History and Logic Model
NASA Goddard Space Flight Center Instrument Projects Division (IPD) Schedule and Cost Study

Geraldine Robbins ASRC/AFSS Contractor, Instrument and Payload Systems Engineering Branch (IPSE)

Stephen M. Schmidt and Robert W. White, Civil Servants, Instrument Projects Division (IPD)

NASA Goddard Space Flight Center

February 2020

IPD Schedule and Cost Study *Context*

Historically, some NASA missions have exceeded schedule and cost commitments.

In 1980, The NASA Project Management Study concluded, *"one of the most significant contributors to cost and schedule growth is inadequate definition of technical and management aspects of a program…"* (cited in GAO/NSIAD-93-97, p. 11).

In 1992, The NASA Program Costs Report stated that NASA officials identified, among other things, *"program and funding instability, overly optimistic assumptions by program officials, and unrealistic contractor estimates"* as reasons why initial estimates changed over time (GAO/NSIAD-93-97, p. 11).

In 2002, The Task Force on Acquisition of National Security Space Programs was chartered to review the acquisition of national security space programs, identify and characterize systemic problems and recommend improvements. The Task Force report is a Defense Science Board publication, May 2003. Findings follow.

IPD Schedule and Cost Study *Context (continued)*

The Task Force report (2003) identified five reasons for schedule and cost growth. Two of the five directly cite cost or cost estimates (p.2):

- *"Cost has replaced mission success as the primary driver in managing space development programs … [resulting] … in excessive technical and schedule risk."*

- *"Unrealistic estimates lead to unrealistic budgets and unexecutable programs. The space acquisition system is strongly biased to produce unrealistically low cost estimates throughout the acquisition process."*

Additionally, the report identified "unhealthy cost bias in proposal evaluation, widespread lack of budget reserves required to implement high risk programs on schedule, and an overall underappreciation of the importance of appropriately staffed and trained system engineering staffs to manage the technologically demanding and unique aspects of space programs" (p.i).

IPD Schedule and Cost Study *Context (continued)*

In 2007, The NASA Office of the Chief Engineer (OCE) chartered the NASA Instrument Capability Study (NICS).

"to determine whether NASA instrument developers are facing challenges that impact the capability to design and build quality instruments or whether there are flaws in the acquisition strategy evidenced by schedule delays, cost overruns, and increased technical risk via design deficiencies. The … team was also chartered to determine if occurrences [are] … isolated cases or if there [are] generic issues … If the issues [are] found to be generic, the team [is] to offer solutions to recover such capability." (NICS Report, 2008, p. vi).

The NICS Report (2008) identified challenges to instrument schedule and cost growth consistent with previous findings.

In 2017, Using the NICS as a guide, the Instrument Projects Division (IPD) initiated the Schedule and Cost Study to determine if there was a change in meeting schedule and cost commitments after implementing certain NICS recommendations. If not, "*Why?*"

IPD Schedule and Cost Study *Problem Statement*

Historically, some NASA GSFC scientific instruments have exceeded schedule and cost commitments.

Research Questions

RQ1) Is the IPD implementing NICS Finding 1 recommendations, Finding 2 recommendation 3, and Finding 5 recommendation 1? **RQ1a)** To what degree are instrument projects aligning with NICS recommendations? *(NICS recommendations are presented on slides 12-16)*

RQ2) At Commissioning, are at least 80% (TBR) of IPD managed instruments meeting CSR/Directed Study schedule and budget with margins (S&B) estimates and/or PDR S&B commitments? **RQ2a)** What is the relationship between IPD managed instruments and meeting CSR/ Directed Study S&B? **RQ2b)** What is the relationship between IPD managed instruments and meeting PDR S&B?

RQ3) Is the Center-level investment sufficient for at least 80% (TBR) of IPD managed instruments to meet Study S&B? **RQ3a)** Is the Center-level investment sufficient for at least 80% (TBR) of managed instruments to meet PDR S&B? *Center-level investment is defined as existence of IPD, supported by resource-level CM&O and Directorate funds.*

RQ4) Is there a relationship between meeting NASA scientific instrument technical success and meeting schedule and budget commitments? **RQ4a)** If yes, what is the relationship?

