Summary of Lessons from Previous PI Missions: Studies and Assessments

Presentation to the PIF-3
July 29, 2011

Cindy Daniels
Science Office for Mission Assessments (SOMA)

Step 1 & 2 Lessons Learned Study

TMC Phase A Performance Study

Step 1 & 2 Lessons Learned Study

Study Purpose & Approach

Space Science Mission Risks

TMC Risk Envelope Concept

Step 1 & 2 Risk Distribution

Step 1 Major Weakness Trends and Common Causes

Step 2 Major Weakness Trends and Common Causes

Study Purpose & Approach

Study Questions

What is the history of TMC Risk Ratings?

Are there common causes of major weaknesses?

For projects selected for implementation did TMC review anticipate subsequent problems encountered in development or flight?

Study Approach

Conduct a comprehensive review of formal records of more than 800 proposals and concept studies retained by SOMA in the on-site archive library – TMC risk ratings, strengths and weaknesses

Utilize the SOMA database of Form C findings and descriptive characteristics

Space Science Mission Risks

Total Risk of Space Science Missions

Inherent Risks

Risks that are unavoidable to do the investigation:

- Launch environments
- Space environments
- Mission durations
- Unknowns
- Etc.

Programmatic Risks

Risks that are uncertainties due to matters beyond project control:

- EnvironmentalAssessment approvals
- Budgetary uncertainties
- Political impacts
- Late/non-delivery of NASA provided project elements
- Etc.

Implementation Risks (Evaluated by TMC)

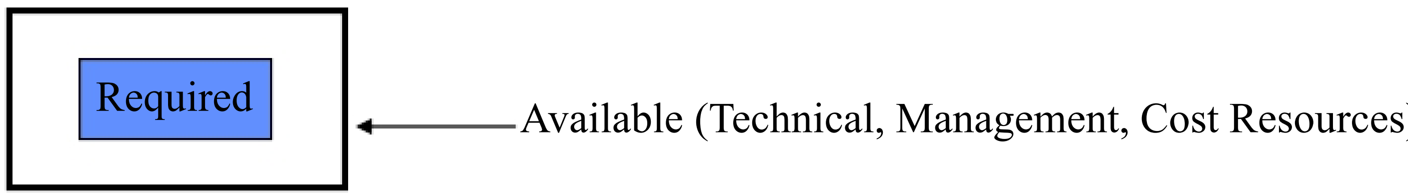
Risks that are associated with implementing the investigation:

- Adequacy of planning
- Adequacy of management
- Adequacy of development
- Adequacy of schedule
- Adequacy of funding
- Adequacy of Risk Management (planning for known & unknown)

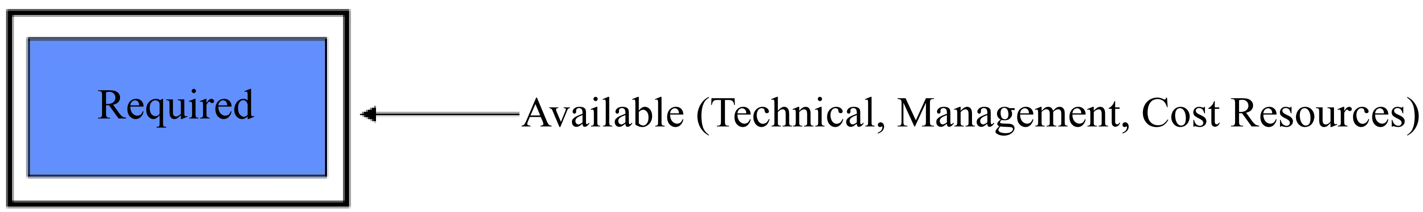
TMC Risk Envelope Concept

Envelope: All TMC Resources available to handle known and unknown development problems that occur.

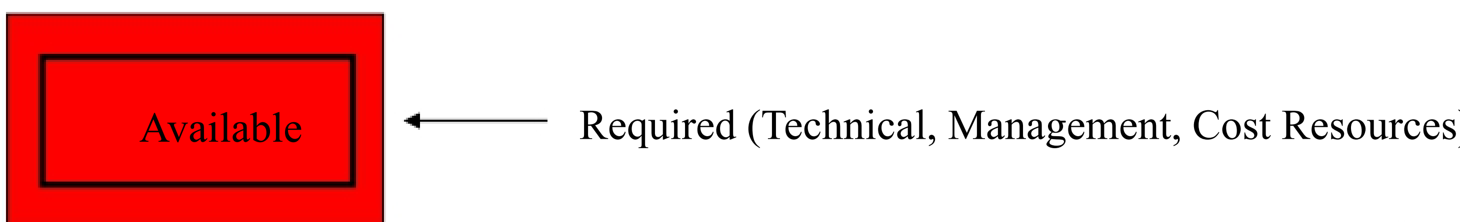
Low Risk: Required resources fit well within available resources



Medium Risk: Required resources just barely inside available resources.

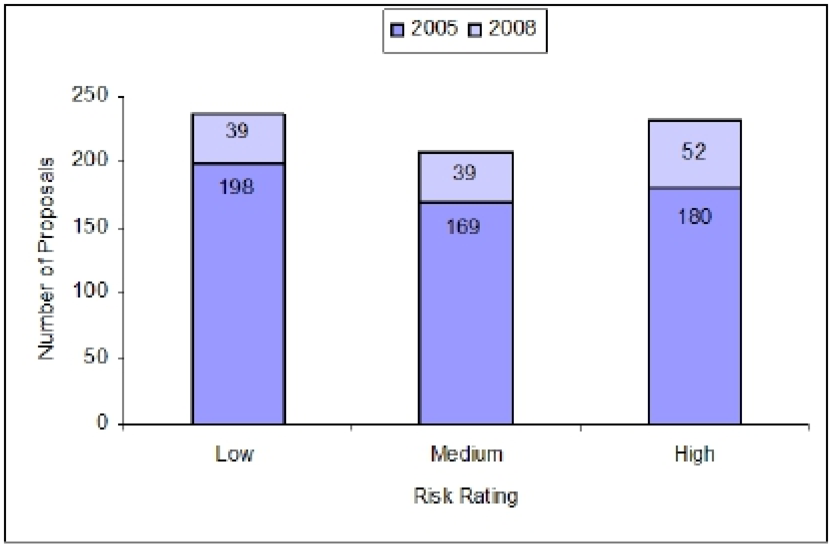


High Risk: Required resources DO NOT fit inside available resources.

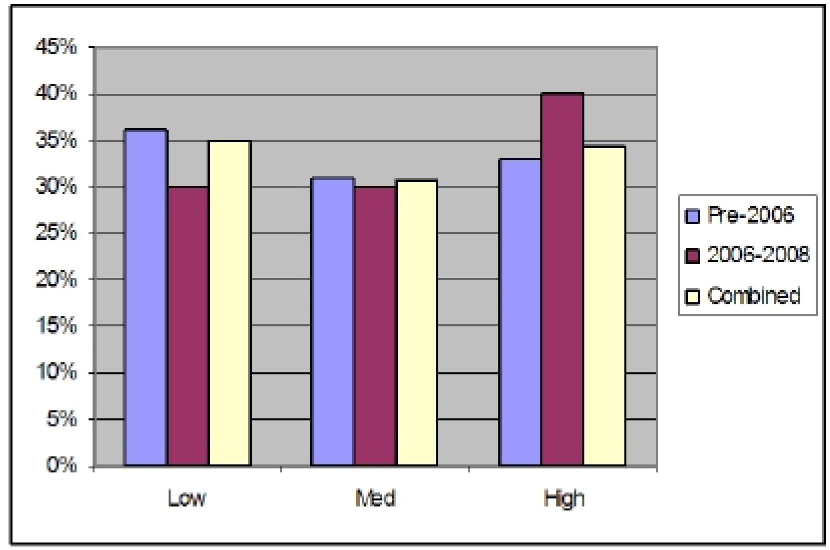


TMC Step 1 Risk Distribution Comparison
Pre-2006 vs. Recent Missions*

Distribution by Number



Distribution by Percentage



There continues to be a slightly bipolar but roughly equal distribution of overall risk ratings

- The distribution is skewed slightly more toward high risk with the addition of the 2006-2008 missions
  - Recent TMC teams have increased expertise and depth of investigation in many areas, e.g. instruments, operations, etc.

