Informational

National Aeronautics and Space Administration

Comparative Analysis of NASA Cost Estimation Methods

April 24, 2024

Cost Estimating, Modeling, and Analysis Office (CEMA)

Chief: Anthony McNair | Deputy Chief: Holly Bryant

Author: Camille Holly (Technomics)

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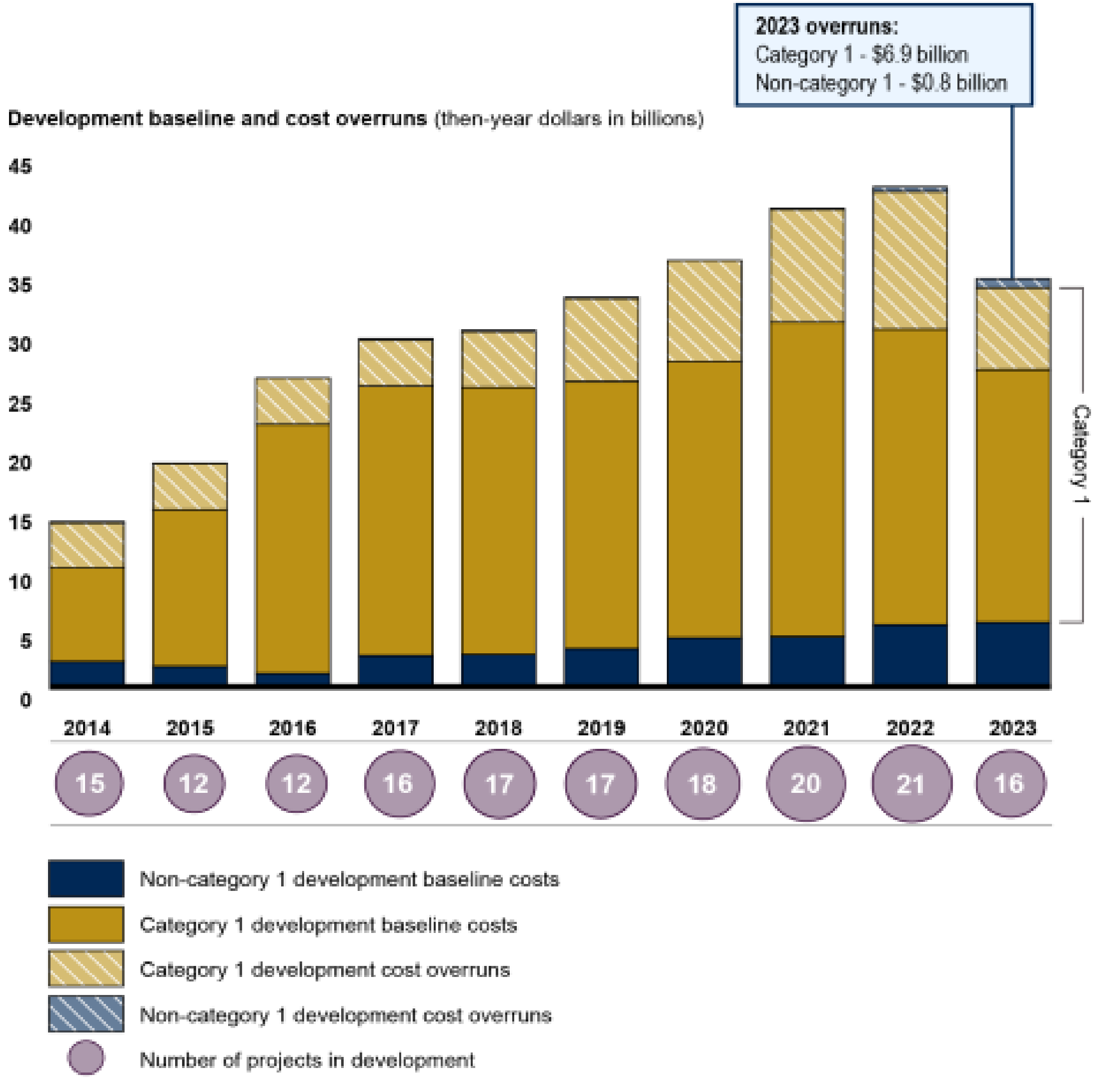
Agenda

