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

Presentation to the PI Team Masters Forum 7

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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) **TMC Phase A Performance Study**

This is an update to the first 2 studies adding data and analysis from Step 1 and Step 2 evaluations completed between 2009 and 2017.

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 1000 proposals and concept studies retained by SOMA in the on-site archive library.

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

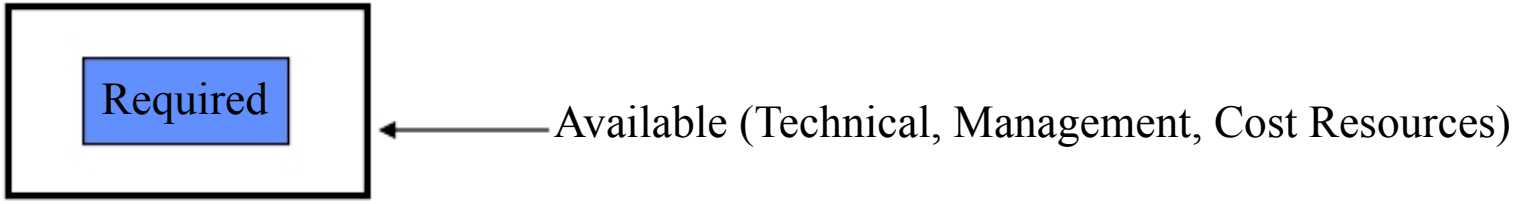
Study Update

This update adds the following step 1 or step 2 evaluations: 2007 SMEX (Full mission and MO), 2009 New Frontiers, Discovery 2010, Astrophysics and Heliophysics Explorers 2011 (Full mission and MO), 2015 Europa Instruments, 2015 Astrophysics SMEX and MO steps 1 and 2, Discovery 2015 steps 1 and 2, 2015 EVI-3, and 2016 EVM-2.

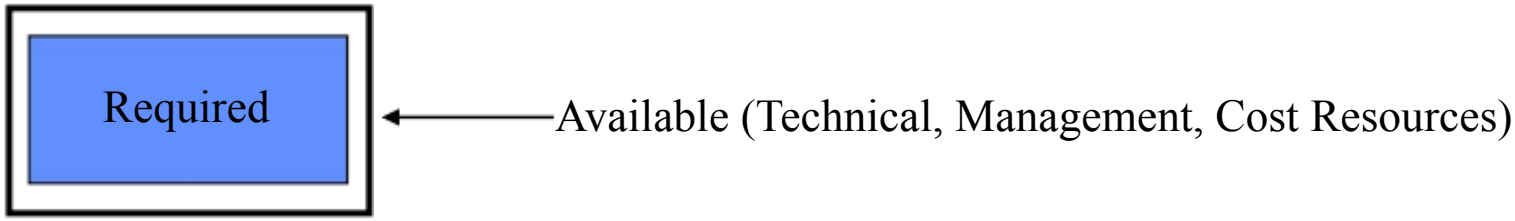
TMC Risk Envelope Concept

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

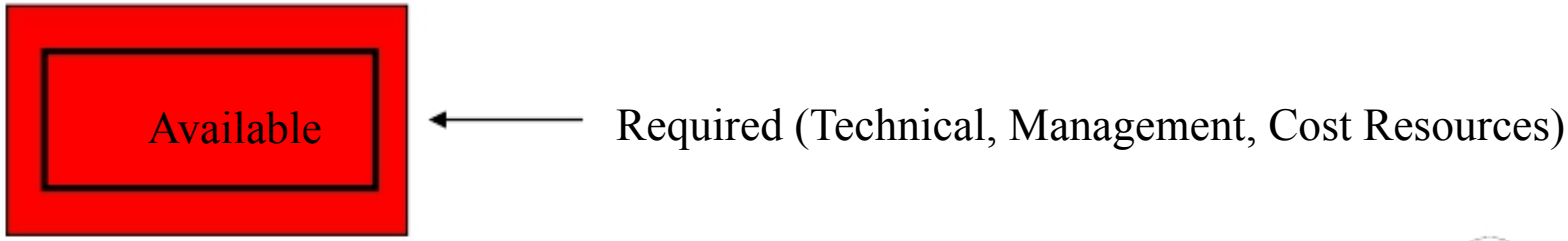
Low Risk: Required resources fit well within available resources



Medium Risk: Required resources just barely inside available resources.

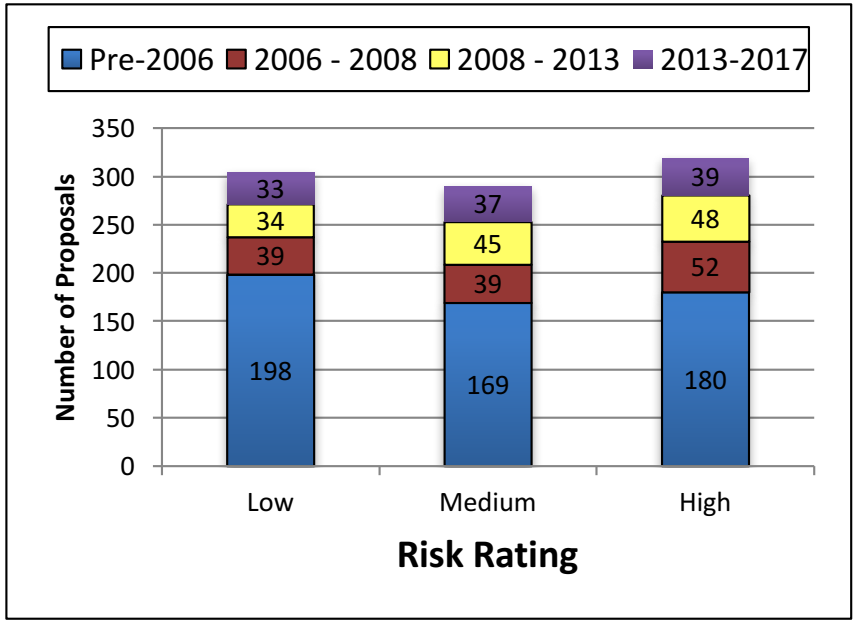


High Risk: Required resources DO NOT fit inside available resources.

