Estimating Challenges & Solutions @ NASA Goddard Space Flight Center:

Past, Present, & Future

Cabin Samuels

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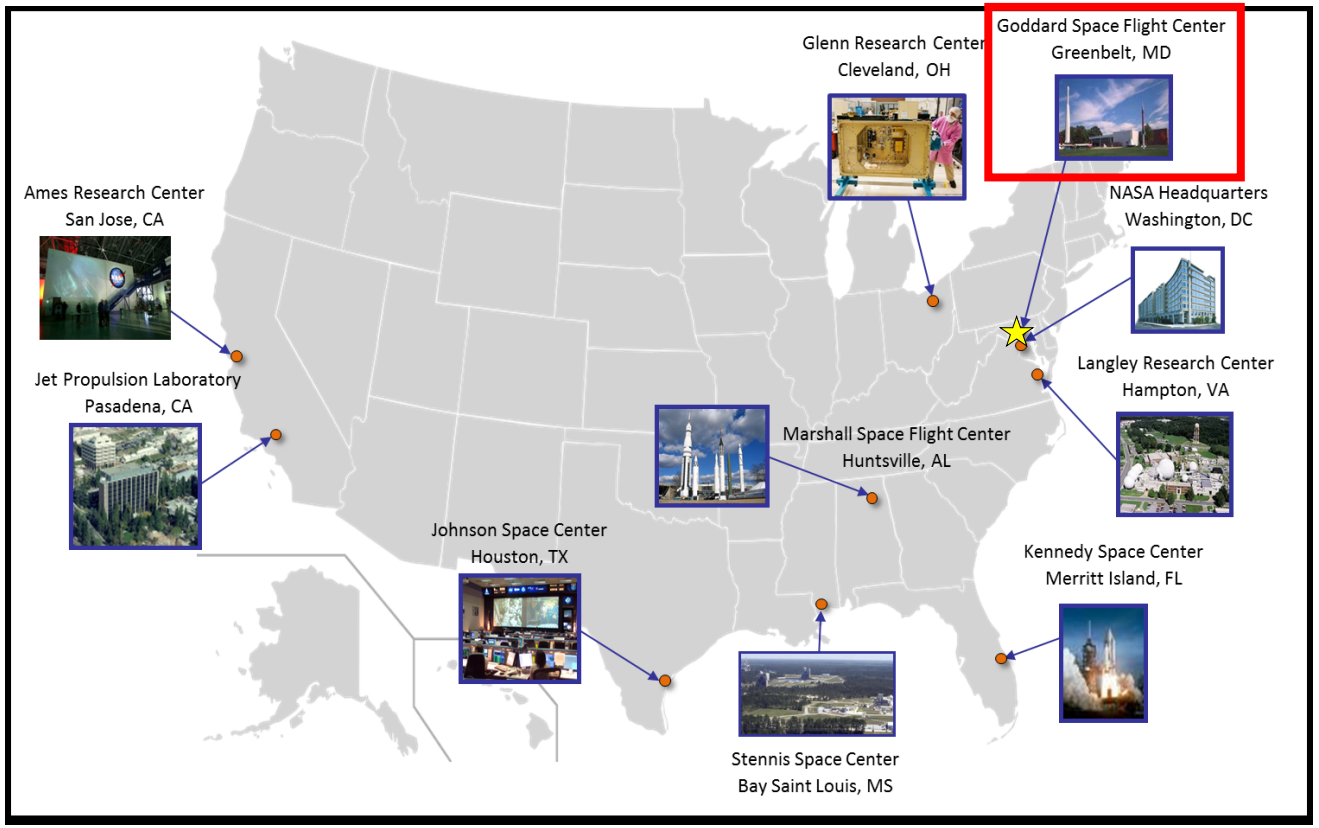
Agenda

- 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?



NASA Centers and Affiliates

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

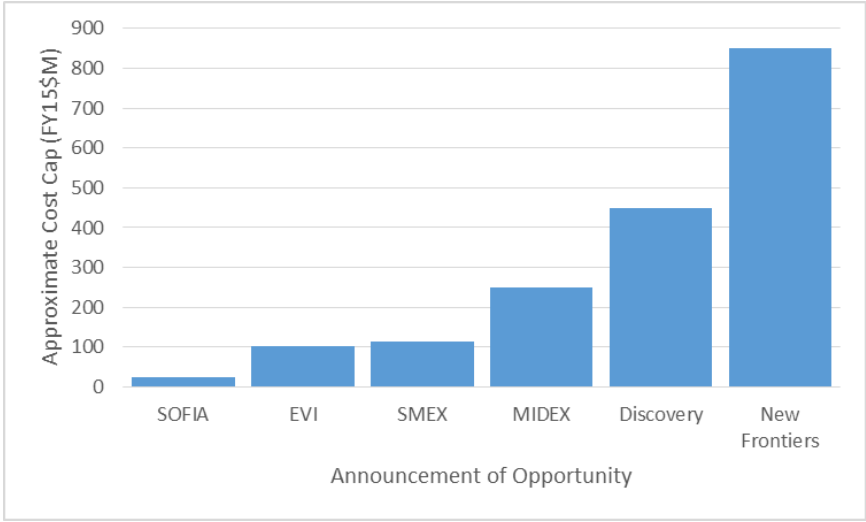
What is CEMA?

- 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

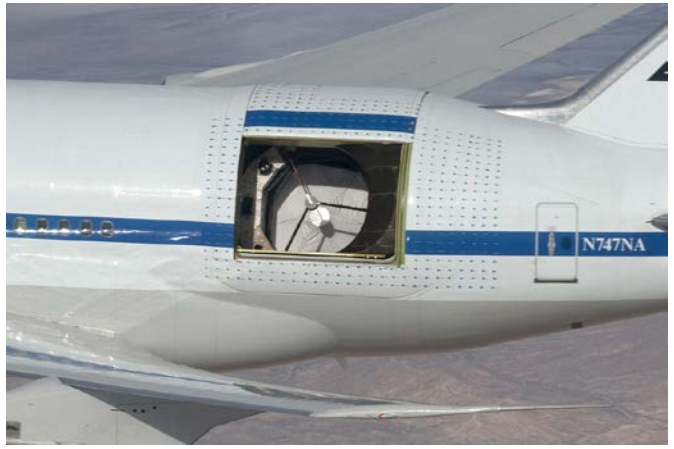
Unique Landscape of Space Science Cost Estimation

Competed Work

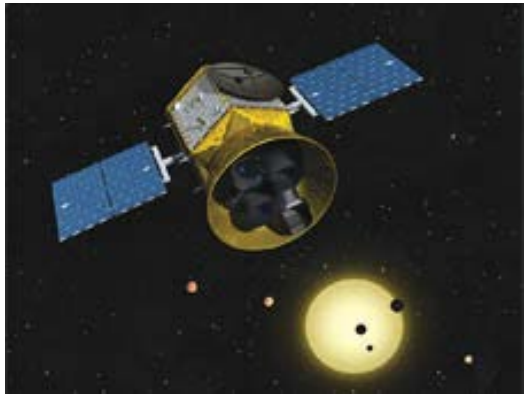
- NASA Announcement of Opportunity (AO) Response Process
  - Cost Caps – Design-to-Cost
  - Time constraints for cost estimating
  - Various mission risk requirements
  - Design & cost iterations



Recent missions GSFC led or partnered on:

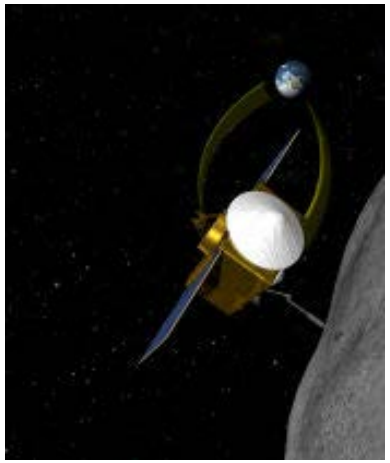


SOFIA



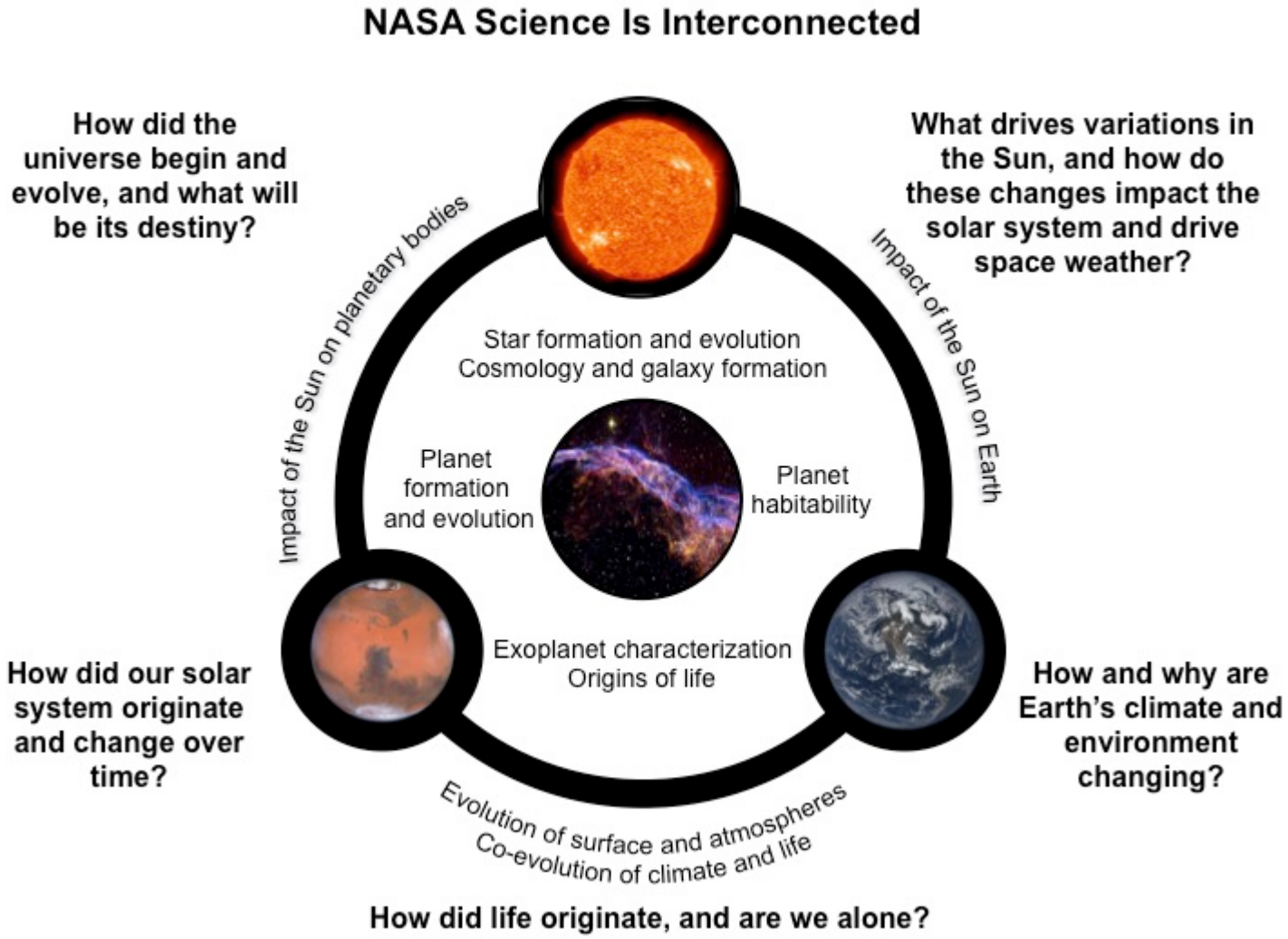
TESS - MIDEX

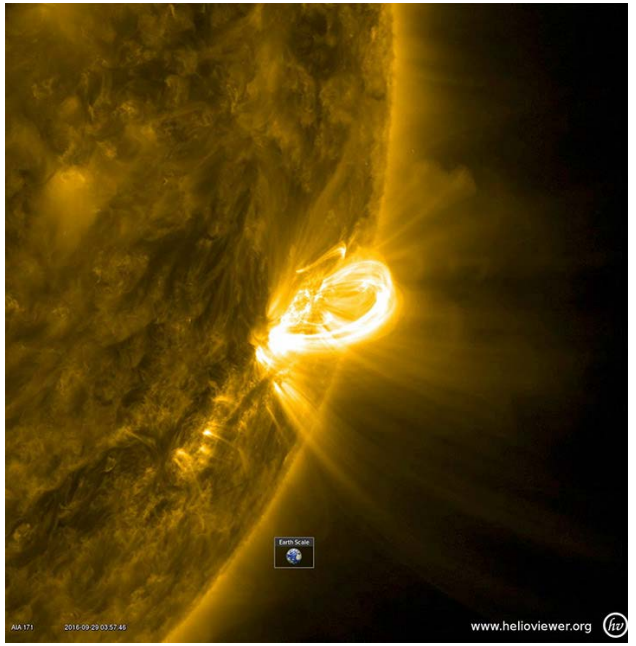
LUCY - Discovery

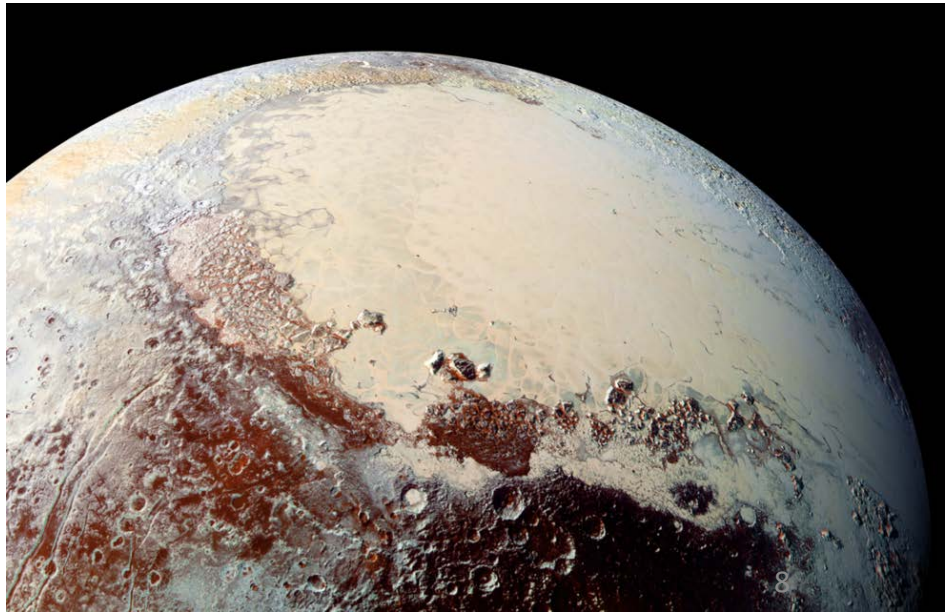


OSIRIS-REx – New Frontiers

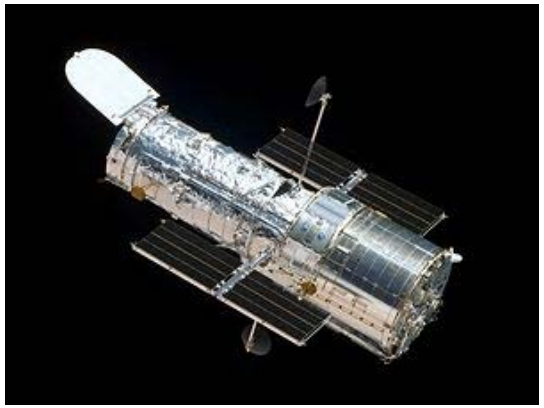
Diverse Environments



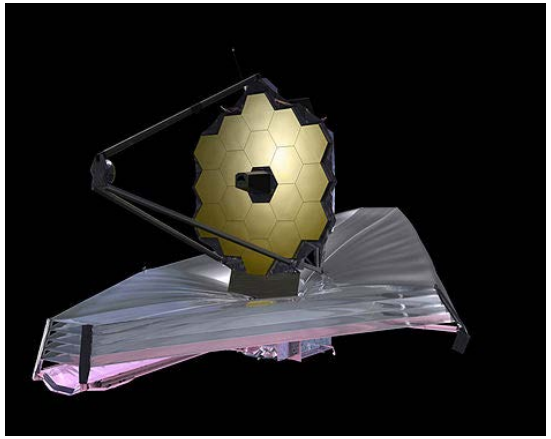




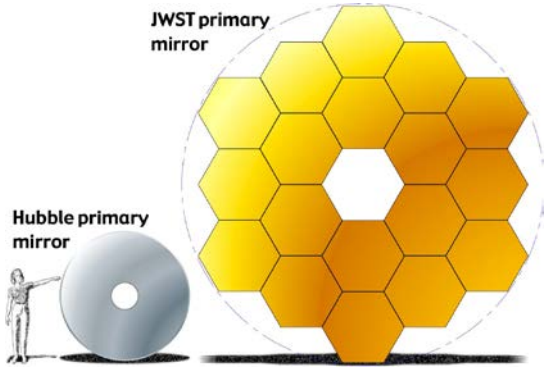
Limited Heritage



Hubble Space Telescope

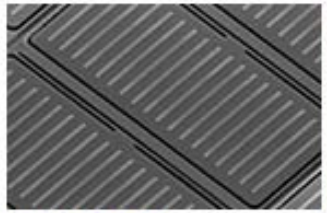


James Webb Space Telescope



HST vs JWST Primary Mirror

HST vs JWST Orbit

