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

For the past 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. For most NASA Science Mission Directorate (SMD) Announcements of Opportunity (AO's), the proposal evaluation process leading from initial submission to final selection involves two steps. In Step 1 all compliant proposals are evaluated under a standardized TMC process and assigned a TMC risk rating. NASA factors the TMC rating into the overall selection process, which includes the science evaluation and programmatic considerations, to select a set of missions for Phase A funding. In Phase A proposers are asked to further develop the mission and implementation concept, address major weaknesses from the Step 1 evaluation, and submit a Concept Study Report (CSR). In the Step 2 evaluation, the CSRs are subjected to a more rigorous TMC evaluation that includes relevant specialist reviewers and the opportunity for structured interaction between the TMC evaluation team and the proposing team. Each CSR is given a TMC risk rating and under several AO's in recent years, a separate Cost risk rating has also been assigned. In 2005 SSO commissioned a study to investigate and report on trends and collect lessons learned from the TMC evaluation process. In 2008, the study was updated to include recent AO's and to create a separate written report, this paper, on lessons learned in the Step 2 evaluation of CSRs. The Step 1 report "Lessons Learned from Technical, Management and Cost Review of Proposals" is available from the SSO library.

The primary purpose of the Lessons Learned Study is to gather data to support the ongoing effort by SSO to enhance the effectiveness of the TMC evaluation process, and to provide useful feedback to the proposing community. NASA strives to assist both new and experienced proposers in developing successful proposals, and to continually improve the overall quality and maturity of all proposals submitted. Therefore, proposers to future AO's are strongly encouraged to consider the insights gleaned from both the Step 1 and Step 2 TMC evaluations. The Lessons Learned Study addresses the TMC process only and does not address the science peer review of proposals.

The Step 2 TMC Evaluation Process

The two step proposal evaluation process enables NASA to accept and evaluate all compliant proposals for a given AO while ensuring that the investment of finite resources will produce the maximum science return with an acceptable level of risk. Where the Step 1 goal is to identify high value science missions that appear to be feasible to implement within the boundaries of the AO, Step 2 seeks to "downselect" from that group mission(s) having both compelling science and an implementation that is highly likely to succeed. The Step 1 and Step 2 evaluations differ in three key ways: 1) the depth to which individual project elements are investigated, 2) the degree to which the proposers are given the benefit of the doubt, and 3) in Step 1, only major strengths and weaknesses are considered in the overall risk rating whereas in Step 2, minor strengths and weaknesses can also influence the risk rating. In both evaluations the assessed likelihood of a project to succeed is expressed in the TMC risk rating of Low, Medium, or High which results from an in depth assessment of an extensive number of factors under the broader categories of Technical, Management & Cost. Although a proposal rated High Risk is considered not feasible within the program resources available, NASA does retain the option to consider additional funding for projects to develop concepts where the science is considered highly valuable but the TMC evaluation has identified specific issues that drive the overall project risk high.

Strengths and weaknesses, as identified by the TMC team and supported by information from the CSR and site visit, form the basis from which the TMC assesses the feasibility and risk of the proposed implementation, and provide the supporting data for the TMC risk rating. For reference, the definition of strengths and weaknesses as defined for the TMC evaluation team members is:

- 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.
- A ***Minor Strength***: is a strength that is substantial enough to be worthy of note and brought to the attention of proposers in debriefings.
- A ***Minor Weakness***: is a weakness that is substantial enough to be worthy of note and brought to the attention of proposers in debriefings.

The Step 2 Study Findings

The complete set of Step 2 missions contained in the SSO database includes 109 CSRs submitted during the period 1996-2008. 92 of these are full missions (including instruments) and 17 were Missions of Opportunity (MoOs). Due to process variations in the early years of TMC evaluations, not all CSRs were included in all aspects of the Step 2 Lessons Learned study data. MoOs likewise, which can be submitted under both full and instrument AOs, often have unique or limited objectives, such as science support, or data reduction. Therefore, they were included in the data only in cases where inclusion did not obscure or skew the findings.

