National Aeronautics and Space Administration

Way Forward

Space Launch System (SLS)

Garry Lyles
SLS Chief Engineer
April 2011

Policies and Processes

2009

Augustine Committee Final Report (October)

"A heavy-lift launch capability to LEO, combined with the ability to inject heavy payloads away from the Earth, is beneficial to exploration and it also will be useful to the national security space and scientific communities."

2010

FY11 Budget Submittal (February)

2010 U.S. Space Policy (June)

"U.S. access to space depends…on launch capabilities. U.S. Government payloads shall be launched on vehicles manufactured in the United States unless exempted…"

President Signs Budget Authorization (October)

"Directs NASA to initiate development of an SLS with the capability to lift between 70 and 100 tons into LEO without an upper stage, to carry an Earth departure stage bringing the total lift capability to 130 tons or more, to lift the MPCV, and to serve as cargo backup for ISS cargo requirements or crew delivery not otherwise met by available commercial or partner-supplied vehicles. Sets a goal for core operational capability by 12/31/16."

2011

2011 NASA Strategic Plan (February)

Goal 1: Extend & sustain human activities across the solar system.

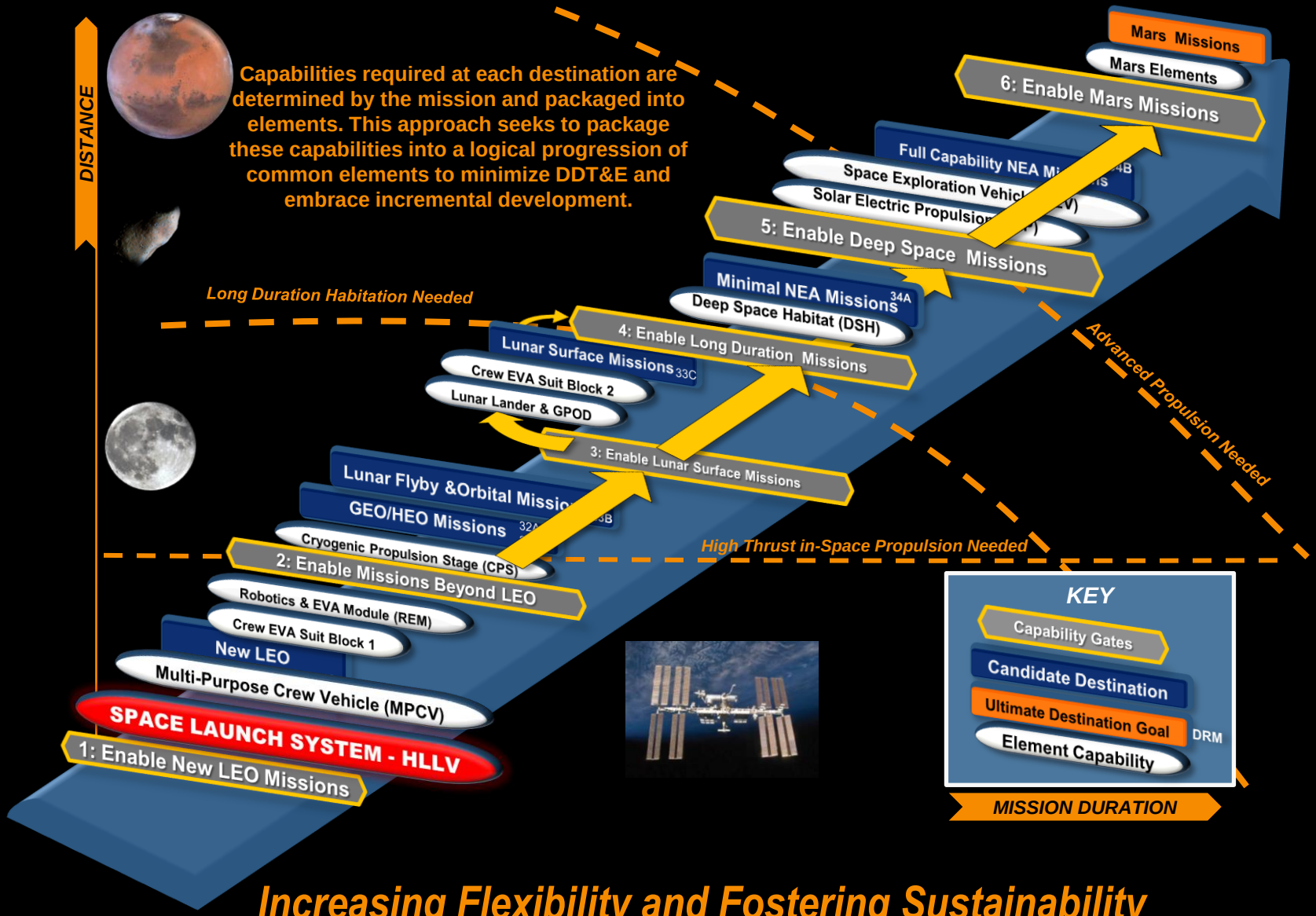
Objective 1.3: Develop an integrated architecture & capabilities for safe crewed & cargo missions beyond LEO.