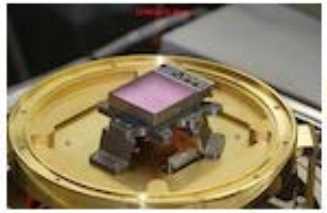


Microshutters

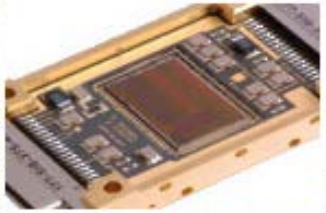
Backplane

Lightweight Cryogenic Mirrors

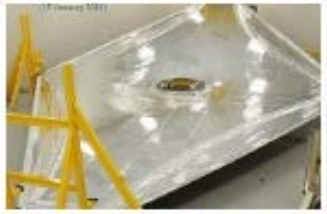
Wavefront Sensing and Control



Infrared Detectors



Cryogenic Data Acquisition Integrated Circuit

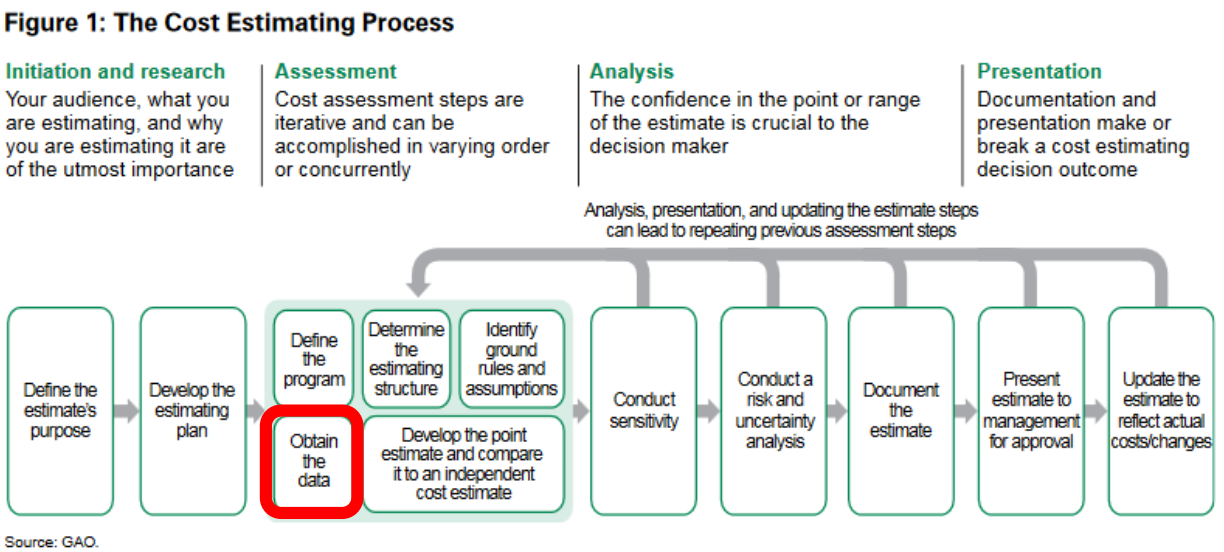


Sunshield Coating

Cryocooler

Data Limitations

- Full cost accounting
  - Implemented in 2004*
- Lack of Relevant Historical Data
  - Obsolescence
  - Incomplete Data
  - No Analogs
  - Insufficient Granularity



