SMD Cost/Schedule Performance Study

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Study Charter

- **Study Objective:** Evaluate the cost/schedule performance record of selected SMD flight projects to determine:
  - Key drivers of cost/schedule performance, and
  - Implementation approaches that enhance performance of SMD missions.
- **Approach:**
  - Select a subset of current projects that span SMD disciplines, size classes and experience base. This subset constitutes the Baseline data set.
  - For each project, collect a detailed performance history of cost, schedule and technical data by key milestones – the *Project Milestone Performance History (PMPH).*
  - Interview the Project Manager and other key staff members to collect narrative description to compare with and explain the detailed history data.
  - Collect existing data from other sources and prior studies. This additional data constitutes the Supplemental data set. The Augmented data set consists of the Baseline data augmented by the Supplemental data set. This terminology will be used throughout.
  - Characterize cost/schedule drivers for each project.
  - Identify cross-project trends in cost/schedule performance.
  - Develop findings and conclusions from project analysis and cross-project trends.
  - Recommend actions/approaches to ensure successful performance of future projects.
- **Products:**
  - Interim Reports and Midterm Report.
  - Final Report - presentation and narrative.
  - Detailed *PMPH* data in readily accessible electronic template formats.

SMD Projects Included in the Baseline Set

- Baseline projects were selected in collaboration with HQ managers; SMD gave final approval to the set.
- Baseline projects were selected to balance several factors:
  - Select from current portfolio.
  - Cover all SMD programs.
  - Cover all mission size classes.
  - Include various management institutions and PI-led missions.
  - Where possible, leverage existing data sources and prior study team experience.
- Final set of 15 Baseline projects balances these factors with available resources and the time needed to set up and conduct interviews, and to perform the data collection and analysis for the cost/schedule performance assessment.
- Limitations for data collection (all data for all milestones was not available) required some trends to be investigated with less than 15 Baseline projects.

Initial Project List for Cost/Schedule Study	
SMD Division	**Projects Selected**
Earth Sciences	CloudSat
	ACRIMSAT
	Aqua
	Terra *
Heliophysics	RHESSI
	STEREO
Planetary Sciences	CONTOUR
	Deep Impact
	New Horizons
	MESSENGER
	MER
	MRO
Astrophysics	GALEX
	Swift
	Chandra
	Spitzer

** The initial list was reduced because of difficulty in:*
- *arranging interviews with PM and team*
- *finding and collecting available PMPH data.*

For these reasons, the Terra mission was removed from further consideration in the study (with SMD concurrence).

SMD Projects Included in the Supplemental Data

- In response to a request from NASA HQ, the study team mined additional sources of previously compiled project cost and schedule data. The goal was to determine if a larger mission set would significantly alter the findings derived from the baseline mission set. A total of *9 mission data sets* were added. *Interviews were not conducted for these missions.*

- **Data Selection Criteria**
  - Supplemental data used must be comparable to data collected for the Baseline mission set.
    - Cost and schedule data must be available from milestones prior to, or including, CDR as well as at launch in order to evaluate cost and schedule growth.
    - Cost data must be available at sufficient detail, i.e. Development, Launch Services and Operations.
  - Primary data source was the 40-mission data set used for the IEEE Paper #1545. Of the 40 mission data sets:
    - 17 data sets did not include cost and schedule data prior to CDR.
    - 3 data sets did not included sufficient cost detail.
    - 12 missions were already included in the current baseline mission set.
    - The remaining 8 data sets were added along with corresponding data from the Dawn mission.