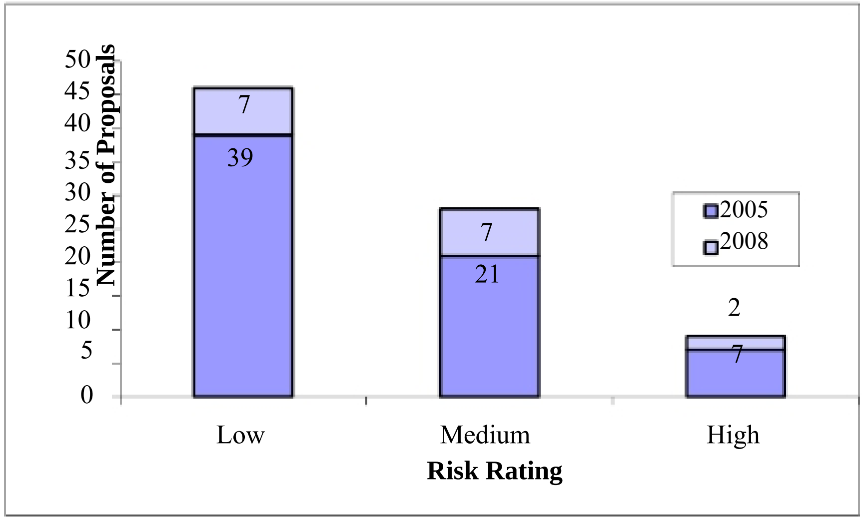
Overall, more than a third of Step 1 proposals are still rated Low Risk

- Step 1 AO responses contain many proposals with serious implementation flaws so this suggests that benefit of the doubt is still being applied.

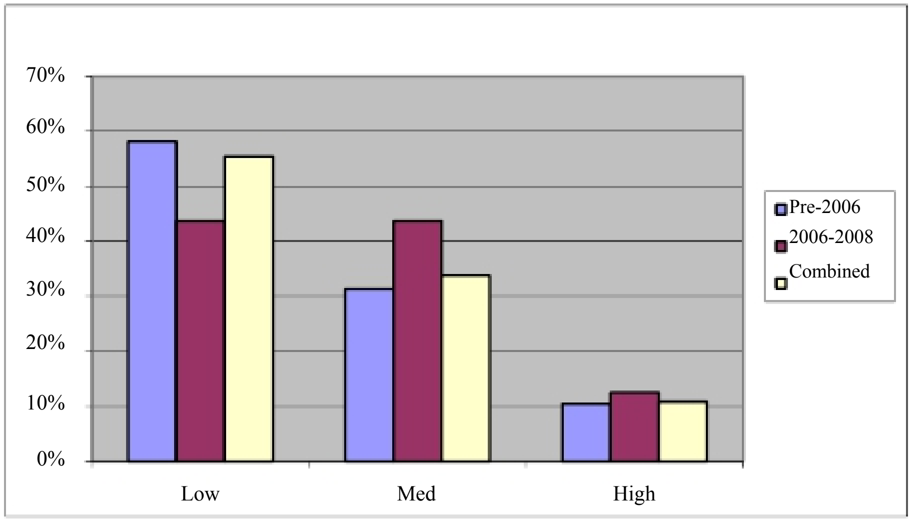
**Includes full & MOO proposals*

TMC Step 2 Risk Distribution Comparison

Distribution by Number



Distribution by Percentage



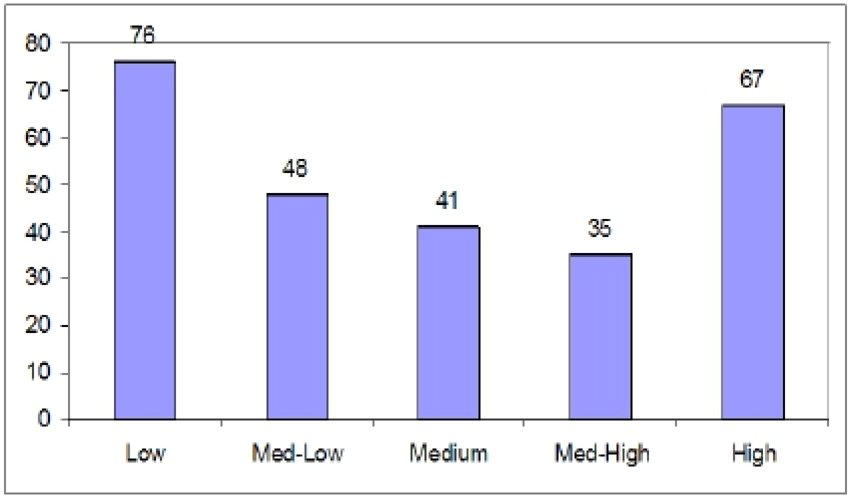
Step 2 proposals evaluated between 2006-2008 data suggest a trend toward a more even split between low and medium risk, though the low sample size does not provide conclusive evidence of this.

The percentage of Step 2 proposals rated high risk remains steady at about 10%.

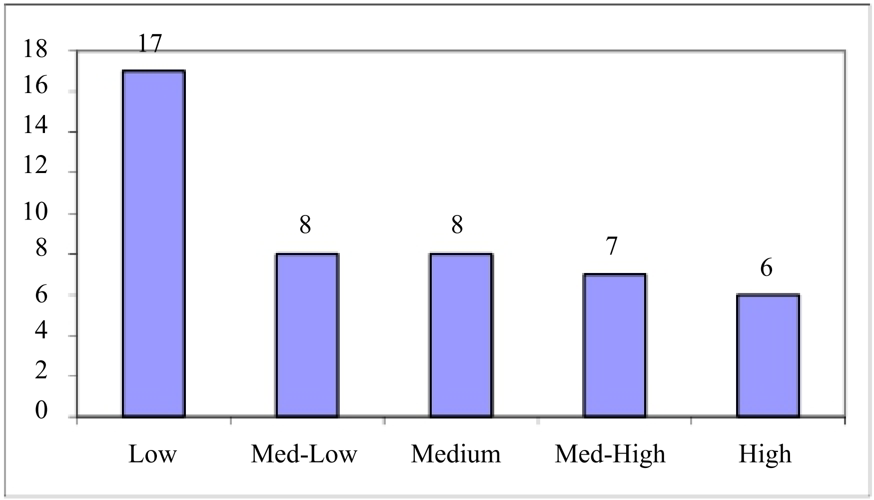
The two step evaluation process remains effective in reducing the set of candidate missions to those with acceptable risk

TMC Risk Evaluations

Step 1 Cost Risk



Step 2 Cost Risk



Smaller totals than for TMC risk, because cost risk has not always been reported separately, and the number of reporting categories has evolved from three to five