Figure 1 shows the distribution of risk ratings among the full missions studied and breaks out proposals evaluated from 2005 and prior, from the recent evaluations. Figure 2 highlights the relative distribution of risk ratings for the same data set.

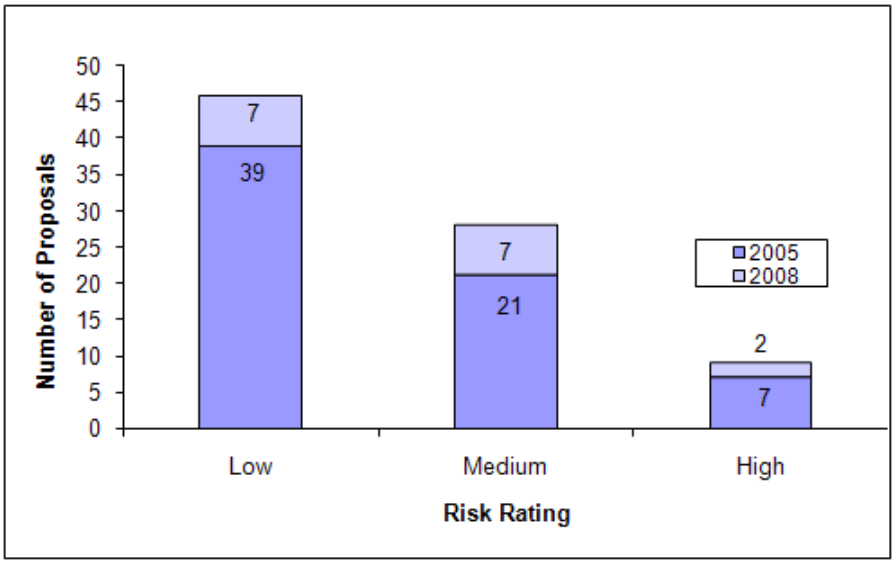

Figure 1. – Numerical Distribution of Risk Ratings

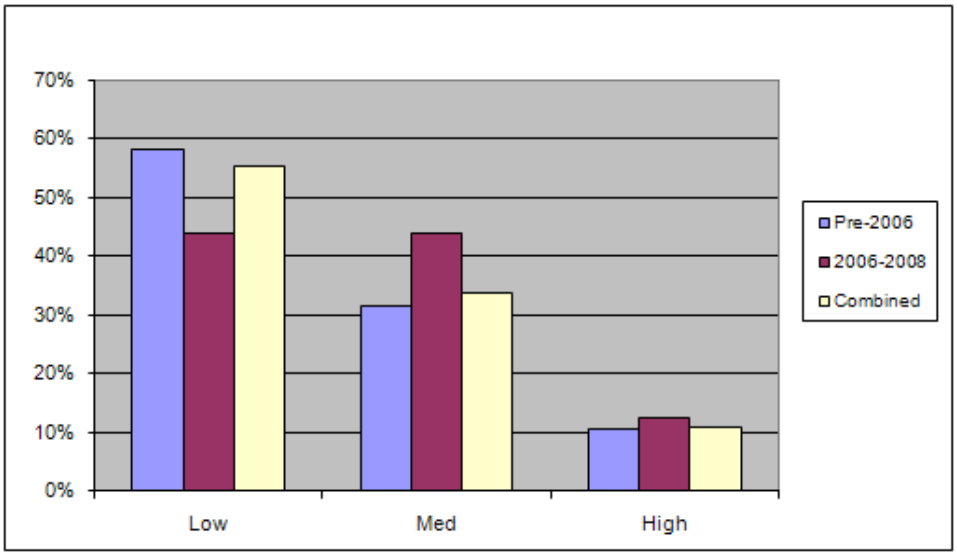

Figure 2. – Relative Distribution of Risk Ratings

Figure 1 demonstrates that in the evaluations conducted prior 2006, there was a clear majority of CSRs rated low risk. While the 2006-2008 data suggest a trend toward a more even split between low and medium risk, the low sample size does not provide conclusive evidence of this. Figure 2 indicates that the percentage of proposals rated high risk has remained steady at about 10%.

