United Launch Alliance

Presentation to the

National Research Council

04 February 2013

Image Courtesy NASA

United Launch Alliance

- ❑ Two World Class Launch Systems Operating as a Single Provider to the U.S. Government
  - – Atlas V Product Line, Delta IV Product Line, Delta II Product Line
- ❑ More Than a Century of Combined Experience in Expendable Launch Systems & Providing Assured Access to Space
  - – Pooled Experience of More Than 1,300 Launches
  - – Legacy Reaching Back to the 1950s
- ❑ Responsible for Design, Development, Production, Spacecraft Integration, and Launch

Atlas

Delta

ULA Launch History (Through 2012)

Sixty-Six Launches, 100% Mission Success


TDRSS-K

Sixty-Six Launches, 100 % Mission Success


ATLAS

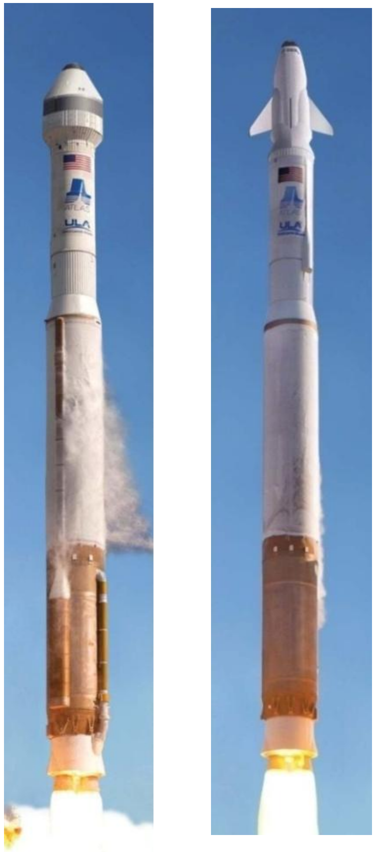
United Launch Alliance

ULA Human Spaceflight Programs

Exploration Flight Test

Delta IV HLV Launch of
Orion Capsule in 2014

Commercial Crew



Atlas Launch of Commercial
Human Spacecraft in 2016

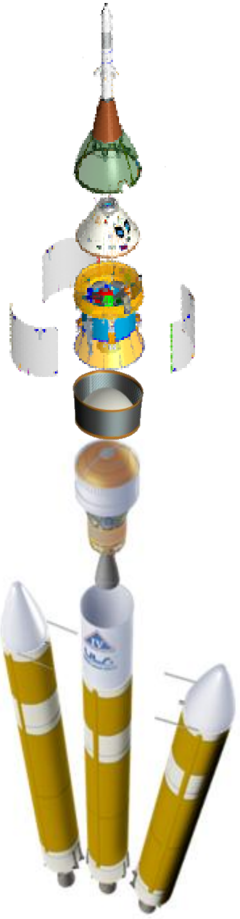
Space Launch System

Interim Cryogenic Upper
Stage for Heavy Lift in 2017

Broad ULA Support to the Nation’s Human Spaceflight Program

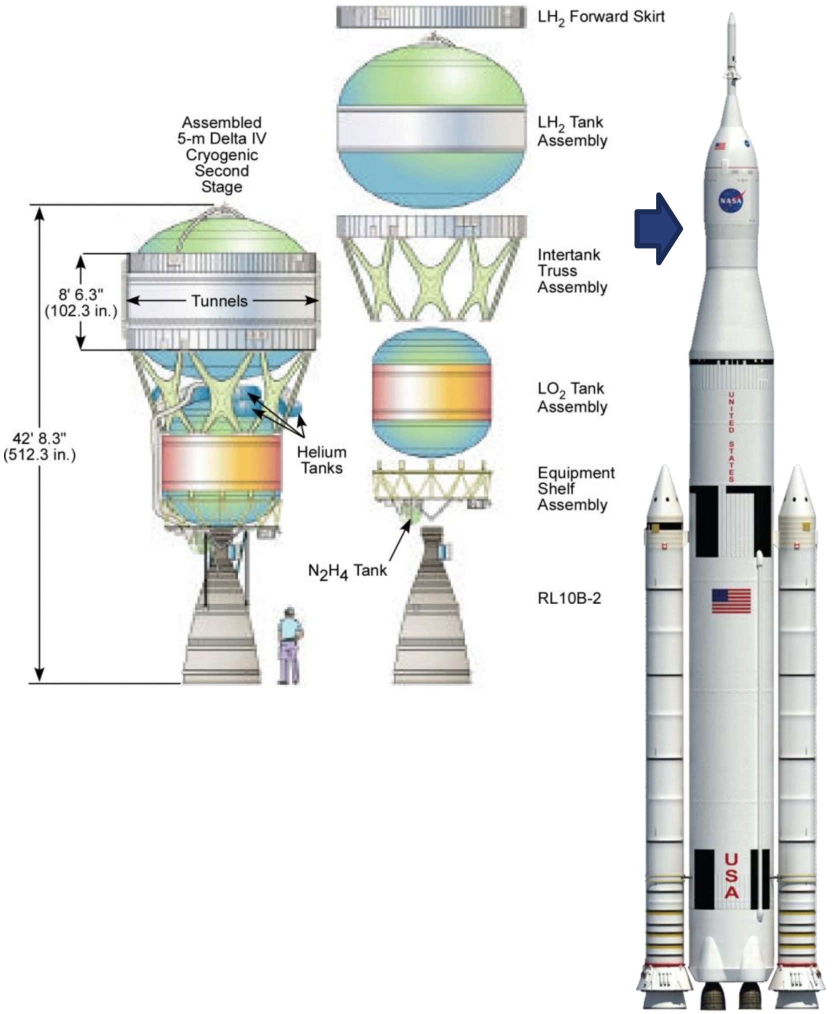
Exploration Flight Test

- Exploration Flight Test 1 (EFT-1) of LMC Orion Capsule
  - Integrate and Launch on Delta IV HLV
  - Controlled Re-Entry of Orion Capsule
- ULA Effort Includes
  - Mission Unique Accommodations
  - LC-37 Infrastructure Upgrades
    - Modify MST Platforms at Levels 9/10 for 5.5M Capsule
    - Modify Swing Arm #3 umbilical carrier for Orion Interfaces
    - Run EGSE Fiber Optic Cables
- Launch in September 2014