Cost risk distributions for both Steps follow the overall TMC risk distributions

Step 1 Common Causes of Major Weaknesses (1 of 5)

Step 1 findings are based on data from 783 Step 1 proposals

Technical design margins for flight system and payload

- Step 1: *Mass*, Power, Data Handling & Communications Links, other concerns
  - 119 with one or more Major Weaknesses (MW) on mass margins – further details next page [= 22% of population]
  - 68 MW on power/energy margins [13%]
  - 53MW on Data Handling & Communications Links
  - 38 MW on propellant margins
  - 26 MW on thermal design margins
  - 6 MW on volume margin
  - 11 MW on radiation protection factor

Reasons for Major Weakness on Margin

<u>Mass</u>

Insufficient description presented to allow TMC to do an independent verification of the claimed mass margin

- Heritage masses don't account for potential design modifications

No clearly stated mass margin

- None given at all
- Conflicting statements
- Confusion between contingency and margin
  - Some of this is failure to follow AO directions which are clear and explicit
  - Some is deliberate proposal puffery

Margin is clearly stated and verifiable, but deemed by TMC to be too low

Missing and undersized elements (e.g., launch vehicle payload adapter) create immediate lien on claimed margin

<u>Power</u>

Similar concerns

Power margin not always calculated against the most critical or most demanding operating mode

Step 1 Common Causes of Major Weaknesses (2 of 5)

Cost Reserve

- Out of 783 Step 1 proposals – 124 proposals [16%] have a cost reserve-related MW (261 proposals have a cost MW)

- Reserve is below the stated AO requirement
  - Overall level
  - Or by project Phase
- Liens against reserve already identified – e.g., contractor incentive fee
- Reserve is too low to cover cost threats, as identified by proposer or TMC analysis
- Reserves are phased too late in the funding profile to be available when the schedule of activity suggests the need is greatest
  - a recent trend that appears to be partly in response to the 25% rule in recent AOs

Step 1 Common Causes of Major Weaknesses (3 of 5)

Instruments

- Step 1: ~255 proposals [32%] with instrument-related MW some or all of these concerns
  - Complex, new design
  - Inadequate or inconsistent description and detail
  - Weak heritage claims
  - Integration and accommodations: mismatch between stated instrument requirements and known bus capacity
  - Integration and test program; end-to-end verification testing
  - Some issues with pointing performance, detector contamination

Complex Operations

- Step 1: 64 proposals [8%] with complex operational requirements – for payload, observing sequence, landers, etc.

Step 1 Common Causes of Major Weaknesses (4 of 5)

Systems Engineering

- Step 1: ~235 proposals with a related MW [30%]
  - Science requirements and flow down to instruments, payload accommodations and flight systems.
    - Note: this concern seems to occur more often in earlierAOs; recent experience suggests improvement in submittals, perhaps in response to firmAO requirements traceability matrix…?
  - Project-wide systems engineering responsibility
  - Credible plans for success
  - Underestimates of the cost of this function

Step 1 Common Causes of Major Weaknesses (5 of 5)

Step 1 **Management**– 203 MW [26%]

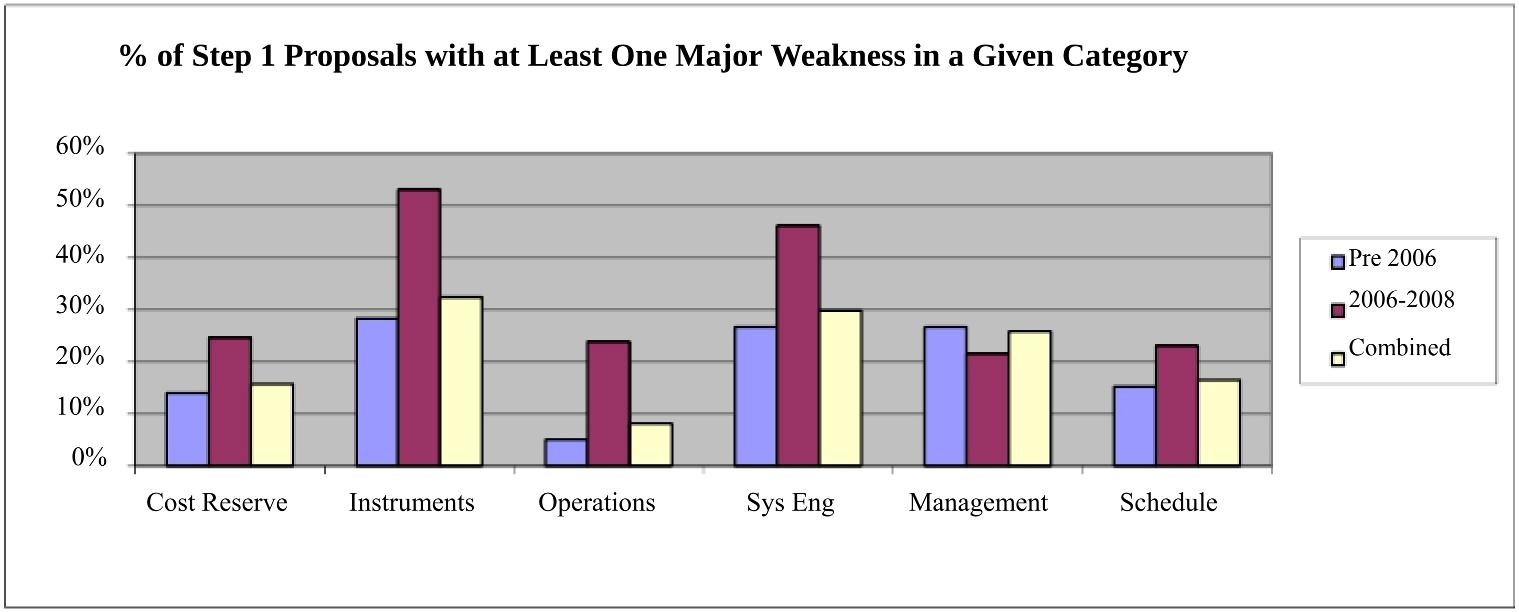
- Low time commitments for essential members of the core management team
- Confusing organization roles & responsibilities
- Unclear lines of authority
- Missing commitment letters and/or endorsements from institutions and international partners

Step 1 **Schedule** detail and (funded) margins – 130+ with MW [17%]

- Inadequate detail presented for TMC evaluation
- No reserve or inadequate reserve
- Too ambitious or success-oriented for what needs to be done, especially during ATLO
- Unrealistic timing of key milestones

Trend of Common Causes in Step 1 Proposals

This chart compares data on Major Weaknesses of evaluations conducted in 2006 thru 2008 with earlier evaluations.



While the relative distribution of Major Weaknesses remains approximately the same, the percentage of major weaknesses increased in all categories except Management for the four AOs evaluated between 2006 & 2008

- ***reflects increased focus of TMC teams & rigor of evaluation process***

Step 2 Common Causes of Major Weaknesses (1 of 4)

79 full mission CSRs (MoOs excluded) were examined.