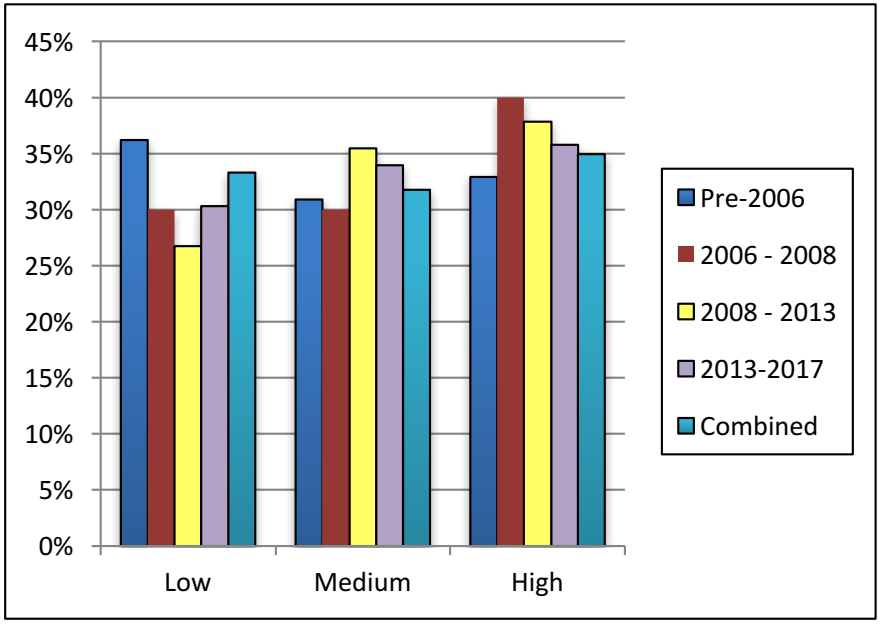


TMC Step 1 Risk Distribution Comparisons* Pre-2006, 2006-2008, 2009-2013 and 2013-2017

Distribution by Number



Distribution by Percentage

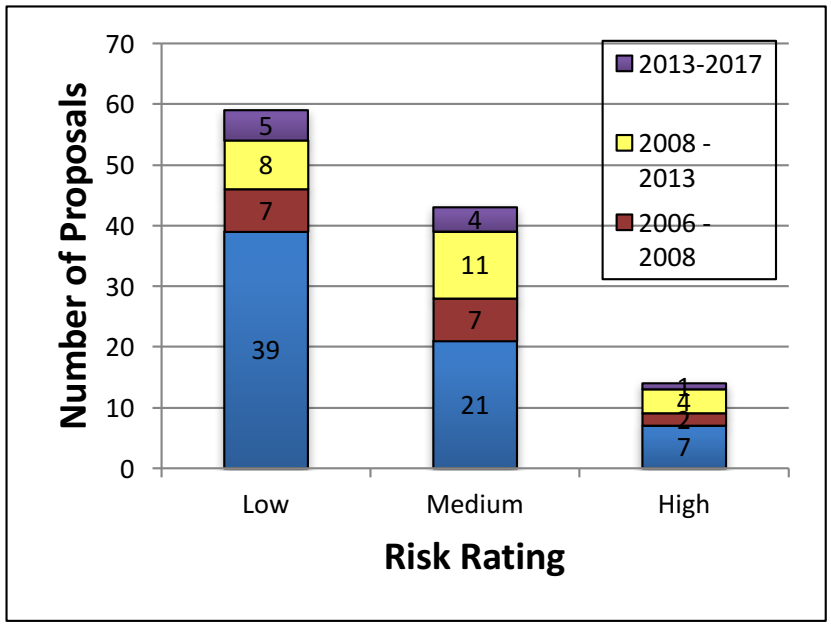


The overall distribution of over 900 Step 1 TMC risk assessments are evenly split among Low, Medium and High. While the L, M, H distribution has remained relatively constant, the number of major weaknesses per proposal has risen from 2.5 in the pre-2009 proposals to 3.5 in the post-2013 proposals.

