THOUGHTS ON MISSION IMPLEMENTATION OPTIONS FOR HELIOPHYSICS

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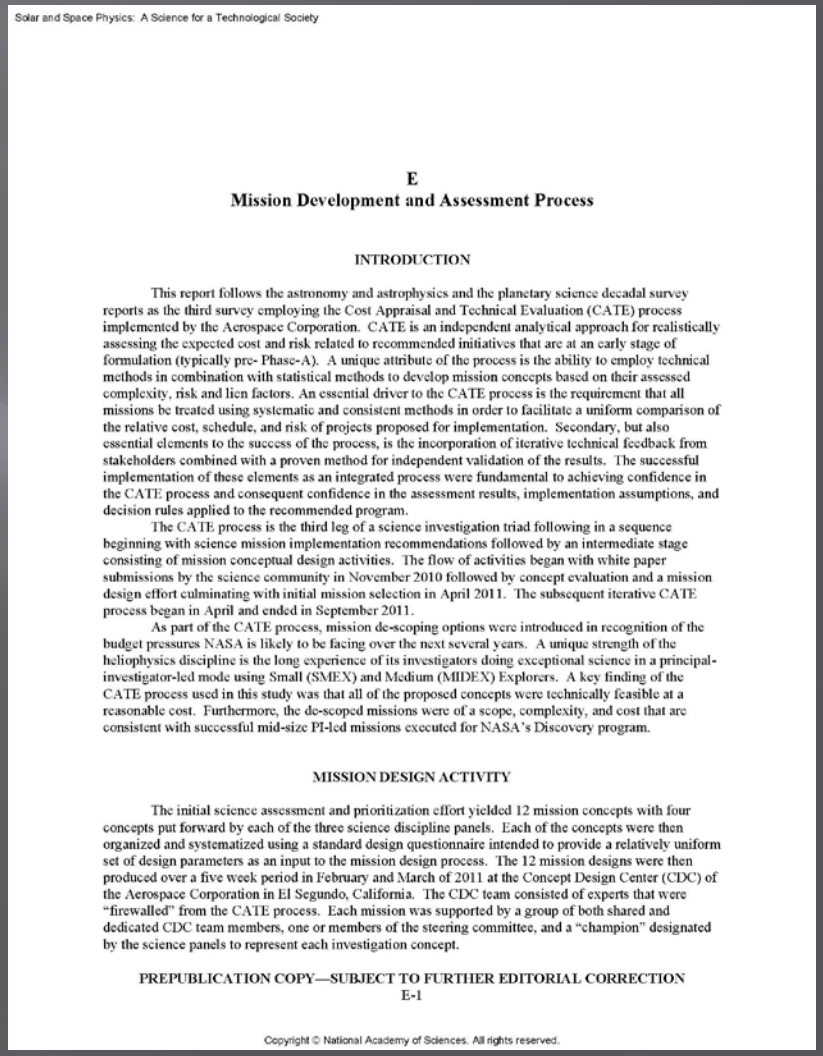
Decadal Survey Mission Strategy…

- Mission implementation strategy was described in Appendix-E of the survey.
- Budget constraints resulted in a focus on small missions in the Explorer classes plus modestly larger STP missions in order to achieve a fast cadence.
- STP missions were scaled to fit in the cost range between the successful PI-Led Discovery class ($450M) and New Frontiers class ($700M+).
- Larger LWS missions in the 1B+ range were designed to be "Center-Led".



E
Mission Development and Assessment Process

INTRODUCTION

This report follows the astronomy and astrophysics and the planetary science decadal survey reports as the third survey employing the Cost Appraisal and Technical Evaluation (CATE) process implemented by the Aerospace Corporation. CATE is an independent analytical approach for realistically assessing the expected cost and risk related to recommended initiatives that are at an early stage of formulation (typically pre- Phase-A). A unique attribute of the process is the ability to employ technical methods in combination with statistical methods to develop mission concepts based on their assessed complexity, risk and lien factors. An essential driver to the CATE process is the requirement that all missions be treated using systematic and consistent methods in order to facilitate a uniform comparison of the relative cost, schedule, and risk of projects proposed for implementation. Secondary, but also essential elements to the success of the process, is the incorporation of iterative technical feedback from stakeholders combined with a proven method for independent validation of the results. The successful implementation of these elements as an integrated process were fundamental to achieving confidence in the CATE process and consequent confidence in the assessment results, implementation assumptions, and decision rules applied to the recommended program.

The CATE process is the third leg of a science investigation triad following in a sequence beginning with science mission implementation recommendations followed by an intermediate stage consisting of mission conceptual design activities. The flow of activities began with white paper submissions by the science community in November 2010 followed by concept evaluation and a mission design effort culminating with initial mission selection in April 2011. The subsequent iterative CATE process began in April and ended in September 2011.

