Lessons Learned from Technical, Management, and Cost Review of Proposals
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A Summary of 13 Years Experience in Reviewing Competitively Selected Proposals for New Science Missions

R. Brad Perry

Science Support Office

NASA Langley Research Center

Hampton, VA

John R. Rogers, Michael L. Stancati, Beth Wahl

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Abstract

NASA's selection of new space science missions via competitive solicitation follows a rigorous two step evaluation process that aims to produce the richest science return under a pre-defined cost cap. Most proposers consider it a daunting task to prepare a proposal that both answers the requirements of the Announcement of Opportunity, and contains the level of quality in scientific and technical detail to successfully withstand the evaluation process. To ensure robust participation in new missions by the space science community and to encourage the submission of the highest quality proposals, NASA maintains an ongoing effort to identify the characteristics that successful proposals share, and to capture lessons learned that can provide valuable guidance to future proposers. The purpose of this study is to produce a comprehensive set of insights and recommendations that will assist both new and experienced proposers in preparing complete and mature proposals. Data from hundreds of proposal evaluations is examined to identify the underlying causes of common major weaknesses and to make fundamental recommendations on how these weaknesses can be avoided. Mirroring the two-step evaluation process, the study is divided into two parts that allows for individual and in-depth focus on each of the Step 1 and Step 2 evaluations, with relationships across each phase integrated into the discussion. This paper provides the results of the Step 1 study.

Lessons Learned from Technical, Management, and Cost Review of Proposals

Introduction

For the last 13 years, the Science Support Office (SSO) at NASA Langley Research Center has directed the Technical Management and Cost (TMC) evaluation of proposals submitted for PI-led science missions. A comprehensive review of this effort has identified several trends which are summarized and presented herein for the benefit of the proposing community. NASA strives to assist new and experienced proposers in developing successful proposals, and to continually improve the overall quality and maturity of all proposals submitted. Proposer's to future NASA Science Mission Directorate (SMD) Announcements of Opportunity (AO's) are encouraged to consider these lessons learned in their proposal preparation effort.

This paper addresses the TMC review process only and does not address the science peer review of proposals. The TMC review is used for both the Step 1 evaluation of proposals and the Step 2 evaluation of Concept Study Reports. The observations and suggestions that follow are derived from the Step 1 TMC proposal evaluation history for all full missions, science instruments, and missions of opportunity (MoO) during the period 1996-2008. The first edition of this paper covered the evaluation history from 1996-2005. The current edition incorporates the results of subsequent evaluations thru 2008.

The history of Step 1 TMC risk ratings provides a useful context for the discussion of major weaknesses in the following sections. Figure 1 summarizes the TMC implementation risk ratings for all Step 1 proposals that were rated according to Low-Medium-High risk categories.

> *A **Low Risk** proposal is one that TMC reviewers expect will accomplish its goals within the schedule and cost proposed.*

Of 677 proposals, only 237 (35%) received a Low Risk rating. This is noteworthy since the TMC process gives each proposer the benefit of the doubt by recognizing that many Step 1 proposals are in the early stages of concept development and that the proposer has only limited space in which to present the complete development approach.

Most Step 1 proposers selected for a Step 2 Concept Study respond to the TMC findings by attempting to fix identified major weaknesses. This is important because major weaknesses are among the most significant factors considered in the TMC assessment of implementation risk. In general, a lower implementation risk rating increases a proposal's chance of selection to proceed to the next step towards authorization to implement the project for flight.