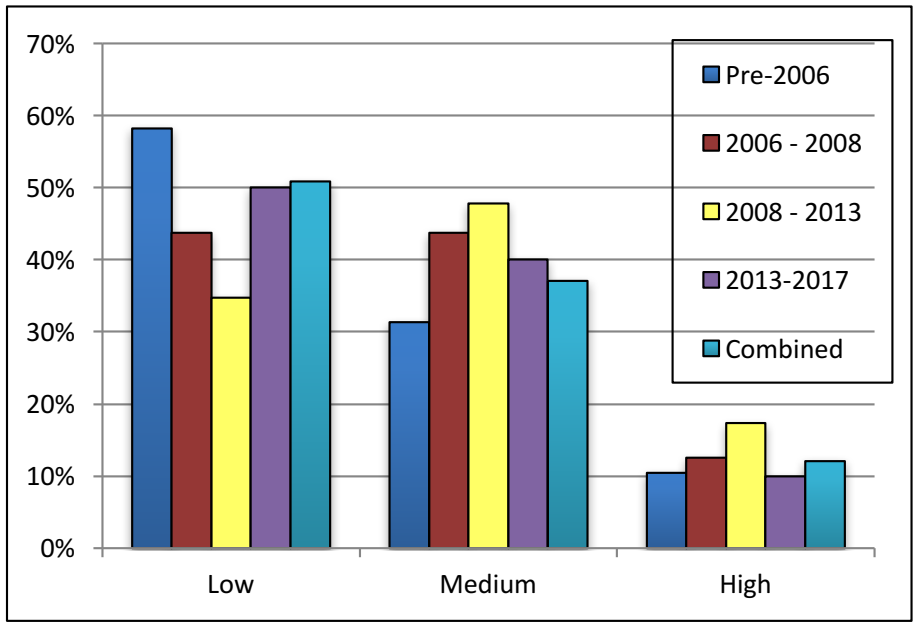
**Includes full and MO proposals*

TMC Step 2 Risk Distribution Comparison

Distribution by Number



Distribution by Percentage

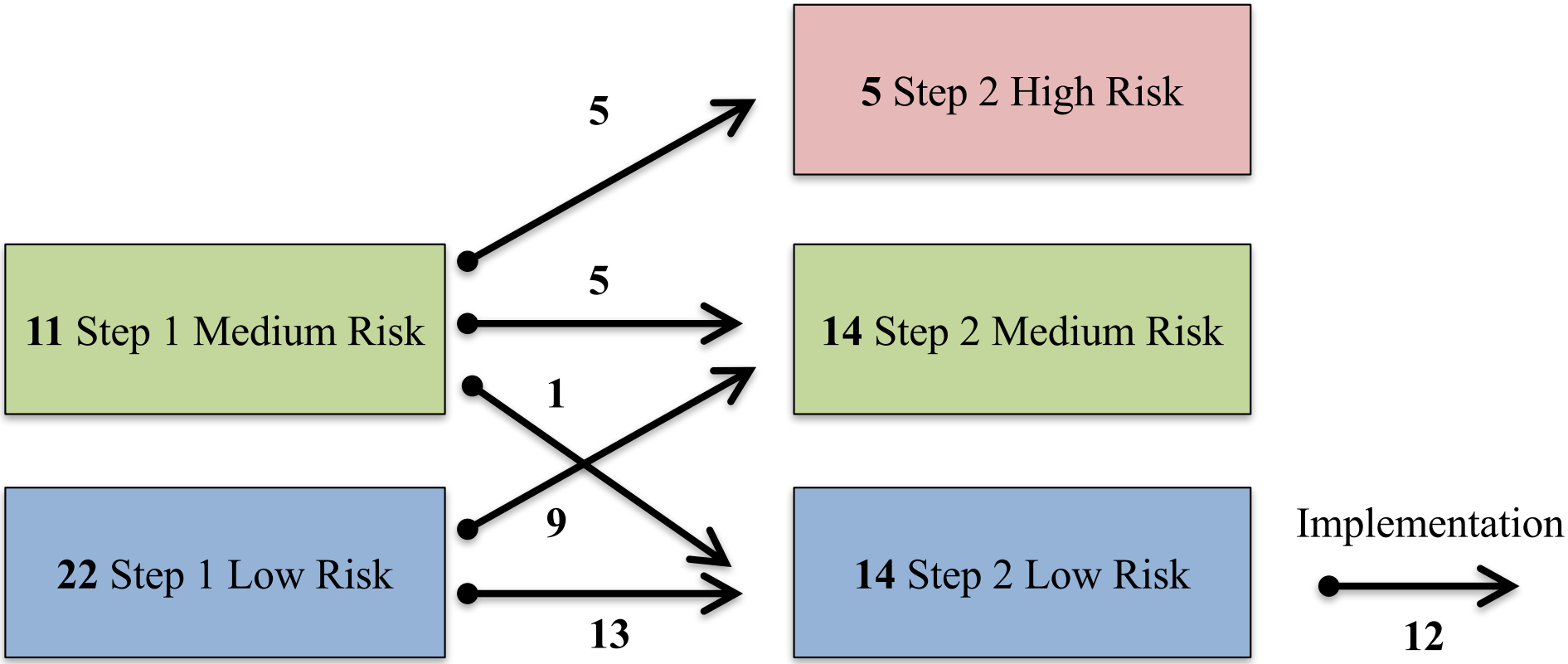


About half of all Step 2 proposals are rated low risk, with the remaining half primarily medium risk.

High risk Step 2 proposals continue to be about 10% of the total.

Step 2 Risk Ratings of Selected Step 1 Proposals

33 Step 1 Proposals Selected → 33 Rated Concept Study Reports



The risk rating for the set of missions (2009-2017) selected for step 2 either improved or remained the same (19/33) or got worse (14/33). This may be explained, in part, by more detailed reviews and less "benefit of the doubt" given in Step 2. The twelve missions selected for implementation were all rated Low Risk in Step 2.

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

Instruments

The number of Instrument MWs is trending up.

A third (33%; 255/783) of the pre-2009 evaluations had instrument MWs compared with 46% (58/127) for the 2009-2013 evaluations and 56% (61/109) of those from 2013-2017.

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

1) Overstated instrument TRLs (usually based on overstated heritage) or inadequate plans to demonstrate existing component technologies in newly integrated systems or operating in new environments. Also a common development plan flaw leading to a major weakness was a missing or inadequate technology backup plan in the event that the TRL development efforts are unsuccessful.

2) Insufficient support for instrument performance claims (via first principles or heritage scaling) that 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 5)

The percentage of evaluations with a **technical margin** major weakness has dropped from over 40% (41%; 321/783) for evaluations completed before 2009 to 28% (35/127) for 2009-2013 to 12% (13/109) for the evaluations completed between 2013 and 2017.

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 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 (3 of 5)

Operations

About 13% (14/109) of the 2013-2017 evaluations 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.

Systems Engineering

Systems Engineering (SE) MWs have trending down from 30% (pre-2009) to 8% (2009-2013) and 12% (2013-2017). The most common causes of these MWs were:

Inadequate or flawed systems engineering plans, tools or processes for requirements and interface development and risk management.

The scope of the systems engineering effort was significantly underestimated or the systems engineering roles and responsibilities were poorly described.

Significantly flawed or incomplete science traceability matrixes (STMs) are included in this MW category. Typical STM flaws include missing, untraceable or unquantified requirements, or the expected performance does not meet the proposed requirements.

