

You Get What You Pay For: The New Frontiers 5 Operations Cost Cap

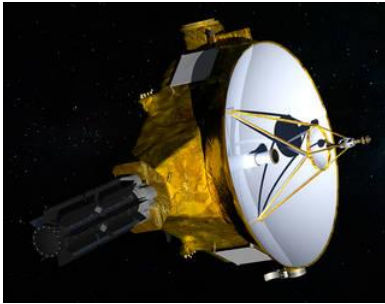
NASA Cost & Schedule Symposium 2023

Kathy Kha
Kathy.kha@jhuapl.edu

Ben Clare
Benjamin.Clare@jhuapl.edu

A Brief History

- New Frontiers missions tackle specific solar system exploration goals identified by the planetary science community
 - Builds upon the innovative approaches used in the Discovery Program but cannot be accomplished within the cost and time constraints of Discovery
- New Frontiers 1-4 were not subject to an operations cost cap.
 - No Discovery missions have been yet either.



New Horizons



OSIRIS-REx



Dragonfly



Juno

New Frontiers 5 - Mission Themes

- Comet Surface Sample Return
- Io Observer
- Lunar Geophysical Network
- Lunar South Pole-Aitken Basin Sample Return
- Ocean Worlds (only Enceladus)
- Saturn Probe

Introduction

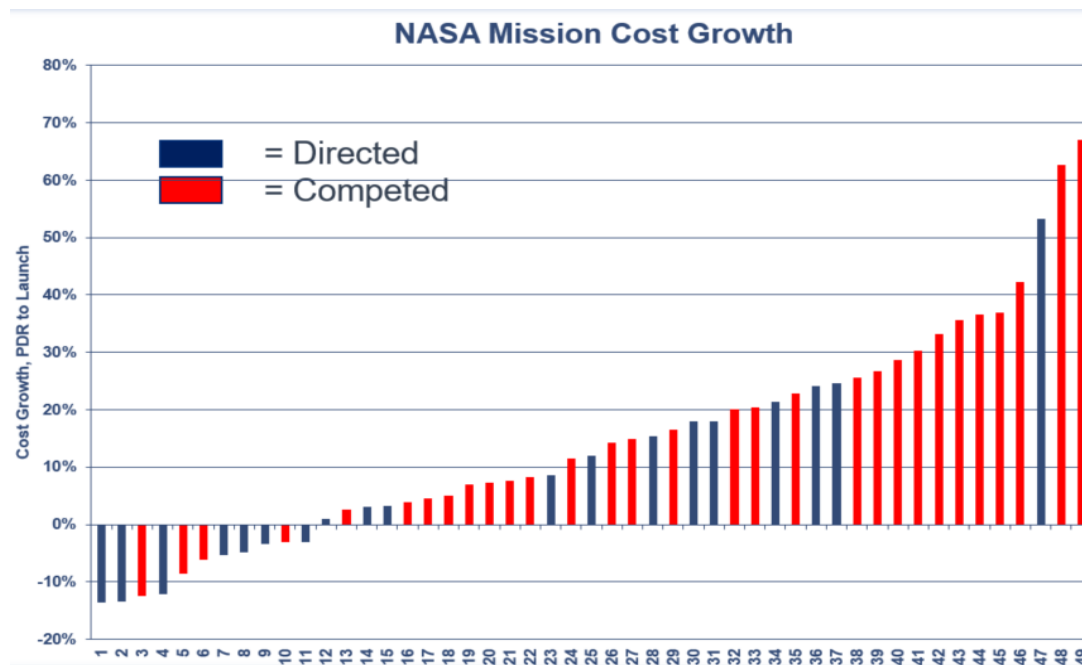
- The purpose of this study is not to criticize the implementation of a Phase E cost cap, nor is it to campaign for the removal of the cost cap. Rather, we believe more consideration should be taken in the implementation
- The primary goals of this study were:
 - To assess the feasibility of various New Frontiers 5 mission themes against the proposed cost cap
 - Start the discussion on a path forward in applying the same level of rigor to operations cost estimates as are given to development cost estimates
 - To share our observations with the community to facilitate thought and conversations on the topic
- We welcome any dialogue and discussions