Step 2 Technical Major Weaknesses

Issues with requirements definition & flow down, overstated heritage, and inadequate plans for verification dominate the technical category

•Requirements - 17% of Technical major weaknesses are due to problems with requirements definition, traceability, & flow down

– Program size and profile don't seem to matter; a SMEX CSR and a Mars Scout CSR are equally likely to have a requirements major weakness

•Verification – 15% are due to issues with inadequate plans for verification

– CSRs with this weakness also often had a major weakness related to requirements, system complexity, or design maturity

•Heritage – 15% are due to issues with the implementation of heritage elements

– Overstatement of the benefit of the heritage
– Modifications to the heritage element is required but not adequately accounted for

Step 2 Common Causes of Major Weaknesses (2 of 4)

Step 2 Technical Major Weaknesses

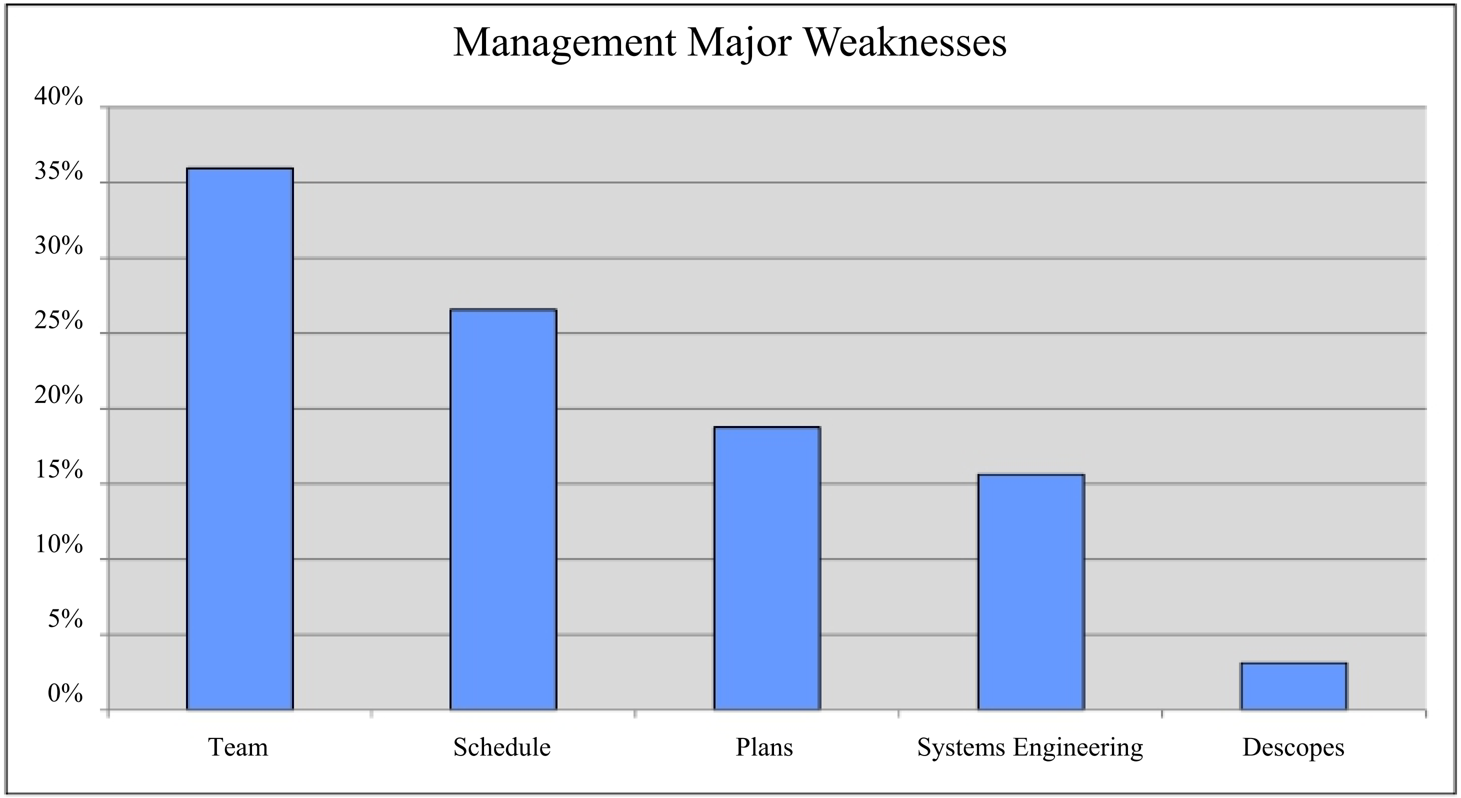
- Mass Margin – 9% are issues with mass margin in some aspect of the design concept
  - Mass margin major weaknesses still occur but much less frequently than in Step 1
- Thermal – 7% are due to inadequate thermal design
  - Many of these are at the instrument level
- Optics/Focal Plane – 7% are related to the design & development of the instrument instrument optics and focal plane
  - Overstatement of performance is often cited
- ACS – 6% are issues with attitude determination & control
  - Inadequate understanding of pointing budget
  - Mismatch between hardware capability and required performance
- Low Maturity/TRL – 6% are related to dispute of the claimed TRL
  - These are more often related to instrument implementation

Step 2 Common Causes of Major Weaknesses (3 of 4)

Step 2 Management Major Weaknesses

- 36% are issues associated with key individuals
  - Lack of relevant experience among core team
    - Many recent PM candidates proposed have good management credentials, but limited/no history of flight project accountability
  - Low time commitments for key members of the core team: Project Manager, Systems Engineer, Flight System Manager, Key Instrument Engineer, etc.
- 27% are schedule related major weaknesses
  - Inadequate /inappropriately placed schedule reserve
  - Missing key elements
  - Inadequate definition or complete lack of critical path
- 19% are related to management plans
  - Key elements such as risk management, are inadequate
- 16% are due to systems engineering
  - Often reflects lack of consistency among project elements
- 3% are due to definition of descopes
  - Often associated with overstatement of heritage or TRL

Step 2 Distribution of Management Major Weaknesses*



* Includes only the most common major weaknesses

Step 2 Common Causes of Major Weaknesses (4 of 4)