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

Management

The percentage of proposals with a management MW has remained approximately constant at 26% prior to 2009, 29% between 2009 and 2013 and 33% for 2013 to 2017. The primary causes of these management MWs were:

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

Schedule

The percentage of proposals with a schedule MWs has also remain approximately constant with 17% of all proposals having a schedule MW prior to 2009, 23% between 2009 and 2013 and 15% for 2013-2017. The primary causes of these schedule MWs were:

- Inadequate schedule detail presented for the TMC to verify its feasibility
- Inadequate funded schedule reserve
- Too ambitious of a schedule for the planned activities, especially during AI&T

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

Cost

For evaluations since 2009 about half of all proposals (50% for 2009-2013 and 51% for 2013-2017) had at least one **Cost** major weakness. The most common causes of these MWs were:

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.

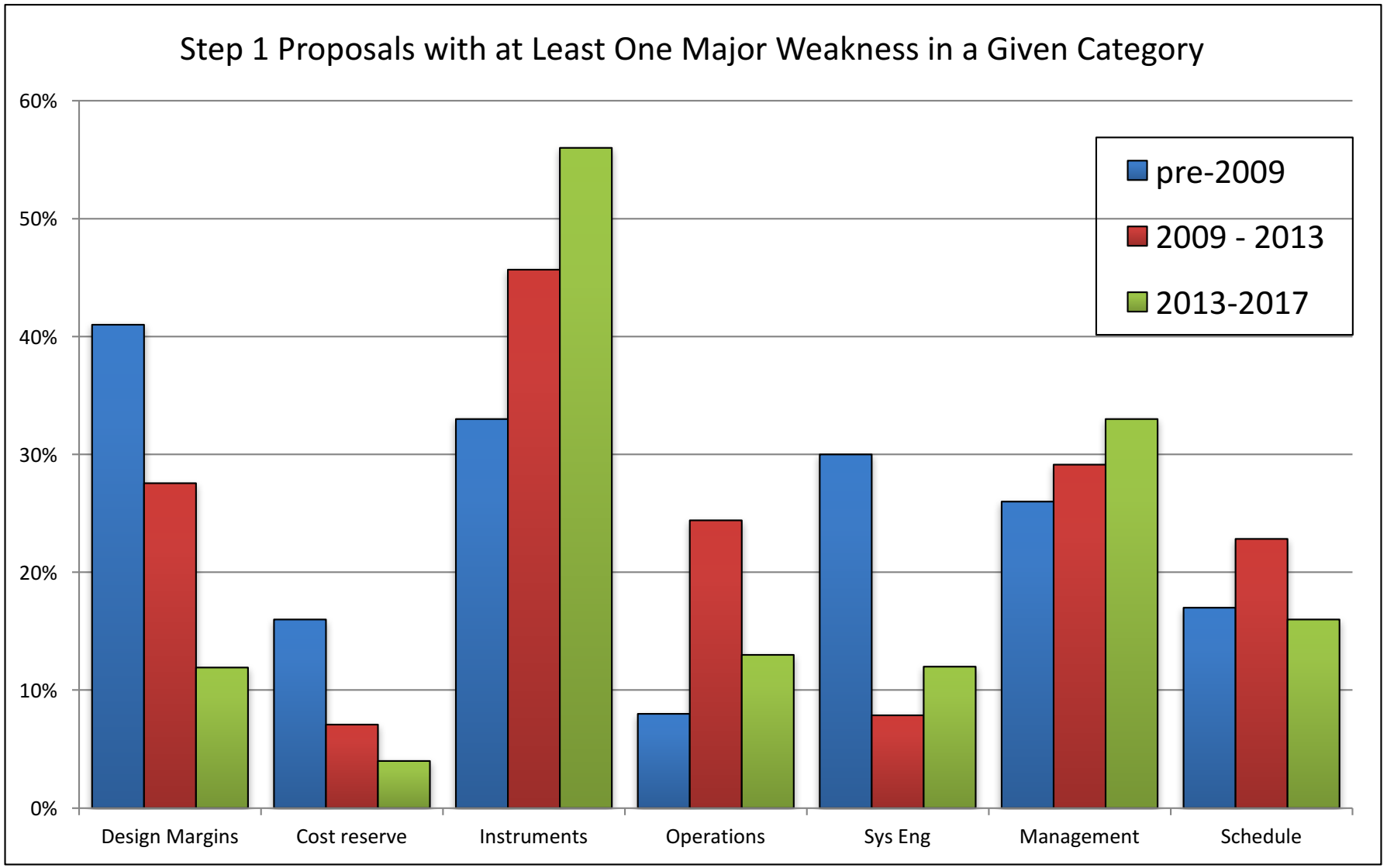
The cost Basis of Estimate (BOE) is flawed – there are missing cost elements or the rationale is incomplete, inconsistent or has unsupported assumptions

The cost reserves are too low.

Step 1 proposals with at least one Cost *reserve* MWs has trended down.

Prior to 2009 16% (124/783) of all proposals had a cost reserve MW, while between 2009 and 2013 this number had dropped to 7% (9/127) and between 2013 and 2017 to 4% (4/109).

