Structure
				• Electrical
				Micro-meteoroid susceptibility assessment
				Fastener and connector standards

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Design (cont.)				
Architecture				Probabilistic risk assessment
				System-level fault-tree analysis
				Single point failure analysis
				Redundancy
				Cross-strapping
				Reliability block diagrams
Product design				Stress analysis
				• Thermal, structure
				• Electrical
				Software requirements traceability
				Software architecture/detailed design reviews
				Software interface documentation reviews
				Software user interface
Design for manufacture/assembly/test				Engineering model development
				Independent assessment
				• Stress
				• Thermal
				• Structural
				• Materials and processes
				• Contamination control
				Quality assurance assessment
				• Accessibility
				• Producibility
Analysis				
Feasibility analysis				Probabilistic risk assessment
				System-level fault-tree analysis
Mission analysis				Margin assessment
				• Link
				• Mass
				• Power
				• Throughput
				• Data storage
				Fault protection approach

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Analysis (cont.)				
Functional analysis				Single point failure
				Reliability block diagrams
				Torque margins
				• Loads
				• Mechanisms
				• Motors
				• Drive circuits
Operational analysis				Assessment of hazardous command
				Operation procedures
				Ground system reliability
				Ground communication stations
				Contingency planning
Performance analysis				Margin assessment
				• Link
				• Mass
				• Power
				• Throughput
				• Data storage
				Fault protection approach
Requirements Verification/Validation				
Verification and validation plan				Peer reviews
				Robust verification and validation approach
Verification and validation execution				Mandatory inspection points
				Test witnessing
				Systems safety surveys
				Independent reviews
				Test and analysis reports
				Anomaly resolution reports e.g. material review board reports
Testability				
Integration and test plan				Peer review
Test support equipment				Safety review; ground support equipment interface failure mode and effects analysis; safe to mate check-out

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
Product Design				
Drawing release plan				Peer review
Flight drawings				Engineering model development
				Independent assessment
				• Stress
				• Thermal
				• Structural
				• Materials and processes
				• Contamination control
				Quality assurance assessment
				• Accessibility
				• Producibility
				• “Redlines” control
Product data structure				Functional audits
				Information audits
				Configuration audits
Manufacturability				
Parts and material				Electrical, electronic, electromechanical parts list review
				• As designed
				• As-built
Assembly flow				Mandatory inspection points
				Review of sequences
				Audit of storage facilities
Drawings				Review by quality assurance
Tooling				Calibration
				First articles
Machinability				Tolerance policy
				First article
Producibility				
				Process review
				Application of standards
Inspectability				
				Mandatory inspection points
				Non-destructive evaluation methods
				Acceptance criteria

Design Element	Low Risk	Medium Risk	High Risk	Suggested Design Assurance Activities
System Safety				
Safety plan				Peer review
System safety requirements				Hazard identification/control analysis
				Systems safety surveys
				Safe-to-mate testing
				Ground support equipment interface failure mode and effects analysis
Risk				
Risk management plan				Peer review
Risks assessment				Mission assurance independent assessment
Risk analysis				Mission assurance independent assessment
				Redundancy and common mode failures
Risk handling				Mission assurance independent assessment
Lessons Learned				
				Continuous review
				Database review
				Non-advocate review
Cost/Schedule				
				Periodic programmatic reviews
				Earned value metrics
Process Assessment				
				Thorough review process
				• Peer review
				• System requirements review
				• Preliminary design review
				• Critical design review
				• Delivery review with end-item-data-package
				• Test readiness review
				• Pre-ship review
				Audits
				• Supplier monitoring
				• Calibration
				• Anomaly resolution records

Appendix F. Frequently Asked Questions

F1. What is the business case for design assurance?

Design assurance takes some of the resources that a program would use to correct design escapes, and uses those resources earlier in the program to prevent design escapes. The notional figure below shows how the cost of a program would be effected by applying a structured design assurance process.