As part of the CATE process, mission de-scoping options were introduced in recognition of the budget pressures NASA is likely to be facing over the next several years. A unique strength of the heliophysics discipline is the long experience of its investigators doing exceptional science in a principal-investigator-led mode using Small (SMEX) and Medium (MIDEX) Explorers. A key finding of the CATE process used in this study was that all of the proposed concepts were technically feasible at a reasonable cost. Furthermore, the de-scoped missions were of a scope, complexity, and cost that are consistent with successful mid-size PI-led missions executed for NASA's Discovery program.

MISSION DESIGN ACTIVITY

The initial science assessment and prioritization effort yielded 12 mission concepts with four concepts put forward by each of the three science discipline panels. Each of the concepts were then organized and systematized using a standard design questionnaire intended to provide a relatively uniform set of design parameters as an input to the mission design process. The 12 mission designs were then produced over a five week period in February and March of 2011 at the Concept Design Center (CDC) of the Aerospace Corporation in El Segundo, California. The CDC team consisted of experts that were "firewalled" from the CATE process. Each mission was supported by a group of both shared and dedicated CDC team members, one or members of the steering committee, and a "champion" designated by the science panels to represent each investigation concept.

Decadal Survey Mission Strategy…

- A core assumption related to the PI-Led mission approach proposed for the Survey was related to the cost advantage expected to be achieved on smaller missions.
- Projected cost advantages based on an analysis of Aerospace data was in the range of 30 percent.
- Heliospheric missions were judged especially effective as PI-Led mission with respect to both cost and scientific return.

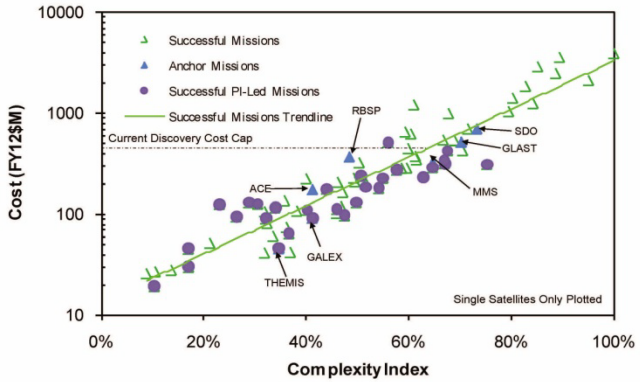


FIGURE E.9 CATE missions on CoBRA cost versus complexity plot. The green trend line is the median of the complexity-dependent costs of all successful missions. The costs of PI-led missions with >40% complexity are mostly below the median cost line. SOURCE: Provided by Aerospace Corporation under contract with the National Research Council.

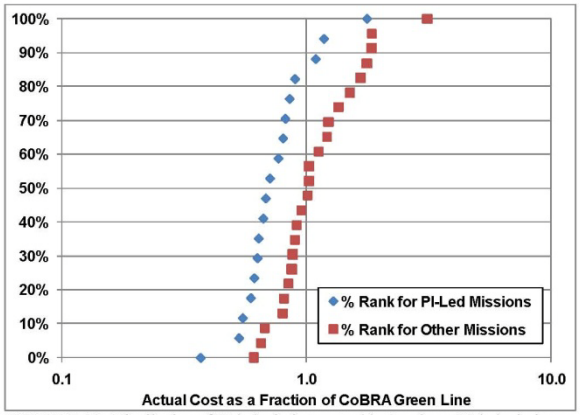


FIGURE E.10 Distribution of PI-led mission costs (blue) and non-PI-led mission costs (red) as a fraction of the median cost of all missions with 40% to 80% complexity (green trendline in Figure E.9). The median cost of PI-led missions is 0.7 times that of the other missions, with only 16% of the PI-led mission costs exceeding the median of the costs of other missions. The PI-led missions also have a smaller fractional cost variance. SOURCE: Provided by Aerospace Corporation under contract with the National Research Council.

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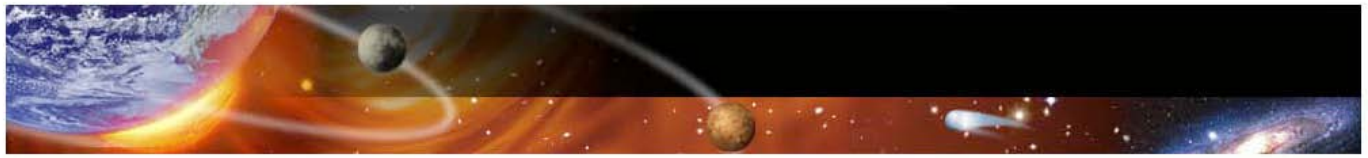

Science Mission Directorate Implementation of Spacecraft Risk Classifications

July 6, 2006

Kenneth W. Ledbetter
Science Mission Directorate Chief Engineer

NASA Management Process…

SMD Missions Initiated in Two Ways

The Strategic Planning Cycle

- Strategic missions (Dedicated-purpose missions, "flagship" missions) are planned.
  - Working groups develop discipline-specific "roadmaps"
  - Roadmaps are then combined into a Strategic Plan, defining specific mission goals.
  - Science goals and mission priorities are vetted by NASA's advisory bodies.
  - Spacecraft procured via RFP from Center.