- The Challenge of Quality Cost Estimation in Space Missions
- Case Study Methodology
- Challenges Encountered During the Estimation Process
- Conclusion

The Challenge of Quality Cost Estimation in Space Missions

NASA HISTORICAL COST PERFORMANCE



Source: GAO analysis of NASA data. | GAO-23-106021

Notes: The years in the figure denote the year we issued our annual assessment of major NASA projects. Data are primarily as of January 2023.

- A 2023 U.S. Government Accountability Office (GAO) report shows that NASA's portfolio of major projects in development sustained $7.6 billion in cost overruns in 2023.
- A previous GAO report (2019) states that overly optimistic initial estimates are one of the many factors contributing to cost overruns within NASA projects.

THE CHALLENGES IN EARLY COST ESTIMATION

Technical Data + Approaches in Cost Estimating Methodology = Initial Cost Estimates

Technical Data
- New technology
- Lack of design maturity
- Rapidly changing design
- Involving stakeholders

Approaches in Cost Estimating Methodology
- Method choice
- Making assumptions
- Assigning complexity factors
- Lack of analogs

Initial Cost Estimates
- Risk
- Low credibility
- Cost overrun

WHERE DO WE GO FROM HERE?

THE GOAL FOR THIS STUDY

This is a preliminary case study that was conducted to communicate the qualitative challenges of using different parametric estimating methodologies and find possible improvements.

DISCLAIMER

- This case study is not a validation study. It does not compare to actual cost data or aim to determine if one method is "better" than the other.
- While the limitations within this case study touch on lack of both historical data and technical data, we will not discuss their fine points.

Case Study Methodology

PARAMETRIC METHODOLOGY

Analogy

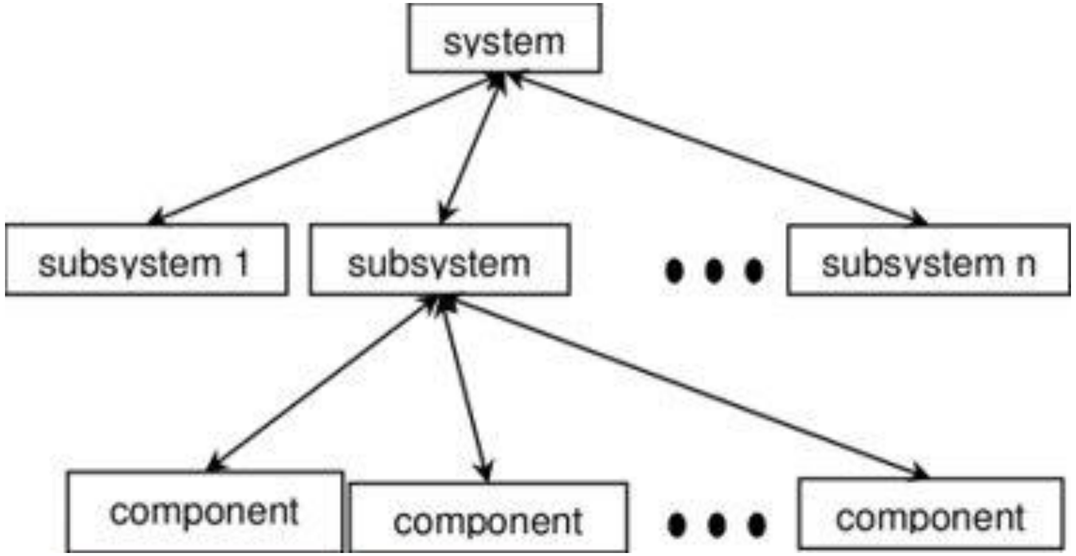
Parametric

Engineering Build-Up

Extrapolation from Actuals

Subsystem-Level

Component-Level



TWO SIDES OF THE PARAMETRIC MODELING COIN

HIGH-LEVEL

SUBSYSTEM-LEVEL

- Time-efficient
- Can be utilized very early in concept development
- May fail to capture granular cost drivers
- More generalization for unique systems
- Beneficial when time is restricted, and less detail is provided

