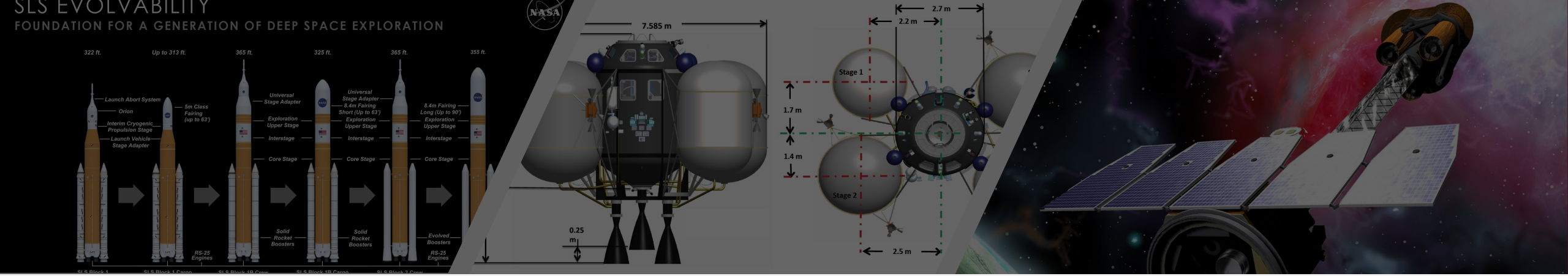


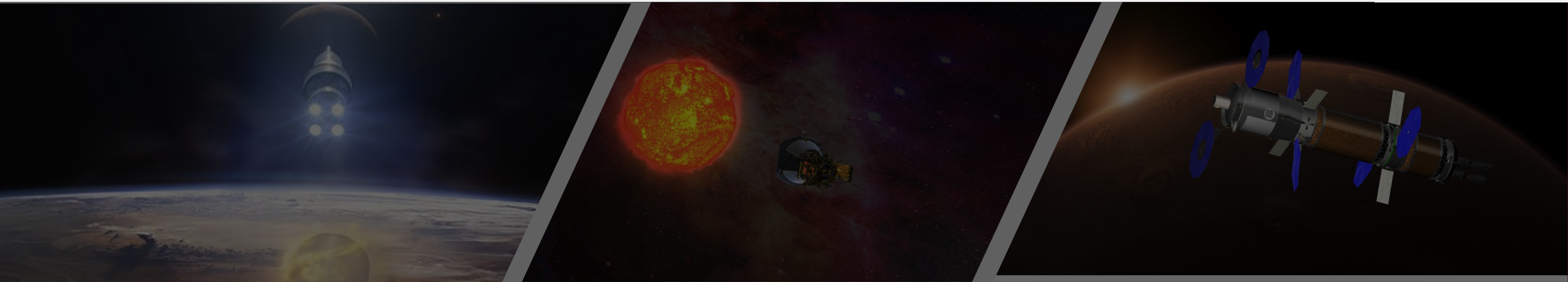
Advanced Concepts Office

NASA George C. Marshall Space Flight Center

Eric C. Sholes, Ph.D., CSEP

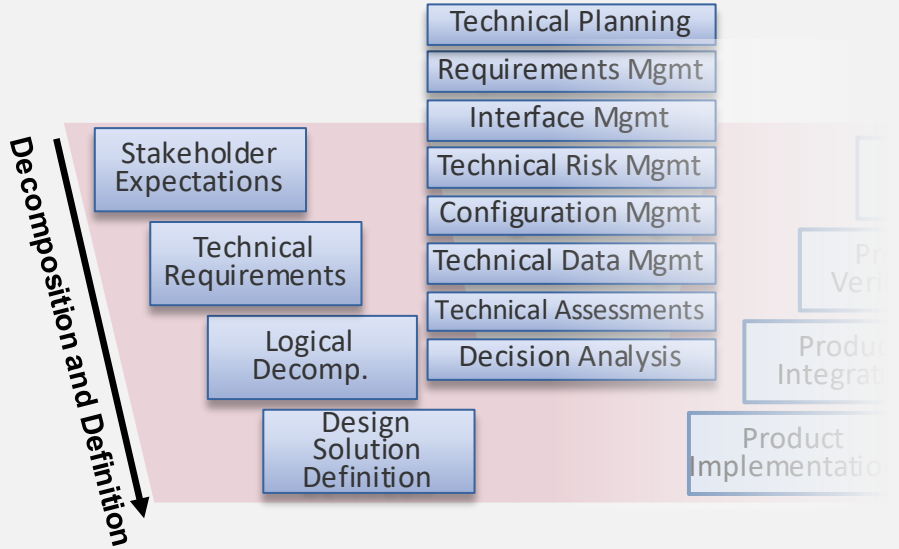
Manager

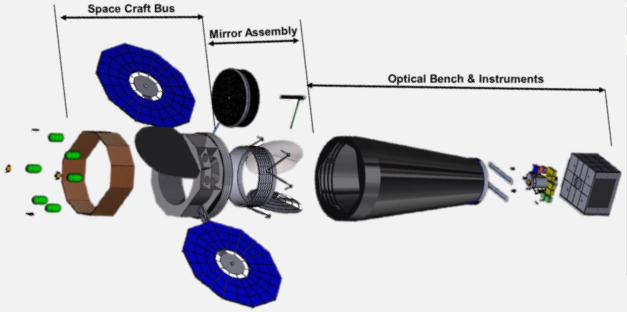
Eric.C.Sholes@nasa.gov

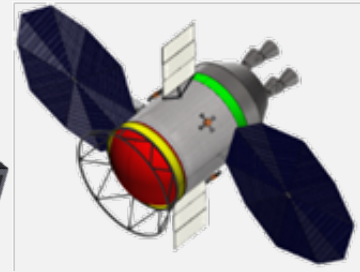


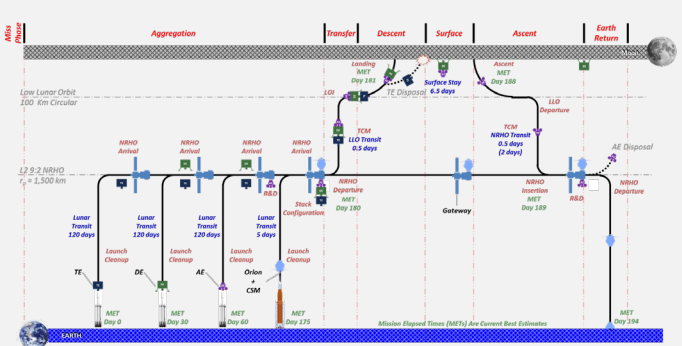
About the Advanced Concepts Office

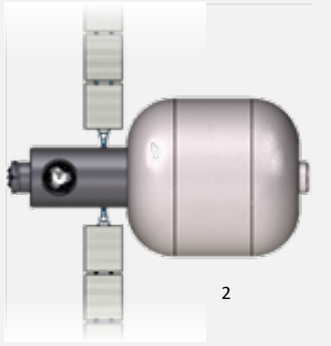
- ACO informs decision makers by providing rapid, Pre-Phase A concept designs and studies for space systems
- Multi-disciplinary team representing all engineering disciplines
- Work Pre-Phase A concept designs and studies
  - Analysis of alternatives
  - Quantitative technology assessments
  - Systems analysis and optimization











The Value of Pre-Phase A Design and Analysis

- It's important to spend a small amount up front to get it right
- Impacts of early decisions reverberates throughout the whole lifecycle
- Explore and compare other COA/alternatives, including ways and means
- Has the potential to reduce cost, risk, performance deficiencies, and uncertainty on programs/projects' lifecycle