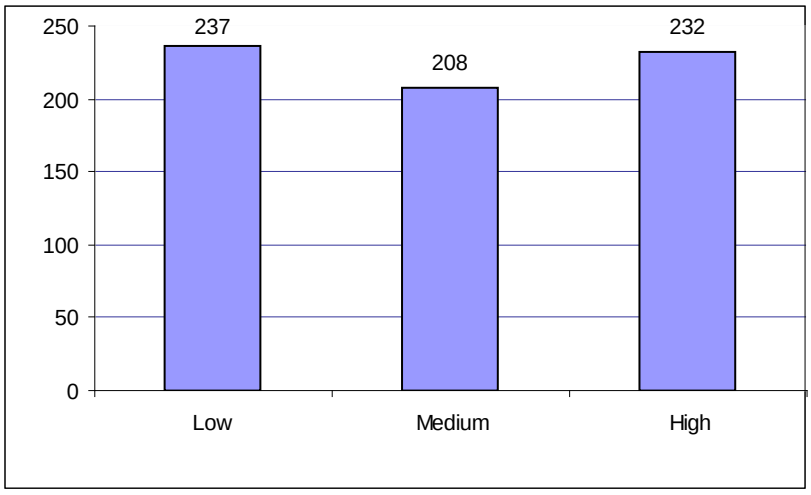

Figure 1 – Summary of Risk Ratings for Step 1 Proposals

The TMC Step 1 Review Process

The purpose of the TMC review is to assess the feasibility of the proposed approach for mission implementation (technical, management, schedule, and cost), and to express the TMC team's consensus finding of implementation risk as Low, Medium or High. The TMC review team is staffed to perform a comprehensive assessment of all aspects of the proposed implementation. The objective is to assess the likelihood that the project can be implemented as proposed and within the proposed cost and schedule.

The evaluation considers implementation factors such as proposed launch vehicle performance and reliability, mission design, spacecraft design and design margins, telecommunications, and the proposer's understanding of the processes, products, and activities required to accomplish development and integration of all elements. The assessment also includes the adequacy of the proposed organization structure, the roles and experience of the partner organizations, the management approach, the roles and experience of key individuals, the commitments of the partners and contributors, and the team's understanding of the scope of work. Relationships between the work and the project schedule, the project element interdependencies, and associated schedule margins are also evaluated. Risks associated with implementing new technologies are assessed along with the methods and rationale used to develop the estimated cost and cost risks.

Each member of the TMC team develops findings of strengths and weaknesses which, through a rigorous and systematic process, are integrated into consensus Major and Minor strengths and weaknesses. By ground rule, only major findings may influence TMC's view of implementation risk for Step 1 proposal evaluations. For reference:

- A ***Major Strength*** is a facet of the implementation response that is judged to be well above expectations and that can substantially contribute to the project's ability to meet its technical requirements on schedule and within cost.

- A ***Major Weakness*** is a deficiency, or set of deficiencies taken together, judged to substantially affect the proposer's ability to meet the technical objectives within the proposed cost and schedule.

Figure 2 shows the history of major weaknesses recorded for proposals evaluated by TMC teams over the past 13 years. Of 786 proposals[*] reviewed, 253 (32%) were judged to have no major weaknesses in their implementation plans with respect to technical, management and cost issues. Of these proposals, 130 had exactly one identified major weakness, 94 had two, and 182 proposals had five or more major weaknesses. The number and severity of major weaknesses directly affect the TMC review team's view of implementation risk, so it is incumbent upon the proposers to minimize or eliminate major weaknesses. When determining implementation risk, not all major weaknesses are of equal importance, nor are they equally correctable. Just one serious issue may be enough to convince the TMC review team that risk is high. However, minimizing the number of issues that may rise to major weaknesses will always be beneficial.

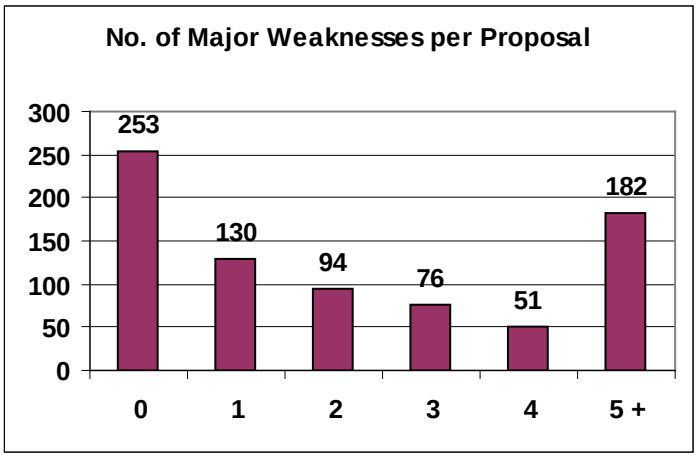

Figure 2. – History of Major Weaknesses per Proposal Evaluated

The study also identified a trend over all the SSO-managed TMC reviews of the last 10 years. As Figure 3 shows, the percentage of proposals submitted that are judged to have one or more TMC major weaknesses is generally *increasing*. Although this trend is not a strong one and there are several possible explanations for it and a full discussion is beyond the scope of this paper, it demonstrates that proposal implementation plans continue to receive close scrutiny in the TMC evaluation process, as directed by NASA.

