Launch Options - Future Options

- Constellation Architecture
- Commercial Alternatives
  - SpaceX
  - Orbital Sciences
- EELV Options
- DIRECT
- Side-Mount Shuttle Derived
- Space (or “Senate”) Launch System
- Recent Developments

Attribution

- Slides shown are from the public record of the deliberations of the Augustine Commission (2009)
- Full presentation packages available at http://www.nasa.gov/offices/hsf/meetings/index.html

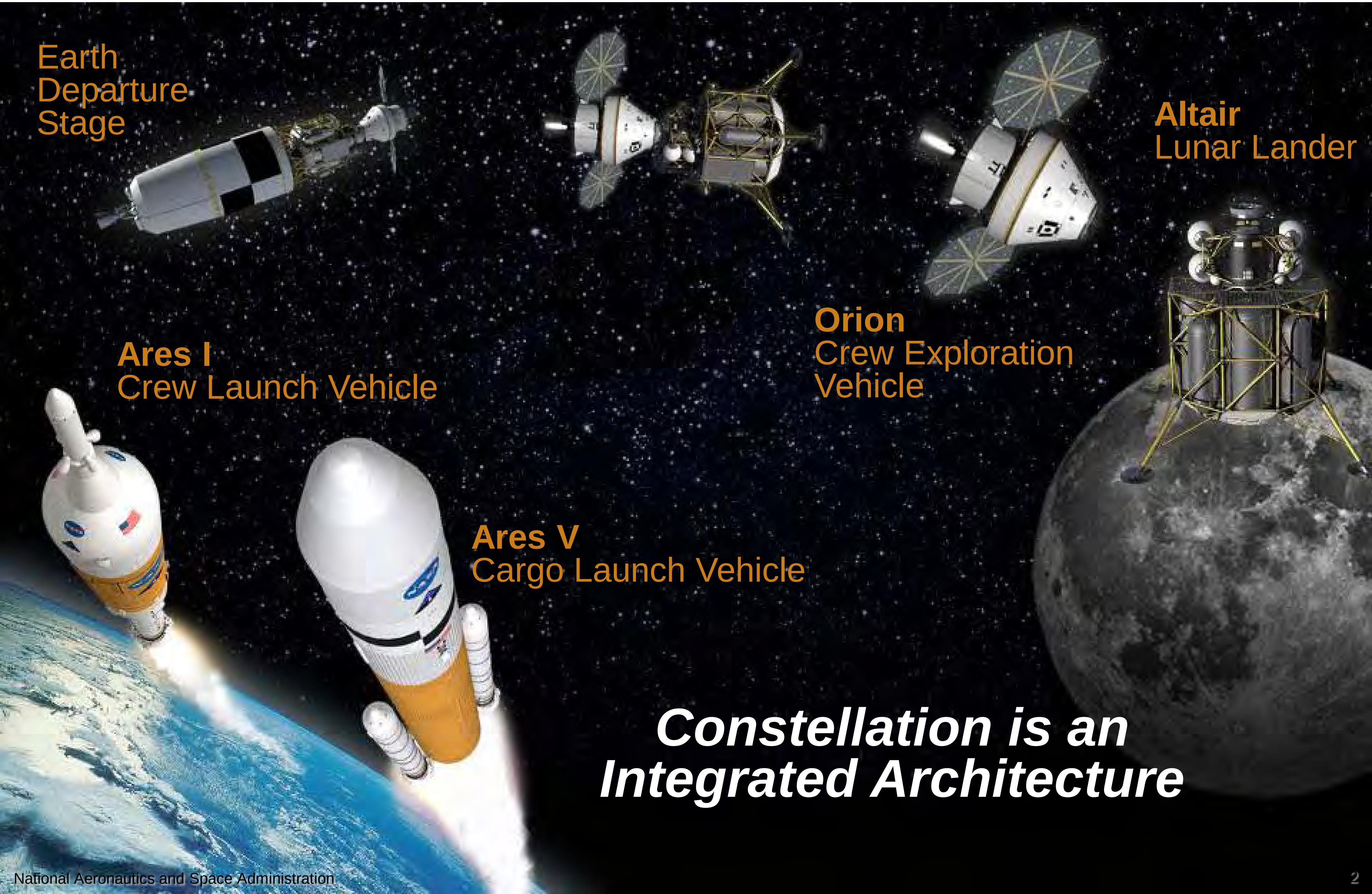
Review of Human Spaceflight Plans

Constellation Overview

June 17, 2009

Doug Cooke
Jeff Hanley

Constellation Architecture

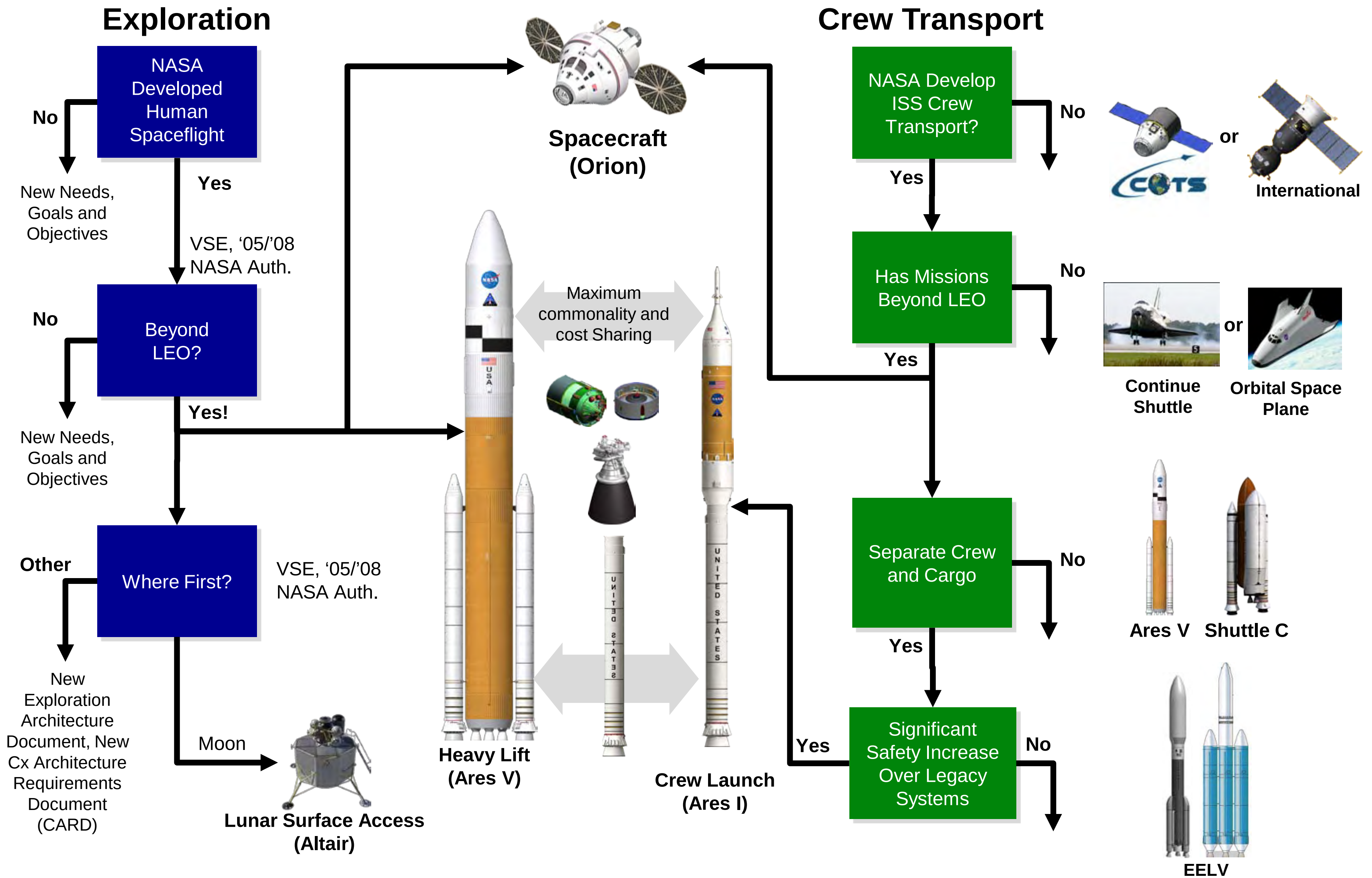


Key Exploration Objectives

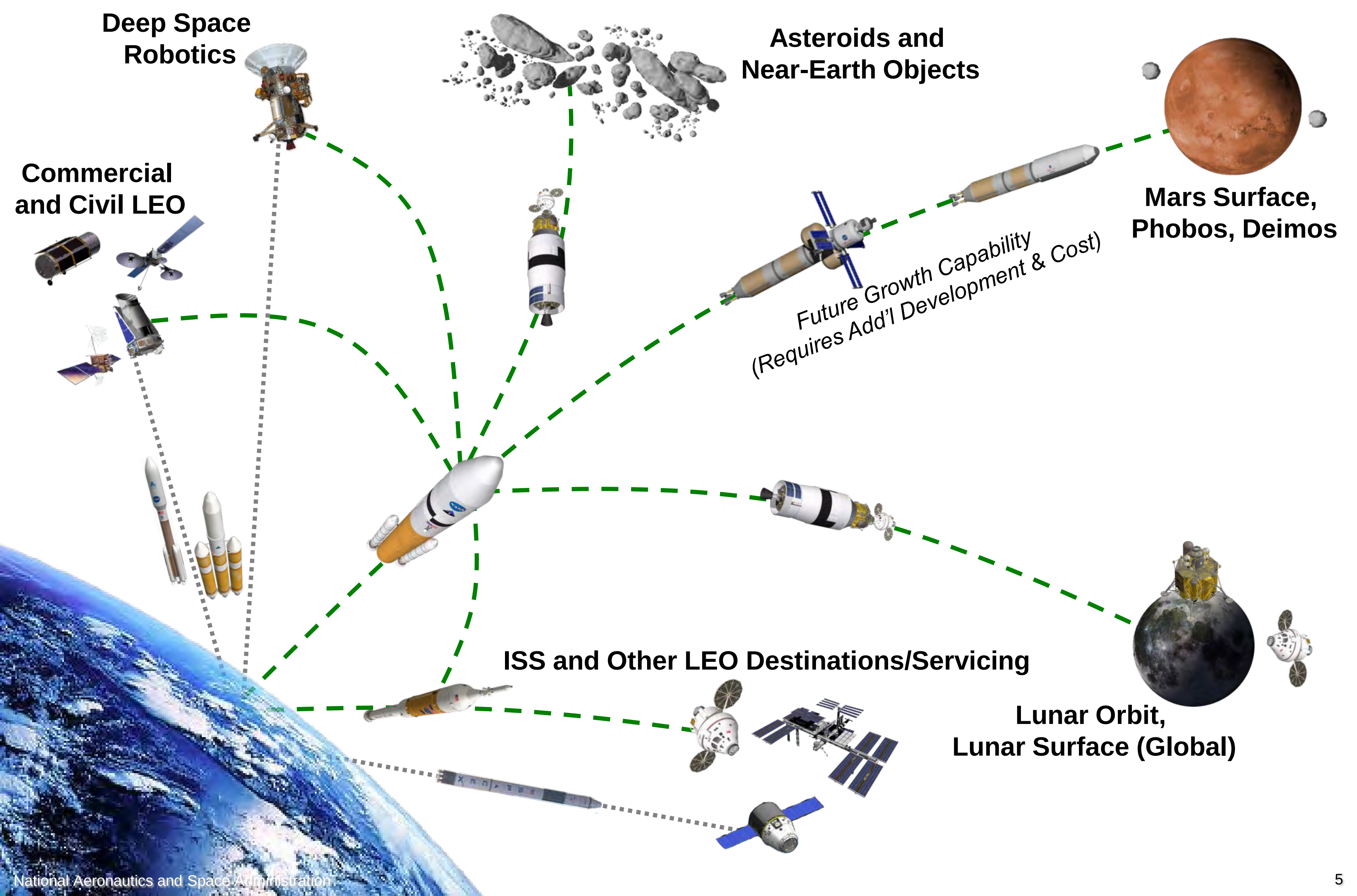
1. Replace Space Shuttle capability, with Shuttle retirement in 2010
2. To ensure sustainability, development and operations costs must be minimized
3. Develop systems to serve as building blocks for human exploration of the solar system using the Moon as a test bed
4. Design future human spaceflight systems to be significantly safer than heritage systems
5. Provide crew transport to ISS by 2015, to the lunar surface for extended durations by 2020, and to Mars by TBD
6. Separate crew from cargo delivery to orbit
7. Maintain and grow existing national aerospace supplier base
8. Provide global lunar access to maximize science return
9. Lunar "any time return" is a safety requirement
10. Utilize ISS to support exploration goals
11. Promote international and commercial participation in exploration

Solutions Must Be Addressed Through an Integrated Architecture

Influence of Key Drivers on Architecture Selection



Current Development for Future Exploration Capabilities



Transition of Shuttle Capabilities

- **Constellation makes extensive use of Shuttle capabilities, but in a leaner, smaller footprint to reduce life cycle costs:**
  - JSC: Crew systems and mission operations
  - KSC: LC39, VAB, O&C, SSPF
  - MSFC: Large scale launch vehicle development and test
  - SSC: Large scale liquid propulsion test
  - MAF: Large scale cryogenic stage production
  - ATK: Large solid rocket motor development, production and test
  - PWR: Large liquid engine development and production

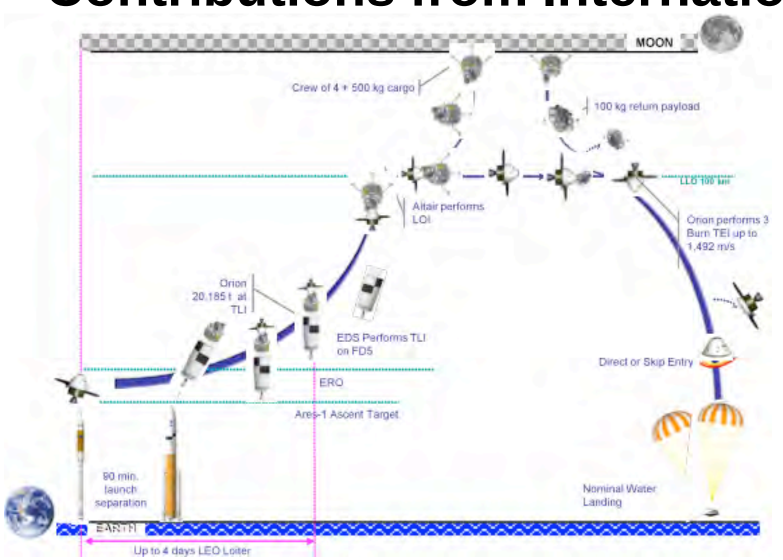
- **Significant synergy in capabilities of the human spaceflight workforce between Shuttle, ISS and Constellation**

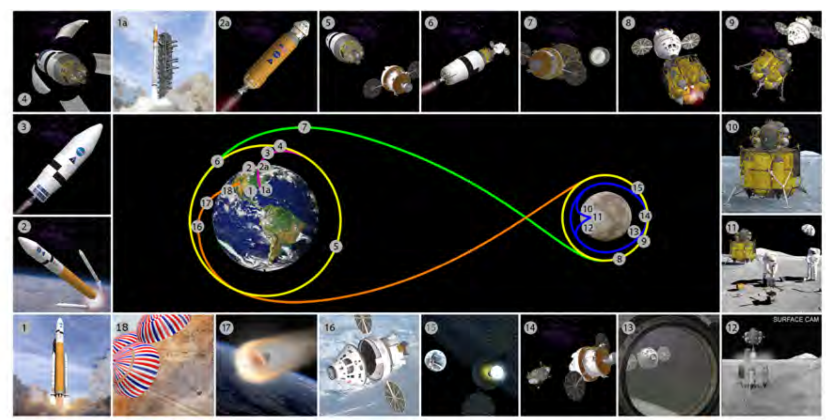
- **Challenge is in converting a large, fixed base LEO-capable workforce to a beyond-LEO architecture in a cost effective manner**

- **The U.S. has a unique, once-in-a-generation opportunity to capitalize on Apollo and Shuttle investments**

Overview of Lunar Capability

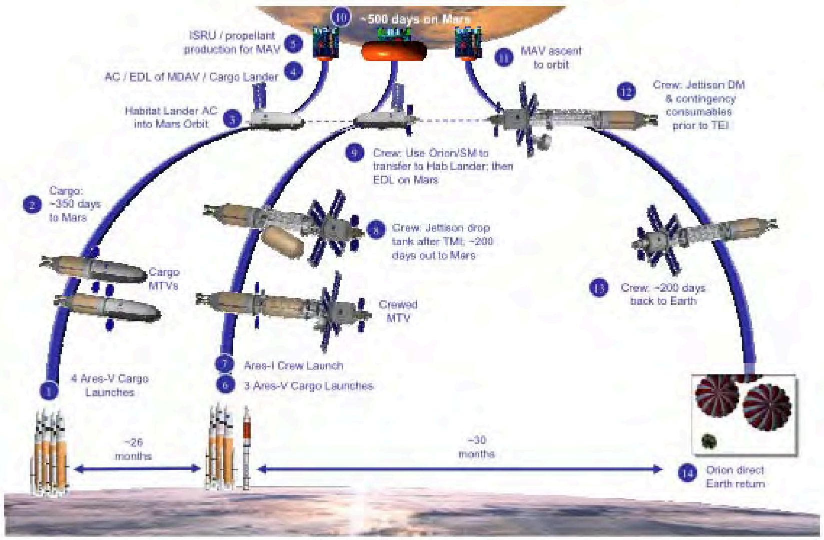
- **Constellation Transportation Architecture Enables Independent Delivery of Crew and Large Cargo to the Surface of the Moon:**
  - 4 crew members
  - 7 days (living out of lander in sortie mode)
  - 210 days (crew at outpost with lander waiting in standby)
  - Global surface access
  - Anytime return to Earth
  - 14 metric ton cargo to surface on a single launch
- **Lunar Surface Systems Currently Under Study, Including Contributions from International Partners**





1. Ares V liftoff.
2. Solid Rocket Booster (SRB) separation.
3. Earth Departure Stage (EDS) fires for Earth Orbit Insertion (EOI).
4. Payload shroud separates to expose Altair Lunar Lander.
1a. Ares I liftoff.
2a. Upper Stage fires for EOI.
5. Orion docks with Altair/EDS.
6. EDS fires for Trans-Lunar Injection (TLI).
7. Orion and Altair undock from EDS.
8. Altair fires for Lunar Orbit Insertion (LOI).
9. Altair separates from Orion.
10. Altair lands on lunar surface.
11. Conducting activities on the lunar surface.
12. Altair ascent stage liftoff viewed from surface camera.
13. Altair ascent stage prepares to dock with Orion.
14. Altair ascent stage and Orion separate.
15. Service Module (SM) fires for Trans Earth Injection (TEI).
16. Orion separates from SM.
17. Orion re-enters Earth atmosphere.
18. Chutes open for recovery.

Overview of Mars Extensibility



Mission Cargo (2) | Propulsion Systems (3)

Cargo Mission
- Surface Habitat
- Cargo Lander
- Outbound Propulsion

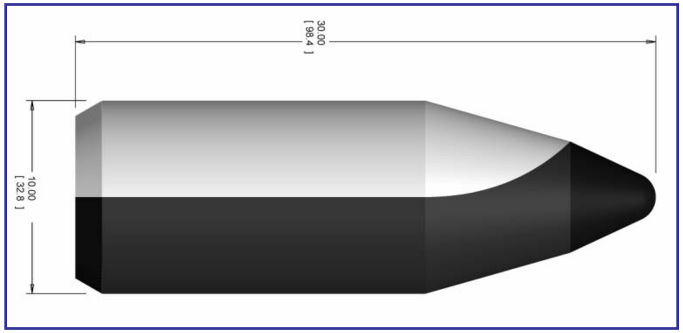
Previous Opportunity
5 Ares V Launches

Crew Hab (1) | Propulsion Systems (3) | Crew

Crew Mission
- Transfer Habitat
- Roundtrip Propulsion
- Orion

Current Opportunity
4 Ares V Launches

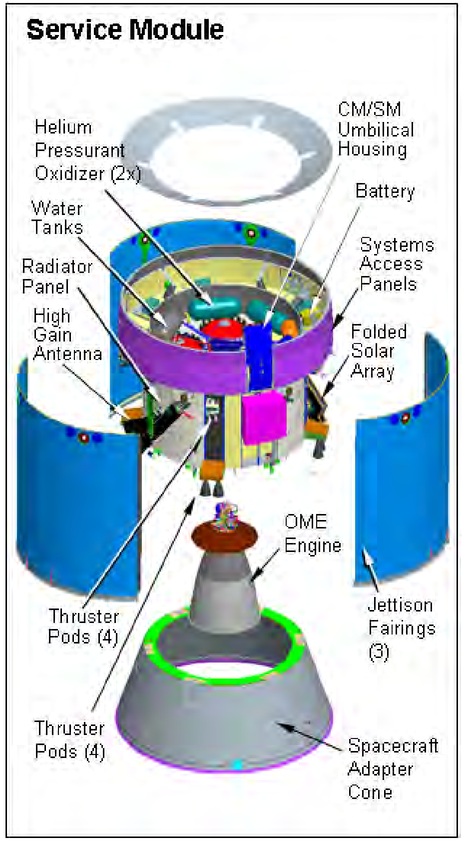
- **Current Human Mars Mission Highlights:**
  - Long stay (conjunction)
  - Pre-deployed assets
  - Nuclear thermal in-space propulsion
  - 9 Ares V launches
  - Preliminary assessments indicate launch vehicle shroud can be used for both ascent to LEO as well as entry, descent, & landing aeroshell structural element

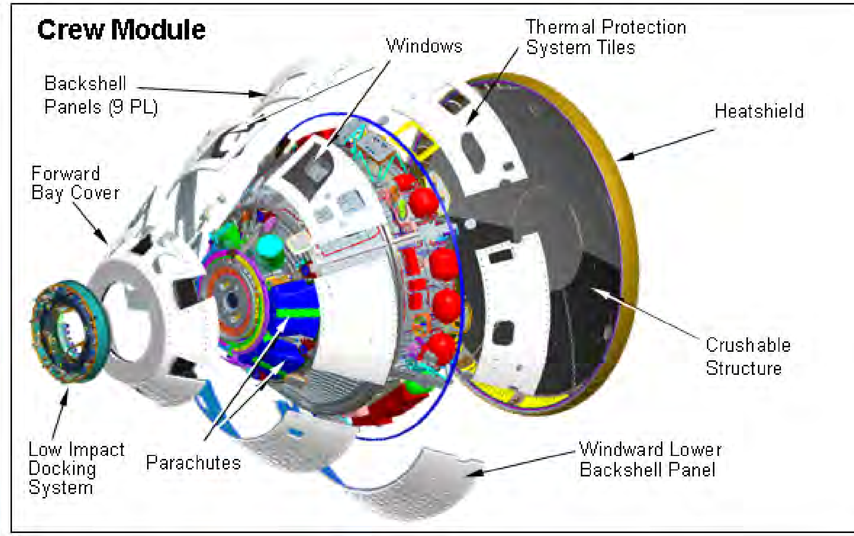


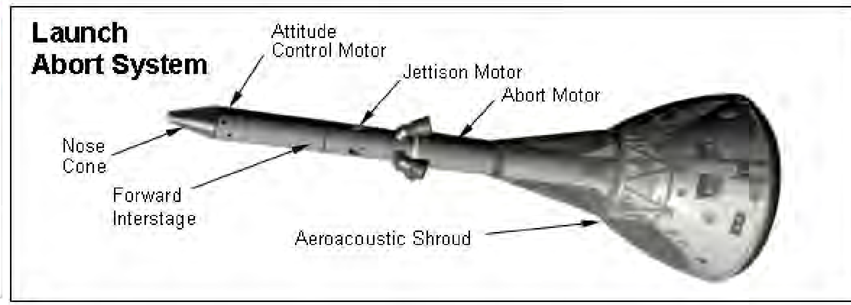
Orion Elements

Over $6.3B in Prime Contract Value

- ***Prime Integration Contractor Team***
  - Lockheed Martin-led consortium with:
    - Honeywell
    - Hamilton Sundstrand
    - Aerojet
    - Orbital Sciences
    - United Space Alliance