Study-tailored study processes

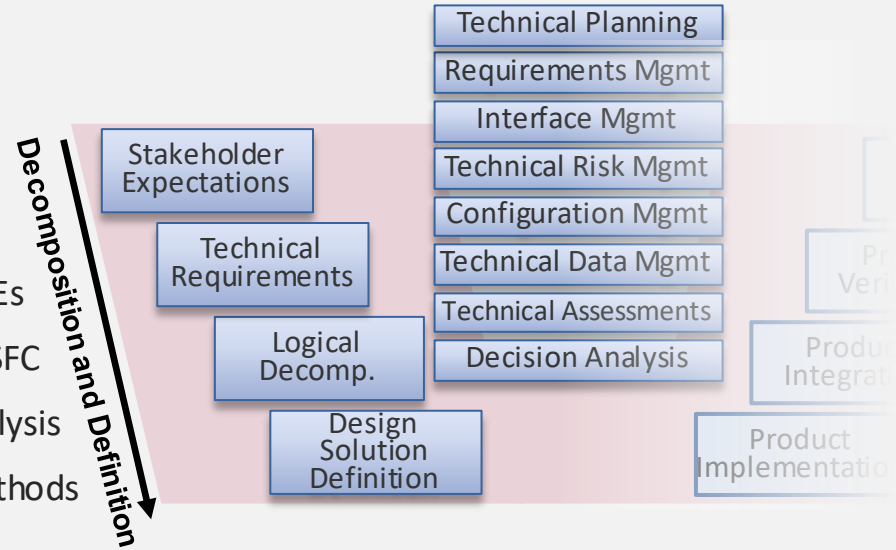
Mature M&S tools

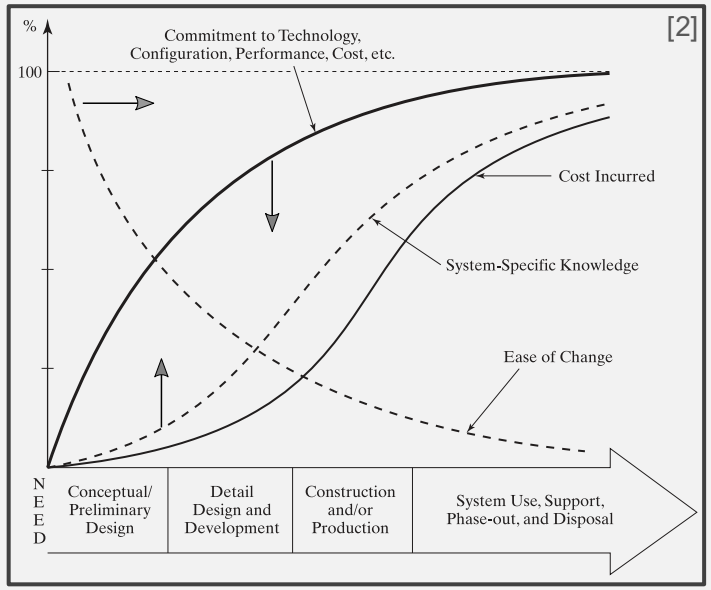
In-house SMEs

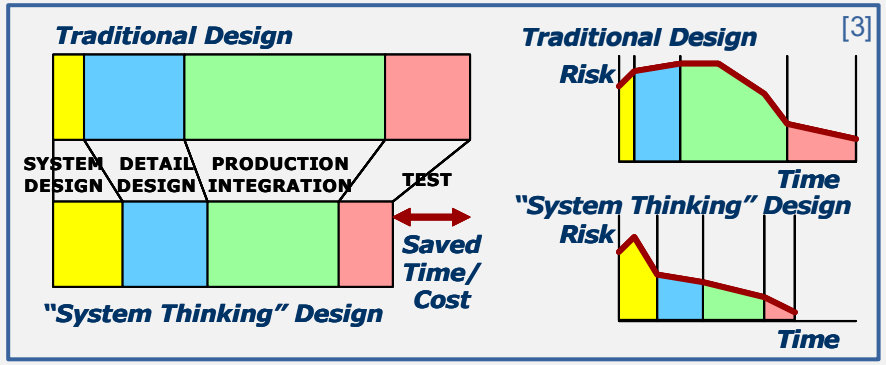
SME reach across MSFC

Multi-disciplinary design and analysis

Suite of design methods



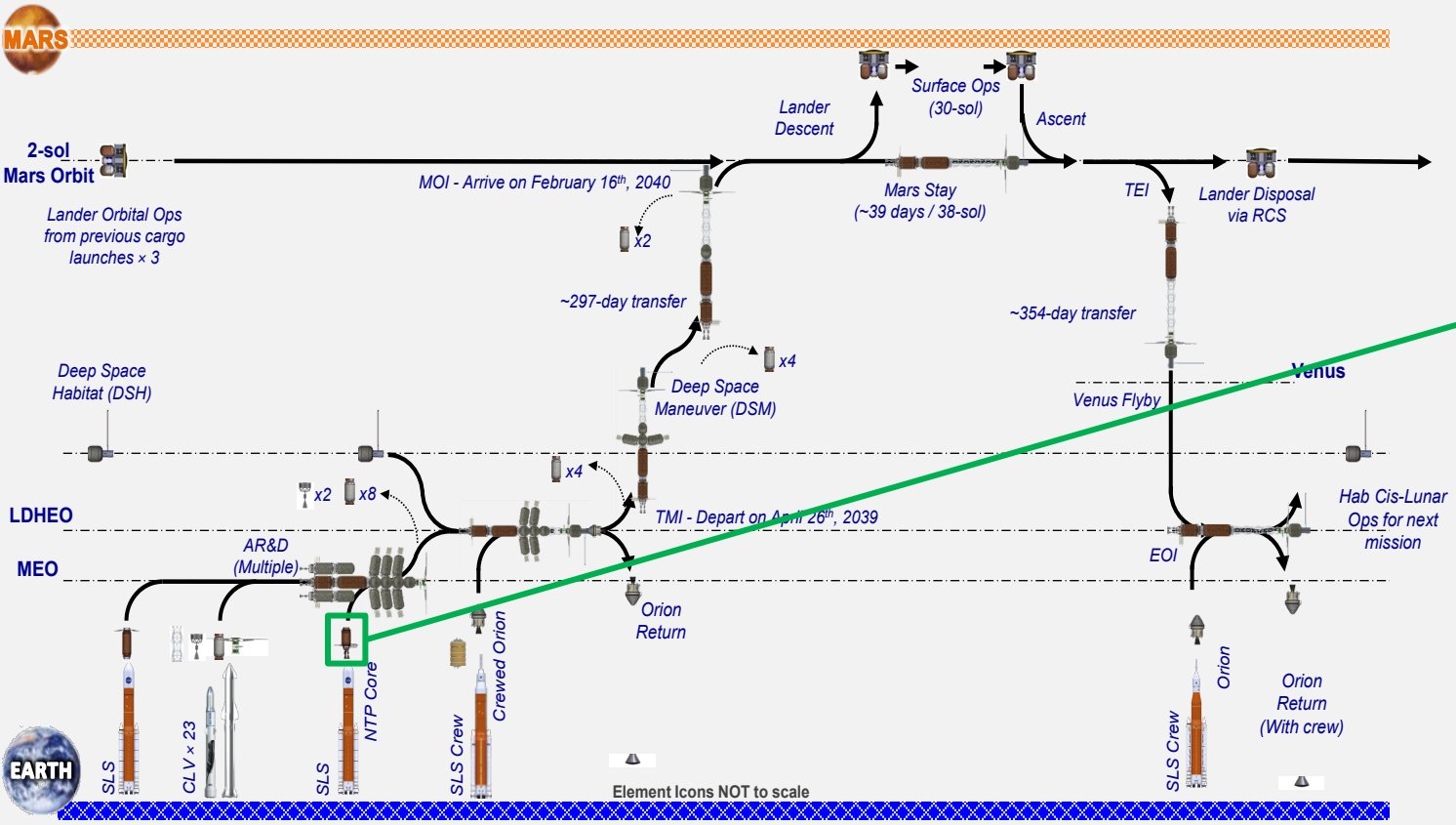


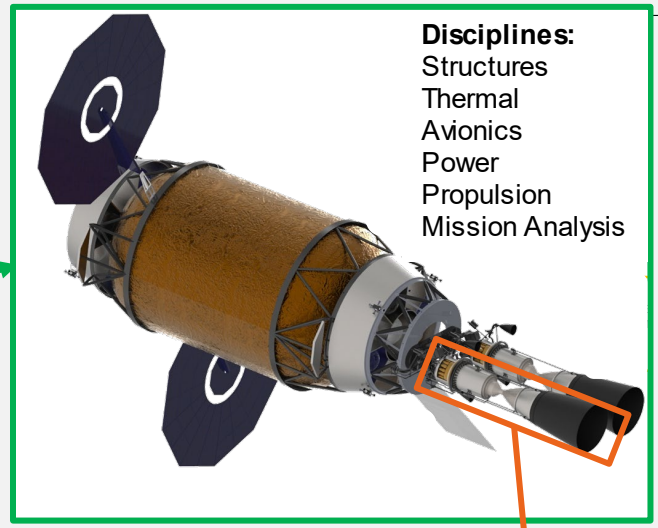