Step 2 Cost Major Weaknesses

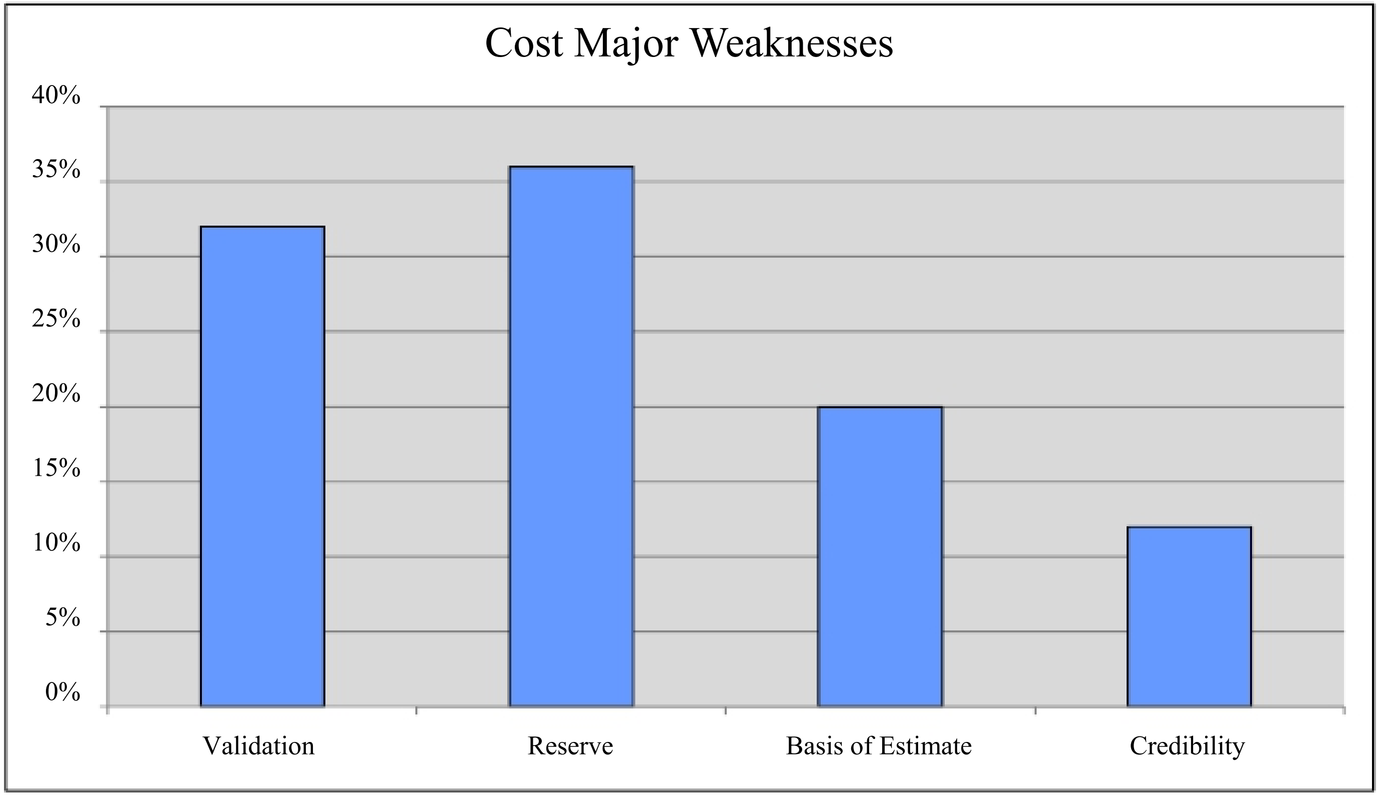
- 36 % are due to inadequate cost reserve
  - Increased definition in the design and implementation in Phase A often results in erosion of cost reserve
  - Cost reserve is often an issue in proposals where low maturity and/or issues with heritage are also cited

- 32 % are related to significant and unreconciled differences between the proposed cost and the independent cost estimates.
  - This is often associated with a dispute in the proposer's underlying assumptions in areas such as technical performance, TRLs, heritage, etc.

- 20% are due to an inadequate basis of estimate

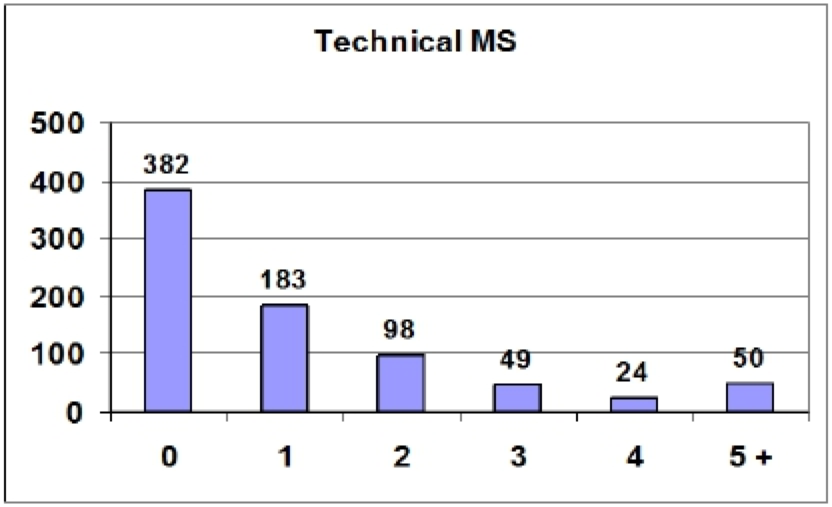
- 12 % are related to the credibility or relevance of the supporting cost data

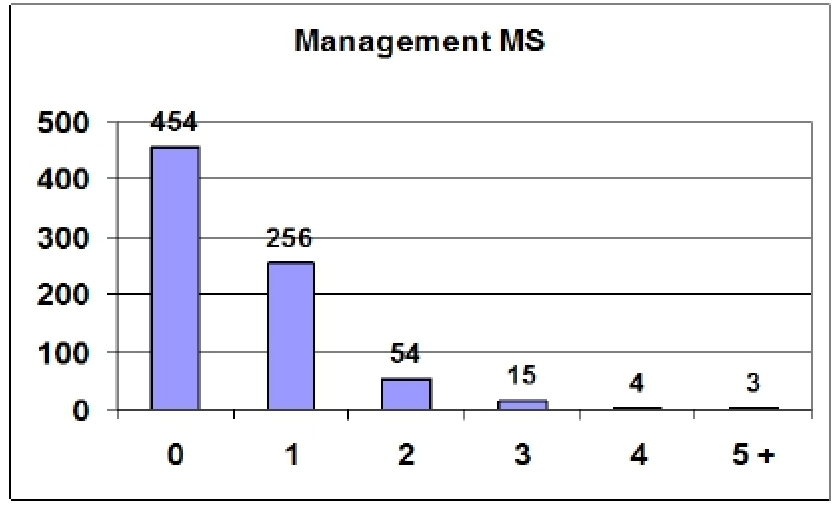
Step 2 Distribution of Cost Major Weaknesses*

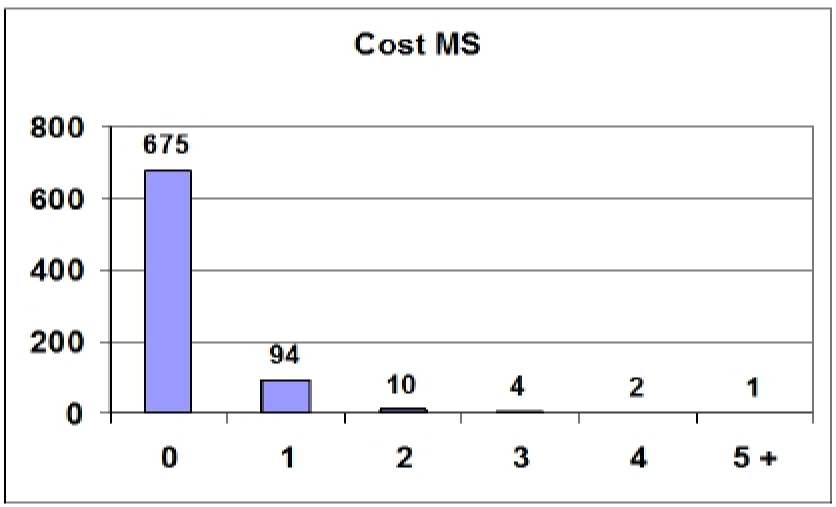


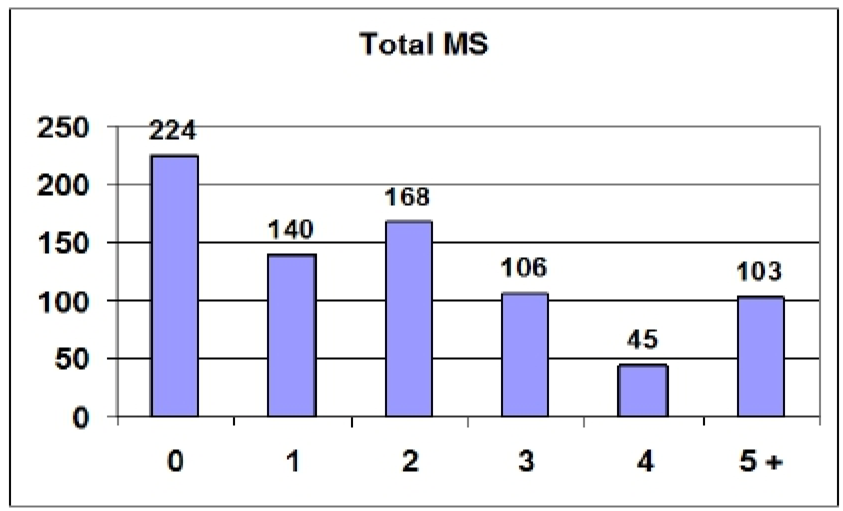
* Includes only the most common major weaknesses

