Estimating Challenges & Solutions @ NASA Goddard Space Flight Center: Past, Present, & Future

Cabin Samuels
Jeff Brown
Agenda

• What is Goddard / Cost Estimating Modeling & Analysis (CEMA) Office?
• Unique Landscape of Space Cost Estimation
• CEMA’s Current Approach to Cost Estimating
• Future Considerations
What is Goddard / CEMA Office?
What is Goddard Space Flight Center?

- First NASA space flight complex
- Earth science, astrophysics, heliophysics focus
- Primarily unmanned missions
- 10,000+ civil servants and contractors
- ~$5.3B budget in 2016
What is CEMA?

- Cost Estimating, Modeling & Analysis (CEMA) Office
- Established within GSFC Office of the CFO in 2012
- Central focus point for GSFC new business cost estimating guidance and support
- Provides a consistent approach to cost estimating for the Center
Unique Landscape of Space Science Cost Estimation
Competed Work

• NASA Announcement of Opportunity (AO) Response Process
  • Cost Caps – Design-to-Cost
  • Time constraints for cost estimating
  • Various mission risk requirements
  • Design & cost iterations

Recent missions GSFC led or partnered on:

- SOFIA
- TESS - MIDEX
- LUCY - Discovery
- OSIRIS-REx – New Frontiers
Diverse Environments

NASA Science Is Interconnected

How did the universe begin and evolve, and what will be its destiny?

What drives variations in the Sun, and how do these changes impact the solar system and drive space weather?

How did our solar system originate and change over time?

How and why are Earth’s climate and environment changing?

How did life originate, and are we alone?

Star formation and evolution
Cosmology and galaxy formation
Impact of the Sun on planetary bodies
Impact of the Sun on Earth
Planet formation and evolution
Planet habitability
Exoplanet characterization
Origins of life
Evolution of surface and atmospheres
Co-evolution of climate and life
Limited Heritage

Hubble Space Telescope

James Webb Space Telescope

HST vs JWST Primary Mirror

HST vs JWST Orbit

Microshutters
Backplane
Lightweight Cryogenic Mirrors
Wavefront Sensing and Control

Infrared Detectors
Cryogenic Data Acquisition
Integrated Circuit
Sunshield Coating
Cryocooler
Data Limitations

• Full cost accounting
  • Implemented in 2004*

• Lack of Relevant Historical Data
  • Obsolescence
  • Incomplete Data
  • No Analogs
  • Insufficient Granularity

Historical GAO Findings

1990 – NASA added to GAO “High Risk List” due to cost and schedule increases

1999 and prior – primarily analogy & grassroots estimating

2000 – Parametric cost estimating support of Integrated Design Center & proposal development (Science Proposal Support Office)

2005 – requirement to report cost & schedule baseline for projects with LCCE > $250M

2011 – “Additional Cost Transparency and Design Criteria Needed”

2012 – 38% of projects met technology maturity standards at PDR

2016 - Improvements made in maturing technologies prior to commitments; 77% met technology maturity standards at PDR

GSFC Cost Estimating

GAO Reports

Report citations from GAO.gov

Presented at the ICEAA 2017 Professional Development & Training Workshop - www.iceaaonline.com/portland2017
CEMA’s Current Approach to Space Science Cost Estimation
CEMA Work Scope

• CEMA primarily provides cost support to:
  • GSFC’s Integrated Design Center (IDC)
    • Condensed conceptual design studies
    • ~20 IDC studies / yr.
  • Mission/Instrument Proposal Teams
    • Responsible for developing GSFC’s proposal submissions in response to NASA HQ announcements of opportunity (AOs)
    • ~25 proposals / yr. (3+ iterations ea.)

• Both efforts represent early lifecycle cost estimating
GSFC Proposal Cost Estimating Process

Concept/Formulation  Science/Design Study  Develop Proposal

GO / NO-GO

Project Mgmt, Engineering, Science Development, Cost

Parametric Cost Model ROM  Parametric Cost Model Refinement  Validate Grassroots

Grassroots ROM  Grassroots refinement  Grassroots estimate

Independent Cost Assessment  Independent Cost Estimate

Proposal Bid

CEMA Functions
Parametric Tools

- CEMA utilizes multiple parametric tools in an effort to increase traceability and align our parametric cost estimating approach with:
  - NASA HQ guidance
  - NASA HQ proposal evaluation

- Picking the right tool for the job
  - A few key pieces of known data
    - NASA Instrument Cost Model (NICM)
    - NASA Project Cost Estimating Capability (PCEC)
  - More detailed data (e.g., Master Equipment List)
    - NASA HQ recommended commercial parametric tools
Master Equipment List (MEL)