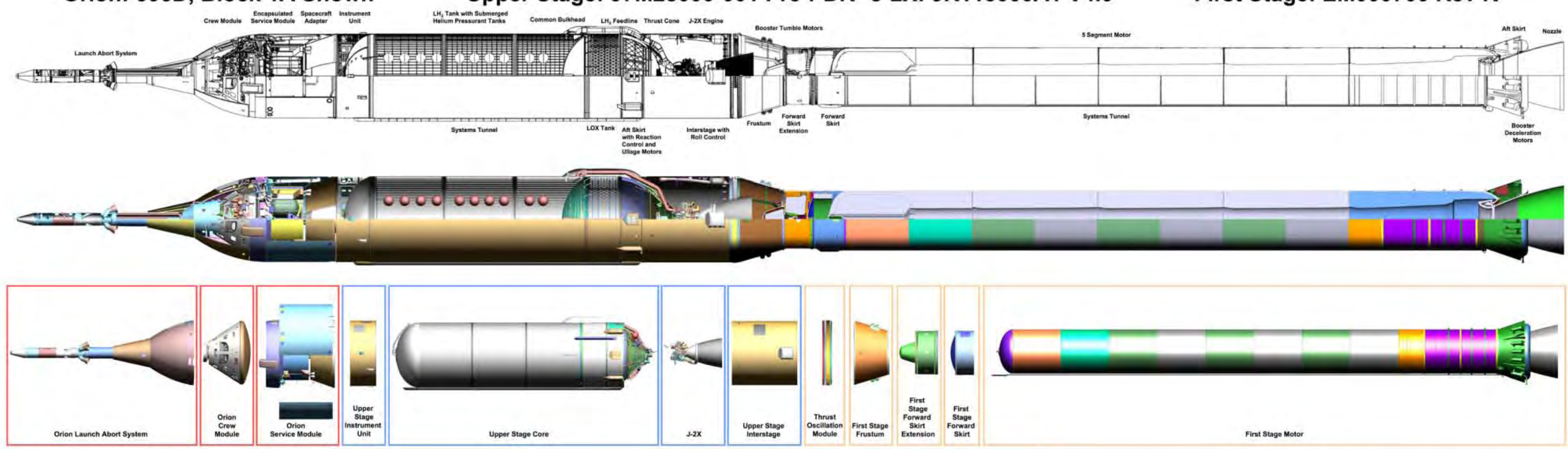
- ***Contract Value***
  - $6.3B through 2014 for two spacecraft

- ***Procurement Approach***
  - Single contract award through full and open competition for the design, development, test, & evaluation of the Orion crew exploration vehicle. Follow-on schedules for production and sustaining and operations support.
  - Contract type: CPAF

Ares I Elements (A106)

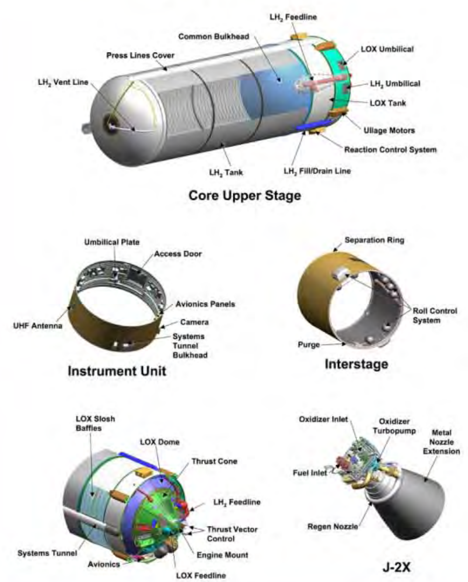
Over $5.18B in Prime Contract Value

Orion: 606D, Block 1A Shown | Upper Stage: 97M25000-001 Pre-PDR | J-2X: 9R115000A1 V4.0 | First Stage: EM000700 Rev K

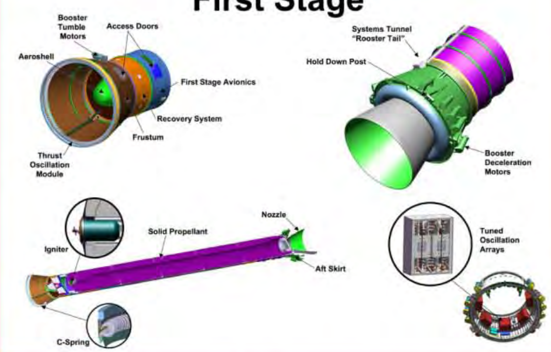


- ♦ ***Instrument Unit***
  - NASA design
  - Boeing production
  - $0.8B contract value
- ♦ ***Upper Stage***
  - NASA design
  - Boeing production
  - $1.14B contract value
- ♦ **Upper Stage Engine (J-2X)**
  - Saturn derived
  - Pratt & Whitney/Rocketdyne
  - $1.28B contract value
- ♦ **First Stage**
  - Shuttle derived
  - ATK Space Systems
  - $1.96B contract value

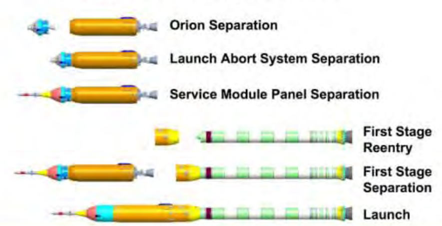
Upper Stage



First Stage



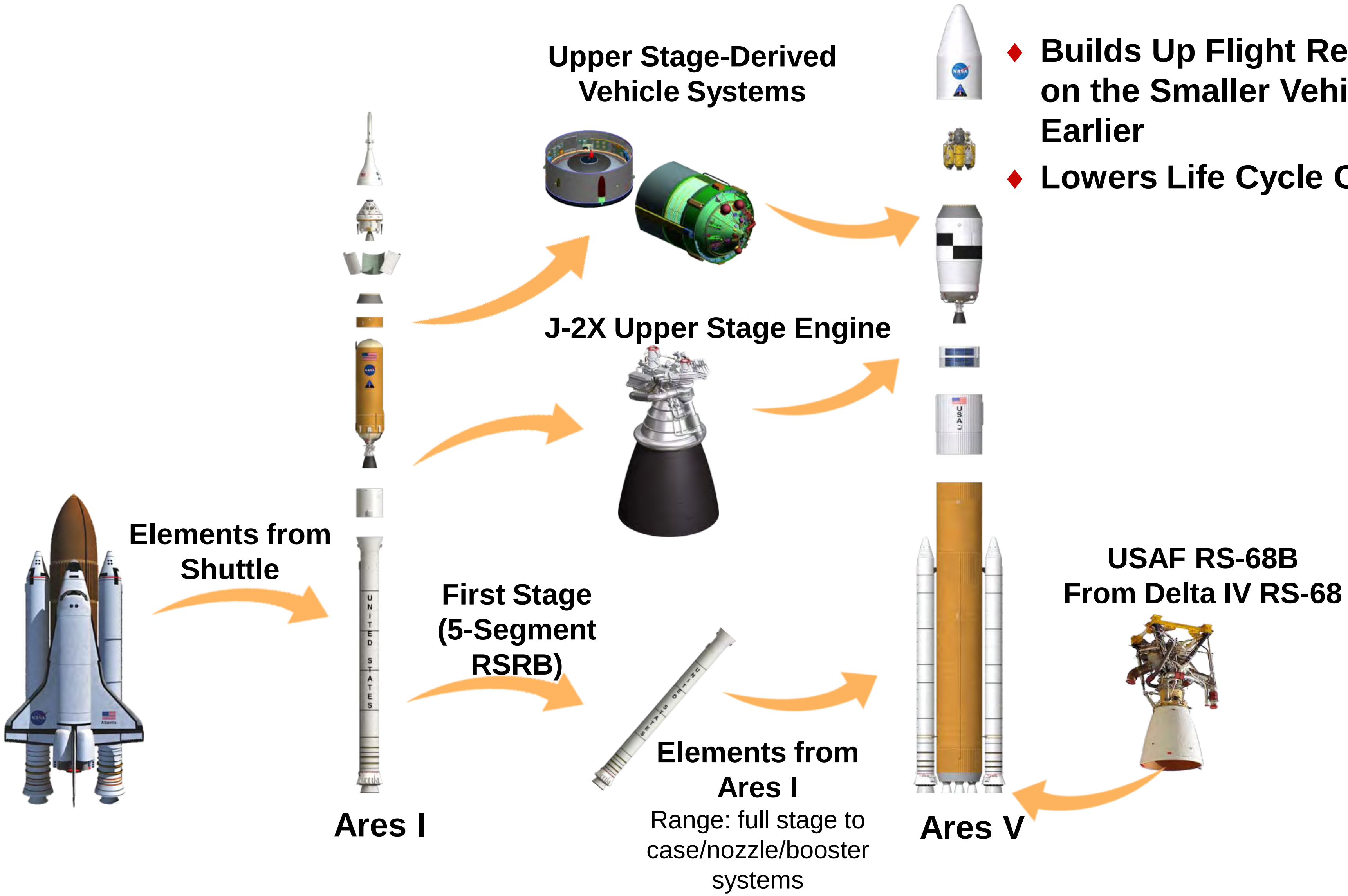
Launch Sequence



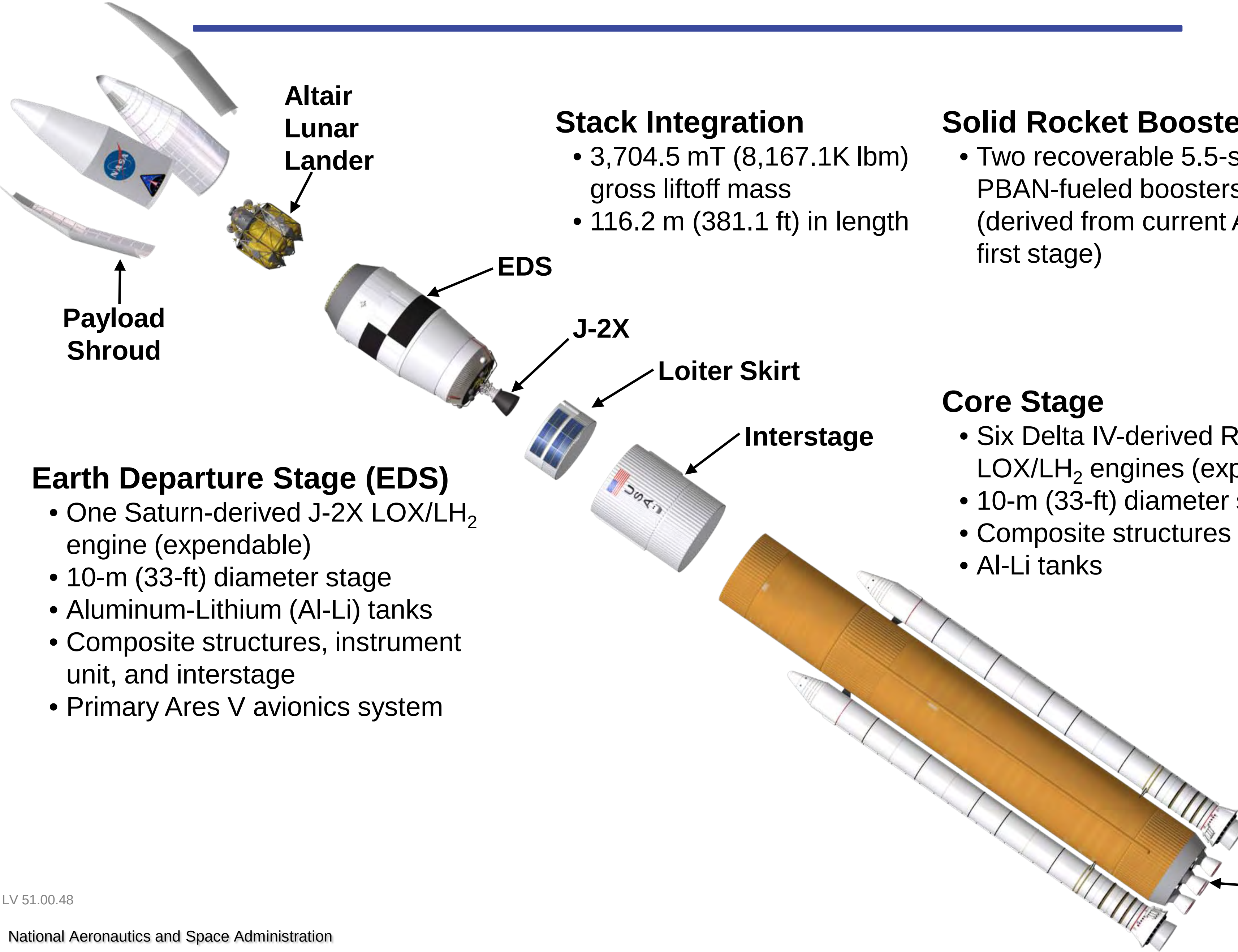
April 2009

Ares I and Ares V Commonality

- Builds Up Flight Reliability on the Smaller Vehicle, Earlier
- Lowers Life Cycle Cost



Ares V Elements



Stack Integration

- 3,704.5 mT (8,167.1K lbm) gross liftoff mass
- 116.2 m (381.1 ft) in length

Solid Rocket Boosters

- Two recoverable 5.5-segment PBAN-fueled boosters (derived from current Ares I first stage)

Core Stage

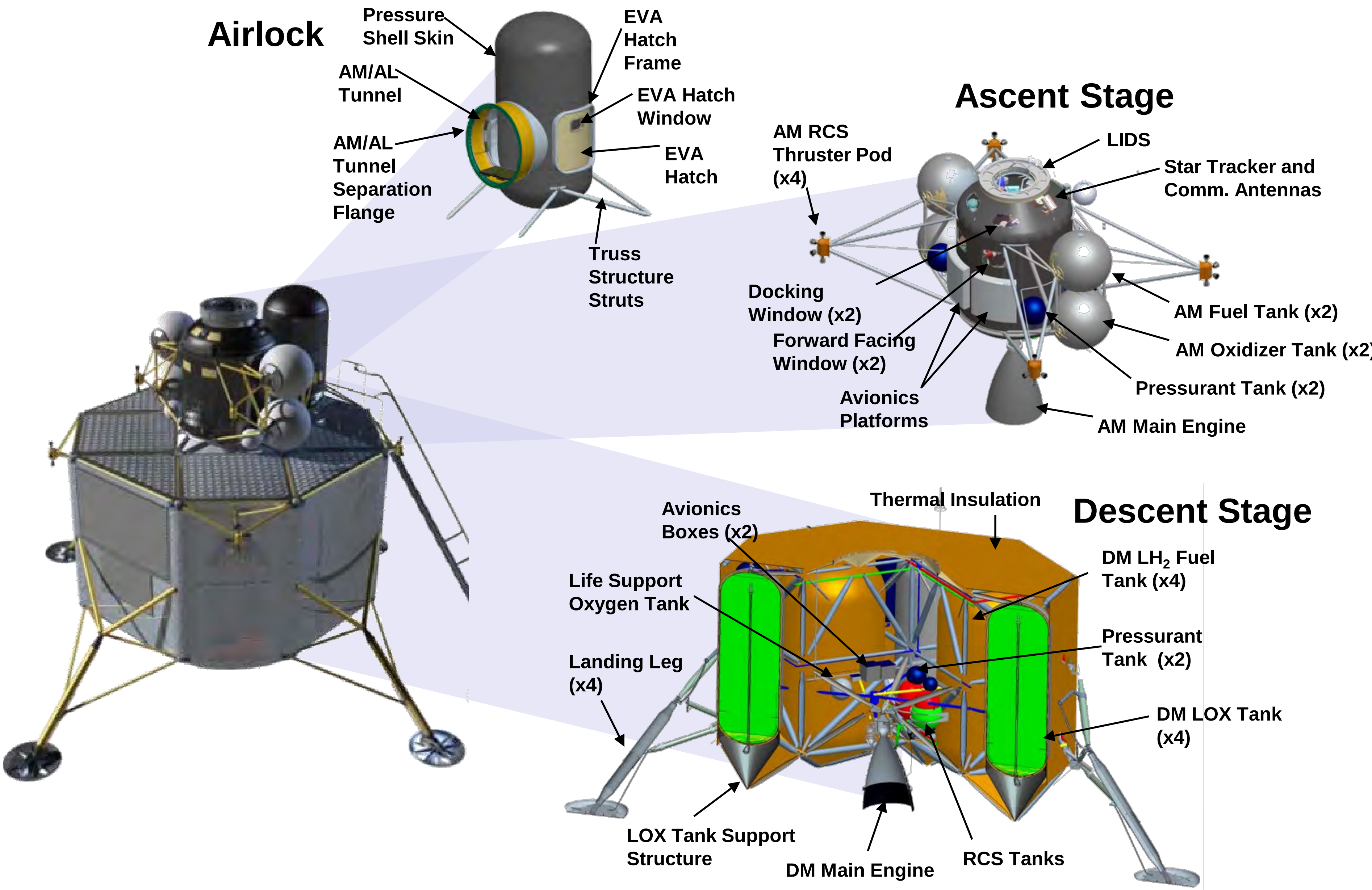
- Six Delta IV-derived RS-68 LOX/LH_2 engines (expendable)
- 10-m (33-ft) diameter stage
- Composite structures
- Al-Li tanks

Earth Departure Stage (EDS)

- One Saturn-derived J-2X LOX/LH_2 engine (expendable)
- 10-m (33-ft) diameter stage
- Aluminum-Lithium (Al-Li) tanks
- Composite structures, instrument unit, and interstage
- Primary Ares V avionics system

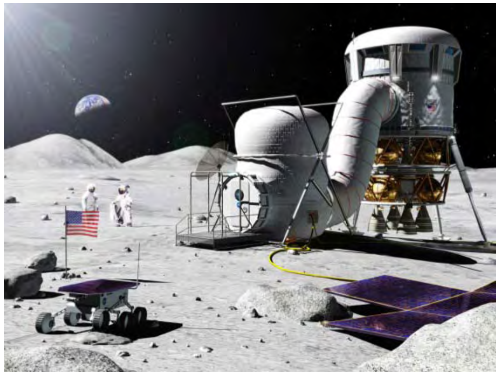
LV 51.00.48

Altair Elements



Lunar Surface Systems Key Capabilities

- **Early Lunar Surface System Studies Explored Lunar Outpost Concepts Which Drove Out Key Issues and Informed Altair/Ares V Requirements Development**
  - Lunar Architecture Team (LAT)-1 in 2006
  - LAT-2 in 2007
  - LCCR in 2008
- **Key Capabilities**
  - Sortie, Extended Stay, and Outpost capability
  - Pervasive Mobility; ability to explore an extended range (25–100 km) around landing sites
  - Solar power with sufficient energy storage to keep assets alive between human visits
  - Habitation
  - Emphasis on understanding the lunar environment and its applicability to human exploration objectives
    - Developing & testing science protocols
    - Testing planetary protection approaches
    - Improving reliability and functionality of EVA & life support systems
    - Testing systematic approaches for resolving complex problems such as dust mitigation and radiation protection
- **NASA's Point of Departure Surface Architecture Will Be Informed by NASA's Lunar Exploration Objectives As Well As International Partner Interests and Budget**



Pervasive Mobility Scenario

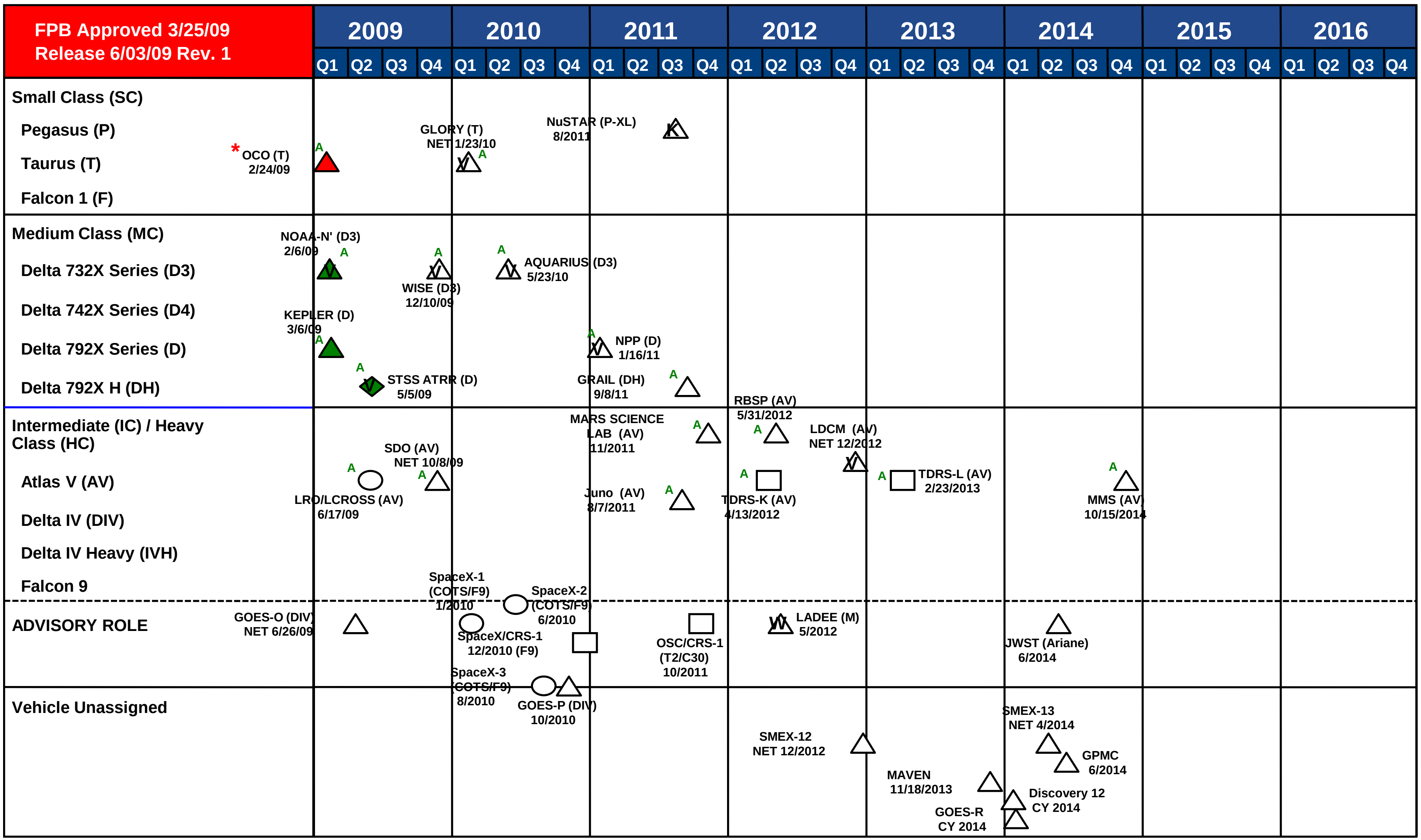
NASA Expendable Launch Services
Current Use of EELV

Lynn F. H. Cline
Deputy Associate Administrator
for Space Operations
National Aeronautics and Space Administration
June 17, 2009

Overview

- NASA's expendable launch vehicles are run by the Launch Services Program (LSP) consolidated at Kennedy Space Center in 1998
  - LSP provides acquisition, technical management, mission integration and launch management
- NASA utilizes a mixed fleet of vehicles (small, medium & intermediate) with varying levels of performance used to support a mix of mission sizes
  - Mainly for Science Mission Directorate payloads, but other NASA Directorates and other government agencies also use NASA launch services
  - Launches conducted from multiple ranges, including RTS, WFF, Kodiak
- Vehicles are selected from the NASA Launch Services Contract (NLS)
  - Through competition based on mass, orbit, class of payload, and best value
  - Current NLS contract expires in 2010, RFP released to extend the contract
- Most recent contract action purchased four intermediate class missions
  - TDRS – K & L, RBSP and MMS
- Important issues
  - Loss of Medium Class launch service provider, which has been 50% of NASA missions historically
  - Compressed manifest
  - Possibility that NASA incurs a portion of the intermediate class infrastructure costs post 2010