Step 1 Major Strengths

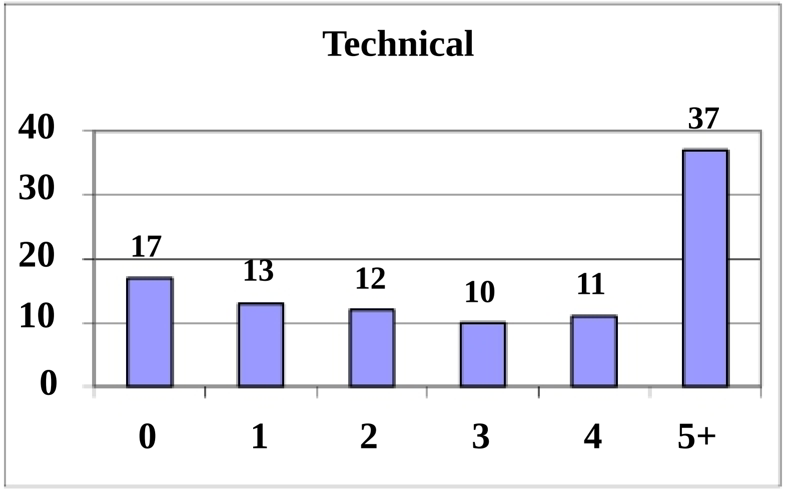


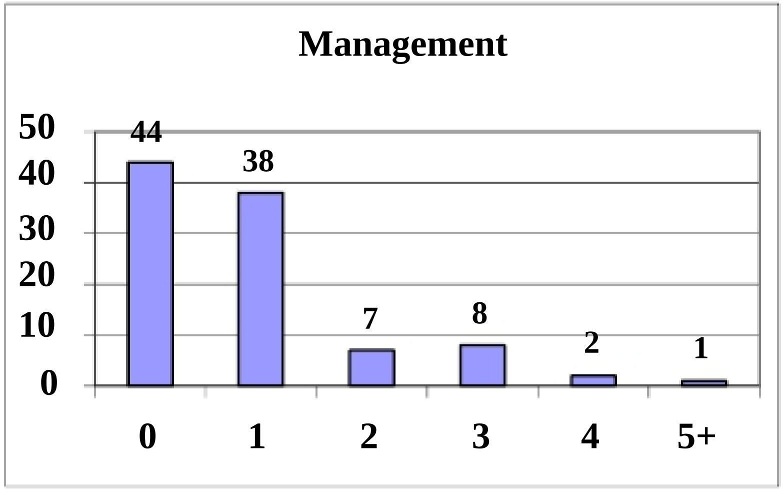


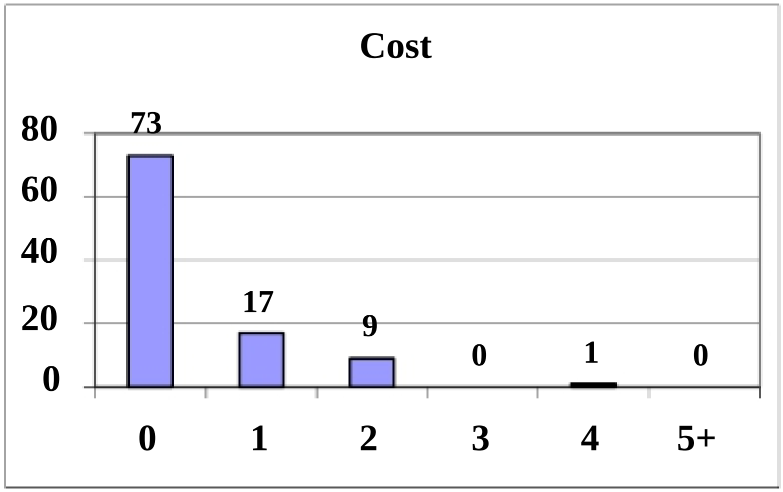


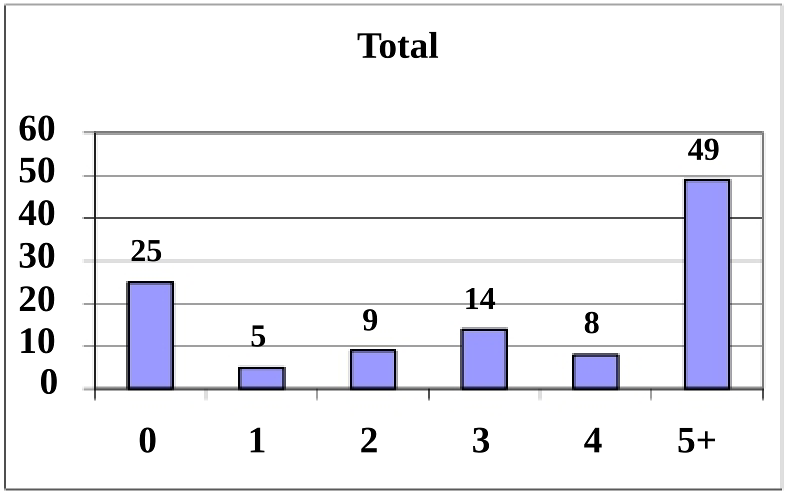


Step 2 Major Strengths









Summary

SOMA has directed evaluation of more than 800 proposals and concept studies submitted by PI-led teams since the office was formed

Review of specific strengths and weaknesses indicates that most successful proposers respond to TMC findings by attempting to fix identified weaknesses

Certain types of weaknesses such as requirements definition and flow down persist in Step 2

Are there common causes of major weaknesses in TMC reviews? Yes!

- Overstatement of heritage and maturity
- Inadequate definition, traceability and flowdown of requirements
- Technical margins – especially mass margin
  - Less frequent in Step 2 than Step 1
- Cost reserve
- Instruments: complexity, over-reaching development
- Attitude control and pointing

Looking at overall risk ratings shows a relatively small percentage of proposals had improved risk ratings in Step 2. An equal number stayed the same or got worse

- May be explained in part by more detailed review and with less “benefit of the doubt” given to proposer at Step 2

Public Summary of the TMC Phase A Performance Study

Introduction and Background

- SMD directed SOMA in December 2009 to
  - Compare SMD TMC Phase A evaluation process findings to actual experience of projects selected for implementation and
  - Assess whether the TMC process might be improved to better anticipate and circumvent potential problems encountered in SMD's experience base.
- The study was kicked off January 11, 2010.
- All findings, conclusions, and recommendations have been reviewed by SMD.
- This presentation and the associated final report document the study effort's methodology and results. The final report contains more detail and a more comprehensive set of appendices with supporting information.

