AEROSPACE REPORT NO.
TOR-2013-00294

Key Considerations for Mission Success for Class C/D Mission

June 3, 2013

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Mission Assurance Subdivision

Prepared for:

Space and Missile Systems Center
Air Force Space Command
483 N. Aviation Blvd.
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Contract No. FA8802-09-C-0001

Authorized by: Engineering and Technology 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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Executive Summary

The "Key Considerations for Mission Success for Class C/D Missions- Leading with Class D" document is a team product from the 2012-2013 Mission Assurance Improvement Workshop (MAIW) program. The goal of the team, which consisted of government and industry partners, was to survey current civil and national security space (NSS) efforts with an objective of redefining Mission Class C&D profiles with industry participation.

Current acquisition mission class profiles for Class C include embedded requirements that are beyond the scope of a Class C moderate risk tolerance and exhibit significant variability between government acquisition agencies. Current Class D higher risk profile is primarily viewed as an unbounded experiment development with very few considerations or detailed requirements for mission success but with the customer expectation that the product must perform the mission.

The MAIW team created a survey to review negotiated baselines for current Class C and Class D mission planning and execution. The foundation of the effort was based on the disciplined application of program management, systems engineering, and mission assurance practices for achieving mission success verses a top down requirement tailoring approach offered in a previous MAIW publication. The team leveraged the 2011 MAIW product, "Mission Assurance Guidelines for A-D Mission Risk Classes," that defined characteristic profiles for mission assurance processes for a given space vehicle mission risk classes (A, B, C, or D)[1]. Additional references provided detail on the mission success technical practices, and additional descriptions and attributes of Class A, B, C, and D missions to include recently published guidance from NASA Goddard [2]–[8].

The presentation at the MAIW plenary session held in Boulder, Colorado on 1 May 2013, represented the final team product. The presentation included details of the survey findings that included best practices and common characteristics and considerations for mission Class C and D mission success risk management strategies with a focus on Class D attributes. The briefing is included in this document with notes pages. The appendix material includes the set of survey questions (Appendix 1), results from the survey (Appendix 2), and some additional descriptions and differences between the mission classes (Appendix 3).

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Acknowledgments

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

The document was created by multiple authors throughout the government and the aerospace industry. We thank the following contributing authors for making this collaborative effort possible:

Frank Chong	Northrop Grumman Aerospace Systems
Matthew Fahl	Harris Corporation
Robert Friend	The Boeing Company
John Haney	Lockheed Martin Corporation
William Hoehn	Raytheon Missile Systems
Dave Makowski	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:

Gail Johnson-Roth(co-lead)	The Aerospace Corporation
Dave Pinkley (co-lead)	Ball Aerospace and Technologies
Michael Verzuh(co-lead)	Ball Aerospace and Technologies

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- Company Internal Surveys
  - The Aerospace Corporation
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  - MIT Lincoln Laboratory
  - Lockheed Martin Corporation Space Systems Company
  - Northrop Grumman Aerospace Systems
  - Orbital Sciences Corporation
  - Raytheon: Missile Systems, Space and Airborne Systems
- Government Agency Surveys
  - NASA: Headquarters, GSFC, Ames, JPL
  - Air Force Research Laboratory
  - Operational Responsive Space Office
  - Space Test Program
  - Missile Defense Agency

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1. Introduction

This document provides the results of a survey conducted by an Mission Assurance Improvement Workshop (MAIW) government-industry team to review negotiated baselines for current Class C and Class D mission planning and execution. MAIW is a government/industry/academic collaboration with focus on mission assurance critical areas; a working adjunct of the Space Quality Improvement Council. The goal of the team was to further define mission Class C and Class D profiles.

Current acquisition mission class profiles for Class C include requirements that appear beyond the scope of a moderate risk tolerant program and exhibit significant variability across government authorities in their acquisition approaches. Current Class D missions, higher risk profiles, are primarily viewed as unbounded experiment development with varied considerations for mission success but with the customer expectation that the product must perform the mission. These Class D missions also show a significant variability across government authorities in their acquisition approaches, and are primarily dependent on the programmatic constraints of cost and/or schedule. Class D projects can range from a payload or instrument development to a complete mission implementation.

"Key Considerations for Mission Success for Class C/D Missions – Leading with Class D" document is a team product from the 2012-2013 MAIW program. The foundation of the effort was based on the disciplined application of program management, systems engineering and mission assurance practices for achieving mission success verses a top down requirement tailoring approach offered in a previous MAIW publication [1]. The initial focus included a review of NASA and national security space (NSS) historical relationships and publications. The team leveraged the 2011 MAIW product, "Mission Assurance Guidelines for A – D Mission Risk Classes," that defined characteristic profiles for mission assurance processes for a given space vehicle mission risk classes (A, B, C, or D). [1] Additional references provided detail on the mission success technical practices, and additional descriptions and attributes of Class A, B, C, and D missions to include recently published guidance from NASA Goddard, "D constitution." [2]–[8].

The US space programs enterprise is entering into a challenging fiscal environment that requires critical evaluation of methods for ensuring mission success within programmatic constraints. The MAIW team survey included interviews with current civil and NSS efforts with regard to defining mission Class C and D from both the government acquisition authority and the processes and procedures implemented by the contractor, with a goal of determining best practices for managing Class D missions.

The presentation at the MAIW plenary session held in Boulder, Colorado on 1 May 2013, represents the final team product which included details of the survey findings, best practices and common characteristics of mission Class C and D mission success risk management strategies with a focus on Class D attributes. This presentation is incorporated in this document with notes pages in the following section.

The appendix material of this document includes the set of survey questions crafted by the MAIW team (Appendix 1), results and answers from the various surveys conducted (Appendix 2), and some additional descriptions and differences between the different mission classes (Appendix 3).

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2. Key Considerations for Mission Success for Class C/D Missions – Leading with Class D

Presentation delivered at MAIW plenary session in Boulder, Colorado on 1 May 2013.

Key Considerations for Mission Success for Class C/D Missions – Leading with Class D

Team Leads	Team Members
Dave Pinkley (Ball) Mike Verzuh (Ball) Gail Johnson-Roth (Aerospace)	Frank Chong (NG) Matthew Fahl (Harris) Bob Friend (Boeing) John Haney (LM) Bill Hoehn(Raytheon) Dave Makowski (Raytheon)

Key Considerations for Mission Success for Class C/D Missions – Leading with Class D (Notes)

This plenary session briefing produced as a product of MAIW the indicated Aerospace-industry members.

The team:

- Examined the execution paradigms for Mission Class C and Class D missions

- Focused on Class D missions to include those that go beyond a “Cause no Harm” experiment to those that produce real science and or include some that provide operational information

Agenda

- Quad Chart (Backup)
  - Problem, Examples, Charter, Products
- Survey Development and Execution
  - Enhanced Class “D” expectations, Surveys
  - Relationships to previous Mission Class Guidance (Backup)
- Survey Themes and Divergences
  - Success Criteria, Risk, Standards, Processes, Winners, Losers
  - NASA/NSS Agency Comparison, GSFC Class D Constitution
- Class “Enhanced D” Template
  - Summary Characteristics and Considerations, Notable Insights
  - Class D Definition (Backup) and Class C Relationship
  - Conclusions
- Product Implementation Recommendations
- Team Membership and Recognition

Agenda (Notes)

Background on this project is provided on Quad chart provided in the back up chart. The primary goal of the team was to review negotiated baselines through a survey of current Class C and Class D mission planning and execution. Survey results were used to flush out both key characteristics and execution considerations for an "Enhanced Class D" mission class addressing medium agency priority and a moderate risk profile of a Mission Class C, but with the fiscal constraints of a Class D experiment.

Surveys were conducted with prime contractors that develop programs, and civil and national security space government agencies that require Class C and D mission type systems. Relationships to previous mission class work were examined to bound the enhanced Class D effort. The net result of the surveys is a set of raw data that addresses responses to six key questions for Class C and D mission development. This plenary briefing product captures key survey common themes and divergences for success criteria, risk, standards, processes, winners and losers.

From the summary of the survey themes and divergences, an enhanced Class D template was created with a table of characteristics and execution considerations with notable insights.

This presentation also includes recommendations for usage and team recognition.

Key Considerations for Mission Success for Class C/D Missions – Leading with Class D

Survey Development

Starting Point: A-D Mission Class Risk Profiles (1983-2011)

Characteristic	Class A	Class B	Class C	Class D
Payload type	Operational	Operational or Demo Op	Demonstration or Experimental	Experimental
Acquisition costs	Highest LCC	High LCC	Medium LCC	Lowest LCC
Mission Life	>7 years	≤7 years	≤4 years	< 1 yrs
Mission Success	All practical measures	Stringent minor compromises	Reduced assurance stds	Minimal assurance stds
Typical Contract Type	Cost Plus	Cost Plus or Firm Fixed Price	Cost Plus or Firm Fixed Price	Firm Fixed Price

Starting Point: A-D Mission Class Risk Profiles (1983-2011) (Notes)

This table examines A through D mission risk class key characteristics. Mission class profiles lay out a structured approach for defining a hierarchy of risk combinations for the US space systems enterprise.

- Class A missions are extremely critical operational systems where all practical measures are taken to ensure mission success. They have the highest cost, are of high complexity, and the longest mission life with tight launch constraints. Class A missions include the GPS satellites and military communications satellites.
- Class B missions are defined as critical operational, exploration and technical demonstrators in which only minor compromises are taken in stringent processes for mission success to achieve a low risk profile. Class B is the principal mission class for a large variety of NASA science missions examples include Discovery programs such as KEPLER and the Mars Reconnaissance Orbiter.
- Class C missions are defined a lower national significance, exploratory or experimental missions with a reduced set of MA standards applied resulting in a moderate risk profile. They are moderate to low cost and moderate to low complexity with a reduced mission scope. These missions include explorer payloads and have a shorter mission life.
- Class D missions are defined as having low national criticality. NPR8705.4 NASA procedural requirements for payloads defines Class D as medium or significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted. The main intent is to do rapid prototypes and teach the workforce, and find better and less expensive ways of expanding into new technologies and new capabilities. The principle assurance focus is safety of the workforce.

The team focus for this project is to further define Class D missions achieving "Mission Success" versus just cause no harm affordably. The focus is using capability based designs to accomplish significant science or significant support for the warfighter in quick reaction.

Class D Development Expectations

- **Current NASA Class D**
  - Experimental Class, akin to notional "E" sounding rockets (90% historical success) or "F" in some NASA discussions
  - Do No Harm
  - Designed for teaching next generation of space developers
- **NASA challenge**
  - "Real executable" missions, "D" footprint, "C" contrasting
  - "More aggressive cost" than Class C, but with robust science capability
- **Cost Gap**
  - Total Mission Cost: Class C/D ($250M) to UNEX Class D ($5-10M)
  - Significant cost gap between small and university level explorers

Class D Development Expectations (Notes)

Chris Scolese Director of the NASA Goddard Space Flight Center, challenged industry to come up with a development paradigm for executable missions with a mission Class D footprint but with a more aggressive costing posture than a Class C type system to reflect our current and foreseeable fiscal future. The current Class D defined in NPR8705.4 is as an experimental class for training of future scientists and had a “cause no harm” mandate versus a mission success mandate. In some NASA circles this mission class is more akin to the notional Class “E” of sounding rockets or a Class F system even though these are not formal mission types. There is a need to take more risk and be at least as reliable as the sounding rockets in the notional Class E. (Just a note of interest, the sounding rockets have a short mission duration and their Ps is on the order of 90% which is well below the 98% of EELV type rockets, but still significant.)

A notional costing range for Class D missions is large and ranges from the $250M mission established by NASA GSFC for their enhanced D in their just release Class D Constitution to the Air Force Research Lab university experiments to UNEX Class D at $15M. There are even less expensive CubeSat and university systems that range less than <$5M. These cost ranges establish a significant range of variability of these systems from experiments to overlapping with Class C explorers.

Surveys Conducted

- Company Internal Surveys
  - The Aerospace Corporation
  - Ball Aerospace and Technologies Corp
  - The Boeing Company
  - MIT Lincoln Laboratory
  - Lockheed Martin Corporation Space Systems Company
  - Northrop Grumman Aerospace Systems
  - Orbital Sciences Corporation
  - Raytheon: Missile Systems, Space and Airborne Systems
- Government Agency Surveys
  - NASA: Headquarters, GSFC, Ames, JPL
  - Air Force Research Laboratory
  - Operational Responsive Space Office
  - Space Test Program
  - Missile Defense Agency

Note: Backup Chart Captures Specific organizations/programs

Surveys Conducted (Notes)

Surveys were conducted and completed in discussions with both prime contractor and government agencies.

The survey focused on Mission Class “D” execution paradigms, concentrating on mission planning and execution from internal command media on extant programs. Internal company surveys ranged from (a) classical D type programs such as Aerospace Corp CubeSats and Lincoln Labs research and development programs, to (b) command media-driven product and process architectures at Ball Aerospace and Technologies Corp, to (c) independent execution division of Boeing, to (d) Class C-D type programs and internal command media at Northrop Grumman, Raytheon, and Lockheed Martin.

Government agency surveys included different NASA centers acquisition and execution approaches, and Air Force Class C-D systems houses including Air Force Research Labs, Operationally Responsive Space, and Space Test Program. The Missile Defense Agency was also examined for their independent approach.

Development Survey Questions

P=Primary
S=Supplemental

#	P/S	Survey Question
1	P	Where does **mission success rank** among the program objectives on an experimental or technology demonstration mission (commonly referred to as a Class C or D mission)?
	S	….
2	P	Which of the listed **MS processes** should be **trusted to contractor best practices** (versus through specification or oversight) on Class D?
	S	…
3	P	How is **risk managed** on the program?
	S	…
4	P	Do you identify Class C and/or D program characteristics in accord with industry, government, or internal **standards** (e.g. DoD-HDBK-343, NASA instruction 8705.4, Aerospace TORs, etc.) and establish contractor expectations as an outcome?
	S	…
5	P	What program behaviors/approaches have you observed which you believe to be **strong contributors to mission success**?
	S	…
6	P	What program behaviors/approaches have you observed which you believe **compromised or negated mission success**?
	S	…

Development Survey Questions (Notes)

The surveys consisted of six primary questions shown in the table that were formulated to extract characteristics and execution considerations knowledge from the companies and agencies surveyed. Additional supplementary questions examined key attributes of planning and execution of Class C and D type missions and provided examples to further clarify the question. The full set of the questions can be found in Appendix A of the published report. The questions stimulated lots of excellent interchange and further discussion.

Each of the primary questions is highlighted with some results in the material that follows. The questions were as follows:

- Question 1 addressed how mission success ranked with regards to programmatic constraints such as cost and schedule, and if mission objectives were coupled to mission success criteria.
- Question 2 addressed the 16 processes for Mission Success, formulated from a 2012 MAIW product, centering on the trusted execution of these processes by the contractor versus acquisition control.
- Question 3 addressed how risk is managed on these programs both in a formal sense, how it is traded against program objectives, and the level of risk assumed.
- Question 4 addressed if Class C-D type systems followed industry, government or internal standards such as NPR 8705.4 or DOD-HDBK 343 with established expectations from both MA activities and how the CDRL(deliverable) set was impacted.
- Question 5 focused on identification of “Winners” in terms of winning approaches with strong contributors to mission success, risk worth taking or should have been taken.
- Question 6 examined what doesn’t work in terms of execution, the “losers,” that compromised or negated mission success, led to failure, or risks that should not be taken again.

Key Considerations for Mission Success for Class C/D Missions – Leading with Class D

Survey Themes and Divergences

Considerations: Mission Success

Where does ***mission success rank among the program objectives*** on an experimental or technology demonstration mission commonly referred to as a Class C/D mission?

- Rank?
  - Mission success threshold requirements
  - Constraint balancing: cost, schedule, technical (threshold performance), and mission success (acceptable risk)
  - 75% responders: cost-schedule highest priority, technical below programmatic risk
- Flow Down?
  - Contractor best practice reliance
  - SOW: Stress success criteria (objectives), not process, manage risk focus
  - Critical areas, areas of uncomfortableness
- Objectives?
  - Streamlined mission objectives - success criteria
  - Corresponding oversight and audits
  - Customer alignment - negotiated
- Divergences:
  - Class A & B just insurance
  - Mission success ranked equal with cost and schedule

Considerations: Mission Success (Notes)

This slide summarizes the results for the first primary and supplemental questions on “mission success.” (The primary question is shown in the upper right of the briefing slide.)

- Mission success (MS) responses can be categorizes in terms of: Rank, Flow Down (requirements and processes), Objectives, and Divergences.

- Rank: A common theme was defining mission success in terms of achieving threshold requirements that have a significant probability of successful fulfillment. This is akin to minimum floor science requirements, minimum performance requirements, minimum demo objectives, etc. The most common ranking: cost (first); schedule; technical, in terms of threshold performance; and mission success (last) against what is considered acceptable risk. In essence MS is ranked and examined in context and balanced against programmatic constraints. The point is emphasized with 75% of the responders stating programmatic risks are the highest priority with technical below these risks.

- Flow Down: The majority of survey responders stated for this class of systems mission success achievement is reliant on contractor best practices. In this contractor centric approach the acquisition specifies the “what” success criteria, not process requirements in the statement of work and is focused on managing risk to the level required to understand critical areas and areas of uncomfortableness. JPL stated the level of risk knowledge is what is required to report mission risk status to headquarters.

- Break Down: The actual break down of items flowed to the contractor is a small number of focused mission objectives with their success criteria and corresponding oversight and audits to those objectives/success criteria. These success criteria breakdowns are developed in concert with the customer and defined at contract negotiation.

- Divergences. Notable insights provided include AFRL’s approach: “Class A & B is just insurance and unnecessary with demonstrated empirical evidence to prove.” Mission success is more equal with cost and schedule at NASA centers (MS insight vs. bounding), and launch vehicles are uniqueness - in that they have predefined requirements which are for the most part non-negotiable.

U.S. Space Program Mission Assurance Improvement Workshop

Considerations: 16 MS Processes

Which of the ***listed MS processes should trusted to contractor best practices*** (versus through specification or oversight) on class D?

- Program Execution
  - **Prime**: Pinpoint high risk (reuse review), audit process integrity others; distributed authority. Off nominal TAYF
  - **Agency**: "What" & Risk Ownership, Trust Contractor best practices
- Risk, Oversight & Assurance
  - **Prime**: Programmatic focus/Technical bounding, Frequent graybeard peer reviews, Quality insight/test coverage focus, Supplier capability/sustainability
  - **Agency**: Reduced Milestones, Problem Intervention
- Triage, Info, Lessons Learned
  - **Prime**: Systemic, Significant compliance anomalies, Program alert authority
  - **Agency**: Collaboration not authority

Category	Mission Success Process
Program Execution	Design Assurance
	Requirement Analysis and Validation
	Parts, Materials, and Processes
	Environmental Compatibility
	Reliability Engineering
	System Safety
	Configuration/Change Mgmt.
	Integration, Test, and Evaluation
Risk, Oversight, and Assurance	Risk Assessment and Management
	Independent Reviews
	Hardware Quality Assurance
	Software Assurance
	Supplier Quality Assurance
Triage, Information, Lessons Learned	Failure Review Board
	Corrective/Preventative Action Board
	Alerts and Information Bulletins

TOR 2010-(8591)-18, Mission Assurance Program Framework

Considerations:
16 MS Processes (Notes)

This slide summarizes the responses for the second primary and supplemental questions on “mission success processes.” (The primary question is shown in the upper right.) The embedded table lists the 16 mission success processes for mission success and their tailoring for Class C-D type missions. The mission success processes can be grouped under three categories Program execution; Risk Oversight and Assurance; and Triage, Information and Lessons Learned processes.

Program execution. Prime contractor: minimized contract deliverables; mission assurance focused on higher risk with audits; reduced performance margins, predictive reliability analysis; and off-nominal test as you fly testing. Agency (AFRL): focus is independence at the integration and test level; ownership of high level requirements and risk decisions; environmental vetting; and testing to reduce infant mortality.

Risk, Oversight, and Assurance. Prime contractor: continuously manages programmatic risks, bounds technical risk, supports small peer reviews with integrity audits, supports a delayed risk posture and commercial build/test/fix approach, ensures quality management compliance to process and pre- verifying subcontractor ability to perform. Agency (AFRL) has minimum involvement at this level with focus on key milestones and top 10 risk/mitigation lists.

Triage, Information, and Lessons Learned category. Prime contractor: Customers collaborate on failure review boards, not approval, with systemic corrective action board/alerts reviewed for risk impact only. Agency (AFRL): Relies on contractors best practices prior to system integration and test, and uses engineering to focus efforts.

Divergences observed include: different approaches to configuration management – some acquisitions require configuration management, while others trust contractor best practices; elimination of failure modes and effects analysis requirements (two responders); elimination of parts materials and processes requirements (one responder); and no tailoring of core processes (two responders). One agency (STP) required an independent engineering review in the design phases with a Class A mentality with later buyoff of identified issues not in alignment with program thresholds to discover all risks to mission.