NASA Launch Services Manifest



For NASA Planning Purposes Only

UR = UNDER REVIEW
* = MISSION UNSUCCESSFUL
A = ATP'd

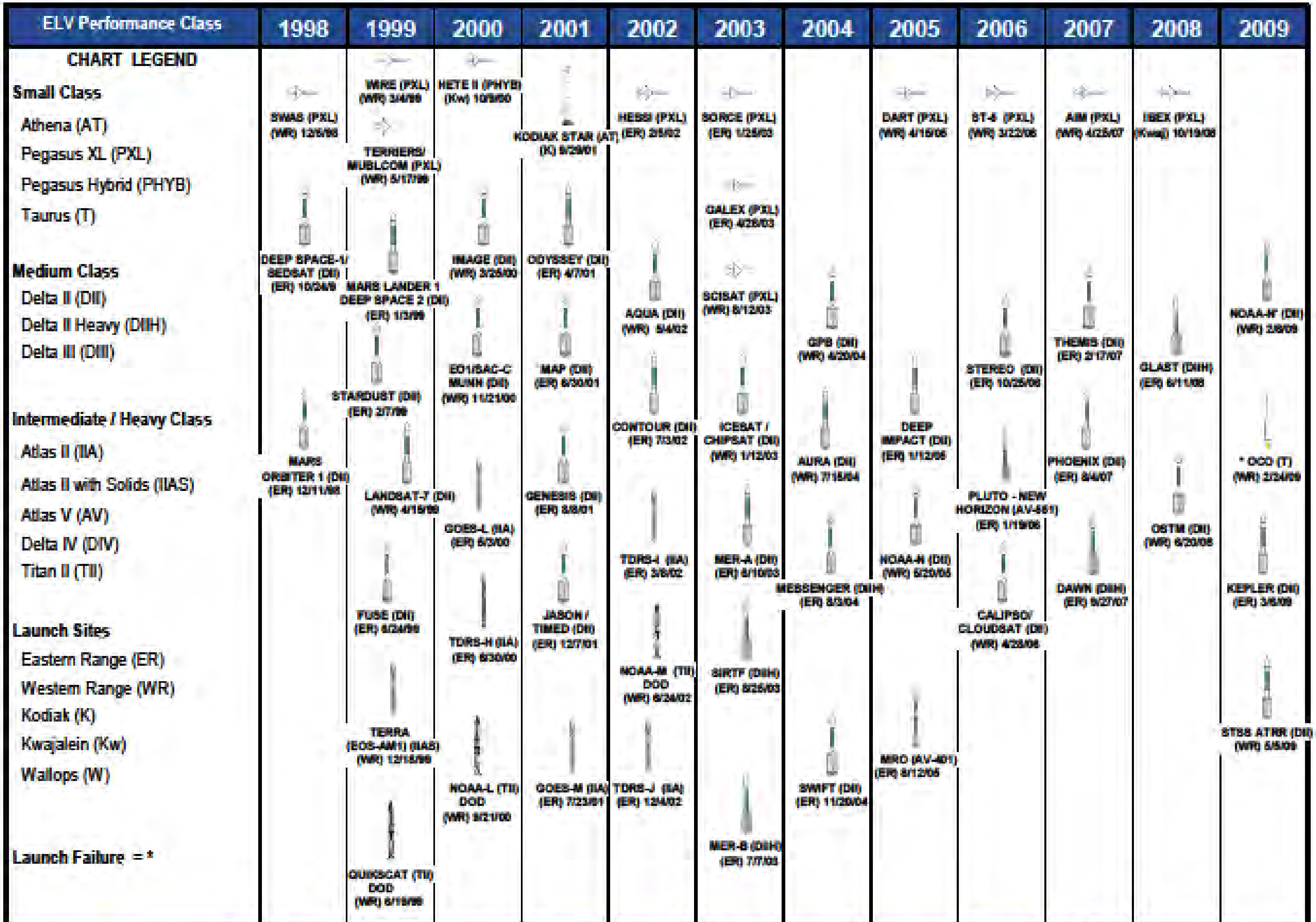
△ = SCIENCE
○ = EXPLORATION SYSTEMS

□ = SPACE OPERATIONS
◇ = DOD REIMBURSABLE

V = VAFB LAUNCH
K = KWAJALEIN

W = WALLOPS LAUNCH

NASA-LSP Managed ELV Launch History (1998 – 2009)

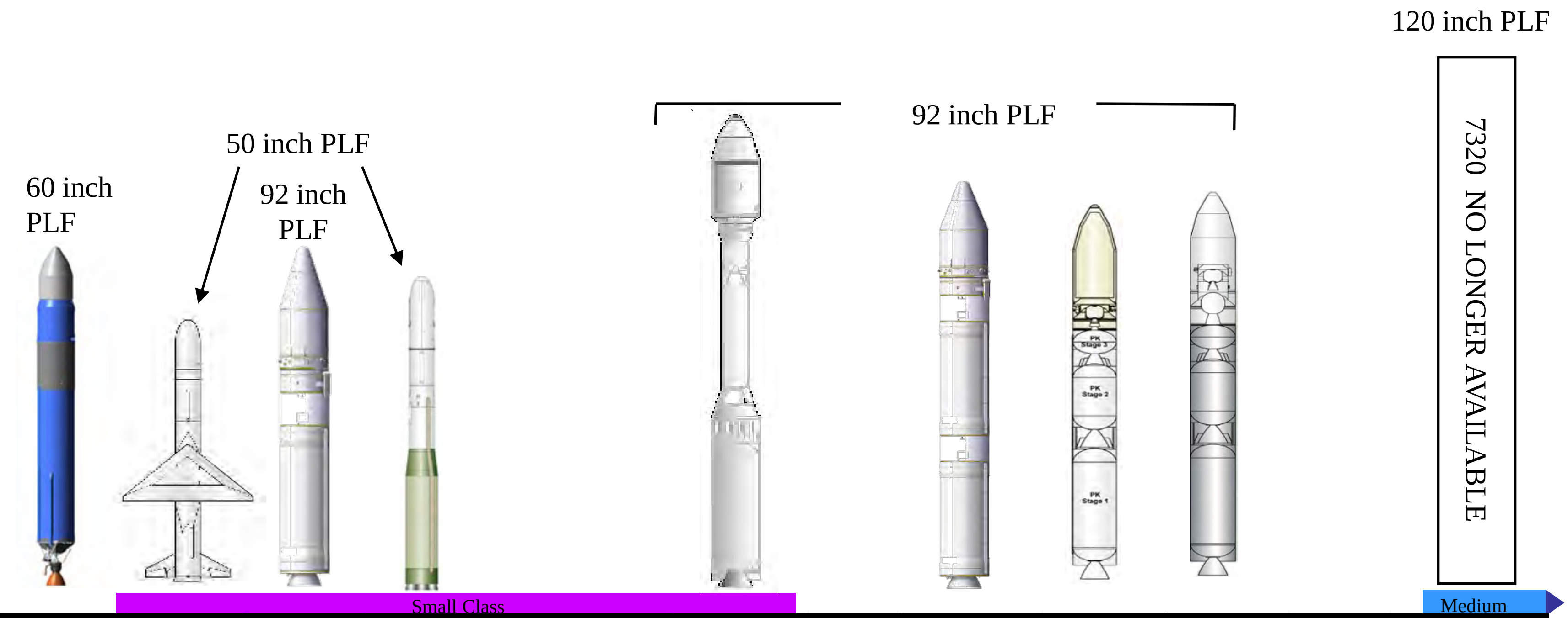


NASA LSP LV Launch Success Rate: 59 Attempts / 58 Successes = 98.3%
Refer to success/failure guidelines in Metric 0773 within the LSP BOA.

Tiffany Nail / KSC
5/6/09

Small Launch Vehicle Performance Range (Kg)

Performance From Payload Planner's Guides or Company Estimates

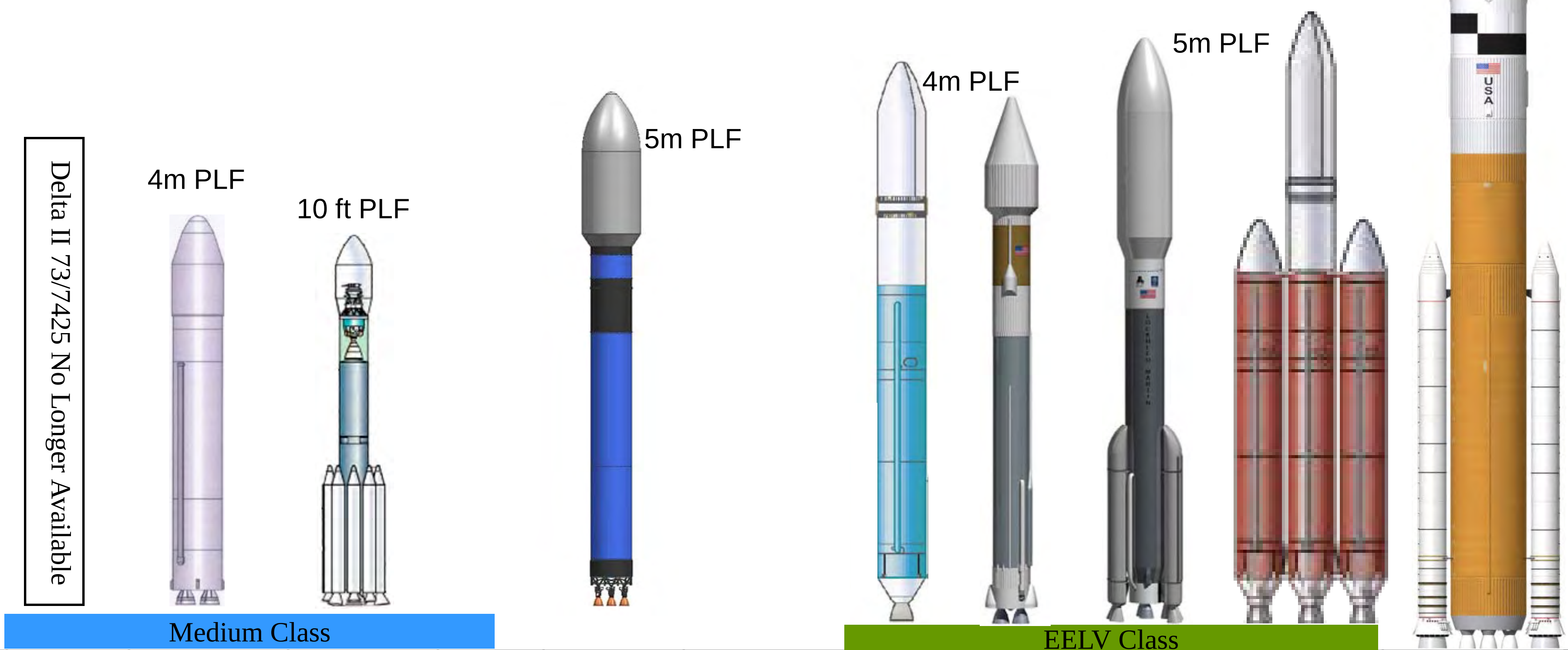


Vehicle Orbit	Falcon 1	Pegasus XL	Athena I	Minotaur I	SIGNIFICANT GAP	Taurus XL	GAP	Athena II	Minotaur IV	Minotaur V	GAP	Delta 7320
600 km 90 deg	200 (a)	250	~300	375		900		~1150	~1200	NA		1650
675 km SS		225		325		750-800			1100	NA		1550
C3=0	NA	NA	NA	NA		~280(kg)		~425(b)	NA	~390		7425=750(b)
Perf risk	Low-Med	Low	Med	Low		Low		Med	Low	Low		Low
Avail for Science Msn (c)	Now	Now -	~Late CY 2014	Now		Now		~Late CY 2014	~3rd qtr 2011	~3rd qtr 2011		N/A -

(a): Falcon 1e concept with higher performance (~400kg) exists, but is in early development stage
(b): Requires additional LV provided stage for high energy missions
(c): Significant schedule risk exists for first flight date of any new launch vehicle configuration, therefore actual availability is likely 6 to 18 months after dates noted above.

Medium, Intermediate and Heavy Launch Vehicle Performance Range (Kg)

Performance From Payload Planner's Guides or Company Estimates



Vehicle Orbit	Delta II 7320/5	Taurus 2 WFF	Delta II 7920/5 H		Falcon 9 Block 1 (b)	SIGNIFICANT GAP	Delta 4040	Atlas V 401	Atlas V 551	Delta IV Heavy	Ares V (c)
C3=0	750 (a)	1150 (a)	1400 (a)		2000		2750	3450	6300	9305	62.8 mT(to TLI)
C3=10	650 (a)	950 (a)	1200 (a)		1350		2100	2850	5300	7010	
675 km sun sync	1550	Not achievable from WFF	Not achievable from CCAS		~6500		6800	7250	13600	20250	~187.7 mT (to 29 deg incl, 130 nm)
GTO	N/A	TBS	900		3495		3985	4765	8570	12980	
Perf risk	Low	High	Low		Med		Low	Low	Low	Low	Med
Available for Science Msn	N/A	~1st qtr 2014 (d)	Now		(d)		Now	Now	Now	Now	2nd half CY2019 (d)

(a) Requires additional LV supplied upper stage for high energy missions (b) Falcon 9 Block 2 upgrade planned (higher performing) – available ~4th qtr 2013 (c) On hold until conclusion of Augustine Commission (d) Significant schedule risk exists for first flight of any new LV configuration, therefore actual availability is likely 6 -18 mo after dates noted above.

ULA United Launch Alliance

Briefing to the Review of U.S. Human Space Flight Plans Committee

Michael C. Gass
President and CEO
United Launch Alliance

17 June, 2009

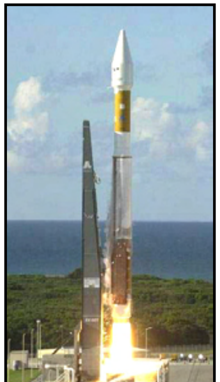
Images Courtesy of Lockheed Martin & The Boeing Company

A Safe, Affordable, and Sustainable Launch Approach

- Joint utilization of flight-proven systems by NASA, DoD, and commercial provides a safe, affordable, and sustainable approach to exploration
  - Leverages existing investments and reduces annual standalone lien
- Delta IV Heavy provides safe, low cost capability to launch Orion by 2014 with greater than 20% performance margin
- Atlas V provides commercial crew to ISS by 2013
- Further evolution of EELV systems and components provides options and flexibility for exploration to the Moon and beyond
- Options available for manufacturing, integration and launch operations to address workforce transition and unique requirements

ULA is prepared to support the thorough evaluation of options with the Committee

ULA Operates the Nation’s Expendable Launch Fleet



Atlas V
401

Delta IV
Med+ (4,2)

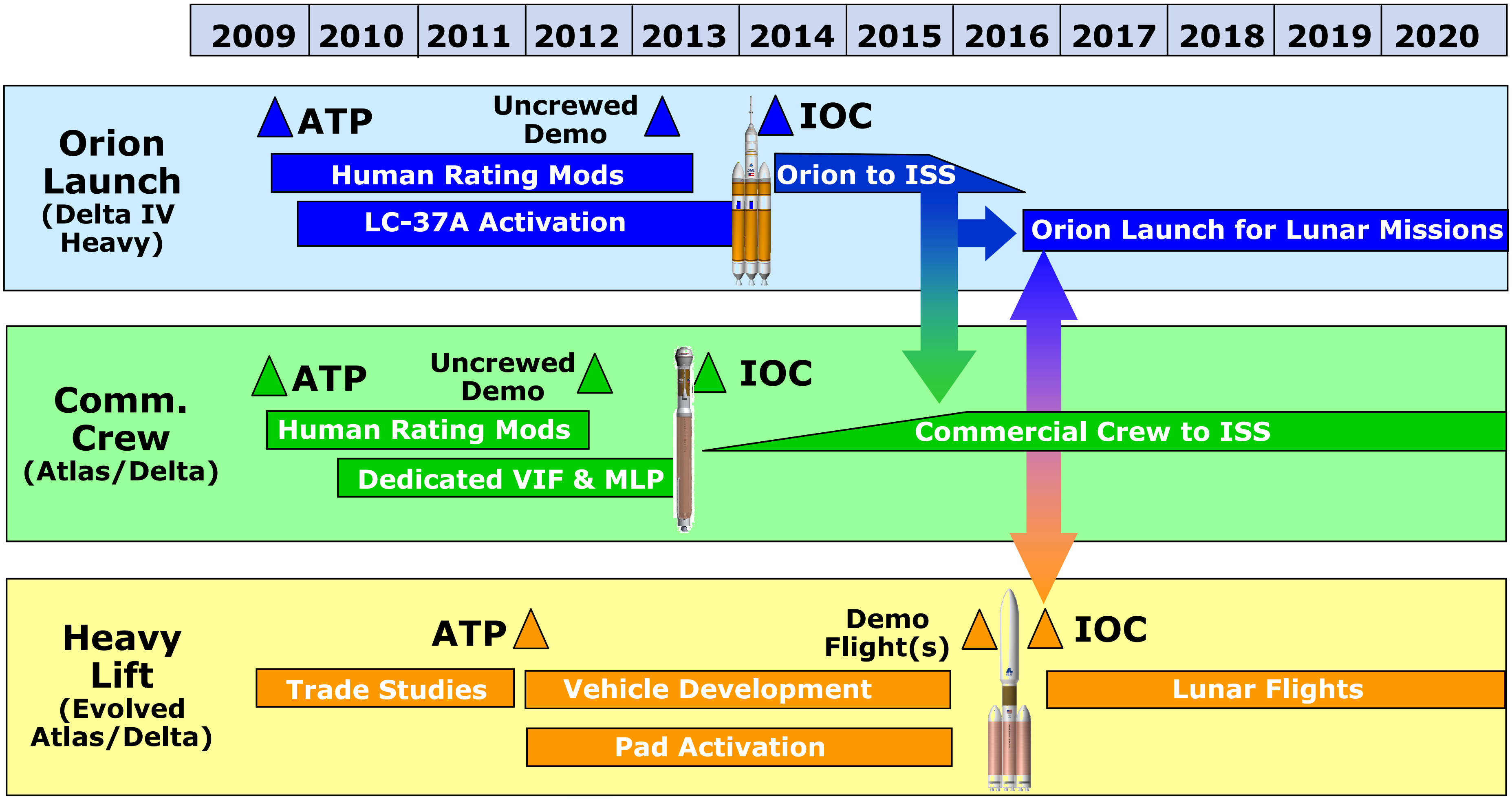
Atlas V
551

Delta IV
Heavy

- Proven Government-Industry Partnership
  - More than 50 years and 1,300 launches
  - Experienced workforce and proven management systems
- Recent, successful development experience
  - Delta IV and Atlas V developed within the last decade
- Fully operational state-of-the-art launch systems
  - ULA’s stewardship has delivered 100% mission success over 24 missions

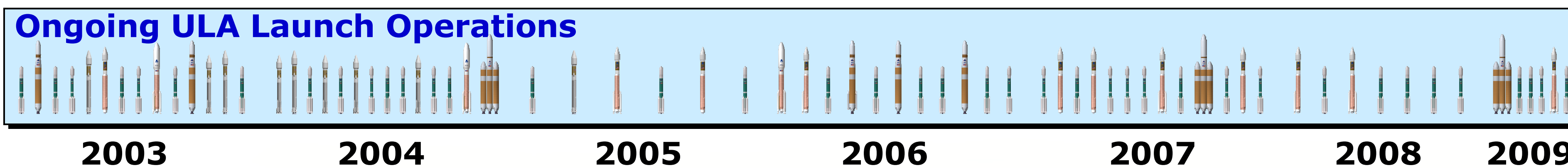
ULA is the Nation’s center of expertise for expendable launch systems

Building Blocks for Exploration



ULA Experience with Human Rating

- Involved with NASA and commercial human rating launch studies over the past 8 years
  - Orbital Space Plane, NASA Exploration Launch Studies, NASA CE&R studies, NASA ESAS studies, Bigelow, NASA COTS, FAA studies
  - Input to NASA Human Rating Requirements (8705.2A and 2B)
- Flight experience key to human rating
  - Detailed understanding of system behavior and environments
    - System margins and risks
    - Precise abort criteria for Emergency Detection System (EDS)
  - Non-crewed missions retire risk prior to first crewed mission



Human rating is the interaction between requirements and in-depth systems knowledge best gained with Flight Experience

Delta IV Heavy Launch of Orion

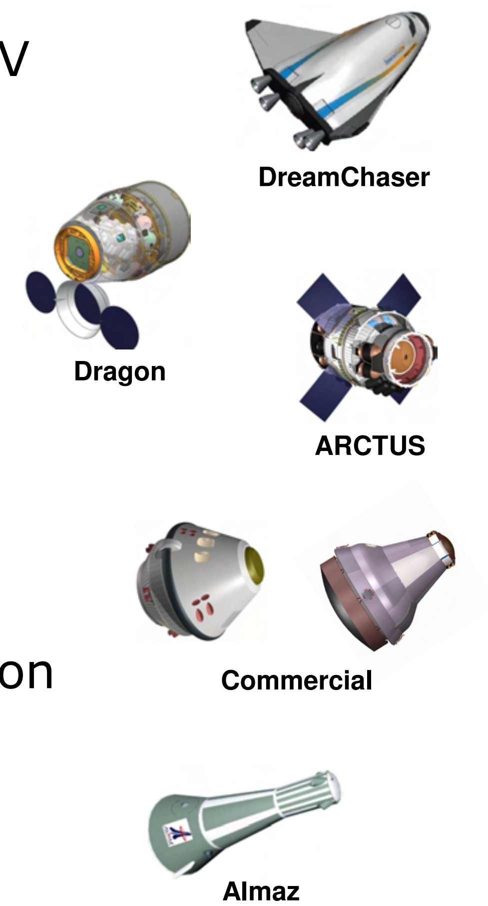
- Delta IV Heavy has launched 2 operational missions with 100% mission success
- Human rating Delta IV Heavy is understood
  - Addition of an Emergency Detection System (EDS)
  - Separate launch pad with crew ingress/egress
  - Additional reliability improvements options identified
- Greater than 20% performance margin for both ISS and lunar missions
  - Trajectories shaped to eliminate black zones
  - DoD planned propulsion improvements benefit NASA
- Benign launch and abort environments reduce risks for Orion
- Affordable and credible costs
  - Non-recurring ($800M pad, $500M human rating)
  - Recurring ($300M/launch)
- Available within 4.5 years from start

Minimum change to existing, flight-proven system

EELV Launch of a Commercial Human Spacecraft

United Launch Alliance

- Human rating impacts to flight-proven existing EELV are understood
  - Addition of an Emergency Detection System (EDS)
  - Separate VIF/MLP or pad with crew ingress/egress
- Low non-recurring ($400M) and recurring costs ($130M/launch)
- Human rated Atlas V offered by numerous Prime Contractors during NASA COTS competitions
  - Ongoing integration of entrepreneurial and traditional prime designed commercial crew vehicles
- Non-crewed missions provide vehicle characterization and flight data prior to first crewed mission
- EELV is not the critical path to launch a commercial crew transfer vehicle
  - Launch within 4 years of start



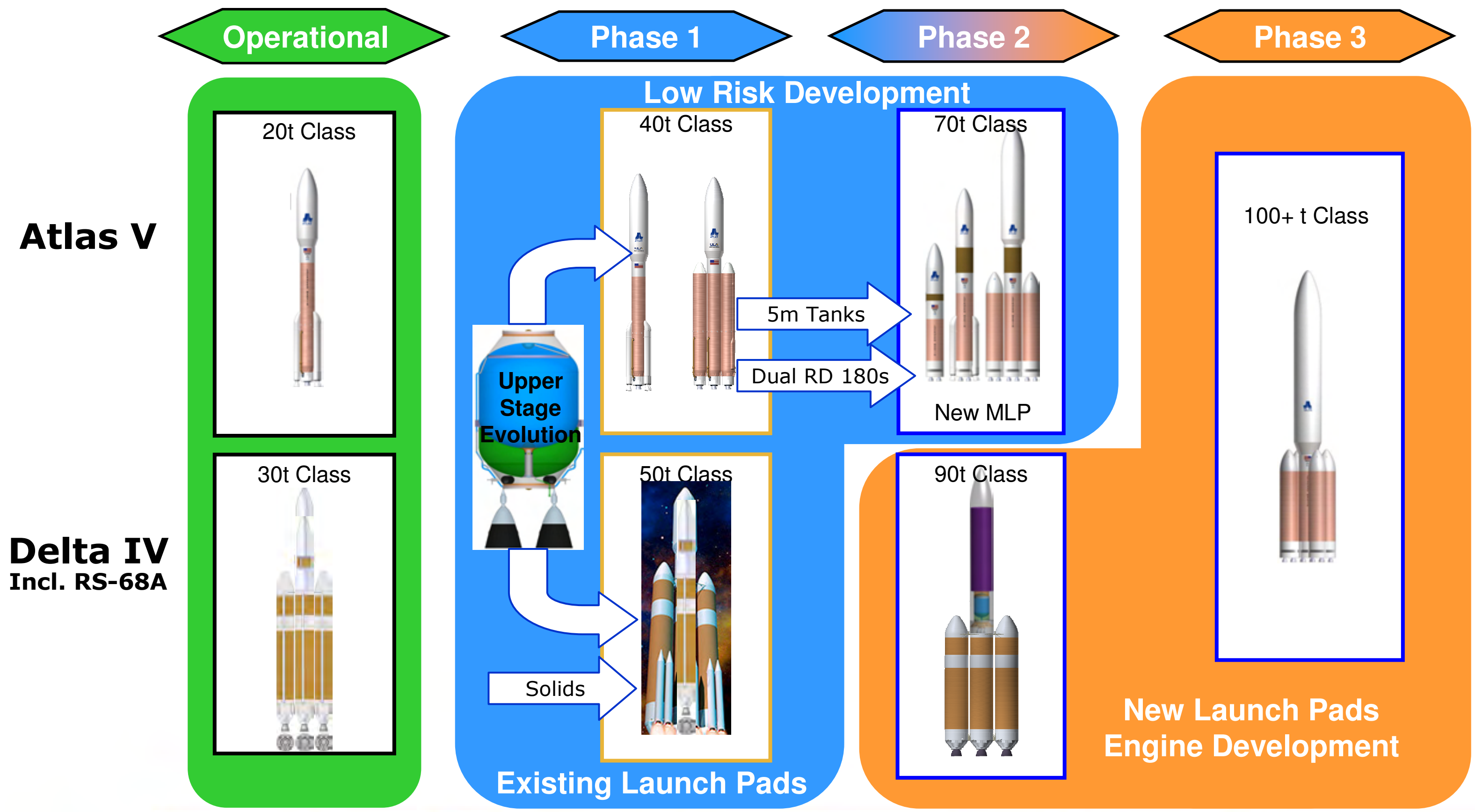
Flight-proven EELV Provides Low-Risk Launch Solution To Launch Commercial Crew Vehicles to LEO