Motivation

- In a Sept 2022 presentation to the National Academies, Dr. Curt Niebur indicated that the newly implemented cost cap on Phase E “reflects concern over growing total mission cost due to cost cap increases and exclusion of Phase E from recent caps”
 - The intent of the Phase E cost cap is to “force earlier attention to be given to ops planning and complexity to address trend in Phase E cost growth”
- Additionally, what the Phase E cost cap does not take into account is that, regardless of complexity, it will take longer (and therefore more costs) to get to some targets than others.
 - The Phase E cost cap puts outer planet missions at a disadvantage

Motivation

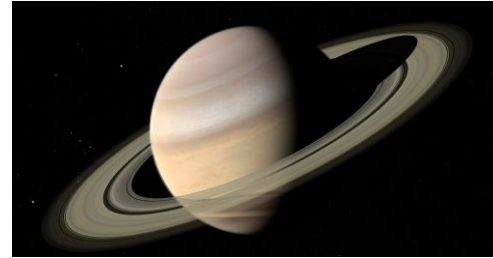
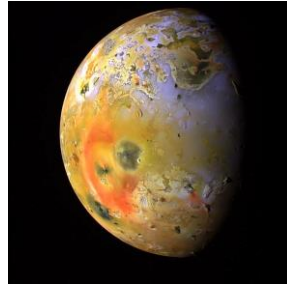
- Rachel Sholder’s paper on Tuesday (“Competed vs Directed Missions, Tigers, and Bears, oh my”) showed a correlation between competed missions and higher levels of cost growth (versus directed missions)
 - Competed missions are generally subject to cost caps



NF-5 Outer Planet Targets

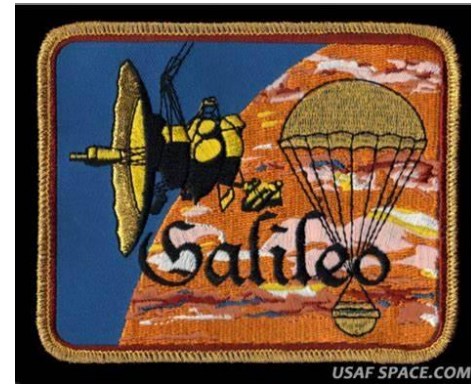
- 3 of the 6 NF-5 Mission Themes involve outer planet targets

- Io
- Enceladus
- Saturn



- Previous NASA missions to the outer planets include:

- Pioneer 10 & 11
- Voyager
- Galileo
- Cassini
- Juno



- Missions in development to the outer planets include:

- Europa Clipper
- Dragonfly

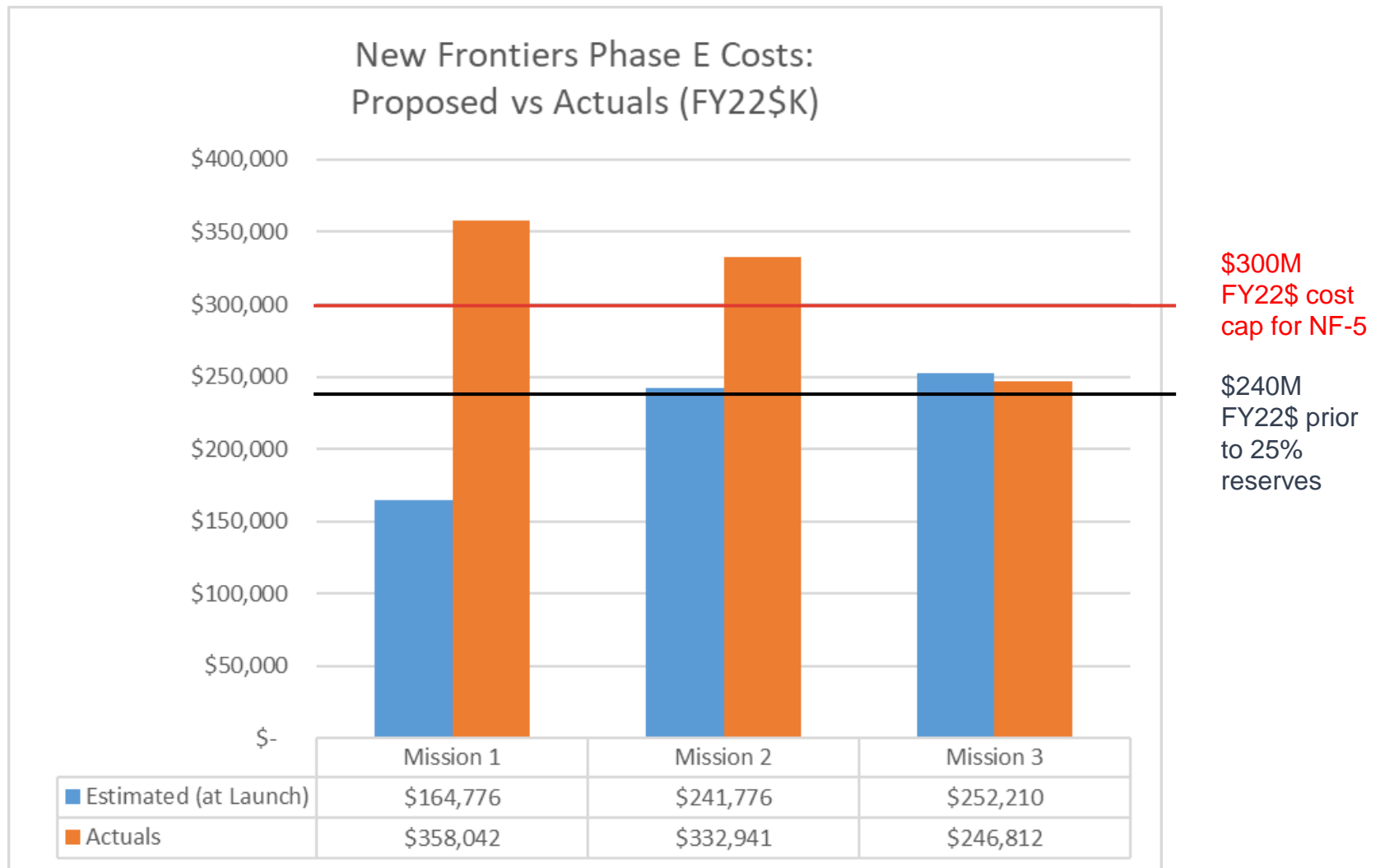
Objectives

- Determine how well prior NF missions fared against the NF-5 operations cost cap
- Explore cost drivers for mission operations
- Determine the characteristics that drive outer planet mission cost
- Gather data to support the development of an outer planets/long duration operations cost model

Assumptions and Methodology

- Costs baselined to FY22\$
 - NF-5 draft AO cost cap is given in FY22\$
- Costs are for operations of prime mission phase only
 - No costs included for extended mission phases
- Cost actuals gathered from The Planetary Society Exploration Budget Dataset
- Cost estimates gathered from CADRe

How Have NF Ph E Costs Fared So Far?