Trend of Common Causes in Step 1 Proposal



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

The common causes of Major Weaknesses from 112 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 - 18% of Technical major weaknesses are due to problems with requirements definition, traceability and flow down

- Verification – 13% 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 – 12% are due to issues with the implementation of heritage elements
  - Overstatement of the benefits of the heritage
  - Modifications of the heritage element is required but not adequately accounted for

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

Step 2 Technical Major Weaknesses (continued)

- TRLs – 9% are related to overstated TRLs or inadequate technology development plans
  - These are primarily instrument related

- Mass Margin – 7% are issues with mass margin
  - Mass margin major weaknesses still occur but less frequently than in Step 1

- Thermal – 7% are due to inadequate thermal design
  - These are primarily instrument related

- ACS – 7% are issues with attitude determination and control
  - Inadequate description of the pointing budget
  - Mismatch between hardware capability and required performance

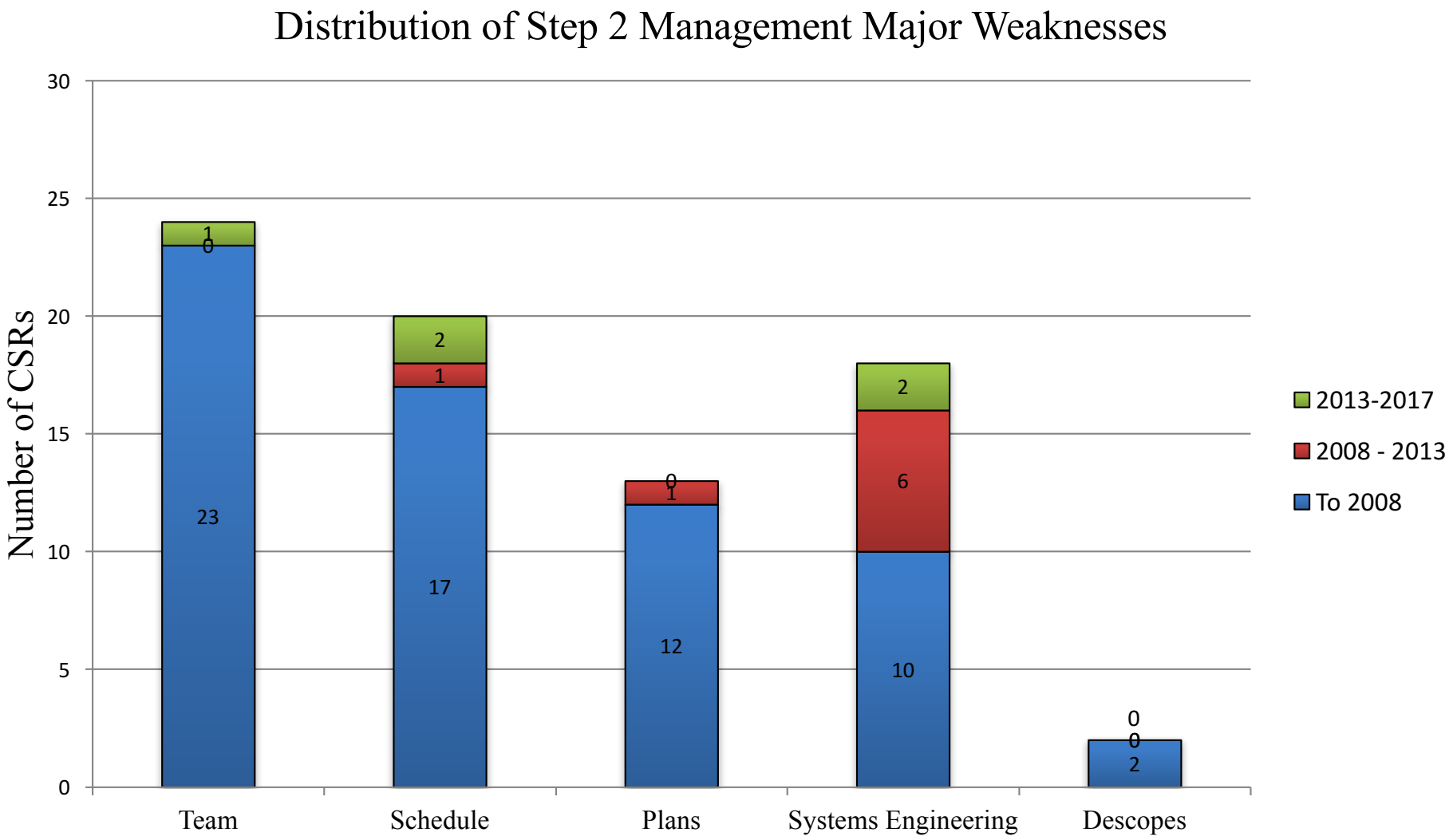
- Optics or Focal Plane – 5% are related to the design and development of the instrument optics and focal plane
  - Overstatement of performance is often cited

Step 2 Common Causes of Major Weaknesses (3 of 5)

Step 2 Management Major Weaknesses

- 30% are issues associated with key individuals
  - Lack of relevant experience among core team
    - Many recent PM candidates proposed have 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.
- 25% 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
- 23% are due to systems engineering
  - Often reflects lack of consistency among project elements
- 3% are due to descopes taking the mission below Threshold

Step 2 Distribution of Management Major Weaknesses*



*Includes only the most common major weaknesses

Step 2 Common Causes of Major Weaknesses (4 of 5)

Step 2 Systems Engineering Major Weaknesses

There are two primary sources of Step 2 Systems Engineering major weaknesses for evaluations completed after 2008 are:

1) The flowdown, traceability, completeness, consistency or stability of the top level mission or flight hardware requirements is flawed.