  - 2 MEO Orbits with Targeted Re-entry into Pacific Ocean

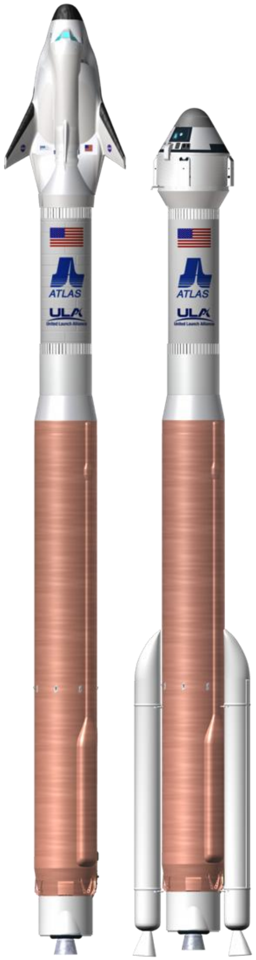


Space Launch System

- ❑ Two Delta IV 5m Cryogenic Second Stages, Rebranded as NASA Interim Cryogenic Propulsion Stage (ICPS) with the Option for 2 Additional
  - – Mission Unique Modifications
    - 18” Tank Stretch
    - Emergency Detection System
    - Common Avionics on DCSS
- ❑ Launches from SLC-39 in December 2017 (Uncrewed) and 2021 (Crewed)
  - – Lunar free-return mission



Commercial Crew



- Commercial Crew Integrated Capability (CCiCap) Development and Launch of the Boeing CST-100 and Sierra Nevada Dream Chaser on Atlas V-4X2
  - POP through May 2014

- ULA Effort Includes
  - Human Spaceflight Certification
  - Emergency Detection System
  - Dual Engine Centaur
  - Common Avionics
  - LC-41 Modifications
    - Crew Access Tower & Arm
    - Elevator & Stairway
    - Slide Wires

- Two Launch Services (BA Dates)
  - Uncrewed Mission in August 2016
  - Crewed Mission in December 2016

United Launch Alliance

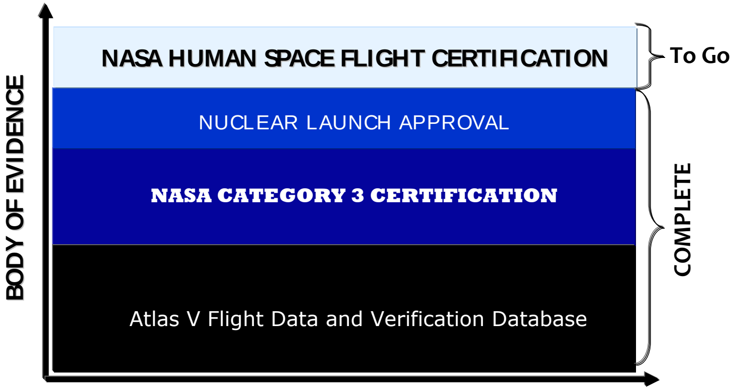
Human Spaceflight Certification

- CCiCap Base Phase includes Integrated HSF Certification Effort
  - Atlas V compliance with NASA CTS-1100 and spacecraft requirements
  - Integrate Crew Safety baseline
  - Integrate Loss of Crew/Mission PRA
  - Integrate Hazard Analyses
- Leverage NASA Atlas V Certification
  - Atlas V certified to NASA Risk Category 3 (highest certification level)
  - Atlas V nuclear safety launch approval
- Human Spaceflight Certification is a combination of technical/operations requirements satisfaction, flight history