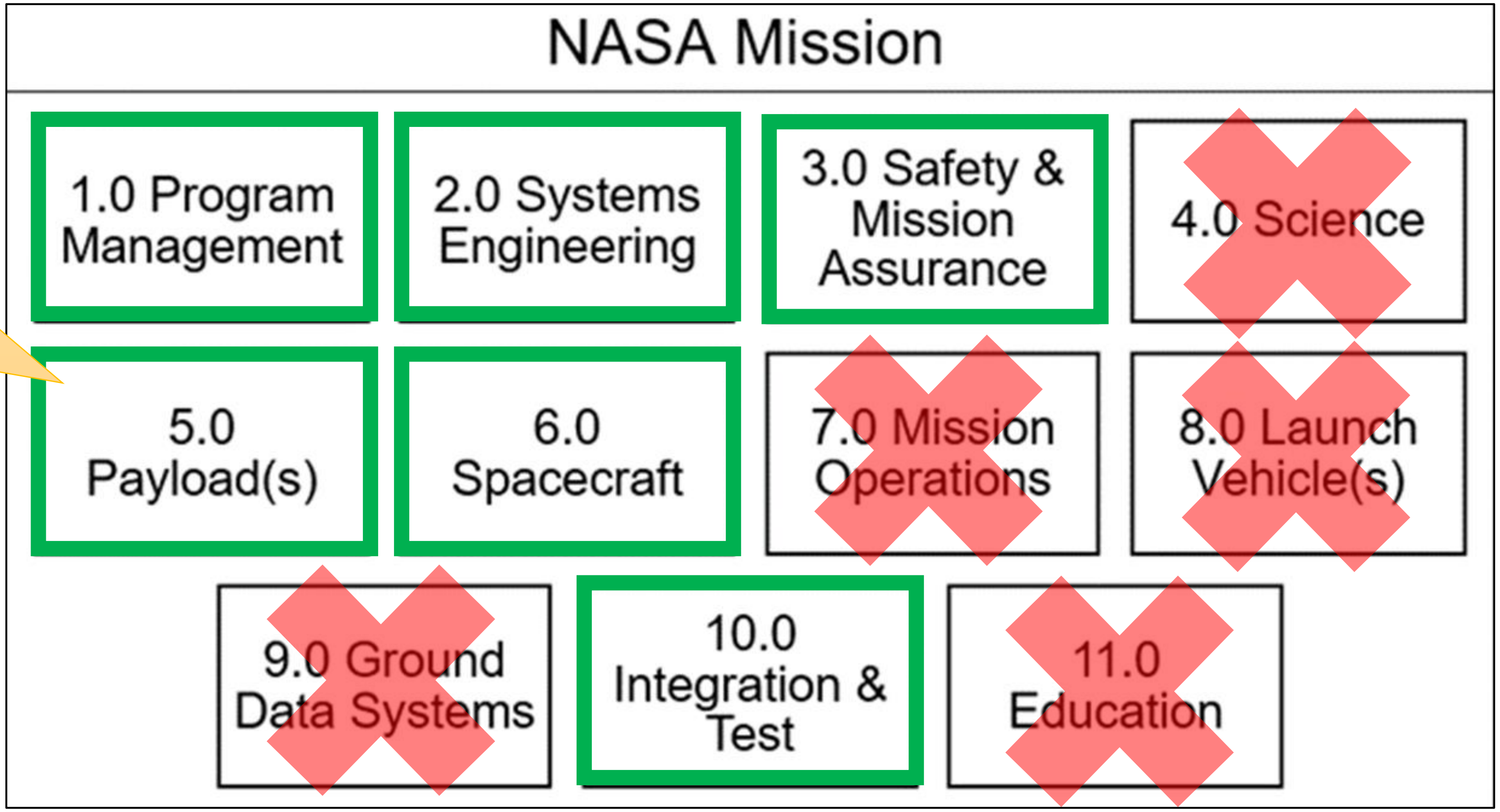
COMPONENT-LEVEL

- Time-intensive
- Utilized when technical baseline is more mature
- More granular technical baseline and assumptions
- Beneficial when time is abundant and component-level details are available