Community-Proposed Mission Announcements of Opportunity

- Announcements of Opportunity are issued periodically to request proposals for cost capped PI-class missions.
  - The **Explorer** mission line consists of three mission sizes, and serves the Astrophysics and Heliophysics disciplines.
  - The **Earth Science System Pathfinders (ESSP)** serves the Earth Science discipline.
  - The **Discovery** mission line serves the Planetary Science discipline and the "Search for new Planetary Systems" theme in Astrophysics.
  - **New Frontiers** serves Planetary Science.
  - **Mars Scouts** serve the Mars Exploration Program.

NASA Management Process…

Principles for Implementation

- Strategic missions tend to be more expansive and costly.
- Community proposed missions tend to be less costly and more frequent.
- Accepted risk is usually inversely proportional to development cost.
- Both types of missions are subject to risk classification.
- Each type follows standard processes which are designed to account for these variations.

Two principal requirements documents are relevant in this discussion:

- NPR 8705.4 - Risk Classification for NASA Payloads
- NPR 7120.5 - NASA Space Flight Program and Project Management Requirements

NASA Management Process…

NPR 8705.4 Appendix A

Characterization	Class A	Class B	Class C	Class D
Priority (Criticality to Agency Strategic Plan) and Acceptable Risk Level	High priority, very low (minimized) risk	High priority, low risk	Medium priority, medium risk	Low priority, high risk
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, >5years	Medium, 2-5 years	Short, <2 years	Short < 2 years
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	May be 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
Achievement of Mission Success Criteria	All practical measures are taken to achieve minimum risk to mission success. The highest assurance standards are used.	Stringent assurance standards with only minor compromises in application to maintain a low risk to mission success.	Medium risk of not achieving mission success may be acceptable. Reduced assurance standards are permitted.	Medium or significant risk of not achieving mission success is permitted. Minimal assurance standards are permitted.

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	Class A	Class B	Class C	Class D
Examples	HST, Cassini, Europa Orbiter	MER, MRO, Discovery payloads, ISS Facility Class Payloads, Attached ISS payloads	ESSP, Explorer Payloads (MIDEX, SMEX), ISS complex subrack payloads	SPARTAN, GAS Can, technology demonstrators, simple ISS, express middeck and subrack payloads

NASA Management Process…

Examples:

Development Topic	Class A	Class B	Class C	Class D
Single Point Failures (SPFs)	Critical SPFs (for Level 1 requirements) are not permitted unless authorized by formal waiver. Waiver approval of critical SPFs requires justification based on risk analysis and implementation of measures to mitigate risk.	Critical SPFs (for Level 1 requirements) may be permitted but are minimized and mitigated by use of high reliability parts and additional testing. Essential spacecraft functions and key instruments are typically fully redundant. Other hardware has partial redundancy and/or provisions for graceful degradation.	Critical SPFs (for Level 1 requirements) may be permitted but are mitigated by use of high reliability parts, additional testing, or by other means. Single string and selectively redundant design approaches may be used.	Same as Class C.
Materials	Verify heritage of previously used materials and qualify all new or changed materials and applications or configurations. Use source controls on procured materials and acceptance test each lot/batch.	Use previously tested/flown materials or qualify new materials and applications or configurations. Acceptance test each lot of procured materials.	Use previously tested/flown materials or characterize new materials. Acceptance test sample lots of procured materials.	Requirements are based on applicable safety standards. Materials should be assessed for application and life limits.

NASA Management Process…

NPR 7120.5D - NASA Space Flight Program and Project Management Requirements*

- Paragraph 2.1.6. Based on inputs from the Mission Directorate Associate Administrator (MDAA), the NASA Associate Administrator (AA) determines whether a project is Category 1, 2, or 3 using Table 2-1 as a guide.

	Life Cycle Cost		
Risk Classification	LCC<$250M	$250M<LCC <$1000M	LCC>$1000M
A	Category 2	Category 1	Category 1
B	Category 3	Category 2	Category 1
C or D	Category 3	Category 3	Category 2

Table 2-1 Project Categorization Guidelines

**Note: The "D" version is currently DRAFT; final approval is in progress.*

Examining the PI option…

- NASA management modes for science missions can be broadly divided into 3 categories:
  - PI-Managed (Explorers, Discovery, New Frontiers)
  - PI-Guided (New Frontiers plus some others)
  - Institutionally Managed (Directed plus some others)
- NASA has gradually toward processes based management driven by rigid requirement flowdown and risk management.
- "Normalization due to enforcement of similar processes on smaller missions has resulted in "complexity inflation" with a corresponding inflation of mission cost.

Advocating the PI option…

- There are advantages associated with cost-capped missions under PI leadership that are easily misunderstood when cost growth metrics are examined without context.
- Cost growth is actually the same (~30%) but cost-capped missions require constraints on performance and requirements in order to create resource margins.