A comparison of the Step 1 and Step 2 TMC risk ratings for a set of 52 full missions reveals that 7 improved (lowered) their risk rating in Step 2, 23 maintained the same risk rating, and 22 received a worse (higher) risk rating. Of the 22 that got worse, only 6 went from low or medium to high. The relatively small percentage of proposals achieving improved ratings is likely explained by the combination of a more thorough evaluation and less benefit of the doubt in Step 2. In addition, some of the most compelling science missions have inherently high risk elements that are difficult to mitigate in the short schedule and limited resources of Phase A. So although it is expected that proposers selected for Phase A funding will address significant risks identified in Step 1 and most do, it is often not the case that the Phase A effort produces an improved risk rating.

The number and severity of major weaknesses directly affects the TMC 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. In Step 2 the TMC team expects proposers to clearly identify the major implementation risks, define the project's plan to manage and retire them, and demonstrate adequate resources and reserves to support the plan. Figures 3 and 4 illustrate the relationship between a CSR's risk rating and its number of major strengths and weaknesses. As expected, CSR's with a Low risk rating clearly have a predominance of major strengths and very few major weaknesses. More than a quarter of the Low risk missions examined had no major weaknesses at all. Conversely, all of the CSR's rated High risk had more than one major weakness and nearly three quarters had 5 or more major weaknesses. Predictably, CSRs with a Medium risk rating generally fall in the middle, having both major strengths and weaknesses but not an overwhelming number of either. A CSR that would otherwise be rated Low or High will sometimes move to a Medium risk rating based on the weight of minor strengths or weaknesses respectively.