* Photos courtesy of Bigelow Aerospace, SpaceX, SpaceHab, Sierra Nevada, Space Development Corporation

EELV Evolution Enables Flexible Mission Architectures

United Launch Alliance

- EELV evolution plans developed for NASA studies during 2003/4
  - Low risk developments achieve 70t Class to LEO
  - With new propulsion and launch site >100t payloads



COTS Status Update & Crew Capabilities

Elon Musk
June 17, 2009

SpaceX Overview

- Founded in 2002 with the singular goal of providing **highly reliable, low cost space transportation**
  - Expand into human transportation once technology is proven
- 800 employees — growing ~50% per year
- Facilities:
  - 550,000 sqft of offices, manufacturing & production in Hawthorne, CA
  - 300 acre state-of-the-art Propulsion and Structural Test Facility in central Texas
  - Launch sites at Kwajalein & Cape Canaveral

Kwajalein

Hawthorne Headquarters

Central Texas

SLC-40, Cape Canaveral

SpaceX Manifest

Customer	Launch	Vehicle	Departure Point
ATSB (Malaysia)	Q3 2009	Falcon 1	Kwajalein
Falcon 9 Maiden Flight	2009	Falcon 9	Cape Canaveral
NASA COTS - Demo C1	2010	Falcon 9/Dragon	Cape Canaveral
Avanti Communications (UK)	2010	Falcon 9	Cape Canaveral
NASA COTS - Demo C2	2010	Falcon9/Dragon	Cape Canaveral
MDA Corp (Canada)	2010	Falcon 1	Kwajalein
NASA COTS - Demo C3	2010	Falcon9/Dragon	Cape Canaveral
NASA CRS1	2010	Falcon 9/Dragon	Cape Canaveral
DragonLab Mission 1	2010	Falcon 9/Dragon	Cape Canaveral
Swedish Space Corp. (Sweden)	2011	Falcon 1	Kwajalein
Bigelow Aerospace	2011	Falcon 9	Cape Canaveral
NASA CRS2	2011	Falcon 9/Dragon	Cape Canaveral
DragonLab Mission 2	2011	Falcon 9/Dragon	Cape Canaveral
CONAE 1A (Argentina)	2012	Falcon 9	Kwajalein
CONAE 1B (Argentina)	2013	Falcon 9	Kwajalein
NASA CRS3-12 (10 additional missions)	2012-15	Falcon 9/Dragon	Cape Canaveral

Falcon 1 commercial | Falcon 9 commercial | COTS Demo | ISS Cargo Delivery | DragonLab

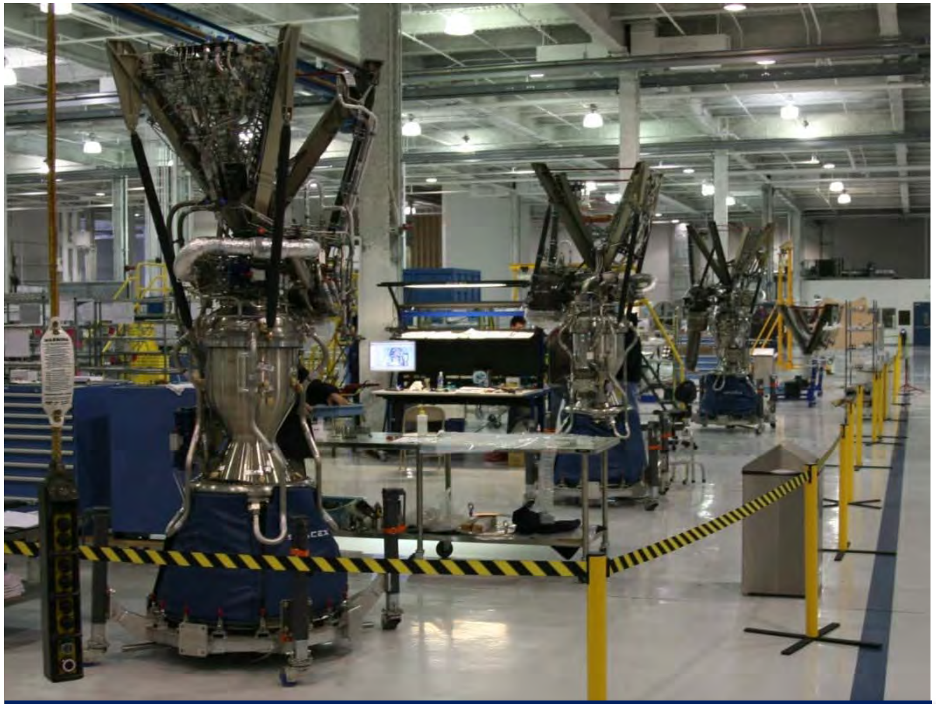
Falcon 9 Status

- **Inaugural mission Q4 2009**
- >5x cost reduction compared to domestic competitors
- Designed from inception for crew transportation
  - Simple, high-reliability architecture
  - Engine-out reliability, similar to Saturn I & V
  - Meets NASA crew-rated safety margins and failure tolerances

All structures, engines, most avionics and all ground systems designed (and mostly built) by SpaceX

Falcon 9 Status - Merlin

Falcon 9 Engines, Truss & Skirt

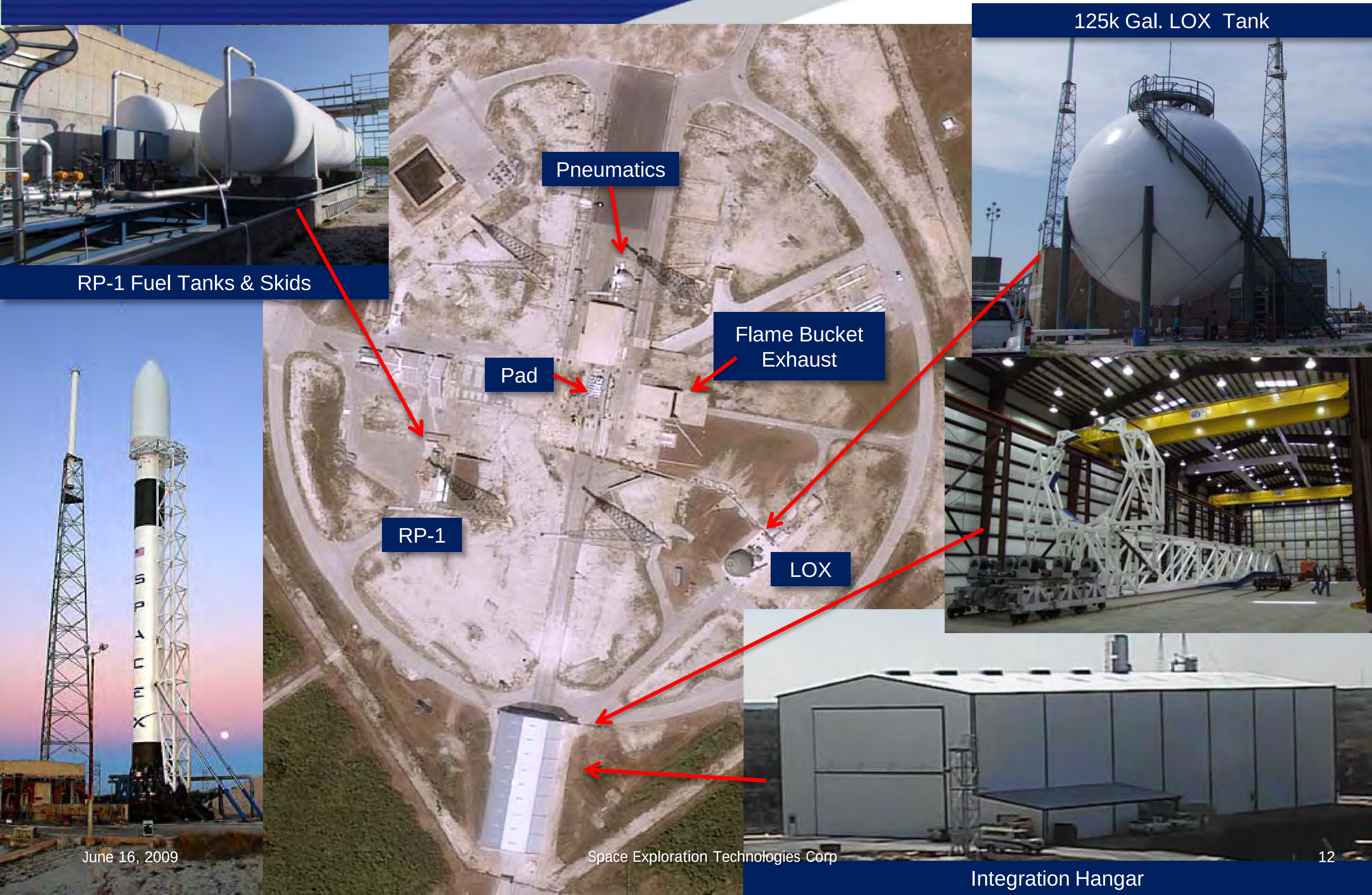


Merlin Production Line

Falcon 9 on launch pad

SLC-40 Cape Canaveral, January 2009

Cape Canaveral Launch Site



Dragon Status

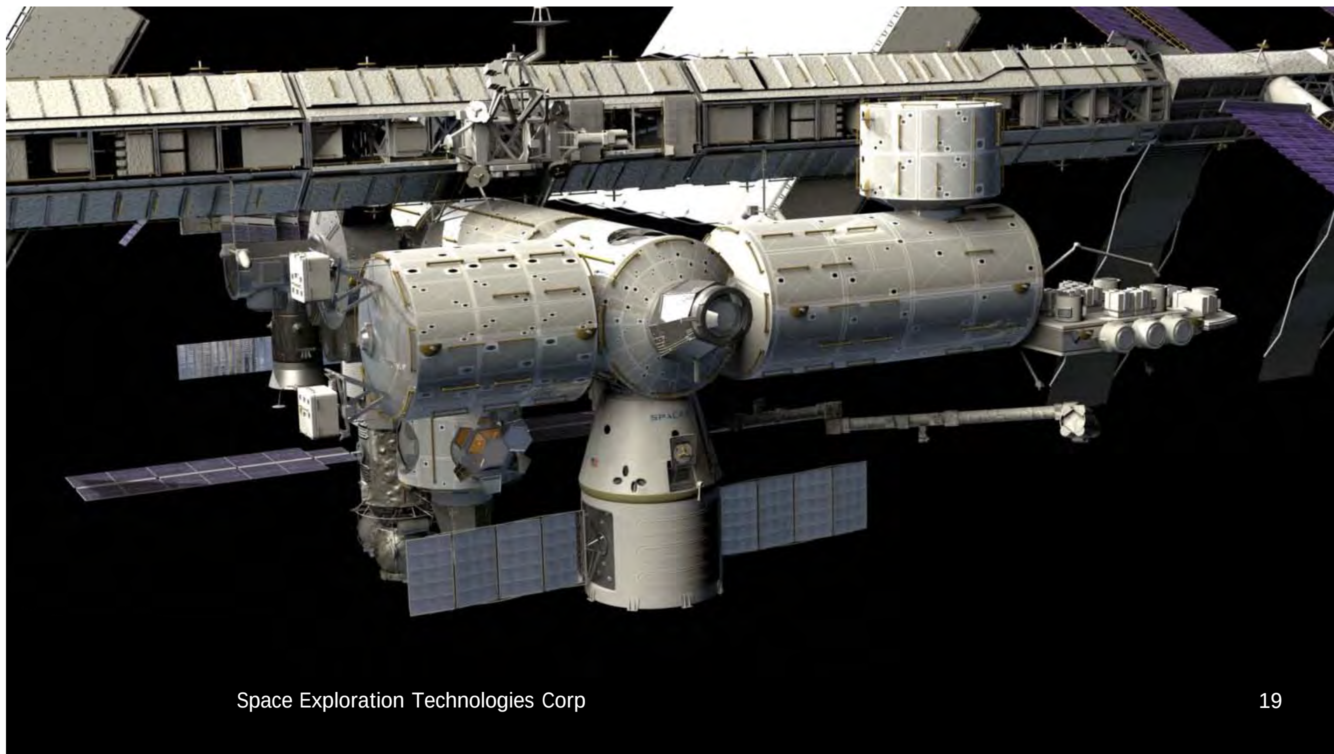
- **Inaugural mission Q1 2010**
- 1st flight Qualification testing 90% complete
- 1st flight hardware in fabrication
- Designed from inception for crew transportation
  - Meets NASA crew-rated safety margins and failure tolerances

All structures, engines, most avionics and all ground systems designed (and mostly built) by SpaceX

ISS Integration Status

- Completed ISS Safety Review Panel (SRP) Phase 1 & most of 2
  - Phase 3 (final) scheduled early 2010
- Cargo integration planning in-work with both COTS and CRS programs
- Integration testing (including Joint Integration) is underway

- Also, end-to-end tests of integrated SpaceX-NASA ground system successfully completed



COTS Program Status

- Completed 14 of 22 milestones on schedule
  - Including all 3 financing rounds
  - Including SRR, PDR and CDR for each Demo
  - CUCU delivery scheduled for June 30^{th}
- Some slips expected in remaining milestones
  - NASA has been fully informed regarding progress toward these milestones
- Demo flights now scheduled for:
  - Demo C1: January 2010 (2 months after inaugural F9 flight)
  - Demo C2: June 2010
  - Demo C3: Aug. 2010

Crew Capability

SPACEX

- Both Dragon & Falcon 9 were designed from inception to readily accommodate crew

This is why SpaceX was founded

- Immediate focus is on cargo for COTS & CRS commitments, BUT…

- In every design decision, the ability to attain human rating rapidly & at low additional cost is paramount

Note: Many human-rating requirements are mandated on the cargo vehicle because it must be safe for ISS crew

Dragon Already Designed to Accommodate ISS Crew

- For COTS Capabilities A-C, astronauts will enter (and temporarily inhabit) the Dragon spacecraft for loading and unloading of cargo to and from the International Space Station
- Therefore, Dragon already meets the manned requirements to allow this activity, as called out in SSP 50808
  - Air sampling and circulation
    - ISS crew sample Dragon's air supply through the Air Revitalization System (ARS) port before entering the spacecraft, breathing in the air as provided by the Dragon Environmental Control System.
    - Air circulation is provided to ensure safe breathability throughout the spacecraft
  - Temperature and humidity requirements
  - Touch temperature limits: between 39 F and 113 F
  - Human Factors
    - Protection from shock
    - Restrictions on sharp corners, sharp edges, exposed screw threads, burrs, and pinch points.
    - All fonts, colors, and labels are consistent with SSP 50005.

Additional Dragon Design Features Added for Crew Accommodation

SPACEX

- **Factors of Safety:** primary structures designed to 1.4 or 1.5 on ultimate factors of safety per SSP 30559 (instead of 1.25)
- **Driving Design Load Cases** are specific to crewed missions:
  - Launch escape system ignition, burn & worst-case abort reentry
  - These loads are 30% higher than any loads potentially occurring on a cargo mission
- **Usable Volume:** Selected to accommodate at least 6 crew
- **Fault Tolerance:** At least 2-fault-tolerant, as required for human rating, including Flight Computers & Propulsion systems
- **3.5 g's nominal reentry acceleration** (similar to Gemini)
- **Crew Egress:** 2 hatches one opens outwards, the other inwards
- **Three windows**, even in cargo version
- **Thermal Control System & radiator** are sized for crew requirements
- **>210 days orbital life span:** Positive energy balance, lots of propellant for station-keeping etc.

Additional Development Required to Fly Crew

SPACEX

- **Launch Escape System**
  - Preliminary designs already defined
  - Leverages heavily off existing SpaceX designs and capabilities
- **Crew Accommodations**
  - Seats, monitoring & overrides
- Up-rate Environmental Control System to full **Life Support**
  - Add CO2 & Humidity Control
- **2.5 years** required for first crewed mission
- "**Life-boat Dragon**" (return only) capability could be achieved within 1.5 years

…and NASA is NOT the only customer…

“Life-Boat” Dragon

- Lifeboat Dragon could actually be a simpler vehicle than Cargo Dragon
  – Would not require solar arrays (or possibly a radiator), due to short mission duration
  – Cargo Dragon is already two-fault tolerant, as required for ISS safety
- The only significant developments are:
  – Upgraded Environmental Control to sustain crew for return trip duration
  – Crew accommodations (seats etc.) instead of cargo racks
  – Vehicle overrides and monitoring for the crew, as mandated by Human Rating Requirements
    - Note: Dragon cargo vehicle is capable of fully autonomous return to Earth
  – Docking/berthing adapter capable of rapid departure

All other necessary capabilities are already provided by Cargo Dragon

Orbital's

ISS Commercial Resupply Service

Presented to:

Augustine Commission

June 17, 2009

Innovation You Can Count On™

ORB Listed NYSE THE NEW YORK STOCK EXCHANGE

Orbital COTS Systems Architecture

The Orbital COTS System is comprised of 5 Major Elements

Cygnus Visiting Vehicle

Orbital COTS System

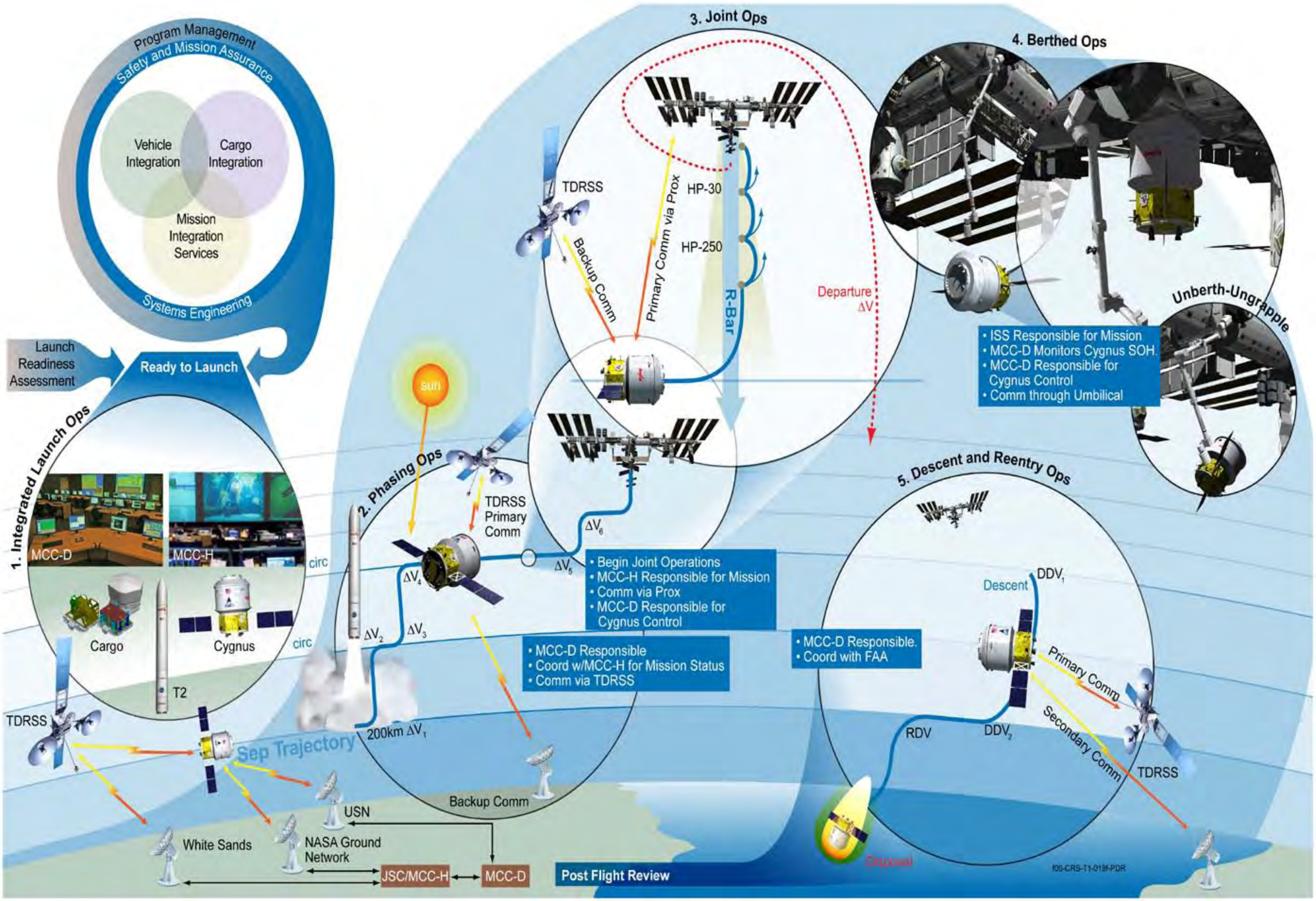
Taurus II

Cargo Operations

Mission Operations

Integrated Launch Site Operations

COTS Mission Overview



Taurus II

MEDIUM-CLASS LAUNCH SERVICES FOR THE 21ST CENTURY

- **Two-Stage Launch Vehicle Designed to Provide Reliable, Cost-Effective, and Responsive Access to Orbit and Earth Escape for Medium-Class Payloads**
- **Designed to be a Highly-Reliable Launcher to Meet NASA Category 3 and Similar DoD Mission Success Standards, and Incorporates Flight-Proven Subsystems to Reduce Development Cost, Schedule and Risk**
- **Initial Missions are Nine Cargo Delivery Launches to the International Space Station (ISS) Under a Demonstration of Commercial Orbital Transportation Services (COTS) Agreement and Under a Commercial Re-Supply (CRS) of the ISS Contract**

Leverages Flight-Proven Technologies

- First Stage Powered by Dual AJ26-62 Engines, Second Stage Propulsion Provided by a Castor 30 Solid Motor (Castor 120 Heritage)
- Optional N2H4/NTO-Fueled Orbit Raising Kit is Available
- Enhanced Second Stage will be Available in 2013

Fills Medium-Class Launch Services Gap

- Fills the Gap Between Medium-Light Minotaur IV-Class Vehicles and Heavy-Lift Delta IV and Atlas 5 Offerings