Considerations: Risk

How is ***risk managed*** on the program?

- Managed?
  - PM or Chief Engineer exception management – ownership, acceptance, classifying
  - Push down technical decision authority, experienced individuals
  - Formality: Tools – Standard to spreadsheet, Team size driven, Ease of use
- Tradeoffs?
  - Threshold performance vs. cost and schedule vs. bounded risk
- Risk Level?
  - Moderate risk: Programmatic lower tolerance (fixed requirements/goals), technical (high against goals but low relative to thresholds)
  - Single string, good parts, selective, system, and dissimilar redundancy
  - Startup yellow, not all green at launch
- Divergences:
  - Opportunity management is as important as risk management
  - Formal RMBs: Propagation-management of mission risk
  - Audits conducted against Class A risk posture
  - Range: 10-20% failure rate, to low program and mission risk
  - Red: 2% cost, 1 week schedule vs. yellow technical
  - Design for success/minimize risk: System, Selective, Higher risk on redundant side

U.S. Space Program Mission Assurance Improvement Workshop

Considerations: Risk (Notes)

This slide summarizes the results for the third primary and supplemental questions on “how risk is managed.” The risk management response can be categorized in terms of how risk is managed, risk tradeoffs, risk level assumed, and divergences.

Managed. Risk is typically managed by highly experienced personnel with a program manager or chief engineer with at least monthly risk management boards. The level of technical authority for managing individual risk to mitigation closure is pushed downward to responsible or cognizant engineers. A key aspect of this distributed decision making is execution of risk management processes from unknowns to knowns which need to be cognizant to systems for impact assessment. Tools supporting this process can range from standard company risk tools to Excel spreadsheets dependent on team ease of use and size.

Risk Level. Moderate risk level is typical. This translates into lower tolerance on programmatic risk with fixed requirements and goals, but higher technical risks – high against goals but low relative to thresholds set for minimum mission success. Fulfillment of this moderate technical risk is often accomplished with single string designs but with good Level 2 parts to compensate for potential single point failures associated with the single string design. Selective redundancy is a typical design strategy used often with a dissimilar redundancy model to sponsor tradeoffs between performance and graceful degradation. Often yellow and red risks are acceptable at startup and some technical risk may remain yellow at launch. The key is bounded risk, knowing the risk you take in terms of the mission objectives.

Divergences. Notable divergences/insights include: focus on opportunity as well as managed risk to find opportunities to manage the tight programmatic tolerance to risk; and the use of formal risk management boards for propagation and management of mission risk (conducted with a small team, not committees). Failure rates deemed acceptable across the agencies was 1—20% to low risk for both program and mission risk. For STP, 2% was stated as a large cost risk and 1 week a large schedule risk, but yellow was acceptable technical risk even at launch.

Considerations: Standards

Do you identify class C and/or D program ***characteristics in accord with industry, government, or internal standards*** (e.g. DoD-HDBK-343, NASA instruction 8705.4, Aerospace TORs, etc.) and establish contractor expectations as an outcome?

- Standards?
  - Contractor best practices dependence, standards intent
  - Aerospace TORs guidance “how to" in command media
  - RFP primary response, mission class sets expectations
  - Funding agencies each use own document to define baseline
- MA Activities?
  - Mission Class Tailoring: MA Plan captures standards and/or tailoring
  - Expectation based activities versus formal requirements
  - MA focus process integrity, delegated to engineering, step ahead gates, with larger teams more process rigor
- CDRL Set?
  - Lean and limited, reliance on contractor practices and format
  - Critical information focus, development documentation used not shelved
- Divergences:
  - No difference (one response), No MA plan - decision gates (one response)
  - Evaluating CDRLs now (request more than needed) feedback to NASA HQ drives
  - Formal MA moderate improvement, is it worth the cost? (one response)

Considerations:
Standards (Notes)

This slide summarizes the results for the fourth primary and supplemental questions on “standards.” Responses can be categorized in terms of standards used, mission assurance(MA) activities, the contract deliverables (CDRLs), and divergences.

Standards. Standards focus for Class C/D missions relies on high dependence on contractor best practices with standards only examined for intent. Many of the agencies found this acceptable since the known primes are using Aerospace TORs and NASA standards on other mission classes and those requirements are built into the “how” of their command media. The agencies stated that adherence to the request for proposal formed the primary response from the contractors with mission class setting fundamental expectations.

MA Activities. MA activities are based on the mission class tailoring as shown in the process table in question 2 with standards used and or tailoring captured at program inception in an MA plan. In general, MA activities are expectation based versus formal requirements based. Classical MA focus for this class of missions is on ensuring process integrity.

CDRL Set. The CDRL set is lean and limited with reliance on contractor practices and format. The focus of the CDRLs required is critical information and documentation that is needed for development and used. No documentation is required that is shelved and not used for the actual build and test. The CDRLs are codified differently focused on contractor developed needs and customer core insight versus the nominal detail parallel knowledge of class B and somewhat of Class C systems.

Divergences. MDA claimed no differences in standards for Class D since all their systems were equally critical. One contractor responded that there was no required MA plan, but they did have decision gates with criteria established. JPL stated they are now evaluating CDRLs to assess what should actually be required as they tend to request more than needed to satisfy NASA requirements; as feedback to NASA HQ drives the required CDRLs. One respondent stated there was moderate improvement due to MA activities, but questioned if it was worth the cost.

U.S. Space Program Mission Assurance Improvement Workshop

Considerations: "Winners"

What program behaviors/approaches have you observed which you believe to be ***strong contributors to mission success***?

- Management
  - Strong MS Contributors: Empowered small dynamic teams with engineering culture, Strong management, Technically astute/experienced chief engineers, Minimum layers of authority, Team continuity, Solid risk management, Transparency, No scope creep, No edicts
  - Worked Superbly: Program planning, Single stakeholder risk and requirements owner, Customer/contractor collaborative partners, Stable requirements, "Side-by-side" peer reviews, Surveillance vs. repeat supplier testing, Embedded system I&T
  - Risk Taking Payoff: Maintain process intent and on-site "systems" liaison eyes engendered trust
- Product
  - Worked Superbly: Operational burn-in, Simplicity, Don't repeat supplier testing, Selective redundancy, Mission iteration, Single string design
  - Risk Payoffs: Common sense PMP, High heritage/reuse, System vs. physical redundancy, High risk payload as redundant
- Divergences:
  - Process integrity independent MA audit team
  - 100% receiving inspection
  - Redundancy: CubeStats (qualification, on-orbit test to failure, mission), dissimilar

Considerations: “Winners” (Notes)

This slide summarizes the results for the primary and supplemental questions on “contributors to mission success.” “Winners” responses can be categorized in terms of management, product, and divergences.

Management. Strong mission success contributors included empowered small dynamic teams with an engineering culture; strong management with technically astute chief engineers; minimum layers of authority; team continuity; solid risk management; transparency; no scope creep; and no management edicts. A collaborative relationship between the customer (single stakeholder) and contractor worked superbly on these classes of systems in which the span of control vs. span of influence is reduced to minimum levels possible with stable requirements, local side by side peer reviews, subcontractor surveillance over repeating supplier testing, and an indigenous integration and test process. Risk that was worth taking included maintaining process intent versus hard requirements with on-site systems liaison eyes to engender trust.

Product. Strong mission success contributors to product included extended operational level burn-in; maintaining simplicity; not repeating supplier testing; and designing with selective redundancy and mission iteration. Risk payoffs for the product included common sense parts, materials and processes such as risk-based prohibited materials testing; single string design; high heritage/reuse; and system vs. physical redundancy.

Divergences. Strong contributors that provided notable insights included an independent process integrity focused MA team. One respondent always required receiving inspections. Another respondent claimed opportunity management is captured at the same level as risk management.

Considerations: "Losers"

What program behaviors/approaches have you observed which you believe ***compromised or negated mission success***?

- Management
  - Mission Compromising: Autocratic pressure, Unstable budgets, Excessive financials focus, Leadership/personnel mismatch, Technologist as project manager
  - Failure: Low likelihood / low perceptivity testing, Straying from best practices (SE rigor required), Poor program/home organization communication, Incomplete development planning, Training
  - Never Again: Inexperienced contractor/supplier/team member (pay for expertise)
- Product
  - Mission Compromising: "Sunny Day" TAYF
  - Failure: Excessive rework (PWAs)
  - Never again: Lower quality piece parts (don't skimp), Reduce testing/skipping lower level tests, Over-conservative qualification/design stacked up margins
- Divergences:
  - Attracting "antibodies"
  - No mission failures, frequent schedule and budget ruptures
  - Spinning in place

Considerations: “Losers” (Notes)

This slide summarizes the results for the primary and supplemental questions on activities that “compromised or negated mission success.” What doesn’t work responses can be categorized in terms of management, product, and divergences as before for the What works question.

Management. Mission compromising behavior included autocratic management, extreme pressure, and unstable budgets with an excessive focus on financials. Also cited was leadership and personnel matches are critical for these missions- personnel mismatch to the program and mission needs must be handled quickly to ensure team and program performance does not suffer as a consequence. Failure sources for these mission classes included low likelihood/low perceptivity testing with limited budgets, straying from minimum best practices, poor communications, and incomplete development planning. Risks that would “never be taken again” included picking an inexperienced contractor or supplier. STP and ORS stated you must pay for the expertise.

Product. Mission compromising behavior included sunny day “Test-as-you-Fly” as the assurance of test completeness without consideration of off-nominal conditions and contributions as potential failure sources. One respondent stated excessive rework led to failure. Product risk that would “never be taken again” was the use of lower quality parts especially in single string designs; reduced testing/skipping of lower level tests where perception is higher; and over-conservative qualification/design leading to stacked up margins not required for the mission.

Divergences. Notable insights included ORS’s stated experience about attracting antibodies, (e.g., unwanted outside help); the prevalence of schedule and budget rupture from AFRL and STP but not mission failures; and a prime contractor’s wasting resources spinning in place on how to execute a PMP program when the net result was to use better parts.

Considerations: Agency Comparison

Question	NASA (AMES/JPL)	MDA	ORS	STP	AFRL
Mission Success Rank	(A) Threshold (J) Tailor 4Ws not HOW - App., Relationship, - I&T+	Same all programs	Cost /Schedule/ Acceptable Risk/ Threshold Performance	Cost/Schedule absolutes, technical negotiation.	Threshold based Chief Engineer trades SPFs with programmatic (Conops)
Contractor MS Process	(A) Safety, Best practices (J) Best practice but risk rating control	Oversight of all 16 processes	Contractor Best practices based on empirical evidence	Contractor Equivalent Processes with gate spiral down comments	EDTS, workmanship, for contractor build not AFRL insight
Risk Management	(A) Joint RMB trade risk vs. resources (J) Rate all mitigate less	Chief Engineers own, accept, classify risks	- Partners manage risk - Mitigation high/mod - Quarterly RMB	Critical programmatic - 1 wk., $10K Design to D, Build to C, Test to B, cost to D	- Risk-MA awareness (accountability) - Failure judged by knowledge gained
Standards Followed	(A) NPR8705.4 min (J) FPP/DVVOP/HQ Aligned - Too Many CDRLs - FAR driven - Appraise of risk	Internal Standards with MAP tailoring for mission	- Proven mission partner practices - Gates entry/exit criteria support payments	- Focus is on intent of standards - Look for innovation.	Critical Contractor build documents only
What Works	(A) Collaborative risk & opportunity mgmt (J) Systems team, advisory board, test less analysis	Engineering diligence, discipline and focus	SMES use risk to focus resource allocation	- STP I&T Focus - 200 hours week in life.	- Independent I&T - Single stakeholder - Risk/Reqmts trade - Simplicity, best practices, peer
What Doesn't	(A) TAYF/FAYT nominal (J) Poor teamwork, inexperienced sub, tailoring struggle	- Unknown-Unknowns - Part failure biggest problem (envir)	Interference form other government agencies	- Schedule failure 300% - Cost failure 200% - No technical failures	- Critical C&DH, TT&C - Minimum practices, - Quick non-elegant decisions

- Mission Success Rank
  - Threshold performance, Cost/schedule absolutes, Technical negotiation
- Contractor MS Process
  - Contractor best practices (rating control, empirical evidence, spiral process)
- Risk Management
  - Joint RMB, Partners manage, Risk-MA awareness
- Standards Followed
  - Standard intent, Build critical, Too many CDRLs /risk assessment
- Winners
  - Collaboration, Embedded system I&T, Single stakeholder, Simplicity, Ops burn-in
- Losers
  - Nominal TAYF, Outside interference, Best practice violation, Programmatic rupture

Considerations:
Agency Comparison (Notes)

This chart summarizes the responses of the agencies surveyed, with the exception of GSFC, which is captured separately. Agencies responses include NASA Ames and JPL, MDA, ORS, STP, and AFRL. A notable outlier for the agencies was MDA whose mission criticalities treats all of their missions regardless of their class or operational demo nature as more akin to a Class A or B mission class with minimum roll off of standards, requirements or processes.

Mission Success Requirements. All the agencies agreed on defined threshold performance for mission success with focus on the "What" and not the "How" to perform. Cost and schedule requirements tended to be absolutes with fixed price contracts. Development and delivery was based on launch available.

Contractor Mission Success Process. Focus was on contractor best practice implementation based on risk ratings, empirical evidence, and outside subject matter expert spiral burn down. The spiral burn down was an interesting STP approach where the initial preliminary design review was treated as a Class A – an independent review was conducted with engineering subject matter experts whose comments then were accepted or rejected based on mission applicability.

Risk Management. Customer and contractor partnership in risk management to include risk management boards(formal or informal) was cited as key. Typically trading performance risk against resources was acceptable; mitigation focused on high/moderate risk only; and a close focus on eliminating programmatic risk vs. bounding the technical risk. AFRL was the only agency that claimed failure acceptability based on the knowledge gained as long as you got the information to the experimenter.

Standards. Documentation followed ranged from NASA NPR 8705.4 and internal practices for the NASA centers to internal contractor practices for the national security space agencies. NASA was much more prescriptive per their policy; other government agencies tended to use what worked best for them verses using published guidelines. Contractors valued the Aerospace TORs and incorporated much of the technical best practices captured into their own internal command media processes as applicable to the different mission classes.

Winners. Unique across the agencies with key concepts included a collaborative risk and opportunity management approach, advisory boards, subject matter expert's focus of risk efforts, indigenous integration & test processes/procedure, and extended operational burn-in being cited as mission success contributors.

Losers. What doesn't work was also unique across the agencies with key issues including sunny day TAYF, poor teamwork, outside interference, programmatic failures, and dipping *below minimum practices and the inability to perform quick non-elegant decisions.*

Considerations: GSFC Class D Constitution

Question	NASA GSFC Class D Constitution
Mission Success Rank	• Mission success ranks high, **GSFC policy states failure can be tolerated (lower cost/more missions)** • Not expected to decrease Ps • PIP Threshold performance • Mission objectives / Success requirements - internal SMAP/Updated MARs for initial recipe
Contractor MS Process	• **Contractor practices trust, compromises under evaluation** • SW safety critical items and limited mission critical compliance • Performance based MAR relevant mission critical HW-SW requirements • Commercial parts commensurate with cost, lifetime, criticality, derating, redundancy
Risk Management	• **Senior Executive Champion (SEC)/ advisory development to PIP** • Risk-informed: Design/build-to-cost trading science, lifetime, minimum compliance • implied use of mature technologies for all components • Single string, proto-flight testing, limited EMs and spares
Standards Followed	• **AS9100 Compliance with commercial standards** • Narrowed CDRL/updated MARs - no requirements beyond customer • Project relevant GPRs guidance for execution • Combined SRR-SDR, PDR-CDR, TRR and MRR/ORR
What Works	• Proposal Credibility • Performance Floor • Project level authority • **Clear communication, timely decisions** • Product oriented processes, minimum development distraction, low overhead • Expert advise-stewardship: Design and execution to cost • Maintain the thee legs of the stool Project, Engineering, and tailored S&MA working hand in hand
What Doesn't	• **Excessive Reviews** • **Forced GSFC policies adherence** • **Substandard performance by any Project team member**

- Mission Success Rank
  - Policy: Failure tolerated with lower cost and more missions
- Contractor MS Process
  - Trust contractor practices, evaluation compromises
- Risk Management
  - Senior Executive champion / advisory to PIP
- Standards Followed
  - AS9100 fundamental compliance with commercial standards
- Winners
  - Performance floor, project authority, clear/timely communication
- Losers
  - Excessive reviews, forced policy adherence, project mismatch

Considerations: GSFC Class D Constitution (Notes)

Goddard Space Flight Center published their "Constitution for In-House NASA Goddard Space Flight Center Class D Projects." This Class D constitution effort focused on restoring a GSFC competitive posture with regard to developing and winning Class D projects. Class D programmatic and technical integrity can be achieved by removal and or modification of high resource overhead processes. The Constitution includes an approach to a Simplified Class D and an Enhanced Class D.

Mission Success. Rank is in alignment with other agencies with the caveat that the process is ongoing with internal mission assurance processes and updated mission assurance requirements recipes not yet developed.

Contractor MS Processes. There is more trust in contractor practices but the process is ongoing to determine relevant mission critical hardware-software requirements, and compromises to be considered in evaluation.

Risk. Approach to risk is championed by having a single project implementation plan with executive oversight to ensure program management is in alignment.

Standards. Focus is on the basics such as AS9100 compliance. Contract deliverables are narrowed, but that determination of which deliverables is still to be made.

Winners. The foundation of the Class D constitution is early credibility using a preliminary project implementation plan that establishes a performance floor, project level authority, timely decision process, streamlined processes, stewardship and maintaining inter-discipline collaboration.

Losers. The Constitution is being written to avoid losers focusing on an increase of Class D competitiveness with excessive review avoidance. Adherence to the many NASA requirements should be waived with strong collaborative teams with appropriate expertise and project/mission mindset.

Key Considerations for Mission Success for Class C/D Missions – Leading with Class D

Class “Enhanced D” Template

Summary Table of Characteristics

Category	Class C/D Characteristic
Risk Acceptance	Moderate acquisition risk with achievable threshold performance contractor acceptance
Mission Types	Experiment, explorer, demonstrator, gap filler, spare backup, instrument left over
National Significance	Low to moderate criticality
Acquisition Cost	Low ($5-10M to $250M), Total mission cost
Complexity	Low to moderate complexity managed via capability based design
Mission Life	Weeks to 1 year and some built >2 year expectation of mission life
Launch Constraints	None to Few
Alternatives	Some, dependent on mission type
Mission Success	Moderately high probability of success against threshold performance
Typical Contract Type	Cost Plus & Firm Fixed Price
Assurance Practices	Limited Tailored Specifications with contactor equivalent best practices dominant
Architecture	Single string design compensated with higher reliability parts (constrained by mission cost and schedule) and testing, plus system/dissimilar redundancy as applicable
Development Units	Limited engineering model and spare flight hardware (relying on heritage makes true)
Test	Full Acceptance Test Program

Summary Table of Characteristics (Notes)

This slide captures a summary table of characteristics for an enhanced Class D

Characteristic categories are given on the left with the corresponding Enhanced D characteristics as a blend of Class C and D

Key enhanced D discriminators include:

- Differing risk acceptance of the acquisition agency versus contractor execution
- Many mission types that this class of system can play a significant agency role
- Large cost range from true experiments to Class C light systems
- Capability managed complexity
- Mission class versus mission life expectations
- Threshold performance measurement of mission success
- Assurance practices dominated by contractor equivalent best practices
- Balanced risk architecture

Summary Considerations

Category	Class C/D Consideration
Mission Success	- Threshold requirements limit mission scope and establish measurement criteria - Constraint balancing: Cost, schedule, performance, mission success - Contractor best practice reliance
Risk	- Exceptions managed by experienced leadership, delegated authority - Low programmatic tolerance, higher technical (goals) with low (threshold) - Objective bound (understand) risk with selective yellow/red mitigation
Standards	- High dependence on contractor best practices, standards examined for intent - CDRLs lean/limited for critical risk and development documentation - Process integrity MA focus, key decision gates - Oversight vs. Insight – contractor data transparency
Processes	- See slide 12 Class D tailoring for execution, risk oversight, and triage processes
“Winners”	- Small dynamic teams, minimum layers authority, continuity, transparency - Customer-Contractor reduced span of control vs. influence - Operational burn-in, simplicity, subcontractor reliance w/audits, embedded T&I - Common sense PMP, high heritage reuse, single string with select redundancy
“Losers”	- Autocratic pressure, unstable budgets, personnel mismatch - Low perceptivity/low value added testing, straying from best practices - “Sunny Day” TAYF, Use of lower quality parts, skipping lower level tests

Summary Considerations (Notes)

This slide captures a summary table of enhanced Class D execution considerations. Consideration categories are given on the left corresponding to the survey questions with the corresponding Enhanced D core core considerations as a blend of Class C and D.