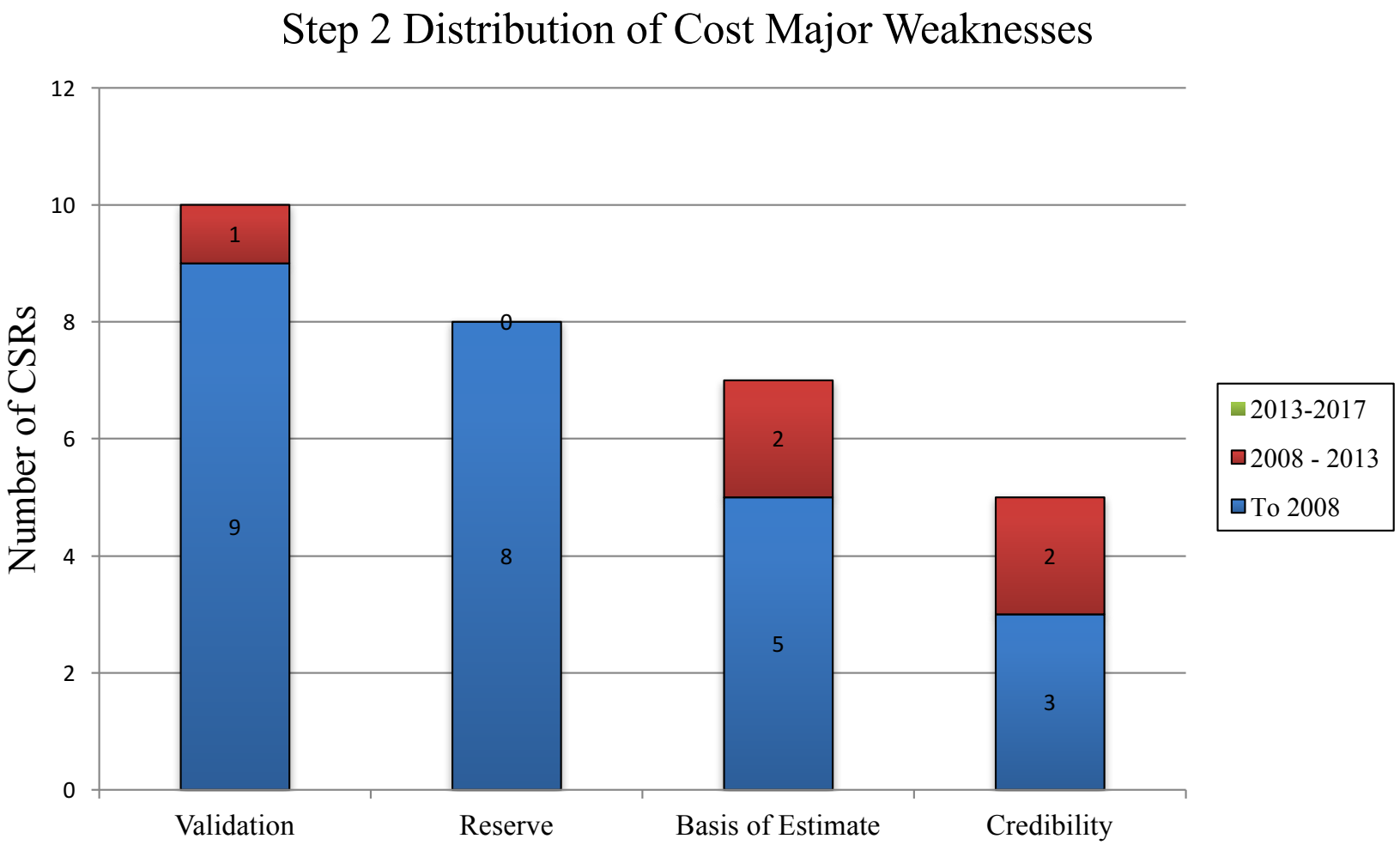
2) The Systems Engineering plans or approach, including clearly identifying the roles and responsibilities of the Project Systems Engineer are flawed.

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

Step 2 Cost Major Weaknesses

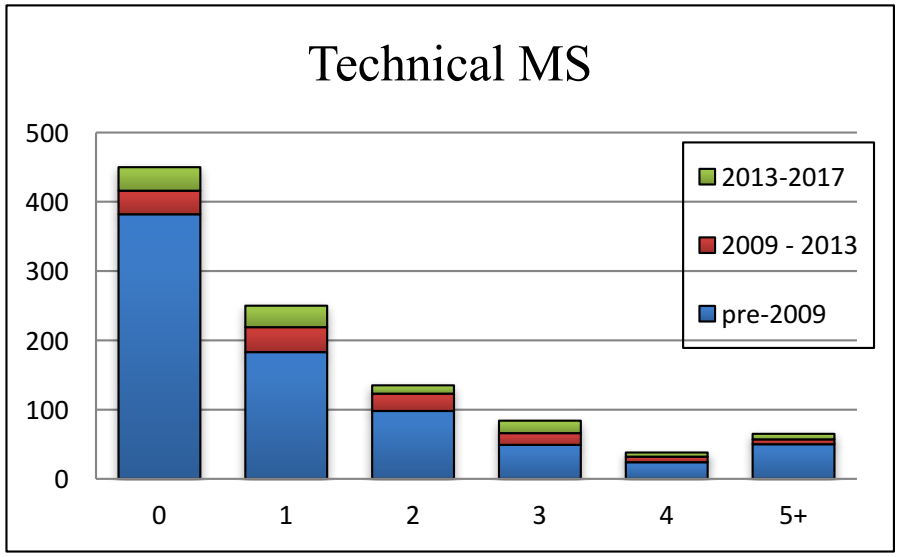
- 29 % are due to inadequate cost reserves
  - Increased definition in the design and implementation in Phase A often results in erosion of cost reserve
  - Cost reserve is often an issue in proposals with low maturity or overstated heritage
- 32 % are related to significant and unreconciled differences 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.
- 23 % are due to an inadequate basis of estimate
- 13 % are related to the credibility or relevance of the supporting cost data