Decadal Survey Recommended Cost

- The Decadal Survey recommended a New Frontiers Phase A-F cost cap (excluding LV) of \$1.227B FY22\$
 - Their findings found that recent Discovery and New Frontiers cruise costs indicates that a quiet cruise phase costs ~\$27M per year
 - They also estimated nominal two-year New Frontiers active mission ops to be ~\$147M
 - Using these assumptions, a 10 year mission would need ~\$363M FY22\$

All costs cited have been deflated from FY25\$ to FY22\$ using the NASA New Start Inflation indices

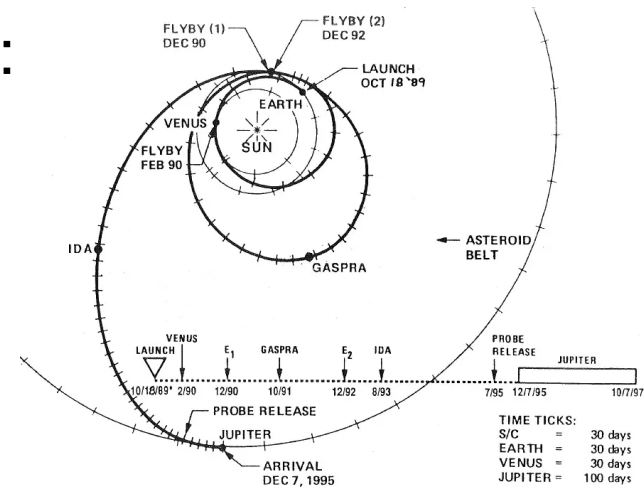
How Much Have Other Outer Planet Missions Cost?

Mission	Program Line	Destination	Primary Mission Ops (FY22\$M)
Mission 4	Flagship	Jupiter	\$ 1,057.4
Mission 5	Flagship	Saturn	\$ 1,191.6
Mission 2	New Frontiers	Jupiter	\$ 332.9
Mission 1	New Frontiers	Pluto	\$ 358.0
Mission 6 (in dev)	Flagship	Jupiter Orbiter/ Europa Flyby	\$ 985.7

- While it's clear that ops costs on a flagship mission will be much higher than New Frontiers, neither outer planets New Frontiers mission has come in within the newly implemented NF-5 cap.
 - While categorized as a small bodies mission, Mission 1 is shown as an example of another long duration Phase E, similar in duration to what an outer planets mission would expect
- Mission duration is a major cost driver
 - Outer Planet missions, on average, have a primary mission duration of ~10 years
 - Longer duration missions require longevity planning costs not inherent in shorter duration (Lunar, Earth science, etc.) missions

Preliminary Data

- Along with duration, the number of events is also a major cost driver. These include:
 - Launch
 - Gravity Assists
 - Flybys
 - Trajectory Correction Maneuvers
 - Etc.
- Preliminary results on costs of events from Discovery and New Frontiers shows that preparation, execution and ramp down for these events can run approximately \$10-20M each



Expectation and Reality

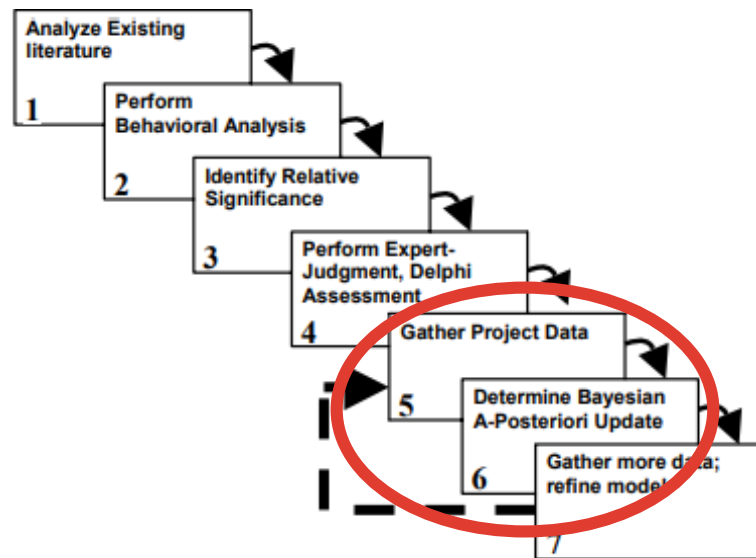
- Potential disconnect between cost expectations and desired science targets/ themes
 - Only 1 of 3 previously selected New Frontiers missions has come in under \$300M FY22\$ in Phase E costs
- Cost savings recommendations
 - Prioritize minimizing the # of events needed to meet baseline science requirements
 - Efficiently design the payload to minimize redundant instrument capabilities
- Are outer planet missions definitively more expensive than other missions?
 - Outer Planet missions have characteristics, such as mission duration and longevity planning, that will incur additional costs that other missions may not
 - However, this does not preclude those missions from also being expensive in Phase E for other reasons