Key enhanced D discriminators include:

- Bounded mission success objectives with contractor trust in achieving
- Risk managed by leadership to ensure hard resource trades but distributed mitigation authority and bounding analysis and test execution
- Standards based on contractor practices with limited CDRLs for risk criticality understanding
- Limited MA focus on process integrity, and insight with contractor transparency processes tailoring
- Success derived from both empowered team capability and product common sense design and test techniques appropriate for this class of mission
- What doesn’t work from management and team volatility, inadequate testing and assurance practices, and shortcutting fundamentals such as part quality

Notable Insights

- Process Tailoring: Who, What, When, Where, not How
- Class A&B insurance: Eliminate infant mortalities
- System, dissimilar redundancy and graceful degradation
- All risks assessed, difference mitigation thresholds
- Reviews unbounded to risk profile exploring unknowns
- CDRLs for risk insight and development
- Process integrity focused MA
- Opportunity management constraint innovation
- Support quick decisions
- Contractor and customer expectations set at award

Notable Insights (Notes)

This element of the Class D template provides notable insights from the raw data of company and agency surveys.

These include: the 4 Ws focus versus the how; the assurance that infant mortalities are eliminated; the bounding of all risk with selective mitigation; the need to evaluate project unknowns; limited CDRLS focused on risk insight and development enablers; MA focus on process integrity; opportunity management supplementing risk management for programmatic constraints; risk as a resource trade criticality; quick non elegant decisions; and development architecture expectations such as these Class D considerations are established at proposal phase and contract award.

Conclusions

- Surveys bring out common themes and divergences
- Agencies highlight expectations and conops
- Acquisition risk (moderate), Product risk (low to moderate)
- Mission success threshold performance
- “What” is required and not “how” work accomplished
- Contractor best practices with specs/stds intent
- Process tailoring roadmap for streamlined execution
- Minimum separation of span of control vs. influence
- More organic with small empowered teams
- Fertile approaches for “New Enhanced D” missions

Conclusions (Notes)

Conclusions summarize the key takeaways from the topic team study highlighting the core of what makes an enhanced Class D development and product architecture, a Class D template that establish a recipe for Class D implementation plan, and the specific elements identified that will help in enhanced Class D execution.

Enhanced Class D Product Implementation Recommendations

- **Acquisition agencies and contractors:**
  - Understand this is a different way of doing business
  - Negotiate/Collaborate early and continuously (non-prescriptive)
  - Document program approach with internal and external buy-in
  - Expect to tailor standard command media to match mission
- **Industry and government roadmap:** Implement enhanced Class D template instantiated to needs and constraints
- **Acquisition management:** Document successful approaches and maintain best practices guide

Team Membership and Recognition

Core Team Members

- **The Aerospace Corporation**
  Gail Johnson-Roth (Co-Lead)
- **Ball Aerospace & Technologies Corp**
  David R. Pinkley (Co-Lead)
  Mike Verzuh (Co-Lead)
- **The Boeing Company**
  Robert Friend
- **Harris Corporation**
  Matthew Fahl
- **Lockheed Martin Corporation**
  John Haney
- **Northrop Grumman Aerospace Systems**
  Frank Chong
- **Raytheon Space and Airborne Systems**
  David Makowski
- **Raytheon Missile Systems**
  William Hoehn

Team Membership and Recognition (Notes)

Core Team Members

Slide was alphabetized per company name multiple names listed under common company name

Team Membership and Recognition

Additional SMEs

- **The Aerospace Corporation**
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- **The Boeing Company**
  - Gerry Kochevar, Geoff Orias
- **Lockheed Martin Corporation**
  - Gary Kushner, Arleen Knaub, Larry Capots
- **Lincoln Laboratory**
  - Deborah Valley
- **Orbital Sciences Corporation**
  - John McBride, Larry DeFillipo, Ben Hoang
- **Raytheon Space and Airborne Systems**
  - Mark Baldwin, Neil Barberis, Lesley Foster, Randall Kanemoto, Karen Nourcier, Jeff Orr, Jeff Rold, Albert Ross, Ronald Townsend
- **SSL**
  - Gerrit VanOmmering, Ken Dodson
- **Missile Defense Agency**
  - Joshua Lindley
- **NASA HQ**
  - Patrick Martin
- **NASA/Goddard**
  - Michael Kelly, Anthony Diventi
- **NASA/Jet Propulsion Laboratories**
  - James Marr, Janis Chodas, Karla Clark
- **NASA Ames**
  - Daniel Andrews
- **Northrop Grumman Aerospace Systems**
  - Craig Elder
  - Bill McMullen
- **Air Force Research Laboratories**
  - Stanley Straight, Capt Doug McFarland
- **Space Test Program**
  - Michael Marlow, Kenneth Reese
- **Operational Responsive Space**
  - Dr. Thomas Atwood
- **APL**
  - Steve Pereira

Team Membership and Recognition (Notes)

Additional SMEs

Slide was alphabetized per company name multiple names listed under common company name

Questions?

Back-Up

U.S. Space Program Mission Assurance Improvement Workshop

Quad Chart

Team

- **Team Leads**
  - **Dave Pinkley (Ball)**
  - **Mike Verzuh (Ball)**
  - **Gail Johnson-Roth (Aerospace)**
- **Team Members**
  - **Bob Friend (Boeing)**
  - **John Haney (LM)**
  - **Frank Chong (NG)**
  - **Dave Makowski, Bill Hoehn (Raytheon)**
  - **Matthew Fahl (Harris)**

Problem Statement

- The US Space Enterprise is entering into a challenging fiscal environment that will require ***critical evaluation of methods*** for ensuring ***Mission Success*** within ***programmatic constraints***.

Examples

- Current acquisition mission class profiles for ***Class C*** see embedded requirements that are beyond the scope of a Moderate Risk Tolerance and ***show significant variability*** between agencies and centers.
- Currently ***Class D*** higher risk profile is seen as a ***totally unbounded experiment development*** with very few considerations for mission success but with ***the customer expectation that it must work***.

Stakeholders

SMC
NRO
MDA
NASA
Industry

Charter

- ***Survey of current civil and NSS efforts*** with regard to ***redefining Mission Class C & D Profiles*** with industry participation.
- **(1)** Review ***negotiated baselines:*** Current C/D planning execution.
- **(2)** Work with ***NASA HQ and Selected Centers:*** Current payload reclassification effort
- **(3)** Work with ***NSS, other relevant agencies*** to understand implications to DEMO Missions
- ***Foundation of effort should be based on the disciplined application of program management, systems engineering, and assurance practices for achieving Mission Success vs. Top Down Requirement tailoring.***

Products

- ***MAIW Plenary session Briefing*** detailing survey findings and common characteristics of Mission Class C and D Mission Success Risk Management Strategies
- **Note: Lead with Class D**

Quad Chart (Notes)

This topic team originated in 2011 in response to a challenge by Chris Scolese to industry to find a execution paradigm as an enhanced Class “D” that NASA could execute science with ever increasing fiscal pressures. This challenging fiscal environment requires the re-evaluation of methods for assurance of Mission Success within these programmatic constraints. The enhanced Class “D” falls between NPR 8705.4 Class C and Class D. Class C is seen as having embedded requirements that go beyond the scope of a moderate risk tolerance acquisition and also has significant variability between agencies and centers. Class D is defined by NASA as a high risk profile for a totally unbounded experiment with few acquisition considerations for mission success beyond “cause no harm” and expectations that it will work. A pure experiment has a major requirement to “do no harm” to other rideshares has expectations of learning even from failure.

In order to define characteristics and considerations for this enhanced Class D an MAIW industry team was charged with surveying of current civil and national security space efforts with regards to Class C and D profiles. The team reviewed internal company baselines; surveyed government agency charters with Class D systems; reviewed NASA HQ and centers classification efforts; and tied back results to the GSFC parallel effort that Chris initiated.

The result is this plenary session briefing. This outbrief will be a overview of that briefing with much of the detail captured in backup and to be published in a presentation TOR product.

Relationships to Previous Mission Class Evaluations

- **TOR 2011 8591-21: A-D typical execution against 16 processes**
  - Class D based on scaling of existing approach insufficient, new paradigms
  - Mission Life <1 year, minimum standards on contract, cause no harm to greater system
- **TOR 2011 8591-5: specification and standard applicability A-D**
  - Experimental, reduced standards, cost < $10M, milestone oversight
- **NPR 8705.4 NASA Payload Risks A-D and DOD-HDBK-343 one of a kind definitions**
  - Class D: Safety, best practices, guidance, subsystem analysis
  - System acceptance test only for HDBK 343
- **Goddard Standard MA Requirements (320 MAR-1001D)**
  - Extensive requirements, 47 CDRLs, negotiated authority

Previous baseline documents don't map to this revitalized Class D

Relationships to Previous Mission Class Evaluations (Notes)

An early topic team effort was to examine the relationships of this enhanced Class D to existing mission class efforts. Four existing products are examined. The third bullet lists the two foundation products for mission classes including the NASA NPR 8705.4 risk classification A-D for NASA payloads and the DOD Handbook 343 which also address mission Class A-D for one-of-a-kind systems. The top two TORs were released in 2011 addressing A-D execution against 16 processes for Mission Success and against specification and standard applicability. Both TORs were focused on covering the range for minimum practical risk Class A to experimental Class D. The bottoms up typical process execution of 16 processes scaled those processes from Class A to Class D, fit Class D in the “cause no harm” paradigm, but did not look at Class D as a clean sheet development. The second TOR was more of a top down examination of the scaling of Specification and Standard requirements against the classes.

The final standard examined was the GSFC set of standard MA requirements with a table of characteristics for different mission Classes. This document had extensive requirements flow-down, 47 required CDRLs, and a negotiated baseline for authority sharing. In the just released Class D Constitution, GSFC acknowledges that the MA requirements need to re-examined for this new enhanced Class D.

The topic teams’ findings were that none of these previous baseline documents adequately map to the this revitalized enhanced Class D development paradigm.

Surveys Conducted

Company Internal Surveys

- The Aerospace Corporation – Office of innovative Materials, Space Materials Lab Engineering &Tech (SMC/XR and other funding)
- Ball Aerospace and Technologies Corp – Quality Management Resources
- The Boeing Company – Phantom Works Space and Intelligence, Exploration, Networks & Space Sys
- MIT Lincoln Laboratory – Safety, Mission Assurance and Program Support
- Lockheed Martin Corporation – Space System Company (IRIS and a restricted program)
- Northrop Grumman Aerospace Systems –Safety and Mission Assurance (LCROSS program)
- Orbital Science Corporation – Mission Assurance
- Raytheon Missile Systems – (ORS, DARPA SeeMe programs)
- Raytheon Space and Airborne Systems – Space Systems Mission Assurance, (NPOES VIIRS, Tier II Programs, Civil Space, Operations)

• Government Agency Surveys

- NASA: Headquarters (S&MA), GSFC (S&MA), Ames (OSMA, LCROSS), JPL (FINESSE)
- Air Force Research Laboratory – AFMC
- Operational Responsive Space Office – SMSC/AFSC
- Space Test Program – Space development and test wing, SMSC/AFSC
- Missile Defense Agency – QSA

Surveys Conducted (Notes)

Surveys conducted included both prime contractor and government agencies. The Survey focused on Class D mission-like execution paradigms from internal command media and extant programs. Internal company surveys ranged from (a) classic D programs such as CubeSat R&D at The Aerospace Corporation, (b) command media driven Product and Process Architectures at Ball Aerospace, (c) independent execution division of Boeing, (d) to Class C-D type programs and internal command media at NGAS, OSC, RMS, and RSAS. Government agency surveys included NASA centers execution, and Air Force Class C-D systems houses including AFRL, ORS, and STP. The MDA was also examined for their independent approach.

Development Survey Questions

#	P/S	Survey Question
1	P	Where does mission success rank among the program objectives on an experimental or technology demonstration mission (commonly referred to as a Class C or D mission)?
	S	Does meeting cost and/or schedule imperatives eclipse mission success imperatives?
		Do you typically include missions success or mission assurance requirements in the program requirements (e.g., in the SOW, in the TRD, via compliance documents, through oversight, etc.)?
		Do you break down the mission into separate mission objectives with associated success criteria?
		How is risk factored into your considerations of mission success considerations, if at all?
2	P	Which of the listed MA processes should be trusted to contractor best practices (versus through specification or oversight) on Class D?
	S	Is there something on the list (excerpted below from the TOR) which you would eliminate from consideration on a Class D program?
		Is there something you would add to the list for a Class D program?
3	P	How is risk managed on the program?
	S	Will risk be formally identified and managed?
		Can risk be traded against other program objectives?
		What level of risk is assumed/approved on a Class D program at start; distinguish between mission and program/execution risk?
		Is risk managed through formalized tools or through informal tools (e.g., spreadsheets or presentation charts)?
4	P	Do you identify Class C and/or D program characteristics in accord with industry, government, or internal standards (e.g., DoD-HDBK-343, NASA instruction 8705.4, Aerospace TORs, etc.) and establish contractor expectations as an outcome?
	S	Do you have or refer to formal program MA activity expectations associated with Class D or experimental missions?
		How does your identification of program characteristics and contractor expectations influence the contract data requirements set?
		Do you believe Class C/D missions would benefit from having formal MA activity expectations associated with such programs?
5	P	What program behaviors/approaches have you observed which you believe to be strong contributors to mission success?
	S	What has worked superbly well?
		What risks were worth taking?
		In hindsight, are there any risks that should have been taken or less aggressively avoided?
6	P	What program behaviors/approaches have you observed which you believe compromised or negated mission success?
	S	What has failed or led to failure?
		What risks were taken that would not be taken again?

Development Survey Questions (Notes)

The six survey questions shown in this table were formulated to extract characteristics and execution considerations knowledge from the companies and agencies surveyed. Questions were organized with a primary question followed by supplemental questions to examine key attributes of planning and execution of Class C and D type missions.

Question 1 addressed how mission success ranked with regard to programmatic constraints such as cost and schedule and if mission objectives were coupled to mission success criteria.

Question 2 addressed the 16 processes for Mission Success (formulated from a 2012 MAIW product), from the standpoint of trusted contractor execution of these processes versus acquisition control.

Question 3 addressed how risk is managed on these programs both in a formal sense, how it is traded against program objectives and the level of risk assumed.

Question 4 addressed if Class C-D type systems followed industry, government, or internal standards such as NPR 8705.4 or DOD-HDBK 343 with established expectations from both MA activities and how the CDRL set was required/delivered.

Question 5 focused on what works in terms of winning approaches with strong contributors to mission success, risk worth taking, or risk that should have been taken.

Question 6 examined what doesn't work in terms of execution that compromised or negated mission success, has led to failure, or risks that should not be taken again.

Characteristics/Considerations Surveys

- **Surveys Motivation**
  - Class D mission needs and programmatic constraints based on NASA AFRL, ORS, and STP characteristics
  - Considerations established from common survey themes and divergences
- **Survey Planning and Execution**
  - Cover broad SQIC foundation for Mission Assurance
    - ***Disciplined application of program management, systems engineering, and assurance practices for achieving Mission Success.***
  - Evaluate Key Execution Criteria
    - Evaluate Mission Success Ranking
    - Risk Management
    - Standards and Process Expectations
    - What Works and What Doesn't
  - Explore alignment NASA, Industry Partners, NSS agencies

Characteristics/Considerations Surveys (Notes)

The approach taken to explore the enhanced Class D mission needs was to examine current mission Class C-D execution within NASA centers and at national security space centers of excellence including AFRL, ORS, and STP. The raw data produced from these surveys were summarized for common survey themes and divergences as input to understanding the boundaries of an enhanced Class D. A mandate from the MAIW steering committee was that our examination of Class D should be approached with the broad SQIC definition of MA which includes Program Management, Systems Engineering, and assurance practices for mission success. This mandate was to look at this enhanced Class D from a bottom-up approach versus the scaling approach that was detailed in 2011 for the execution of 16 mission success processes against Mission Class A-D. This focus was to look at a fresh clean-sheet input versus more traditional approaches.

The industry team developed a set of key execution criteria that served as the foundation for survey questions for extracting characteristics and consideration knowledge. These criteria include how mission success ranked with regards to programmatic constraints such as cost and schedule, how risk is managed on these programs, what standards are used in their execution, and corresponding mission success processes including tailoring appropriate for this class of missions. Finally the criteria focused on what works in terms of winning approaches with strong contributors to mission success and what doesn’t work in terms of execution that compromised or negated mission success. As the raw data was collected the team explored the alignment of our industry partners, NASA centers and NSS agencies.

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Considerations: Processes

Which of the ***listed MA processes should trusted to contractor best practices*** (versus through specification or oversight) on class D?

Category	Mission Success Process	Class C-D Tailoring	Mission Success Class C-D Tailoring (AFRL)
Program Execution	Design Assurance	Train & certify personnel, **minimize CDRLs**, standard processes, **MA focus on higher risk items (**TRL maturity, new development, complexity, empirical issue, etc.**) and audit engineering process for others**.	- AFRL Concurrence through normal review cycle - TLYF with limited exceptions - **AFRL I&T facility independent assess** - Manfufacturing not focused on since one-offs - Do not require MIPs, but address high risk items.
	Requirement Analysis and Validation	Customer concurred defined validation approach, **process integrity (audit), validation methods match to show compliance to threshold requirements, others goals**	- AFRL RVE **owns level 2 sys reqmts** - AFRL RVE **approval level 3 subsystem** - Internal V&V, analysis, and evalaution knowledge
	Parts, Materials, and Processes	Implement PMP across programs which include a **composite approved part/material/processes list maintaining build history** of parts used. Internal PMPCB	- **Prohibited materials** - Address as needed (C&DH & TT&C primary)
	Environmental Compatibility	Follow standard/generic requirements and test levels. (For example NASA GEVS or 1540E tailored to **reduced set of margins (positive) to knowns & bound known-unknowns**.)	- Perfer test to analysis verification - **Environment vetting** (ESPA RUG, GEVS) - CE & I&T Lead adjudicate waivers
	Reliability Engineering	**Predictive analysis for system reliability/availability (result not method). Parts stress analysis to ensure part reliability** for shorter mission duration. No PRA, WCCA, LLI. On Call for identified supplier exceptions.	- Single String baseline - **Test to reduce infant mortality rate** - Reduce design complexity
	System Safety	Follow institutional processes. **No short cuts on hardware, system of personnel safety procedures. Use common sense surveillance.** Compliance to AFSPCMAN 91-710.	- MSPSP required for all DoD launches - **Range Safety input for all launches**
	Configuration/Change Mgmt.	Engineering control using contractor tools. **Minimize signatures required. Engineering/Production authority at component level** (MAM oversight), with greater MA (HQA) involvement at subsystem and I&T.	- AFRL CE responsible subystem/system change - **Increased oversight if CM issue surface**
	Integration, Test, and Evaluation	Use simplified test plans vs. detailed procedures with complete documentation of as built/preformed "as run". **Test as close to operational conditions as possible and critical off-nominal conditions**	- Flagship RV Major I&T performed in-house - **TAYF to maximum extent practice**
Risk, Oversight, and Assurance	Risk Assessment and Management	Ensure regular and candid discussions with customer regarding risk sources and their management, **PM manages, higher tolerance, programmatic risk trades, informal tools**, **monthly customer collaboration with RMB.** Plan program to focus additional resources (MA) on higher risk items and audit for process execution and residual risk elsewhere.	- **Top 10 Risk/Mitigation List for PM** - Increase oversight failure to address or update
	Independent Reviews	Senior technical advisory board, No independent reviews **Frequent small peer reviews. Major reviews less comprehensive/status oriented. Peer Review Integrity**	- Flagship (PDR, CDR, TRR, and PSR) **milestones** - SMEs Directorates, Aerospace, Contractors)
	Hardware Quality Assurance	Tailored MRB, NCR, FRB, CAB process. Minimize voting members. Have on call during key stages. Reliance on Engineering/Production for early subassembly build anomalies. **Test coverage focus subsystem and System I&T. (Delayed risk posture), Commercial Build/Test/Fix approach**	- Intervention for high risk or problems
	Software Assurance	Similar to design assurance. Process Integrity Surveillance, **SQA focus on compliance to process, coordinating anomaly resolution (SCCB), simple metrics**	- Contractor Requirements with AFRL oversight - Indepdendent Software Testing
	Supplier Quality Assurance	Use approved suppliers and their **internal PA (best) practices. Verify prior to award ability to execute desire processes and produce desired product**. Augment as needed via program staff.	- **AFRL doesn't perform**
Triage, Information, Lessons Learned	Failure Review Board	Internal contractor FRB for difficult root cause identification, systemic issues, and major system (compliance) impacts. **Customer collaboration but not approval authority**. Plan ahead with FRB membership (minimize) on call	- **Contractor reliance prior System I&T** - Combined Sysem I&T at AFRL - Rely on PFRs, FRB Held if needed
	Corrective/Preventative Action Board	Internal process (tailorable) external to program. **Identify issues to program for risk assessment decision.**	- **No C/PAB**
	Alerts and Information Bulletins	Standard in house process/system **passed to program for their assessment and response. Ability to bypass institutional holds**	**Engineer Pool & Lessons Learned tracking/sharing** of historical/systemic problems

Considerations: Processes (Notes)

This table lists the 16 mission success processes for mission success and tailoring for Class C-D type missions compared to AFRL's approach. The mission success processes can be grouped under three categories: (1) Program Execution; (2) Risk, Oversight, and Assurance; and (3) Triage, Information and Lessons Learned processes. The bold highlights key industry and AFRL tailoring.