MRO/Atlas 401
Aug 2005


Pluto/Atlas 551
Jan 2006


Mars Science Lab
Nov 2011


BODY OF EVIDENCE

NASA HUMAN SPACE FLIGHT CERTIFICATION

NUCLEAR LAUNCH APPROVAL

NASA CATEGORY 3 CERTIFICATION

Atlas V Flight Data and Verification Database

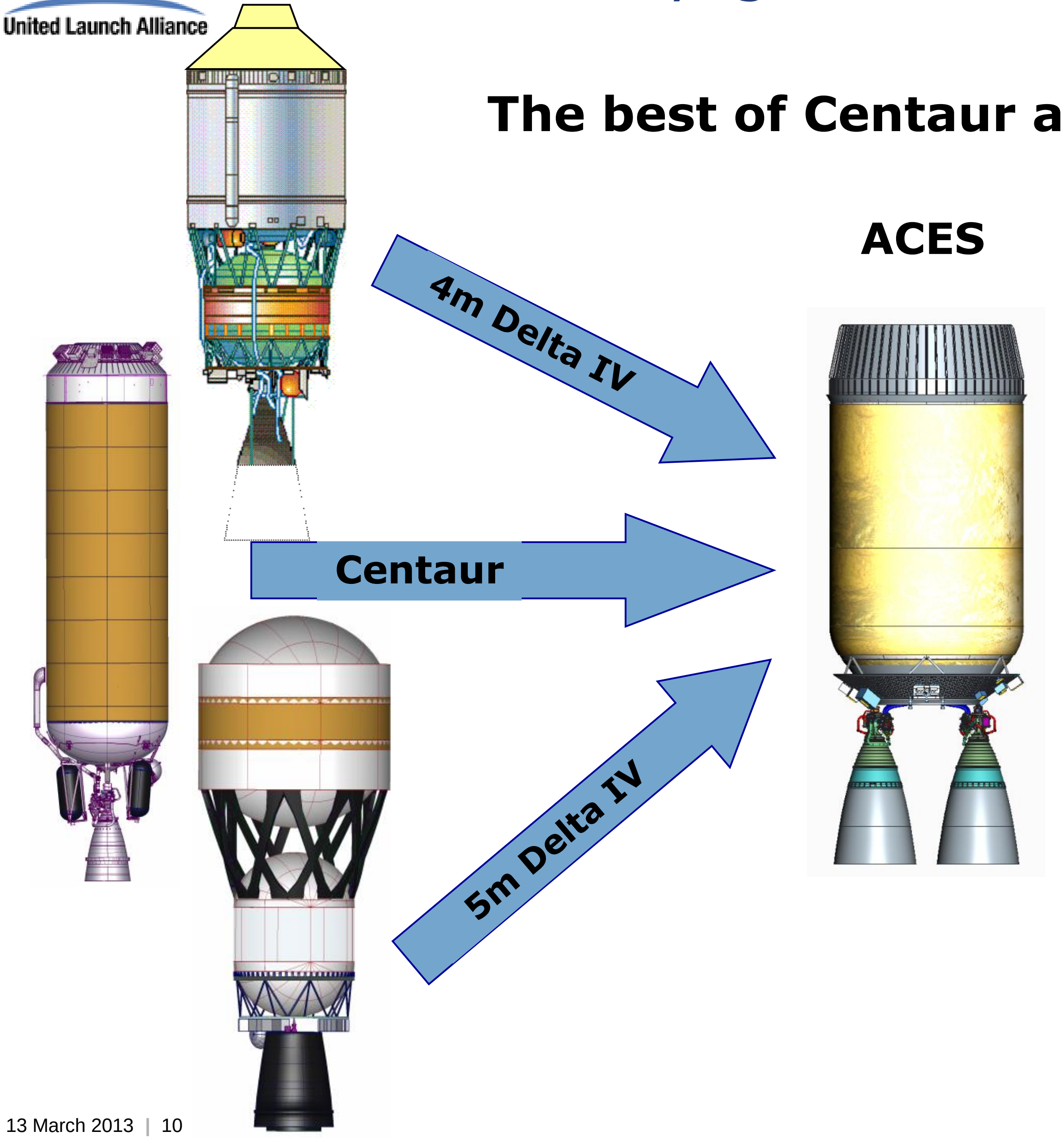
To Go

COMPLETE

NASA can leverage the body of evidence already available for Atlas V HSF Certification

Advanced Cryogenic Evolved Stage (ACES)