Cost Evaluations on Capped Phase E

- Analysis of the data brings up another concern regarding cost evaluations on proposed NF-5 Phase E costs
 - The cost modeling tools and the historical data on which they are built do not support a \$300M cost cap for outer planet missions
 - There is a disconnect between the available tool set and desired proposed science themes
 - Proposal evaluations need to take this into account
 - There needs to be a plan to bridge the gap between available Phase E evaluation tools and the Phase E cost cap
- We want to explore the creation of a cost model geared towards outer planets and long duration missions that looks at cost drivers not currently present in the available toolset

Path Forward Towards an Outer Planets/ Long Duration Cost Model

- In the case of estimating missions with a long duration Phase E, we do not have a large set of data points on which to develop traditional CERs
 - However, this does not prevent us from working towards developing a parametric cost model



Source: Seven step modeling methodology adopted from Dr. Barry Boehm (USC)

Potential Parameters

- Mission Level/ Programmatic
 - Program Line (New Frontiers, Flagship, etc.)
 - Mission Type (Orbiter, Flyby, Lander, etc.)
 - Mission Duration
 - # of flight systems
 - Risk Class
 - Estimated # of Events
 - # of partner organizations
 - Experience level of managing organization
 - Pre-launch \$ invested in longevity planning
- Payload
 - # of Instruments
 - Type of instruments
 - Instrument sensitivity requirements
- Spacecraft
 - Complexity
 - Level of dependency/ use of mechanisms
- MOS/GDS Description
 - Level of automation
 - GDS upgrade refresh schedule
 - Ease of GDS SW maintenance
 - Level of infrastructure/ facility reuse

Conclusion and Path Forward

- A blanket \$300M cost cap on Phase E, without regard for mission destination/ mission themes, disadvantages Outer Planet mission concepts
 - The Decadal Survey recommendation of ~\$147M for active mission ops and ~\$27M per year for quiescent cruise would be a better compromise for implementation of a Phase E cost cap for NF-5
- A \$300M Phase E cost cap is not impossible, but would most likely require compromise on science and simplifying mission ops planning
- Next step is creating a mission operations cost model for long duration missions
 - Could be used to estimate costs for outer planet mission concepts
 - Incorporates longevity costs

References

- New Frontiers 5 Draft Announcement of Opportunity NNH23ZDA006J
- Origins, Worlds, and Life A Decadal Strategy for Planetary Science and Astrobiology 2023-2032 (2022) National Academies of Sciences, Engineering, and Medicine
- Kha, Kathy. Cost and Considerations for Successful Implementation of Long Duration Space Missions. IEEE Aerospace Conference 2023
- Niebur, Curt. Planning for New Frontiers 5. National Academies of Sciences, Engineering, and Medicine. 2022
- Sholder, Rachel. Competed vs Directed Missions, Tigers, and Bears, oh my. NASA Cost Symposium 2023
- Web: The Planetary Society Exploration Budget Dataset (<https://www.planetary.org/space-policy/planetary-exploration-budget-dataset>)



JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Backup Slides

Decadal Survey Recommended Cost

Recommendation: New Frontiers should have a single cost cap that includes both Phase A-D and the primary mission Phase E-F costs, with a separate, additional cost cap allocation for a mission's quiet cruise phase. This approach will enable the NF Program to optimize mission science, independent of cruise duration.