1) Program Execution: Minimize CDRLs; MA focused on higher risk with audits; reduced margins, Predictive reliability analysis and PSA; and off-nominal TAYF. AFRL focus is independence at the I&T level, ownership of high level requirements and risk decisions, environmental vetting, and testing to reduce infant mortality.
2) Risk, Oversight, and Assurance: PM continuously manages programmatic risks, bounds technical risk, supports small peers with integrity audits, supports a delayed risk posture and commercial build/test/fix approach, ensures SQA compliance to process, and pre-verifies subcontractor ability to perform. AFRL has minimum involvement at this level, keeping a focus on key milestones and top 10 risk/mitigation lists.
3) Triage, Information, and Lessons Learned: Customers collaborate on FRBs not approval, and systemic corrective action boards/Alerts reviewed for risk impact only. ARFL relies on contractor best practices prior to System I&T, and uses engineering to focus efforts.

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Considerations: Agency Comparison

Question	NASA (AMES/JPL)	MDA	ORS	STP	AFRL
Mission Success Rank	(A) Threshold (J) Tailor 4Ws not HOW - App., Relationship, - I&T+	Same all programs	Cost /Schedule/ Acceptable Risk/ Threshold Performance	Cost/Schedule absolutes, technical negotiation	Threshold based Chief Engineer trades SPFs with programmatic (Conops)
Contractor MS Process	(A) Safety, Best practices (J) Best practice but risk rating control	Oversight of all 16 processes	Contractor Best practices based on empirical evidence	Contractor Equivalent Processes with gate spiral down comments	EDTS, workmanship, for contractor build not AFRL insight
Risk Management	(A) Joint RMB trade risk vs. resources (J) Rate all mitigate less	Chief Engineers own, accept, classify risks	- Partners manage risk - Mitigation high/mod - Quarterly RMB	Critical programmatic - 1 wk., $10K Design to D, Build to C, Test to B, cost to D	- Risk-MA awareness (accountability) - Failure judged by knowledge gained
Standards Followed	(A) NPR8705.4 min (J) FPP/DVVOP/HQ Aligned - Too Many CDRLs - FAR driven - Appraise of risk	Internal Standards with MAP tailoring for mission	- Proven mission partner practices - Gates entry/exit criteria support payments	- Focus is on intent of standards - Look for innovation	Critical Contractor build documents only
What Works	(A) Collaborative risk & opportunity mgmt (J) Systems team, advisory board, test less analysis	Engineering diligence, discipline and focus	SMES use risk to focus resource allocation	- STP I&T Focus - 200 hours week in life	- Independent I&T - Single stakeholder - Risk/Reqmts trade - Simplicity, best practices, peer
What Doesn't	(A) TAYF/FAYT nominal (J) Poor teamwork, inexperienced sub, tailoring struggle	- Unknown-Unknowns - Part failure biggest problem (envir)	Interference from other government agencies	- Schedule failure 300% - Cost failure 200% - No technical failures	- Critical C&DH, TT&C - Minimum practices, - Quick non-elegant decisions

Considerations: Agency Comparison (Notes)

This table summarizes agency survey response, with the exception of GSFC, which is captured separately. A notable outlier for nearly all responses was MDA whose mission criticality treats all missions regardless of class, or operational or demo nature, like a Class A or B mission class with minimum roll off of standards or processes.

All the agencies agreed on threshold performance for mission success with a focus on the “What” and not the “how” to perform. Contractor MS process focus was on contractor best practices controlled by either risk ratings, empirical evidence, and outside SME spiral burn down. The spiral burn down was an interesting STP approach where the initial PDR level reviews were treated as Class A. The subject matter experts’ comments were then accepted or rejected based on mission applicability. Risk management was a partnership between the customer and contractor with risk management boards trading risk vs. resources, mitigation of high/moderate risk only, and a close focus on eliminating programmatic risk vs. bounding technical risk. AFRL was the only agency that discussed failure acceptability based on the knowledge gained as long as you got the data down. Requirements implemented ranged from NASA NPR 8705.4 and internal practices for the NASA centers to internal contractor practices for the NSS agencies. What works was more unique across the agencies. Key concepts included: collaborative risk and opportunity management; advisory boards; SMEs’ focus of risk efforts; and indigenous T&I, with extended operational burn-in. What doesn’t work was also unique across the agencies with key issues including: sunny day TAYF; poor teamwork; outside interference; programmatic failures; dipping below minimum practices; and the inability to perform quick non-elegant decisions.

Considerations:
Class D Constitution

Question	NASA GSFC Class D Constitution
Mission Success Rank	• Mission success ranks high, **GSFC policy states failure can be tolerated (lower cost/more missions)** • Not expected to decrease Ps • PIP Threshold performance • Mission objectives / Success requirements - internal SMAP/Updated MARs for initial recipe
Contractor MS Process	• **Contractor practices trust, compromises under evaluation** • SW safety critical items and limited mission critical compliance • Performance based MAR relevant mission critical HW-SW requirements • Commercial parts commensurate with cost, lifetime, criticality, derating, redundancy
Risk Management	• **Senior Executive Champion (SEC)/ advisory development to PIP** • Risk-informed: Design/build-to-cost trading science, lifetime, minimum compliance • implied use of mature technologies for all components • Single string, proto-flight testing, limited EMs and spares
Standards Followed	• **AS9100 Compliance with commercial standards** • Narrowed CDRL/updated MARs - no requirements beyond customer • Project relevant GPRs guidance for execution • Combined SRR-SDR, PDR-CDR, TRR and MRR/ORR
What Works	• Proposal Credibility • Performance Floor • Project level authority • **Clear communication, timely decisions** • Product oriented processes, minimum development distraction, low overhead • Expert advise-stewardship: Design and execution to cost • Maintain the thee legs of the stool Project, Engineering, and tailored S&MA working hand in hand
What Doesn't	• **Excessive Reviews** • **Forced GSFC policies adherence** • **Substandard performance by any Project team member**

Considerations:
Class D Constitution (Notes)

The GFSC Class D Constitution effort focused on restoring competitive posture with regard to developing and winning Class D projects. Class D programmatic and technical integrity can be achieved by removal/modification of high overhead processes. The Constitution focused on a Simplified Class D and an Enhanced Class D. Enhanced D is closely aligned with the objective of this topic team.

1) Mission Success Rank is in alignment with other agencies with the caveat that the process is ongoing with internal SMAP and updated MAR recipes not yet developed.
2) There is more trust in contractor practices but the process is ongoing to determine relevant mission critical HW-SW requirements, compromise in evaluation
3) Risk is championed by having a single Project Implementation Plan with executive oversight to ensure the latitude of the PM is in alignment.
4) Standard implementation is focusing on the basics such as AS9100 compliance. CDRLs will be narrowed but that determination is not yet made.
5) The foundation of the Class D Constitution is early credibility using a preliminary project implementation plan that establishes a performance floor, project level authority, timely decision process, streamlined processes, stewardship and maintaining inter-discipline collaboration.
6) To increase Class D competitiveness excessive reviews are to be avoided, adherence to the many NASA and GPR requirements waived, and strong collaborative teams with appropriate expertise and project/mission mindset.

Class-D Definition

- Missions that have a low-to-moderate risk tolerance from experiments, demonstrators, and explorers to gap fillers and quick response missions. MA standards are based on contactor best practices meeting the intent of standards with with a low to moderate contractor risk profile. They have low cost, are of low to moderate complexity with reduced threshold based performance objectives. Contract types for these systems are typically a combination of cost plus for new development such as instruments and fixed price for spacecraft buses with a mission life of weeks to <1 year.

Mission Class “C” Relationships

- Share moderate acquisition risk with Class C
- Moderate risk profile denotes acceptance of green and some yellow 5X5 risks that have bounding knowledge.
- Enhanced D missions have low to moderate significance with broader purpose and objective than Class C
- Enhanced D efforts are more organic, managed differently, have small empowered teams, and are contractor best practices driven
- Mission life from <1 year vs. Class C baseline up to 5 years
- Limited milestones with reviews center on advisory boards and peers
- Minimum non-flight development hardware
- Lower acquisition cost range

Mission Class “C” Relationships (Notes)

The element of the Class D template captures a a definition for the enhanced D composed of the previous characteristics and considerations.

The Class C relationships examines the similarities and differences with Mission Class C. They share a moderate acquisition risk but manage it through different means with bounding of risk with selective mitigation. The Class Ds have a much broader purpose and objective, are more organic in nature with leadership and management structured with small empowered teams using internal best practices for execution. Mission life is shorter allowing a more bounded risk approach, oversight is limited based on advisory boards and localized peer reviews. The designs are nominally capability based supporting minimum modifications. Acquisition cost has a much lower range than Class C, although the upper range at $250 million overlaps the Class C mission.

3. Summary

The team effort concluded with the presentation of findings at the 2013 MAIW plenary session. Key findings from the survey shaped Class D profiles: (1) 75% of the responses, programmatic risk outweighs technical risk which had bounded uncertainty; (2) many programs rely on contractor best practices meeting the intent of specifications and standards; and (3) program objectives are streamlined to focus on threshold performance. Based on the tabulation and understanding of survey results, the team developed an "Enhanced Class D Template." The template and associated implementation recommendations can be used by acquisition agencies to support planning of Class D acquisitions, as well as at program startup up to reach alignment with the contractor team on program priorities and run rules. The Enhanced Class D Template may also be used throughout the program to maintain focus of essential Class D priorities.

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4. Acronyms

SRR	System Requirements Review
PDR	Preliminary Design Review
CDR	Critical Design Review
TRR	Test Readiness Review
CTS	Consent to Ship
TRB	Technical Review Board
ERB	Engineering Review Board
MRB	Manufacturing Review Board
FRB	Failure Review Board
ICD	Interface Control Document
DOORS	Dynamic Object Oriented Requirements System
ATP	Authorization to Proceed
CM	Configuration Management
DM	Data Management
BU	Business Unit
TMR	Technical Management Review
ToX	Team of X (Formal SME and peer group)
SE	Systems Engineering
PMO	Program Management Office
CD	Conceptual Design
PD	Preliminary Design
DD	Detailed Design
STE	Special Test Equipment
REA	Responsible Engineering Authority
RE	Responsible Engineer
ENB	Engineering Notebook
MA	Mission Assurance
MS	Mission Success
NSS	National Security Space
NASA	

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5. Definitions

A specification	Top level mission requirements document typically owned by customer even if it is prepared by contractor
B specification	Major element level requirements such as a spacecraft bus or mission payload
C specification	Significant subsystem such as: power, propulsion, processing, sensing, etc.
Mission Assurance	The disciplined application of proven scientific, engineering, quality and program management principles towards the goal of achieving mission success.
Mission Success	The achievement by an acquired system (or system of systems) to singularly or in combination meet not only specified performance requirements but also the expectations of the users and operators in terms of safety, operability, suitability, and supportability.

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6. References

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3. B. Bjorndahl, TOR-2010 (8591)-18, Mission Assurance Program Framework, 30 June 2010

4. NPR 8705.4: Risk Classification for NASA Payloads, 7/9/2008

5. DOD-HDBK-343: Design, Construction, and Testing Requirements for One Of A Kind Space Equipment, 2/1/1986

6. L. F. Hall and M. D. LeGoullon, TOR-2006(3907)-541, Best Practices for Fast Acquisitions of Space Systems, 10 July 2006

7. TOR-2011(3907)-20, Rapid Pathfinder

8. Constitution for In-House NASA Goddard Space Flight Center Class D Projects, 26 March 2013, http://director.gsfc.nasa.gov/classd.html

Appendix A. Key Considerations for Mission Success for Class C/D Missions Leading with Class D

This appendix represents the set of survey questions created by the MAIW team and used at each of the identified organizations that participated to facilitate discussion and record approaches to Class C and Class D Missions. Survey results (answers) can be found in Appendix B.

1	**Primary Question:**	**Where does mission success rank among the program objectives on an experimental or technology demonstration mission (commonly referred to as a Class C or D mission)?**
	Supplemental Questions:	Does meeting cost and/or schedule imperatives eclipse mission success imperatives?
		Do you typically include missions success or mission assurance requirements in the program requirements (e.g., in the SOW, in the TRD, via compliance documents, through oversight, etc.)?
		Do you break down the mission into separate mission objectives with associated success criteria?
		How is risk factored into your considerations of mission success considerations, if at all?
	Example Approaches:	Class D program mission success can be defined as successfully completing a mission events campaign, collecting mission data for XX months, or completing a one-time activity such as a deployment, a docking, or a performance characterization.
		Class D program mission success can be defined as successfully completing one of several mission objectives (but not all).
2	**Primary Question:**	**Which of the listed MA processes should be trusted to contractor best practices (versus through specification or oversight) on a Class D program?**
	Supplemental Questions:	Is there something on the list (excerpted below from the TOR) which you would eliminate from consideration on a Class D program?
		Is there something you would add to the list for a Class D program?
	Example Approaches:	Class D programs typically cite compliance documents in the context of “meeting the intent” or “guidance.”
		Class D programs typically compel the delivery of very few MA-related contract data items (i.e., no SW dvlpmnt plan, no risk mgmt plan, no master test plan, no EVM reports, etc.).
3	**Primary Question:**	**How is risk managed on the program?**
	Supplemental Questions:	Will risk be formally identified and managed?
		Can risk be traded against other program objectives?
		What level of risk is assumed/approved on a Class D program at program start and do you distinguish between mission risk and program/execution risk?
		Is risk managed through formalized tools or through informal tools (e.g., spreadsheets or presentation charts)?
	Example Approaches:	Program office acknowledgement of moderately high or high risks with a focus on a key technology or mission objective.
		Program office explicit association of risk with one or more MA activities.
		Program office invocation of risk management standards such as ISO 17666.

4	**Primary Question:**	**Do you identify Class C and/or D program characteristics in accord with industry, government, or internal standards (e.g., DoD-HDBK-343, NASA instruction 8705.4, Aerospace TORs, etc.) and establish contractor expectations as an outcome?**
	Supplemental Questions:	Do you have or refer to formal program MA activity expectations associated with Class D or experimental missions?
		How does your identification of program characteristics and contractor expectations influence the contract data requirements set?
		Do you believe Class C/D missions would benefit from having formal MA activity expectations associated with such programs?
	Example Approaches:	Invoke Class D characteristics as defined in 343 or 8705.4.
		Explicitly allow or require contractors to define mission assurance objectives and associated approaches/processes.
5	**Primary Question:**	**What program behaviors/approaches have you observed which you believe to be strong contributors to mission success?**
	Supplemental Questions:	What has worked superbly well?
		What risks were worth taking?
		In hindsight, are there any risks that should have been taken or less aggressively avoided?
6	**Primary Question:**	**What program behaviors/approaches have you observed which you believe compromised or negated mission success?**
	Supplemental Questions:	What has failed or led to failure?
		What risks were taken that would not be taken again?

Appendix B. Key Considerations for Mission Success Survey Results

Question #1: Primary	Where does <u>mission success rank among the program objectives</u> on an experimental or technology demonstration mission (commonly referred to as a class C or D mission)?
Example Approach	Class D program mission success can be defined as successfully completing a mission events campaign, collecting mission data for XX months, or completing a one-time activity such as a deployment, a docking, or a performance characterization.
Company 1	Mission success is ranked fairly high, but risk is taken to meet cost and schedule targets/constraints; usually ranked 4th or so (Technical, Cost, Schedule, Mission Success)
Company 2	Mission is the overarching constraint. Cost/schedule is secondary. There should be a paradigm change whereby cost/schedule/mission should be equal. In some cases, cost should be the guide.
Company 3	Mission Success as the primary goal on any program. For a given program class mission success needs to be defined in an appropriate way. Class D's are by their nature technology demonstrators. Often no one knows what can be reliably achieved and the effort is to determine those parameters. It is important to work with the customer to define success criteria that make sense for the specific program.
Company 4	Need to distinguish between threshold success vs. full mission success. Risk decisions are based on these definitions and determine the allowable degrees of freedom. Threshold success required that space vehicle create an impact plume; full mission success required separation from the spent Centaur rocket and collect scientific data within the plume. Due to cost concerns, the program manager decided not to qualify the detachment mechanism because separation was not required for threshold success.
Company 5	Mission success is still the priority. We don't want the mission to fail. There are a lot of moving pieces on a program. We perform activities to increase confidence. Steps taken to keep management and/or the customer involved is expensive. The more people involved in decision, the higher the cost. Complexity, heritage and willingness to take risk are all factors. We ask: Why do we perform an activity? Is it value added? For example, how useful is a failure review board on a Class D mission? Is it worth the cost/time? Risk management: How complicated is the process? How many people are on the risk board? How long does it take to make decisions? and can we trust suppliers in their risk process? Depending on the nature of involvement, customer engagement in the risk process could adversely impact cost. Reuse instituted whenever possible. The amount of reuse will directly affect reliability.
Company 6	Mission Success is always defined as meeting the customer's ultimate objectives, typically defined as a small number of quantified goals or system capabilities provided explicitly in a customer requirements document. Meeting these objectives, however specified, are always the highest priority, especially on Class D programs because they may comprise the bulk of the customer's requirements. The particular activities and methods associated with the design, construction, and verification of the deliverable products can be influenced by formal mission assurance requirements. The sources of mission assurance requirements can be internal, customer specified, or both. It has been our experience that expectations for MA processes and rigor can change between the pre-award (pursuit) environment and the post-award (execution) environment. Mission Success is also manifested as an eponymous organization that provides specific contributions to each and every program. These contributions take the form, primarily, of independent technical advice and the awareness/management of failures or problems. Mission Success is a funded participant on all programs commensurate with the program's size, life cycle state, and the nature of the contract deliverables.
Company 7	Stays very high. Process and other criterion is different as adjusted by customer requirements.

Question #1: Primary	Where does mission success rank among the program objectives on an experimental or technology demonstration mission (commonly referred to as a class C or D mission)?
Company 8	Company has CEO executive policies. We will not sacrifice MS for the cost of the program, or the schedule of the program. We will not sacrifice MS beyond what the customer has indicated as consistent with mission objectives, e.g., single string satellite. Customer dictates the limit.
The Aerospace Corp	Schedule is driver; got to make launch date as a secondary payload. Cost is a constraint but can request additional funds if really need. What is the definition of failure for a tech demo? MS criteria are negotiated with customer as objectives with flexibility built in. Risk only if everything is new. Usual approach is having a bonified bus and processor that has flown before and then add new hardware without jeopardy of mission failure. Iteration with each mission is key for cubesats mission with a launch rate of 2-4/year. Collaboration with the customer, i.e., funding source, is imperative.
LCROSS PM	Distinguish between threshold success vs. full mission success. Risk decisions based on those definitions and determine the allowable degrees of freedom.
Ames (LCROSS)	8705.4 criteria. LCROSS: moderate high risk with a 50/50 Ps; Class D; no MA Requirements; just safety. Additional testing since time allowed.
MDA	No difference between experiments and operational missions
ORS	Schedule (responsive space; meet urgent needs) driven by: JFC timeliness requirements; enable with capabilities based approach; threshold performance (good enough capabilities); design to cost (Congress production cost goals - ORS3 $40M SV and $20M launch); acceptable risk (decided by tailored MA processes, Single string, 1-3 year design life.) Priority: Cost, Schedule, Acceptable Risk, Threshold performance. Mission: Reconstitute loss capabilities, augment surge, fill gaps, exploit innovations, respond episodic events, enhance survivability and deterrence.
STP	Going in concept is what are you going to acquire and how many resources you have to acquire it. No correlation between mission assurance and mission life. Class A is just insurance. Don't need all the rigor or knowledge. Schedule and cost rules but MS as chosen between B, C, D is in the trade space. 2 year POP. Cost design to Class D; Build to Class C; Test to Class B. Objectives presented in the TRD/RFP with the key being to get “data down to the experimenter;” with graceful degradation and responsive space to allow flexibility in objective to allow for appropriate trade space.
AFRL	MA defined as deliver the promised technical content to the promised cost in the promised schedule. AFRL good track record to this objective. MA uses SQIC definition. Cognizance of Class A with a budget of D. Class D payloads on ESPA rink are a challenge when primary Payload is class A. Expectations moved from “Do no Harm” to “System Must Work.” Primary objectives, Mission Success criteria – High level mission requirements with minimum threshold. Both agree prior to Broad Area Announcement how we are going to measure MS, drive low level criteria. It is an art to be successful. Consequence of failure relative to this – learned objectives are not a failure. Measurable metrics to the objectives (objective and success criteria) require very specific wording. Primary importance is the primary objective, but they are constrained by cost and schedule. Focus is experiments with individual hosted technologies. Entire satellites - explore, test, and evaluate technologies for future operational missions and in some case for technological readiness as a technology transition. Risk is calibrated in accordance with the mission. Flow requirements, but there is no system or reliability number. They do not do FEMCAs, everything is single string. 1yr missions with 3 to 5 yr expectations with consumable never limiting the lifetime, Sized for 2 years. Total mission cost are typically $90M to $150M including launch and on-orbit experiment. Systems should be as simple as possible.
JPL	Mission success is high for all classes. Need to define what constitutes a Class D. Class D requirements are scaled down, but overall

Question #1: Primary	Where does mission success rank among the program objectives on an experimental or technology demonstration mission (commonly referred to as a class C or D mission)?
	need MS. In tailoring, start with standard process and evaluate risk. Reduce scope. JPL targeted at Class B. Looking at tailoring now for Class D. Plan to have one approach to do something not different ways to do it. You either do or don't do them. Can tailor for example problem failure reporting starts at 1st power on in Class B, but in Class D at system test. Have pillars of reliability. Can tailor the who, what, when and where. For example no change in inspection method. Don't tailor the how.
NASA HQ	What is Mission success on a tech demo program? The mission success criteria? Criteria is to teach and learn, regardless of outcome of tech demo.

