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A New Approach to Mission Classification and Risk Management for NASA Space Flight Missions

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Abstract

The NASA risk classification system is meant to guide space mission development from formulation through completion of implementation. It is also meant to be the basis on which program and project managers develop and implement appropriate mission assurance and risk management strategies for the mission. In order to be useful, the risk classification system needs to provide consistent and reproducible classification results so that missions may be designed with the appropriate components, subsystems, and testing philosophy, all of which impacts mission schedule and cost. In a cost-constrained environment, a clear, robust, and reproducible approach to mission implementation becomes more critical than ever before. Once a project's risk classification level is established, the managers can define the appropriate management controls, systems engineering processes, mission assurance requirements, safety, and testing for that mission. The current NASA mission classification system will be reviewed before a new system is proposed.

NASA manages space flight missions according to a four-tiered classification which assumes increasing levels of risk. We argue that risk does not change between classes. What changes are the means available to reduce risk. In performance-driven missions, the project will spend money in order to maintain performance without reducing margins. In cost-constrained missions, performance will be reduced in order to stay within budget or to maintain schedule: measurement requirements may be traded, design life may be reduced, or both. We then propose a new approach to the classification of NASA space flight missions, based on an assessment of how flexible the requirements, how exquisite the measurements, how long the lifetime, and how rigid the budget.

Our proposed approach makes possible a clearer differentiation between classification levels and more effective guidance to program and project managers.

1. Introduction: The Problem

The NASA risk classification system[1] [2] [3] is meant to guide mission payload development fro Phase A through completion of Phase C. It is meant to be the basis on which program and project managers develop and implement appropriate mission assurance and risk management strategies for a mission. In order to be useful, the risk classification system needs to provide consistent and reproducible classification results so that missions may be designed with the appropriate components, subsystems, and testing philosophy, all of which impacts mission schedule and cost. In our cost-constrained environment, a clear, robust, and reproducible approach to mission implementation for fixed cost missions becomes more critical than ever before. Once a project's risk classification level is established, the managers can define the appropriate management controls, systems engineering processes, mission assurance requirements, safety, and testing for that mission. The current NASA mission classification system will be reviewed before a new system is proposed.

2. Risk Classification System for NASA Payloads

The NASA Procedural Requirements (NPR) document 8705.4[2] describes the risk classification for NASA payloads. Its purpose is to establish baseline criteria that will enable a user to define the risk classification level for a NASA payload and the design and test philosophy and common assurance practices for that level. Table 1 below describes the four risk levels, using criteria such as Agency priority.

Characterization	Class A	Class B	Class C	Class D
Priority (Criticality to Agency strategic plan)	High priority	High priority	Medium priority	Low priority
National significance	Very high	High	Medium	Low to medium
Complexity	Very high to high	High to medium	Medium to low	Medium to low
Mission lifetime (primary baseline mission)	Long, >5 yrs	Medium, 2-5 yrs	Short, <2 yrs	Short, <2 yrs
Cost	High	High to medium	Medium to low	Low
Launch constraints	Critical	Medium	Few	Few to none
In-flight maintenance	N/A	Not feasible or difficult	Maybe feasible	Maybe feasible and planned
Alternative research opportunities or re-flight opportunities	No alternative or re-flight opportunities	Few or no alternative or re-flight opportunities	Some or few alternative or re-flight opportunities	Significant alternative or re-flight opportunities
Examples	HST, Cassini, JIMO, JWST	MER, MRO, Discovery payloads, ISS facility-class payloads, attached ISS payloads	ESSP, Explorer payloads, MIDEX, ISS complex subrack payloads	SPARTAN, GAS can, technology demonstrators, simple ISS, express middeck and subrack payloads, SMEX

Figure 1: Classification Considerations for NASA Class A-D Payloads (NASA Procedural Requirement-NPR 8705.4 Appendix B)

3. Issues With The Current Classification System

The current system allows engineers, scientists, and managers at NASA to argue over terminology, implementation plans, and risk postures. This lack of consensus is impacting NASA's ability to smoothly develop innovative space-based missions. There are three main issues with the current classification system.