The best of Centaur and Delta Combined



Benefits

Reduced Cost

Increased Performance

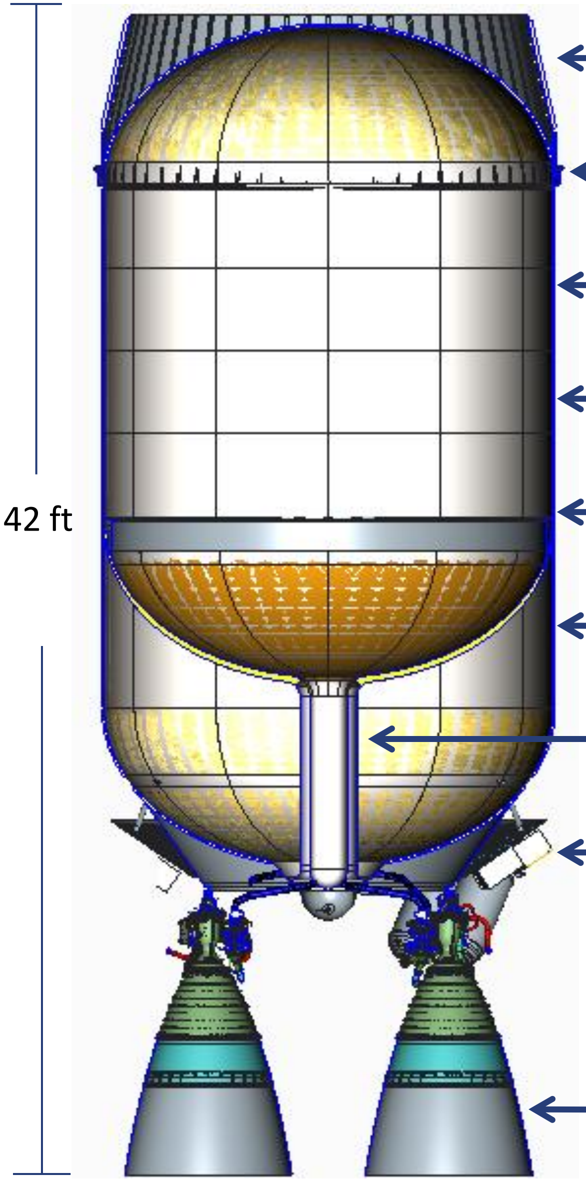
Mission Flexibility

Long Duration

Numerous Burns

Improved Reliability

ACES Baseline Characteristics
Compatible with Atlas V and Delta IV



PAF (Multiple Configurations)