[*] The total of 786 proposals exceeds the total shown above in Figure 1 because not all TMC review teams were directed to report implementation risk as High, Medium, or Low.

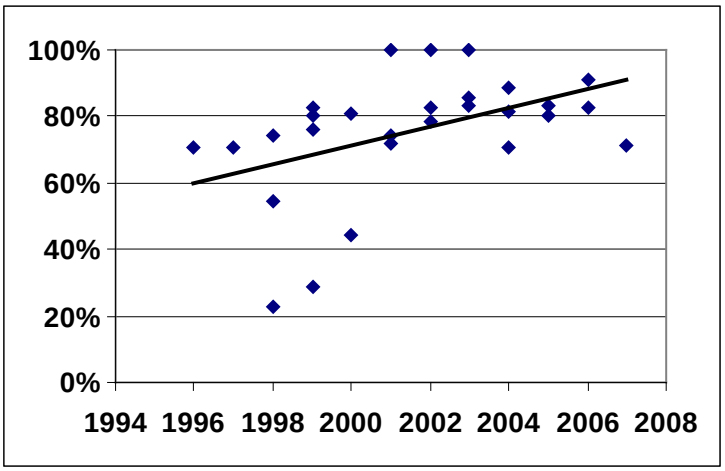

Figure 3. – Percentage of Proposals with One or More Major Weaknesses is Increasing

With the above considerations in mind, the SSO examined its archive of the records of all proposal evaluations to determine whether there are common causes of major weaknesses that should be identified to prospective proposers as potential pitfalls. The rest of this paper describes the results of this research, and identifies several areas that should be given especially careful consideration by proposers.

Common Causes of Major Weaknesses

Common causes for major weaknesses can be categorized in six areas: technical design margins, cost issues, instrument implementation, complex operations, systems engineering, and management plans. Figure 4 shows the percentage of Step 1 proposals with one or more identified major weaknesses in each of these categories. Two issues – mass margin and cost reserve – are highlighted for special attention, since they are prominent as sources of many major weakness findings. The following sections describe each category in further detail, and give some insight into what the TMC review panel found to be deficient.

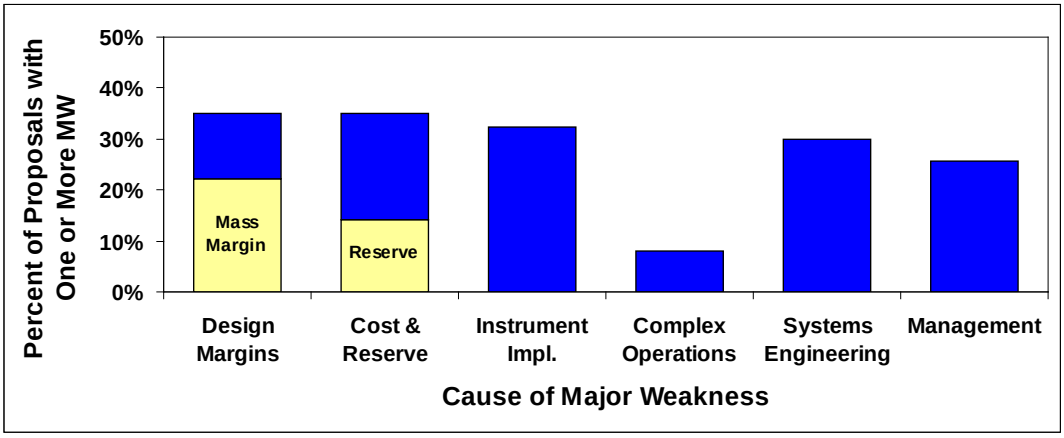

Figure 4. – Common Causes of Step 1 Proposal Major Weaknesses

Technical Design Margins

The technical design margins category includes all aspects of the flight system and instrument payload, such as mass, power and energy, data handling and communication links, ΔV impulse budgets and propellant margins. Of the proposals submitted over the 13-year period, 321 (40%) were judged to have at least one major weakness in this category. Of these, the mass and power margins were the most prevalent areas of concern, with mass margin issues accounting for about 38% of the noted major weaknesses.

