



PCAT FINAL REPORT

Main Report Section



PCAT Summary

The PCAT conducted the bulk of its efforts over the period from Feb. 2019 to September 2019; the schedule shifted following the 2019 U.S. Government shutdown. The shift was also accompanied by a more extended evaluation period as accommodations were made to account for prior commitments by PCAT members, especially over the summer months.

Overall, the PCAT was impressed with the quality of the submissions from the Probe teams, especially given the very limited funding that had been made available to conduct the studies. The PCAT would like to thank the Probe concept teams for the open conversations that were had as a part of this process.

The results of the PCAT effort indicate that a number of the concepts are potentially viable within a \$1B cost cap. It should be recognized that the stated cost cap assumes that all technology development has been completed (i.e., all major elements are at TRL 5 or higher at the start of Phase A). We assume that the concepts are allowed to follow optimized schedules.

We also note that some concepts do not appear to be executable within the \$1B cost cap, and that PCAT felt that these concepts required additional maturation before a cost re-evaluation should be done.



The 10 Probe Studies

Name	Principal Investigator	PI Affiliation
AXIS	R. Mushotzky	UMD
CETUS	W. Danchi	NASA's GSFC
CDIM	A. Cooray	Univ. CA Irvine
GEP	J. Glenn	Univ. of CO
PICO	S. Hanany	Univ. of MN
STROBE-X	P. Ray	NRL
TAP	J. Camp	NASA's GSFC
POEMMA	A. Olinto	Univ. of Chicago
Starshade Rendezvous	S. Seager	MIT
EarthFinder*	P. Plavchan	GMU

* Proof of concept only, not evaluated by the PCAT.



Introduction and Background

- To prepare the community for the 2020 Astrophysics Decadal Survey, in 2015 NASA initiated 10 mission concept studies for missions in the cost range \$400M - \$1B, a.k.a. Probes
- The studies, selected competitively and PI-led, typically lasted 18 months and received modest funding, including a single run at a Center design lab.
- The Probes Teams submitted their final reports to NASA HQ on March 4, 2019. These are archived at <https://science.nasa.gov/astrophysics/2020-decadal-survey-planning>

Independent Probe Cost Assessment Team (PCAT)



- To assess concept feasibility and cost fidelity, NASA assembled a group of subject matter experts from the community, the Probes Cost Assessment Team (PCAT).
- The PCAT was tasked with two principal objectives:
 - Assess the likelihood that a mission concept could be achieved within the \$1B mark set by SMD/APD.
 - Assess whether the JPL-led and GSFC-led costing approaches were reasonably in agreement.
- The PCAT was tasked with conducting a “sniff test” of 9 of the 10 Probes reports (all except the Proof of Concept).
- The details of the review team Terms of Reference (ToR) follow



ToR: Key Statements

(see <https://science.nasa.gov/astrophysics/2020-decadal-survey-planning>)

The PCAT will:

- Provide a high-level assessment of whether the proposed Probe can achieve the stated science goals and objectives with the proposed architecture
- Comment on the technology maturity of any enabling technologies
- Develop a process for cost validation of the costing offices assessments. This will be a qualitative estimate of the likelihood that the Probe concept is feasible within \$1 billion based on the Probe Final Reports and Engineering Data Packages.



ToR: Deliverables

A written report consisting of:

- Overall Summary
- Brief description of PCAT Methodology and Process
- High-level assessment of whether the proposed mission addresses the science goals and objectives
- Strengths and Weaknesses in the context of costing models.
- Qualitative assessment of the confidence that the Probe Mission Cost is under the \$1B maximum cost target (Likely, Possible, Unlikely)
- Comments to NASA



PCAT Methodology and Process: I

- The PCAT had several interactions with APD to establish “ground rules” for the costing. In particular, the decision was made to cost concepts assuming that their key technologies were at TRL5.
- To achieve the objectives set out in the TOR, the PCAT team members first read in detail each of the teams’ submitted NASA reports. The reports were then discussed in weekly team calls.
- After thorough review and discussions by the PCAT, a series of general and specific clarifying questions were developed and sent to each team.
- In conjunction with the Astro 2020 Landscape meeting, members of the PCAT observed each Probe team presentation. At the conclusion of the Astro 2020 meeting a face to face (4/4,5/2019) was held with each Probe Team at the Goddard Space Flight Center.
 - The Teams answered verbally and in writing the clarifying questions previously submitted by the PCAT. Questions were both generic for all teams, as well as concept-specific.
- At this point the PCAT believed it had a good understanding of the proposals to enable the high level assessment of whether the mission could achieve the stated science goals and objectives with the proposed architecture along with an understanding of the maturity of the enabling technology.