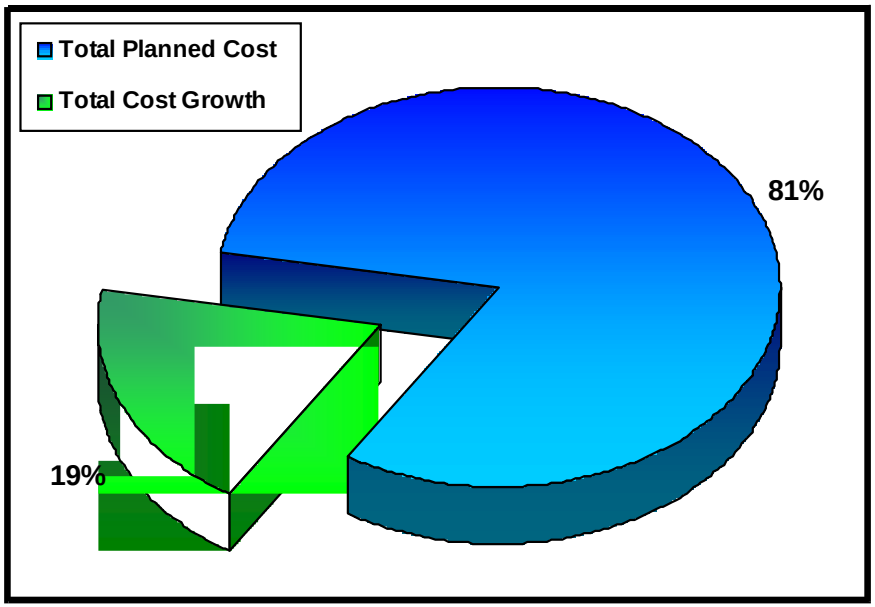
- **Missions added:**
  - Near Earth Asteroid Rendezvous (NEAR)
  - Genesis
  - Wide Field Infrared Explorer (WIRE)
  - Wilkinson Microwave Anisotropy Probe (WMAP)
  - Gravity Recovery and Climate Experiment (GRACE)
  - Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO)
  - Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED)
  - Gravity Probe B (GP-B)
  - Dawn

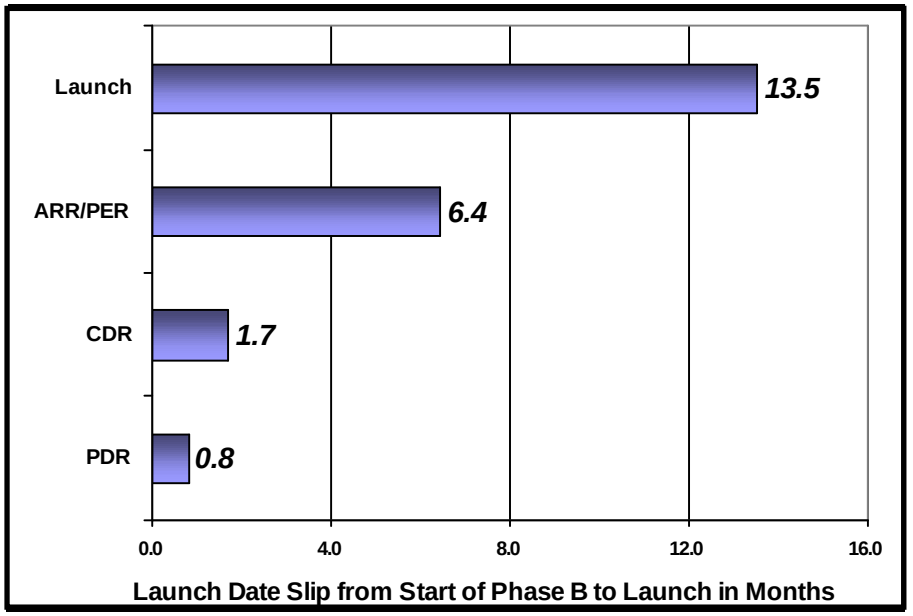
- **The Augmented data set consists of Baseline data plus Supplemental data.**

Findings (1 of 6)

- **Cost history data for 21 of the 24 projects studied shows cost growth.**
  Total cost growth from Phase B start to Estimate-to-Complete (ETC) @ Launch for all projects studied represents a combined impact of $2.0 Billion to SMD's mission portfolio.