Question #1: Supplemental	Does meeting cost and/or schedule imperatives eclipse mission success imperatives?
Example Approach	Class D program mission success can be defined as successfully completing one of several mission objectives (but not all).
Company 1	Frequently yes, but not always. We have spent extra funds and schedule to make sure that a single string or high risk item was going to work.
Company 2	Mission rules the roost
Company 3	Most often cost and schedule will be key measures of Mission Success. Technical requirements will generally be goals and not hard requirements. For example, a top level requirement may be stated as “Perform a meaningful demo of sensor performance in a relevant environment at the agreed to cost/schedule”
Company 4	No data
Company 5	No data
Company 6	Mission Success is defined by meeting program objectives. This definition may not match with definitions by others. We also had 24 requirements that were not crisply defined. We were tailoring our Mission Success plans and Quality plans, e.g., AS9100. If vendor was not certified, we handled risk designated the vendor as a watch item. We watched our flowdown requirements to the vendors and evaluated the impacts (cost and schedule). We were holding payload to Class D level, bus to Class C level. It influenced the amount of testing performed. We required less verification at the system level for the Class D payload, relative to what we would normally do for a Class C payload.
Company 7	Cost and schedule don't eclipse requirements.
Company 8	Constantly trading risks/mission performance in a redundant system causes loss of redundancy, trading - even then pretty conservative, vs. mission success.
The Aerospace Corp	Will trade technical capability if schedule is an issue. Trade aspects of Mission Success against delivery.
LCROSS PM	LCROSS threshold success – impact plume, full MS separate from spent Centaur rocket and collect scientific data within plume; decided not to qualify detachment mechanism because separation not required for threshold success.
Ames (LCROSS)	LCROSS driven by $80M cost cap; willing to take risk since free ride; risk tolerant.
MDA	Cost/Schedule drivers; MS sacrifice entertained.
ORS	Yes
STP	Schedule driven. In most cases STP doesn't make the decision: 40% bus, 10% I&T, 5% to margin, 30% payload etc. Independent review team has funding constrained as specified level of effort. SMC requirements have to be pushed against. STP budget was $50 M in 2011; now <$35 M in 2013. Cost growth for a specific program impacts future programs, and may even represent lost opportunities. Focused in program empowerment & consistency in decision making. Since STP is level loaded. You rob peter to pay paul to an extent for the most current and earliest to launch. Schedule/cost is highest priority. Define acquisition risk using a 5X5 matrix in the beginning and do not revisit, that is what was bought.
AFRL	Carefully, will trade conops for cost and schedule. Chief Engineer is empowered to make the decisions for risks, costs, schedule, performance. Nearly every mission flown has some risks in the “yellow” - typical to fly with some amount of risk.

Question #1: Supplemental	Does meeting cost and/or schedule imperatives eclipse mission success imperatives?
JPL	Class C missions always limited in cost and schedule. In design, cost and schedule remain a high priority, then carry margin. In implementation, decisions are driven by cost and schedule. When in I&T things shift a bit. You really want insure mission success further “as you are close”. Always interact strongly with contractors in a badge-less fashion. In class D many times contractor interaction is more “What do you already have?” Brand new things tend to be in-house. Buy less risky thing from industry. Limit risky parts overall in class D. For example, control scope to envelop class requirements during formulation phase.
NASA HQ	No. Design and define for mission success criteria.

2nd Question #1: Supplemental	Do you typically include missions success or mission assurance requirements in the program requirements (e.g. in the SOW, in the TRD, via compliance documents, through oversight, etc.)?
Example Approach	Orbital express had 23 objectives that were also criterion used to determine success.
Company 1	Yes. Mission objectives are often called success criteria. For example, the program had 23 objectives that were also criterion used to determine success.
Company 2	For experimental; typically doesn't have specific requirements. Implied, not spelled out
Company 3	For a class D program we would not expect to have any prescriptive MA or process requirements. We would expect the customer to specify in house/industry best practices
Company 4	No data
Company 5	No data
Company 6	We negotiated our command media internally and got buyoff. Some parts successful, some were not. Term “Reference” was helpful in tailoring approach. We verified by high level test.
Company 7	Yes. Should be our experience the customer is leaning on.
Company 8	Yes. In spacecraft not launch vehicles– standard product assurance requirements – in SPAR – pre-tailored by mission class. But not Company standard for all programs – lower class missions generally manage smaller subset of their risks. Guidance does not tailor but the implementation does.
The Aerospace Corp	Negotiate the SOW in terms of what can actually be accomplished vs. being dictated a capability requirement. Experience in engineering a need and having collaboration with funding agent may actual result in a better solution than dictating a solution.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	Yes
ORS	Case by case with empirical evidence.
STP	Environmental testing: 1540E –contractor recommends tailoring and then adjusts what testing to do in environmental plan, testing notching, and modified EVM. Meet the intent of tests depends on leadership environment since get a new director every two years. Sculpt what you want to be, and work to keep in place. Buy commercial buses – understand what is different and what is equivalent.
AFRL	Always conserve. PM on contractor side. Example: Always deploy a cover but afterward never specify a system reliability. Specifically: “Fly a redundant telescope cover opening.” This was not initially prescribed but as part of the design process. Also address specific places not comfortable with. Mission lifetime for product vendors, certainty of on-time performance, at kickoff do risk calibration. TT&C radio must work. Proven component waiver.
JPL	Yes
NASA HQ	We do this, but maybe it really is not a Class D space vehicle.

3rd Question #1: Supplemental	Do you break down the mission into separate mission objectives with associated success criteria?
Example Approach	No data
Company 1	Yes
Company 2	Yes
Company 3	Mission success criteria both technical and programmatic would be developed in concert with the customer and defined at contract negotiation.
Company 4	No data
Company 5	No data
Company 6	Difference in level of oversight required and level of ownership of buyoff. Influences level of auditing. Can meet intent vs. strict compliance. Ownership of meeting intent determined by the payload.
Company 7	Yes. The same as any class goals or sub goals in general
Company 8	No. We have weighted objectives. Generic set of weighting on objectives and share with our customer - robustness vs. life for their GEO birds. Break interim of outage, performance, lifetime, capacity in commercial discrete success criteria.
The Aerospace Corp	Usually define specific objectives that we know can meet with existing technology and then strive to exceed expected performance.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	Yes
ORS	Yes. We do multiple objectives and prioritize
STP	Don’t have 15K requirements. Narrow objectives and make value judgments. Graceful degrading objectives.
AFRL	Yes. Every program is unit with unique mission success criteria and programmatic constraints. Application of MA processes must be unique to a given program.
JPL	Yes Class has multiple level 1 requirements. Depends on type of mission. Even with D you may have different risk elements.
NASA HQ	Yes. Done for all of the missions, but for true Class D missions, so should not?

4th Question #1: Supplemental	How is risk factored into your considerations of mission success considerations, if at all?
Example Approach	No data
Company 1	Risk is not really factored in, other than to acknowledge the risk could result in limited or no mission success if realized.
Company 2	Yes – a risk register used to track risk and is tied to mission success. On ORS, risk is tracked at program level and discussed at program reviews.
Company 3	Risk in achieving Mission Success is a key factor in determining success criteria. We strive for 100% MS on all programs. Criteria need to be defined that make this possible.
Company 4	No data
Company 5	No data
Company 6	Level of technical authority moved downward. On Class A, customer is matched 1:1 to buy off requirements; on Class D there is much less customer oversight. Greater level of trust granted to contractor on Class D missions. Less formal reporting required. Design authority approval not required to technical peer for every minor detail. Limited customer attendance, approx 5-10 to where it was manageable.
Company 7	Separate mission risk from program risk. Program risk may use more informal methods are used. Use experience and knowledge balanced by test (for example).
Company 8	Corporate guidance document that governs how manage risk. Programs obligated to use, not guidance on corporate management risk but year ago corporate risk management at the product line, business unit, and enterprise level. Evolving processing as we close higher level and at the program level (EERB1). Layer risk management appropriately.
The Aerospace Corp	Risk is considered in design approach. Risk only if everything is new. Usual approach is having a bus and processor that has flown before and then add new hardware without jeopardy of mission failure. Iteration is key for cubesat missions, using parts/components with previous flight history and adding in new capability or technology. We can do this because of launch rate of 2-4/year. Provides a no lose strategy.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	Mission Readiness Review (MRR) for each flight test. Risk discussed and vetted through Risk Review Board; mission risks require MDA director approval.
ORS	Empirical evidence, current systems going strong, works - ORS-1, TACSAT 2
STP	Risk defined upfront. Establish a baseline and then what it delta from that baseline. Low risk tolerance to cost growth, cost and schedule growth more important than technical. Risk is a negotiation. Make the trade will to fix or told to fix comes down to within tolerance.
AFRL	Tenet is that single stakeholder/primary owner. Owner = risk owner. Less complex systems with low integration. Based on the risk management posture of the program. Historically not all satellites are high priority, long life, SMC-class programs. Still have a requirement for high reliability. Trade risk for cost-savings measures in design, review, manufacture, test, etc., Rely heavily on contractor best practices. Small PM/eng organizations with engineering pod & operations cadre.
JPL	Basic management process is based on risk. Try to identify risks and mitigation early and continuously. Programmatic and technical risks, aware of both. Mission Success allocated more with scope. Based on level 1 requirements. Reviewed different program examples from just deliver to get on orbit and start data capture.
NASA HQ	Class D has unbounded risk. For “in between mission” for things expected to work there are standard risk management processes.

Question #2: Primary	Which of the listed MA processes should trusted to contractor best practices (versus through specification or oversight) on a class D program?
Example Approach	Class D programs typically cite compliance documents in the context of "meeting the intent" or "guidance."
Company 1	To give the contractor greatest freedom in addressing mission success in context of the cost and schedule constraints it is often best to let them determine the success criterion and management approaches. Different programs often use different approaches based on risk tolerance of the customer or individual PM.
Company 2	No data
Company 3	All MA process should be per contractor best practice on a Class D program. Company strives to have a open relationship with customers. Process command media can be reviewed and customer surveillance allowed as requested
Company 4	Safety was the one mission assurance process that was a hard flowdown. This was interpreted as follows: If it impacted anything outside of the space vehicle e.g., the other satellite flying on the same rocket; hazard to personnel; harm to NASA reputation, then the Company deferred to NASA. We could do no harm outside of the mission itself. On other items, we used our best practices. For example, sending someone to conduct a source inspection may not be as cost effective as having the vendor ship the part to us and inspecting it in house.
Company 5	Need to use some judgment. For off-the-shelf items, why not use contractor best practices? If the contractor is normally a Class A provider, let it use its best practices. In the subcontractor arena, let trusted suppliers use best practices. Limited resources should be used to help the weaker suppliers, not evenly spread across all vendors.
Company 6	All MA processes should be trusted to the contractor on a Class D program. All such processes should be identified and described/negotiated early to demonstrate the adequacy of contractor processes in supporting program objectives and in establishing customer confidence in the contractor's processes and people. Often the success or failure of an activity on a Class D program is more dependent upon the people comprising the program team than it is on the contractor's processes.
Company 7	All, with the possible exception of system safety (e.g., secondary payload) where it affects other systems.
Company 8	We have a flow down requirement for everything in the 16 areas with the exception of qualification and certain required program assurance requirements where we trust all the requirements to subcontractors. Some parts, materials and quality inspections where there is not rigid compliance with standards and qualification as well. Qualification envelopes the MIL, NASA, and ESA standards, Protoqual, Protoflight, and ATP.
The Aerospace Corp	Use best practices as defined and refined in the laboratory. Schedule limitations sometimes require to cut corners on some of the processes where there should be more rigor – system engineering, test cut short, etc.
LCROSS PM	Safety flowed down; cause no harm to space vehicle and personnel. NASA reputation, on the line Company deferred to NASA. Other items best practices.
Ames (LCROSS)	Safety & build best practices; no NASA mandates; small project team; insight only; contractor experimental category matches.
MDA	MDA maintains oversight of all 16 process areas for all programs.

Question #2: Primary	Which of the listed MA processes should trusted to contractor best practices (versus through specification or oversight) on a class D program?
ORS	Tailored & selective based on expert knowledge to achieve confidence in MS consistent with ORS objectives with proven standards and policies. ORS does not duplicate MA and flight certification that is adequately performed by other organizations or their systems: Partners follow their internal processes and ORS participates in mission reviews and provides status and recommendations on readiness. Trust but verify. If familiar with established practices then allow. Generally defer to acquisition agent processes. EX ORS-3 uses STP-3 spacecraft and STP processes. Contractors have reputation to maintain, therefore tend to trust them. Requirements Analysis/Validation: TRD for ref and validation but not formal performance requirements; PDR/CDR for design assurance; and not engaged in manufacturability I&T Eval: data review; anomaly resolutions; Ops readiness: early orbit rehearsals; TRRs and SV Preship; Risk by subsystem; Reliability not considered; configuration management have no visibility; no active PMP management; quality assurance no role; MSPSP required; IRRT for flight software assessed low risk.
STP	D project: do not relying on standards. Consistency in leadership and decision making. Give industry room for trade space and process trades with some validation and understanding of what is going on, what meets the intent, and what doesn't. Acquire contractors standards and their practices. First litmus test use contractor equivalent; are they equivalent. SIV number to target. Not going to specify something subjective - reliability, consumable, or something along that line. No oversight of contractor processes. Some insight. Heavy participation in integration and test. Typically no insight into subs. There is NO Aerospace insight clause flowed down beyond prime. Maintain good relationship with contractors because PMs are not that senior (young officers) 99% of time infant mortality – first level of defense; 2nd level who cares about the data, 3rd government trying to do dumb stuff. Design Assurance – PDRs, CDRS bring out ETG (Independent Review) person to review SME (15 to 20) Comments are made. Run in 100-120 comment against PDR (ETG doesn't know Class). STP rejects those that are not class D/D with rationale why did not accept providing understanding of the ramification of that decision. Less comment CDR. Follow accepted to closure.
AFRL	Do not levy processes but want to know that the contractor has them. Part of the design review discussion. System engineering is not about documentation; it's about managing complexity and applying design rules. Mission safety primary requirement. Requirements owner empowered to adjust their practices for Class D. EDTS required; workmanship required; for UMP (university) – informing process for building spacecraft, program planning SE to manage complexity, craft the system. University nanosat programs is about education; informal documents may say more than formal. This program is an outlier as it is based on best effort for time, effort and experience. Want to know how they are used. Documents not written for AFRL but by the contractors for them to execute, mass, power, conops as there are many ways to accomplish; innovative ways to approach spacecraft problems. Small satellite community becoming fairly sophisticated - learning how to trade the requirements across the system. How entire system works together. Every school different but document bare minimum to handle turnover of students.

Question #2: Primary	Which of the listed MA processes should trusted to contractor best practices (versus through specification or oversight) on a class D program?
JPL	Depends on what the mission is and who the contractor is. Look at the JPL contractor relationship is and contractor capability. Idea is to push as much into contractor's process as possible. Some technology demonstrators there is high risk. There is still oversight even in Class D. Day to day system safety is still held in house (JPL) also on ISS. Preferthe contractor to own as much as possible. Do complete audit of analysis. Less things required.
NASA HQ	NASA centers responsible for rolling out dependent on mission. Typically those are included as part of the SOW, but knowing the contractor has these processes in place.

Question #2: Supplemental	Is there something on the list (excerpted below from the TOR) which you would eliminate from consideration on a class D program?
Example Approach	No data
Company 1	No, but they should be considered with varying degrees of weighting. Meeting the intent is a good way to put it.
Company 2	Execution should include government. The government should be heavily involved in requirements and should be included in changes to design or requirements. Configuration management should be managed by customer, e.g., configuration control board chair. Wouldn't eliminate any – should look at tailoring level based on program type. Example: Class D may have fewer suppliers, so may reduce process oversight/execution.
Company 3	All 16 MA processes and appropriate internal processes should be tailored and executed as applicable on every program. See comments on typical Class D.
Company 4	No data
Company 5	No data
Company 6	We were basing decisions on duration of mission.
Company 7	All should be considered with appropriate tailoring
Company 8	Little experience with Class D. Program verges on Class C and did not expect anything to be tailored. Go through process for supply chain, minimize design reviews and gate reviews. Do something in each area - Nothing in configuration management flowed to Subcontractors.
The Aerospace Corp	Desirement is to have more time for more formal system engineering processes. Small teams and limited schedule prevent formal process implementation and documentation. No PMP program – primarily use COTs components. Testing is limited to vibration and some thermal cycling at ambient pressure (no thermal vac) – small satellites don't have big coefficient of thermal expansion mismatches. Software development plan is not likely a reality with one developer. Plans required as teams get larger and more developers involved. No formal reliability requirements, although experience has led to design with redundancy in critical areas: power systems; flight computers, and communication channels are good examples.
LCROSS PM	Beyond safety trades made for instance in-house inspection vs. source inspection at vendor.
Ames (LCROSS)	Collaborative, no edicts, transparency, candid, on-site liaison eyes engendered trust, I&T completely indigenous, self reporting
MDA	No. Would not recommend pulling any out.
ORS	Collaboration should be more than the IPTs, better/closer working relationship with contractor. No hammer to sponsor relationship of “We are thinking about doing; What do you think about it?”
STP	FMEA being tailored out.
AFRL	No data

Question #2: Supplemental	Is there something on the list (excerpted below from the TOR) which you would eliminate from consideration on a class D program?
JPL	Sometimes we will eliminate parts requirements - have allowed commercial parts. Environment test program often tailored, and in some cases has been eliminated. Configuration management tailored for Class D. More engineering control vs. independent CM activity. Independent reviews may be done differently. Smaller number of high level reviews and look more like table top reviews. Reduce preparation time but still maintain function of gate review. Limit size of review board. How do you communicate to contractors on review tailoring? Have a review plan that flows in the project implementation plan with contractor participation. For failure review boards, JPL retains approval authority for impact to mission success. Every failure is risk rated. Allow contractor to have process, must assess risk, then elevated to JPL. Same basic corrective action process.
NASA HQ	Soften the processes, i.e., independent review, Failure Review Boards. PMP – limit to screening vs. part classification. Need to do something for all of these areas.

2nd Question #2: Supplemental	Is there something you would add to the list for a class D program?
Example Approach	Class D programs typically compel the delivery of very few MA-related contract data items (i.e., no software development plan, no risk management plan, no master test plan, no earned value management reports, etc.)
Company 1	No. Wouldn't really add anything for a Class C (Hdbk-343) mission either.
Company 2	None noted. All process areas important. process area
Company 3	No data
Company 4	No data
Company 5	No data
Company 6	Requirements analysis and verification – contractor and customer agreed upon amount, even on Class D. Contractor managed/not contractor discretion.
Company 7	None come to mind.
Company 8	Can't think of anything we would add.
The Aerospace Corp	Design assurance with cubesat mentality led to creation of redundant cubesats with exact capability. Thought is if one fails it was workmanship; if both fail it's a design issue. Because relatively cheap to build, we build a qual vehicle to test and fix flight articles. Would like to add more time for testing which often is cut short at end of program.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	No
ORS	CM is biggest weakness. Zero insight, bit them couple of times. Readiness process providing insight to the ORS director/mission partners - partner authority and responsibilities, mission risk posture, element status, verification to objectives. – system is built right: verification plan at all phases – Flight Worthiness: degree element can perform mission with confidence significant risks known, deemed acceptable.
STP	Payload requirements based on bus constraints and create envelope constraining power, mass, design requirement goals. 2 weeks to milestone charts, 1 week ETG, PDR-CDR 6 months- kickoff-4 – 5 months SRR PDR, 9 months CDR, 1 yr. delivery. STP paradigm being challenge with SMC SPO model very difficult.
AFRL	No data
JPL	Perhaps contamination control.
NASA HQ	No.