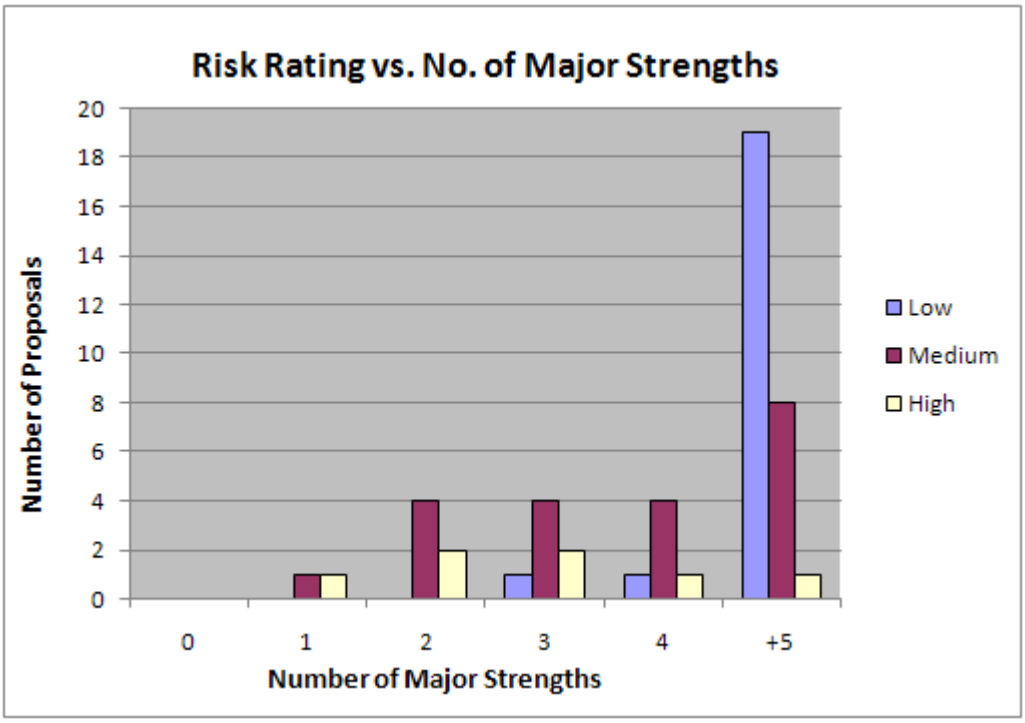

Figure 3. – Risk Rating versus Number of Major Strengths

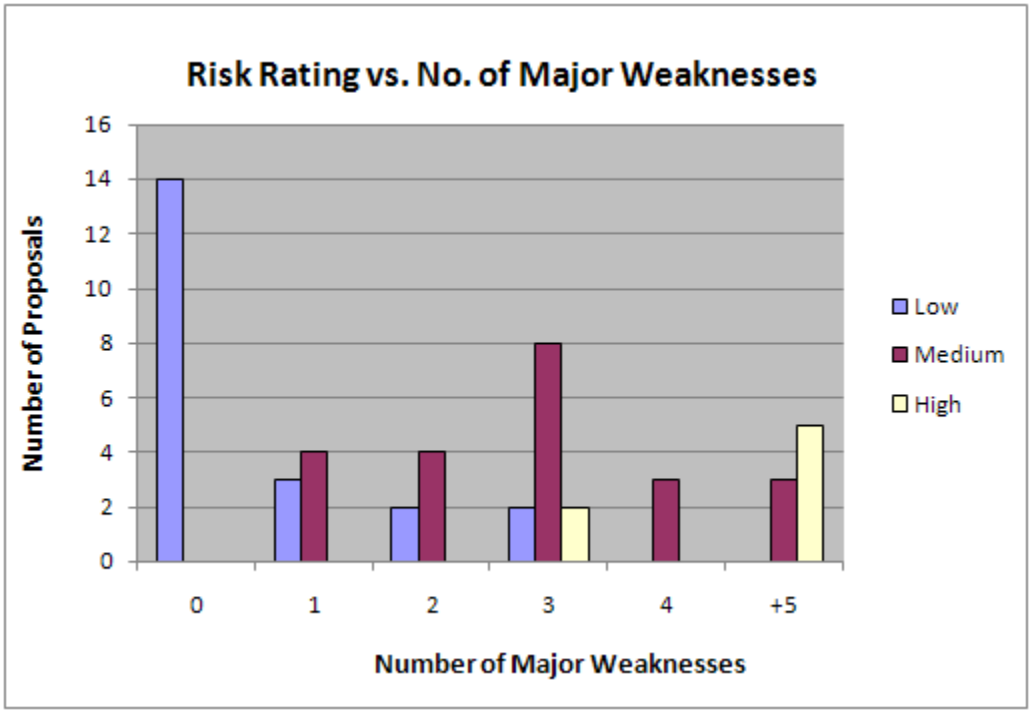

Figure 4. – Risk Rating versus Number of Major Weaknesses

Common Causes of Major Weaknesses

In Step 1 the nature of major weaknesses varies widely but the lessons learned study showed that the majority can be classified into six broad categories: technical design margins, cost issues, instrument

implementation, overall complexity, systems engineering, and management plans. In Step 2 these same classifications appear but the issues are typically more narrowly focused. For example, a Step 1 weakness on insufficient schedule reserve, when not adequately addressed in Phase A, may become focused on the development schedule for a specific piece of hardware in Step 2. The graphs of Figures 5, 6 and 7 are derived from close examination of all major weaknesses occurring in a data set of 79 full missions and show the distribution of those major weaknesses among specific areas within the Technical, Management and Cost categories respectively.

