Summary of Lessons from Previous PI-Led Missions: Studies and Assessments

Presentation to the 2019 Discovery AO Phase A Kickoff

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TMC Studies and Assessments

There are five lessons learned studies on the evaluation of Step 1 proposals and Step 2 CSRs that are available on the SOMA homepage. They are:

1) **Lessons Learned from TMC Review of Step 1 Proposals**
2) **Lessons Learned from TMC Review of Step 2 Concept Study Reports**
3) **Instrument Considerations for Pre-Phase A Proposals**
4) **Instrument Considerations for Step 1 and Step 2 Proposals**
5) **Common Management Major Weaknesses in Step 1 Proposals**

This is an update to the first 2 studies adding data and analysis from Step 1 and Step 2 evaluations completed between 2017 and 2019.

SOMA homepage - http://soma.larc.nasa.gov/

Step 1 & 2 Lessons Learned Study Update

Study Questions

What is the history of TMC Risk Ratings?

Are there common causes of major weaknesses?

Results

Conduct a review of formal records of more than 1200 proposals and concept study reports retained by SOMA in the on-site archive library.

- Step 1 and Risk Distribution
- Step 1 Major Weakness Trends and Common Causes
- Step 2 Major Weakness Trends and Common Causes

Study Update

This update adds twelve new step 1 and four new step 2 evaluations that were completed between 2017 and 2019.

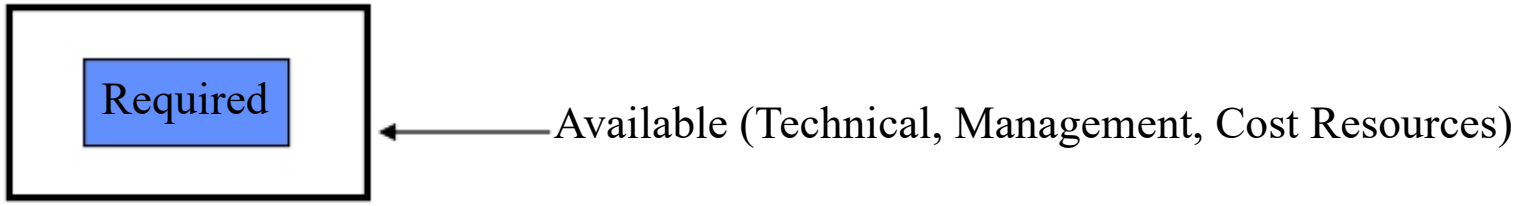
The Step 1 reviews are: Astrophysics MIDEX 2016, Astrophysics MO 2016, EVC-1, EVI-4, EVI-5, Heliophysics MO 2016, Heliophysics SMEX 2016, Heliophysics TDMO 2018, Helioscience MO 2018, MMX NGRS, New Frontiers 4, SIMPLEx 2018

The Step 2 reviews are: Astrophysics MIDEX 2016, Astrophysics MO 2016, Heliophysics MO 2016, Heliophysics SMEX 2016, New Frontiers 4

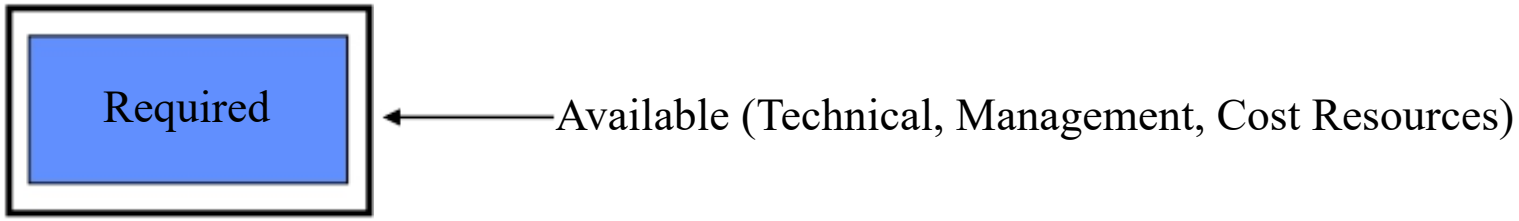
TMC Risk Envelope Concept

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

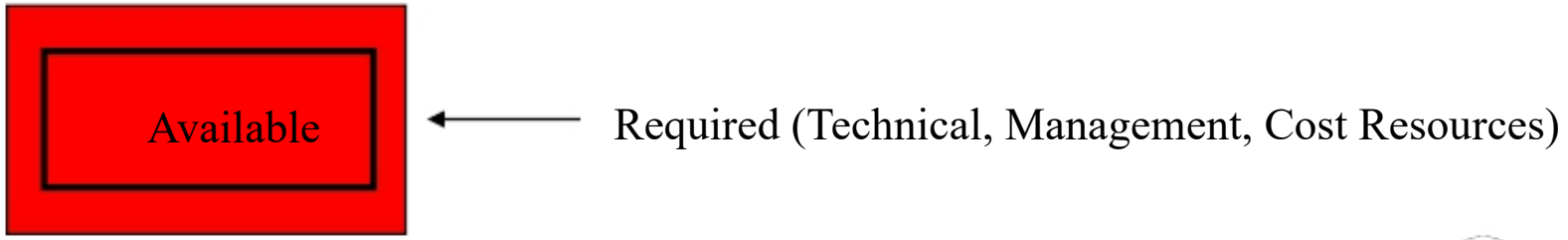
Low Risk: Required resources fit well within available resources



Medium Risk: Required resources just barely inside available resources.