IPD Schedule and Cost Study *Objectives*

Desired results

- *Determine* if at least 80% (TBR) of IPD managed instrument projects meet Study S&B.
- *Determine* if at least 80% (TBR) of IPD managed instrument projects meet PDR S&B.
- *Determine* if Center-level commitment is sufficient for at least 80% (TBR) of IPD managed instruments to meet Study S&B.
- *Determine* if Center-level commitment is sufficient for at least 80% (TBR) of IPD managed instruments to meet PDR S&B.
- *Determine* if there was a change in meeting schedule and cost commitments after implementing certain NICS recommendations.
- *Determine* if there is a relationship between instrument technical success and meeting schedule and cost commitments.

Definitions/ methods

- Success is defined as at least 80% (TBR) of IPD managed instrument projects meet Study S&B and/or PDR S&B. Success is tracked as costs variance and schedule variance using CSR/Directed Study as the starting point and PDR as the S&B commitment. To meet S&B, an instrument must deliver on or before the agreed to delivery date, and at or below agreed to cost at the end of commissioning.

IPD Schedule and Cost Study *Logic Model excerpt*

Inputs	Activities	Outputs	Level 3 Outcome						Level 2 Outcome	Level 1 Outcome
			CSR/Directed Study	SRR	PDR	CDR	Delivery	Commissioning		
Authority to direct personnel to cooperate and respond to Study Space on TDMS WYE (TDMS, data collection, analysis, survey management report preparation) FTE (allocate resources to IPMs to complete survey, cooperate with investigation) Python and modules Adobe Acrobat pro Survey Monkey	**1)** Capture budget and schedule data at time of CSR/ Directed Study, SRR, PDR, CDR, Delivery, and Commissioning **2)** Analyze collected data using NICs report as control/ baseline: "~70% of the instruments reported 25% or more cost overruns and ~60% of the instruments reported schedule delays of 5 months or more." *NICS report 12 2008 [NP-2008-11-058-GSFC] p.51* **3)** Generate report(s) to include presentation-level summaries	**1)** Analyzed data. Analyses reflect types of data collected **2)** Reports. Reports include data summaries, visualizations, recommendations and presentation-level summaries	**Start = CSR/ Directed Study** Schedule and budget with margins (S&B) from CSR/Directed Study define starting point. The starting point is the "estimate" or Study S&B	O1) At SRR, instrument meets Study S&B To meet S&B, an instrument must deliver on or before the agreed to delivery date, *and* at or below agreed to cost at the end of commissioning **Q1)** At SRR are we meeting the Study S&B? If not, what are the variances? Why?	**Commitment = PDR S&B** O1) At PDR, instrument meets SRR S&B O2) At PDR, instrument meets Study S&B Q1) At PDR are we meeting SRR S&B? If not, what are the variances? Why? Q2) At PDR are we meeting the Study S&B? If not, what are the variances? Why?	O1) At CDR, instrument meets PDR S&B O2) At CDR, instrument meets Study S&B Q1) At CDR are we meeting PDR S&B? If not, what are the variances? Why? Q2) At CDR are we meeting Study S&B? If not, what are the variances? Why?	O1) At Delivery, instrument meets CDR S&B O2) At Delivery, instrument meets PDR S&B O3) At Delivery, instrument meets Study S&B Q1) At Delivery are we meeting CDR S&B? If not, what are the variances? Why? Q2) At Delivery are we meeting PDR S&B? If not, what are the variances? Why? Q3) At Delivery are we meeting the Study S&B? If not, what are the variances? Why?	O1) At Commissioning, instrument meets Delivery S&B O2) At Commissioning, instrument meets PDR S&B O3) At Commissioning, instrument meets Study S&B Q1) At Commissioning are we meeting Delivery S&B? If not, what are the variances? Why? Q2) At Commissioning are we meeting PDR S&B? If not, what are the variances? Why? Q3) At Commissioning are we meeting the Study SBE? If not, what are the variances? Why?	O1) Individual instruments implement NICS Finding 1 recs, Finding 2 rec 3, Finding 5 rec 1 O2) Individual instruments meet PDR S&B O3) Individual instruments meet Study S&B Q1) Have individual instruments implemented NICS Finding 1 recs, Finding 2 rec 3, and Finding 5 rec 1? If not, why? Q2) Have individual instruments met Study S&B? If not, why? Q3) Have individual instruments met PDR S&B? If not, why?	O1) IPD managed instruments implement NICS Finding 1 recs, Finding 2 rec 3, Finding 5 rec 1 O2) At least 80% (TBR) of IPD managed instruments meet Study S&B. O3) At least 80% (TBR) of IPD managed instruments meet PDR S&B O4) Center-level investment is sufficient for at least 80% (TBR) of IPD managed instruments to meet Study S&B O5) Center-level investment is sufficient for at least 80% (TBR) of IPD managed instruments to meet PDR S&B Q1) Have IPD managed instruments implemented NICS Finding 1 recs, Finding 2 rec 3, Finding 5 rec 1? If not, what action(s) does IPD need to take to implement findings? Q2) Have at least 80% (TBR) of IPD managed instruments met Study S&B? If not, what action(s) does IPD need to take to improve instrument performance? Q3) Have at least 80% (TBR) of IPD managed instruments met PDR S&B? If not, what action(s) does IPD need to take to improve instrument performance? Q3) Are Center-level resources sufficient for at least 80% (TBR) of IPD managed instruments to meet Study S&B? If not, how much more Center investment is needed? Q3) Are Center-level resources sufficient for at least 80% (TBR) of IPD managed instruments to meet PDR S&B? If not, how much more Center investment is needed?