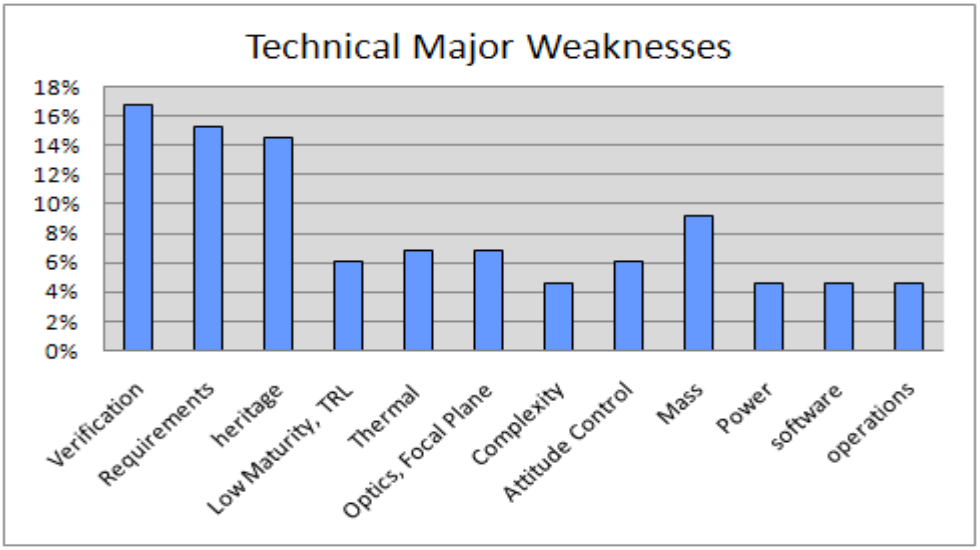

Figure 5. – Technical Major Weaknesses

Step 2 major weaknesses in the technical category are clustered heavily in the topic areas of Verification, Requirements and Heritage. In Step 2, proposers are expected to a) show clear traceability of the science and mission requirements to implementation and performance, b) outline a complete plan for how the proposed performance will be verified at appropriate points throughout development, and c) provide an accurate assessment of how heritage elements support the mission requirements and a plan for additional work needed to overcome any shortfall in performance or qualification. These major weaknesses are also common in Step 1 but occur in lower percentages relative to other weaknesses, such as those related to design margins, and are often characterized by lack of information. The fact that the collective Step 2 Technical major weaknesses aren't dominated by classic space mission challenges such as resource margins, attitude control and thermal design seems surprising initially. That issues with Verification, Requirements and Heritage emerge in higher proportion in CSR evaluations suggests that some types of weaknesses may more "fixable" with Phase A funding than others. Indeed it's logical for example, that while a specific mission design or subsystem implementation can often be refined to improve resource margins, it's typically more difficult to resolve shortcomings in heritage hardware without substantially increasing other project resources such as cost or schedule, particularly when the alternative is a new design. Likewise, clear traceability and flow down of requirements only becomes more complex as definition of the mission implementation and design evolves. Serious problems with verification, which is often discussed in only general terms in Step 1, emerge in Step 2 as proposers wrestle with how to accomplish end to end verification and "test as you fly" within the proposed resources. Proposers should therefore recognize that while it's often straightforward to apply Phase A resources to resolve issues with a proposed design approach, an inadequate foundation in requirements definition and basic verification planning, or overestimation of heritage benefits can impede Phase A development in many areas. Therefore, careful attention to requirements definition, and also traceability

of requirements to the design implementation, particularly where heritage hardware is involved, is critical in Step 1 in order to provide a strong and stable foundation for future development. Among the other technical areas where a noteworthy number of major weaknesses occurred in Step 2, only mass stands out in slightly higher numbers. As proposers strive to produce the best science within the rigid constraints of mission profile and launch capability, mass is most often the pivot point between choices in new development and risk reduction.