Suspension Interface

LH2 Tank

Sidewall
Multi-Layer Insulation

Common Bulkhead

LO2 Tank

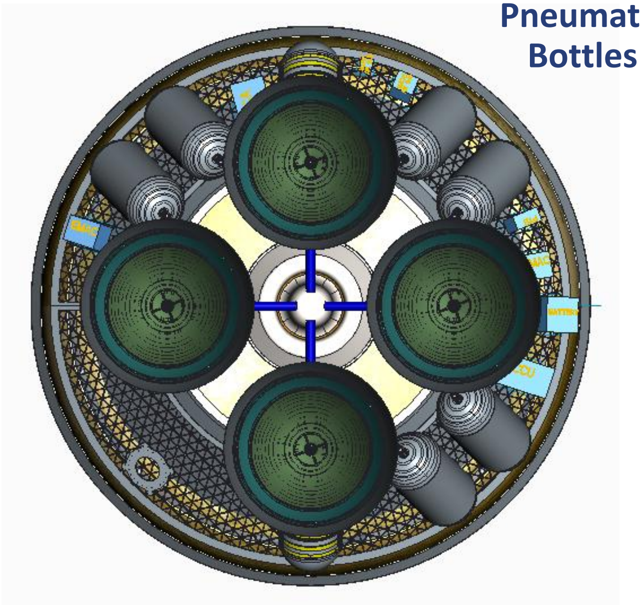
LH2 Sump

Aft Equipment Shelf
Existing Fluid Systems and Avionics Components

RL10C (B)– Fixed A/B cones

N2H4 Bottles

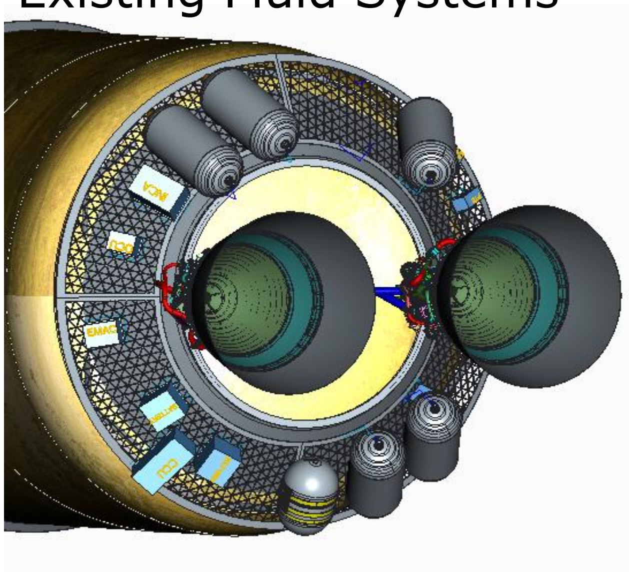
Pneumatic Bottles

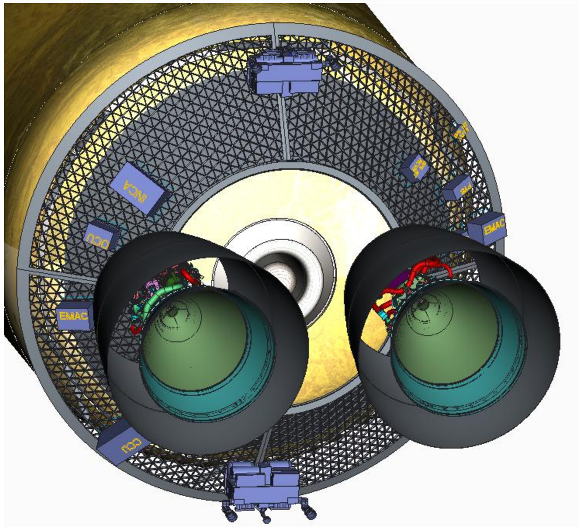


Common Avionics Components

Integrated Vehicle Fluids

Existing Fluid Systems



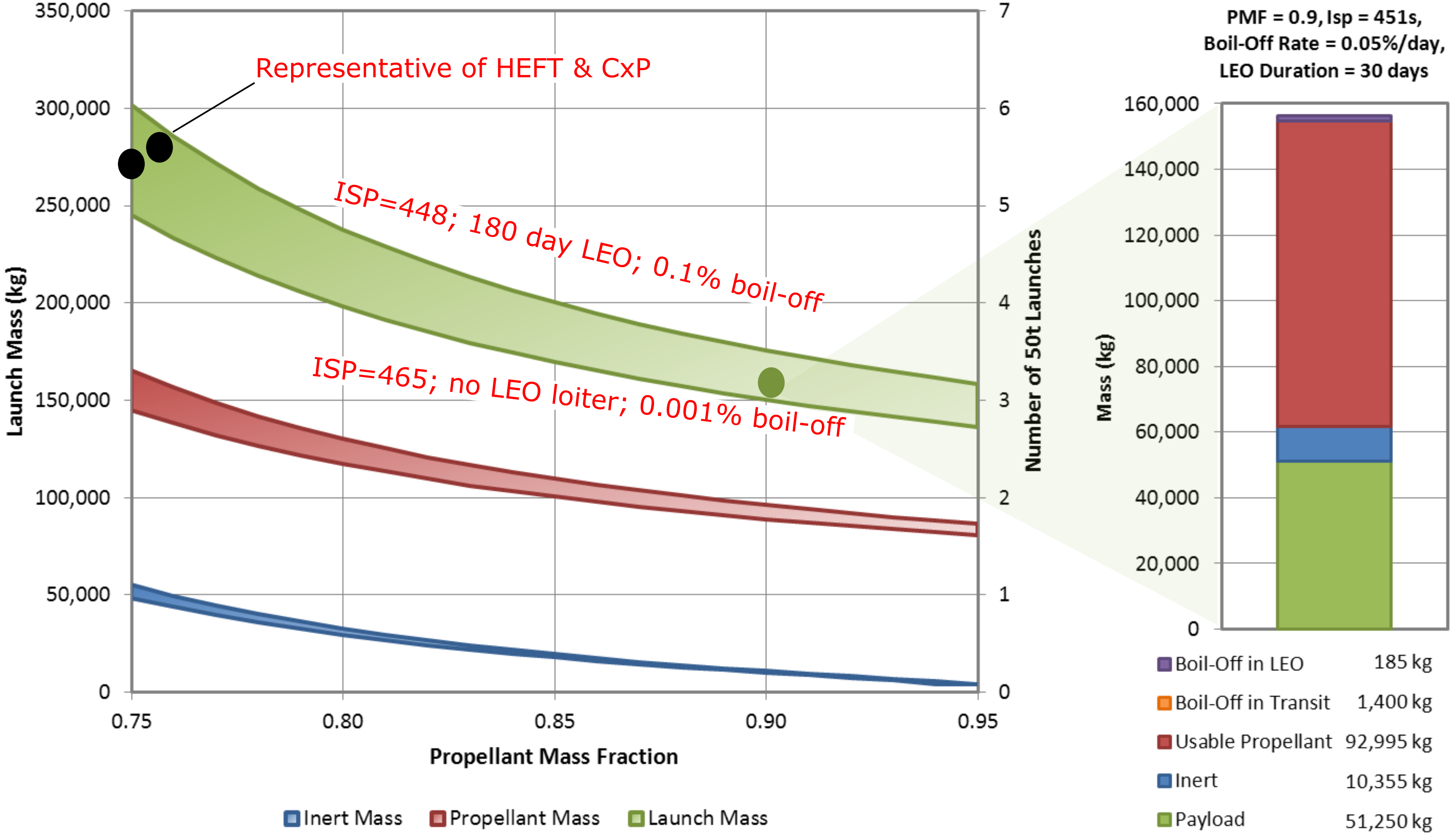


Redundant IVF Modules

- ❑ IVF is an Auxiliary Power Unit
  - Burns Waste H2/O2