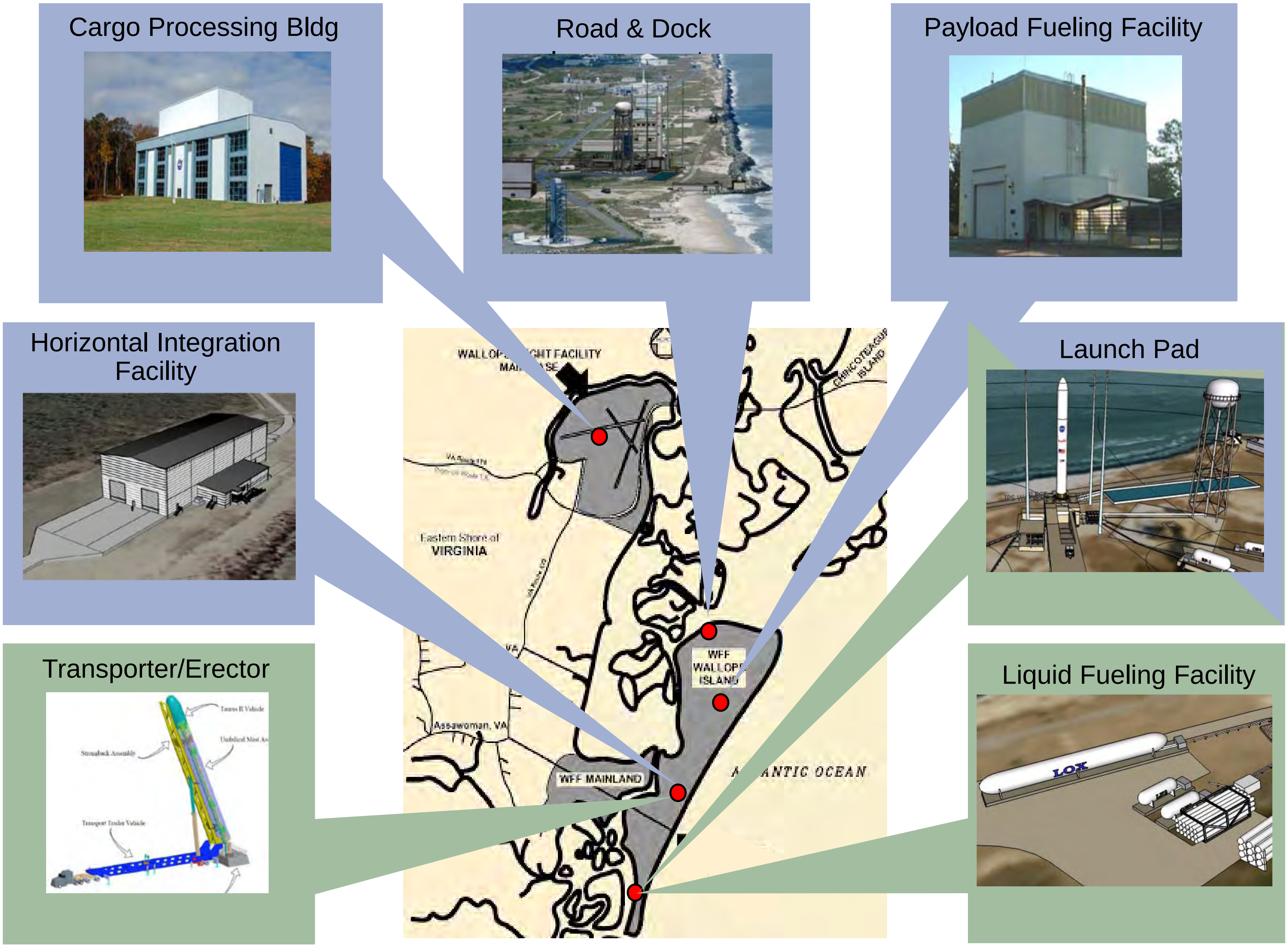
Low Risk Design

- Incorporates Flight-Proven Components from Leading Global Suppliers
- Uses Subsystems Already Successfully Deployed on other Orbital Launch Vehicles

Affordable

- Projected Launch Services Prices Represent Significant Savings Over Existing Medium-and Heavy-Class Launchers, Reducing Total Mission Cost

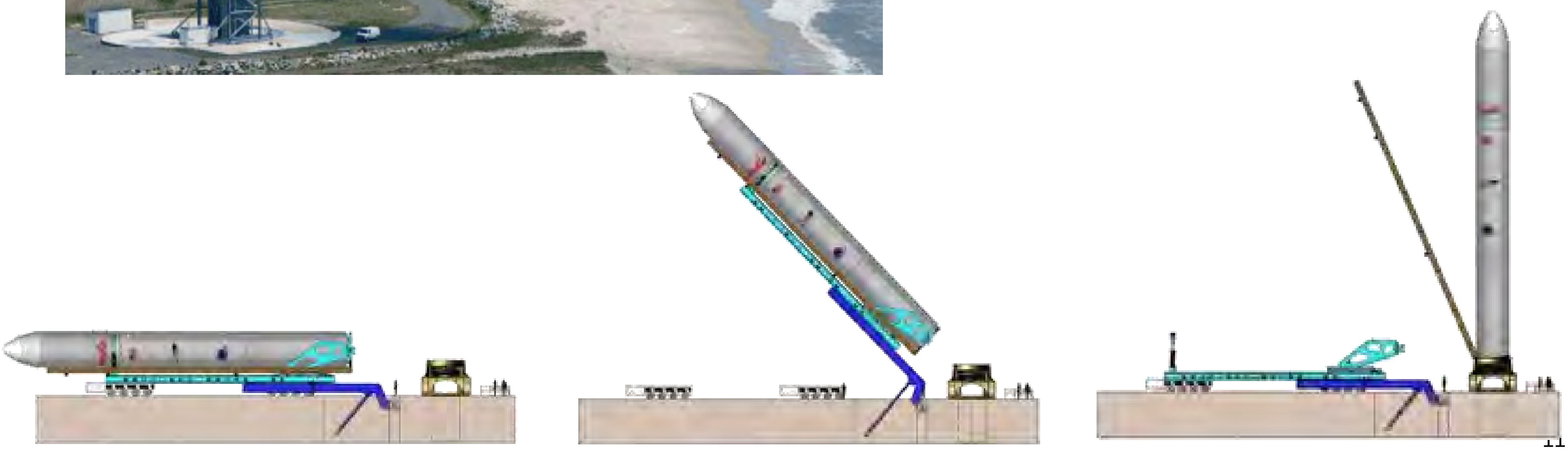
Taurus II Facilities at Wallops Island



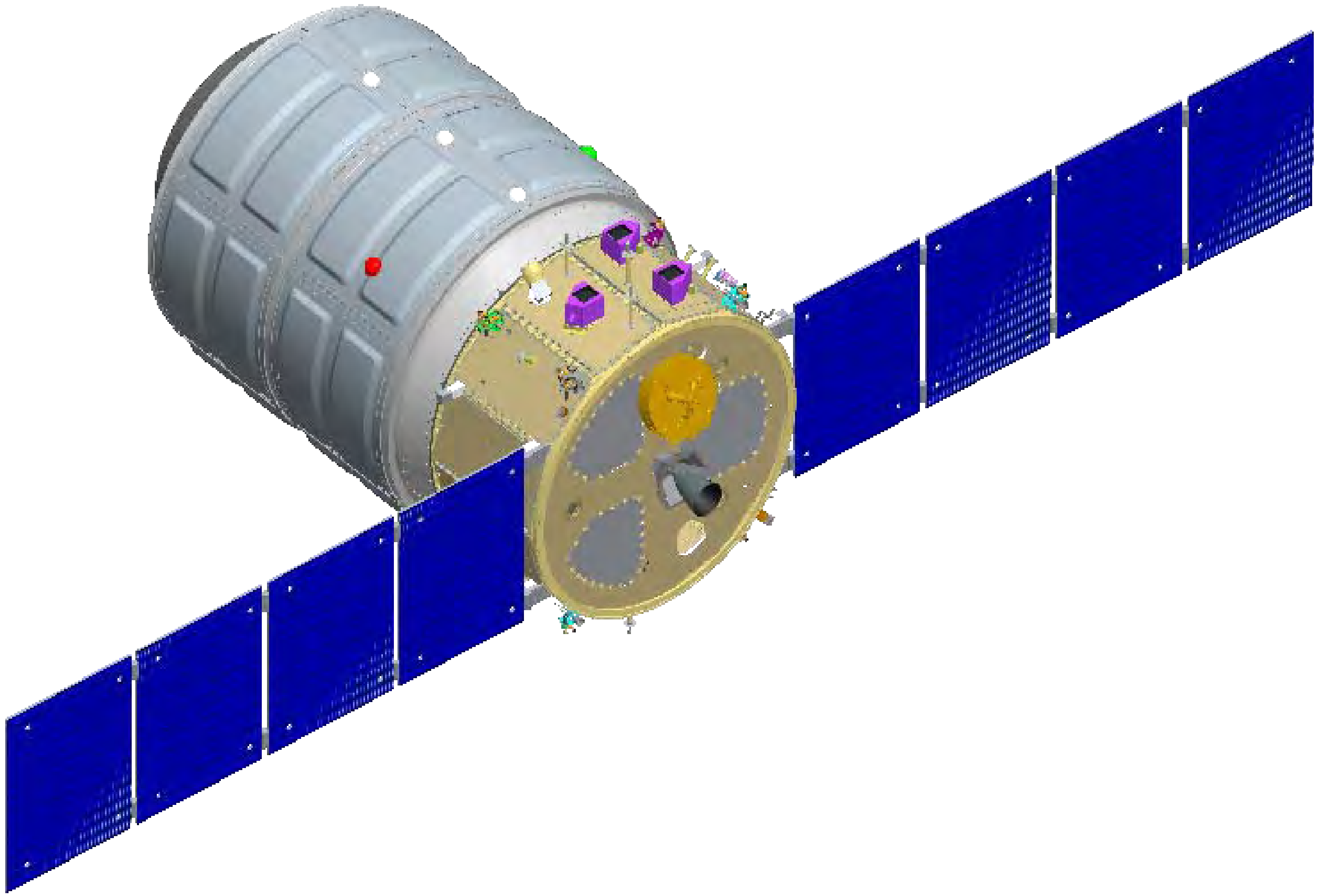
Taurus II Launch Infrastructure

HORIZONTAL LAUNCH VEHICLE PROCESSING

- Horizontal Payload Mate
- Payload Encapsulation Prior to Roll-Out
- Integrated Launch Vehicle Transported 1.2 Miles From HIF to Launch Complex
- Launch Complex Provides Launch Mount, Flame Trench, and Fuel Loading Subsystem



Cygnus Visiting Vehicle



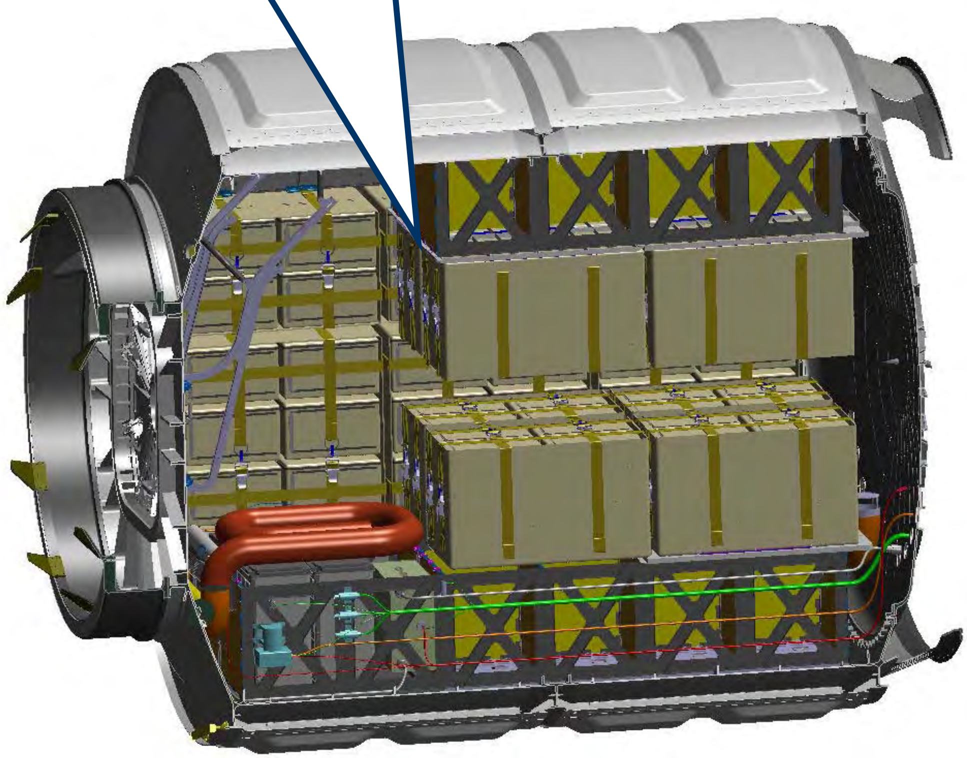
Pressurized Cargo Module Cargo Accommodation

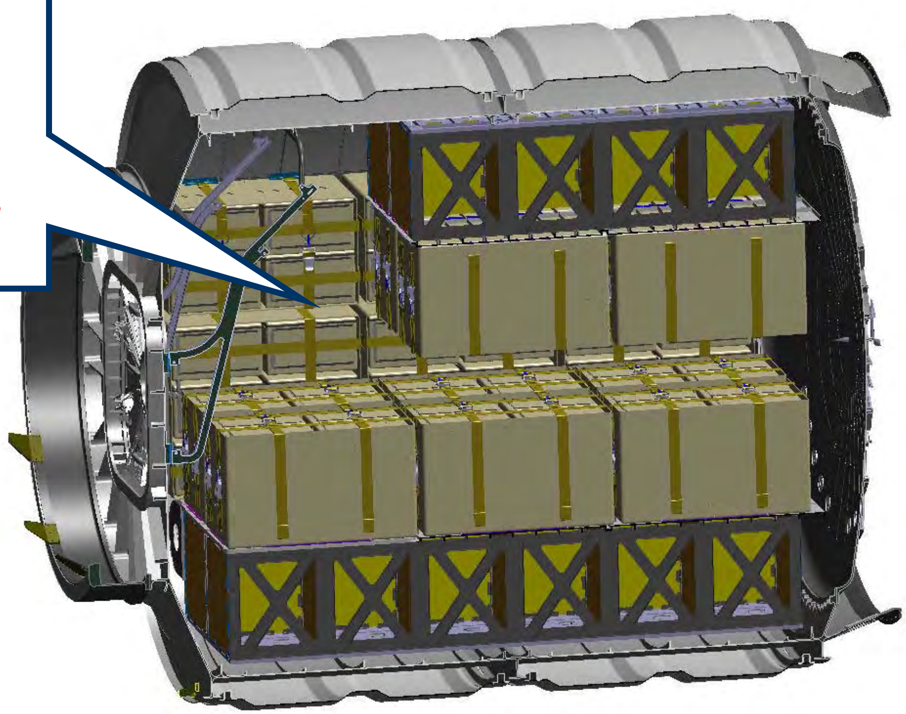
Active Configuration
- Internal Volume 18.75 m^3

Cargo Capabilities:
- 35 CTB's
- 14 M02
- 6 M01
- 4 Mid Deck Lockers
- Equal to 1902 Kg of Cargo Mass

Passive Configuration
- Internal Volume 18.75 m^3

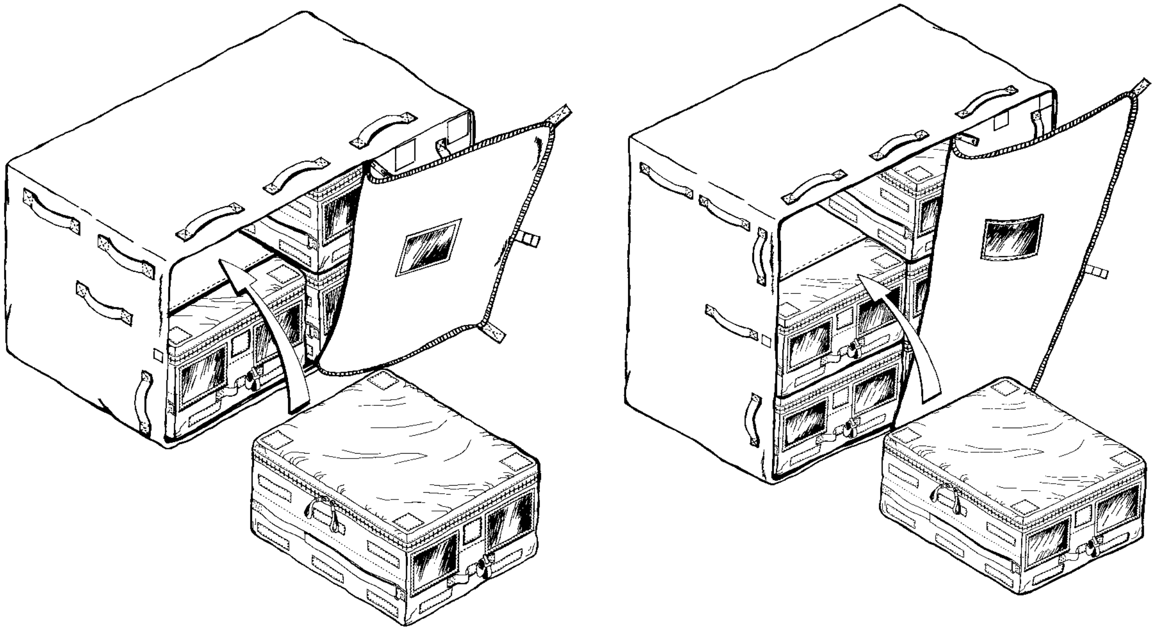
Cargo Capabilities:
- 42 CTB's
- 10 M02
- 6 M01
- Equal to 1988 Kg of Cargo Mass





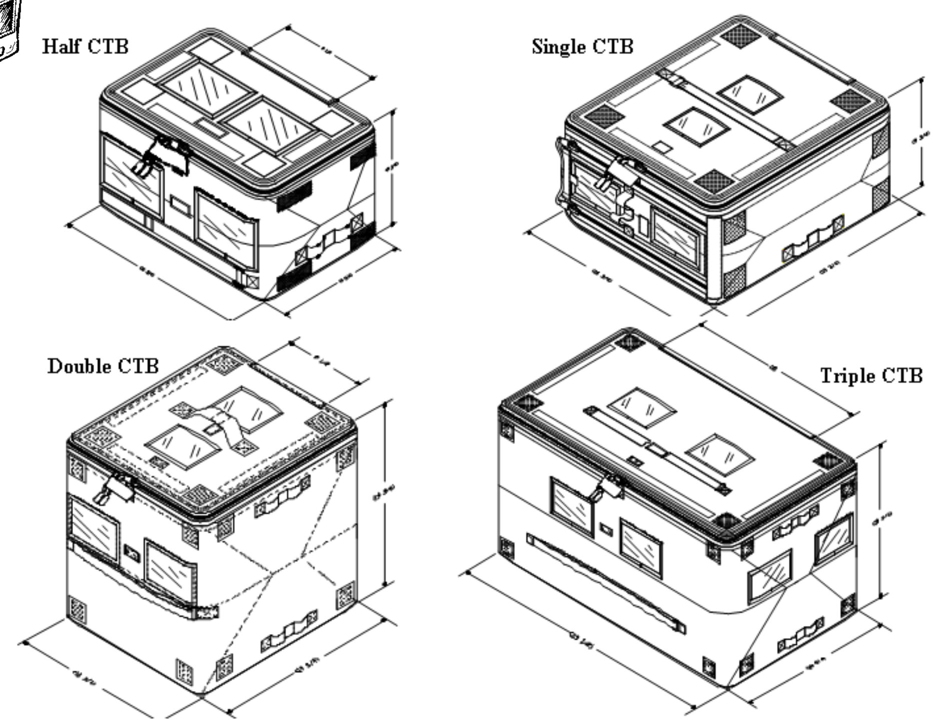
Assumptions:
31 Kg for a single Mid Deck Locker
14 Kg of average mass for each CTB

Standardized Cargo Bags



M1 and M2 Cargo Bags

Cargo Transfer Bags (CTB)



Trash on ISS

iss004e9650

Overview June 2009

DIRECT – Safer, Simpler and Sooner

Presentation before the
Review of U.S. Human Space Flight Plans
Committee
Washington DC, June 17th 2009

www.directlauncher.com

Jupiter Builds upon Existing STS Hardware

Ares-I

New 5-Seg. SRB

New J-2X Engine

New Configuration

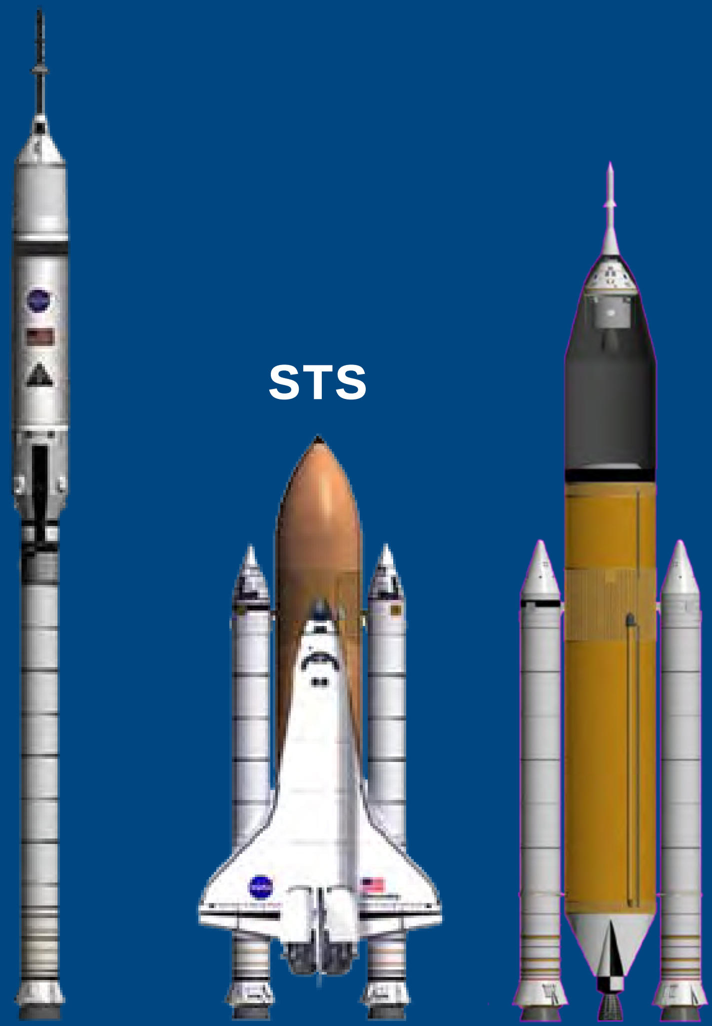
New Infrastructure

New Upper Stage

Limited Orion

Safety Requirements Reduced

$14.4 Billion for system that is less capable than an EELV



Jupiter-130

Existing 4-Seg. SRB

Existing SSME Engines

Existing Configuration

Existing Infrastructure

No Upper Stage

Lunar Class Orion

Safety Requirements Achieved

$8.3 Billion for system that is much more capable than an EELV

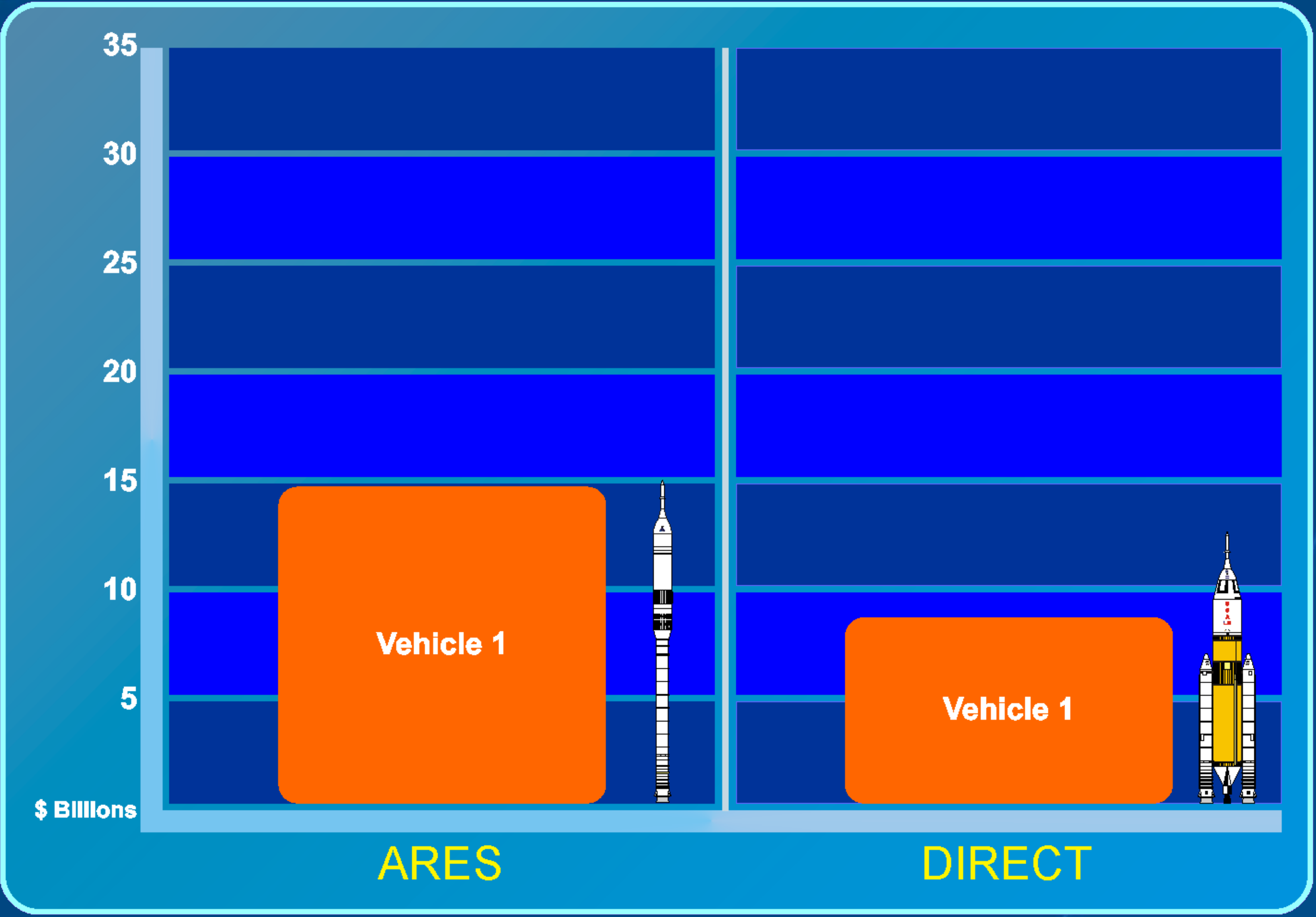
Orion is the Pacing Item not the Launch System