DETAILED

SCOPE OF ANALYSIS

Contains four instruments.



- Costs of a historical interplanetary mission, containing one spacecraft bus and four instruments, were parametrically modeled using tools which define hardware inputs at component level and subsystem level.

PARAMETER INPUTS

- The primary parameter inputs for this study came from Concept Study Report (CSR) and Master Equipment Lists (MELs) for the spacecraft bus and instruments.

- MEL
  - define heritage, mass, composition and materials, quantities (for flight units, engineering design units, and flight spares), contingency design status, planned level of modification, and new developments.

- CSR
  - describe the mission's scientific goals, mission design, hardware, management plan, etc. Technical data, available in CSR documents, served useful in areas where the MEL lacked sufficient detail for cost modeling.

COST ANALYSIS METHODOLOGY

Technical Baseline

Data from MELs and CSR feed into cost model

Component-Level Modeling

Cost estimates including WBS 1,2,3, 5.0, 6.0, and 10 were developed from MELs and CSR data

Subsystem-Level Modeling

Cost estimates including WBS 1,2,3, 5.0, 6.0, and 10 costs were developed from MELs and CSR data

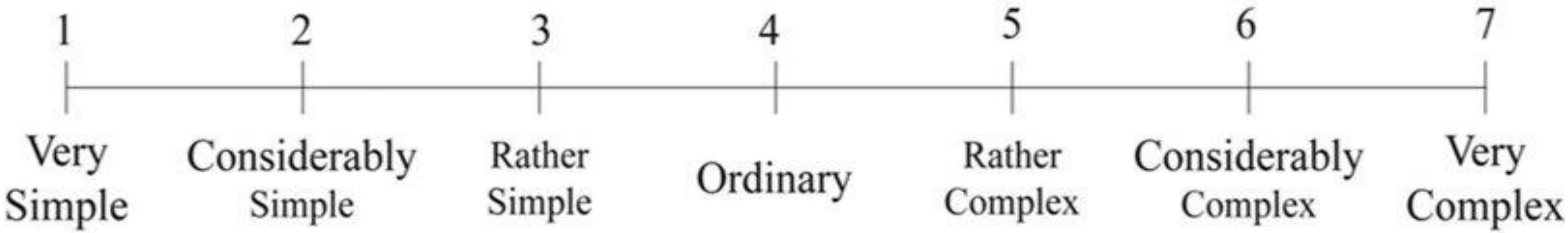
Compare/Contrast

Compared probabilistic 50% output at mission and WBS level 2 and noted similarities, differences, and challenges.