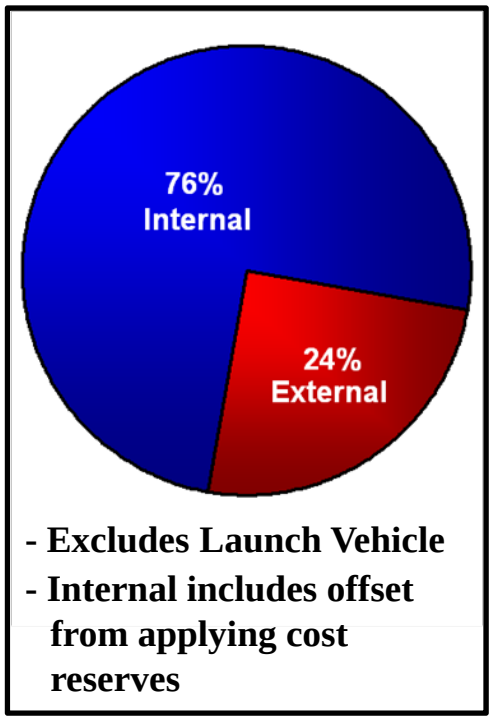
- **Schedule history data indicates schedule slips for 19 of the 24 projects studied.**
  This includes delays from all sources (externally imposed replans as well as slips from delays internal to the project). The delays ranged from 5 to 42 months.