Ares-I		Jupiter-130
$14.4 Billion* ←	Total Development Cost	→ $8.3 Billion
March 2017 ←	Operational Date	→ September 2012

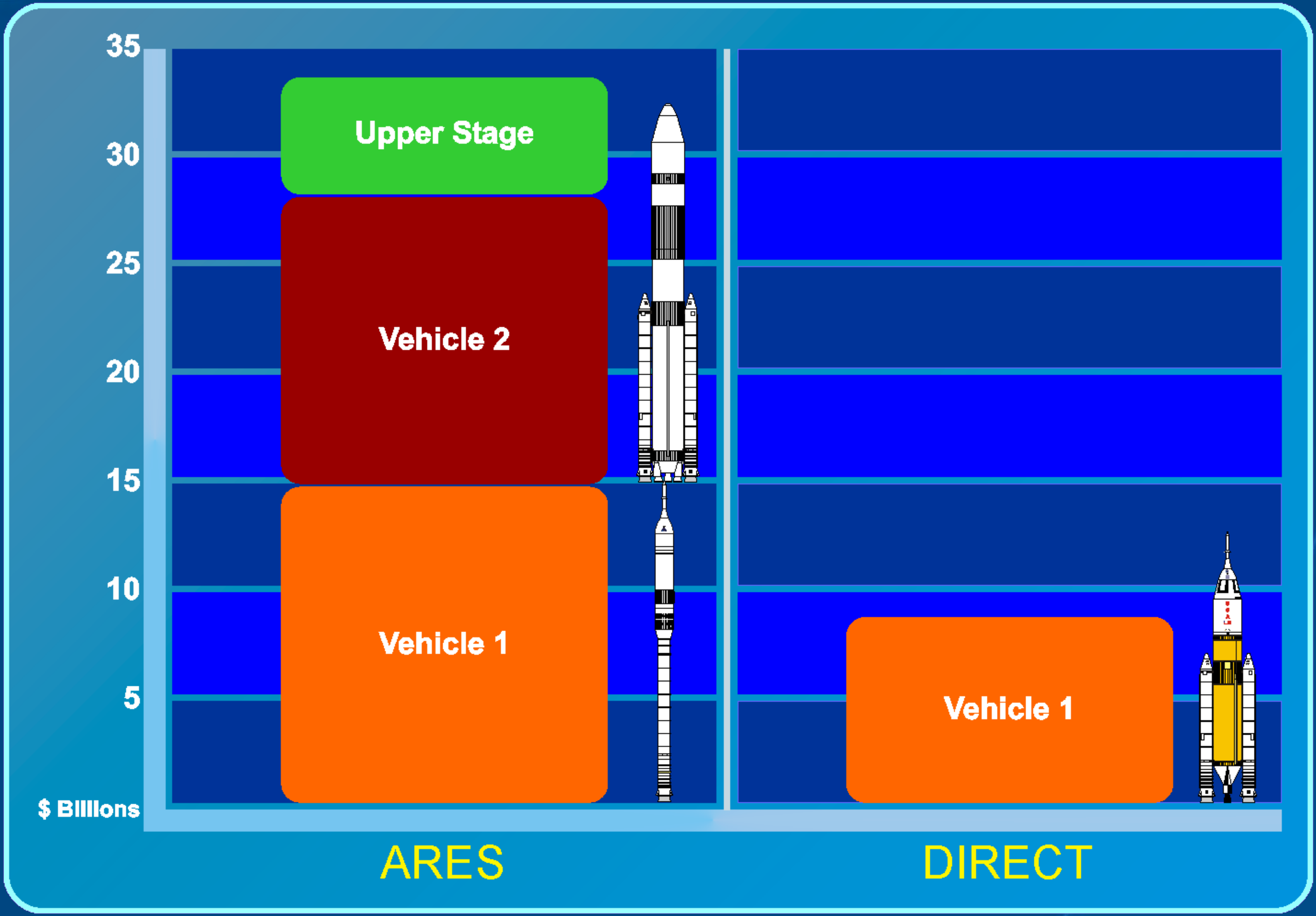
DIRECT <u>Closes the Gap</u> within the <u>Current Budget</u>

**GAO Figure*

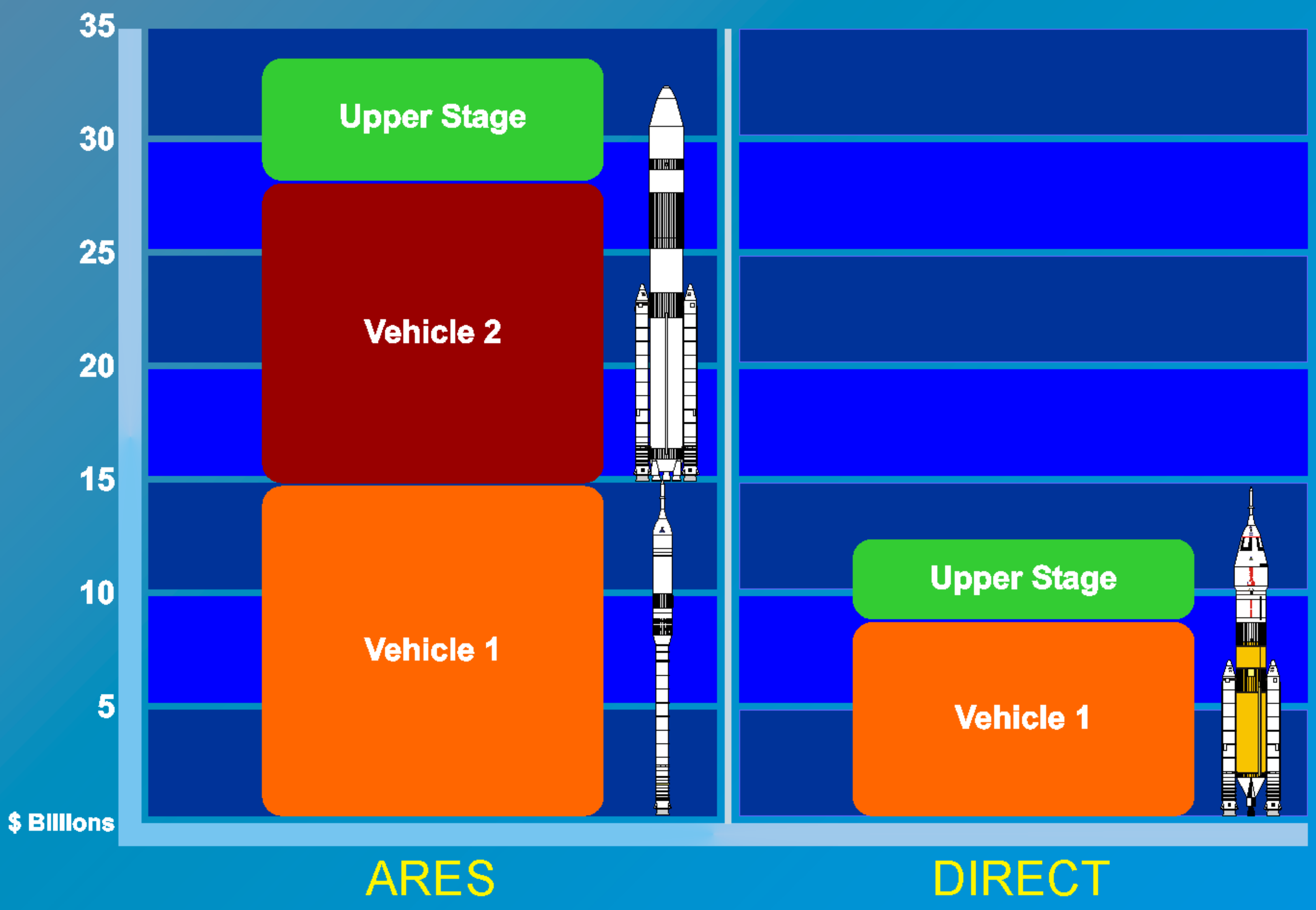
DIRECT Creates New Capabilities at a Lower Cost



Two Different Launch Systems "Busts the Budget"



DIRECT's One Launch System Comfortably Fits the Budget



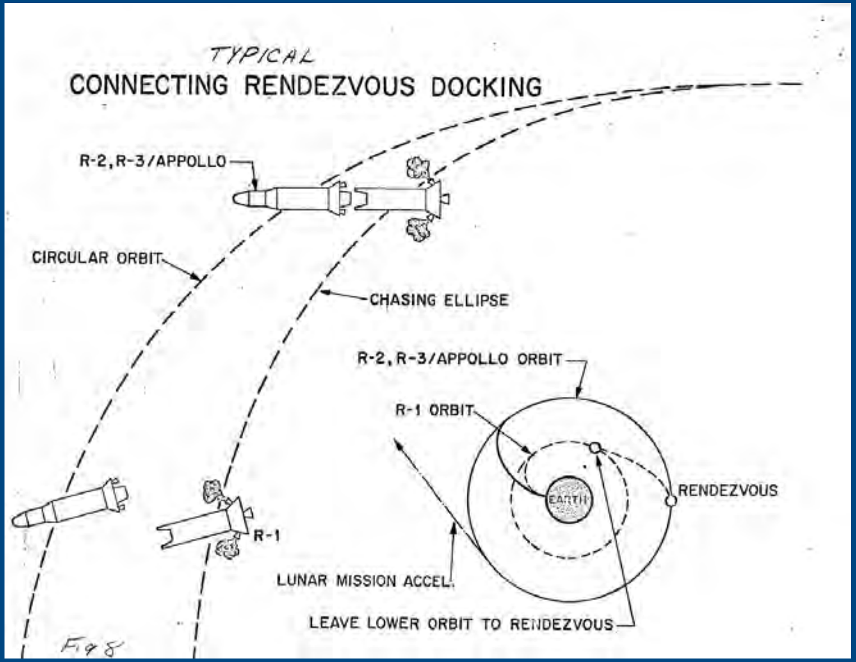
What About the Performance Needed for Mars?

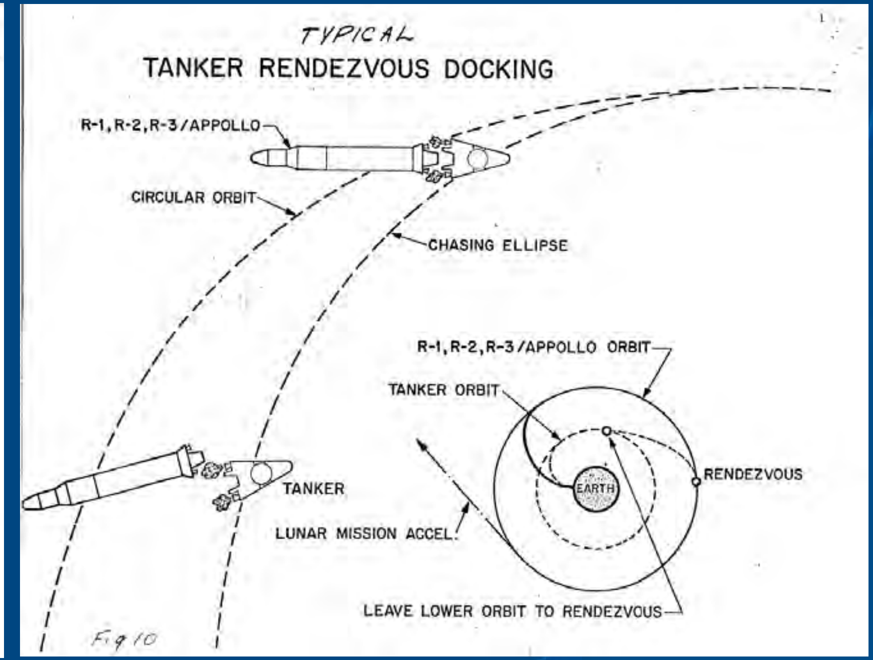
Wernher Von Braun Figured out Performance 46 Years Ago

"We found the *Tanking Mode* substantially superior to the *Connecting Mode*. The performance margin could be enlarged almost indefinitely by the use of additional tankers."

-Dr. Wernher Von Braun June 7, 1962

Most of the Mass Needed for a Mars Mission is Propellant





Propellant Depots are the Bridge to Long Range Exploration

Flexible and Extensible Mission Designs

~70% of the Mission Mass is Open for Commercial & International Supply

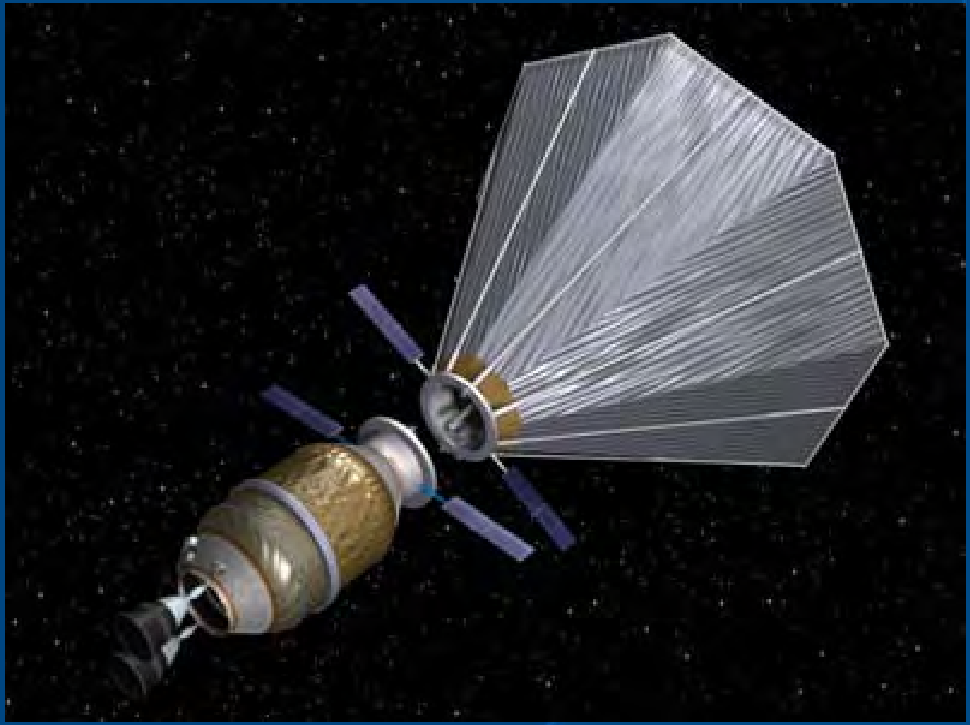
Builds the Infrastructure needed for Leveraging Lunar Resources

Enables Reuse of Expensive Spacecraft

Amplifies the Capabilities of all Missions by Partner Nations

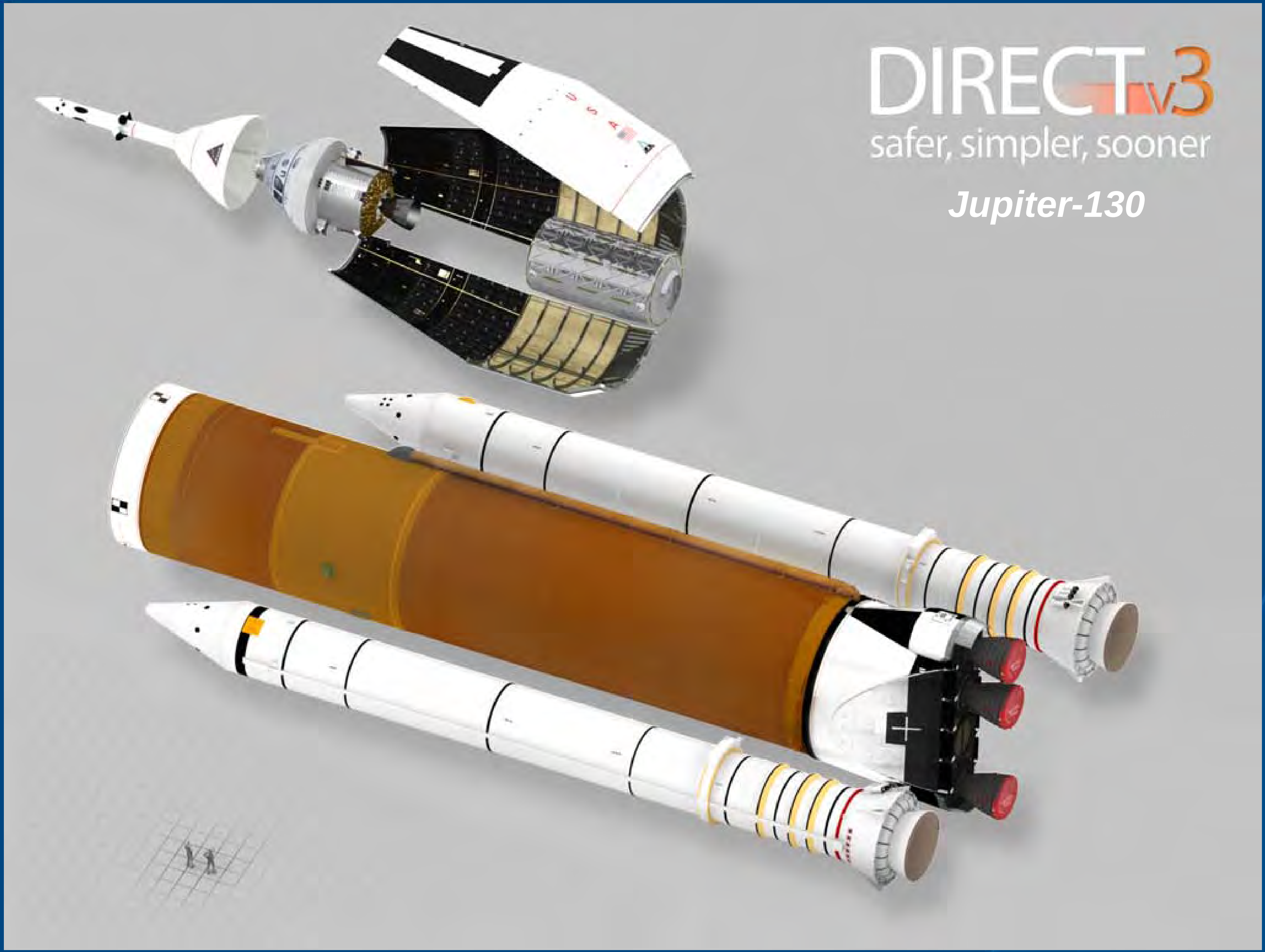
Negates the Need for Super Heavy Lift like the Ares-5

The DIRECT plan meets the advocates of an exclusive EELV/COTS approach more than half way