PCAT Methodology and Process: II

- The PCAT received a briefing from both Centers' independent costing offices prior to their evaluating the mission concepts. The CDIPR, Center-Designated Independent Programmatic Reviewer at JPL (2019/02/12), and the RAO, Resource Analysis Office (2019/02/14) at GSFC, provided separate briefings to the PCAT.
 - The intent of the briefings was to provide the PCAT insight into the tools and methodologies these offices used to assess missions cost and cost risk. The propriety information on methodology and databases was not shared with the PCAT. This limited the ability of the PCAT to execute its charge validating the costing office approaches, which required the PCAT to utilize independent parametric cost models.
- The center independent costing offices then spent several weeks developing the cost estimates for each of their assigned Probe missions.
 - The PCAT reviewed these reports in detail as individuals and during our weekly team discussions
 - We then had a presentation from each of the costing offices to verify our understanding and to discuss several discrepancies.
 - Updates to the reports were then provided to the PCAT.



PCAT Methodology and Process: III

- To address the differences and to provide a cross check function between the JPL and GSFC costing approaches, the PCAT employed the costing expertise within the team to utilize two independent methods (neither used by JPL or GSFC costing offices):
 - SEER-Space (a Galorath Corporation product)
 - A complexity-based model (an Aerospace Corporation derived tool; see reference in appendix).
- Using all of the above information the PCAT was able to assess the probability that each of the missions could achieve its objectives within the \$1 Billion cost cap **with certain caveats.**
- The PCAT offered to brief each of the concept teams on our findings.



RAO Processes

- Process summary
 - RAO presented an overview of the approach to the PCAT on 2/14/2019
 - RAO presented the results of the assessment of the 5 probes to the PCAT on 5/15/19
 - RAO-unique data forms, filled out by the probe teams, were input to the ICE and are in the 5/10/19 presentation
 - RAO used NASA HQ ground rules from 6/27/2017 presentation in the ICE
 - RAO used GSFC proprietary parametric models built on a database with actual cost data
 - RAO modeled 3 scenarios for each probe, providing 3 S-curves, each showing cost estimates at the 50%, 70%, and 80% confidence levels. These scenarios were:
 - Phase A Ready - all technology used in the probe mission is at TRL-5 or higher at the start of Phase A
 - New Engineering - existing technology is used in a different way by the probe mission
 - New Technology – technology required by the probe does not exist and requires substantial maturation



GSFC ICE Normalization

- GSFC ICE produced three separate estimates for each mission. The PCAT was left to select between the three for each mission.
 - 1. Phase A Ready
 - 2. New Engineering
 - 3. New Technology
- After reviewing each concept, the PCAT determined that none of the missions were in Category 1.
- Given the ground-rules (we were to assume that the new technology development for the missions would be fully funded) we selected Category 2 New Engineering as the most appropriate price point for comparison.



JPL CE&P Process (1 of 2)

- Process summary
 - JPL Cost & Pricing Section (CE&P) presented an overview of the approach to the PCAT on 2/12/2019
 - CE&P presented the results of the assessment of the 4 probes to the PCAT on 6/26/19
 - CE&P process takes NASA HQ SOW Deliverables as the guideline and two inputs: Study Team Proposal and Team-X Study Report.
 - Tools include Cost Models and Analogy data to develop a Cost and Schedule Estimate
 - Preliminary assessment results are “clarified” with Proposal Team / Team-X
 - Final Assessment includes: methodology, summary result, schedule analogy, and key findings.
 - CE&P utilized a suite of parametric cost estimating tools accepted through the NASA costing community (PRICE H/S, SEER H/S, SSCM, NAFCOM, SOCM)
 - Subject matter experts run the models
 - Uses repository of JPL data to ensure the pedigree and consistent usage of laboratory historical data including 50 flight project missions and 20 instrument projects with data from CADRe (cost, schedule and technical data)



JPL CE&P Process (2 of 2)