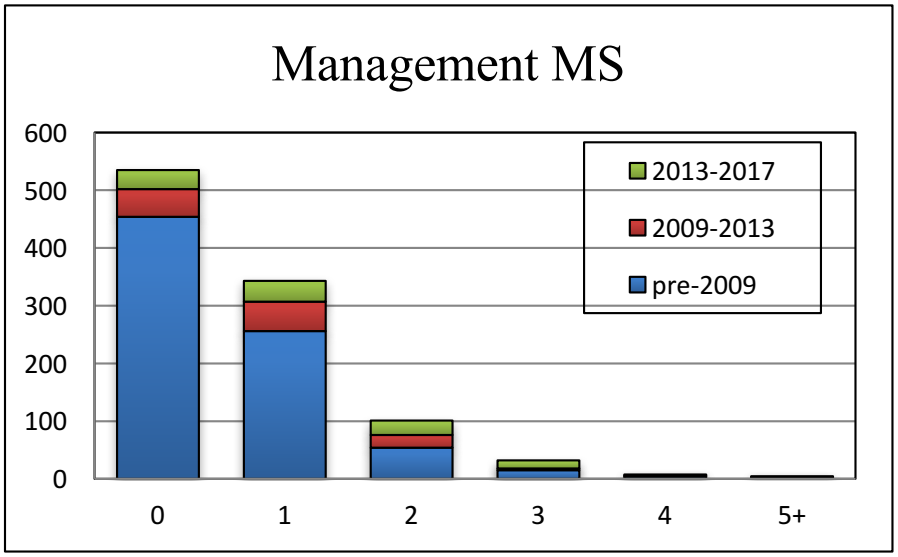
Step 2 Distribution of Cost Major Weaknesses*

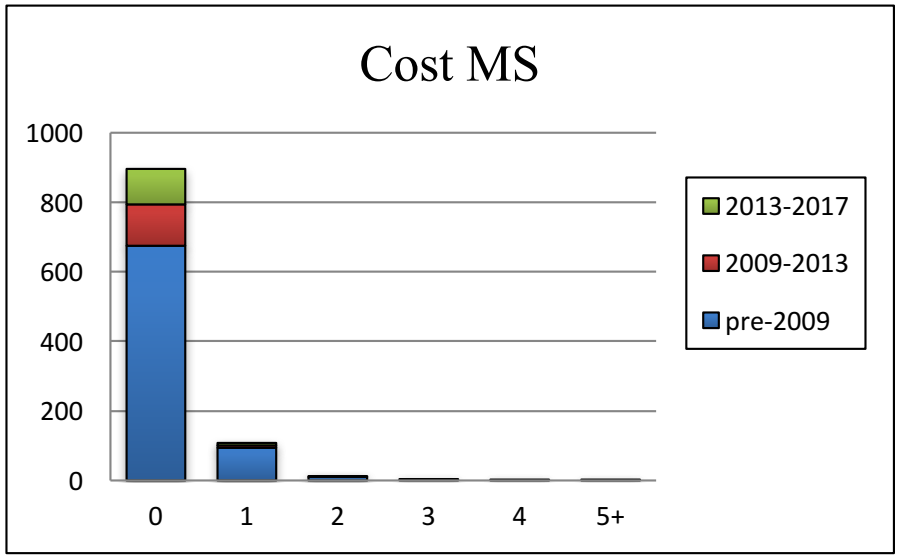


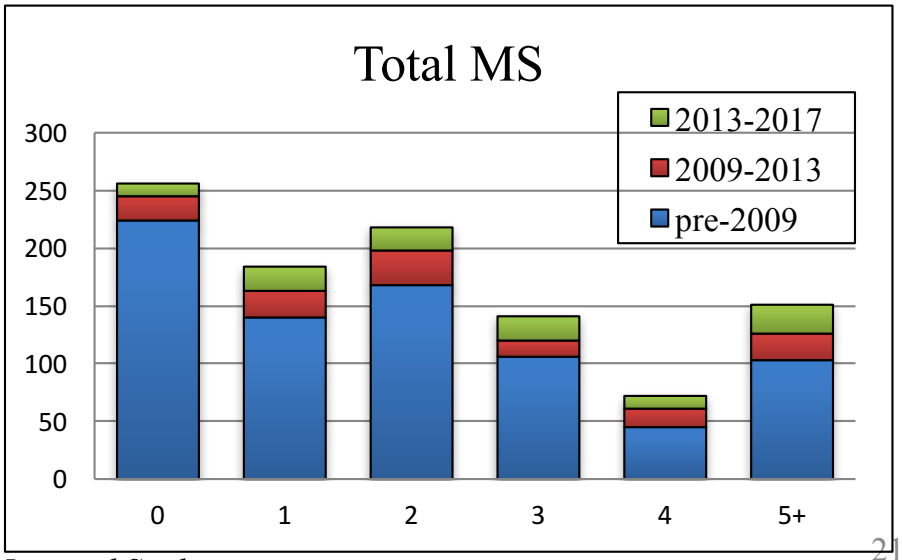
*Includes only the most common major weaknesses