FY12 Budget Submittal (February)

"NASA will continue architecture planning for the MPCV capable of taking human explorers to distant locations throughout the inner solar system. The SLS Program will develop the heavy-lift vehicle that will launch the MPCV, other modules, and cargo for these missions."

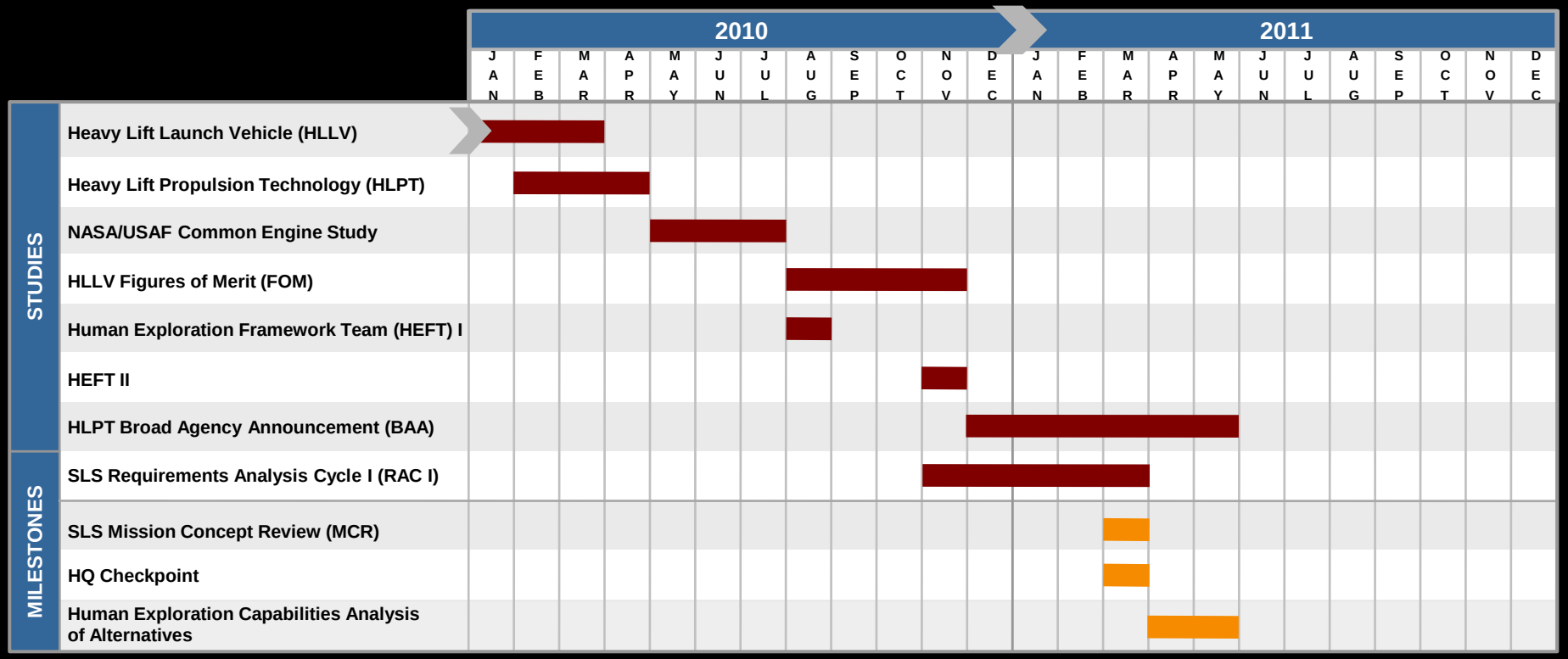
Implementing the Nation's Space Agenda

Capabilities-Driven Framework



Increasing Flexibility and Fostering Sustainability

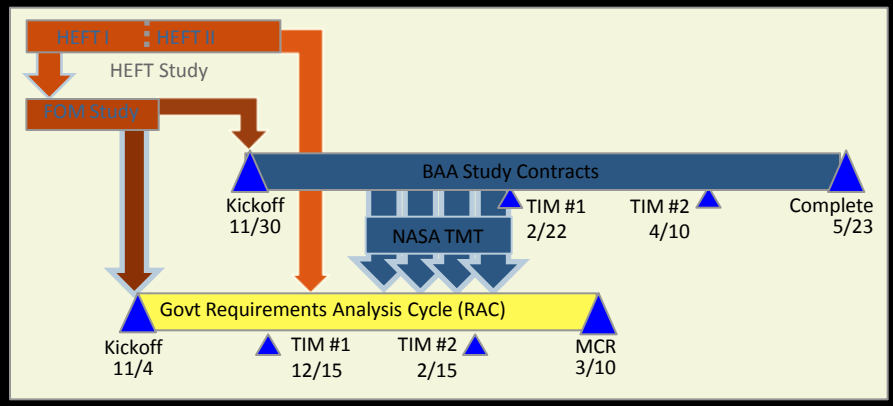
Space Launch System Progress Report



Using the Results of Over 2,000 Architectures Studied Over the Last 10 Years

Background

- **HEFT and FOM studies (Fall 2010) concluded without architecture decisions**
- **Government Requirements Analysis Cycle (RAC) – K/O Nov 4**
  - Three competing configurations with fourth team looking at cross-cutting affordability
  - Common requirements (from HEFT), goals/threshold approach - tradeable
  - Incorporate incremental inputs from BAAs
  - Play-to-win marching orders
  - Outbrief to SLS Feb 16-18