Vision and Voyages recommended a New Frontiers Phase A-F cost cap (excluding launch vehicle) equivalent to \$1.34 billion in FY25 dollars. This recommendation merits reassessment based on actual and projected NF mission costs. The initial reconnaissance of the solar system has demonstrated its remarkable diversity and complexity, raising questions in planetary and astrobiological science of increasing sophistication that require increasingly advanced instrumentation and/or mission design. The exciting and aspirational Dragonfly mission selected in NF-4—involving a drone that lands on Titan and then performs multiple flights to explore varied regions and perform in situ analyses—is an example case. While the NF-4 competition had a Phase A-D cost cap equivalent to \$1.14 billion in FY25 dollars, the NASA pre-launch budget for Dragonfly through FY26 is about \$1.7 billion (launch is planned for 2027), suggesting that the total life cycle mission cost will likely be significantly higher than the original cost cap. As indicated earlier in this chapter, the committee endorses the Dragonfly mission at this budgetary level. Indeed, its costs are not too dissimilar from those of the scientifically compelling NF mission concepts considered by the committee, which had independently estimated (see next section) Phase A-D costs in the \$1.2 billion to \$2 billion range (FY25 dollars). These missions are representative of the nature and breadth of the science that will optimally be accomplished in the NF program in the coming decade, and a Phase A-D cost of ~ \$1.5 billion is thus representative of the associated hardware costs. A nominal two-year NF primary mission with a cost of \$80 million per year would yield a primary mission Phase E cost of \$160 million. Examination of recent Discovery and NF cruise costs indicates that a representative quiet cruise phase costs approximately \$30 million per year.

Source: *Origins, Worlds, and Life A Decadal Strategy for Planetary Science and Astrobiology 2023-2032*

Decadal Survey Recommended Cost

Vision and Voyages recommended a New Frontiers Phase A-F cost cap (excluding launch vehicle) equivalent to \$1.34 billion in FY25 dollars. This recommendation merits reassessment based on actual and projected NF mission costs. The initial reconnaissance of the solar system has demonstrated its remarkable diversity and complexity, raising questions in planetary and astrobiological science of increasing sophistication that require increasingly advanced instrumentation and/or mission design. The exciting and aspirational Dragonfly mission selected in NF-4—involving a drone that lands on Titan and then performs multiple flights to explore varied regions and perform in situ analyses—is an example case. While the NF-4 competition had a Phase A-D cost cap equivalent to \$1.14 billion in FY25 dollars, the NASA pre-launch budget for Dragonfly through FY26 is about \$1.7 billion (launch is planned for 2027), suggesting that the total life cycle mission cost will likely be significantly higher than the original cost cap. As indicated earlier in this chapter, the committee endorses the Dragonfly mission at this budgetary level. Indeed, its costs are not too dissimilar from those of the scientifically compelling NF mission concepts considered by the committee, which had independently estimated (see next section) Phase A-D costs in the \$1.2 billion to \$2 billion range (FY25 dollars). These missions are representative of the nature and breadth of the science that will optimally be accomplished in the NF program in the coming decade, and a Phase A-D cost of ~ \$1.5 billion is thus representative of the associated hardware costs. A nominal two-year NF primary mission with a cost of \$80 million per year would yield a primary mission Phase E cost of \$160 million. Examination of recent Discovery and NF cruise costs indicates that a representative quiet cruise phase costs approximately \$30 million per year.

Recommendation: The NF Phase A-F cost cap, exclusive of quiet cruise phase and launch vehicle costs, should be increased to \$1.65 billion in FY25 dollars. A quiet cruise allocation of \$30 million per year should be added to this cap, with quiet cruise to include normal cruise instrument checkout and simple flyby measurements, outbound and inbound trajectories for sample return missions, and long transit times between objects for multiple-target missions.