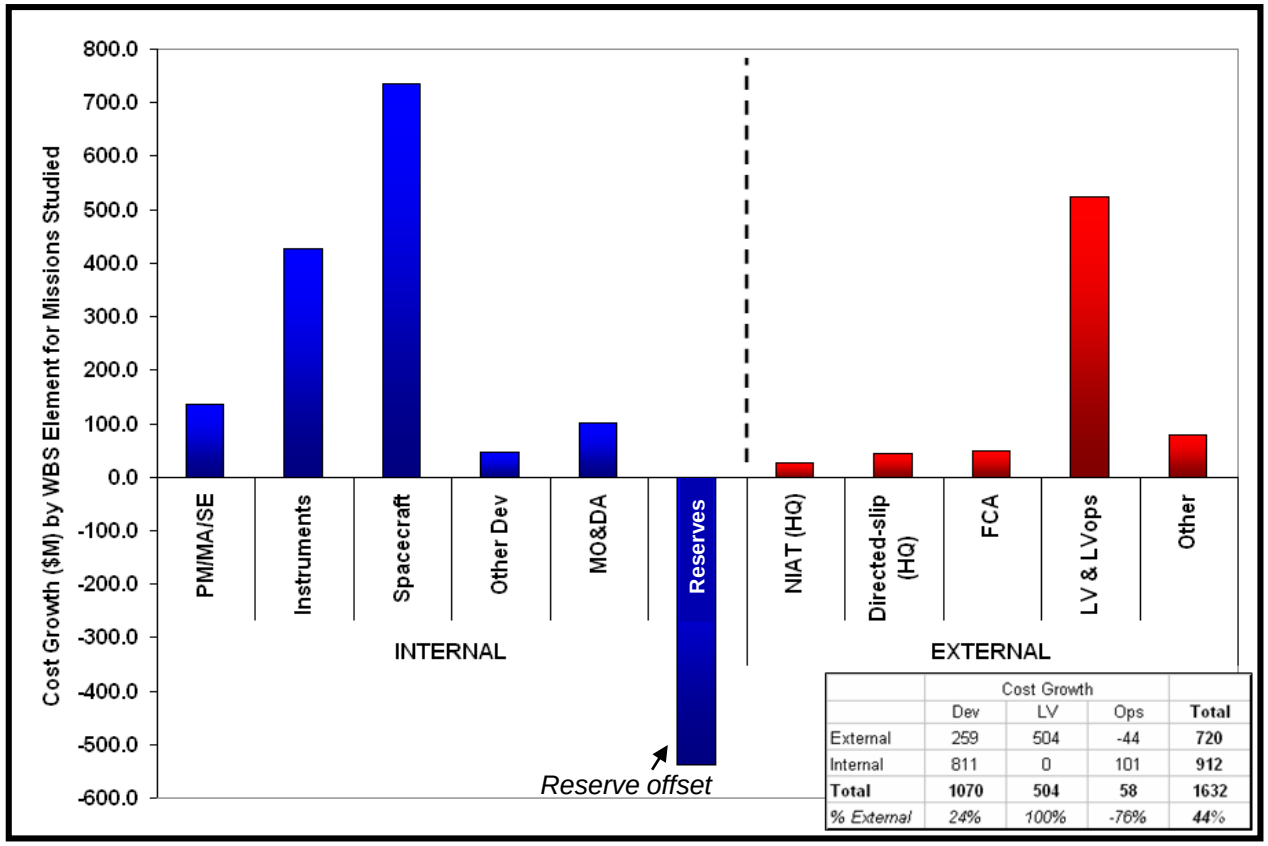


Findings (2 of 6)

- **Data analysis of the 21 projects with cost growth indicates 24% of the overall development cost growth (excluding the launch vehicle) is from External impacts (outside project's direct control), with the remaining 76% of cost growth attributable to factors controlled internally by the project.**
  Internal and External impacts can both produce significant cost growth. While Internal impacts appear larger than External impacts, some of the Internal cost growth may result from the indirect effects of an External impact.



- **Excludes Launch Vehicle**
- **Internal includes offset from applying cost reserves**

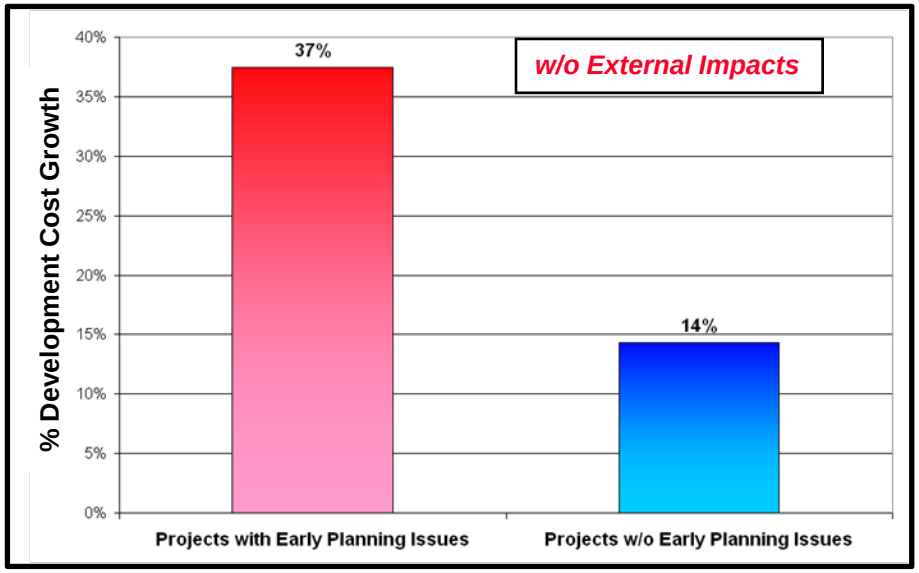


	Cost Growth			
	Dev	LV	Ops	Total
External	259	504	-44	720
Internal	811	0	101	912
Total	**1070**	**504**	**58**	**1632**
% External	*24%*	*100%*	*-76%*	*44%*