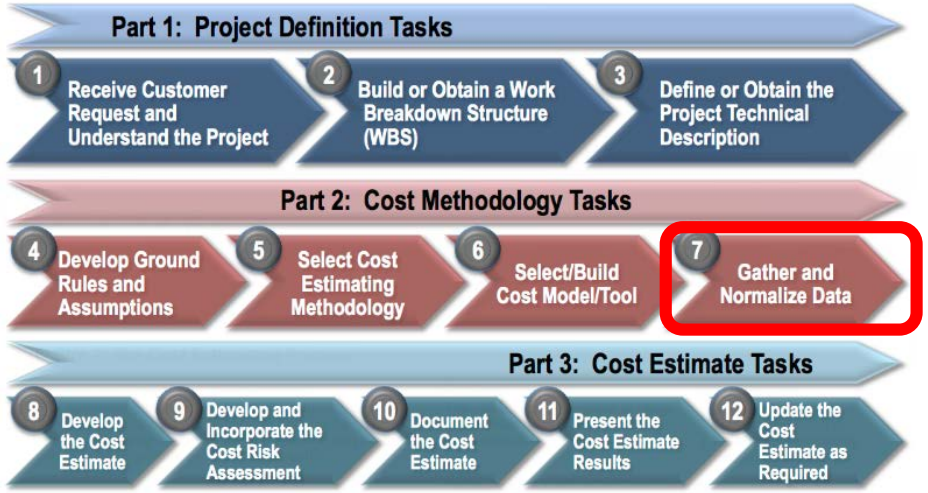
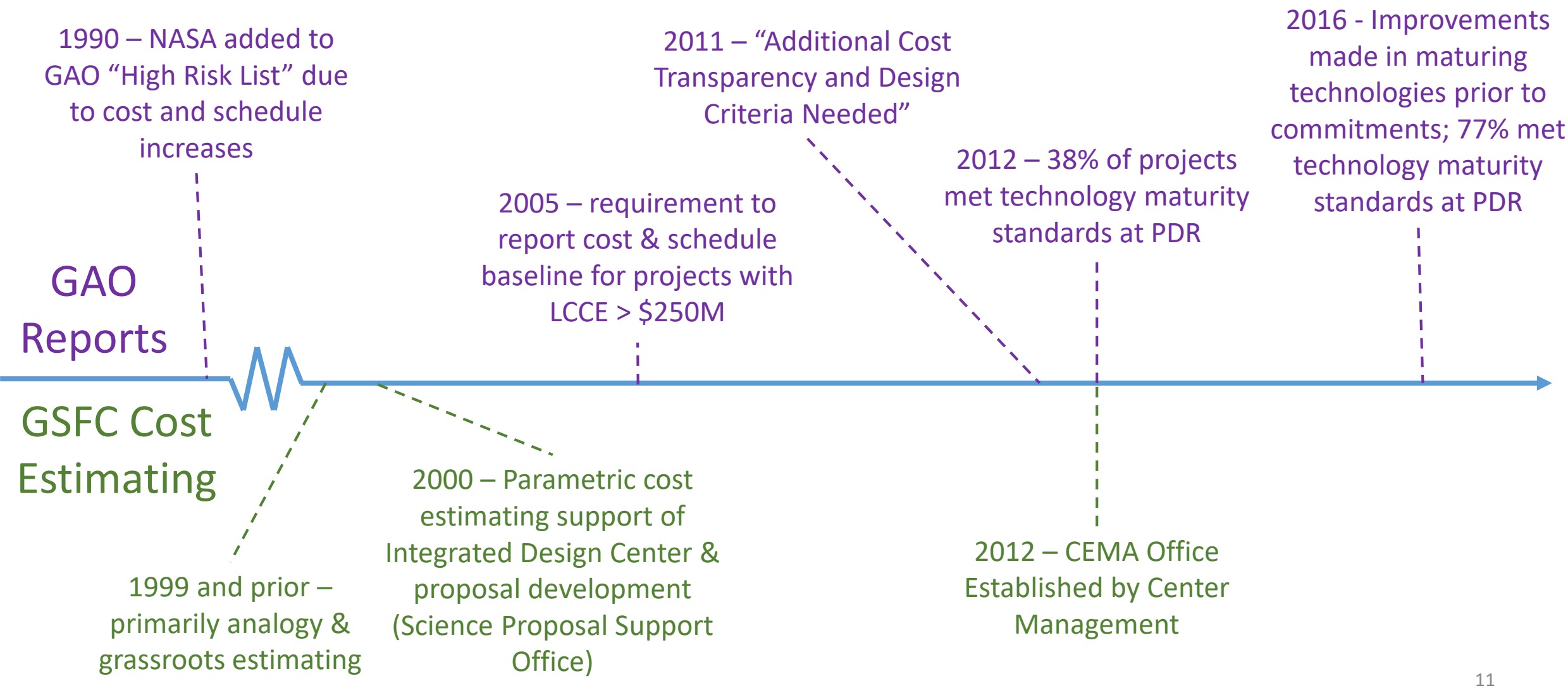