Comprehensive, right-sized early systems engineering has high ROI by enabling programmatic success

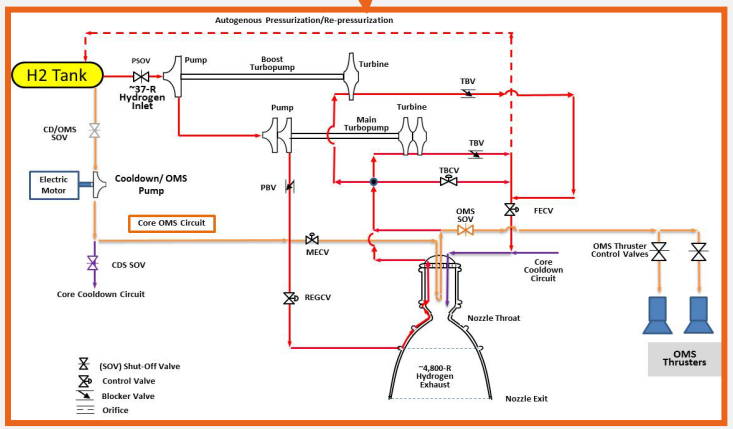
[1] NASA's Systems Engineering Handbook, 2016. NASA SP-2016-6105 Rev2
[2] Blanchard
[3] Honour, E, "Systems Engineering Return on Investment," Defence and Systems Institute, University of South Australia. 2013. Dissertation.