- Process summary (cont.)
 - CE&P delivered ICEs for 4 probe studies:
 - Cost, schedule and mass fact sheet and Methodology matrix (showing tool used by WBS item); where analogies were used the project names are provided.
 - Tabular ICE comparison table showing Concept Team, Team-X and CE&P model estimates by WBS
 - Regression curve (WBS 6&10) showing Cost vs. Spacecraft Dry Mass with analogy projects
 - Statistical Assessment “S-curve” project value, 50 and 70th percentile confidence numbers
 - Independent schedule estimate showing Concept compared with average of analogy schedules by phase
 - Reserves were calculated as the difference between the 70th and 50th percentile

RAO / CE&P Comparison ICEs



Topic	GSFC RAO	JPL CE&P
Independent of probe team and Center organizations helping with probe costs	Yes	Yes
Parametric models	Home-grown model (models?), characteristics not identified	Used known aerospace models SEER, Price/True Planning, etc.
Models use actual Center completed missions cost data	Cadre database used. Specific missions used not identified	Only JPL missions used. Missions “included” for analogies listed, others not identified
Number of ICEs/approaches for each probe	3 “S-curves” (Phase A Ready, New Engineering. New Technology)	2 (Price/True Planning), SEER. Also used SOCM and analogies for some WBS element shown in the 2 ICEs.
Input data for ICE	Probe team filled out RAO-unique spreadsheets which were included in report.	Used MELs developed by Team-X plus the team reports
Interacted with probe teams	Yes, but it is unknown what was discussed and at what level	Unclear, may have only worked with Team-X
New Technology approach	PCAT must decide which model to use	Assumed all technology was ready (TRL 6) at Phase A start, did not show technology “knobs” settings in models
Cost reserves	Used NASA HQ provided reserve 25% from 2017 instructions.	“Reserves based on 70 th percentile Confidence level from statistical assessments” JPL 6/26/19



Normalization of RAO / CE&P ICE

- JPL's Center-Designated Independent Programmatic Reviewer (CDIPR) utilized two primary models and the concept's MEL to produce mission cost estimates:
 - PRICE/TruePlanning
 - SEER
- GSFC Resource Allocation Office (RAO) utilizes an internally developed top down approach, with few input details, that relies on a database of historical cost, technical and programmatic data collected and normalized internally along with top-down statistical models.
- Given these substantially different approaches, no formal normalization was possible between the RAO and CE&P approaches.
- The PCAT noted a systematic offset in cost predictions between the CE&P and RAO approaches of approximately 17%, with the RAO costing being consistently higher compared to the PCAT's SEER-Space estimate.

Caveats about Cost Realism for the Study



Model-based

- Lack of Class B missions, especially for astrophysics in CADRE.
- Parametric models have a wide range of uncertainty
 - Relevance of underlying data (mission class, age of data, ...)
 - Again, technical baseline will change.
- CADRE and other underlying databases have errors and are incomplete
- Current models do not adequately address mass production of subsystems and production quality control

Costing Office Approaches

- JPL/RAO approaches and outputs are not identical

Team Approach

- Mission concepts are early in life cycle (pre-Phase A) –
 - Technical baselines are certain to change
 - Some concepts have seen significantly more development than others

Instructions to Team

- Costing instructions did not require use of standard WBS
- The direction to assume all efforts at TRL 5 at the start of Phase A was unrealistic, especially given potential funding uncertainties.
- The stipulated launch services cost is likely to change



Concept Likelihood Summary*

Concept Title	PCAT Assessment
AXIS	Possible
CDIM	Likely
CETUS	Unlikely
GEP	Possible
PICO	Possible
POEMMA	Unlikely
StarShade	Possible
Strobe-X	Unlikely
TAP	Possible

* Qualitative assessment of the confidence that the Probe Mission Cost is under the \$1B maximum cost target



APPENDIX I

PCAT MEMBERSHIP



PCAT Committee Membership

- N. Batalha
 - S. Baum
 - D. Bearden
 - J. Bookbinder, Co-Chair
 - J. Crocker, Co-Chair
 - J. Fulford
 - K. Halterman
 - J. Hamaker
 - R. Polidan
 - R. Rothschild
-
- HQ Liason: Rita Sambruna
 - GSFC Liason: Gabe Karpati
 - JPL Liason: Keith Warfield