Figure 2. The NASA Cost Estimating Process

*https://www.nasa.gov/pdf/1964main_fullcost.pdf

Historical GAO Findings



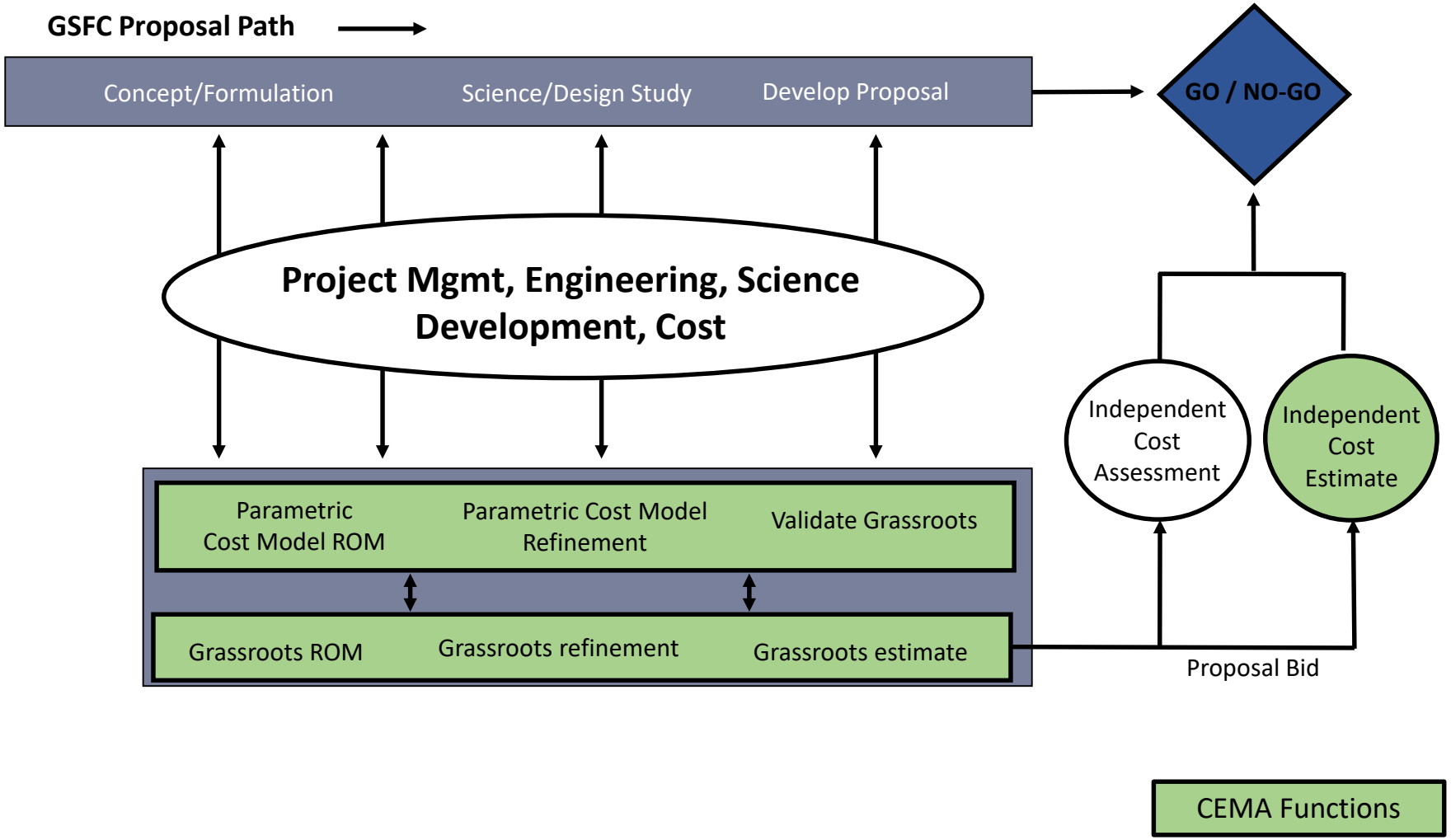
Report citations from GAO.gov

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



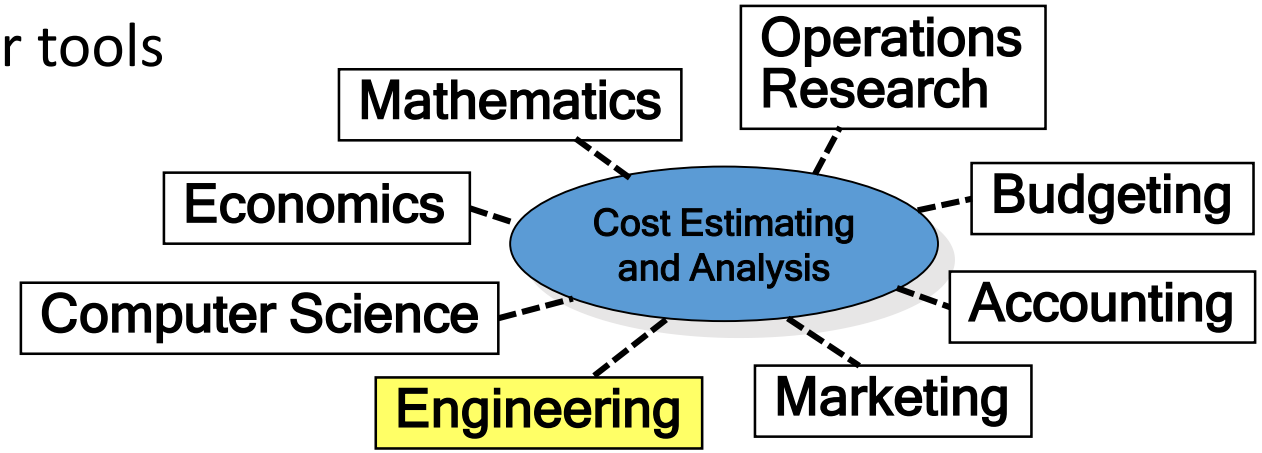
Parametric Tools

- 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

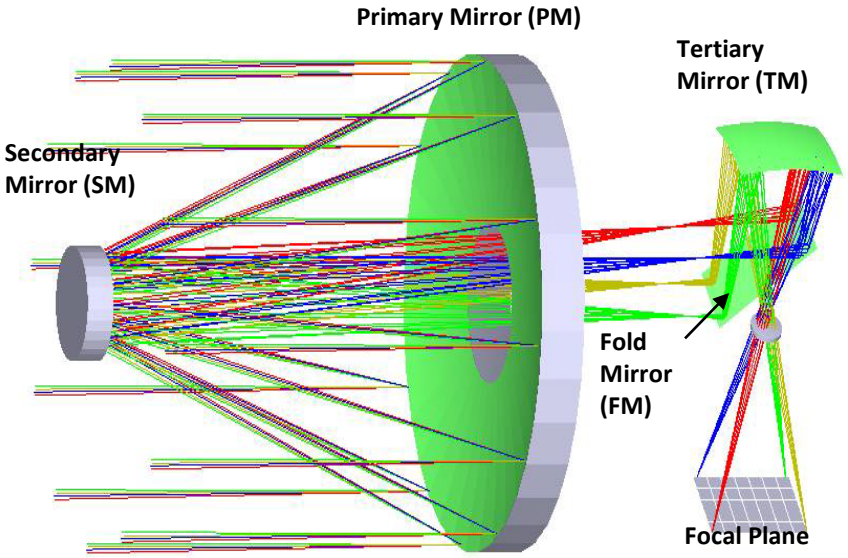
Tool Type			Estimating Methodology Applicability: Parametric	Analogy	Build Up
NASA-Sponsored Models and Tools		**ONCE Portal[1]**			
Project Cost Estimating Capability (PCEC)			✓		
NASA Air Force Cost Model (NAFCOM)	*(Transitioning users to PCEC)*		✓		
NASA Instrument Cost Model (NICM)		x	✓	✓	
Technology Cost and Schedule Estimation (TCASE) Tool		x		✓	
Schedule Management and Relationship Tool (SMART)		*soon*	✓	✓	
Phasing Model		x	✓		
Schedule Estimating Relationship Risk Analysis (SERRA)			✓	✓	✓
Quantitative Techniques Incorporating Phasing and Schedule (QTIPS)			✓	✓	✓
QuickCost			✓		
One NASA Cost Engineering (ONCE) Database		x	✓	✓	✓
REDSTAR Database			✓	✓	✓
Models and Tools with NASA-Provided Licenses					
Polaris[4]	*(JCL Analysis)*	x	✓	✓	✓
Argo (Monte Carlo simulation)		x	✓	✓	✓
Automated Cost Estimating Integrated Tools (ACEIT)		x	✓	✓	✓
CO$TAT (statistical analysis package)		x	✓	✓	✓
Joint Analysis of Cost and Schedule (JACS)	*(JCL Analysis)*	x	✓	✓	✓
SEER for Hardware, Electronics, & Systems (SEER-H)		*soon*	✓		
SEER for Software (SEER-SEM)		*soon*	✓		
PRICE® TruePlanning™			✓		
PRICE® Estimation Suite (PES)			✓		

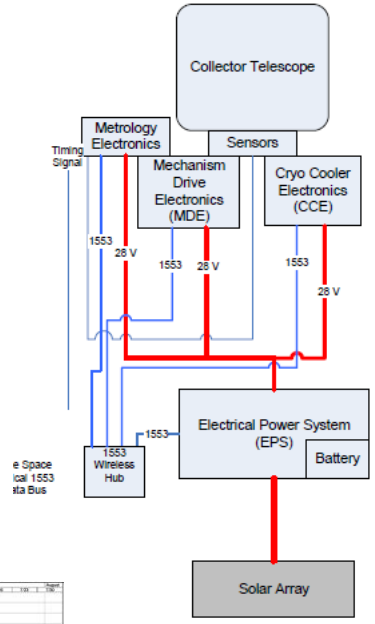
Master Equipment List (MEL)

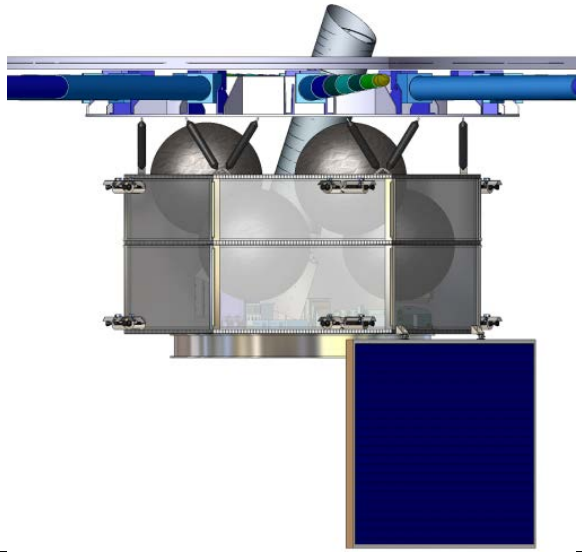
- Captures major subsystems, components, integration hierarchy, & technical information relevant to cost modeling
- Necessitates strong systems engineering understanding of mission
  - Design maturity, engineering, manufacturing, I&T strategy, etc.
  - Objective technical parameters and subjective parameters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

