History and Logic Model
NASA Goddard Space Flight Center Instrument and Payload Systems Engineering Technical Performance Study

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Instrument Technical Performance Study *Context*

Historically, some NASA missions have exceeded schedule and cost commitments. Previous studies indicate technical performance is a contributor.

The 1980 NASA Project Management Study concludes, "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).

The 1991 NASA Roles and Missions Report identified a "need for increased technological readiness and requirements on the front end of a program" (cited in GAO/NSIAD-93-97, p. 11).

The 1992 NASA Program Costs Report stated that NASA officials identified, among other things, "insufficient definition studies…" as reasons why initial estimates changed over time (GAO/NSIAD-93-97, p.11).

The 2002 Task Force on Acquisition of National Security Space Programs reviewed national security space programs and found "requirements definition and control issues, 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" (Task Force Report, 2003, p. i).

Instrument Technical Performance Study *Context (cont)*

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 2008 NICS Report, led by GSFC, identified challenges to instrument technical performance consistent with findings from previous reports.

In 2018, The Instrument Technical Performance Study was initiated by the Instrument and Payload Systems Engineering Branch (IPSE) to determine the current state of Technical Performance in GSFC Payload & Instrument Systems Engineering.

Instrument Technical Performance Study *Problem Statement*

Historically, some NASA GSFC missions have exceeded schedule and cost commitments. Studies indicate technical performance is a contributor.

Technical Research Questions – programmatic questions are addressed in a separate study

RQ1) Is there a set of proxies that identify behaviors consistent with [payload/instrument] technical success? **RQ1a)** What proxies identify technically successful instruments?

RQ2) Does at least 80% (TBR) of IPSE in-house payload/instrument portfolio meet technical success? *Technical success is measured as a ratio of data products meeting key Level 2 (TBR) requirements defined at Mission Preliminary Design Review (MPDR) to mission life (see next slide).* **RQ2a)** What is the relationship between IPSE support/approach, and NICS Systems Engineering (SE) threads & technical success? *(NICS Report SE threads are presented on slide 11)*

RQ3) Is the Center-level investment sufficient for at least 80% (TBR) of the IPSE managed in-house payloads/instruments to meet technical success as defined in the Logic Model? *Center-level investment is defined as existence of IPSE staff and contractors.*

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

Instrument Technical Performance Study *Objectives*

Desired results – Using the proxies from RQ1) and RQ1a)

- *Determine* the extent to which IPSE has addressed the lack of critical SE skills and/or expertise identified in the NICS report in the areas of instrument development, implementation of unique one-of-a-kind high technology development, and requirements formulation.
- *Determine* if at least 80% (TBR) of the IPSE in-house payload/instrument portfolio meets mission preliminary design review (MPDR) key Level2 (TBR) requirements during operations.
- *Determine* if Center-level investment is sufficient for at least 80% (TBR) of IPSE managed in-house payloads/instruments to meet technical success as defined here:

$$Technical\ Success = ROI = \left\{ \frac{f(data\ products\ that\ meet\ key\ Level\ 2\ (TBR)\ requirements, x, y)}{f\left(Mission\ life, \frac{S}{N}, x\right) \ldots} \right\}$$

- *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 instrument/ projects meet technical success measured as a ratio of data products meeting key Level 2 (TBR) requirements defined at MPDR to mission life (above).