There are several common reasons why a major weakness might be assigned for mass margin. First, the TMC team performs an independent verification of the claimed margin. If the proposal does not present sufficient description of the mission design, the current baseline mass, and the mass margin, the TMC team is unable to verify the margin, which results in a major weakness in most cases. Another common cause is that no mass margin is identified or that the proposal contains conflicting statements regarding the mass margin that cannot be resolved by the independent assessment. Still other proposals show mass margins that are too low based on the maturity of the proposed design, or that omit required elements (the spacecraft-to-launch vehicle adapter is one example of a mass element that can be overlooked). There is often confusion between mass contingency and mass margin. The following definitions, taken from the standard AO Appendix B instructions to proposers, are provided to help alleviate this confusion:

$$\text{Contingency} = \text{Max Expected Resource Value} - \text{Proposed Resource Value}$$

$$\%\ \text{Contingency} = \frac{\text{Contingency}}{\text{Max Expected Resource Value} - \text{Contingency}} \times 100$$

$$\text{Margin} = \text{Max Possible Resource Value} - \text{Max Expected Resource Value}$$

$$\%\ \text{Margin} = \frac{\text{Margin}}{\text{Max Expected Resource Value}} \times 100$$

TMC review teams look for a comprehensive engineering concept design that includes levels of contingency *and* margin appropriate for the phase of development, along with suitable rationale for the size of both.

TMC reviewers also examine stated power margins, which is another common cause of major weaknesses. There is no minimum acceptable value, but reviewers look for margins that suit the complexity and demands of each mission design, flight system, and operations sequence. TMC reviewers look to see whether margins are calculated against the most critical or demanding operating mode. If high power operation occurs during only a small fraction of the spacecraft operating life, it may be appropriate to call out separate margins for each significant operating mode.

TMC reviewers also attempt to verify maneuver impulse budgets and propellant requirements, and verify and assess suitability of stated margins for both high-thrust and low-thrust propulsion systems.

Cost

Of all Step 1 proposals reviewed, 201 (33%) had at least one major weakness regarding cost. There are three common reasons why a proposal received a cost major weakness.

1. Cost Reserve is too low. The most common cause of a cost major weakness is a deficient plan for the cost reserve. Several common findings may lead to a reserve major weakness.
    a. A reserve level (percent of cost-to-go) below the stated AO requirement.
    b. Liens already identified against the reserves.
    c. Reserves too low to cover cost threats identified during evaluation.
    d. Phasing of reserves in the funding profile too late to be useful. (If reserve amounts are placed in the out-years of a project to stay within the early funding profile limits, the reserve may not be available when needed to address development problems.)

2. Basis of Estimate is flawed. The proposer's explanation of the rationale and methodology used to prepare the cost proposal is found to be incomplete, unconvincing, or deficient in some other significant area.

3. The TMC team cannot validate proposer's cost estimate. The standard TMC process is to prepare multiple independent cost analyses for each proposal. These analyses are derived using different methods, and are based upon the historical record of actual costs for similar projects. Since independent analyses tend to be higher than the proposed cost, a generous allowance for errors and uncertainty is made. A proposed cost that falls outside this cost interval is likely to be flagged as a major weakness.

Except for AO requirements, there are no expected or "rule-of-thumb" values for cost reserve or other cost elements. Just as with design margins, the implementation plan for each proposed project is judged on its merits.

Instrument Implementation

Major weaknesses in the instrument category appear in 255 (32%) of Step 1 proposals. Because instrument purposes and designs address many different disciplines and measurement objectives, it is difficult to characterize or group weaknesses observed over a large set of proposed implementations. However, certain trends are evident. Areas of concern that produce major weaknesses include the following.

1. Overstated maturity and / or underscoped resources for technology development for which the development risks are not adequately addressed. TMC reviewers pay particular

attention to the development risks for new designs, and regularly engage subject matter experts in the requisite fields to evaluate the performance predictions and development risks of a proposed payload with respect to current state of the art.