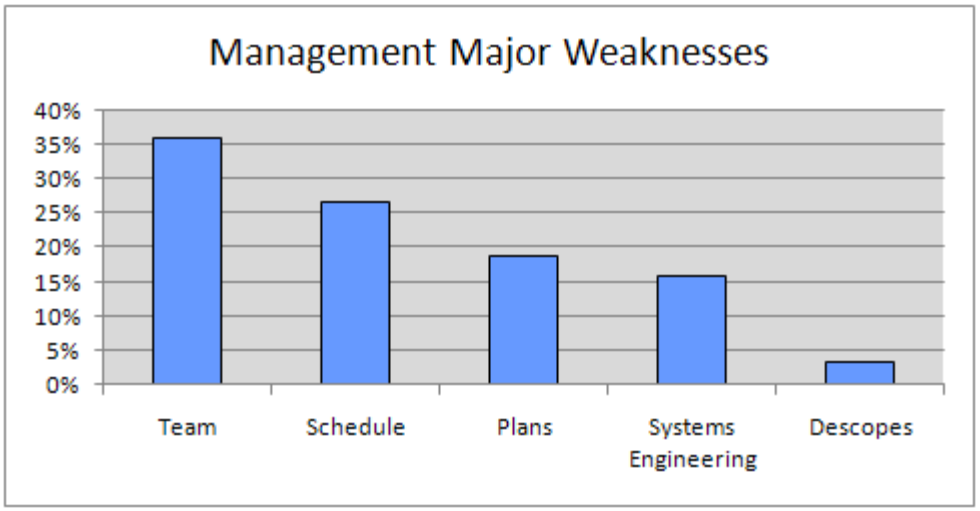

Figure 6. - Management Major Weaknesses

Teaming arrangements and organizational issues are the primary source of Step 2 major weaknesses in the Management category. The most common causes noted are a) key staff lack the expected level of experience for the proposed assignment, and b) on-site presence and time commitment of key team members is inadequate to support the mission. Again, these issues were apparent in the Step 1 examination of common causes but were less obvious among other general group of management major weaknesses. That the problem of finding and committing qualified key staff persists in Step 2 is not surprising and underscores a persistent concern of all highly specialized engineering projects. Specific issues with schedule appear more often in Step 2. This is consistent with the fact that NASA expects significantly more schedule definition in the CSR than in Step 1 proposals and likewise, the Step 2 schedule receives commensurately more scrutiny by the TMC team.