Challenges Encountered During the Estimation Process

SUBJECTIVITY IN PARAMETERS

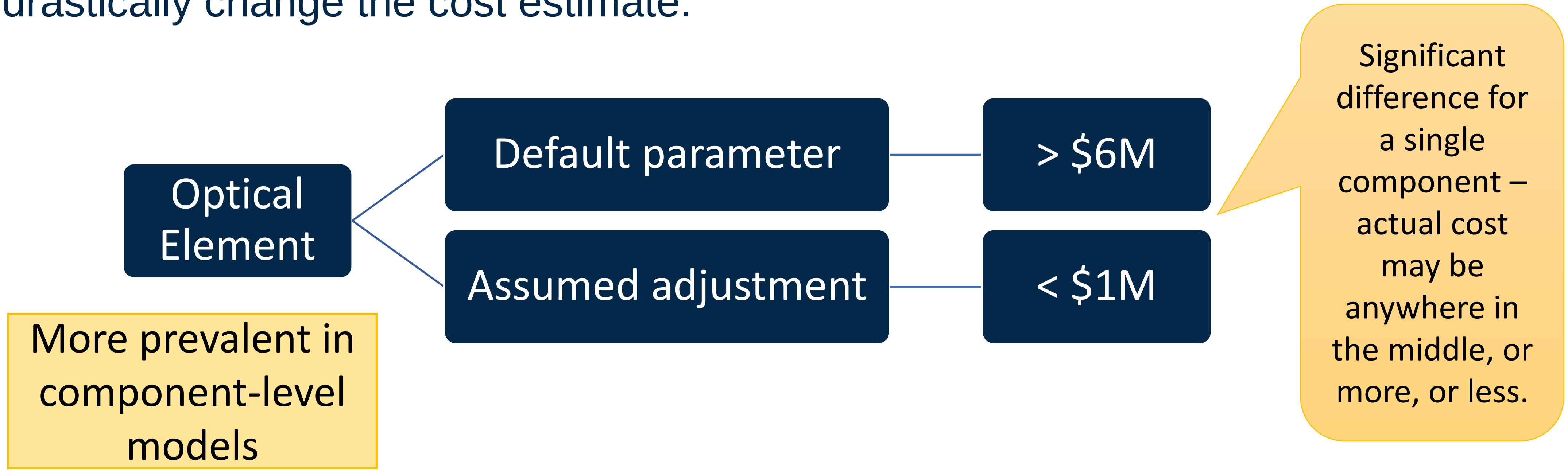
- Using intuition to assign a heritage rating or adjust the level of complexity of hardware is not something that can be easily taught and requires significant consideration.
- These subjective choices directly impact the cost estimate. Therefore, analysts should get input from experts and test the sensitivity of the model to these types of inputs.



Found in both component-level and subsystem-level models

ASSUMPTIONS VS. DATA

- Assumptions made for key input parameters not defined in the technical data could drastically change the cost estimate.



- Engineers should be consulted for input in this situation, as any assumptions that a cost analyst is required to make may be beyond their expertise.

LACK OF GRANULARITY

- Lack of granularity can be a limitation, as it may not allow analysts to account for special considerations reflected in the model. Consider a question in one model:

"Does this instrument include a Charge-Coupled Device (CCD) detector?"

Instrument contains a CCD detector

But not a similar CCD detector on which the CERs are based

Yes, but no, but yes?

More prevalent in subsystem-level models

OTHER MODELING OBSERVATIONS

Subsystem-Level

- Mission environment is a factor when considering subsystem heritage.
- Often do not have any adjustment for heritage or little sensitivity to heritage inputs.
- Clearer complexity factors for spacecraft orbit, mission risk class, mission type, orgs involved, etc.
- Some utilize schedule inputs.