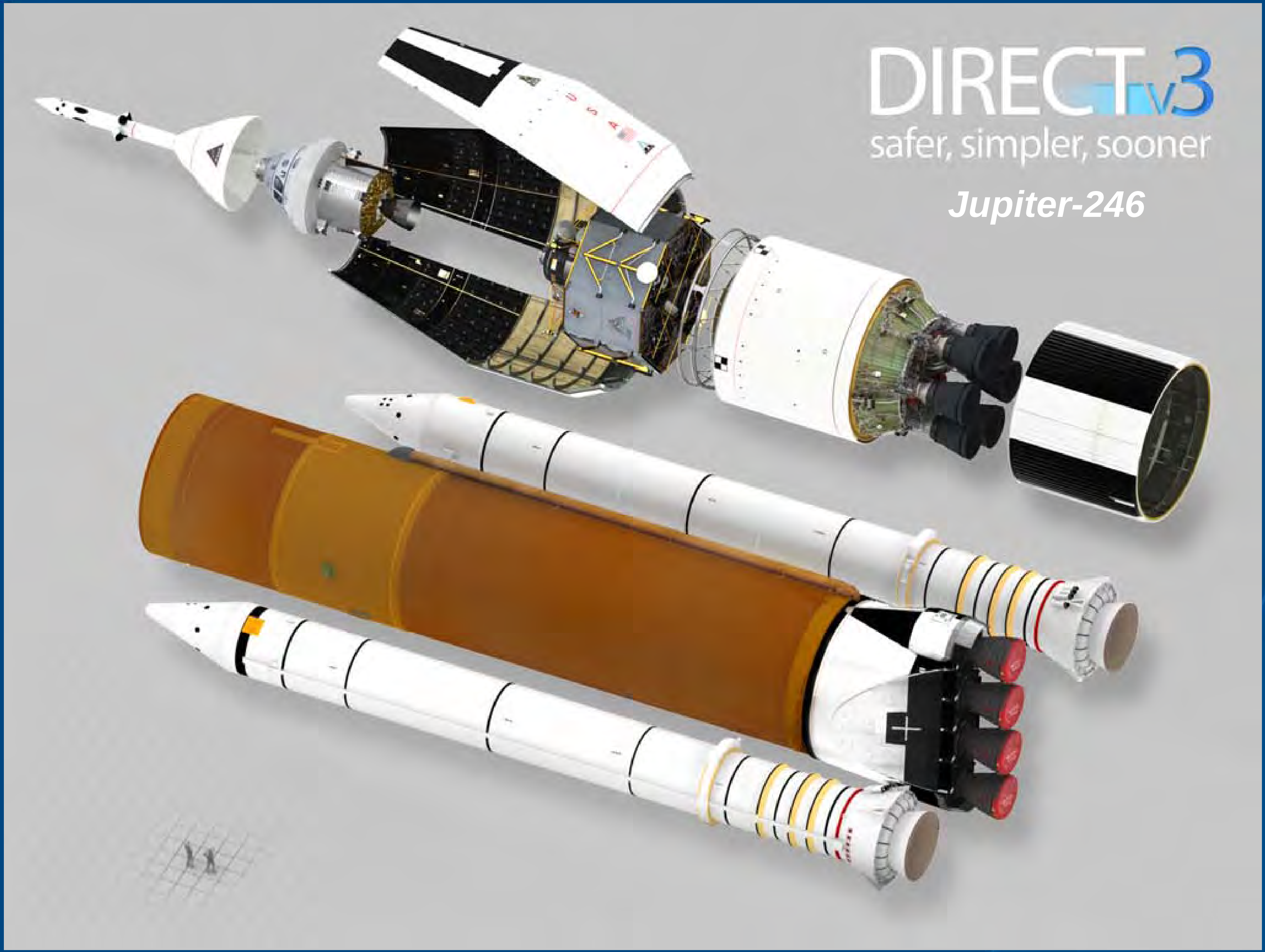


With more than enough demand to max out their existing facilities

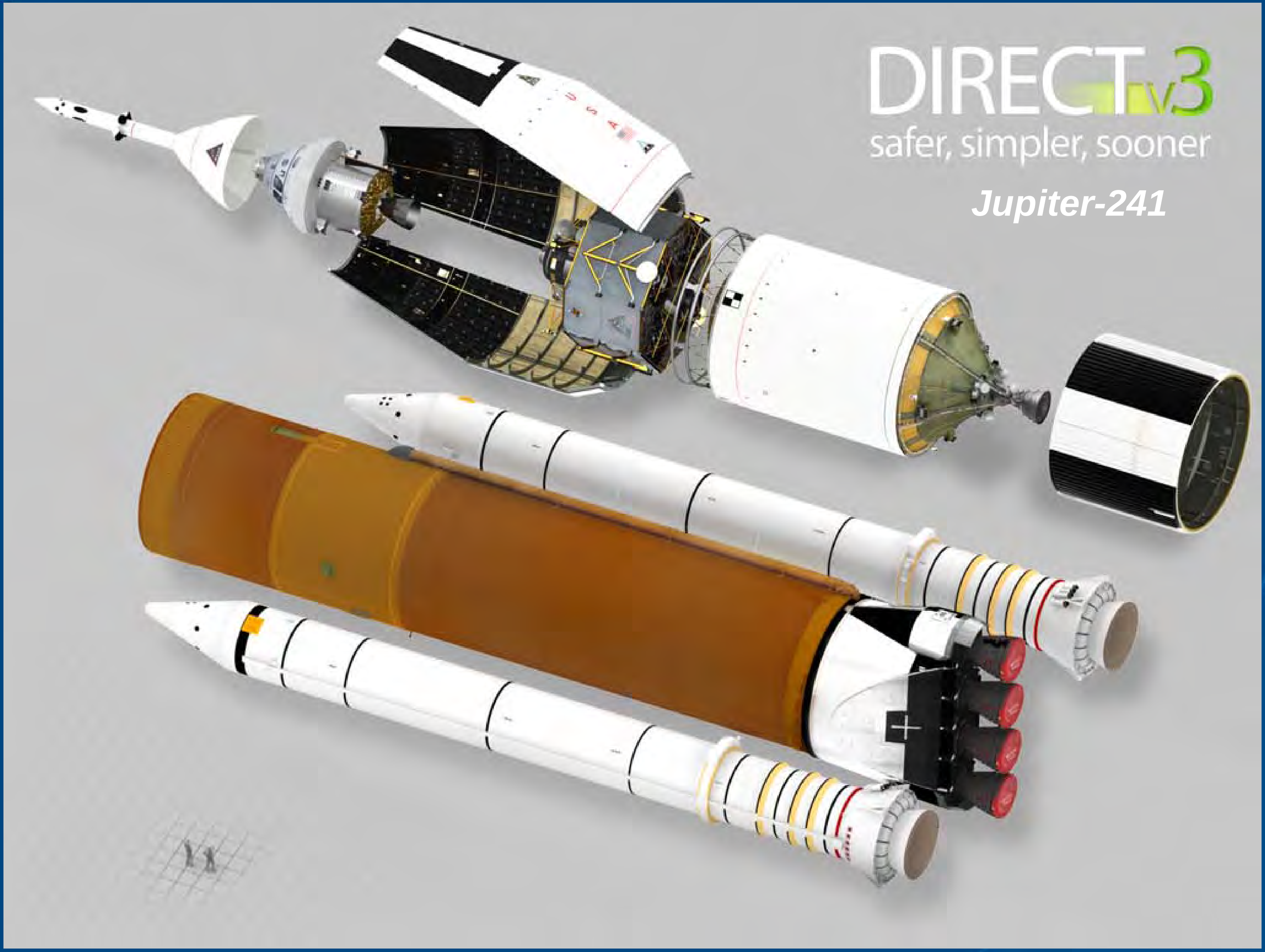
The Jupiter-130 Protects All Our Options Going Forward



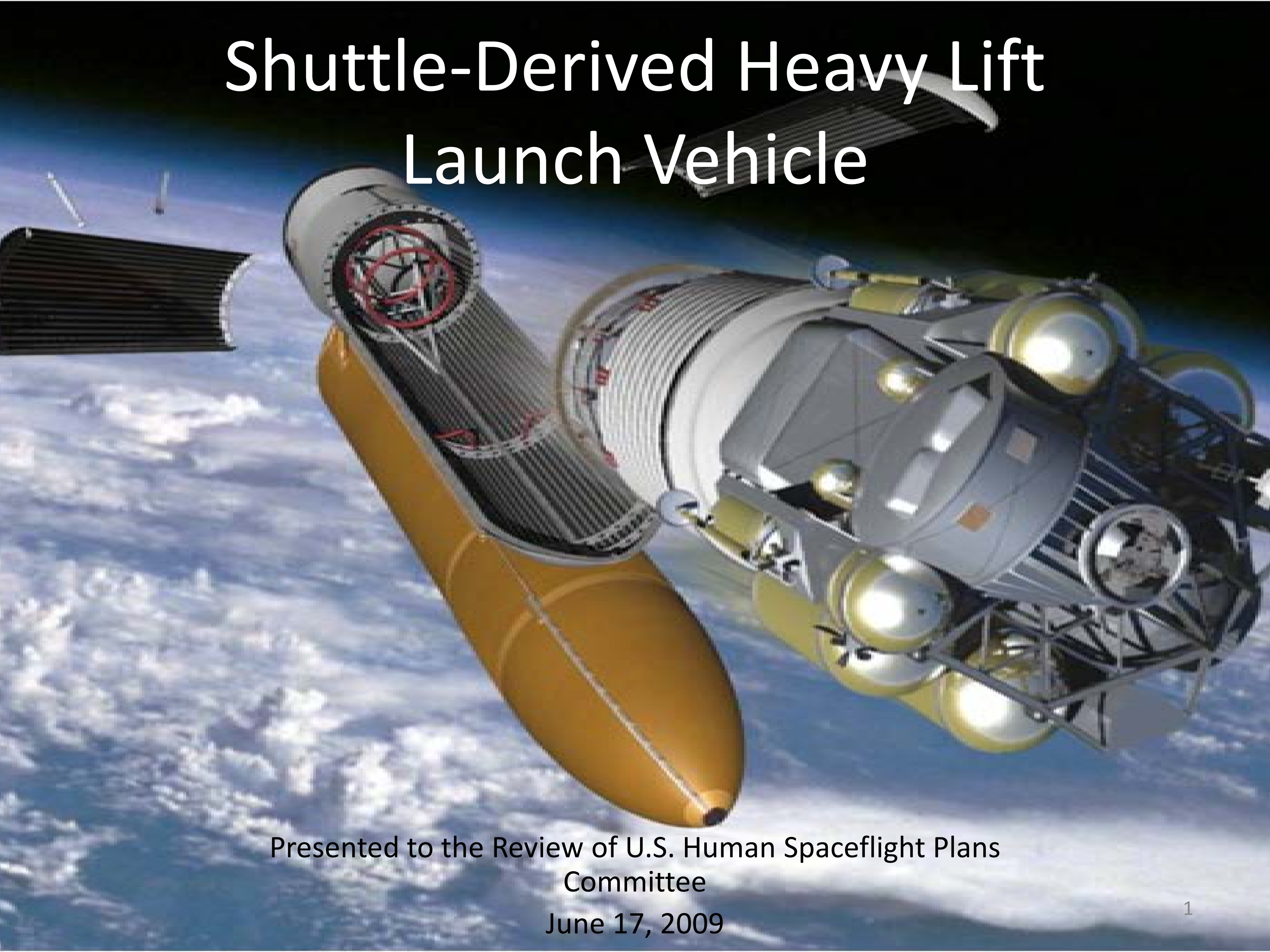
One Option Protected is Breakthrough Missions Beyond Earth



Jupiter-241 (SSME/J-2X)



Shuttle-Derived Heavy Lift Launch Vehicle

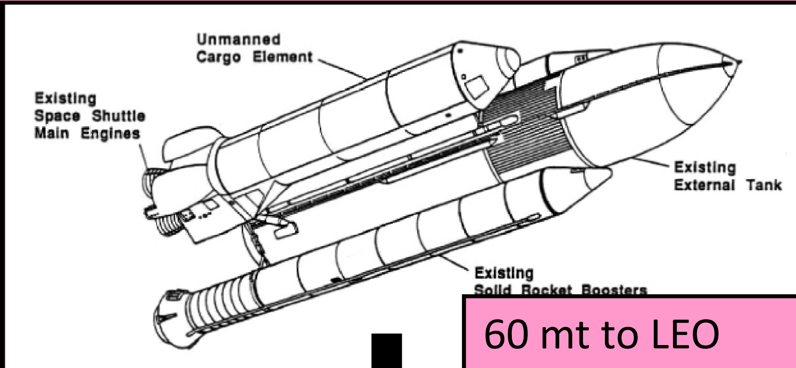


Presented to the Review of U.S. Human Spaceflight Plans Committee

June 17, 2009

Side-Mount Shuttle Derived Vehicle Concepts Have Matured Via Several Major Design Studies

1990's NASA sponsored Shuttle C

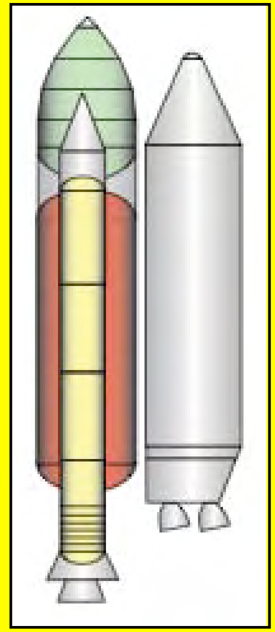


60 mt to LEO

68 mt to LEO

2004 – 2005 Shuttle Derived Launch Vehicle Industry Team Concept B

66 mt to LEO



2005 Exploration Systems Architecture Study (ESAS)

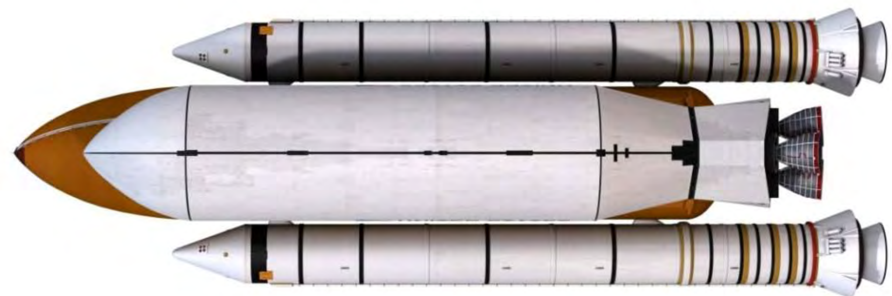
72.1 mt to LEO

2009 HLV Concept

All performance quotes are net payload (consistent 10% performance reserves)

HLV Configuration

- 4,544,684 lb at liftoff
- 647 psf max q
- 3.0 g max



- 7.5-m inner diameter payload carrier
- Modified Shuttle boat tail / Avionics
- Existing 4-segment RSRBs
- Existing ET design

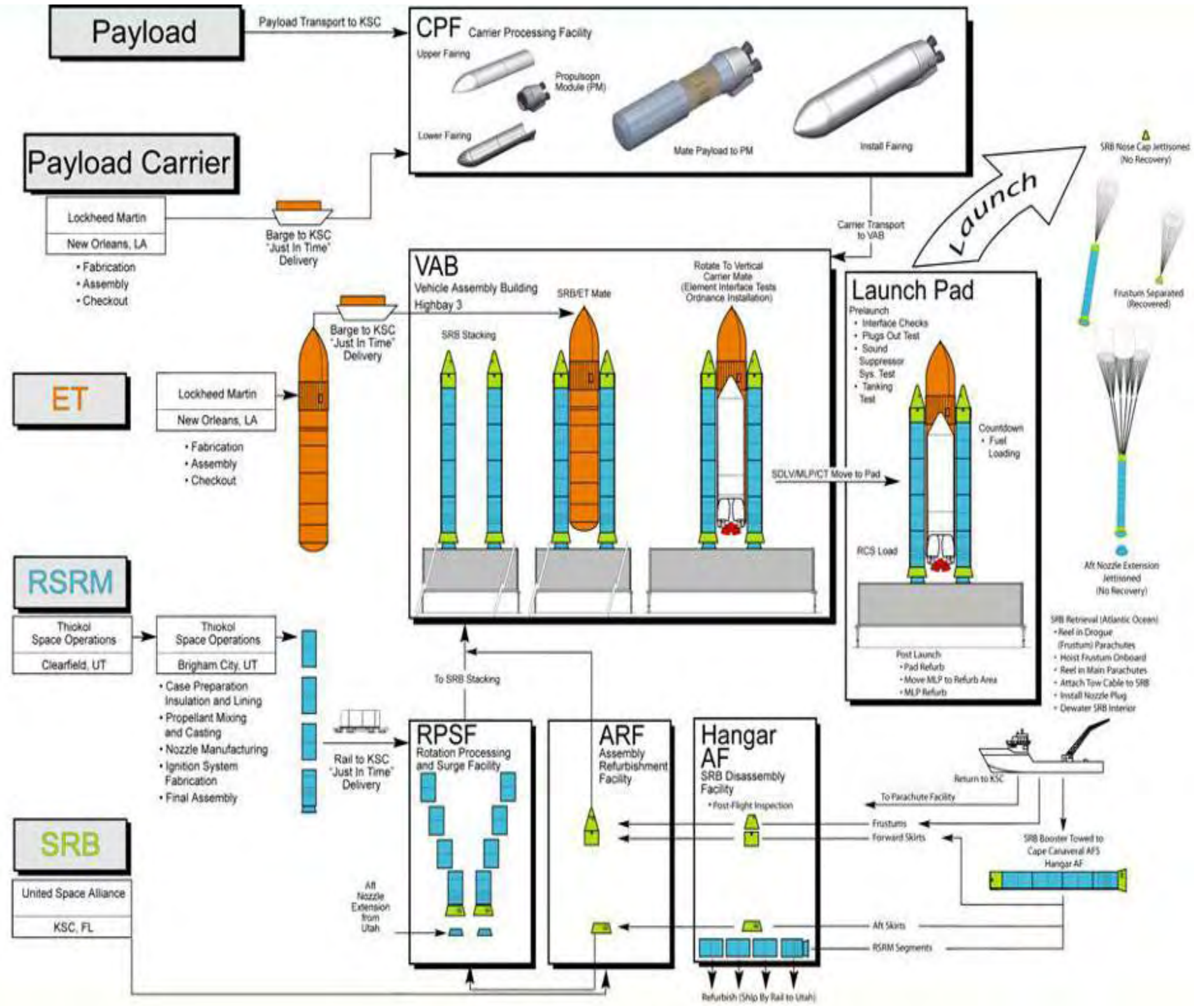
Design Approach

Two block design approach:

- Block I - fly existing Shuttle assets, avionics and software
  - No change to External Tank
  - No change to Solid Rocket Boosters
  - No change to SSMEs
  - Use existing Avionics
  - Use existing Flight Software
  - Use/modify SEI tools (Acoustic, Aerodynamic, Structures, Loads)
  - Existing pad structure
  - Launch and Ground Control software
  - Simplify High-risk aft interface
  - Delete Fuel cells, Cryo, Nitrogen, Cooling systems , OMS, RCS systems

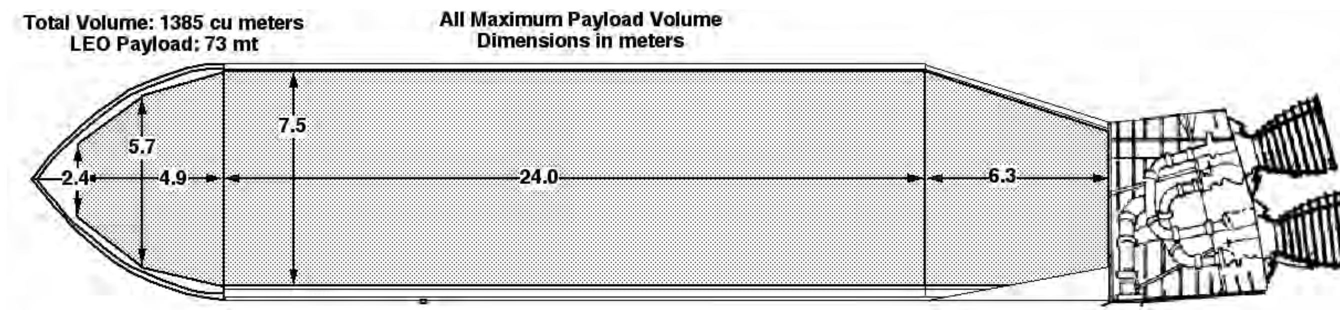
- Block II - Block I upgrade to fly new capabilities as Shuttle spares run out

Use Existing Space Shuttle Infrastructure/Facilities

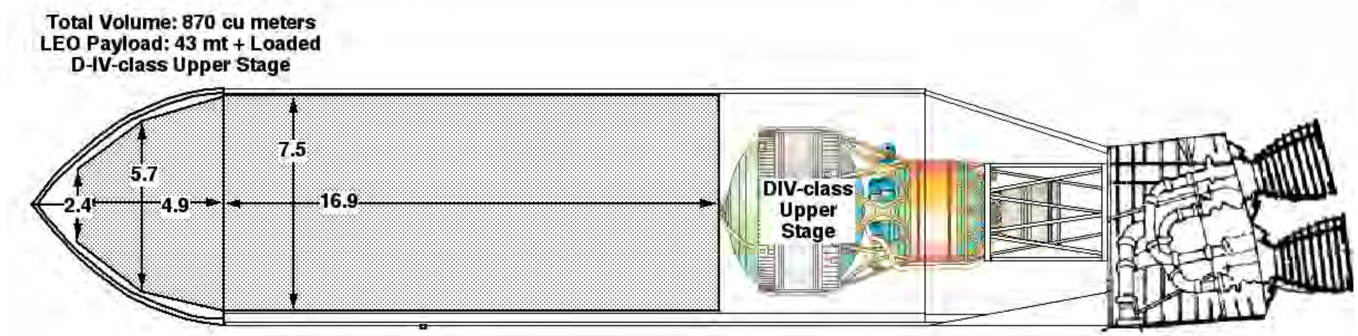


Block I & Block II HLV Carrier Design Payload Envelopes

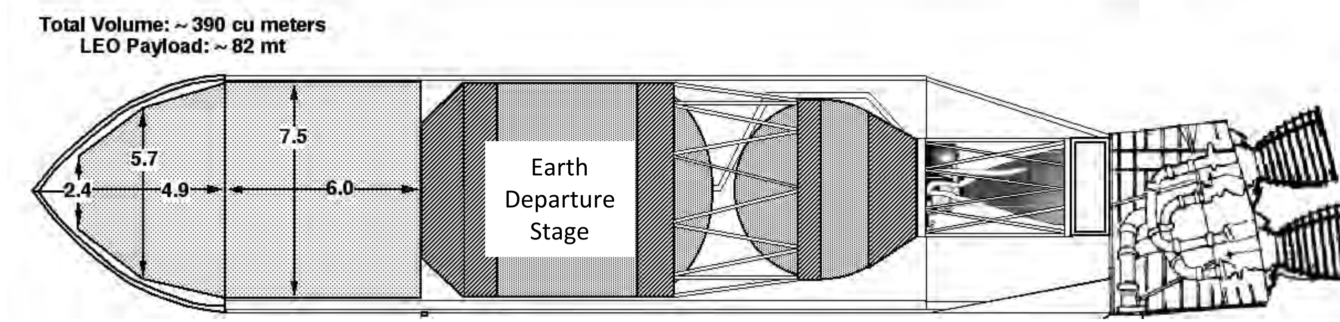
Block I & II



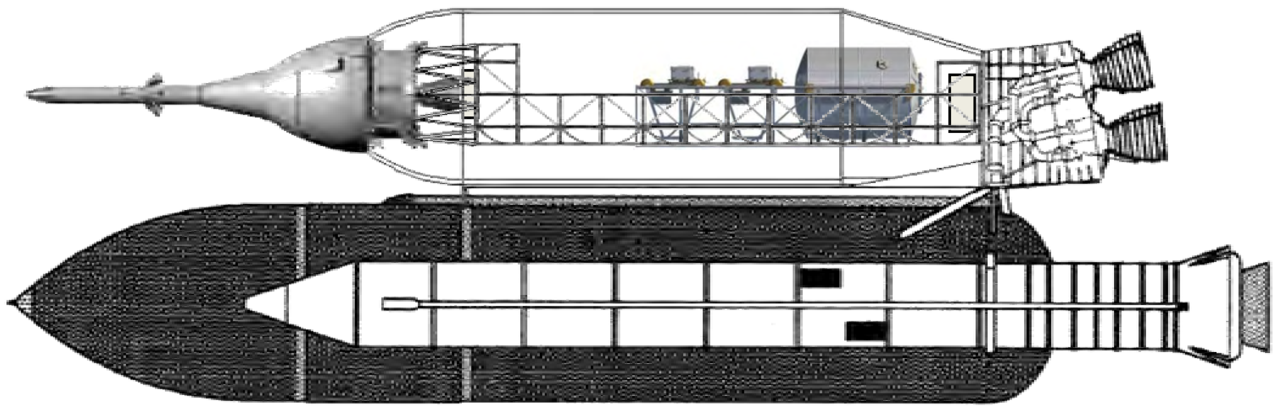
Block I & II



Block II



HLV-CEV Option 2 - ISS Crew & Logistics

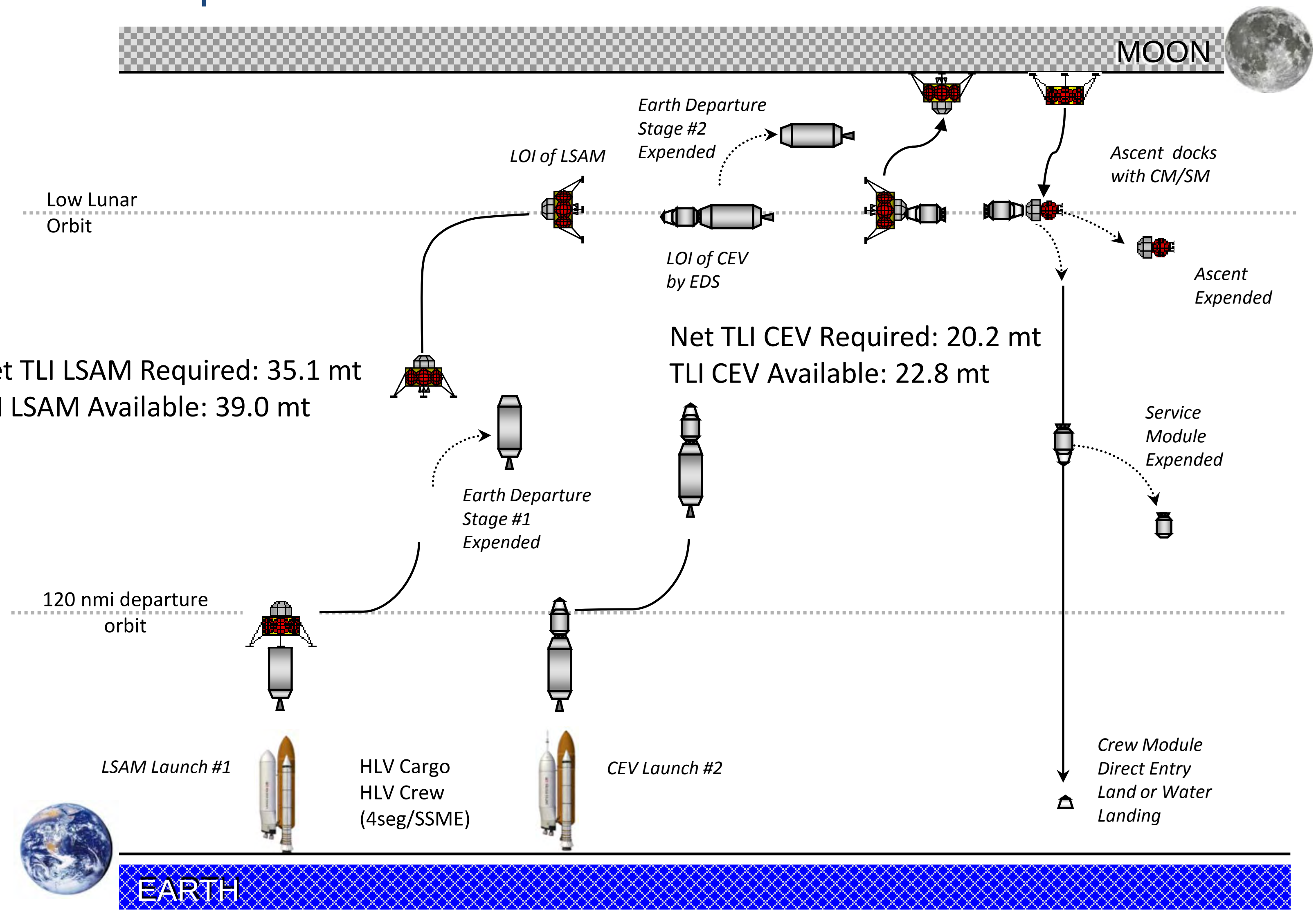


HLV to 51.6 deg MECO: 72 mt

- Orion w/o LAS: 21.2 mt (full propellant load)
- ASE Structure w/docking adapter: 16 mt (estimated)
- 120 nmi circularization propulsion: 1.6 mt
- MPLM: 13.2 mt
- Available: 11.3 mt (unpressurized logistics w/carriers)