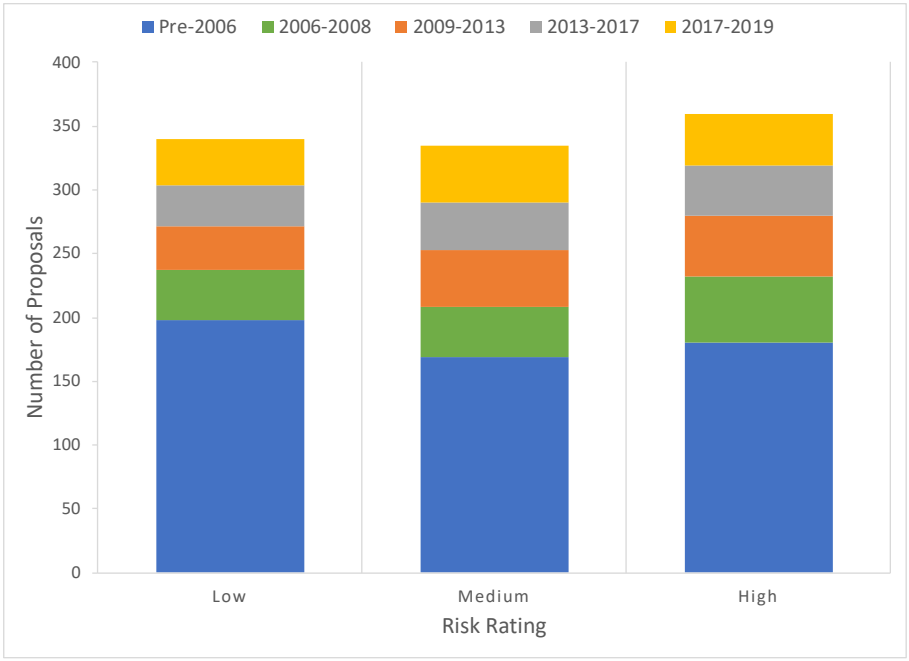


High Risk: Required resources DO NOT fit inside available resources.