  - Small Internal Combustion Engine, Thrusters, Heat exchanger
  - Produces
    - Attitude Thrust
    - Electrical Power
    - Tank Pressurization Gases
  - Prototype hardware in development testing
    - IVF Heat Exchanger selected by NASA “SLS Advanced Technology” for CRAD

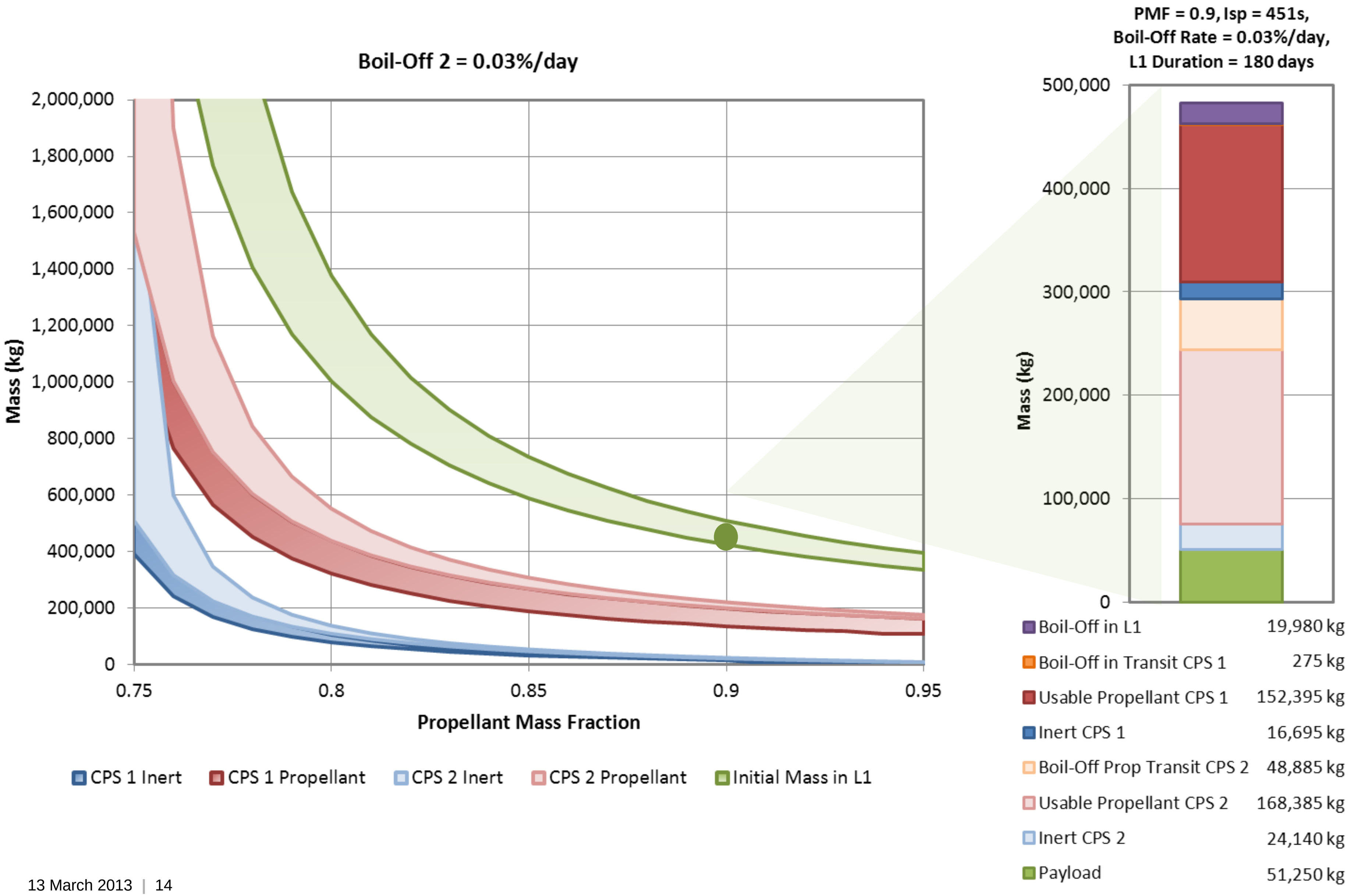
- ❑ Mission Benefits
  - Mission Flexibility
  - Large Mass Reduction
  - Low Penalty Vehicle Disposal
  - Eliminates all Hydrazine, Helium
  - Eliminates Large Batteries
  - Long Duration, Numerous Burns
  - Block-redundancy for Reliability
  - Large Functional Margins