Question #3: Primary	How is risk managed on the program?
Example Approach	Program office acknowledgement of moderately high or high risks with a focus on a key technology or mission objective.
Company 1	Larger programs use formal tools like BORIS. Smaller efforts, particularly internal research and development funded programs or non-flight demos frequently use Excel
Company 2	No data
Company 3	Program manager is risk manger. Reviewed at regular internal business reviews. Informal process with close collaboration with customer.
Company 4	Opportunity management was critical on a Class D program. Risks and opportunities were aggressively managed, and often viewed as the most rewarding part of the program. We were always looking for opportunity, and we needed to make sure that the opportunities were relevant to the program. Everyone knew that managing these risks/opportunities were critical to mission success.
Company 5	The activity of the risk management board is more important. For example, a program may choose to manage the risks via spreadsheet and that may be appropriate. This is in contrast to using a rigid risk management tool. Some other considerations: How often does the risk board meet?; How many members does it have?; and How quickly does it take to make decisions and to act upon them?
Company 6	Program managers should have the latitude to identify risks and monitor them in a method that is robust and effective. If the customer compels a formal risk management plan and rhythm, then it must be established as such. The creation of plans/boards to satisfy internal requirements (such as may be found in the business capture process) is not always beneficial. An element of risk is implicit in the nature of Class D efforts, only the truly unique and unfamiliar risks should be tracked (risk lists on Class D programs should not contain "the supplier might not deliver the reaction wheels on time").
Company 7	Risk is fully managed. It is important that it is consciously managed, but may be done so in a more informal matter.
Company 8	Have a standard process that has guidance to program and is consistently managed, defining, 5X5, reporting. Differences in number of risks the programs are ask to manager. For Class D only, request management of mission ending technical risks with risk retirement and waterfalls.
The Aerospace Corp	Weekly meetings where risks and issues are discussed as a team.
LCROSS PM	Opportunity management also critical. Risk and opportunity aggressively managed most rewarding.
Ames (LCROSS)	Monthly reporting, 3 months in discussions, 3–4 hour meeting difficult but essential with resource/schedule constraints, decisions made.
MDA	Through Engineering, Chief Engineers own, accept, classify risks
ORS	ORS defined overall acceptable risk posture based on mission concept of technology demonstration enable launch and range to reduce call up time and decrease overall costs. Low degree of design modification higher degree of similarity to commercial satellite program.Commercial launch procurement/execution vs. each mission is unique. Payload partners with secondary and tertiary payloads.Partners track risks, risk mitigation plans for all high/medium risks, RMB convened bimonthly/quarterly. Formal risk management. Triaged to yellows and watch closely. Stakeholders must understand and agree. MA is everything that makes the mission go. Risk is traded vs. objectives. IPTs manage risk and determine effect on mission. If does not affect mission, then IPTs manage, otherwise goes to director.
STP	STP does B, C, D mission, (C maybe the most). Design to D, Build to C, and test to B, cost to D. Pick and chose per the mission objectives.Document risk at acquisition on 5X5 accepted by the acquisition team, e.g., single string, tin parts, don't revisit those. Remind customer at the Flight Readiness Review. Authority is Senior Air Force in chain of command who you must convince.

Question #3: Primary	How is risk managed on the program?
AFRL	AFRL is center around D but most prove evolution to Class A. AFRLs approach back and forth in A-D paradigm. Must look at context of entire mission. None a firewall Class D, UMP (universities) D, E, F, pick and chose. AFRL/RV flight programs typically fall on a floating B/C/D scale. Money reduces risk, if it supports high fidelity mission assurance activities. Risk management and MA briefing: Get everyone talking about MA; papers on lessons learned and how we applied; rely on smart buyers; information sharing; and culture. Let top 50 float, worked by the contactor, 1–2 propagate to AFRL Chief Engineer level
JPL	Risk management process, identify, rate, 5x5 Class D projects may mitigate less. Difference is mitigation thresholds.7120.5e used. Tech authorities required to be of this mechanisms.
NASA HQ	Formal risk management process.

Question #3: Supplemental	Will risk be formally identified and managed?
Example Approach	No data
Company 1	Yes. Risks, issues, and opportunities are identified by program team members. The Chief Engineer owns technical risks and manages through risk and opportunity management process
Company 2	Yes
Company 3	Informal management with customer participation
Company 4	No data
Company 5	No data
Company 6	Risk management board and process in name only. Had very little money. Customer didn't really care about risk management, he cared about the technology. Class C/D is all about technology development.
Company 7	Not formally, should be consciously managed.
Company 8	Yes
The Aerospace Corp	Risks are informally identified to more formal identification depending on level of risk to mission impact.
LCROSS PM	Always looking for program relevant opportunities. Everyone knew managing risks were critical to MS.
Ames (LCROSS)	Clamping system identified Risk 110 days after launch; contingency due to lack of funding for qualification
MDA	Yes
ORS	Broader definition of MA to include everything necessary. For instance frequency authorization, and information assurance.
STP	Contractor risk process. For multiple payload mission STP creates government risk management plan for component risk to system, meeting monthly.
AFRL	No data
JPL	Yes. Institutional process.
NASA HQ	Yes

2nd Question #3: Supplemental	Can risk be traded against other program objectives?
Example Approach	Program office invocation of risk management standards such as ISO 17666.
Company 1	Yes. The Chief Engineer and the Program Manager have control over this process and it is usually done through an engineering requirements board and Program change board.
Company 2	Yes. Risk should be traded against cost: Cost vs. life expectancy.
Company 3	Risk should be traded within program constraints. Risk needs to be understood in the context of the entire program and managed in total.
Company 4	No data
Company 5	No data
Company 6	Risk management good until integration and test, then it becomes a formality: don't have to fill out risk management proposals, so is a less formal approach; meetings typically 1–2 hours operated informally; held at team level; keep technical focus; kept active watch list; and must be linked to reserves.
Company 7	Yes against cost and schedule. Absolutely must get the customer involved if your are trading any form of mission risk.
Company 8	Yes, have method, informal for doing risk trades for instance extended mission life. Trade solution.
The Aerospace Corp	Yes. Recently imposed a program plan with more formal budget and scheduled completion. Since imposed, there has been less risk of schedule risk and cost overrun.
LCROSS PM	No Data
Ames (LCROSS)	Yes
MDA	Not typically
ORS	Yes and have.
STP	Cost and schedule trades against technical.
AFRL	Apply intelligence where take risk, <$1M for real science investigations. UMP burn it in to get rid of infant mortality. Know what effects are - SEUs, and SELs. Some electronics rad hard (ignore), and triage on the components. Look at system level if graceful degradation is possible. Target mission needs - if how radiation effects SRAMS is the experiment ensure command and data handling robust so know data is good. PIND on bad lot of parts 3 days prior to launch - flew with bad lot after understand failure mode and probabilities better.
JPL	YES, primary in early phases, e.g., implementation verses mission risk. Program verses mission risk such as subsystem test given up if a system test in place.
NASA HQ	This is negotiated prior to program start. Trades made up front with identification of accepted risk. Unknown risks that come up may require additional resources to mitigate.

3rd Question #3: Supplemental	What level of risk is assumed/approved on a class D program at program start and do you distinguish between mission risk and program/execution risk?
Example Approach	No data
Company 1	Yes, we distinguish between types of risk (execution vs. technical). Moderate risk is often assumed at program start, with risk tolerance going down as flight approaches. No one wants to launch a brick.
Company 2	Yes. One program assessed that it will lose 20% of assets at start, and it was deemed acceptable to meet overall mission.
Company 3	Generally would have low programmatic risk because requirements/goals should be fixed. Technical risk may be high against goals but low relative to thresholds.
Company 4	No data
Company 5	No data
Company 6	Should NPR 8705 be incorporated? It would help in denoting on how much latitude can be expected by the contractor. We need to get our own company to move in that direction.
Company 7	Yes. It is hard to understand that with space product you would ever take a high risk. Moderate to medium is more appropriate.
Company 8	No stated level of risk. Basically have rule of thumb-risk balance matches the launch vehicle first. Class D is a secondary mission – hard level of risk propagation since secondary payload. Balanced risk equivalent with launch vehicle reliability and mission costs. Not a Ps 0.6 on and Ps .85 launch vehicle. Level of risk accepted by each program. High level of program risk tolerance if company money; Company risk for programmatic risks. We will fund our risks and trade in favor of our own costs.
The Aerospace Corp	The difference is between a $3M program that delivers vs. a $30M program. Risks are actively identified and preventative/mitigative actions put in place considering program constraints. Not unusual to launch with some high risks for part of the payload as these are technology demonstrators.
LCROSS PM	No Data
Ames (LCROSS)	No Data
MDA	Mission/program distinction. Test risk kept at 0.1 or less.
ORS	PS as low as 0.7 with capability based systems vs. requirements based systems. No design margins - analogous to a Class C system. Not all green, but yellows acceptable. ORS-1 shad a red at launch.
STP	Mission risk and programmatic risks; if more time manage cost and schedule risks vs. technical risk. 2% big on cost and schedule. Yellow accepted on technical. Schedule risk–a week is large. Money limits–$10K, a risk would be red. Each risk viewed independently, not how many yellows make a red.
AFRL	Missions are 1yr with expectations from stakeholder of 3 to 5 yrs. Some yellow risk is always in all systems due to architectural decisions like single string design. Work with leadership to accept some amount of risks. Medium to high risks, tailored standards, quarterly reviews, 2+ years to develop, single string, no spares, single payload, rely on parallel effort for failure plan, lowest to medium acquisition costs.
JPL	Mitigate all red risks. Still can define the threshold of a red risk. Depends on what it is you are trying to prove. What is the impact of failure. Never launch with high safety/personnel risk. Class D does much less mitigation. Depends on recovery. Most important thing is we understand the risk. Early on define an incompressible test list which is different for Class D. Do this up front.
NASA HQ	High for D; Med for C; but moderate risk tolerance is most acceptable.

4th Question #3: Supplemental	Is risk managed through formalized tools or through informal tools (e.g. spreadsheets or presentation charts)?
Example Approach	No data
Company 1	Both
Company 2	Informal tools (spreadsheets and powerpoint charts). Risks are subjective with no defined criteria for scoring
Company 3	Standard formal tools
Company 4	No data
Company 5	No data
Company 6	Would like to see Class D defined in the contract. Would let us know how big of a truck we could drive through it, i.e., set expectations on the amount of tailoring that could be performed.
Company 7	Informal tools. Simple tracking method unless the more complex tool turns out to be easy for the term to use.
Company 8	Yes. The risks are required to be managed in formal tools. No schedule and cost risks for Class D.
The Aerospace Corp	Spreadsheets and or powerpoint charts. Informal: Exception is where a large risk identified at program start that was closely watched and formally managed and discussed risk burn down to acceptable level.
LCROSS PM	Spreadsheets and or powerpoint charts. Informal: Exception is where a large risk identified at program start that was closely watched and formally managed and discussed as risk burned down to acceptable level.
Ames (LCROSS)	Be present, participated regularly
MDA	Mission risk/readiness working group process with formal tool and database
ORS	Local tools. Propagate up only if effect mission system level requirement, end product.
STP	Government risk management for multiple payloads in Excel.
AFRL	No data
JPL	Have an institutional risk tool. Not required to use tool. Have to end up on a 5x5 however. Can use excel spreadsheet. Method document in risk management plan
NASA HQ	Yes

Question #4: Primary	Do you identify class C and/or D program characteristics in accord with industry, government, or internal standards (e.g. DoD-HDBK-343, NASA instruction 8705.4, Aerospace TORs, etc.) and establish contractor expectations as an outcome?
Example Approach	Invoke class D characteristics as defined in 343 or 8705.4.
Company 1	Yes. We try to manage customer expectations but, not always successfull. On Orbital express, for example, we started with a Class C program tolerance on the part of the customer, but as flight approached the Class A mentality definitely took hold on the customer side.
Company 2	No
Company 3	Company has developed command media derived from industry and government instructions. The internal media expands on external documents as applicable to our specific products.
Company 4	We used the customer definition of Class D, per 8705.4 with the understanding that our internal practices either met or exceeded those prescribed in the NASA handbook.
Company 5	Class description is less important. How is the request for proposal written? What requirements does it contain?
Company 6	Company's experience with NASA programs suggests that program classification is typically done, via 8705.4, even for the Class D missions. It is not typical for other customers to invoke standardized definitions for Class D missions. Irrespective of the customer requirements, Company command media establishes expectations for the definition and conduct of MA activities. These expectations vary only slightly as a function of program type/size/mission class and the expectations are not directly traceable to a USG or industry specification.
Company 7	Yes. We are spending a lot of time and investment on alignment. The most important thing is that now we can have an alignment conversation with the customer. Our goal is complete alignment of expectations. This would mean that an internal system is in place.
Company 8	Company (Launch Systems) does not have a Class D; not applicable to them only have A, B, C Follow industry standards attributes of space vehicles A, B, C, D because attributes make it a class and the implementation. Failure modes and effects analysis at the unit level and a reduced set of milestone reviews. Design and readiness review goes from 18 to 4: baseline, flight readiness review; preship; and mission readiness and launch readiness reviews (one design review.) Preliminary/Critical design review hybrid. No test readiness review, no system requirements review, pre-environments, etc. Internally combine flight readiness and certification review with preship.
The Aerospace Corp	No. Don't advertise that it's a high risk program. Emphasize the high value when successful. Have a reputation of successful missions.
LCROSS PM	NASA program so used NPR8705.4 Class D understanding internal practices met or exceeded those in NASA handbook.
Ames (LCROSS)	No data
MDA	Not Typically
ORS	Proven practices of mission partners. (NASA ARC, Cal Poly, SMC/SD, ORS office), ORS SMES- interfaces, structural, environmental.
STP	Focus is on intent of standards. Context rules all a starting point. Innovate - define process and execute how manage the process.
AFRL	Contractor's best practices. Expectation they are using applicable government command media but do not levy a requirement. Expect will do a good job.
JPL	Yes. Have institution best flight practices. Define tailoring in these. Map institution practices to 8705.4. In general 8705.4 not on contract to NASA, but align/map to it.
NASA HQ	NASA 8705.4

Question #4: Supplemental	Do you have or refer to formal program MA activity expectations associated with class D or experimental missions?
Example Approach	No data
Company 1	The programs each have a mission assurance plan tailored to their customer needs and mission expectations
Company 2	No
Company 3	Formal process tailoring is performed on all programs including class D. We have general guidelines for class D but each program is individually tailored.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Yes we have a formal system.
Company 8	Require pre-tailored guidance by mission class. The corporate Class D recommends using a previous flown data rather than recreate. Other program aspects: program manager guidance are general guidance; high-level risk reviews (formal exception): process and procedure deviation by VP level.
The Aerospace Corp	Yes. Certain processes, like configuration management, are very important because of the iterative nature of building on previous missions. Incorporate a final close out sheet that is fully scrutinized (have missed some items in the past because of lack of systems engineering rigor).
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	MAP tailored for mission type
ORS	Yes. Show you format and what you do. Incorporation of processes in tailoring. Processes depend on contracting agency. Use contractor format for CDRLS. More interested into trades and whys and background.
STP	Specifications as expectations, smaller subset applicable and other guidance, meets intent. For STP bus there were 19 stds in the RFP, but the requirements were negotiated after the contract award.
AFRL	No data
JPL	Expectations verses process. Have flight project design practices and aligned to Class D. Take this documents and incorporated into flow down documents, e.g., contract. If a particular process is mandated (not usually for D) it will be flown down, but generally if contractor is AS9100 not required.
NASA HQ	Yes

2nd Question #4: Supplemental	How does your identification of program characteristics and contractor expectations influence the contract data requirements set?
Example Approach	Explicitly allow or require contractors to define mission assurance objectives and associated approaches/processes.
Company 1	Typically minimal influence. We don't want to drive cost through production of unnecessary or superfluous documentation and effort.
Company 2	Influenced by the cost and type of program. These programs have a much smaller list than traditional large development program.
Company 3	A typical class D program will have few contract deliverables, typical monthly financial and technical status only.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Data requirements set is again measured to meet overall program requirements.
Company 8	Both it is influence by deliverables (CDRLs) and influences. We use CDRL set from customer as input to their classification – 2/3 no guidance from customer on Mission Classes. They believe it doesn't influence processes, but it does since it influences our guidance if not explicit. We don't downgrade but have upgraded. One program was identified as a Class C, but criteria stated were Class B, so we followed Class B internal guidance. A, B, C flow down the same requirements to subcontractors. Class A human rated flow though NASA.
The Aerospace Corp	Negotiation with the customer on program characteristics and ultimately requirements is paramount.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	Mission Assurance Plan required on all contracts; Contractors developed systems
ORS	As built required, but more of why you did what you did. How you evolved the system. Documentation for pick up and do the next one, including design trades.
STP	SIV CDRL list 23, biggest and is too many. Worried level of insight not needed but worried about multiple builds made it needed.
AFRL	If we don't read a document we will not do. A Systems Engineering Management Plan, a Systems Engineering Plan or a Test Engineering Management Plan for instance. Only require critical documents: What is the critical information in implementing a space program. For technical performance minimize the risk in TT&C and CDH.
JPL	Yes there are some changes. Evaluating now. Tend to request more than need. Still goes by the main contract to JPL
NASA HQ	Enough CDRLs so can keep headquarters informed on mission risk

3rd Question #4: Supplemental	Do you believe Class C/D missions would benefit from having formal MA activity expectations associated with such programs?
Example Approach	No data
Company 1	There might be a moderate improvement in mission success, but not likely worth the cost. That would be an interesting trade to perform.
Company 2	MA should be involved in program gates involving hardware and/or software (e.g., consent to ship, receiving, etc) to ensure process steps are followed. MA should also be involved in requirements analysis and safety reviews.
Company 3	Establishment of formal MA expectations for class D would help minimize the confusion caused by misunderstanding of run rules. It has been hard to achieve due to the variety of customer expectations.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Yes
Company 8	Absolutely, trying to create since customer is not doing.
The Aerospace Corp	Yes, for the team members developing the space vehicle. Not clear if important to the funding agent.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	Yes, Same scrutiny no matter the mission.
ORS	Formal MA activity, flight readiness, reship, PDR, CDR, entry and exit criteria more to allow the contractor to be paid at the gates.
STP	Formal MA codified - just different, highly tailor able. Hosted payloads to sound rockets to full SV, mission unique tailored MA
AFRL	No data

3rd Question #4: Supplemental	Do you believe Class C/D missions would benefit from having formal MA activity expectations associated with such programs?
JPL	Yes. Not just a matter of mission success, but have to have enough insight to be able to appraise NASA headquarters of mission launch risk. Formed an advisory board to help Class D projects. Inherently Class D has less money and many people have to do more than one job. People have to be able to look across the whole project. Leads to very cohesive teams with good communication. Well functioning teams are successful. Need to be able to build this type of team. Big project team don't have the number of people that need this overarching project view. Need the right people of front with a high level of experience. Really understand the risks. Not an institutional process as many projects are formed in different ways. Have internal center management council process. Whole culture is make projects successful. Don't wait till a project gets in trouble. Have very active line management engaged. All projects reviewed every single month. Program office meets with project managers every week. LOTS of Institutional support.
NASA HQ	Yes

Question #5: Primary	What program behaviors/approaches have you observed which you believe to be strong contributors to mission success?
Example Approach	No data
Company 1	Strong program managers, technically astute chief engineers, and collaborative relationships across the program team. Everyone in leadership typically has a “we are in this together” mentality.
Company 2	Clear, concise direction from government program office about what they want and what is required. Detailed plan and prioritization of tasks by added value.
Company 3	Team experience, continuity, empowerment/ownership are key factors in mission success. Above all open, transparent communication internally and with customer is mandatory.
Company 4	Opportunity management was key. Set up the culture and let success feed success. The propulsion team was challenged to deliver two weeks early; the team delivered six weeks early. This led others to find opportunities in their respective areas, and success fed upon itself. Empowerment was also important. The team was able to tailor to the processes as long as it met the intent; this allowed some thinking outside the box to create opportunities to shorten schedule without adding significant risk.
Company 5	Empower people to make decisions. Reduce the layers of management/approval. If waivers are required, get them done efficiently. Examine the testing protocol. Eliminate non-perceptive tests and reduce complexity when possible.
Company 6	Superb communication channels and rhythms (internal and to the customer) and deeply experienced, dedicated program team members are the necessary starting points for success on class D missions/programs.
Company 7	Responsible engineering centric model with high levels of accountability and a smaller team. People understand that it’s up to them and no one else to be successful.
Company 8	Biggest contributor to MA is staffing. A, B, C standard BOE leads to head count both and positively and negatively affect MS. Don't want too many people, as adds mission risk. A lot of bench depth required: dedicated parts engineer; dedicated expertise. Class D bid to fit within a budget. For Class D mission system safety all expertise part time or function of System Engineer or flight assurance people. Big fall off between C and D.
The Aerospace Corp	Experienced engineers and small teams! Larger teams(25) can bring more capability to the project, but require management of all resources to ensure communication. Key people dedicated to the development is needed. Communication + passion = mission success
LCROSS PM	Opportunity Management Set Up Culture and let success feed success
Ames (LCROSS)	Risk Management, Collaboration
MDA	Risk Management Focus, MA team
ORS	Small reactive team with minimal layers. Worry some people work too hard. Have a program to mentor, transition plan for key SMEs. Continuous vs. formal
STP	Concentrating STP involvement in backend at the system level I&T and avoiding component work on front end. Confidence in system passing test.