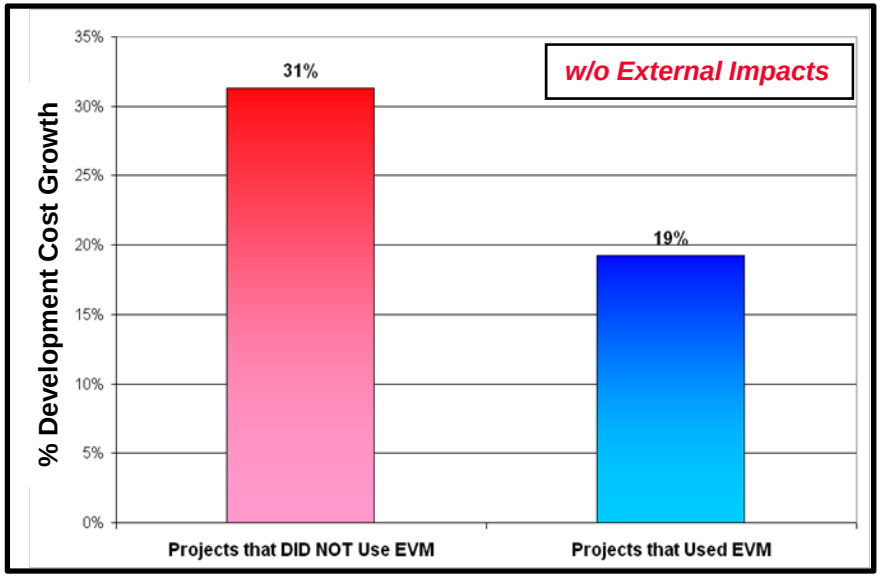
Findings (3 of 6)

- **Interview comments by eight projects cited early planning deficiencies as a significant source of development problems (underestimates, inexperience, inadequate early technology investment, and/or design heritage that was not realized).**

  Analysis shows projects with early planning deficiencies experienced more than twice the development cost growth (w/o External impacts) vs. projects with adequate early planning.



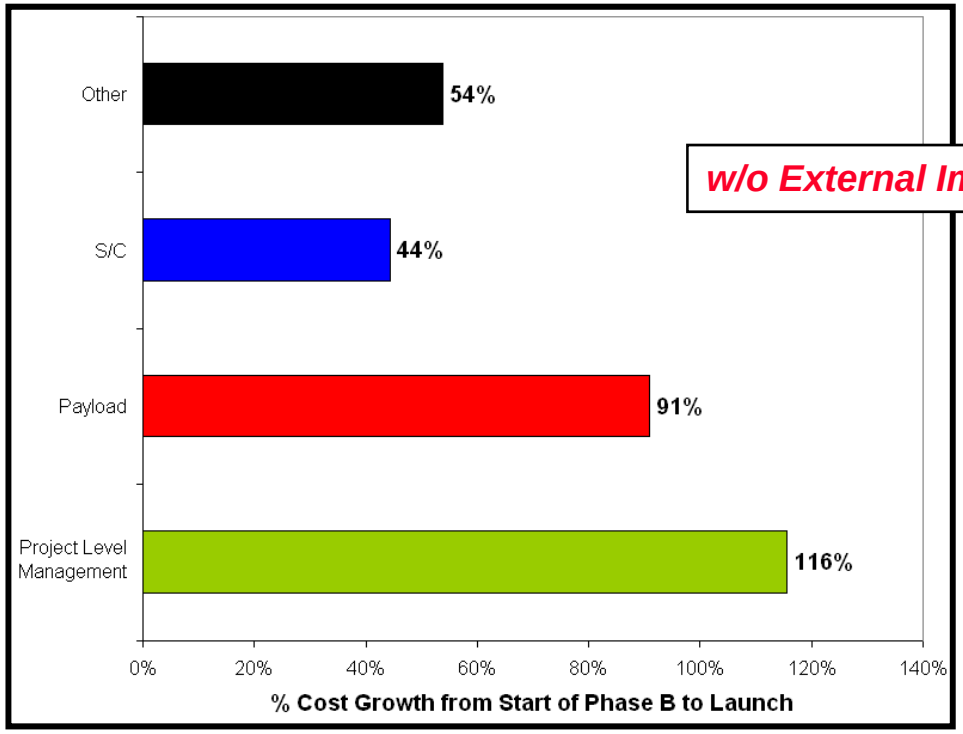
- **The four projects that reported using Earned Value Management (EVM) as a management tool show lower average growth in development costs compared to projects that did not use EVM.**



Findings (4 of 6)