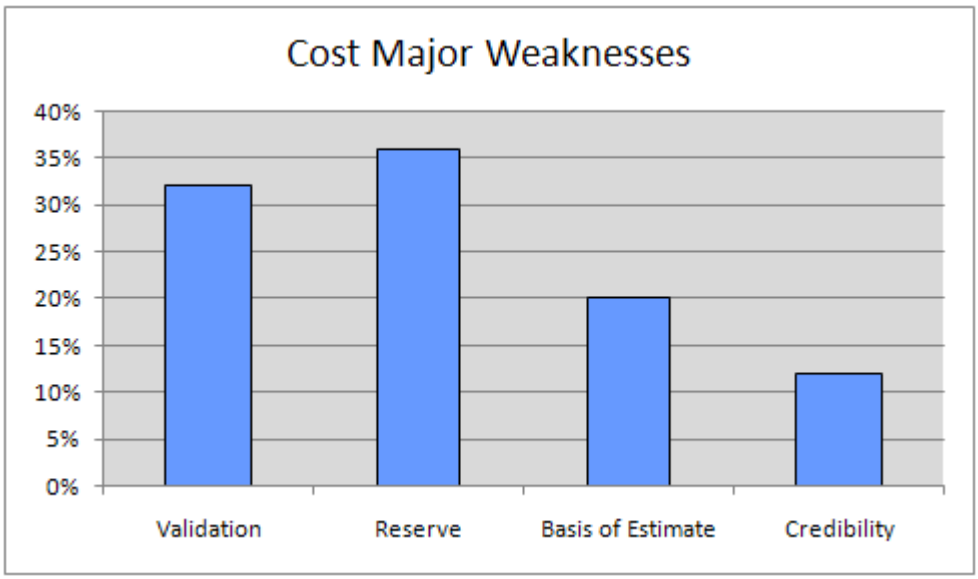

Figure 7. – Cost Major Weaknesses

As in Step 1, inadequate cost reserve and problems in validating the proposed cost continue to be the predominant themes in Step 2 cost major weaknesses. The persistence of cost reserve major weaknesses is logical, as a successful process of increasing design maturity by nature, uncovers development and implementation details that were not evident in the initial concept, and likewise not included in a detailed cost estimate. Since missions are cost capped, erosion of cost reserve is a common predicament for proposers in Phase A, a fact that strongly underscores the critical importance of having robust cost reserves in the Step 1 proposal. Major weaknesses related to validation of the proposed cost typically arise when there is disagreement between the proposer and the TMC about the rationale, relevance, and appropriateness of technical and programmatic assumptions, *and* the aggregate TMC cost estimate varies substantially and irreconcilably from the proposer's. Recognizing that less benefit of the doubt is given proposers in Step 2, both major and minor Step 1 weaknesses related to technical or programmatic assumptions should be addressed aggressively in Phase A to preclude the potential for cost validation major weaknesses in the CSR evaluation. Major weaknesses due to deficiencies in the basis of estimate are not as significant in Step 2 as in Step 1 and again, this likely reflects the ability of proposers to correct that deficiency in the Phase A effort.

Summary

This paper is the second part of a two part study conducted to identify common causes of major weaknesses in proposals evaluated by TMC review panels. Part 1 of the study focused on Step 1 proposals and is titled "Lessons Learned from Technical, Management and Cost Review of Proposals". This paper focuses on the Step 2 review of Concept Study Reports of projects that were selected for Phase A funding as a result of the Step 1 process. The results presented are derived from study and analysis of all TMC CSR evaluation activity conducted by the SSO during the period 1996-2008.

The trends noted from the investigation of common causes of Step 2 major weaknesses are as follows. In the Technical evaluation category, the most prevalent major weaknesses are those concerning Requirements, Verification, and Heritage. This suggests that while proposers are often successful in resolving problems with the design approach in Phase A, issues related to inadequate requirements definition and traceability, or overestimating the value of heritage are more difficult to resolve. Careful attention to these areas is critical in Step 1 in order to provide a strong and stable foundation for Phase A development. In the Management evaluation category the most common causes of major weaknesses are

lack of experience and inadequate time commitments of key staff, a common problem in highly specialized engineering projects. Specific issues with schedule appear more often in Step 2 than Step 1. This is consistent with the fact that NASA expects significantly more schedule definition in the CSR than in Step 1 proposals and likewise, the Step 2 schedule receives commensurately more scrutiny by the TMC team. In the Cost category, inadequate cost reserve remains a major issue. This follows from the fact that increasing definition in the design and mission development typically produces more threats against the cost than opportunities to improve it. Inability of the TMC to validate the proposed costs also persists as a common cause of Cost major weaknesses, with the underlying problem typically due to issues with supporting assumptions. Major weaknesses related to an inadequate basis of estimate are not as common in Step 2 as Step 1. Since these are most often characterized by lack of information, this is clearly a benefit of the Step 2 process where interaction between the proposers and the TMC team is allowed.

In summary, it is worthy of note that of 20 SSO evaluated full flight missions that were selected for implementation with the two step evaluation process, 9 have either completed their mission successfully or are still operational, while 8 continue to proceed successfully in development. Of 3 that were selected but did not realize their mission, one was cancelled at PDR, one was lost on orbit due to hardware failure before executing the science mission, and one was lost due to a launch mishap. Discounting the latter, 18 out of 20, or 90%, of the missions selected via the standard two step evaluation process have been successfully implemented, providing a strong indicator that this process is effective in identifying missions that are likely to succeed.