Question #5: Primary	What program behaviors/approaches have you observed which you believe to be strong contributors to mission success?
AFRL	Beat down the distance between who has span of influence vs. span of control. Designer needs span of control over system requirements that can be trade, mini-system engineer. Feedback loops are very critical to get sphere of control and influence minimized. Dependent on competency of people involved. Chief Engineer (CE) authority and owns risks; must have insight to trade requirements and how well perceptive the testing. Independent test is check on CE competency. CE owns MA, owns risk, makes final decision and listens for outside ideas AFRL independence between Engineering and I&T. Testers increases MA by beating down system level design issues in test. I&T has flexibility to shape. I&T as needed to burn in the unit. Understand the imperfections, how to notch and take risks. People are 90% of MS. Mutual accountability, personality driven. Person that owns the risk must own the cost/schedule: Empowered to make decisions in the context of program goals vs. risks. Look at system redundancy vs. physical redundancy – Tacsat 3 comm units with dissimilar redundancy with graceful degradation - evaluate cost of secondary dissimilar redundancy role target redundancy without complexity – e.g. switching logic.
JPL	Formed an advisory board to help Class D projects. Inherently Class D has less money and many people have to do more than one job. People have to be able to look across the whole project. Leads to very cohesive teams with good communication. Well functioning teams are successful. Need to be able to build this type of team. Big project team don't have the number of people that need this overarching project view. Need the right people of front with a high level of experience. Really understand the risks. Not an institutional process as many projects are formed in different ways. Have internal center management council process. Whole culture is make projects successful. Don't wait till a project gets in trouble. Have very active line management engaged. All projects reviewed every single month. Program office meets with project managers every week. Lots of Institutional support.
NASA HQ	Key to success is staff with people who have experience and operating successful missions. (Will resist doing something stupid) Management challenges and want personnel that have demonstrated their engineering ability and aversion to mistakes with understanding of how things work.

Question #5: Supplemental	What has worked superbly well?
Example Approach	No data
Company 1	Developing a strong supportive team culture. Using regular battle rhythms, controlling customer inputs (scope creep) through contract letters, regular independent technical "side by side" reviews, not chart flips. Throwing individuals off the island no matter how good they were if they did not fit the team well.
Company 2	Reduced cost/schedule by leveraging existing manufacturing approaches. Used existing equipment to fast track this part of program.
Company 3	Engineering control of drawings and specification vs. configuration management/document management. Use of supplier testing with surveillance instead of repeating tests in house. Common sense approaches vs. hard requirements.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Tight team work with highly experienced responsible engineers.
Company 8	Unstated benefit of small localized teams. Can do with lower class missions. Class B, procurement in one location, parts in another. For C and D people are in the same office. Low C, all engineers sit in one row to minimize cost with not a lot of coordination cost meetings. Hall talk socializes the issues. Make decision (parts engineer) and socialize with integration and test engineer and Systems Engineer in same office.
The Aerospace Corp	Connect the designer/developer to the testing; have the engineer write the test plan for that component or subsystem as they are most familiar on what needs to be tested (previously there was a disconnect between the developer and designated tester). Require the engineers to be responsible and accountable. PM must understand the entire system with experience to lead the mission development.
LCROSS PM	Propulsion team challenge to deliver to weeks early - team delivered six weeks early. Other used as example and found opportunities. Empowerment.
Ames (LCROSS)	No Data
MDA	Engineering diligence, discipline and focus.
ORS	SMEs and were to put more effort to focus on risks
STP	200 hours on the ground week in the life, day in the life good practices post the manufacture integrating the system, run system 2-3-4 weeks.

Question #5: Supplemental	What has worked superbly well?
AFRL	TACTSAT 3 – now 2 years 10 months. Flight experiment migrated to operational use. 450 NM orbit with no prop. Simplicity to allow small team dynamics, minimize complexity, make as simple as possible. No reports from contractors, CAD and walkthroughs (tabletops), experience overlook, smart workforce to separate wheat from chaff, focus talk 2–3 time a day (tight communication), not overreaction of AFRL to problem. Trust the Engineers who build. Tenets – Independent I&T with informal documentation – Single stakeholder/primary requirements owner – Requirement's owner is the risk manager – Less complex systems/less payload integration – Contactor best practices – example codes to build houses. Don't engineer each house but just build upon using codes established. – No congressional funding line - fixed budget distributed by mission leads, prevents performance driving cost, e.g., 90% cost increase for 5% performance gain. – Streamlined acquisition/review process – small PM/Engineering Org – low delegation of Engineering oversight – Engineering Pool and Ops Cadre – Peer Review FAYT – fly as we tested, this hard, test fast, ok to break things, 100 PFRs at late state ok, not over till commissioning and early on-orbit. Test critical 70% The Aerospace Corp not independent but an organic partner of AFRL/RV with exception of assigned IRTs
JPL	More test and less analysis. Always do receiving inspection; take more risk on in-process but do final inspections. Delay of formalization till system test.
NASA HQ	Management challenges and want personnel that have demonstrated their engineering ability and aversion to mistakes with understanding of how things work.

2nd Question #5: Supplemental	What risks were worth taking?
Example Approach	No data
Company 1	Going single string on some components (even though critical) because for short missions, the likelihood of total failure is pretty darn small.
Company 2	Define "good enough" utility for short duration missions. Demonstrated equipment ahead of program office buy-in to enable program to keep on schedule
Company 3	Relaxed (common sense) prohibited material screening.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	High heritage, analysis by similarity, design reuse, not putting things you know about through the process "just because".
Company 8	Mission Life risks are the most easily and best taken. Most Class C last twice their mission life or more. The reason being we don't know how to factor out the conservatism build into battery, solar arrays, other components, that is inherently build in. More conservative on fuel. GEO can run out of fuel since known very well. Allocate so many LEO so many pounds with certain amount of confidence. Fail to anticipate our mitigated effects of life – 5 years with on-orbit average power. On-orbit can trim by tailoring how the system is used. Conservatism. Load transition constrained. Don't do a mode transition in eclipse. Thermal management, gently rocking the spacecraft to optimize the thermal environment. Don't plan the efficiencies to start with.
The Aerospace Corp	Adding high risk elements in additional payload for an interactive space vehicle build approach.
LCROSS PM	Team allowed to tailor process as long as meet intent. Allow out of the box thinking to shorten schedule without adding significant risk.
Ames (LCROSS)	No data
MDA	Frequently accepted sibling risks; exonerated parts risks, ground equipment risks, Qual risks not acceptable
ORS	Small staff (50's) program office. $225M program
STP	Smaller launch vehicles ICBMs, schedule driven vs. event driven. First to gets to pad launches. Keep cost inline. Make decision now on standards and interface definitions. Interface with large number of rockets and missions in a given orbit. European no reliability analysis just consumables proven
AFRL	No data
JPL	No data
NASA HQ	Less independent review because of the experience of the team.

3rd Question #5: Supplemental	In hindsight, are there any risks that should have been taken or less aggressively avoided?
Example Approach	No data
Company 1	Yes. We spent huge amounts of money trying to determine the best ways to minimize risk of mission failure and in the end, did nothing other than buy EEE parts. Deciding to buy them up front would have saved on cost.
Company 2	None noted
Company 3	No data
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Don't know right now. All or nothing approach – work smart.
Company 8	Design review are still a good investments. Smaller the program the more you should invest in peer reviews. Lower grade program certification reviews - take days for Class C, should take hours. Risk balance should be the opposite. Depend on TAYF, Rehearsals, high fidelity.
The Aerospace Corp	Test; Took short cuts and or failure in communication of test plans.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	No
ORS	Pushing people too much. Making people work too hard. Always active recruiting.
STP	Why so many different ground systems. More commonality in standards, payload to space vehicles.
AFRL	No data
JPL	No data
NASA HQ	No data

Question #6: Primary	What program behaviors/approaches have you observed which you believe compromised or negated mission success?
Example Approach	No Data
Company 1	Tyrannical management, program managers that yell and scream to intimidate; intimidating behavior on the part of leadership; too great a focus on financial and not listening to the engineers; and Finance in charge of the risk board.
Company 2	Program office had not developed a detailed program plan. This slowed the program down at the outset.
Company 3	Lack of communication at any level especially with internal management. Shortcuts during build or in safety procedures.
Company 4	Need to have stable budget. The adverse impact of financial uncertainty was clearly understood by the NASA project manager. Program had to switch contract vehicles a couple times, and it was potentially disruptive. Letter contract may be the best vehicle for Class D programs as it gives the best flexibility.
Company 5	When people are rushed, they may take shortcuts because they are driven by schedule. When pressured, they may deviate from best practices. On quality of people, we need the first string to work Class D programs. We can't have inexperienced people or underperformers.
Company 6	Insufficient communication among the program stakeholders will always lead to setbacks. Managing requests or expectations for additional information/reviews/activities can be very distracting to the program team if the program leadership is not empowered to manage the external environment associated with the program. In the case of a classified Class D effort, the challenges and consequences can be magnified if not managed particularly well (preferably by program leaders who are experienced in the customer's environment).
Company 7	People compromising on the activities you have chosen to take on. People taking their process(es) less seriously. “If you agree to a task/process do it to the fullest ability.” Standing behind a checklist mentality, rather than systems risk thinking, still have to think criticality.
Company 8	Biggest risks is architectural complexity. Attempt to reduce risks in high classification mission by complex system architectures. Failed to assess the risk imparted by test; Test mitigated a lot of risk but can overstress hardware, and add handling latent failures.
The Aerospace Corp	No data
LCROSS PM	Stable Budget Adverse impact of financial uncertainty understood by NASA PM. Had to switch contract vehicles couple of time – which can be potentially disruptive. Letter contract may be best vehicle for Class D giving best flexibility.
Ames (LCROSS)	TAYF, FAYT on nominal conditions tested like we would fly. Mission anomaly (thruster firing draining tanks due to early acquisition signal) double cascading failure not seen since testing in only nominal, not off-nominal condition - as we flew. Anomaly would not have occurred in a less robust less complexity design - complexity bit us and we did not test.
MDA	Unknown-unknowns – unexpected part failures biggest problem
ORS	Have to depend on 14th Air Force. Added $20M dollars for safety at wallops launch - consolidated safety review board.
STP	No data
AFRL	Redundancy wrong – how many times flipped from A to B. Don't take risk in critical areas such as C&DH and TT&C.

Question #6: Primary	What program behaviors/approaches have you observed which you believe compromised or negated mission success?
JPL	Not good team work. Sometimes a technologist is not the best to run the project. Struggling how to do more tailoring to reduce cost but still achieve success. How to propose Class D. Insufficient training or team member that to inexperienced. Core people without good communication.
NASA HQ	Popular going in advocacy is using low grade unscreened parts. This always will result in issues. Need to screen out weak parts, particularly if design is single string.

Question #6: Supplemental	What has failed or led to failure?
Example Approach	No data
Company 1	No data
Company 2	Requirements analysis and verification not well defined for integration contract; did not assess integration and test of software/hardware at outset. An incompatibility was found during integration. There was lack of thorough design reviews of test fixtures that led to test setup delays and modifications.
Company 3	Disconnects between performing organizations and program. Excessive rework of parts especially electronic circuit boards.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Inadequate attention to detail.
Company 8	Problem is smudge a optical surface setting up EMI testing. Introduce defect into hardware though test. Low perceptivity test late in lifecycle especially on pad testing. Example end-of-line fuel sample test. Fuel sample at launch site, cleanliness of equipment. Retest after blow fuel though to sample ball. Risk to people sit around fuel in GSE for 24 hours and now a wet connect. Risk adding to processes because of idea one last test. Issue never happen. Clean fuel in clean cart and produced contaminated fuel. Never had a bad sample.
The Aerospace Corp	More rigorous system engineering could have prevented an escape from the final checklist. Should have captured a “do not do” as a requirement from the parts information sheet and would have avoided failure. Engineer did not understand the admonishment and did not raise as an issue.
LCROSS PM	No data
Ames (LCROSS)	No data
MDA	Unknown-unknowns
ORS	No Regrets. No Failure. Everything is working so far.
STP	No failure since 1996 technically. Schedule failure 300%; 200% cost growth.
AFRL	TACTSAT-2 went too far below their Class D practices. Class A not a value added complexity. Example: Analysis on bracket for weeks or add 30 mils of aluminum and continue. Develop Class A Systems, not Class A space vehicles.
JPL	Buying from inexperienced subcontractor.
NASA HQ	No data

2nd Question #6: Supplemental	What risks were taken that would not be taken again?
Example Approach	No data
Company 1	Skimping on parts. Use of EEE parts are worth it in critical applications.
Company 2	Eliminate some environmental test, e.g., thermal vac. Eliminate tests that have history of always passing.
Company 3	Skipping lower level tests.
Company 4	No data
Company 5	No data
Company 6	No data
Company 7	Don't know right now.
Company 8	Qualification and design margins established – environmental margin above nominal – 1.1 to 1.2 Gs lateral form launch vehicle. Requirement is 1.2 3db above, design uncertainty, qual test uncertainty, model uncertainty – 8-9 db above expectations – in past might be good but today's tools and GSE, data from launch environments are very good today in many cases not necessary. Now less than 1/2 degrees, quasi state 5% of model. Mission Assurance Summit – Test lab under testing for 20 years – no failure because of it. Test has been worthless so much margin on the designs. Sacrifice the margin or test - vibe, shock – good for workmanship but not qualification. Workmanship below launch environment for workmanship not related good.
The Aerospace Corp	No data
LCROSS PM	No data
Ames (LCROSS)	Incompressible test list is not required. TAYF, FAYT. Rely on smart operators.
MDA	None
ORS	Attracting Antibodies
STP	STPSAT 1 2 years behind. Too small a contactor to have knowledge. Must pay for expertise. Need more thoughtful contractor selection – SIV flow down standards reaction to being burned on STPSAT1.
AFRL	No data
JPL	No data
NASA HQ	Testing risks ended up resulting in problems. Tested a box on one space vehicle so felt did not need to be tested on a follow on vehicle (inside the box was a different configuration that did not work)

Appendix C. Comparing Mission Classes with a Focus on Class D Missions

Due to the development requirements and mission assurance rigor of Class A missions, they tend to be the most expensive and require the most time to execute. These missions can be characterized as first of fleet long-life national assets and flagship missions. The Class A space vehicles tend to be very complex with multiple payloads and capabilities. On the other extreme, Class D missions are the least expensive and vary from small satellites to hosted payloads sharing a ride. This class of mission typically carries more risk against meeting the mission objectives than is the case with the other mission classes (A, B, or C). Risk is not well characterized or quantified on Class D programs due to the less stringent implementation of mission assurance standards and processes as compared to Class A, B, or C missions. However the risk is characterized to the extent to bound the uncertainty providing a high probability of success against threshold performance. Class D missions typically have the fewest formalized mission assurance activities/roles and their nature is often experimental or focuses on development/deployment of a specific technology in a new or novel way. The execution emphasis on such missions is often focused on engineering and integration roles through smaller teams of very experienced engineers. The mission assurance roles typically fulfilled by dedicated personnel on other mission class programs are often fulfilled by the core engineering personnel. Class D missions embody the most risk to mission success, not all of which is well understood due to the application of minimum assurance standards and processes, and the fact that the mission itself may be a risk mitigation effort to prove out a new technology. When a mission's explicit objective is to identify/mitigate risk before fielding a reliable spacecraft or space system, the mission assurance environment is more organic and distributed among the development team.

Each mission class, A through D, must balance accepted risk against mission, cost, and schedule constraints while providing the highest level of mission success achievable within those constraints. The concept of risk balance in the context of minimizing the risk to mission success is illustrated in Figure 1. The figure identifies the four mission classes in terms of program risk exposure in terms of mitigated risk and residual risk. Mitigated risks are those evaluated, quantified, and are formally managed for avoidance. Residual risks may or may not be evaluated, quantified, or formally managed and may also be "hidden" in program areas where scrutiny has not been rigorously applied. Note that while the Class C and D mission profiles embody the greatest residual risk, the probability of mission success must still be relatively high in order to justify the effort and expense that accompany all space hardware development and deployment programs. Class D mission risk balance is critical in the development of the program risk strategy as a greater amount of residual technical risk is acceptable and programmatic trades are less flexible than found in other mission classes.

The Bar chart on the right in Figure 1 shows the increase of probability of mission success (Ps) with mission assurance investment. These class relationships can be instructive in formulating the appropriate risk balance within programmatic constraints. The graph shows as greater MA resources are applied there is a significant valued added benefit to MA investment especially for the Class D and C missions as noted by the increase in Ps for those missions. These mission classes typically employ sufficient self-governance in terms of mission assurance roles to achieve a reasonable Ps. A low Ps is not value added in non-repairable space systems. Note that this graph is representative of improvement in mission success with investment. It is not an absolute and the mission classes can vary and overlap when a specific risk strategy is chosen. The figure intends to portray the comparative relationship that has been seen over time between mission success and mission assurance investment on many programs. Often the distinctions between adjacent mission classes can be difficult to define in absolute terms and the program management team (acquirer and developer) must work closely to set expectations and rules of conduct early in a program lifecycle.

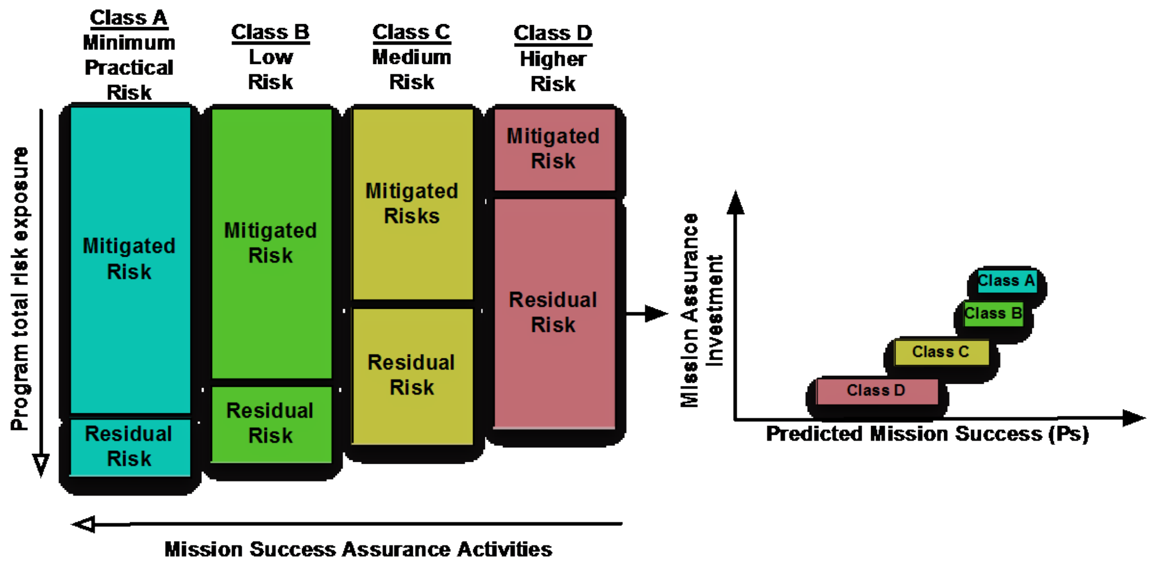

Figure 1. Risk and mission classes.

Industry experience has shown that program execution in general, and mission assurance activities in particular, follow similar rhythms for all the program classes. Differences among them, in terms of mission assurance, are often manifested in declining formality as we cross the spectrum from Class A to Class C. A Class C program will still have key system requirements that must be met, including a flow-down approach reaching down to subsystems and components, including the appropriate verification obligations. The level of formality on a Class C program is significantly more relaxed than on a Class A program and the processes and number and type of data deliverables are usually highly tailored. However, for the most part, the roles, responsibilities, and performing agents/organizations are the same as those on a Class A program.

Class D programs often manifest a significant departure in both the formality and the execution of the mission assurance activities when compared to the other mission classes. Generally there will not be any hard requirements – mission success criteria are written on threshold performance with a focus on the “what and not the how” to perform. Mission success criteria are written against threshold (minimum acceptable) performance expectations. Emphasis is placed on what is to be accomplished, not on how it is to be accomplished. For technology-focused programs, this paradigm intends to demonstrate the ability of a technology to perform in a new or novel application or environment as opposed to designing a device to meet requirements using already demonstrated technology elements. Class D programs rely heavily upon industry contractors’ best practices. Risk management tends to be a partnership between the customer and the contractor.