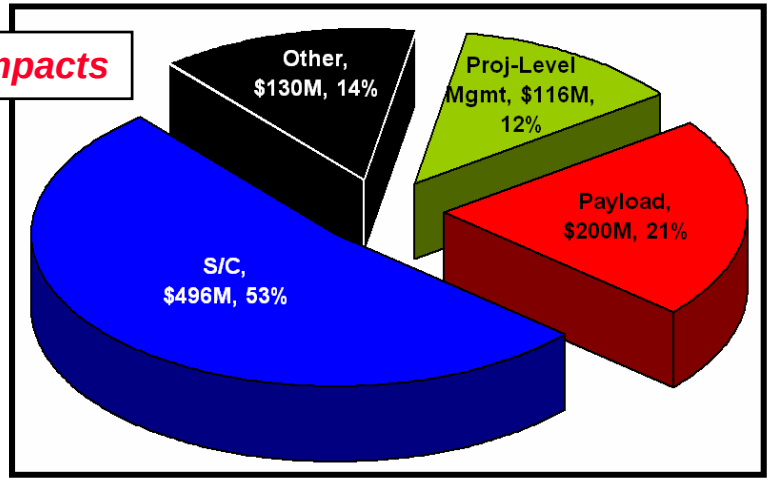
- **For the 21 projects with cost growth studied, average percent cost growth for science instruments (91%) is more than twice the growth for flight systems (44%).**
  Instrument cost growth due to design changes also affects spacecraft costs.

- **On a percentage basis, average cost growth is highest for the WBS elements covering project-level management functions (project management, mission assurance, systems engineering, etc.).**
  Although project management functions typically account for only about 10% of total cost, an average growth of 116% (excluding external impacts) is still large enough to impact the project's cost position.



w/o External Impacts

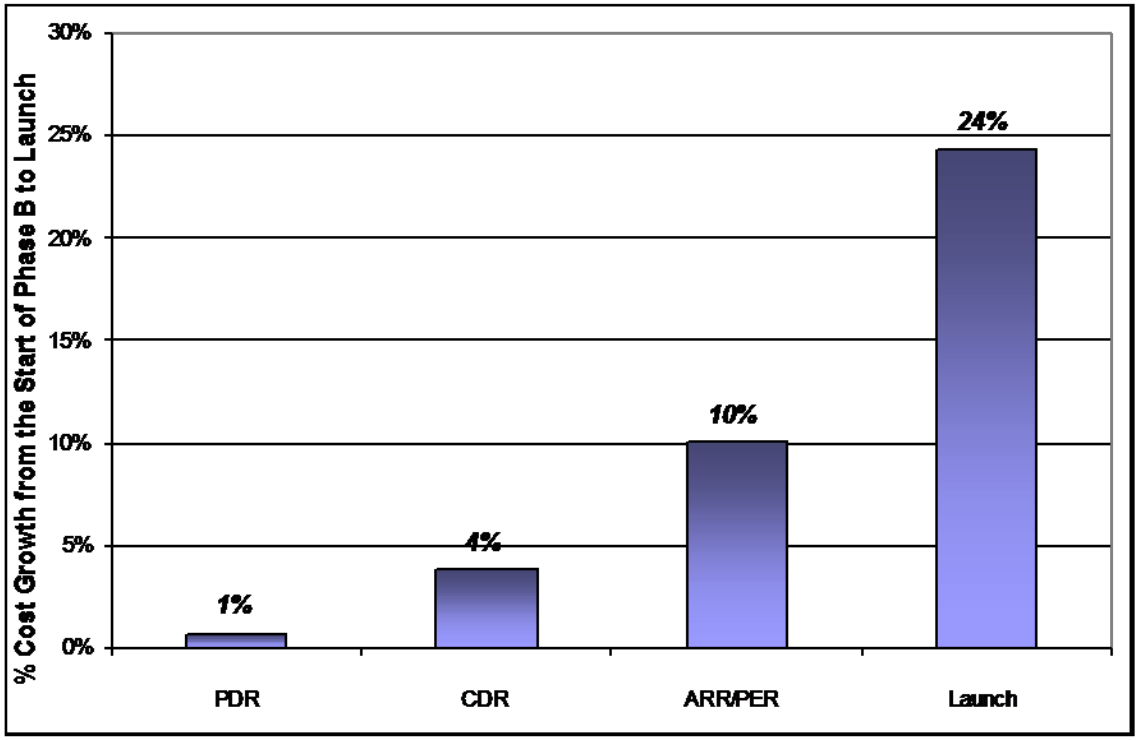
Amount of Cost Growth by Element



Findings (5 of 6)