TMC Step 1 Risk Distribution Comparisons*

Distribution by Number

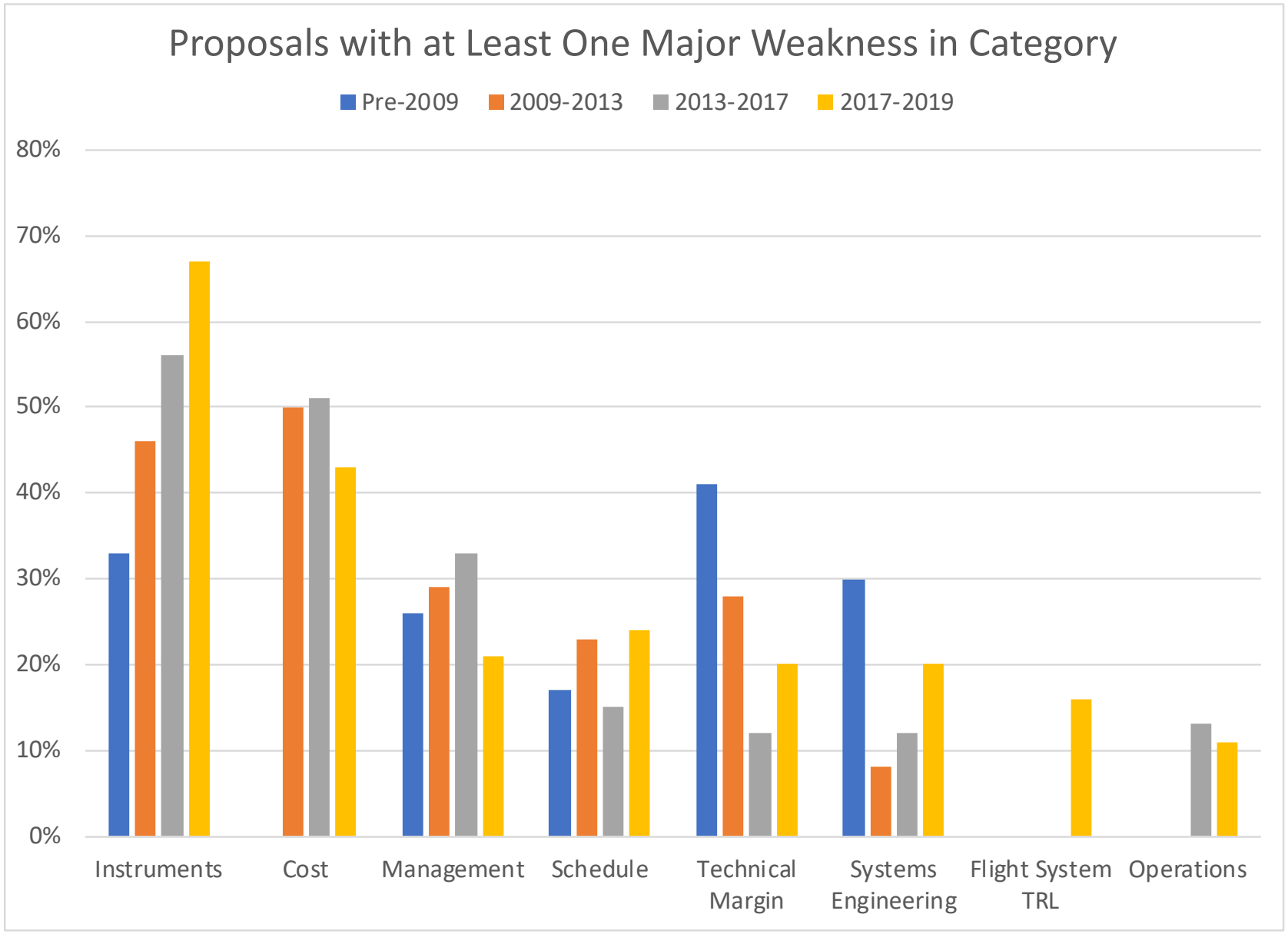


Distribution by Percentage

The overall distribution of over 1100 Step 1 TMC risk assessments are evenly split among Low, Medium and High. No trend in risk ratings is readily apparent in the dataset even though the total number of major weaknesses per proposal has increased. The Step 1 proposals evaluated in 2008 or earlier had an average of 2.5 MWs per proposal, the proposals from 2013-2017 had 3.3 MW per proposal, and the proposals from 2017 to 2019 had 3.8 MW per proposal.

**Includes full and MO proposals*

Trend of Common Causes in Step 1 Proposal



Step 1 Common Causes of Major Weaknesses (1 of 8)

Instruments

The number of Instrument MWs continues to trend up. A third (33%) of the pre-2009 evaluations had instrument MWs compared with 46% for the the 2009-2013 evaluations, 56% of those from 2013-2017, and 67% from 2017-2019.

The two most common sources of instrument MWs from the most recent evaluations are:

1) Overstated instrument TRLs or inadequate plans to demonstrate existing component technologies in newly integrated systems or in new environments. A missing or inadequate technology backup plan in the event that the TRL development efforts are unsuccessful contributed to many of these findings.
2) Insufficient support for instrument performance claims (via first principles or heritage scaling). This issue is usually combined with insufficient instrument design information to independently verify the feasibility of the instrument.

Step 1 Common Causes of Major Weaknesses (2 of 8)

Cost

For evaluations since 2009 about half of all proposals (50% for 2009-2013, 51% for 2013-2017, and 43% for 2017-2019) had at least one Cost major weakness.

The most common causes of these MWs were:

1. The TMC uses independent models with proposal information to estimate costs. When these costs, with generous error bounds, significantly exceed the proposed costs, a cost validation major weakness results.
2. The cost Basis of Estimate (BOE) is flawed – there are missing cost elements or the rationale is incomplete, inconsistent or has unsupported assumptions.

Step 1 Common Causes of Major Weaknesses (3 of 8)

Management

The percentage of proposals with a management MW has remained approximately constant at 26% prior to 2009, 29% between 2009 and 2013, 33% for 2013 to 2017, and 21% for 2017 to 2019.

The primary causes of these management MWs were:

1) Unclear or incomplete discussion of organization roles, responsibilities or lines of authority
2) Organizational or individual expertise for a specific role is missing or inadequately demonstrated
3) Time commitment is too low for essential members of the core management team

Step 1 Common Causes of Major Weaknesses (4 of 8)

Schedule

The percentage of proposals with a schedule MWs has also remained approximately constant with 17% of all proposals having a schedule MW prior to 2009, 23% for 2009-2013, 15% for 2013-2017, and 24% for 2017-2019.

The primary causes of these schedule MWs were:

1) Inadequate schedule detail presented for the TMC to verify its feasibility
2) Inadequate funded schedule reserve
3) Too ambitious of a schedule for the planned activities, especially during AI&T or Phase B TRL advancement efforts.

Step 1 Common Causes of Major Weaknesses (5 of 8)

Technical Margin

The percentage of evaluations with a technical margin major weakness has dropped from 41% for evaluations completed before 2009 to 28% for 2009-2013 to 12% for 2013 and 2017. The evaluations between 2017 and 2019 increased from the previous period to 20%.

The most common technical margin major weaknesses are based on flawed mass margins and contingencies for both flight systems and instruments. For example:

1) Heritage masses do not account for potential design modifications.

2) Margins and contingencies are clearly stated and verifiable, but are deemed by the TMC to be too low given the associated development risks.

3) Missing or undersized elements (e.g., launch vehicle payload adapter) create an immediate lien on the claimed mass margin.

Power margins are the second most common source of technical margin MWs due to these same issues. In addition, not using the most critical or most demanding operating mode for power margin calculations has led to MWs.

Similar MWs have resulted from inadequate margins on other technical resources, including: CPU use, communication links, propellant budgets and static or dynamic launch vehicle envelope.

Step 1 Common Causes of Major Weaknesses (6 of 8)

Systems Engineering

Systems Engineering (SE) MWs dropped significantly from 30% (pre-2009) to 8% (2009-2013), but they have increased to 12% (2013-2017) and 20% (2017-2019) in the more recent periods.