NICS Charter, Objectives, Recommendations, Future Steps

NICS Charter (July 2007) – to determine whether

- "NASA instrument developers are facing challenges that impact the capability to design and build quality instruments… *or …*
- flaws in the acquisition strategy [are] evidenced by schedule delays, cost overruns, and increased technical risk via design deficiencies" *[and]*
- "[Recent] occurrences are coincident, but isolated cases or if generic issues [are] causing this degradation." (NICS Report (2008) p.vi)

NICS team included GSFC (lead), NOAA and DOD (participants)

NICS Objectives (*NICS Report, 2008, p. vi)* – to

- Understand problem areas in instrument development processes
- Determine problem areas impacting primary success indicators (cost, schedule, technical performance) and instrument development processes
- Identify potential issues for higher risk or more complex instrument developments
- Identify common overarching themes spanning instrument development processes
- Recommend solutions

NICS Approach (*NICS Report, 2008, p. vii)*

Implement a top-level assessment of instrument development processes and success indicators for

- Instruments roughly $10m to more than $100m
- Time frame 3 to more than 6 years

Used two surveys, cross-referenced with research

- Instrument Survey n = 71 Instrument Managers, 41 instruments
- General Workforce Survey n = 164 invited civil servants & contractors, and volunteer participants from industry & academia
- Independent research: NASA/ Federal/ RAND publications, lessons learned, SpaceNews (NICS Report, 2008, p.60)

NICS Finding 1 and Recommended Actions

Finding 1: Instrument developments lack resources and authority to successfully manage to cost and schedule requirements (*NICS Report, 2008, p.51)*

Finding 1 Recommended Actions	Rationale
1. Implement changes to policy to define and elevate instrument management requirements and authorities in a manner similar to project-level management. **2. Assign NASA instrument managers full authority and responsibility to manage their cost and schedule reserves and hold them accountable.** **3. Require 30% to 50% cost reserves for instrument developments (>$10M) to account for the fact that most instrument developments are highly complex, single builds.** **4. Require 1-1/2 to 2 months per year of schedule reserve for instrument developments (>$10M).** **5. Require dedicated level of support staff (configuration management, schedule management, risk management and budget management) for instrument developments (>$10M).**	Instrument developments are uniquely complex, often one-of-a-kind, and, as such, require a higher level of visibility, authority, and support than normal spacecraft subsystems. Transition of authority to the lower levels is necessary to permit informed management and mitigation of risks before they turn into more expensive problems. The typical rule of thumb of 25% cost reserve and 1 month per year schedule reserve does not appear to be sufficient for instrument developments. This is corroborated by the data which indicated that ~70% of the instruments reported 25% or more cost overruns and ~60% of the instruments reported schedule delays of 5 months or more.