- **Fifteen of the 21 projects with cost growth show a substantially increased rate of internal cost growth after CDR.**

  Excluding external impacts, cumulative average cost growth to CDR is 4%, but this grows to 24% by launch. So 83% of this growth occurs after CDR.



Findings (6 of 6)

For the projects in this study:

- There is no discernable correlation between planned cost reserve level and actual cost performance (Fig. 1);
- There is no strong correlation between the percent of funds spent up to CDR and actual cost performance (Fig. 2); and
- Although adequate Phase B funding is a necessary condition for project success, it is not sufficient to ensure good overall cost performance (Fig. 3).

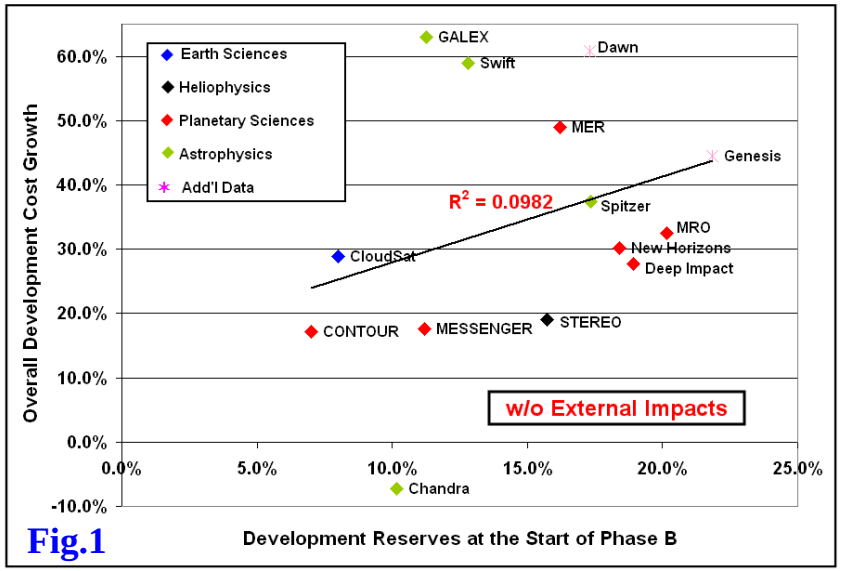


Fig.1

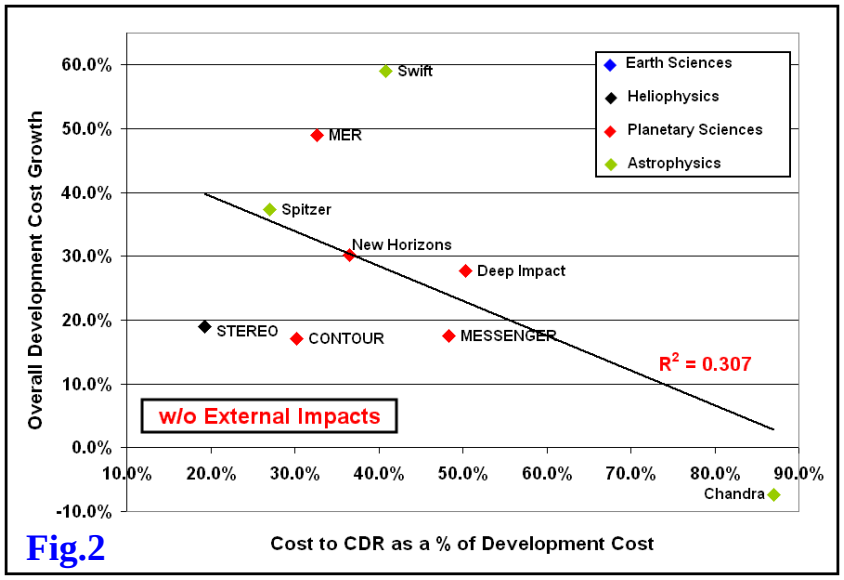


Fig.2

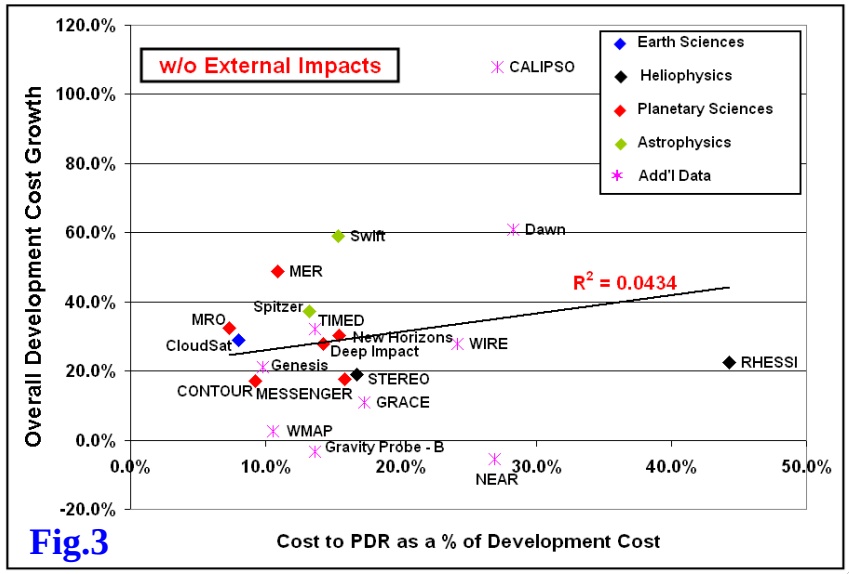


Fig.3

Study Conclusions

What are the key drivers affecting cost/schedule performance for SMD projects?

Internal Factors

Over-optimism early in formulation – Implementers are driven by pressures to maximize science per dollar to enhance attractiveness prior to authority to proceed. Combined with typical early planning deficiencies (underestimates, inexperience, design heritage not captured), the resources required are understood only as the project matures. Baselining project costs too early can lead to cost growth and schedule slips from deficiencies in the early plans. Costs cannot be accurately baselined without a thorough definition of design and schedule.

Instrument development complexity – Design and implementation plans early in formulation typically lack detail and often fail to identify some of the technology or development challenges. Also, spacecraft cost growth can be caused by instrument design changes, late instrument deliveries, and instrument problems encountered during I&T.

External Factors

Launch service issues – Growth in this area, which is not in the project's direct control, account for almost one third of the $2.0B growth across the Augmented data set.

Unstable or inadequate initial funding profile – These problems distract the project management team from the real challenges of implementing the project to work on replanning efforts.

Study Conclusions

What practices contribute to improved cost/schedule stability for programs and projects?

The SMD projects evaluated in this study have experienced cost growth and schedule slips over early budget plans despite having what was considered to be:

1. Ample reserves
2. Best project managers
3. Best management practices
4. Highly qualified and dedicated core teams of engineers and managers
5. Extensive and increased scrutiny by external reviewers

The study team concludes that all of these attributes are necessary, but not sufficient, for meeting cost and schedule performance goals. The study team recommends that SMD ensures that every current or contemplated project is supported by:

1. A **stable external environment** of fixed requirements, funding, and launch services.
2. **Sufficient program-level budget reserves** to address impacts from changes external to the projects.
3. A requirement that each project's activities during formulation focus on **in-depth understanding and disciplined development of the baseline**, which includes the technical mission implementation as well as the cost estimate, funding profile, and the resource-loaded schedule for getting to launch.