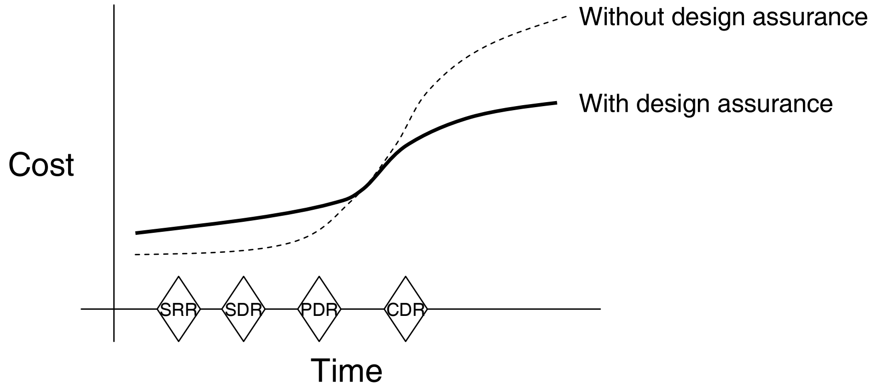


Figure F-1. National Design Assurance program cost.

The overall cost to the program would be no higher than the expected cost if design assurance is not used. The cost to the program could be significantly less if critical design escapes are identified and fixed early, as opposed to dealing with them much later in the life cycle when the cost can be extremely expensive.

F2. How is design assurance risk-based?

The design assurance process complements (augments and does not duplicate) the program's internal and required risk-management process; it does not replace it, nor does it create a parallel risk process. The design assurance process performs an independent assessment of the inherent risk associated with specific programmatic design elements. The program risk identification list is one of the many inputs into the design assurance independent baseline assessment sub-process. Other inputs are enterprise and customer lessons learned related to the design phase, design issues, and risks identified on programs internal to a company (e.g., qualification by similarity; failure mode, effects, and criticality analysis; worst case scenario analysis; etc.), previous supply chain performance, and nonconformance trends and analysis (e.g., manufacturing review board, failure review board, etc.) to name a few.

Based upon this independent assessment, design assurance planning occurs which identifies who, when, where, what, and how design assurance is to be implemented on the program. After the independent design analysis has been executed a report is issued that describes the findings and corrective actions for program and functional organizations alike. One element of the report is an updated assessment of risk. The report is maintained by program mission assurance and any new risks which have been identified in the design assurance process are to be inserted into the program risk list for monitoring and tracking.

F3. Are you going to define entry/exit criteria for the design assurance process?

The design assurance process is defined at a high level on purpose, as it encompasses all elements of design, and because each program has unique design risks associated with it. It has been defined in an analogous manner to the risk management process, as it can be applied to any design element on a program. Entrance and exit criteria will be defined for each sub-process step; however, entrance and exit criteria will not be defined for gated processes; that would of course depend on the specific design risk identified for a particular timeframe in the program life cycle. For example, if the proper definition and execution of the failure mode, effects, and criticality analysis, or worst-case analysis were identified as a major program risk, an independent assessment would use the entrance and exit criteria for those processes and assess the program's ability to properly execute to their own criteria.

F4. Will design assurance enterprise attributes be tied to certain level or scale of risk?

If program resources will be limited, and to ensure best value to the program and customer, only those risks that have the largest impact on mission success will be assessed in design assurance. The process is designed to be living, and as design risks change, so does the independent identification and assessment of those risks change throughout the program life cycle. For example, an early independent assessment of program engineering personnel assigned to a program may show that training to current engineering processes and procedures is outdated or inadequate. Finally, a program elements checklist has been created to aid in the planning of what actions should be taken by design assurance subject matter experts in implementing the execution of design assurance, when a risk has been identified at a particular risk level. (e.g., this is analogous to NASA website on electronic component engineering).

F5. Manufacturability and testability are typically risk areas with new designs. Does design assurance address these?

Yes, design assurance is a mission assurance function applied in the design phase of a program life cycle. It includes assessing a design for manufacturing, assembly, and test, but product assurance and quality assurance activities are responsible for maintaining the integrity of the design throughout subsequent manufacturing, integration, test, and logistics phases of a program life cycle.

F6. If the design assurance process ends with "monitor/report findings," isn't this merely a risk identification process?

No, design assurance activities produce findings, actions, and lessons learned. As an assurance process, follow through on the mitigation/elimination of identified risks includes documenting, reporting, and escalating (if needed) actions, corrections, or recommended design changes. The report, specifying the responsible integrated product team on the program and the recommended actions with due dates commensurate with program milestones, is maintained by program mission assurance and any new risks which have been identified in the design assurance process are to be inserted into the program risk list for monitoring and tracking.

F7. The design assurance process development attribute regarding subject matter experts appears to focus only on the existence of a network. Is it possible to attain maturity level 5 even if the network is never utilized?