• Captures major subsystems, components, integration hierarchy, & technical information relevant to cost modeling
• Necessitates strong systems engineering understanding of mission
  • Design maturity, engineering, manufacturing, I&T strategy, etc.
  • Objective technical parameters and subjective parameters
• Importance of Technology Readiness Level
  • Linked to multiple parameters in our tools
• MEL Evolution
  • Design iteration
  • Engineering judgment
Design Driven Cost Estimating

**Primary Mirror (PM)**

**Secondary Mirror (SM)**

**Tertiary Mirror (TM)**

**Fold Mirror (FM)**

**Focal Plane**

**Engineering/Design Process:** Sometimes, we end up driving the design to a level of maturity we can cost (i.e., facilitating refinement seeking a more credible estimate)
Please see the companion Word document “Common MEL Guidance” for instructions prior to completing this MEL template.

### MASTER EQUIPMENT LIST

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<th>LEVEL</th>
<th>NAME (Mission or Payload Name)</th>
<th>UNIT MASS</th>
<th># OF UNITS</th>
<th>LIGHT HARDWARE MASS</th>
<th>NORMAL FLIGHT HARDWARE POWER</th>
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Additional Information:

- **Technology Readiness Level (TRL)**: This is a ranking of the technology’s readiness to be deployed in a space mission. TRL 1 indicates the technology is still in the concept stage, while TRL 9 indicates the technology is ready for operational use.
- **Heritage Summary**: This section provides a summary of the heritage of the equipment, including its prior use, mission, system, and components.
- **Heritage Justification and Additional Information**: This section includes additional details about the heritage of the equipment, such as its design, manufacture, software provider, and use. It may also include information about the equipment’s location and technology readiness level.

**Heritage Justification**:

- **This new widget has been fully tested in mission environment. It is built by the manufacturer.**
- **This new widget does a new function and we haven’t tested it in the target environment.**
- **This is the exact same thing by a different provider. We used the same exact design and it has been fully verified in the target environment.**

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**Total Flight Hardware**: 3.20 kg

**Quoted Unit Price**: Rs 422

**ADDITIONAL INFORMATION**:

- **As applicable: Vendor, make, model, part #, volume, quote information, notation of identical items, instrument / component characteristics, ETU approach...**

**GSFC Common MEL Template vNov2016a wHeritage**

Presented at the ICEAA 2017 Professional Development & Training Workshop - www.iceaaonline.com/portland2017
Cost Estimating Input Screens

NASA Developed Tool Parameter Screens

Commercial Tool Parameter Screens
Risk Analysis

• Create uncertainty distribution
  • Right skewed triangular distribution on input parameters
  • Proposal defined contingency and margin for mass

• Monte Carlo analysis

• Cumulative Distribution Function Curve

Example Mission
Mission Level S-Curve

Cost Cap: $650M @ 61% CL
Future Considerations
Future Considerations

**Time Horizon**

- **Near Term**
  - MEL template evolution & increased emphasis on inputs to cost
  - Education of input providers and decision makers
  - Evolution of best practices and documentation (Cost Guidelines document)
  - Leverage CADRe growth & ONCE database
  - Incorporation of new models and updates
  - Data collection efforts at GSFC / Engineering discipline-centric CER creation (Optics, Detectors)
  - Joint Confidence Level
  - WBS standardization beyond level 2

- **Long Term**

**GAO Characteristics of Reliable Cost Estimates**

- Well-documented
- Comprehensive
- Accurate
- Credible
Evolving Policy, Guidelines, Best Practices

• External to CEMA – documentation to educate the center/agency on cost estimating policy
• Internally – cost templates for various systems, components, rates, output, briefings, etc.
  • Add new types of systems (ex. Cubesats)
  • New and updated tools require best practices
  • Engineering Judgment is hard to standardize
WBS Comparison

MIL-STD-881C WBS for Space Systems*

VS.

Space Flight Project

Project Management 01
Systems Engineering 02
Safety & Mission Assurance 03
Science & Technology 04
Payload(s) 06
Spacecraft 06
Mission Operations 07

Launch Vehicle / Satellites 09
Ground System(s) 09
Systems Integration & Testing 10
Education and Public Outreach 11

NPR 7120.5E NASA WBS

Key Takeaways

• Unique challenges
• Early conceptual estimating
• Commercial tools estimating esoteric hardware
• Systems engineering emphasis
Questions?