The most common causes of these MWs were:

1) Significantly flawed or incomplete requirement traceability is included in this MW category. These flaws include missing, untraceable or unquantified requirements as well as expected performance that does not meet the proposed requirements.
2) Inadequate or flawed systems engineering plans, tools or processes for requirements and interface development and risk management.
3) The scope of the systems engineering effort was significantly underestimated or the systems engineering roles and responsibilities were poorly described.

Step 1 Common Causes of Major Weaknesses (7 of 8)

Flight System TRL

A common major weakness in the 2017-2019 dataset occurs when the proposal does not demonstrate that a major element of Flight System will reach TRL 6 by PDR. These findings occurred for 16% of these proposals.

The primary causes of these MWs were:

1) Lack of support for assertions that a system (e.g. propulsion) is already at TRL 6. Often the applicability of heritage claims is insufficiently supported.
2) Insufficient evidence that Phase B activities to reach TRL 6 are adequate.
3) Lack of a backup plan for cases where TRL 6 cannot be achieved by PDR.

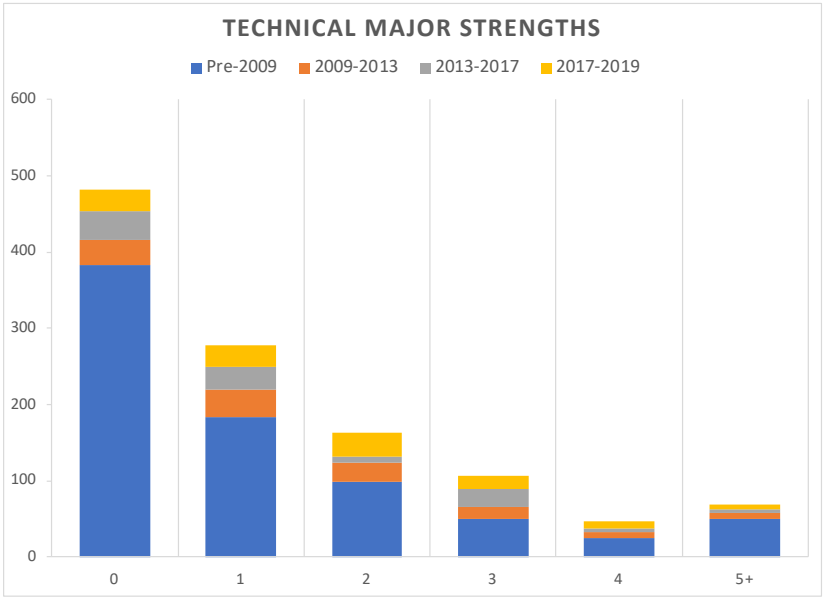
Step 1 Common Causes of Major Weaknesses (8 of 8)