3.1 The current classification system does not provide effective guidance to program and project managers.

Classifying a mission by its criticality to the strategic plan, its national significance, and its complexity does not inform the actions of the project manager and of the project team, for whom the mission is the sole priority and focus.

Likewise the presence of launch constraints, the possibility of in-flight maintenance, and the existence of alternative research opportunities do not affect the behavior of the project, for which mission success is always the objective.

Cost (more specifically capped cost), schedule constraints, and mission lifetime do determine the actions of the project manager and of the project team, as we discuss in what follows.

3.2 It is difficult to tell the difference between classes.

Appendix C of NPR 8705.4 [2] lists specific project guidance for class A-D payloads. The difference in guidance between Class B from Class C, in particular, is often subtle, and typically not observed in practice in the development of flight missions.

For example, the guidance for Engineering Model, Prototype, Flight, and Spare Hardware and is for Reviews is as follows:

	Class B	Class C
Engineering Model, Prototype, Flight, and Spare Hardware	Engineering model hardware for new or significantly modified designs. Protoflight hardware (in lieu of separate prototype and flight models) except where extensive qualification testing is anticipated. Spare (or refurbishable prototype) hardware as needed to avoid major program impact.	Engineering model hardware for new designs. Protoflight hardware permitted (in lieu of separate prototype and flight models). Limited flight spare hardware (for long lead flight units).
Reviews	Full formal review program.Either IPAO external independent reviews or independent reviews managed at the Center level with Mission Directorate participation. Include formal inspections of software requirements, design, verification documents, and peer reviews of code.	Full formal review program. Independent reviews managed at Center level with Mission Directorate participation. Include formal inspections of software requirements, peer reviews of design and code.

Consider for example the flight missions Landsat and Plankton Aerosols Clouds and oceans Ecosystems (PACE), while both missions are cost capped, with similar sized budgets, and both missions are in sun-synchronous Earth orbit and both carry two instruments, Landsat 9 is Class B, PACE is Class C.

3.3 The current classification system is based on the incorrect assumption that moving from class A to class D means taking increasing risk.

The classification system is based on risk increasing with the decreasing importance of the mission. Once the mission is assigned and the project is formed, however, that mission becomes the highest priority for the project manager (whether or not it is of great national importance). Also, naturally no project manager will deliberately increase the mission risk to match the mission classification.

We posit that risk does not increase moving from class A to class D[c]. What changes are the means used to reduce risk. In performance-driven missions (classes A and B) the project will generally spend money in order to maintain performance without reducing margins (which increases risk). In cost-constrained missions (classes C and D) performance will generally be reduced in order to stay within budget or to maintain schedule: measurement requirements may be traded (up to a point), design life may be reduced, or both. Again, margins are maintained and risk does not increase.

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[c] "Once they are on the pad, every mission becomes Class A" (Earl Huckins, SMD DAA FY2000)

Regarding lifetime, any project regardless of the classification of its mission will do whatever is necessary to eliminate infant mortality (failure in the initial months after launch). As shown in Figure 2, mission lifetime after that, as specified by the mission class, is mostly determined by choice of parts and by the redundancy approach, as well as by the depth of testing.