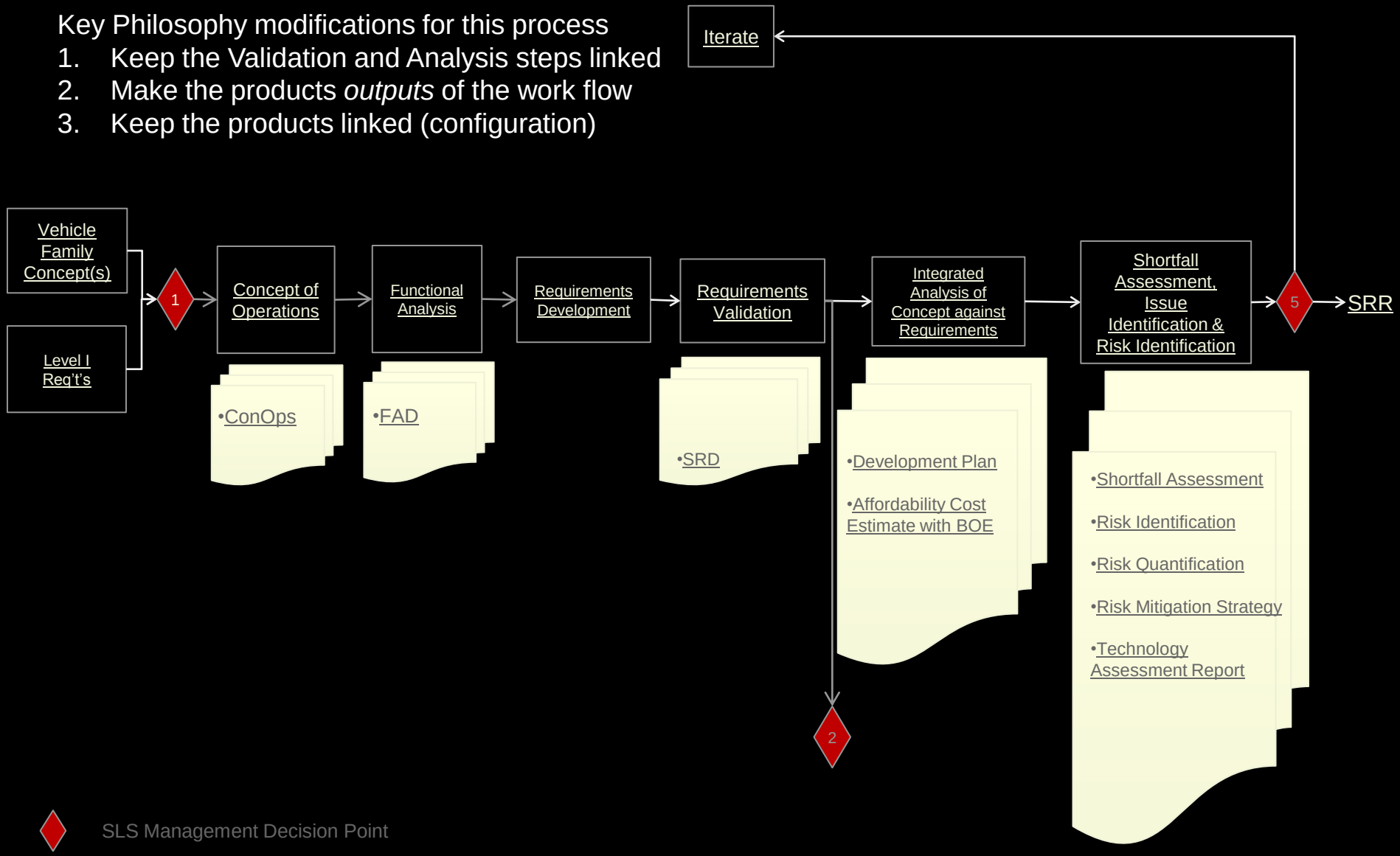


- **Contractor Broad Agency Announcement (BAA) – K/O Nov 30**
  - 13 Contractors, $650K each, 6 month studies – broad SOW ideas
  - Initial Outbriefs Feb 22-24
- **Mission Concept Review (MCR) – Mar 10**
  - Required prior to KDP-A per NPR 7123 and NPR 7120.5
  - Included RAC and BAA inputs and standard MCR products from SLS planning team
  - Independent **Special Review Team (SRT)** : Chair: JPL/Tom Gavin, Members: JSC/Steve Labbe, JPL/Brian Muirhead, MSFC/Dale Thomas, SSC/Rick Gilbrech, Review Mgr: Vern Hall

Work Flow and Product Development to SRR

Key Philosophy modifications for this process

1. Keep the Validation and Analysis steps linked
2. Make the products *outputs* of the work flow
3. Keep the products linked (configuration)



SLS RAC Study Plan

- **RAC Teams Scope:**
  - Team 1 – Hydrogen Core Configuration with multiple evolution paths
  - Team 2 – Large RP Configuration (large diameter tanks) with multiple engine options, including NASA/USAF common engine (ref. May/June joint study)
  - Team 3 – Modular RP Configuration (smaller diameter tanks) with multiple engine options, including NASA/USAF common engine
  - Team 4 - Focused on generic affordability issues (whitepaper released)

- **Three major objectives**
  - Incorporation of **Affordability** into the product life cycle
  - Initial requirements development cycle
  - Incorporate and demonstrate lean systems engineering and integration

- **Collaboration**
  - Teams and/or Steering Committee included reps from 9 of 10 Field Centers