Technical Performance Study *Logic Model 14 January 2020*

Inputs	Activities	Outputs	Level 1 Outcomes						Level 2 Outcome	Level 1 Outcome
			SRR	MPDR	CDR	Delivery	Commissioning	End of Mission		
Authority to direct personnel to cooperate and respond to Study. Access to requirements WYE (requirements, data collection and analysis, survey management, report generation) FTE (allocate resources to Principal Engineer / Sr. Staff and/or other Systems, staff to complete survey, cooperate with study) Python and modules Adobe Acrobat pro Survey Monkey	1) Capture data at time of SRR, PDR, CDR, Delivery, Commissioning, and end of mission (during science operations) 2) Analyze collected data using NICS report as control/baseline: Instruments reported … "2/3 of the design and performance requirements were all or mostly defined and approved prior to PDR… 3/4 of approved requirements changed after PDR… 1/2 changed after CDR… <1/4 of the requirements reviews were very helpful … > 1/4 of the instruments did not hold a requirements review, 57% did not hold one at the instrument subsystem level…. 83% of the instruments and 43% of the general workforce indicated that there were problems with requirements management. All with requirements management problems had design deficiencies that contributed to cost growth or schedule delays" (pp 52-53) 3) Generate report(s) including 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 = SRR** **O1)** Payload/ Instrument key Level2 (TBR) requirements (including mission life) are defined at SRR The output of the SRR is the starting point and is measured as key Level2 (TBR) requirements at SRR	**Commitment = MPDR** **O1)** At MPDR, payload/ instrument key Level2 (TBR) requirements (including mission life) have not changed from SRR	**O1)** At CDR payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from MPDR **O2)** At CDR, payload/ instrument key Level2 (TBR) requirements (including mission life) have not changed from SRR	**O1)** At Delivery payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from CDR **O2)** At Delivery payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from MPDR **O3)** At Delivery payload/ instrument key Level2 (TBR) requirements (including mission life) have not changed from SRR	**O1)** At Commissioning payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from Delivery **O2)** At Commissioning payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from MPDR **O3)** At Commissioning payload/ instrument key Level2 (TBR) requirements (including mission life) have not changed from SRR	**O1)** At End of Mission, payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from Commissioning **O2)** At End of Mission, payload/ instrument key Level 2 (TBR) requirements (including mission life) have not changed from MPDR **O3)** At End of Mission, payload/ instrument key Level2 (TBR) requirements (including mission life) have not changed from SRR	**O1)** Individual payload/ instrument key Level 2 (TBR) requirements (including mission life) do not change from MPDR	**O1)** At least 80% (TBR) of IPSE payload/instrument portfolio key Level 2 (TBR) requirements (including mission life) do not change from MPDR **O5)** Center-level investment is sufficient for at least 80% (TBR) of the IPSE managed in-house payloads/ instruments to meet technical success as defined here $Success = ROI = \left\{ \frac{f\left(data\ products\ that\ meet\ key\ science\ requirements, x, y\right)}{f\left(Mission\ life, \frac{S}{N}, x\right) \ldots} \right\}$
				Q1) At MPDR have key Level 2 (TBR) requirements (including mission life) changed from SRR? If so, what are the variances? Why?	**Q1)** At CDR have key Level 2 (TBR) requirements (including mission life) changed from MPDR? If so, what are the variances? Why? **Q2)** At CDR have key Level 2 (TBR) requirements (including mission life) changed from SRR? If so, what are the variances? Why?	**Q1)** At Delivery have key Level 2 (TBR) requirements (including mission life) changed from CDR? If so, what are the variances? Why? **Q2)** At Delivery have key Level 2 (TBR) requirements (including mission life) changed from MPDR? If so, what are the variances? Why? **Q3)** At Delivery have key Level 2 (TBR) requirements (including mission life) changed from SRR? If so, what are the variances? Why?	**Q1)** At Commissioning have key Level 2 (TBR) requirements (including mission life) changed from Delivery? If so, what are the variances? Why? **Q2)** At Commissioning have key Level 2 (TBR) requirements (including mission life) changed from MPDR? If so, what are the variances? Why? **Q3)** At Commissioning have key Level 2 (TBR) requirements (including mission life)changed from SRR? If so, what are the variances? Why?	**Q1)** At End of Mission have payload/ instrument key Level 2 (TBR) requirements (including mission life) changed from Commissioning? If so, what are the variances? Why? **Q2)** At End of Mission have key Level 2 (TBR) requirements (including mission life) changed from MPDR? If so, what are the variances? Why? **Q3)** At End of Mission have key Level 2 (TBR) requirements (including mission life)changed from SRR? If so, what are the variances? Why?	**Q1)** Have individual payload/ instrument key Level 2 (TBR) requirements (including mission life) changed from MPDR? If so, what are the variances? Why?	**Q1)** Have at least 80% (TBR) of IPSE payload/instrument portfolio key Level 2 (TBR) requirements (including mission life) changed from MPDR? If so, what action(s) should be taken to improve instrument performance? **Q2)** Are Center-level resources sufficient for at least 80% (TBR) of IPSE managed in-house payloads/ instrument to meet technical success as defined in this logic model? 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)*

- 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)*

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

- Instruments roughly $10m to greater 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 Table 3.3.6-1 Summary of SE Threads *(NICS Report, 2008, p.49)*

Theme		Thread	Rationale
Systems Engineering (SE)	**SE-1**	**Requirements management problems**	Requirements management problems Requirements or specifications not clearly communicated Work proceeding at risk ahead of change/waiver approval Implementation of changes not timely
	SE-2	**Requirements formulation issues**	Insufficient requirements traceability Goals or desires stated as requirements Requirements too complex Requirements unverifiable
	SE-3	**Issues with requirements changes**	Design, requirements or interface changes occurring after PDR Design, requirements or interface changes occurring after CDR
	SE-4	**Risk management resource issues**	Lack of resources to manage risks Risks not identified regularly Mitigation plans not developed for all known risks
	SE-5	**Review effectiveness**	Requirements reviews not considered helpful Objectives not met in requirements reviews

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.

Instrument Technical Performance Study *References*

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