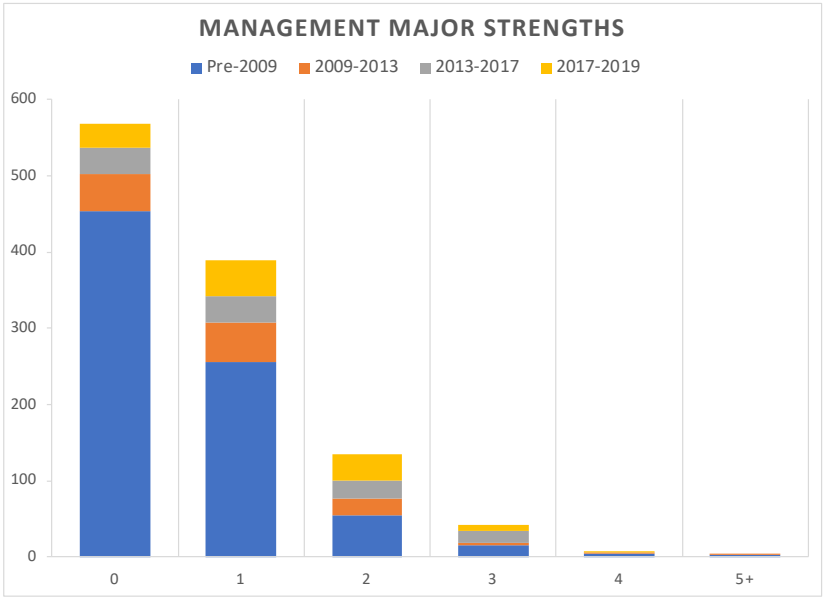
Operations

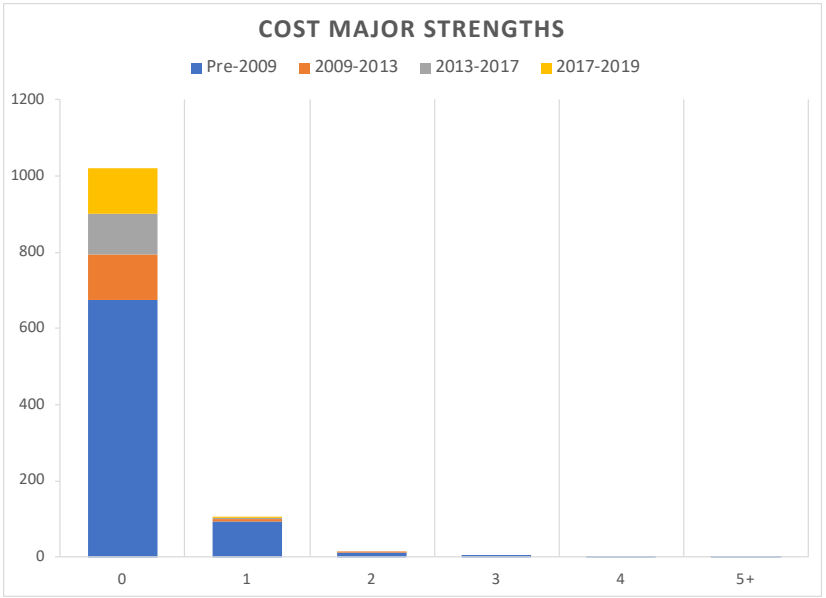
About 13% of the 2013-2017 proposals and 11% of the 2017-2019 proposals had Operations Major Weaknesses.

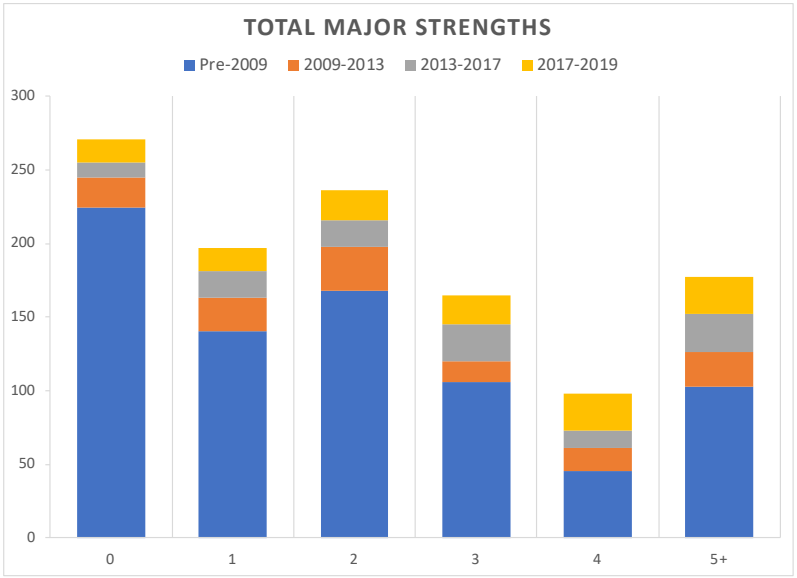
Insufficient or inconsistent proposal information, including operations timelines and data flows, needed to confirm mission operations feasibility was the primary cause.

Step 1 Major Strengths





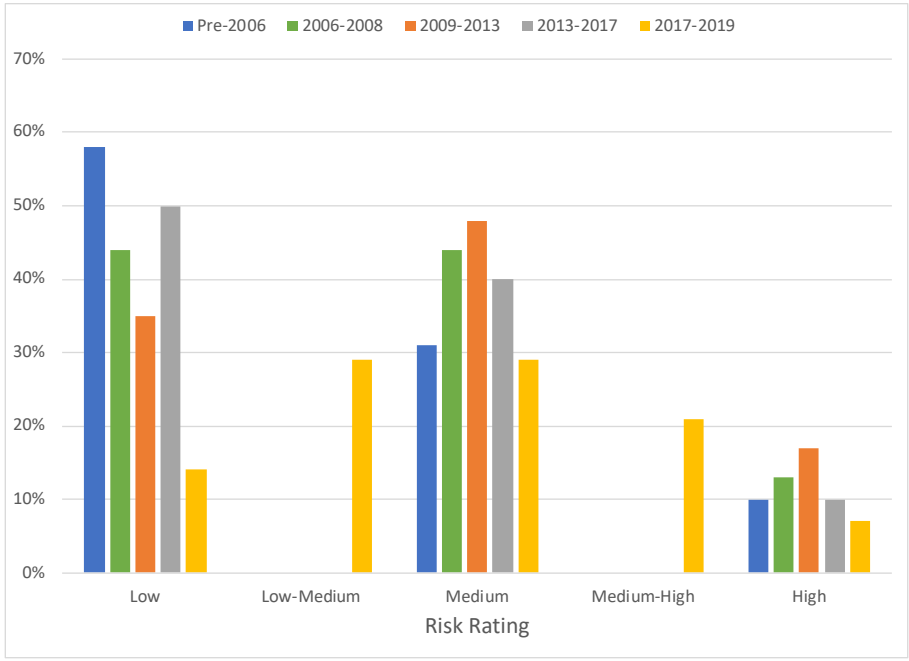




TMC Step 2 Risk Distribution Comparison

Distribution by Number

Distribution by Percentage



Approximately half of all pre-2017 Step 2 CSRs are rated Low risk, with 37% Medium risk and 12% High risk.

Two additional risk ratings (Low-Medium, and Medium-High) were added for the 2017-2019 evaluations. Insufficient data is available to draw conclusions from these data, but the apparent result is the percentage of CSRs rated Low risk has significantly decreased. The small data set shows almost half of the CSRs rated as either Low or Low-Medium risk.

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

The common causes of Major Weaknesses from 145 CSRs are summarized.