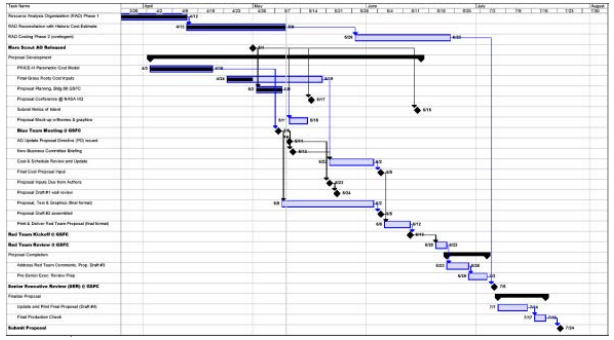


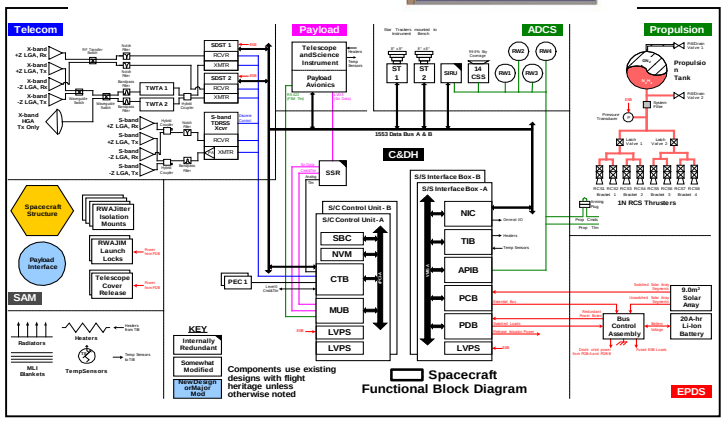
Design Driven Cost Estimating











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)

Master Equipment List Example

Please see the companion Word document "Common MEL Guidance" for instructions prior to completing this MEL template.

Recommended but not required in MEL for proposals.

MASTER EQUIPMENT LIST

LEVEL	NAME (*Mission or Payload Name*)	UNIT MASS	# OF UNITS						FLIGHT HARDWARE MASS			NOMINAL FLIGHT HARDWARE POWER				PEAK FLIGHT HARDWARE POWER				QUIESCENT	Quoted Unit Price ($K)	Composition	ADDITIONAL INFORMATION (As applicable: Vendor, make, model, part #, volume, quote information, notation of identical items, instrument / component characteristics, ETU approach...)
	Subassembly / Component	Unit Mass [kg] (CBE)	Cold Units	Hot Units	Flight Units	Flight Spares	Non-Flight ETU / Qual Units	EM / EDU / Proto-type	Total Mass [kg] (CBE)	Contin-gency [%]	Total Mass [kg] w/ Contgcy (MEV)	Unit Power [W] (CBE)	Total Power [W] (CBE)	Contin-gency [%]	Total Power [W] w/ Contgcy (MEV)	Unit Power [W] (CBE)	Total Power [W] (CBE)	Contin-gency [%]	Total Power [W] w/ Contgcy (MEV)	Total Power [W] (CBE)				
	TOTAL FLIGHT HARDWARE								**3.20**		**3.84**												
1	**INSTRUMENT NAME**								3.20		3.84		0.00		0.00		0.00		0.00	0.00			
2	**Subassembly**								**3.20**		**3.84**		**0.00**		**0.00**		**0.00**		**0.00**	**0.00**			
3	Electronics Card	0.50		1	1	1		1	0.50	20%	0.60		0.00		0.00		0.00		0.00			Digital	
3	Sensor Electronics	0.50		1	1	1		1	0.50	20%	0.60		0.00		0.00		0.00		0.00			90%A / 5%D	
3	Backplane	0.50		1	1	1		1	0.50	15%	0.58		0.00		0.00		0.00		0.00				
3	Enclosure	1.00		1	1	1		1	1.00	15%	1.15		0.00		0.00		0.00		0.00			Machined Al	
3	Harness	0.70		1	1	1		1	0.70	30%	0.91		0.00		0.00		0.00		0.00			RS422	

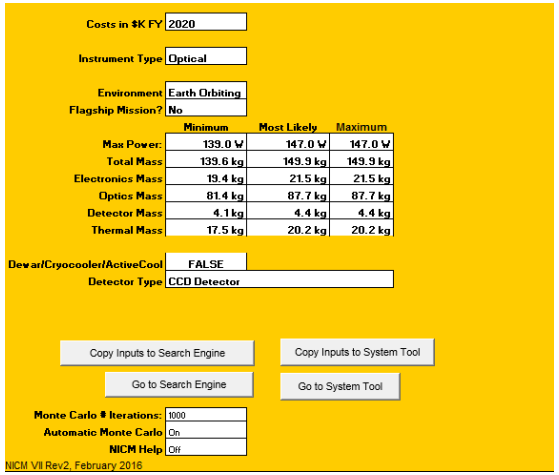
MEL & Heritage

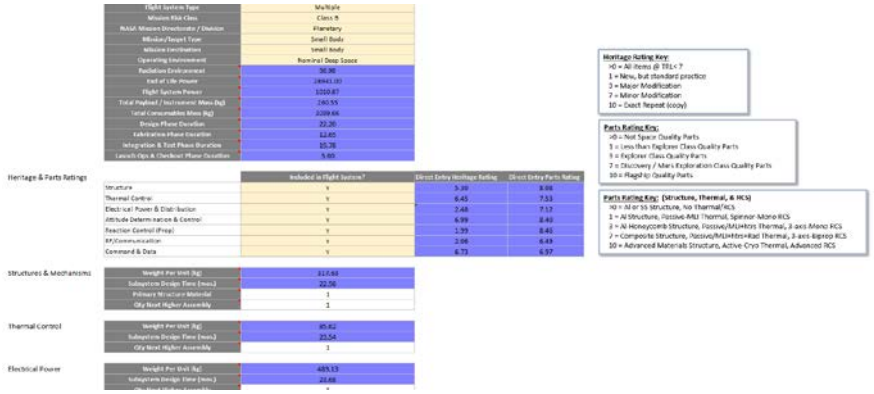
Heritage Columns are for proposals - these cells will be used for a separate Heritage Foldout, with Columns A & B & TRL Repeated.

TECHNOLOGY READINESS LEVEL TRL	VENDOR MATURITY DESCRIPTION	LOCATION	HERITAGE VS ENVIRONMENTAL REQUIREMENTS				NEW TECHNOLOGY or ENGRG CHANGE?	OWNERSHIP?	PERFORMANCE CHANGE?	HERITAGE SUMMARY							REFERENCE MISSION(S)	HERITAGE JUSTIFICATION and ADDITIONAL INFORMATION
			TEMP -X TO Y	PRESSURE X to Y mPa	ENTRY LOAD <X G	RADIATION TID < X krad-Si				DESIGN	MANUFACTURE	SOFTWARE	PROVIDER	USE OPERATING ENVIRONMENT	PRIOR USE			
										F(Full) P(Partial) N(None) NA(Not Applicable)								
6							EC	Own All	No	F	F	NA	F	F	P	F	Mission A	
6							NT	NA	Yes	P	F	P	F	P	P	F	Mission B	This new widget has been fully tested in mission environment. It is built by the
7							Neither	Own All	No	F	F	F	F	F	F	F	Mission A	
5							NT	NA	Yes	P	F	P	F	N	N	N		This new widget does a new function and we haven't tested it in the
6							EC	Own IP	Possibly	F	F	F	N	F	F	F		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. We own the IP.