2. Inadequate or inconsistent definition of performance related requirements (this is sometimes folded into a systems engineering weakness if requirements flowdown is also an issue.
3. Inadequate or inconsistent design concept definition that precludes a reasonable TMC evaluation.
4. Weak heritage claims. Design heritage is given close scrutiny to determine whether the design heritage exists as claimed, and whether the proposed project can leverage that heritage experience effectively.
5. Inconsistencies between instrument requirements and the spacecraft instrument accommodation capabilities.
6. Insufficient integration and test program including an end-to-end verification test.
7. Issues with pointing performance (knowledge, accuracy, etc.) and potential for detector contamination during flight.

Complex Operations

In 64 (8%) proposals, there were major weaknesses identified related to the complexity of the proposed operations. These included planned observing sequences for instruments, particularly when the payload consisted of several instruments that must be scheduled and operated sequentially to avoid interfering with each other or in cases where many critical events must occur in a short period of time.

Proposed landers present additional operational challenges that may not be adequately planned. The TMC review evaluates the concept of operations and how the operations planning will be developed and tested.

Systems Engineering

TMC concerns about systems engineering plans resulted in major weaknesses in 235 (30%) of Step 1 proposals. Requirements definition and flowdown and consistency between the different observatory subystems and mission elements, and the proposed mission resources continues to be a common source of major weaknesses.

Other common findings include an incomplete or unconvincing plan for how systems engineering responsibilities will be executed across the entire project with strong project-level oversight of this critical function, and whether the implementation plan provides for adequate resources for all participating organizations to successfully accomplish this function.

Management

Management issues include two separate areas: management plans and project schedules. Management plans were the source of major weaknesses in 203 (26%) of Step 1 proposals.

Although recent data suggests a decrease in the number of weaknesses in this area, common trends are noted as follows.

1. Confusing organizational roles and responsibilities for the participating institutions or key individuals.
2. Unclear lines of authority within the project, or between the project and the participating institutions.
3. Lack of demonstrated organization or individual expertise for the specific role identified. For example, proposing a project manager or systems engineer with insufficient prior experience.
4. Low time commitments for essential members of the core management team.
5. Missing letters of commitment or endorsement from partners, as required by AO instruction.

Project schedules are also a source of weaknesses. There is a common AO requirement to present the project's master schedule in summary form (1-2 pages). TMC review of these master schedules led to major weaknesses in 130 (17%) of the Step 1 proposals reviewed. Items of concern include the following.

1. Insufficient detail from which to perform a reasonable assessment of whether the proposer understands how all the work will be accomplished in time.
2. The master schedule shows no margin or inadequate margin to address potential delays. Similar to other margin and reserve assessments, the TMC reviewers examine the unencumbered margin against the project's primary critical path.
3. The TMC reviewers assess whether the proposed schedule reflects realistic expectations based on recent experiences in flight system and payload development. It is a common issue in Step 1 proposals to see inadequate schedule detail and margin on Phase C/D activities.).

Summary

This paper summarizes the results of a study conducted to identify common causes of major weaknesses in Step 1 proposals evaluated by TMC review panels. The results presented are derived from a complete census and analysis of all TMC proposal evaluation activity conducted by the SSO during the period 1996-2008.

The TMC review team looks for evidence of comprehensive conceptual designs and robust plans in all aspects of the proposed technical, management, and cost considerations. The final judgment of how well the proposal meets this expectation is the implementation risk rating, which is summarized as low, medium, or high risk. The primary consideration that raises a proposal's risk rating from low to medium or high is the number and nature of major weaknesses

identified during the Step 1 proposal review. Not all major weaknesses are of equal importance; one serious issue may be enough to convince the TMC review team that risk is high.

Review of the 13-year history of proposal evaluations conducted by the SSO identified six areas that are common causes of major weaknesses. These areas are technical design margins, cost issues, instrument implementation, complex operations, systems engineering, and management plans including schedule. The discussion of the findings summarized in this paper has identified several lessons that may be valuable to reduce the learning curve for new proposers, and to improve the overall quality and maturity of all proposals submitted.