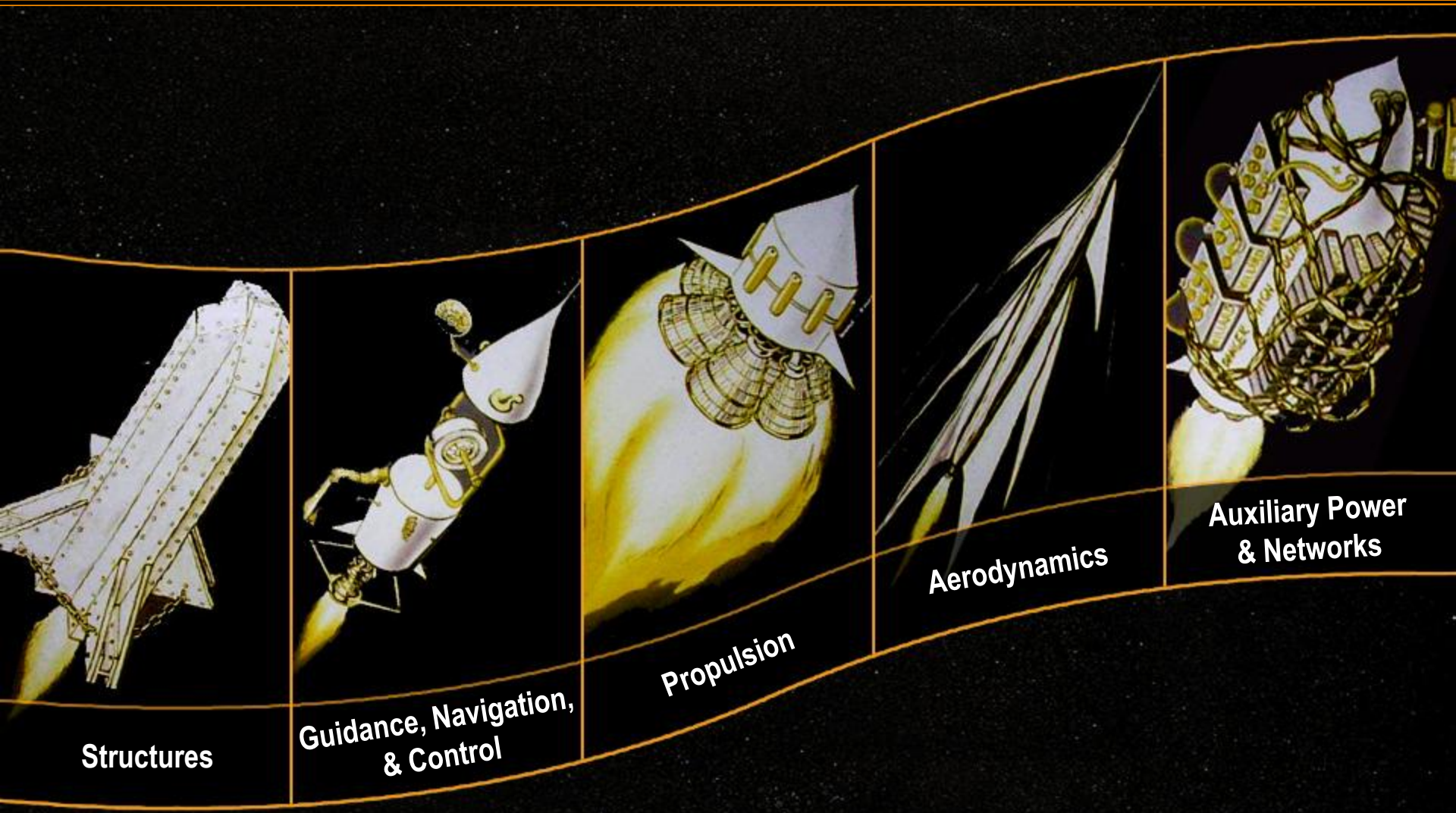
SLS Affordability

- **Affordability – The ability to develop and operate the SLS within the National means to sustain funding for the program.**
- **Architectures which optimize development and operations cost (i.e., meet the performance objectives and minimize cost relative to other options) are considered to be more affordable.**
- **Affordability encompasses**
  - Vehicle Capabilities to enable affordable use and sustaining operations
  - Complete Life Cycle
    - Development
    - Test
    - Manufacturing
    - Sustaining and Operations (fixed costs and variable costs)
- **Affordability Considerations**
  - Block Upgrades to phase capabilities for cost effectiveness

Affordability Team 4 Summary

- **Path to affordability will require changes to management and engineering approaches. Not something added or delegated to an affordability office or group.**
- **Affordability must be a design driver. Decisions made early in program formulation will lay the groundwork for affordability.**
- **Early efforts to solidify requirements and define content of contracts and work packages will result in greatly reduced change traffic.**
- **Time to develop a launch vehicle is a significant cost driver**
- **Specific recommendations based on CxP lessons**
  - Identify approaches that simplify designs, manufacturing and analysis and optimize operations cost
  - Identify and implement specifications and standards appropriately
  - Change the approach to insight/oversight
  - Improve cost management through better program planning
  - Reduce inefficiencies due to premature baselining of documents
  - Tighten control on requirements changes/creep
  - Reduce the timeline for decision making and change processing
  - Implement tracking metrics and feedback systems to measure change effect on cost and schedule
  - Optimize S&MA processes

Requirements Drive the Solution



A designer knows he has achieved perfection not when there is nothing left to add, but when there is nothing left to take away. — Antione de Saint Exupery