Number of Proposals Versus Number of Step 1 Major *Strengths*

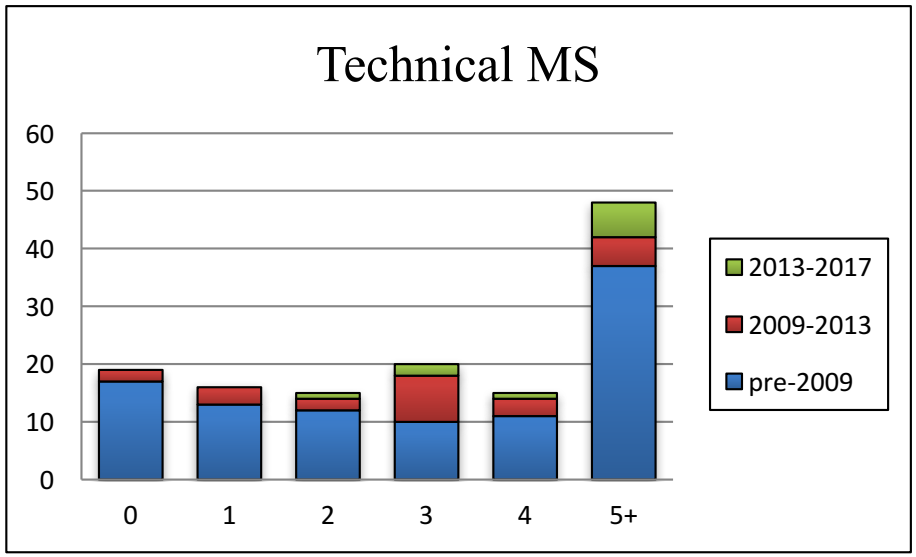


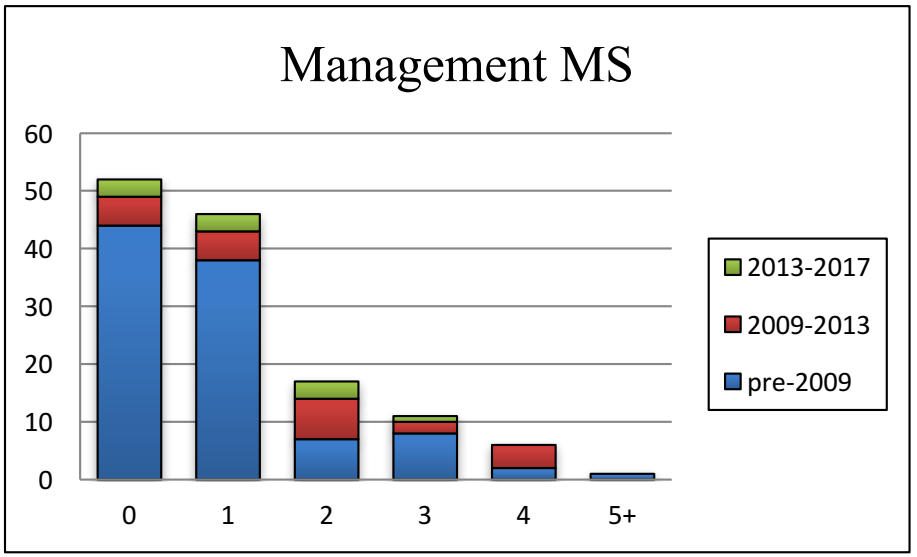


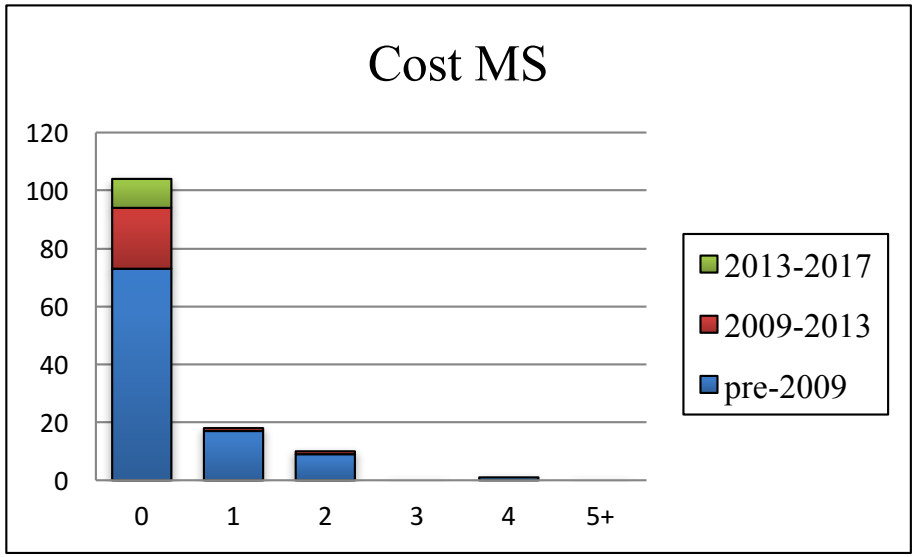


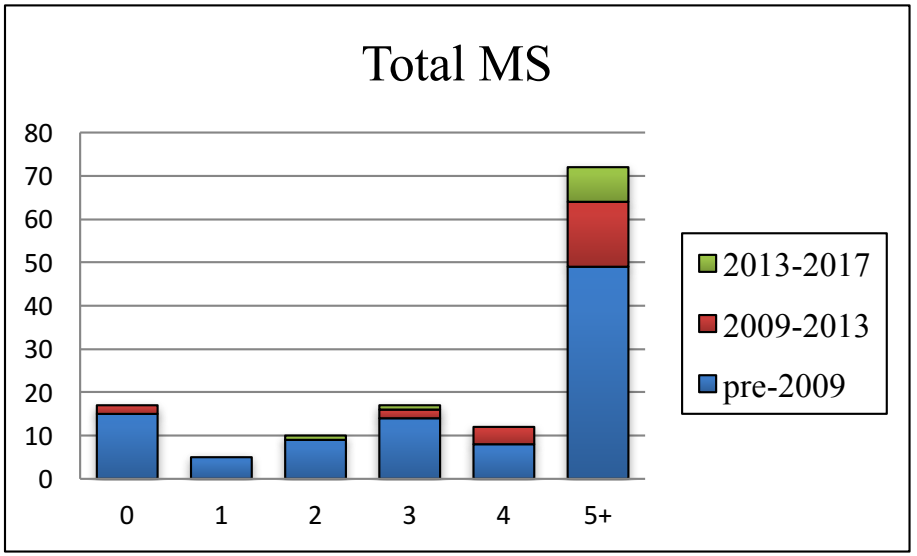


Number of Proposals Versus Number of Step 2 Major *Strengths*









Summary

SOMA has directed the evaluation of more than 1000 proposals and concept studies submitted by PI-led teams since the office was formed. Are there other common causes of major weaknesses in TMC reviews? Yes! Certain types of weaknesses persist, specifically:

Overstated instrument TRLs (usually based on overstated heritage) or inadequate plans to demonstrate existing component technologies in newly integrated systems or operating in new environments. A related weakness is a missing or inadequate technology backup plan in the event that the TRL development efforts are unsuccessful.

Insufficient support for instrument performance claims that is usually combined with insufficient instrument design information to independently verify it's 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.

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.