NICS Finding 2 and Recommended Actions

Finding 2: Instrument developments lack critical skills, expertise or leadership to successfully implement these unique (one-of-a-kind) high technology developments (*NICS Report, 2008, p.52)*

Finding 2 Recommended Actions	Rationale
1. Expedite the planned enhancement of the NASA Engineering Network People, Organization, Project, Skills (POPS) expertise locator to enable instruments to address critical skills shortages by drawing upon personnel from other NASA centers.	Expediting the POPS expertise locator enhancement will allow instrument projects to locate critical skills in the near-term mitigating staffing issues, which is one of the top five problems reported in this Study. POPS allows instruments to draw from a wider pool of potential expertise.
2. Add capability to the POPS locator to include data sources external to the NASA workforce.	
3. Require the addition of a deputy instrument manager position (similar to a deputy project manager), for instrument developments with a budget >$10M.	Given the complexity and scope of instrument developments, the addition of a deputy instrument manager position is warranted. This position creates a mechanism for transfer of corporate knowledge, training and mentoring, and provides critical support to the instrument manager. Finally, it ensures continuity, should leadership transitions occur.

NICS Finding 3 and Recommended Actions

Finding 3: There are significant process problems in the area of requirements formulation, reviews, and management (*NICS Report, 2008, pp.52-53)*

Finding 3 Recommended Actions	Rationale
1. Require NASA instrument team leadership to take requirements formulation/management training, e.g., "Requirements Development and Management (APPEL-REQ)", prior to requirements development. **2. Require instrument teams to conduct Peer Reviews of requirements (for each instrument subsystem), in preparation for instrument SRRs.** **3. Require draft mission Level 1 and 2 technical requirements to be controlled and provided to instrument managers prior to the instrument SRR. Also, notify instrument managers of any changes to the draft requirements so that impact assessments can be performed.**	In order to fix the requirements problems reported in the Study, a wide range of recommendations should be implemented. These recommendations include a greater emphasis on training to provide instrument teams a better understanding of how to formulate and manage requirements. The recommendations also provide an improved requirements review process to account for the fact that instrument SRRs occur much earlier than mission SRRs which often leads to requirements changes, as well as traceability issues. Finally, a recommendation is added to provide instruments with top level requirements early in formulation to allow for a more thorough requirements development and management process.

NICS Finding 4 and Recommended Actions

Finding 4: Unrealistic caps, overly optimistic estimating, externally directed changes correspond to a significant increase in the likelihood of overrunning cost, schedule *(NICS Report,2008, pp.53-54)*

Finding 4 Recommended Actions	Rationale
1. Develop an Agency-level historical cost and schedule database of instruments to provide information that would allow for higher fidelity cost caps. **2. Review cost credibility evaluation and scoring criteria for accuracy and flow-down to the proposal selection process (for use by Technical Management and Cost (TMC) or project Source Evaluation Board (SEB)).** **3. Establish a Peer Review prior to PDR for instruments >$10M to assess budget and schedule baseline credibility and increase the emphasis on cost and schedule assessment at PDR.** **4. Ensure that instrument managers are made aware of externally driven changes in a timely manner and afforded the opportunity to discuss any impacts prior to implementation of changes.**	The costing database will be useful in: establishing higher fidelity cost caps; evaluating government and contractor instrument proposals; and assessing progress during implementation. Furthermore, a data exchange between NASA, NOAA, and DoD on instrument development cost data would allow for a more thorough data set. Improved cost credibility criteria support a more robust and thorough source selection. Adding a budget and schedule baseline credibility Peer Review prior to PDR will increase confidence going in to the Confirmation Review. Early communication of externally driven changes (e.g., budget or schedule changes) down to the instrument level minimizes the impact to the instrument development.

NICS Finding 5 and Recommended Actions

Finding 5: NASA needs a method to continue answering basic questions pertaining to instrument development process to identify any emerging or persistent issues *(NICS Report,2008, p.54)*

Finding 5 Recommended Actions	Rationale
1. Require all instrument managers to take the survey upon delivery of their instrument. **2. Maintain survey results in a historical database.**	The aggregated data could provide the Agency information regarding trends, persistent issues, and emerging issues.

IPD Schedule and Cost Study *References*

Department of Defense Office of the Under Secretary of Defense For Acquisition, Technology, and Logistics. (2003). *The report of the defense science board/ air force scientific advisory board joint task force on acquisition of national security space programs.* (The Young Report). Washington DC

Government Accounting Office. (1992). *NASA program costs: Space missions require substantially more funding than initially estimated. GAO/NSIAD-93-97.* Washington DC

National Aeronautics and Space Administration, National Oceanic and Atmospheric Agency, Department of Defense. (2008). *The NASA instrument capability study final report* (NP-2008-11-058-GSFC). Washington DC