- Aft mounted propulsion conducts 160 ft/sec circularization burn (GNC by Orion)
- Orion separates from logistics carrier - docks with forward adapter on ASE frame
- Orion propulsion used for all subsequent orbit maneuvers to and from ISS
    - Sufficient propellants in lunar version Orion Service Module for maneuvers

Block II HLV
Split Mission LOR Human Lunar Scenario



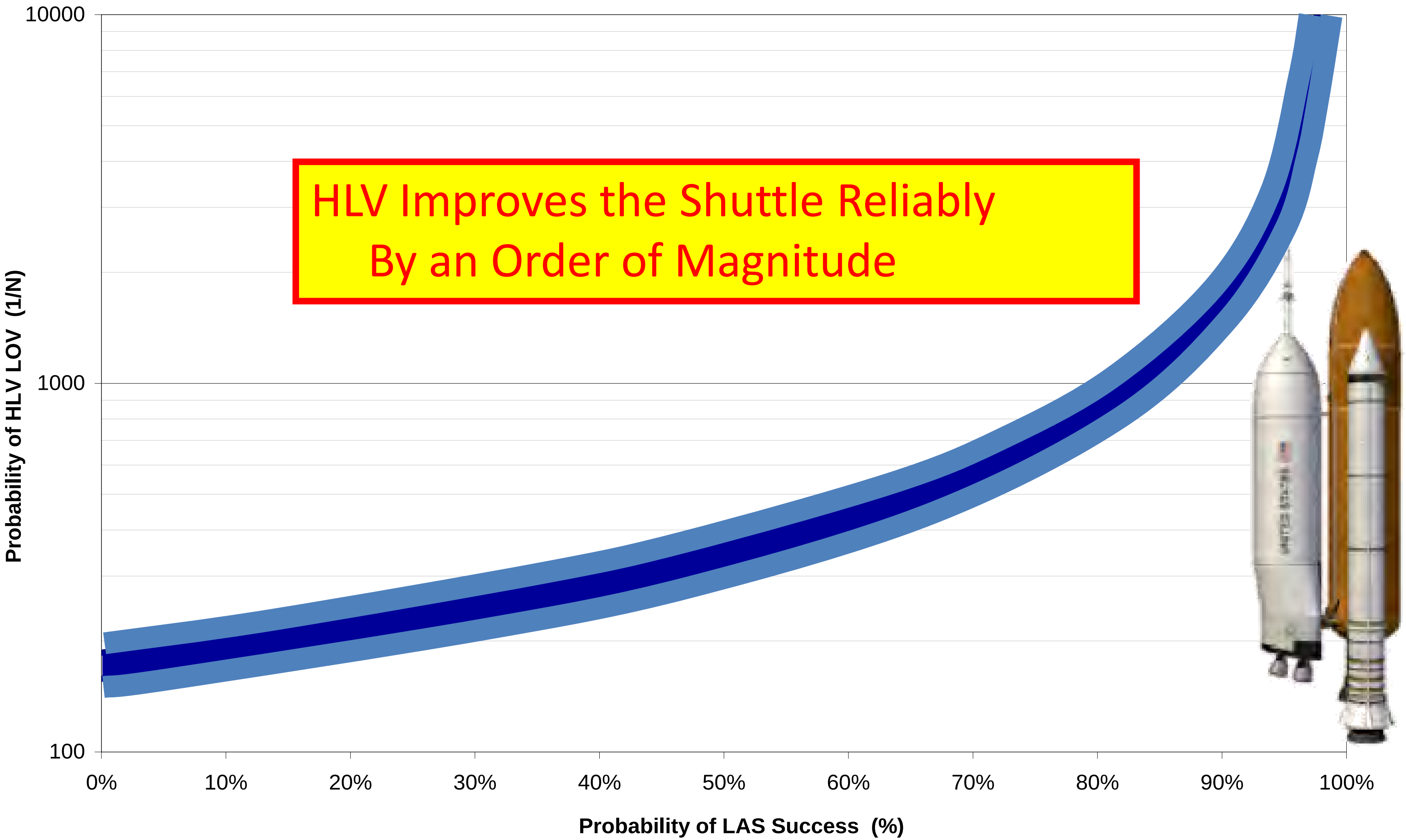
HLV Reliability from the Shuttle PRA

Contributor	High Reliability Scenario	Low Reliability Scenario
SSME	1 in 300	1 in 250
RSRM	1 in 1550	1 in 1550
SRB only	1 in 2104	1 in 2104
Total SRB	1 in 893	1 in 893
External Tank	1 in 4762	1 in 4762
Subtotal (Shuttle Systems Only)	~1 in 214	~1 in 188
Payload Carrier	~1 in 1400	~1 in 1000
Total HLV LOV	**~1 in 186**	**~1 in 158**

<u>Assumptions for SSMEs</u>

- 3 SSMEs
- 104% Power Level
- 540 sec. Duration
- No Engine Out Capability
- TBD Carrier Subsystems

Probability of HLV LOC with LAS



National Aeronautics and Space Administration

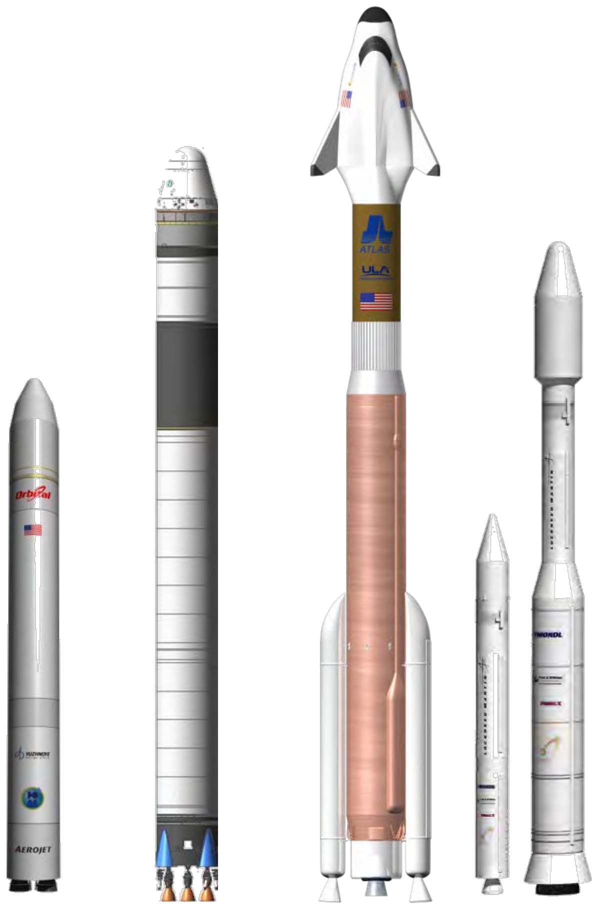
Commercial Crew and Cargo
Program Overview

June 17, 2009
Doug Cooke

COMMERCIAL CREW & CARGO

Program Objectives

- **NASA established the Commercial Crew & Cargo Program in November 2005 to accomplish the following objectives:**
  - **Implement U.S. Space Exploration policy with investments to stimulate the commercial space industry**
  - **Facilitate U.S. private industry demonstration of cargo and crew space transportation capabilities with the goal of achieving safe, reliable, cost effective access to low-Earth orbit**
  - **Create a market environment where commercial space transportation services are available to Government and private sector customers**

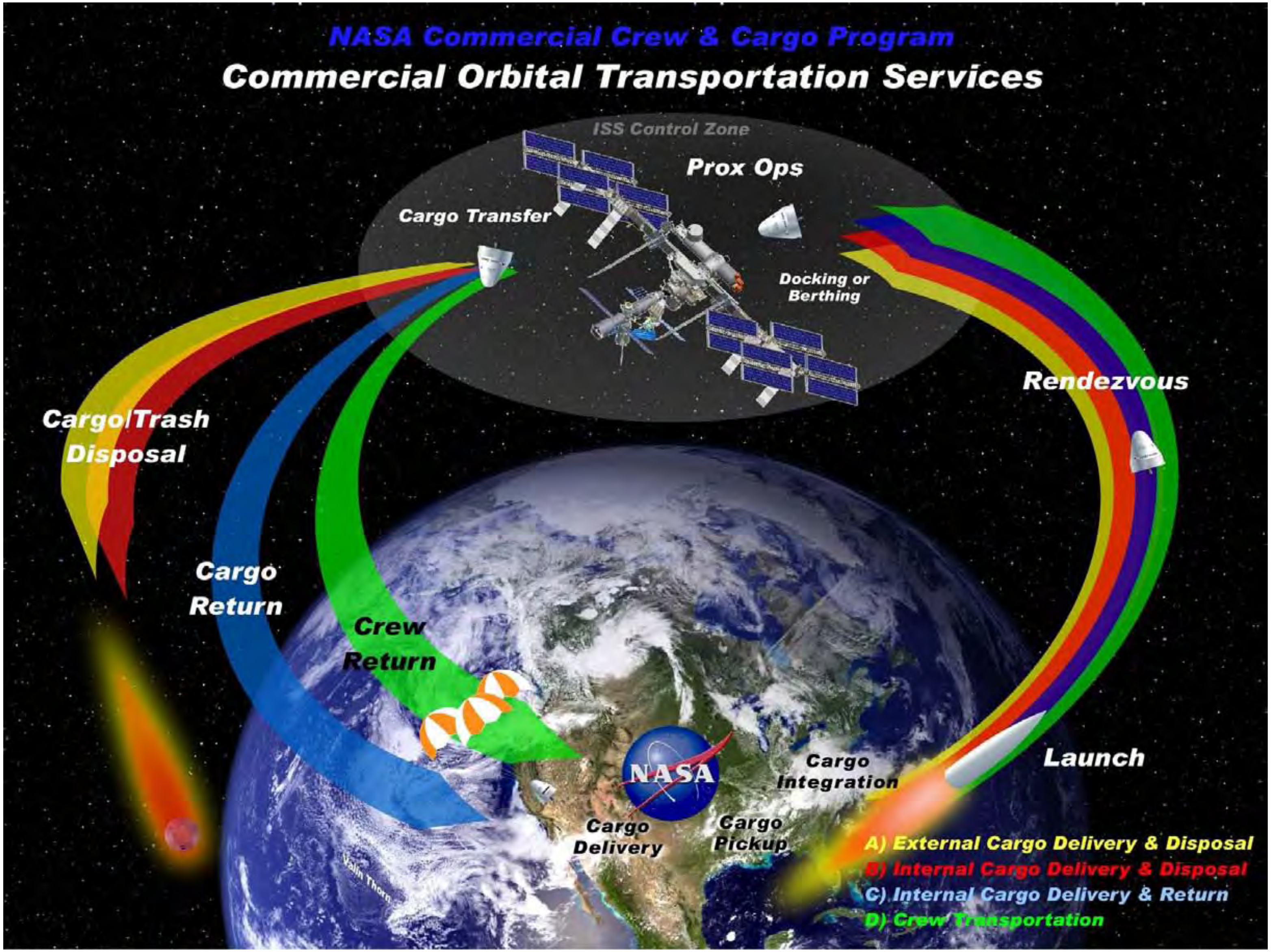


Extending human presence in space by enabling an expanding and robust U.S. commercial space transportation industry

Commercial Orbital Transportation Services (COTS) Overview

- **$500M budgeted in FY06-FY10 as an *investment* for the demonstration of commercial orbital transportation capabilities**
- **COTS executed in two phases:**
  - **Phase 1: Technical Development/Demonstration funded *Space Act Agreements* (SAA)**
  - **Phase 2: Competitive Procurement of ISS Commercial Resupply Services (managed by SOMD/ISS Program)**
- **Phase 1 first round competition for funded SAAs awarded August 2006**
  - **SpaceX awarded $278M SAA**
  - **Rocketplane Kistler awarded $208M SAA (Terminated in Oct 07 for failure to meet milestones)**
- **Phase 1 second round competition awarded February 2008**
  - **Orbital Sciences Corp. awarded $170M SAA**
- **Phase 2 procurement of ISS Commercial Resupply Services (CRS) contracts awarded December 2008**
- **Potential contract value for:**
  - **SpaceX $1.6B for ISS cargo services**
  - **Orbital $1.9B for ISS cargo services**

Potential COTS Capabilities



SpaceX COTS System

SPACEX

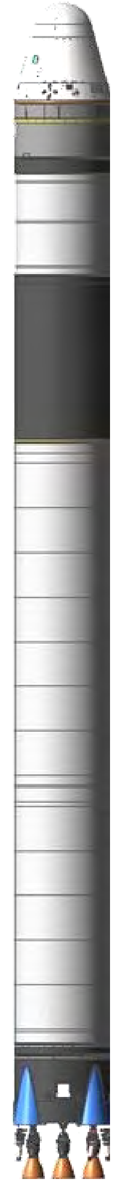
Description and Features:

- **Falcon 9 Medium Class Launch Vehicle**
- **Dragon Crew/Cargo Spacecraft**
- **Recoverable launch vehicle and spacecraft**
- **Cape Canaveral LC-40 Launch Site**
- **ISS Flight Demonstration: March 2010** **(per SAA)**
- **Cargo Demonstration – up to $278 M**
- **Crew Demonstration Option – up to $308 M (not funded)**

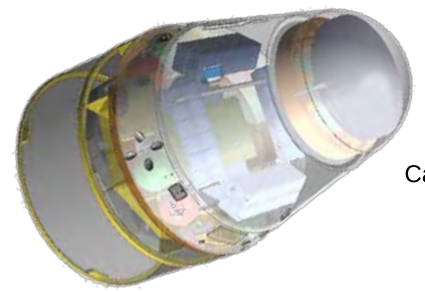
ARES CORPORATION

ODYSSEY SPACE RESEARCH

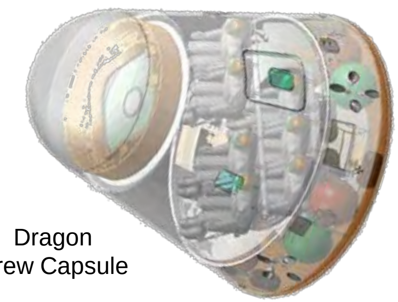
PARAGON SPACE DEVELOPMENT CORPORATION



Falcon 9 Rocket



Dragon Cargo Capsule



Dragon Crew Capsule

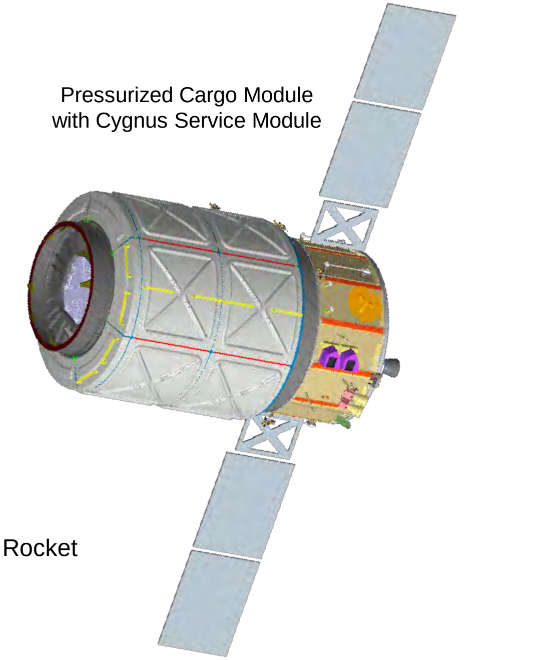
SpaceX Launch Site at Cape SLC 40

Orbital COTS System

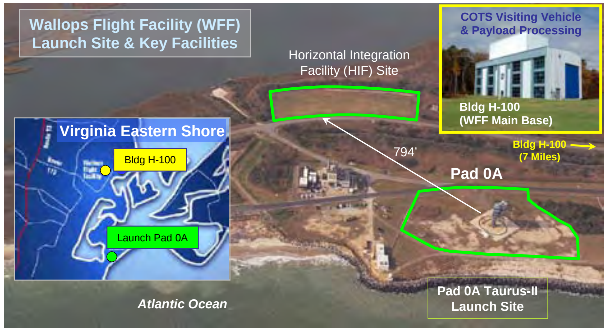
Description & Features:

- **Taurus II Launch Vehicle – derivative of Taurus I with Aerojet AJ-26 engines (2) & Castor 30 2nd stage**
- **Cygnus Service Module used for all missions – derived from STAR™ & Dawn spacecrafts**
- **Pressurized Cargo Module (PCM): Heritage - ISS MPLM**
- **Wallops Flight Facility Launch Site**
- **ISS Flight Demonstration: March 2011**
- **Cargo Demonstration – up to $170 M**

Taurus II Rocket



Pressurized Cargo Module with Cygnus Service Module

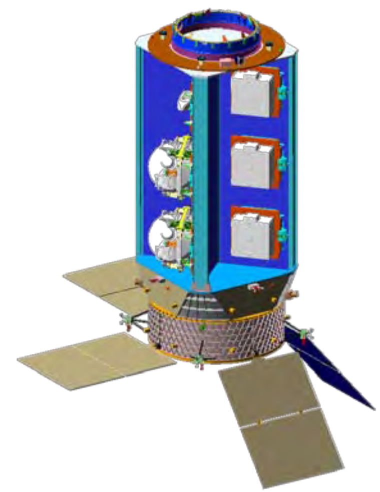


MARS/Wallops Launch Site

ThalesAlenia Space DRAPER LABORATORY SAIC An Employee-Owned Company ODYSSEY SPACE RESEARCH

Other Commercial Partners

- **NASA continues to support two <u>unfunded</u> SAA commercial partners**
  - **PlanetSpace**
  - **SpaceDev**



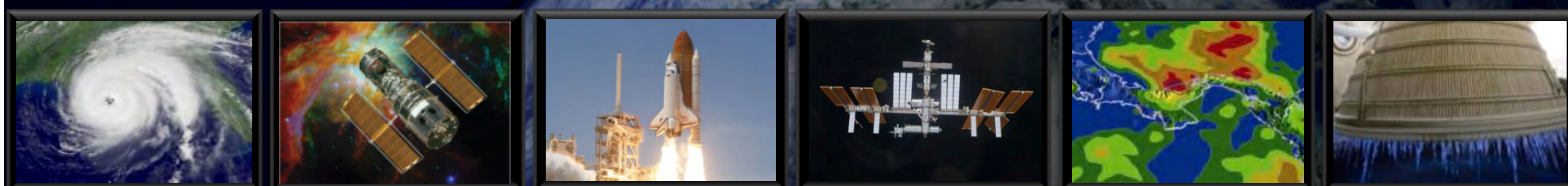
PlanetSpace
Athena III

SpaceDev DreamChaser

National Aeronautics and Space Administration

Space Launch System (SLS) Program Overview NASA Research Announcement (NRA) Advanced Booster (AB) Engineering Demonstration and Risk Reduction (EDRR) Industry Day

Space Launch System



Todd A. May, SLS Program Manager

NASA Marshall Space Flight Center

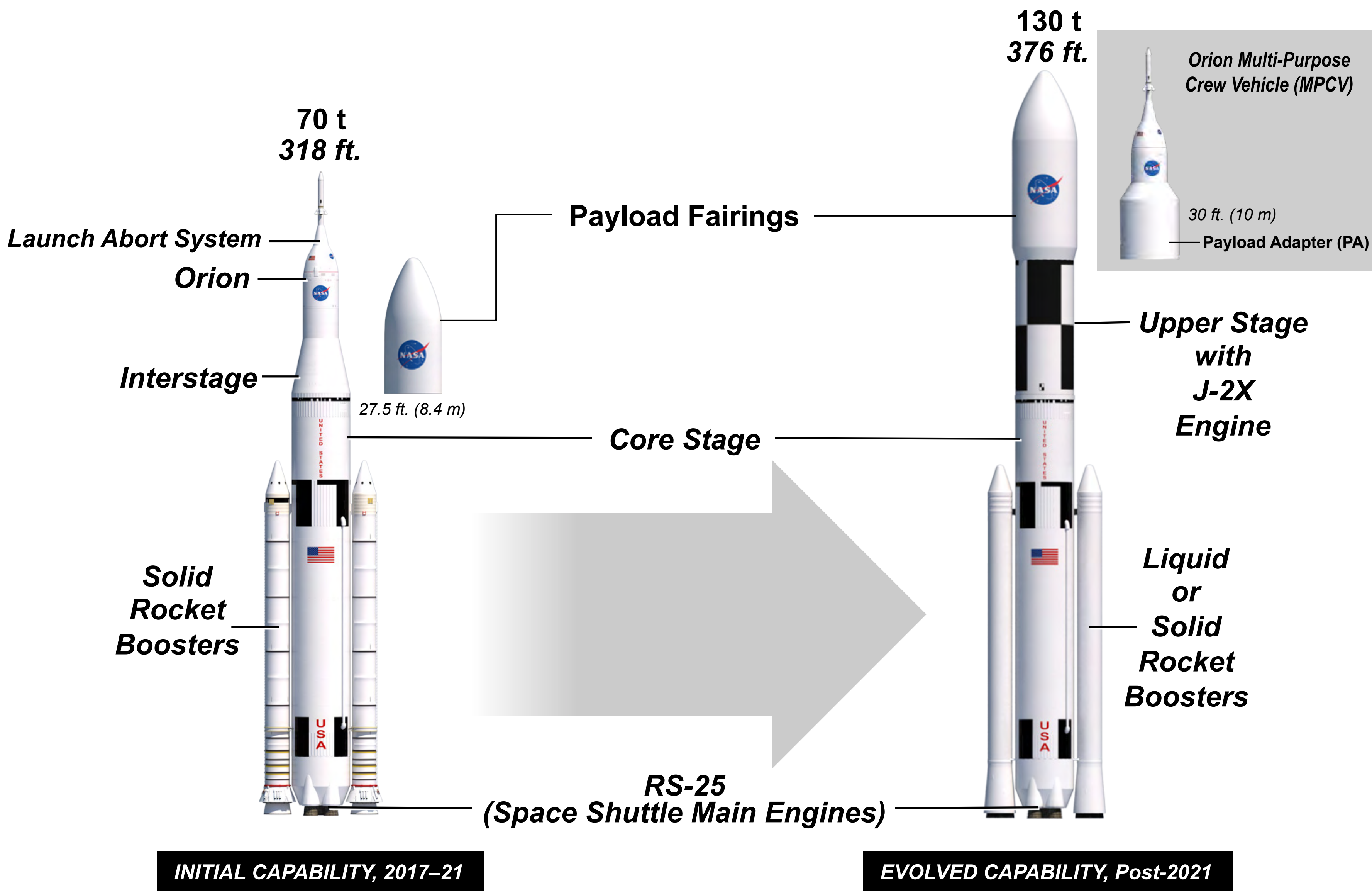
December 15, 2011

SLS Driving Objectives

- **Safe: Human-Rated**
- **Affordable**
  - Constrained budget environment
  - Maximum use of common elements and existing assets, infrastructure, and workforce
  - Competitive opportunities for affordability on-ramps
- **Initial capability: 70 metric tons (t), 2017–2021**
  - Serves as primary transportation for Orion and exploration missions
  - Provides back-up capability for crew/cargo to ISS
- **Evolved capability: 130 t, post–2021**
  - Offers large volume for science missions and payloads
  - Modular and flexible, right-sized for mission requirements

SLS First Flight in 2017

SLS Architecture Uses Existing and Advanced Technologies to Fly in 2017



Built in the U.S.A.

Advancing the U.S. Legacy of Human Exploration

Ares 1-X Test Flight - 10/2009

Falcon 9/Dragon Flight - 12/2010

Dragon Recovery