Scope of Analysis Capabilities





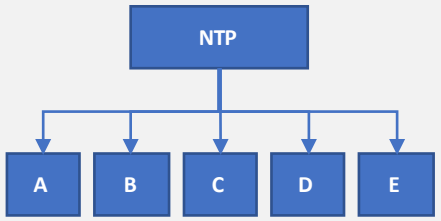
Disciplines:
Structures
Thermal
Avionics
Power
Propulsion
Mission Analysis

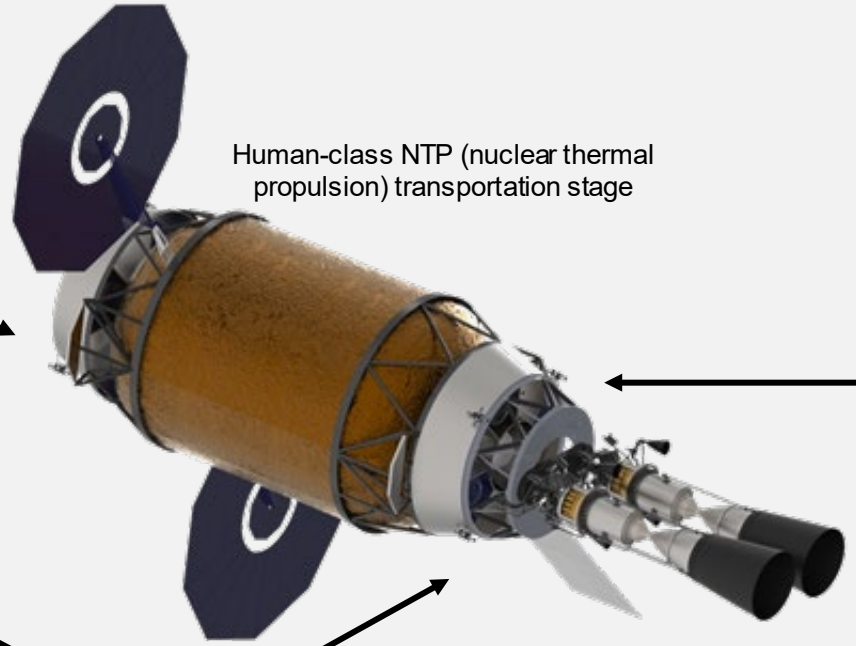


Our expertise includes designing and integrating system-of-systems, systems, and sub systems in Pre-Phase A

Example Architecture Description Products

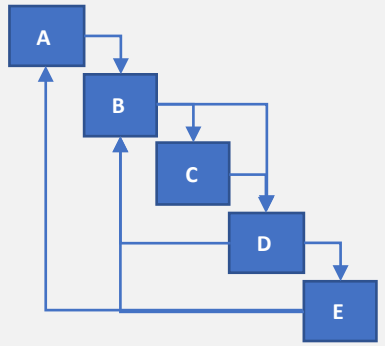
System Architecture





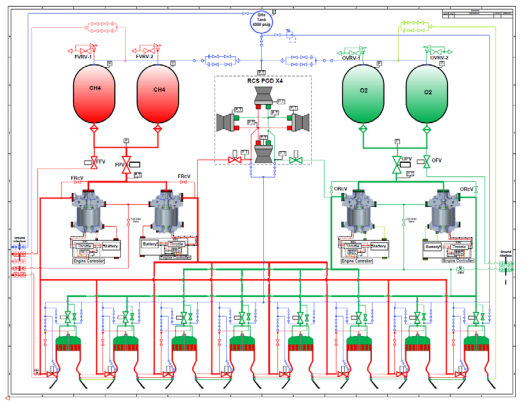
Human-class NTP (nuclear thermal propulsion) transportation stage

Mission Analysis & Design Optimization



Subsystem Design

- Avionics System Design
- Power System Design
- Thermal System Design
- Structural System Design
- Propulsion System Design

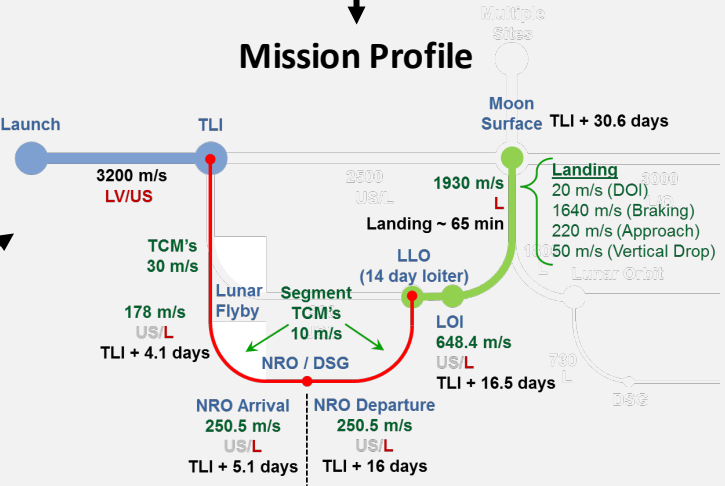


Figures of Merit

- Safety & Reliability
- Environments
- Cost & Schedule
- Risk
- Master Equipment List