Step 2 Technical Major Weaknesses

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

- **Requirements** – These major weaknesses are due to problems with requirements definition, traceability and flow down.
- **Verification** – These weaknesses 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** – These weaknesses are due to issues with the implementation of heritage elements or the support of heritage claims.
  - Overstatement of the benefits of the heritage
  - Modifications of the heritage element is required but not adequately accounted for in the proposal.

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

Step 2 Technical Major Weaknesses (continued)

- **TRLs** – These weaknesses are related to overstated TRLs or inadequate technology development plans.
  - These findings are primarily instrument related.
- **Mass Margin** – These weaknesses are issues with mass margin or contingency.
  - Mass margin major weaknesses still occur but less frequently than in Step 1.
- **Thermal** – These weaknesses are due to inadequate thermal design or performance claims that are not supported.
  - These findings are primarily instrument related.
- **ACS** – These weaknesses are issues with attitude determination and control.
  - Inadequate description of the pointing budget
  - Mismatch between hardware capability and required performance
- **Optics or Focal Plane** – These findings are related to the design and development of the instrument optics and focal plane.
  - Overstatement of performance is often cited.

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

Step 2 Management Major Weaknesses

- 28% are issues associated with key individuals
  - Lack of relevant experience among core team
    - Some PM candidates proposed had good management credentials, but limited or 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.
- 28% relate to systems engineering (SE)
  - Often reflects lack of consistency among project elements
  - Most management weaknesses since 2009 are in systems engineering
- 26% are schedule related major weaknesses
  - Inadequate or inappropriately placed schedule reserve
  - Missing key elements
  - Inadequate definition or missing critical path
- 16% are related to management plans
  - Key elements such as risk management are inadequate

Sources of Step 2 Systems Engineering MWs in New Data

Step 2 Systems Engineering Major Weaknesses

- The flowdown, traceability, completeness, consistency or stability of the top level mission or flight hardware requirements is flawed
- The SE plans or approach, including clearly identifying the roles and responsibilities of the PSE are flawed

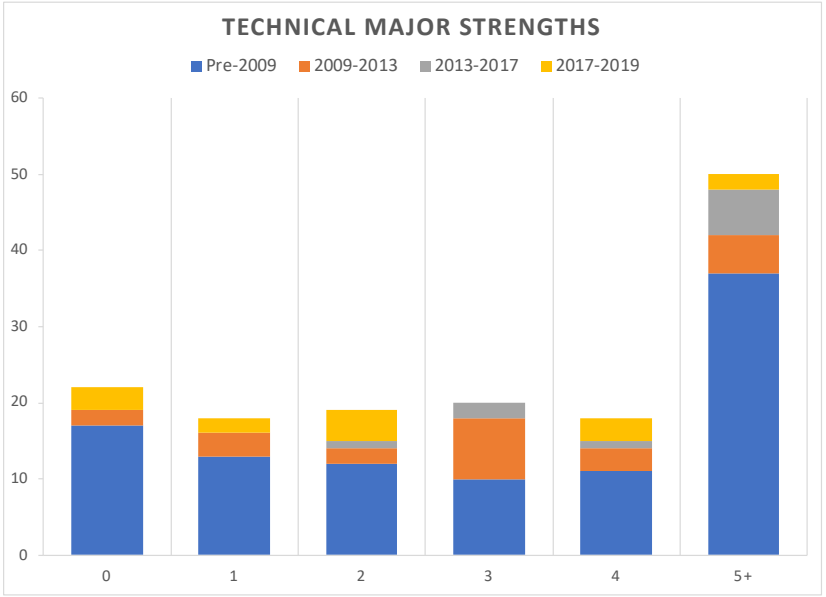
*Includes only the most common major weaknesses

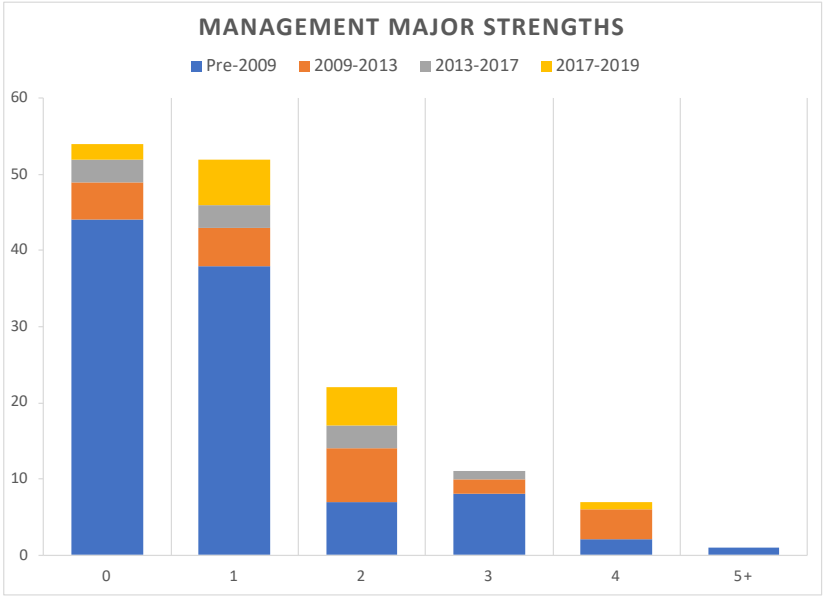
Step 2 Common Causes of Major Weaknesses (4 of 4)