Summary of Study Objective, Approach, and Deliverables

Objective: Assess the historical technical/management/cost performance of SMD's portfolio of PI-led missions to determine how they performed at key project milestones versus the TMC findings at the end of Phase A and recommend improvements to TMC and other processes as appropriate.

Approach

- **Document** the TMC risks for a selected set of 18 SMD projects as reported at the Phase-A TMC CSR Evaluations;
- **Document** the risks and mitigations and impacts of these same missions as reported at each succeeding Key Decision Point (KDP) for each mission as given in the Standing Review Board/Independent Review Team (SRB/IRT) reports and other sources;
- **Interview** the SMD Program Executive for each of these missions to determine whether or not the data collected by the study team accurately reflects the risks and mitigations and impacts reported at each milestone and document the results of these interviews;
- **Integrate** and **analyze** all of the data; and
- **Generate** findings, observations, conclusions, recommendations, and any other considerations for improving SMD TMC mission evaluations based on the study results.

Projects Selection

- This projects used in the study include all mission CSRs that were (a) evaluated by a SOMA-led TMC panel using a standard process, and (b) selected for implementation.
- The resulting 18 missions are shown below. The approach maintained all data points, since even a partially complete data record for a project may yield useful results in a study of this sort. This approach was reviewed and approved by HQ/SMD.

Acq Yr	**1996**	**1998**	**1999**	**2000**	**2001**			**2002**	**2003**		**2006**
Program	Discovery	Discovery	SMEX	Discovery	MIDEX	NF	ESSP	Scout	NF	SMEX	Disc
Project	CONTOUR, Genesis	Deep Impact, MESSENGER	AIM	Kepler, Dawn	Swift, WISE, THEMIS	New Horizons	OCO, Aquarius	Phoenix	Juno	NuSTAR, IBEX	GRAIL

Project PE Interview Questions

1. Does this list agree with your records/recollection of the project's experience?

2. Are there other issues that you recall as being important with regard to the following areas?

   a. The instrument payload

   b. The flight system

   c. Management of the project

   d. Implementation Schedule

   e. Cost and cost reserve

3. After selection, did the project respond to weaknesses or comments documented in the TMC review?

4. Were any changes to the project mandated by the Program Office or NASA Headquarters?

5. Were there significant impacts from any external issues beyond the project's control?

6. Did the project respond effectively to the issues it faced during implementation?

7. What change(s) could be made to the CSR Guidelines or downselect evaluation process that might enable an earlier identification of the issues this project encountered?

8. Given the goal of this study, are there any other comments/recommendations that you'd like to make?

Development of Findings, Observations, Conclusions, and Recommendations

- Findings have been derived from identified project risks and mitigations and associated impacts.
- Observations are based on experiences conducting the study.
- Each Conclusion is supported by one or more Findings or Observations.
- Recommendations follow from the Findings, Observations, and Conclusions.
- Data used for the study has been validated during the PE interviews.

NOTES

- This study explored only a subset of missions evaluated by TMC and does not include hundreds of mission concepts that were not selected for implementation.
- Since the study focused on traceability of issues encountered by the project, there is a greater emphasis on TMC identified major weaknesses. The TMC identified strengths reported are limited to only those that were in conflict with project experience.
- For this report, the Findings, Observations, Conclusions, and Recommendations focus on traceability of project experience to TMC findings from Phase A. However, the data collected for this study could be used to support many other findings that have been reported in prior SOMA studies for SMD.

Technical Issues

Spacecraft Maturity/Complexity/Heritage. These issues include overly optimistic assumptions for the spacecraft hardware/software design and complexity, often related to issues adapting heritage elements for a different application. Issues were identified for 11 of the missions.

I&T Scope & Planning. These issues include cases where deficiencies were discovered with the I&T plan. In project implementations, I&T planning results directly from the systems engineering effort: integration activity is based on system level drawings, and verification requirements are derived from environments definition and requirements flow-down. Issues were identified for 5 of the missions.

Subsystem/Hardware Development. These issues capture problems with specific subsystems and/or critical components. Issues were identified for 4 of the missions.

Instrument Development. These issues include significant problems encountered with development of the science instruments. Issues were identified for 10 of the missions.

Systems Engineering (SE). These issues cover identified deficiencies with the early systems engineering effort and associated processes. Issues were identified for 2 of the missions.

Operations Planning &Testing. These issues involve problems with planning for operations and/or operations testing. Issues were identified for 2 of the missions.

Management Issues

Organizational Experience. This covers problems encountered with organizational roles and commitments. Issues were identified for 3 of the missions.

PM & Key Person Experience & Time Commitment. This covers problems encountered with the experience and/or level of commitment for key people. Issues were identified for 8 of the missions.

Team Dynamics/Communication. These issues include problems identified with communications within the project teams. Issues were identified for 2 of the missions.

International Partners. This category captures problems with delivery of major elements from an international provider. Issues with international partners had significant impact on only one of the missions in this study (Aquarius), but the issue was brought up by several PEs.

Contractor/Subcontractor Oversight. These issues include problems with lack of oversight of the contractor and/or major subcontractors. Issues were identified for 4 of the missions.

Cost and Schedule Issues

COST

Cost Related Descopes. These issues cover occurrences where descopes were necessary to reduce cost and/or cost risk. Issues were identified for 4 of the missions.

Inadequate Basis of Estimate. These issues cover problems/deficiencies in the original basis of estimate that are discovered during development. These issues include unintended omissions of cost elements and inaccurate assumptions related to design maturity, complexity, and heritage. Issues were identified for 12 of the missions.

SCHEDULE

LRD slip (> 2mo) due to development issues. These issues include instances where the LRD was delayed due to internal impacts affecting development. Issues were identified for 7 of the missions.

LRD slip (> 2mo) due to LV issues or conflicts. These issues include instances where the LRD was delayed due to technical issues with the LV, weather anomalies (hurricanes) at the launch site, and conflicts with other mission launches. Issues were identified for 4 of the missions.

LRD slip (> 2mo) driven by HQ redirection and/or funding issues. These issues include instances where the LRD was delayed due to external impacts other than the LV. These are typically related to funding availability. Issues were identified for 8 of the missions.

Other Issues

NIAT Standards Imposed. This covers projects that received funding augmentation to respond to NIAT recommendations. Issues were identified for 5 missions.

Full Cost Accounting Imposed. This covers projects that experienced increased cost due to adding full cost accounting requirements. Issues were identified for 4 missions.

Launch Vehicle Changes/Issues. These issues cover HQ-directed LV changes, technical problems with particular LVs, and/or problems with launch vehicle analysis or processing at the launch site. Issues were identified for 6 missions.

Errors & Mishaps. These issues cover errors and other issues with analysis, fabrication, or testing for a key element. Issues were identified for 6 missions.

Termination Considered. This captures missions that went through one (or more) termination reviews. This includes 3 missions.

Project Changed After Selection. This captures missions that were significantly changed due to external impacts, mostly SMD-directed. There are 9 missions with this issue.

Mapping of Findings & Observations to Conclusions to Recommendations

FINDINGS/OBSERVATIONS

F1: Data suggests that alignment of TMC findings and project experience has improved over time, but many issues are still unanticipated by the TMC process

F2: *Spacecraft* issues – underestimated complexity, overstated heritage

F3: *Instrument* issues – underestimated complexity, overstated heritage

F4: Common management issue – PM & key personnel experience & time commitment

F5: Common cost issue – Inadequate BoE

F6: Only 3 projects implemented TMC-suggested mitigations, and many TMC findings are ignored during implementation

F7: LRD slips for14 of the 18 missions driven by development issues & HQ-directed changes

O1: No single repository of project-specific IRT reports exists

O2: No standard for PE turn-over of responsibilities and files

O3: CADRe data is an excellent resource for cost, schedule and technical data

O4: Insight into some project issues was evident in TMC minor weaknesses and indirect references embedded in major weaknesses

CONCLUSIONS

C1: The significant analysis and assessment effort expended in the TMC process is not adequately captured as projects proceed into Phase B and implementation.