MEL - CFM Lunar Lander Demo	Qty	Unit Mass (kg)	Basic Mass (kg)	Contingency (%)	Contingency (kg)	Predicted Mass (kg)
1.0 Structures			1079.60	9.89%	106.74	1186.34
1.1 Frame	1	523.87	523.87	15.00%	78.58	602.45
1.2 Landing Legs (Deployable)	4	17.50	70.00	15.00%	10.50	80.50
1.3 Landing Legs (Static)	4	20.08	80.32	15.00%	12.05	92.37
1.4 Tank Struts (LOX)	16	1.17	18.72	15.00%	2.81	21.53
1.5 Tank Struts (CH4)	16	1.17	18.72	15.00%	2.81	21.53
1.6 Secondary Structures	1	367.97	367.97	0.00%	0.00	367.97
2.0 Propulsion			760.88	20.68%	157.33	918.21
2.1 Thrusters						
2.1.1 MPS Thrusters (6900 N, 2000 lbf)	8	10.0	79.84	25.00%	19.96	99.80
2.1.2 RCS Thrusters (450 N, 100 lbf)	16	4.5	72.64	25.00%	18.16	90.80
2.1.3 Feedlines / Instrumentation	1	34.00	34.00	25.00%	8.50	42.50
2.2 Tanks						
2.2.1 Fuel Tanks (D = 1.94 m)	2	72.28	144.56	25.00%	36.14	180.70
2.2.2 Oxidizer Tanks (D = 1.94 m)	2	72.28	144.56	25.00%	36.14	180.70
2.2.3 Pressurant Tanks (D = 0.77)	2	33.00	66.01	25.00%	16.50	82.51
2.3 Propellant Hardware						
2.3.1 Fill / Drain Valve, Propellant	2	2.27	4.54	10.00%	0.45	4.99
2.3.2 Filter, Propellant	4	1.63	6.52	10.00%	0.65	7.17
2.3.3 Bleed Valve	2	2.27	4.54	10.00%	0.45	4.99
2.3.4 Control Valve	16	2.27	36.32	10.00%	3.63	39.95
2.3.5 PreValve	2	2.27	4.54	10.00%	0.45	4.99
2.3.6 Igniter Valve	16	0.50	8.00	10.00%	0.80	8.80
2.3.7 Vent / Relief Valve	4	2.27	9.08	10.00%	0.91	9.99
2.3.8 Vent QD	2	1.63	3.26	10.00%	0.33	3.59
2.3.9 Isolation Valve	8	2.27	18.16	10.00%	1.82	19.98

Mission Profile



Robust Mars Intro & Objectives

Goal: to develop and exercise a digitally-integrated architecture analysis capability enabling a robust deliberation over the human Mars trade space

- Capability, not a study
  - To be exercised in a collaborative fashion
  - To be used on behalf of the community
  - To be infused into the MAT as the capability matures
- "Robust deliberation" is understood to require
  - Quantification of programmatic metrics for all scenarios and alternatives considered
  - Rigorous evaluation of multiple alternatives
  - Ability to answer "what if" questions by assembling and characterizing new alternatives

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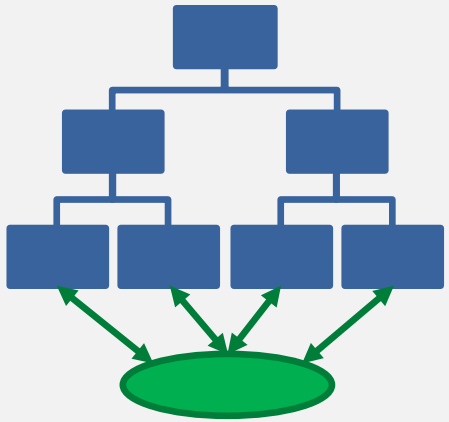
- Why "digitally-integrated?"