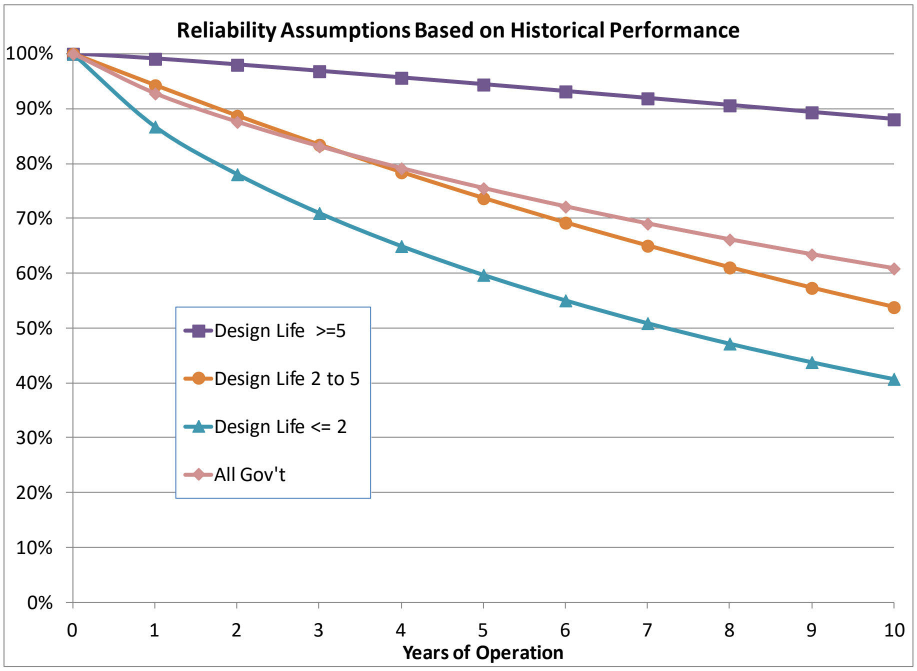

Figure 2: Flight Mission Reliability Based on Historical Performance (Personal communication with Robert Bitten, The Aerospace Corporation)

The reliability of flight missions degrades slowly as a function of years of operation. Design life in the chart is a proxy for mission class.

4. Introducing a New Classification Scheme

In order to address the problems discussed above, we introduce a new mission classification scheme based on four parameters:

1. Direct heritage;
2. Flexibility of requirements;
3. Design lifetime;
4. Budget rigidity.

4.1 Direct heritage

The degree to which an instrument or spacecraft is derived from prior instruments or spacecraft. This parameter is related (inversely) to the amount of technology development needed for the mission.

4.2 Flexibility of requirements

The degree to which requirements can be relaxed to stay within budget and schedule,without compromising the value of the mission. There is also a programmatic aspect to this parameter, having to do with timeliness (does the mission have to launch by a specific time, for example to replace a failing existing capability, or to measure a transient phenomenon).

4.3 Design lifetime

The minimum length of time that the mission must operate in order for it to be worth doing. While for any mission the project will naturally reduce or eliminate infant mortality, in some cases measurements need only be taken for one or two; in other cases up to five years are required to collect the necessary data; in the case of strategic missions of great cost and complexity, or that provide data of national importance (weather data for example) a lifetime of more than five years may be required.

4.4 *Budget rigidity*

This parameter describes whether additional funding (δ$) may be made available at various stages of the mission development in order to meet measurement performance requirements, or to meet programmatic cost and schedule requirements. The δ$ may change depending on how long the mission has been in development and on the amount of sunk resource, as well as on the relative importance of the mission. In the case of strategic missions, relatively unconstrained additional funding may be made available in the initial phases of development, while in the case of cost-capped missions (Discovery, Earth Venture, etc.) no funding that exceeds that initially specified is ever available.

For a Class D mission, there is no flexibility: there will be no additional dollars forthcoming, regardless of the progress made or the sunk investment. However, for a Class C mission, there may be increased monetary investment and the amount of that increase is at least partially based upon the percentage of development that is complete. That is, for a Class C mission, the % dollars over baseline may increase during the middle of mission development. But at some point, the over-run reaches a peak after which no additional over-run funding is forthcoming. Note that this classification applies to flight missions (including instruments), but not to balloon missions nor to sounding rocket missions. A Class B mission must meet performance requirements, but the measurements are (relatively) straightforward and thereis some budgetary fexibility. Operational missions and most planetary missiona are Class B. Class A missions perform exquisite measurements that require the development of new technology. Performance requirements must be met and there are few budgetary constraints.

Realizing that the process to classify a mission is often ambiguous and the result sometime debatable, we have developed Boolean expressions to determine mission class based on the four parameters discussed above (direct heritage; flexibility of requirements; design life; budget rigidity).