Lunar Surface Mission



Mass Fraction more important than ISP, Boil-off & duration combined

Mars Orbit Mission



🟪 Boil-Off in L1	19,980 kg
🟧 Boil-Off in Transit CPS 1	275 kg
🟥 Usable Propellant CPS 1	152,395 kg
🟦 Inert CPS 1	16,695 kg
🟧 Boil-Off Prop Transit CPS 2	48,885 kg
🟥 Usable Propellant CPS 2	168,385 kg
🟦 Inert CPS 2	24,140 kg
🟩 Payload	51,250 kg

Cryo Propellant Storage & Transfer

- Cryogenic Propellant Storage and Transfer Technology is key to achieving a feasible chemical propulsion exploration architecture
  - Enables high mass fraction
    - Launch empty in-space tanks to LEO
    - Top off before departure

- 2010 NRC report of NASA’s technology roadmaps:

  Recommendation. *Cryogenic Storage and Handling. Reduced gravity cryogenic storage and handling technology is close to a “tipping point,” and NASA should perform on-orbit flight testing and flight demonstrations to establish technology readiness.*

- NASA OCT established cryogenic propellant storage and transfer project

Summary

- ☐ Exploration Missions are technically feasible with capabilities currently under development by NASA and commercial companies
  - NASA’s commercial crew program for crew transportation to LEO
  - Advanced upper stage concepts extrapolated for in-space transportation

- ☐ Existing chemical propulsion technology can be the basis of feasible beyond Earth exploration missions
  - Existing commercial and in-development super heavy launchers to deliver mass and crew to LEO
  - LO2/LH2 in-space propulsion
  - Propellant mass fraction is driving parameter
    - Passive thermal management
    - LO2/LH2 for ACS, pressurization, thermal management and power (IVF)
    - Propellant storage and transfer capability enables very high mass fraction

Backup

Further Information

ULA public papers:

2009 Architecture: http://www.ulalaunch.com/site/docs/publications/AffordableExplorationArchitecture2009.pdf

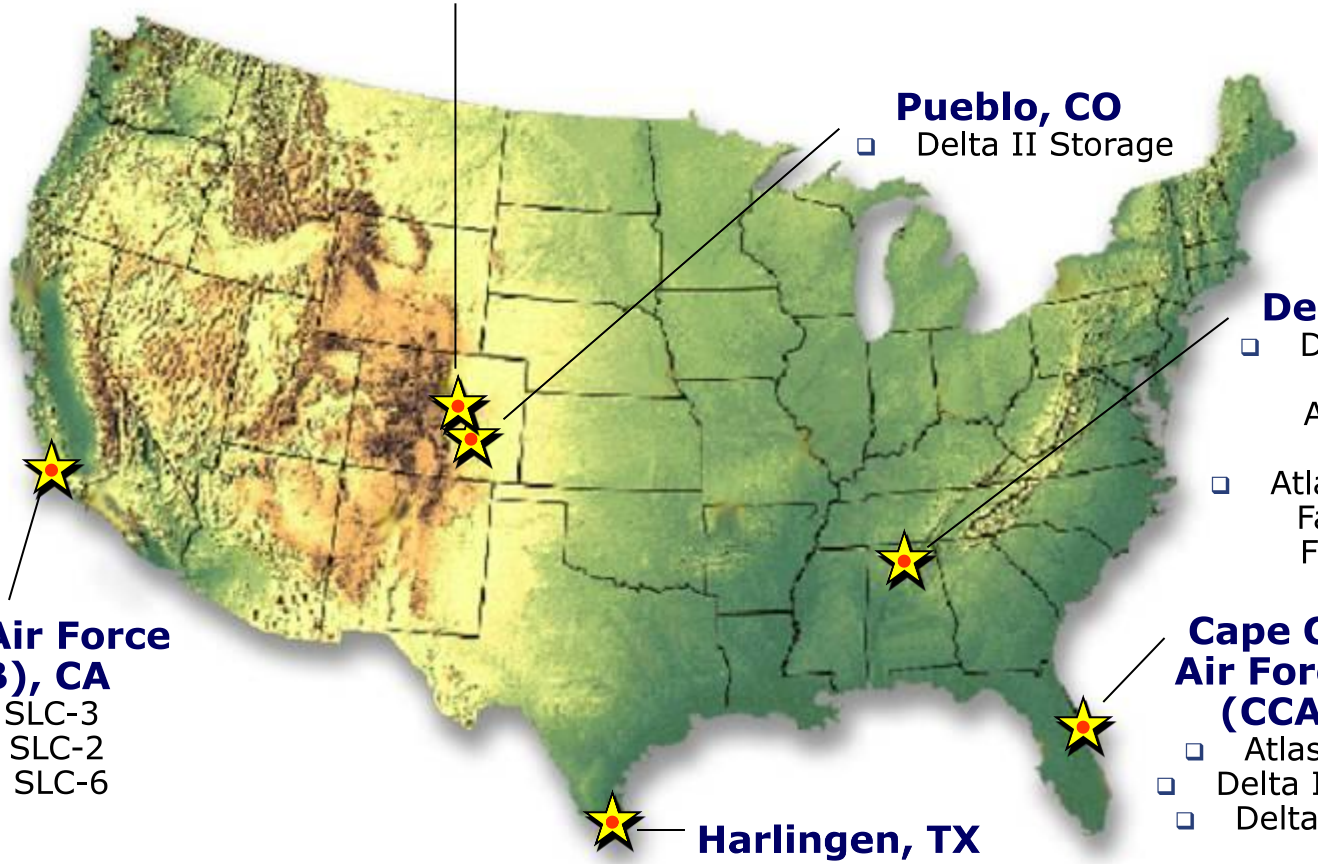
2009 DTAL (XEUS): http://www.ulalaunch.com/site/docs/publications/DualThrustAxisLander(DTAL)2009.pdf