Without Digital Integration

- Standard systems engineering approach: decomposition and compartmentalization to manage complexity
- Synthesis requires significant effort for large complex scopes → long cycle times to propagate and reconcile changes

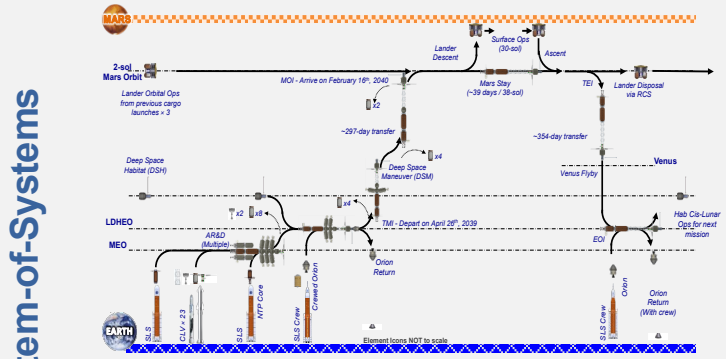


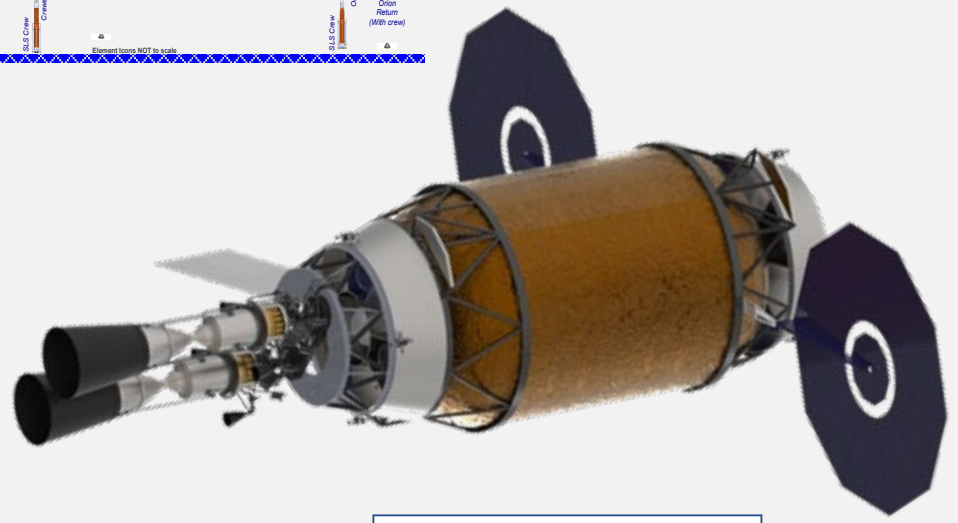
With Digital Integration

- Automation aids integration of complex interfaces
- Provides rigorous configuration management on the architecture
- Reduces architecture synthesis cycle times
- Enables rapid "what if" analyses to be performed, with impacts propagated through the entire architecture

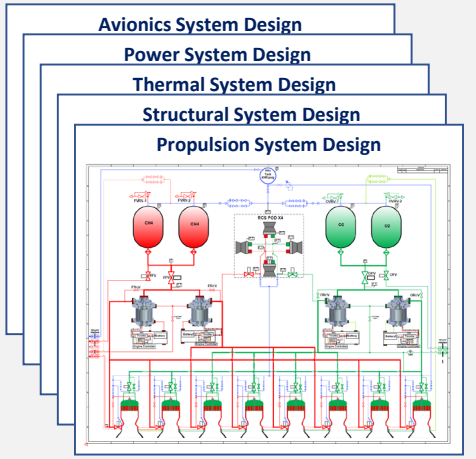
Digitally Integrated System Model

- **Formal Requirements Modeling**
  - Requirements captured in Formal Modeling Language rather than natural (human) language
  - Logic encoded to enable automated Verification
- **Logical Decomposition Modeling**
  - Requirements flowing System-of-Systems→Systems→Subsystems→Components
  - "Correct-by-Construction" architecting paradigm enabled by ontological design axioms
- **Component-based Design & Systems Analysis**
  - Physics and behaviors of components modeled with standardized interfaces for plug-and-play functionality
  - Functional and Physical characteristics encoded
- **Integrated Architecture Synthesis**
  - Integration at the digital (model-based) level enables automation and rapid multi-level trades





System-of-Systems → System → Subsystem → Component



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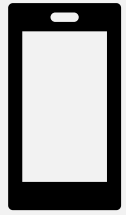