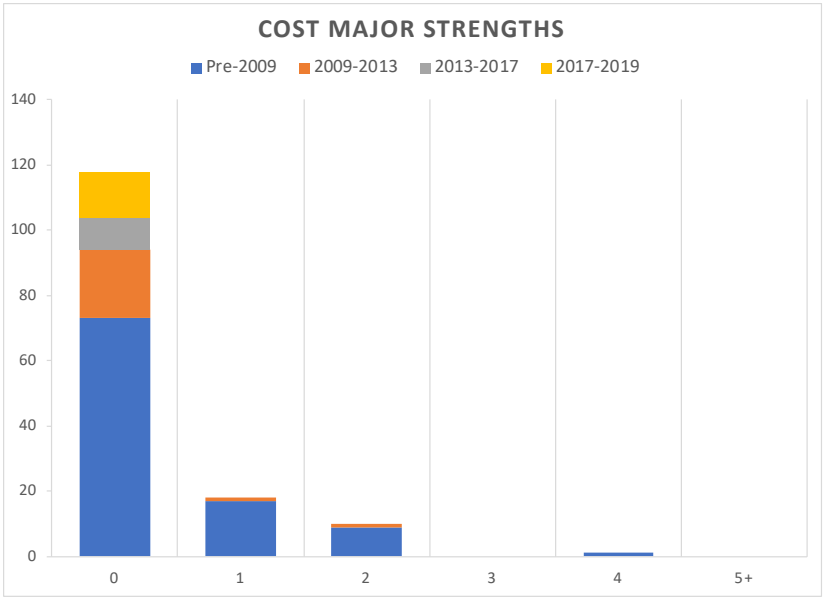
Step 2 Cost Major Weaknesses

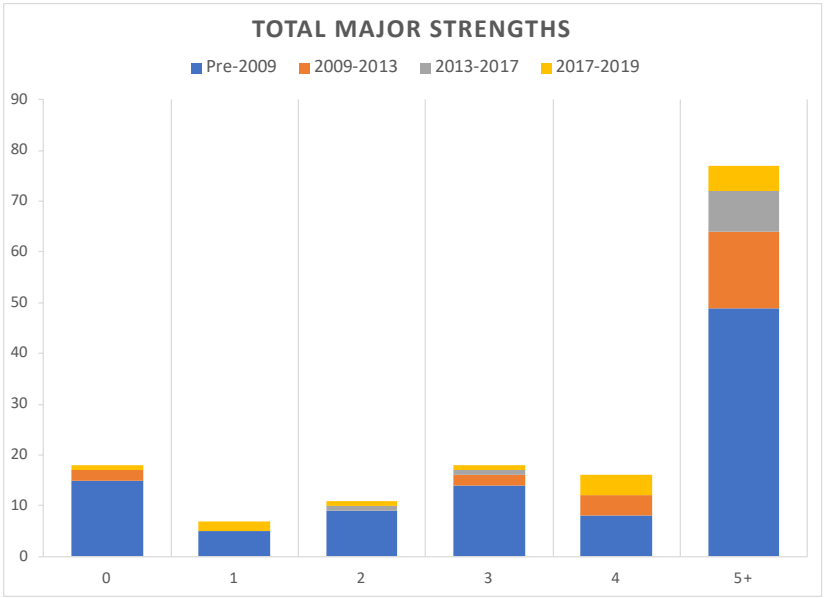
- 41% are related to significant and unreconciled differences between the proposed cost and the independent cost estimate
  - This finding is often associated with a dispute in the proposer's underlying assumptions in areas such as technical performance, TRLs, heritage, etc.
- 23% are due to an inadequate basis of estimate
- 21% are due to inadequate cost reserve
  - No cost reserve Step 2 major weaknesses since 2009
  - Cost reserve was often an issue in proposals with low maturity or overstated heritage
- 15% are related to the credibility or relevance of the supporting cost data