The definition explicitly states that said network of subject matter experts "is used to support design assurance reviews, provide input to lessons learned, and support development and modification of design guides." Utilization of specific expertise is at the discretion of the process owner, but it is the lack of needed expertise that is identified as a risk.

F8. Don't system requirements review, preliminary design review, and critical design review activities already accomplish what is outlined in the design assurance process?

Milestone reviews are important events, but they are often more schedule-driven than design-readiness-driven. Discovery, prevention, and correction of engineering process errors or escapes must be continually performed before, during, and after program milestones. Design assurance activities provide regular independent assessments that transcend potentially artificial schedule constraints.

F9. This appears to be a tool that describes what design assurance is and how it is evaluated, but can this guide be used to create a design assurance program from scratch?

The purpose of this document is to provide guidance in defining and implementing a design assurance process to uncover, prevent, or correct design risks as early in the design cycle as possible. It is intended to accompany systems engineering and program management processes and, in fact, utilize existing elements thereof to the maximum extent possible.

F10. One of the ways shown to identify program risks is to "Monitoring test results throughout the design life cycle especially test failures." What tests does this refer to? Acceptance testing, for example, would be well after the design phase.

Design assurance is an activity that covers the program during its entire life cycle. It is predominantly done at the start of a program, but can continue during engineering and manufacturing development and production and deployment. As such, design assurance would apply to all program testing.

F11. Isn't the design assurance enterprise attributes "process discipline" the stuff that management systems like ISO9001 and CMMI are all about? Can we employ these management systems here?

Process discipline is also an integral element in standards such as AS9100/ISO9001 and CMMI. There are definitely areas of overlap, so if a company or organization is already pursuing either AS9100/ISO9001 or CMMI or Six Sigma, these initiatives can and should be jointly leveraged where it makes sense to accelerate implementation and effectiveness of both. Areas of potential overlap with AS9100 Revision C include product realization (planning of product realization, customer-related processes, design and development, purchasing, production and service provision, control of monitoring and measuring equipment) and measurement, analysis, and improvement (general, monitoring and measurement, control of nonconforming product, analysis of data, and improvement). Areas of potential overlap with CMMI, Second Edition, include requirements development, requirements management, technical solution, product integration, verification, and validation, configuration management, process and product quality assurance, measurement and analysis, decision analysis and resolution, and causal analysis and resolution.

F12. How does design assurance and the design assurance process relate to assessing design feasibility of a space vehicle?

Similar to the earlier question of "Are you going to define entry/exit criteria for the design assurance process?" the design assurance process is defined at a high level to encompass all elements of design, such that any space element (launch vehicle, space vehicle, ground system) or any element (air, naval) could take advantage of this guide. For a specific element, such as a satellite, existing command media can be used to assess the technical, programmatic, and cost feasibility of that design throughout the program life cycle. This command media would be part of the Enterprise Attributes Maturity Assessment and would be used during the Independent Baseline Assessment sub-process of the Design Assurance Program Implementation/Execution process. A command media example for this specific example would be the *AIAA Mass Properties Control for Space Systems* [10] which provides dry-mass margin recommendations for space vehicles at key program milestones.

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Appendix I. Glossary

Command media: Policies, procedures, practices, standards, guides, etc. used by a specific organization to develop and deliver products.

Enterprise: Covers the entire organization.

Design assurance: A formal, systematic process that augments the design effort and increases the probability of product design conformance to requirements and mission needs. Design assurance independently assesses the development of engineering drawings/models/analyses and specifications necessary to physically and functionally describe the intended product, as well as all engineering documentation required to support the procurement, manufacture, test, delivery, use, and maintenance of the product.

Design assurance enterprise attributes: These are the key properties independent of any specific design application related to design assurance. The design assurance enterprise attributes include definitions, risk levels, and maturity rating descriptions and are implemented at the enterprise level.

Design assurance program elements: These are the aspects of design assurance that are applied at a program level. A program's risk profile can be decomposed to key design fundamentals to establish guidance on what activities the DA team will execute based upon the specific risk the design program element embodies.

Design assurance process owner: Mission assurance (e.g., quality, mission excellence, mission success, reliability, etc.) is the owner of the design assurance process. The design assurance process owner should be a technical organization that is independent of the design organization.

Mission assurance: 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. Mission assurance 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.[†]

Program: Relates to a specific project or system within an organization.

[†] From MAG