The goals/objectives of a Class D program are decomposed and flowed to the lower levels with performance tracking to those goals. The program is typically capability based with best effort to achieve the stated goals. Most often cost and sometimes schedule will trump technical performance. Since there are no hard requirements to be reviewed against a system design at systems requirements review (SRR), this event is held earlier often at program kick off and serves as a discussion of goals to ensure all parties are aligned and understand priorities. At the conclusion of the effort the demonstrated performance is compared to the desired goals and recommendations for further work or next phases are documented.

Table 1 depicts a notional program activity summary as a function of mission class to include treatment of requirements, design gates/reviews, technical data packages, and baseline control.

Table 1. Program Elements Approach by Mission Class

Program type	A Operational	B Demonstration	C Experimental	D Experimental to Technology Demo
Requirement				
External	Formal A Spec & ICD flow down Missing any rqmt's would jeopardize program success	Formal A Spec & ICD flow down, Missing key rqmt's would jeopardize program success	Informal A Spec, few Key rqmt's drive program success	Customer Goals, Best effort, Cost/Schedule driver
Internal	Formal: DOORS, B, C, D spec's, internal ICD's; Missing any rqmt's would jeopardize program success	Formal: DOORS, B, C, D spec's, internal ICD's; Missing key rqmt's would jeopardize program success	Informal flow down; B & ICD, DOORS	Less formal, Flow-up B, C & ICD
Design Gates/Reviews	Formal	Formal	Systems Engineering	Responsible Engineering Authority
SRR	– Requirements allocation complete – System conceptual Design closes with requirements – ATP to begin Preliminary Design		– Rqmt's complete – CD closes with minor findings – ATP PD, Purchase Long Lead	– "Kick off mtg" Review of customer goals, proposal – Agreement on KPP's, Conceptual design
PDR	– Requirements Design & Long Lead Dwg's Complete – System shown to meet all requirements by analysis – ATP to Detailed design, Purchase Long Lead		– PD & >30% Dwg's complete – Preliminary/System model meets Reqmt's – ATP DD, Build Flight & STE	– Reqmt's frozen with validation plan – Pre Design & Analysis complete – Dwg release scheduled to meet build schedule
CDR	– Detail Design & >80% drawings complete – System performance demonstrated in Lab/Field tests – ATP to build flight hardware, Design/build STE		– DD & >80% Dwg's complete – Detail analysis meets Reqmt's – ATP subsystem integration	– Detailed analysis complete – >80% of hardware/software in house & test
TRR	– Subsystem, Component & STE testing complete – System integration and functional test complete		– Integration and test plans complete – STE checked out	– Typically part of CDR – Test Flow & STE in place

Program type	A Operational	B Demonstration	C Experimental	D Experimental to Technology Demo
Design Gates/Reviews	Formal	Formal	Systems Engineering	Responsible Engineering Authority
CTS	– All System requirements verified by test – Root cause of all failures found and resolved		– Key reqmt's verified – Root cause of Mission critical failures found/resolved	– Performance capability vs Goals reviewed, analomilites identified – Reliability & Safety issues resolved
Technical Data Package				
Spec's	CM/DM release	CM/DM release	DOORS	REA control
Analysis	TRB aproval	SE approval	REA control	REA control
Engr Data	TRB approval	SE approval	REA control	REA control
Drawings	CM/DM release	CM/DM release	CM/DM release	REA control, Few-no Assy Dwgs
Processes, Procedures	CM/DM release	ENB, SE approval	ENB, RE approval	Minimal document as you go, REA control
Management Reviews	BU, TMR, Tox	BU, TMR, ToX	BU, TMR, ToX	(senior) Technical Advisory Board
Baseline Control				
TRB	Tech Director	Tech Director	SE	REA
ERB	PMO	Tech Director	SE	REA
MRB	PMO	PMO	PMO	PM & REA
FRB	PMO	PMO	PMO	PM & REA
Testing	Formal, Operations	Formal, Operations	SE + Operations	REA

Class D programs will be less complex than Class A, Class B, or Class C programs. Often there will be a single key technology being demonstrated. In this case, work may be performed by a few or a single functional organizations within Engineering. Those organizations are then responsible for performing the same activities that other groups would have performed for Class A – C programs.

On a Class D program, a Responsible Engineer (RE) will typically be the single signature authority (A) for specifications, drawings, reports, etc. In addition, this small group will also execute the design, analysis, build and test processes while maintaining configuration control and product integrity. There will generally be oversight and process check points by the enterprise to verify the work is being performed as planned. However, this surveillance will be at a low and non-interference level with performance tied to goals vs requirements and with fewer multi-role/function people resulting in programs that are much lower in cost with shorter delivery schedules. Such oversight will be provided by fewer, more broadly experienced individuals (whether they are in-house or consultant-based).

The total cost, level of effort, and complexity are major attributes that further define a mission class of a space vehicle. Figure 2 was created based upon notional metrics to further illustrate the quantitative differences that can be recognized between the mission classes. The figure provides relative comparisons normalized against a Class A program/mission. As the focus of this project was to further identify key characteristics and execution of considerations for Class D, a spectrum of Class D projects were included in this graphic to further demonstrate that the relative cost of a Class D mission directly correlates to the complexity of the mission objective(s) and the relative effort expended per item in the development for the mission. An item example is the flight software, or the build and integration of a single box.

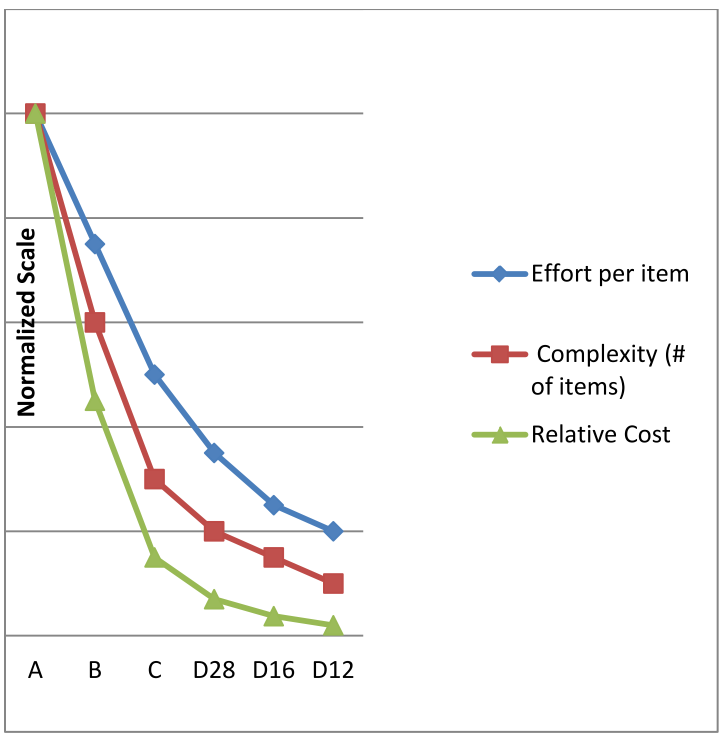

Figure 2. Relative class comparisons: cost, effort, complexity.

Class A missions are the highest priority space vehicles and the risk acceptance is extremely low. Class A missions are more complex with multiple payloads and extensive on-board flight software.

Acquisition costs are the highest as the level of effort per item is the highest to include the level of effort for analysis, design, build/manufacture, and mission assurance. The cost, complexity, and level of effort to include mission assurance in general decreases as a function of a higher risk posture acceptable in the other mission classes. The lowest cost missions, Class D, have been further segregated in the graphic example to reflect a spectrum of missions that range for a development cycle time of 28 months (D28), 16 months (D16), and 12 months (D12). As expected, a 24-month acquisition/development costs more and will most likely have multiple payloads or capabilities (more mission goals/objectives) compared to a 12-month Class D development effort.

Class D missions are considered science or experimental missions. The design and build cycles for these missions are compressed and the budgets are significantly less. The space vehicle, particularly the bus, is much less complex often using heritage product or design, and the focus is the science of the technology with a focus on a few experiments. Characterized by small team design and build, Class D missions have a much lower cost, cost less per item in terms of level of effort and a less complex space vehicle. Design and build processes are tailored to meet the budget and schedule. The mission assurance activities are similarly tailored and typically executed by the engineering team rather than a separate organizational function.

Development of a Class D spacecraft or space system may typically range from a team of 3 – 4 persons up to more than 20. The smallest teams need to develop the science of the program and also are responsible for program management, systems engineering, design, production, and mission assurance. Such small teams can indeed be successful at executing such a broad range of functions/control on a program of modest size and complexity. It has proven to be the case that such programs can afford tremendous opportunities for learning and personnel development to the appropriately prepared and dispositioned individuals.

Larger teams require more program management and more detailed systems engineering processes to facilitate communication and to ensure that all members' contributions are aimed at the same objective/goal. Such teams will also rely more heavily on shared documentation and the associated infrastructure elements. The smallest of teams (3 – 5 persons) require superb interaction and interpersonal communication and their success relies heavily on the dynamic interaction and rapid decision making which often are required on the shorter development cycle missions.

Figure 3 is a notional graphic that further illustrates the proportion of effort performed per organization as a function of mission class. The engineering organization takes on much greater accountability performing the majority of the work for the Class D missions. For Class D missions with longer development timelines additional organizations may execute more formal mission assurance processes aligned with the budgets and customer needs.

Class A missions require formal milestone reviews and formal risk management boards with the customer in order to deliver the required products and execute the development effort in compliance with what are typically substantial contractual requirements. Program management is responsible for satisfactory project execution with regularly-provided cost, schedule, and technical progress reports most often in compliance with an agreed-upon integrated master schedule. Initial cost and schedule estimates are subjected to independent cost assessment(s) by the acquiring agency. The risk management function may be owned by program management but is most commonly executed by multiple disciplines to ensure capture and management of all program and mission-impacting risks. The mission assurance organization or function requires the application of formal quality assurance processes and independent analyses as well as hardware and software assurance processes. Systems Engineering is responsible for decomposing and allocating the system-level requirements down to unit-level (inclusive of verification requirements) and further ensures that configuration management

	Organization Performing the Work
1	Program Management Office, Program Manager, Finance, Contracts, Subcontracts
2	Mission Assurance, Quality Assurance, Operations, Configuration Management
3	Systems Engineering
4	Design Engineering (Mechanical, Electrical, Software, and Operations)

Figure 3. Relative division of work among the mission classes.

is formally implemented to control change management and waiver/deviation approval and reporting. Systems Engineering also ensures that integration and verification planning is both validated and executed to result in delivery of compliant product. The engineering technical functions focus on the mechanics of the design and build/manufacture of the spacecraft or space system from the parts up to the assembled system to ensure that the delivered product will reliably meet all system requirements.

Class B missions are executed similarly to Class A in terms of organizational/functional responsibilities. Class C missions realize a shift to the engineering technical functions taking more responsibility in the areas of hardware and software assurance. The programmatic functions are less formal so there is less effort expended. The acquirer has less oversight and requires fewer contract deliverables relying, instead, more heavily on internal contractor processes for configuration management and quality assurance, for example. This is a direct consequence of the lower cost of the mission and acceptance of a higher acquisition risk posture from the outset of the Class C mission definition. For Class D missions, the customer typically shifts the mission risk nearly entirely to the contractor with formal reviews limited to major milestones (preliminary design review and flight readiness review) and informal meetings to report progress and risks associated with meeting cost, schedule, and performance objectives. In these cases, the engineering technical function is primarily responsible for execution of all functions on the program. A classic space system acquisition includes the following events:

- system requirements review (SRR) to review/validate a system design concept against the viability of the requirements flow down
- preliminary design review (PDR) to confirm that the preliminary design has analytically demonstrated compliance with the requirements and to authorize long lead procurement and detailed design
- critical design review (CDR) to confirm progress in release of engineering drawings (typically >90%), the completion of key engineering modeling and/or development tests, and to authorize flight build
- test readiness review (TRR) to confirm the readiness to conduct major (typically spacecraft-level) testing
- consent to ship review (CTR) to confirm completion of all testing and satisfactory compliance with all requirements

Class A and B programs typically do not stray very much from the above definitions and requires these reviews. Class C programs tend to follow similar gated events but will have a relaxation in the formality of the events. For example SRR will typically not include a flow down requirement to lower levels and perhaps only 50% of the drawings will be released at CDR. Class D programs are typically managed to the build/delivery critical path. The gates will not be used to manage the development and build schedule but will be held when convenient to communicate status to customer and subject matter experts. Figure 4 illustrates how events may be compressed and overlap when the schedule is compressed showing a relative comparison of a typical 60 month Class A acquisition down to a typical 12 month Class D acquisition.

Figure 4 also relates the tasks performed (system engineering, design, analysis, build, assembly, integration and test) executed in a typical integrated management schedule. For Class A and B systems the events are gated with entrance and exit criteria along with the overlay of mission assurance processes. Class C programs typically reflect the importance of critical path and focus on the need for long lead item procurement timelines that support the system deployment objectives. Most often, such procurements begin before CDR. In such cases, the CDR is a gate primarily used to communicate design risk to the customer and stakeholders prior to moving into final assembly and test. Similarly Class D, the long lead items, and even build is compressed occurring concurrently with the CDR which is a gate primarily used to communicate design risks to the customers prior to moving to final assembly and test. The Class D mission activities will vary depending on the scheduled development time with the engineering staff accountable for the classic programmatic functions.

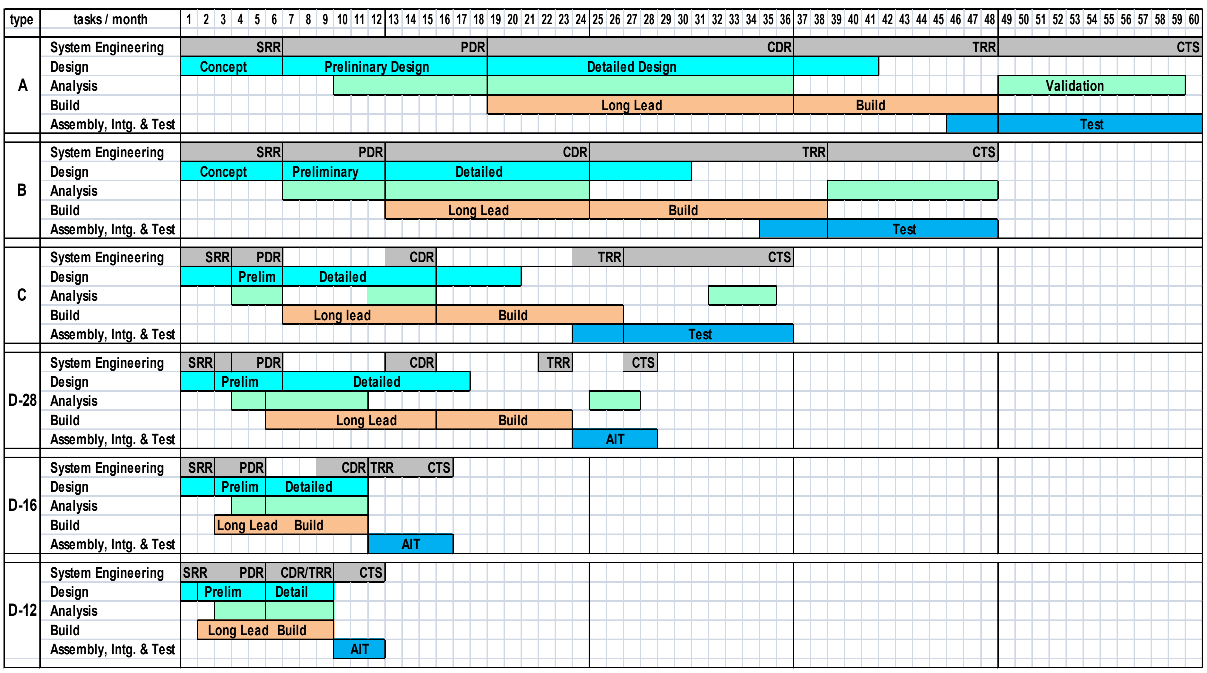

Figure 4. Relative program durations and activities/gates.

All of the 16 Mission Success processes identified in TOR 2011 8591-21 are expected to be performed on every program class type including Class D regardless of the development schedule. Figure 5 is a list of those core processes with a notional depiction of who may be performing the "work." In the higher risk mission classes, work is performed by fewer people. In many cases, several of the processes are performed by Engineering. In the extreme case, Engineering (even a single engineer) will perform all activities, from requirements development through build and test. Such an engineer will need to be cognizant of all applicable processes and best practices. So, it is not

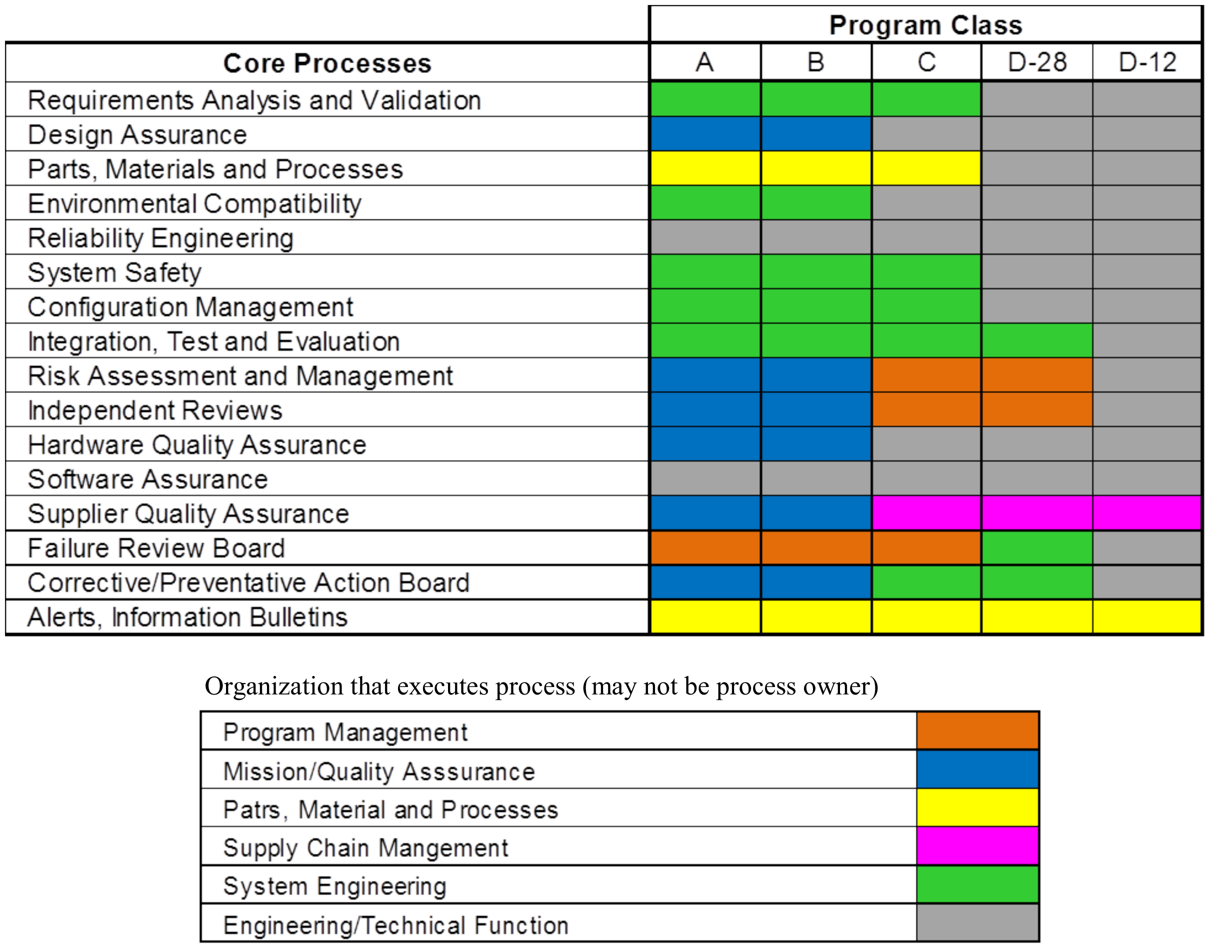

Figure 5. Relative distribution of work among the program classes.

surprising from the surveys conducted as part of this MAIW product, that the best Class D teams were staffed with the most experienced and versatile of engineers.

The purpose of this appendix has been to illustrate the comparative differences between the program classes that have traditionally been identified as Class A, B, C, and D with an emphasis on the attributes of Class D missions as determined through recent surveys and evaluations in the aerospace community. The attributes of each mission risk class can be shown to correlate to the risk posture of the program customer and to reflect the mission planning and execution methods for a given set of cost, schedule, and performance objectives.