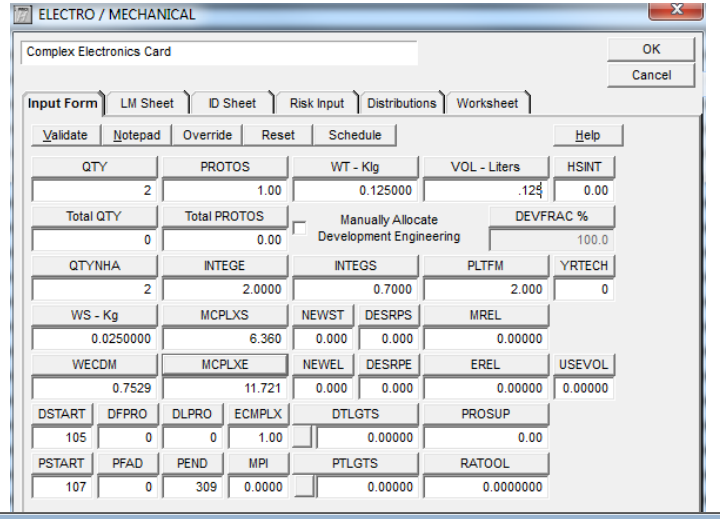
Cost Estimating Input Screens

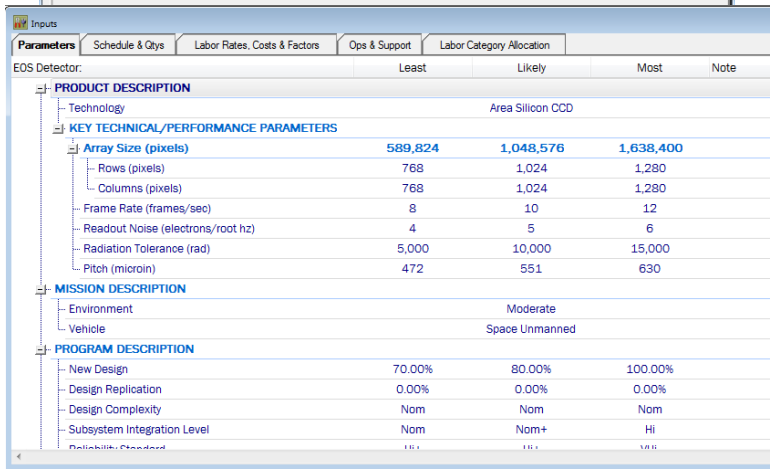
NASA Developed Tool Parameter Screens





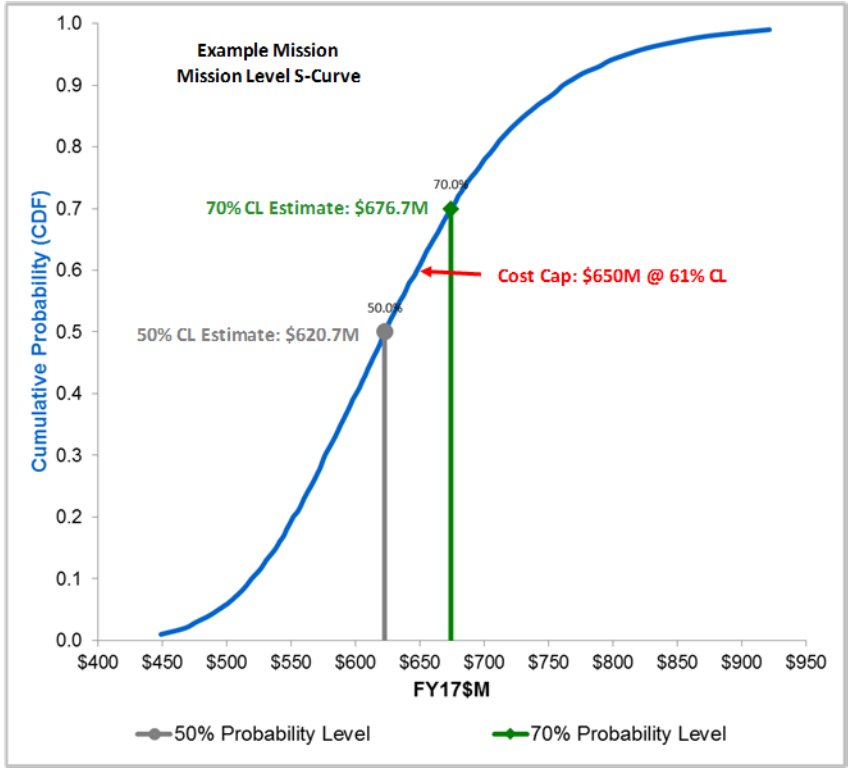
Commercial Tool Parameter Screens





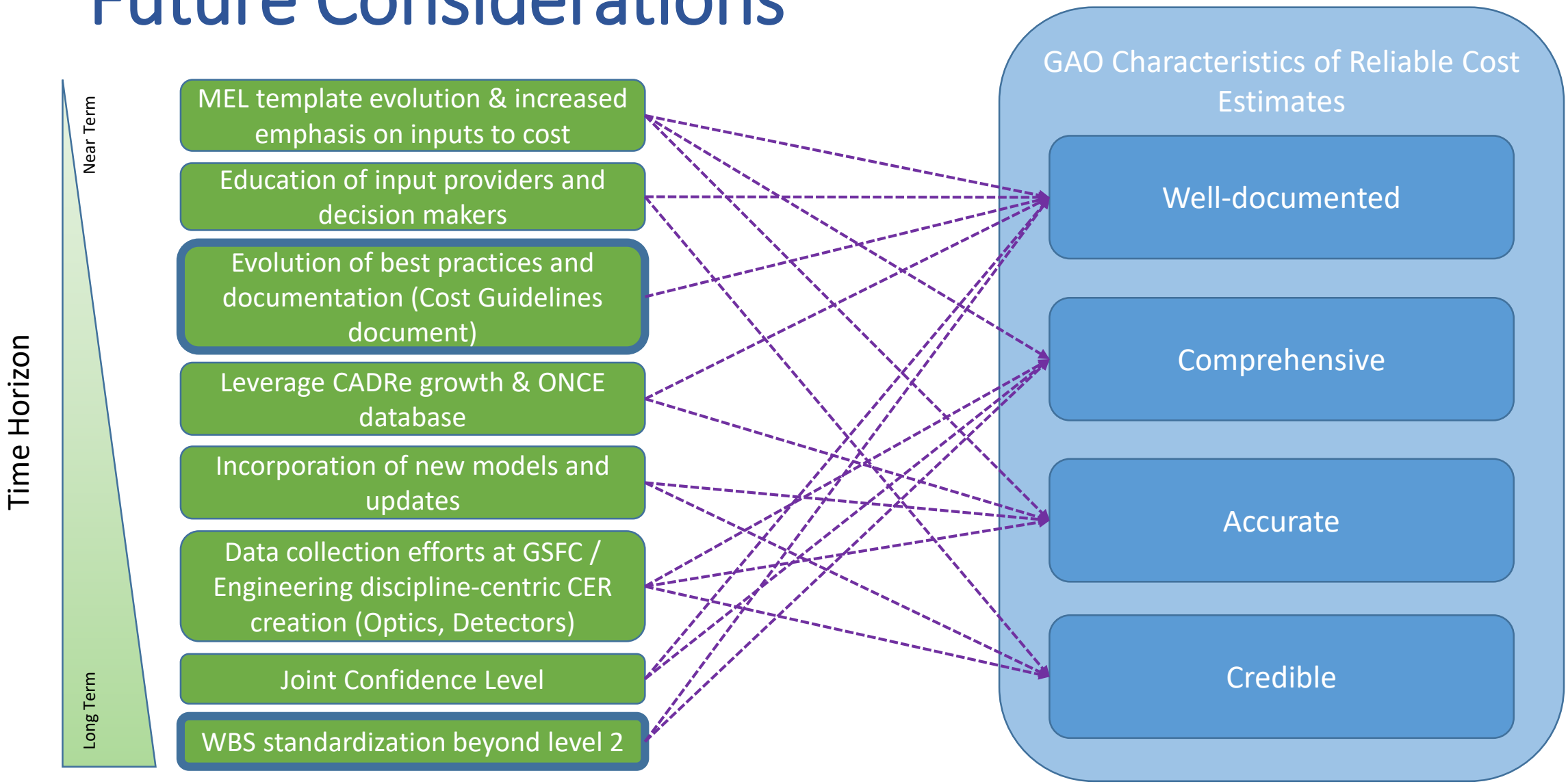
Risk Analysis

- Create uncertainty distribution
  - Right skewed triangular distribution on input parameters
  - Proposal defined contingency and margin for mass
- Monte Carlo analysis
- Cumulative Distribution Function Curve