* RAC Requirements Goals/Thresholds for RAC Team

Objectives	THRESHOLD		Actuals / Notes
DDT&E Cost ($B)	16	11.5	
P&O Cost ($B)	1.75	1.20	
Schedule (years)	2019	2016	
Performance (t)	100	150	
LOM* (w/o engine out) (w/FS engine out)	1:100	1:350	
LOC (w/o engine out) (w/FS engine out)	1:700	1:3500	
Human Rating	Ratable	Rated	
Payload Accommodation (Height / Diameter)	21m x 8.4m dia 30m x 10m dia.	25m x 10m dia 30m x 10m dia.	
Launch Processing	High Assurance	Best in World	
Flight Rate	1 / 2	1 / 4	
Commonality Potential	none	some	
Partnership Potential	none	some	
Other Use Options	none	some	
Extensibility Options	none	some	

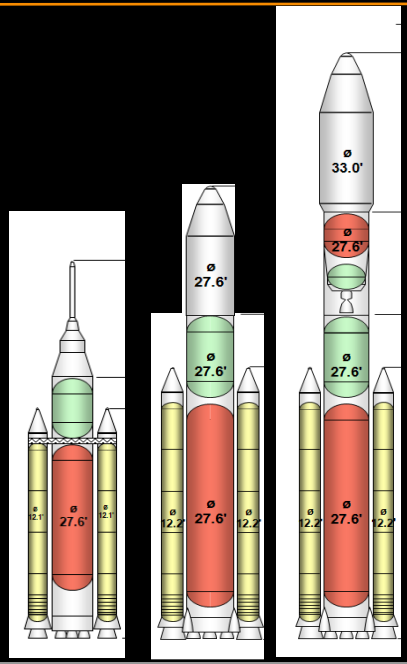
OTS = OFF THE SCALE

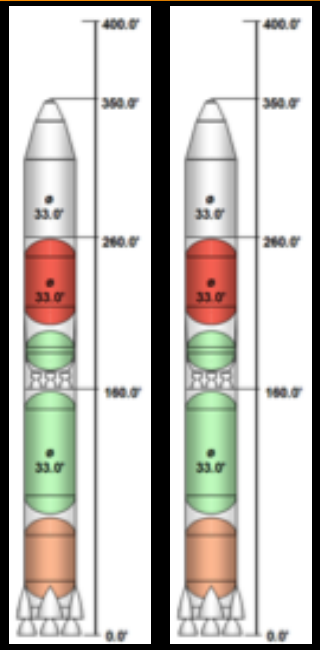
= All Configurations

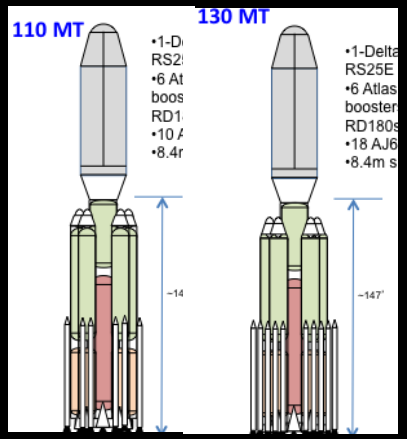
RAC Team Dynamics

- **A competitive undertone was established between the teams to produce the most affordable configuration within the Level 1 Study objective trade space**
  - Prize: Pizza and Beer!
- **Led to a motivated and invigorated trade study**
  - Very open with challenging traditions
- **Each team had a unique group personality**
  - Interpreted implementation of the organizational model
  - Each team adopted different perspectives on how to approach affordability
- **Each team's personality can be seen in the way they structured and presented their analysis**

RAC Configurations Selected for Feasibility Analysis







	RAC Team 1	RAC Team 2	RAC Team 3
Block 1	Block 0 (crew) + Block 1 w/Engine-Out w/ accelerated, competed composite SRBs	"5-3" Configuration* w/ Engine-Out Capability	6 liquid boosters (crew & cargo) + 6x10 solid boosters (cargo)
Block 2	Block 1 w/Engine-Out + RS-25E 2nd Stage	"7-5" Configuration* w/ Engine-Out Capability	6x18 configuration

Same vehicle w/alternative engine arrangement

MCR Summary

- **Concepts are possible that meet a relaxed set of mission requirements and projected budget constraints**
- **Concepts are possible that meet mission requirements and projected budget constraints in a phased approach.**
- **BAA inputs have been evaluated for applicability to SLS; a subset has been incorporated**
- **Significant concept flexibility exists to deal with maturing mission requirements and budget constraints**
- **Recommend proceeding to mature feasible concepts**
  - Phased development approach
  - Stable, internally consistent requirements