Component-Level

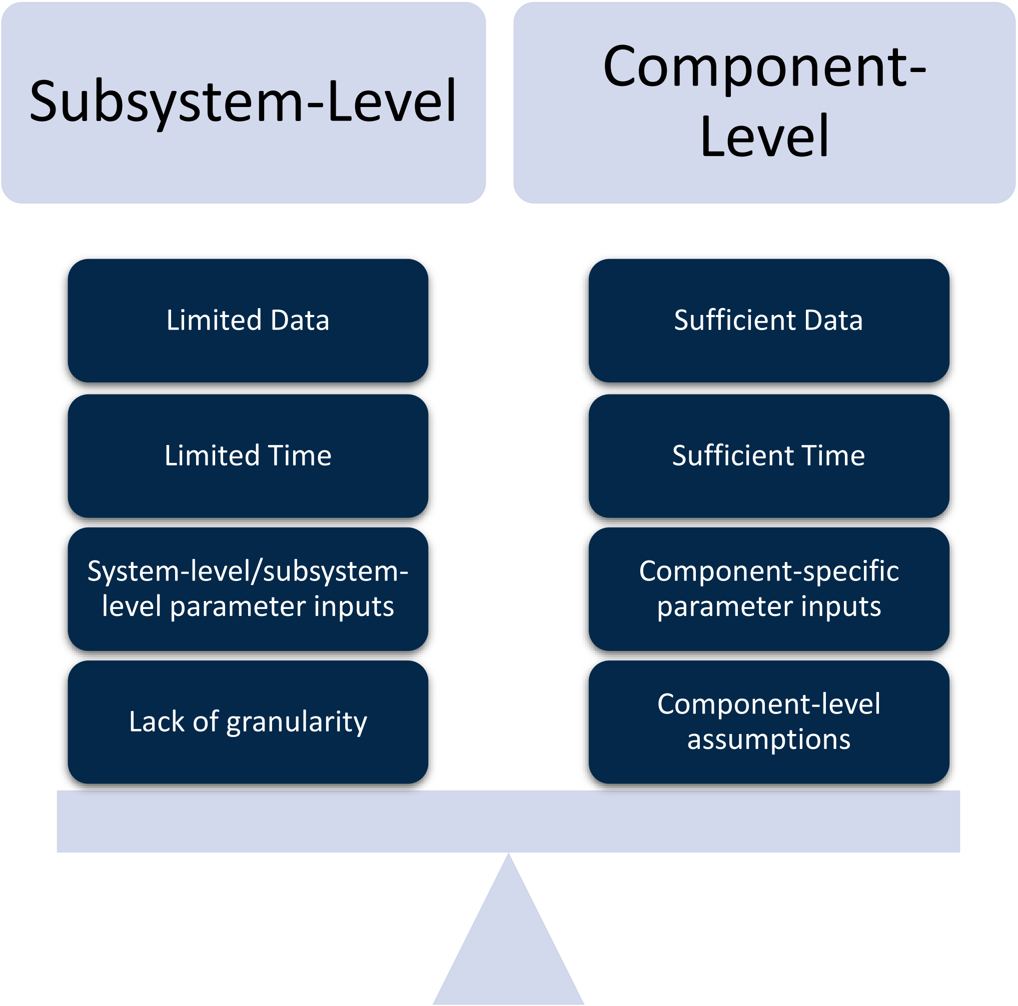
- Components can be treated as high heritage even if they are going to new environment.
- Nuanced complexity factor adjustments for interplanetary mission.
- Model is less sensitive to qualitative characteristics of the system or the mission.
- Can accept schedule inputs but not required and haven’t been validated against historical NASA schedules

CASE STUDY LIMITATIONS (HISTORICAL MISSION)

- Working with historical missions comes with its own set of challenges beyond those faced when modeling a current mission. These limitations include:
  - Incomplete data (leading to questionable assumptions)
  - No ability to talk with engineers

Conclusion & Next Steps

CONCLUSION



- Both methods have their strengths/pros and their weaknesses/cons.
- Both are driven by some similar cost drivers and some unique cost drivers.
- Consider tradeoffs between granularity vs. efficiency and precision vs. pragmatism.
- Both methods should be considered when possible.

ADVICE FOR ANALYSTS

When modeling and presenting costs, it's important to:

Modeling practices:

- Check technical baseline across sources
- Cross-check complexity factors
- Engage stakeholders
- Consider methodology limitations
- Conduct sensitivity analysis when possible

Presenting practices:

- List any significant assumptions
- Emphasize caveats
- Disclose limitations in methodologies
- Address major cost drivers identified through sensitivity analysis
- Present risk mitigation strategies

SUGGESTIONS

Validation Studies

Method Selection Framework

Better initial cost estimates, Better future

Further Research on Complexity Factors within Parametric Tools

Share best practices and guidance across cost estimating community when non-proprietary

Thank You!

Camille Holly
Technomics Support to the CEMA Office
camille.m.holly@nasa.gov

Details of comparative analysis are available in the long-form research paper for this presentation