Step 2 Major Strengths

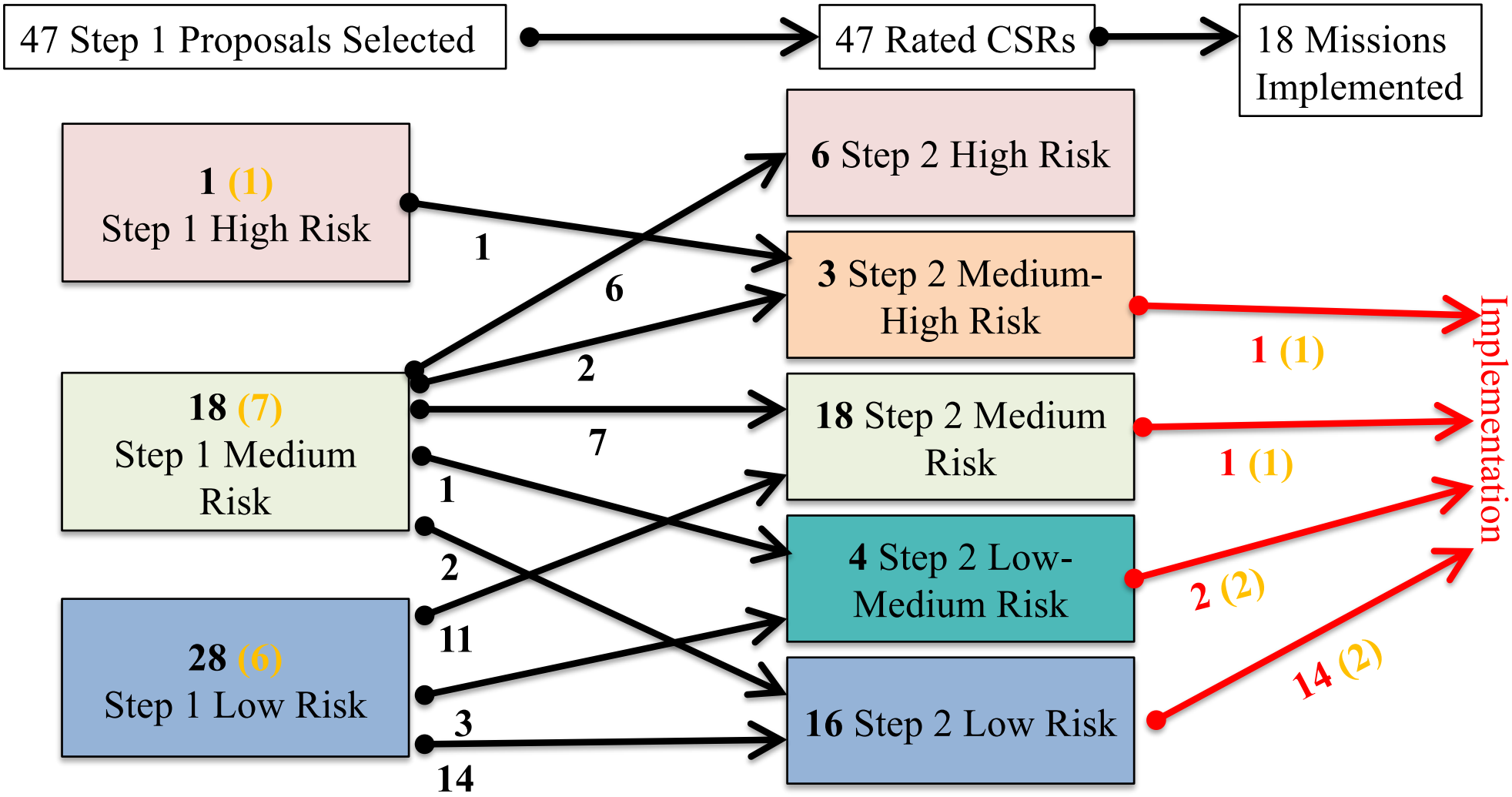








Step 2 Risk Ratings of Selected Step 1 Proposals



The risk rating for most of this small set of missions selected for step 2 either remained the same (21/47) or got worse (22/47). This result may be explained, in part, by more detailed reviews and less "benefit of the doubt" given in Step 2. Between 2017 and 2019 (highlighted in yellow), six Low, seven Medium, and one High Risk proposal were selected. Of these selected proposals, one Medium-High, one Medium Risk, two Low-Medium Risk and two Low Risk CSRs were down-selected for implementation.

Step 1 Summary

SOMA has directed the evaluation of more than 1100 proposals and concept studies submitted by PI-led teams since the office was formed.

Are there common causes of major weaknesses in TMC reviews? Yes! Certain types of weaknesses persist, specifically:

- Overstated instrument or Flight System TRLs (usually based on overstated heritage) or inadequate plans to demonstrate existing component technologies in newly integrated systems or operating in new environments.
- Lack of support for instrument performance claims. These findings are usually combined with insufficient instrument design information to independently verify its feasibility.
- Proposed costs with their supporting BOEs could not be validated using independent cost models.
- Inadequate management plans that usually include unclear or incomplete discussions of organization roles, responsibilities or lines of authority.
- Lack of time commitment from key management team.
- Development schedules that lack sufficient detail to verify their feasibility, have missing elements, allocate too little time for typical activities without sufficient rationale (e.g., AI&T), or have too little funded schedule reserve for the identified development risks.
- Inadequate margins for technical resources. Mass and power are the most frequent cause of these weaknesses.
- Insufficient requirements to demonstrate feasibility at the system level.

Step 2 Summary

SOMA has directed the evaluation of 147 Step 2 CSRs submitted by PI-led teams since the office was formed.

Are there common causes of major weaknesses in Step 2 TMC reviews? Yes! Certain types of weaknesses persist, specifically:

- Proposed costs with their supporting BOEs could not be validated using independent cost models.
- The flowdown, traceability, completeness, consistency or stability of the top level mission or flight hardware requirements is flawed.
- Development schedules that lack sufficient detail to verify their feasibility, have missing elements, allocate too little time for typical activities without sufficient rationale (e.g., AI&T), or have too little funded schedule reserve for the identified development risks.
- Inadequate verification plans.
- Overstated instrument or Flight System TRLs (usually based on overstated heritage) or inadequate plans to demonstrate existing component technologies in newly integrated systems or operating in new environments.
- Inadequate margins for technical resources. Mass is the most common issue.
- Thermal design is not demonstrated to be viable.
- ACS performance claims are not supported.
- Lack of time commitment from key management team