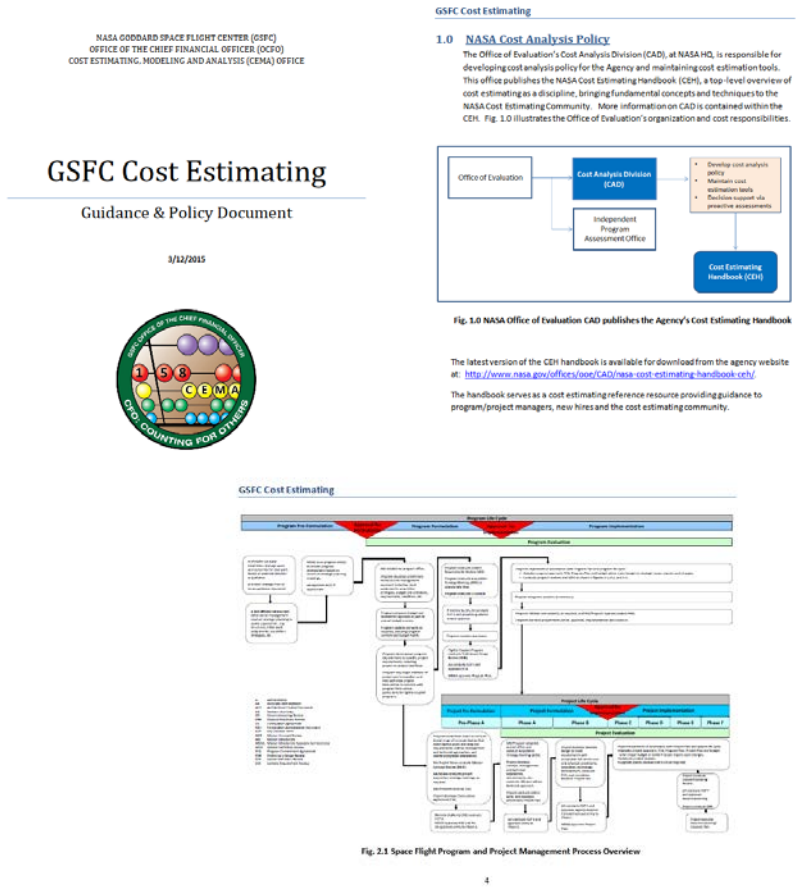


Future Considerations

Future Considerations



Evolving Policy, Guidelines, Best Practices


NASA GODDARD SPACE FLIGHT CENTER (GSFC)
OFFICE OF THE CHIEF FINANCIAL OFFICER (OCFO)
COST ESTIMATING, MODELING AND ANALYSIS (CEMA) OFFICE

GSFC Cost Estimating

Guidance & Policy Document

3/12/2015

GSFC Cost Estimating

1.0 NASA Cost Analysis Policy

The Office of Evaluation's Cost Analysis Division (CAD), at NASA HQ, is responsible for developing cost analysis policy for the Agency and maintaining cost estimation tools. This office publishes the NASA Cost Estimating Handbook (CEH), a top-level overview of cost estimating as a discipline, bringing fundamental concepts and techniques to the NASA Cost Estimating Community. More information on CAD is contained within the CEH. Fig. 1.0 illustrates the Office of Evaluation's organization and cost responsibilities.

Office of Evaluation
Cost Analysis Division (CAD)
Independent Program Assessment Office
Cost Estimating Handbook (CEH)

Fig. 1.0 NASA Office of Evaluation CAD publishes the Agency's Cost Estimating Handbook

The latest version of the CEH handbook is available for download from the agency website at: http://www.nasa.gov/offices/ooe/CAD/nasa-cost-estimating-handbook-ceh/

The handbook serves as a cost estimating reference resource providing guidance to program/project managers, new hires and the cost estimating community.

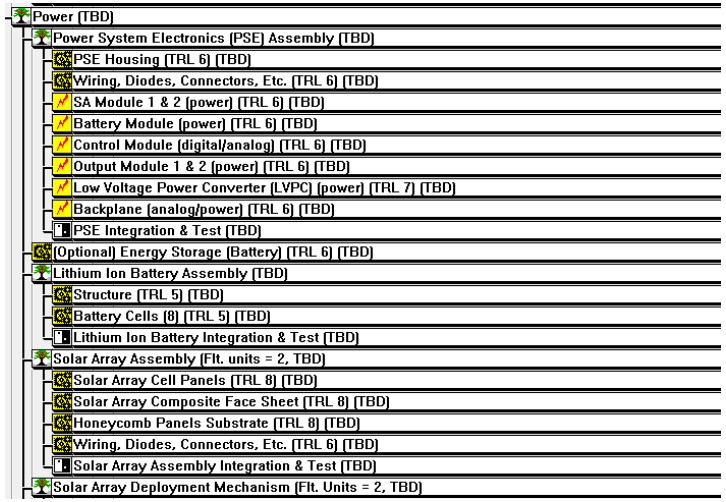
GSFC Cost Estimating

Fig. 2.1 Space Flight Program and Project Management Process Overview

4

CEMA Guidance and Policy Document for GSFC Cost Estimating

- 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

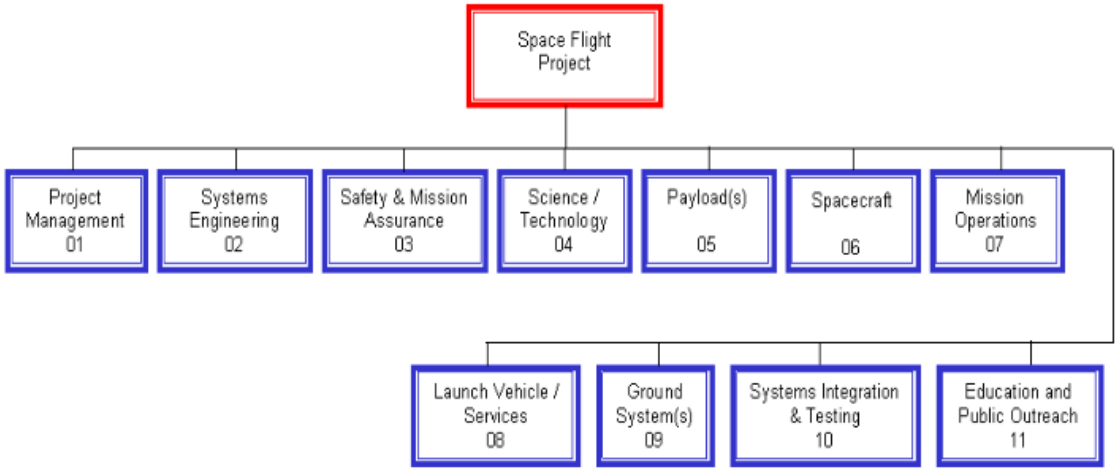


Template for Power Systems Components

WBS Comparison

MIL-STD-881C WBS for Space Systems*

VS.



NPR 7120.5E NASA WBS

*http://www.navair.navy.mil/nawctsd/Resources/Library/Acqguide/MIL-STD%20881C%203%20Oct%2011.pdf

Key Takeaways

- Unique challenges
- Early conceptual estimating
- Commercial tools estimating esoteric hardware
- Systems engineering emphasis

Questions?