C2: Unattained design heritage and underscoped complexity are common causes of significant development issues.

C3: The experience and time commitment of the key management are critical factors in successful project implementation.

C4: Issues with the CSR cost BoE tend to persist in development if not addressed in Phase B.

C5: There is a high degree of interrelationship among common issues that is difficult to account for in the current TMC cost estimating process.

C6: Maintenance of historical files for future access and usage by SMD can greatly assist the acquisition process.

RECOMMENDATIONS

R1: SMD should develop a standardized process for TMC debriefings to Program Offices and PEs and require that each selected project provide a formal response to findings reported by TMC.

R2: SMD should consider including post-selection participation by TMC members in reviewing project formulation and implementation.

R3: The TMC review process should review heritage claims with greater scrutiny and SMD should ensure claims are valid early in development.

R4: The CSR guidelines and TMC's evaluation criteria should emphasize the requirement of relevant experience and time commitment for key personnel.

R5: SOMA should further explore potential modifications to CSR guidelines to better capture applicability of claimed heritage and qualifications of the management team.

R6: SOMA should direct thorough TMC panel discussion of all important cost assumptions prior to generating TMC estimate results.

R7: SMD should continue to support the CADRe efforts but further require that all IRT/SRB review milestone reports be entered and maintained a similar repository.

Recommendation 1

SMD should develop a standardized process for TMC debriefings to Program Offices and PEs and require that each selected project provide a formal response to findings reported by TMC.

- The intent is to ensure TMC findings are fully communicated and to create an audit trail for findings that is similar to the Request For Action (RFA) process used by projects and standing review boards at milestone reviews. This recommendation might be facilitated by a subset of experienced TMC reviewers convened after selections are announced to review the Form C and to write an RFA for each finding determined to require one. Under direction by SOMA and the PE, each Form C entry would be reviewed to determine whether it should be the basis for an RFA. The project would then be expected to respond to and disposition each RFA as part of its Phase B activity.

Recommendation 2

SMD should consider including post-selection participation by TMC members in reviewing project formulation and implementation.

- SMD should consider including that senior members of the SOMA TMC evaluation process are included in the membership of the project's Standing Review Board or as consultants to ensure continuity of reporting and attention to TMC analysis and assessment throughout the project's life. Such participation, together with Recommendation 1, establishes a more structured transition from acquisition to implementation, and would also ensure that current project experience is fed back into future acquisition cycles as AO process improvements.

Recommendation 3, *pg 1 of 2*

The TMC review process should review heritage claims with greater scrutiny and SMD should ensure claims are valid early in development.

- Given that a high percentage of projects experienced significant erosion of resources due to heritage claims that did not materialize, TMC should be cautious in awarding benefit of the doubt for heritage. Although the degree of applying benefit of the doubt is significantly reduced during CSR down-select site visits, the time and level of interaction is limited which precludes fully resolving all benefit of the doubt issues. This is particularly true in cases where the TMC has issues with the basis of estimate or cannot validate the proposed cost estimate. In the CSR evaluations this implies that a) all claims of heritage should be carefully scrutinized and cross checked with the proposed implementation and cost estimates, and b) given the typical (for Phase A) lack of detail and mature planning needed for validation, a proposed strength for design heritage should be held to a high standard of proof to be considered as a TMC finding.
- SMD should remain skeptical of heritage claims after selection. A project claiming significant cost and schedule advantages from design heritage should be expected to perform a rigorous heritage review at the start of Phase B to further refine the project baseline and reserves and verify heritage applications are credible and properly accounted for. Currently, many projects perform these reviews, but there is no standard practice or requirement for when the review should occur or the expected level of detail.

Recommendation 3, *pg 2 of 2*

The TMC review process should review heritage claims with greater scrutiny and SMD should ensure claims are valid early in development.

continued

- Because of the significant and overarching impact that systems engineering has on successful project development, SMD should require that all projects be subject to a standard review of systems engineering plans. In addition, for any TMC CSR review that identifies specific systems engineering threats, the project should be expected to address the TMC concerns as part of the standard review. The systems engineering review could be conducted concurrently with the heritage review. To minimize impact to the project, these activities could be part of the SRB's SRR charter, or could be directed by the cognizant Program Office, and scheduled early in Phase B to cause the least disruption to the project's work.

Recommendation 4

The CSR guidelines and TMC's evaluation criteria should emphasize the requirement of relevant experience and time commitment for key personnel.

- SMD should continue to promote training for new PI's, PMs, and SEs. TMC should continue to evaluate experience and qualifications and time commitments of key personnel proposed, and should ensure that this experience has direct relevance to each individual's proposed role.

Recommendation 5

SOMA should further explore potential modifications to CSR guidelines to better capture applicability of claimed heritage and qualifications of the management team.

- Recognizing that Recommendations 3 and 4, if adopted, are likely to result in more conservative evaluations by TMC, guidelines for CSR preparation should be reviewed to ensure that proposers are preparing the right information for the TMC review of the CSR, and that the proposers are not over-burdened by submitting unnecessary information. The detailed heritage appendix, now required for all CSRs, does a much better job of communicating to TMC a complete picture of the heritage elements and their claimed impact on the project's plans, but many issues still arise during TMC regarding heritage.

Recommendation 6

SOMA should direct thorough TMC panel discussion of all important TMC cost assumptions prior to generating TMC estimate results.

- Early discussion (during panel or sub-panel teleconferences) should focus on clear and complete description of the key assumptions, cost threats, and related issues – the Basis of Estimate – instead of an early comparison of numbers against proposed costs. This redirection of focus would: (1) improve efficiency of the TMC cost estimating process, and; (2) make best use of the combined panel's expertise to direct cost analysts to the most important driving assumptions. This effort can help focus TMC initial findings and site visit interactions on the key technical and programmatic issues with the greatest potential for significant cost and/or schedule impact.

Recommendation 7

SMD should continue to support CADRe efforts but further require that all IRT/SRB review milestone reports be entered and maintained in a similar repository.

- CADRe reports are a valuable asset for technical, schedule, and cost data, but there is no comparable effort to collect IRT/SRB milestone review reports with the NASA-sponsored independent assessment review findings, which contain valuable insights for lessons-learned and other SMD studies. These should be collected from each project's SRR, PDR, CDR, System Integration Review (SIR), and MRR. SMD should consider implementation of a system to ensure project histories are carefully documented from the SMD oversight perspective and maintained in a location that provides ready access by SMD. It is recognized that various program offices maintain this information for their missions, but this data could not be shared for use in this study. This data could be included in the SMD Science Works Data base or a similar repository. Improved procedures for project turnover when a Program Executive succession occurs would be needed to support this. (This is not intended to duplicate in any way records maintained by a project office at the lead Center.)

Concluding Remarks

- This report has presented Findings, Observations, Conclusions, and Recommendations, which can be used to improve the TMC process.

- Some Recommendations are already in SOMA's domain, so it is planned that SOMA will immediately proceed to develop recommended changes for the acquisition process that address these issues.

- Several Recommendations have been implemented (1 – 6)