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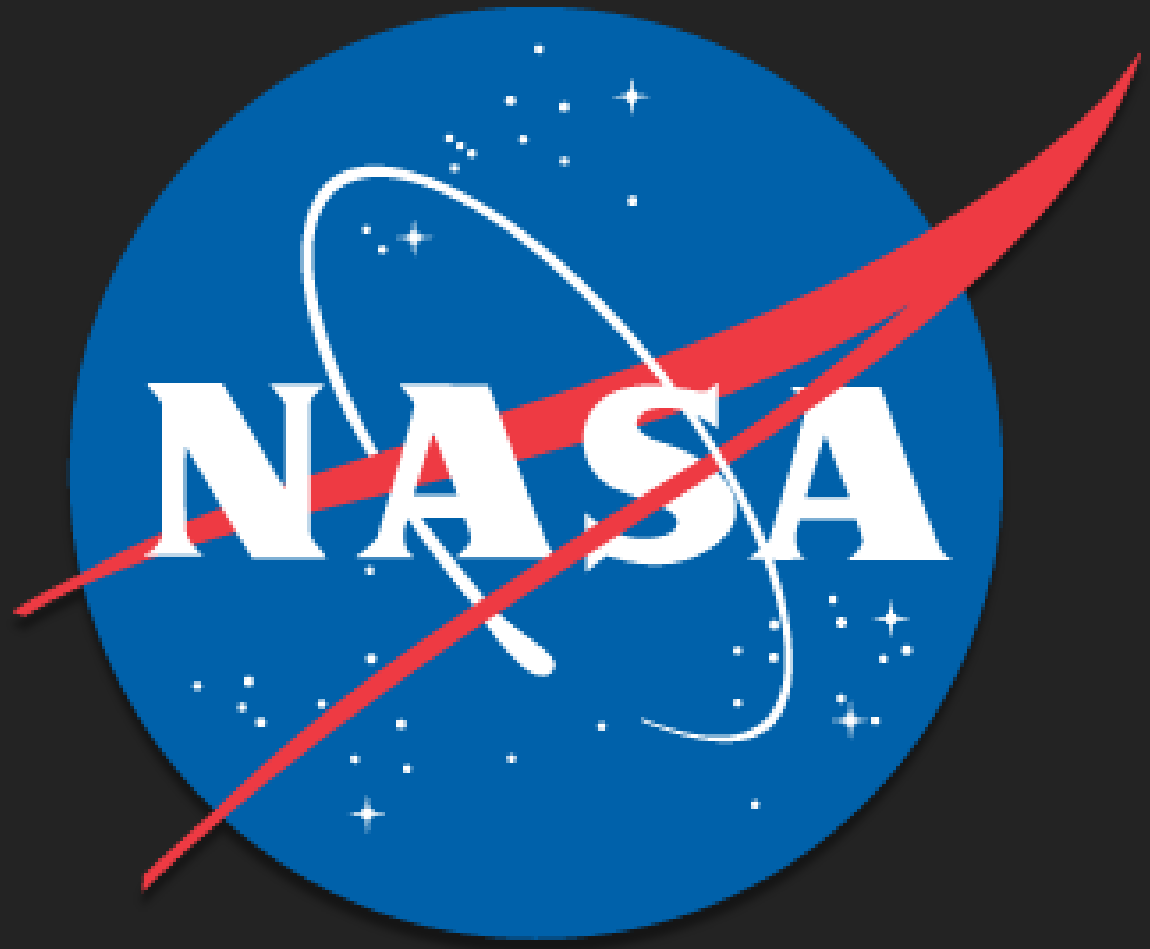
(256) 200-5056

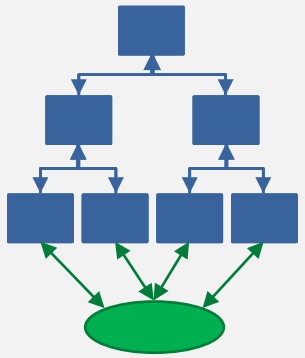

NASA

Evolving Pre-Phase A Capabilities at NASA

- Transformation objectives remain
  - Reduced analysis cycle times
  - More AoA throughput
  - Facilitating complex decisions w large, multi-faceted datasets
  - Propagate impact of decisions from the component to SoS level

Without Digital Integration

- Standard systems engineering approach employs decomposition and compartmentalization to manage complexity
- Synthesis requires significant effort for large, complex scopes
- Extended analysis cycle time to propagate and reconcile changes
- Configuration management becomes increasingly difficult with large multi-element architectures
- Limited AoA trades



With Digital Integration

- Enables concurrent processes
- Aids integration of complex SoS and interfaces
- Provides rigorous configuration management on the architecture
- Reduces architecture synthesis cycle times
- Enables rapid "what if" analyses to be performed, including impacts propagated through the entire architecture
- Provides a basis to evolve the SoS, e.g. open architectures

The need for a **digitally-integrated** Pre-Phase A paradigm provides a compelling value proposition

Our on-going investments to realizing DI