IF δ$ ∩ ¬heritage ∩ reqts not flex ∩ >5yr life → class A/B

IF δ$ ∩ (¬heritage ∩ ¬reqts not flex) ∪ (heritage ∩ 2-5yr life) → class C

IF ¬δ$ ∩ ¬reqts not flex) ∩ (¬heritage ∩ <1yr life) ∪ (heritage ∩ 1-2yr life) → class D

δ$	Percentage cost overrun which is acceptable
Heritage	Measurements have been demonstrated
Reqs not flex	When requirements (either technical or schedule) cannot be relaxed
Life	The minimum length of time that the mission must operate in order for it to be worth doing

Table 1: Definitions of the Boolean terms.

Let us now go through the logic with a few examples.

A mission is said to be class A if three criteria are met: first, the measurements have no direct heritage. Second, the requirements must be met (due to the exquisite nature of the measurements) and cannot be traded against cost and schedule. Third, the mission needs to last for more than five years.

This results in a design-to-performance approach, with relatively unconstrained budget at least in the initial phases.

Example: The James Webb Space Telescope (JWST) because the measurements have no direct heritage and cannot be traded.

For a Class B missions the schedule is not flexible (because the mission is operational and of national importance, or because planetary launch constraints need to be met). The requirements must be met, but the measurements are straightforward. The design lifetime is five years or more.

Examples: The Joint Polar Satellite System (JPSS) and Landsat because they are missions of national importance (weather and environmental monitoring).

For a class C mission either the measurements have no direct heritage but the schedule is flexible, or the measurements are relatively straightforward but the schedule is not flexible. In either case the requirements are flexible and can be traded against cost and schedule. The mission lifetime in this case is between two and five years.

This results in a soft design-to-cost approach where funds could be added to keep schedule, but not to keep performance.

Examples: PACE, ICESat, because the requirements are flexible and can be traded against cost and schedule (even though, in the case of ICESat, they actually were not traded) and the mission needs to last up to five years.

For a class D mission the measurements are relatively straightforward, or there could be measurements of an experimental nature. Both budget and schedule are typically capped, and therefore the performance requirements are flexible and can be traded. The mission lifetime is usually between one and three years.

Examples: NICER, CATS, Earth Venture. Both NICER and CATS are ISS attached payloads, with CATS being a technology demonstration which was only under “do no harm” ISS requirements (can be thought of as Class D minus). In all three cases the budget is capped and the mission lifetime is up to three years. and Goddard developed a way to mitigate unnecessary requirements on Class D projects and same should be developed for Class B and C missions as well.

Characteristic/Class for SMD	**A**	**B**	**C**	**D**
NASA Significance	High	High	Moderate	Low
Performance Requirements	Must meet agreed to performance requirements	Must meet agreed to performance requirements	Performance requirements may be reduced or schedule slipped	Performance requirements may be reduced
Launch constraints	Some	Critical	None	Some
New technology	Required	Not required	As Needed	As Needed
Lifetime	≥5 yrs.	≥5 yrs.	2-5 yrs.	< 2 yr.
JCL	.8	.7	.7	.7
Risk reduction	risk minimized by applying budget resources	risk minimized by applying budget resources	risk minimized by reducing performance or slipping schedule	risk minimized by reducing performance and lifetime
Example	JWST WFIRST	Landsat 9 GOES JPSS TDRS TSIS MAVEN (schedule) O-REX (schedule) Restore L (schedule)	MMS TESS ICON LUCY PACE	GEDI NICER

5. Conclusion

We argue that risk is always minimized in any flight mission, and is therefore not useful as a classification criterion. We then propose a new approach to the classification of NASA space flight missions, based on an assessment of how flexible the requirements, how exquisite the measurements, how long the lifetime, and how rigid the budget.

We argue that risk does not change between classes. What changes are the means available to reduce risk. In performance-driven missions, the project will spend money in order to maintain performance without reducing margins. In cost-constrained missions, performance will be reduced in order to stay within budget or to maintain schedule: measurement requirements may be traded, design life may be reduced, or both. Thus, our proposed approach makes possible a clearer differentiation between classification levels and more effective guidance to program and project managers.

Mission classification at NASA is controlled by the Office of Safety and Mission Assurance (OSMA)via NPR 8705.4, which was last updated in 2004. We hope with this paper to start a fruitful discussion in the community on this new classification approach with a view towards updating the NPR to reflect these suggestions.

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