2012 IVF: http://www.ulalaunch.com/site/docs/publications/IVF-Space-2012.pdf

SpaceWorks LEO: http://www.ulalaunch.com/site/docs/publications/SEI%20-%20CPS%20Mission%20Sensitivity%20Study%20-%20LEO%20Departure%20-%20revD.pdf

SpaceWorks L1: http://www.ulalaunch.com/site/docs/publications/SEI%20-%20CPS%20Mission%20Sensitivity%20Study%20-%20L1%20Departure%20revB.pdf

Locations



Denver, CO
- ULA Headquarters
- Program Management, Engineering, and Mission Support

Pueblo, CO
- Delta II Storage

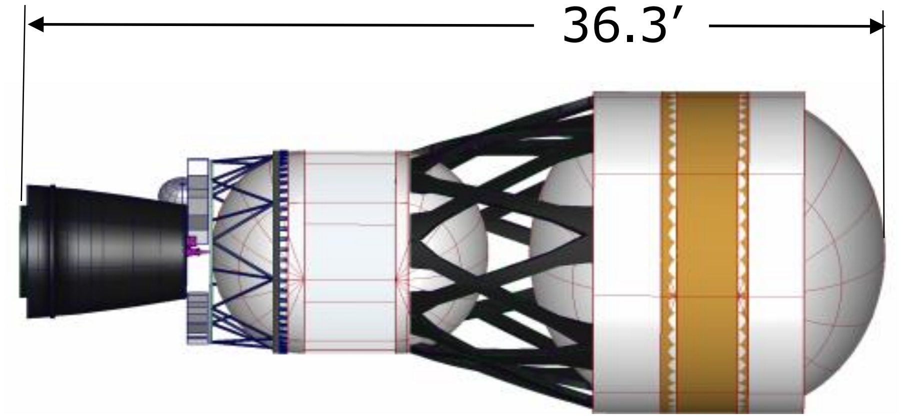
Decatur, AL
- Delta II and IV Fabrication, Assembly, and Test
- Atlas Booster Tank Fabrication and Final Assembly

Vandenberg Air Force Base (VAFB), CA
- Atlas V – SLC-3
- Delta II – SLC-2
- Delta IV – SLC-6

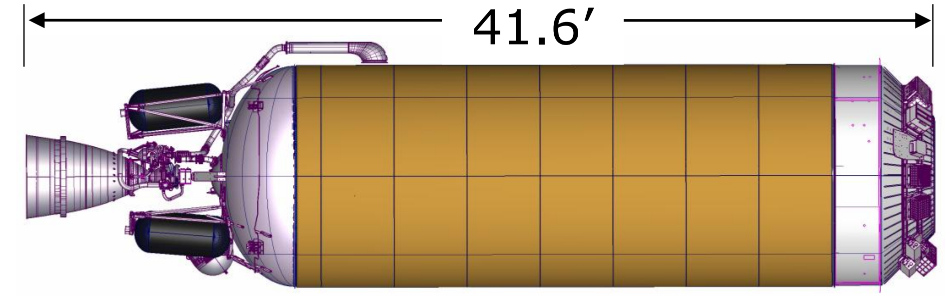
Cape Canaveral Air Force Station (CCAFS), FL
- Atlas V – SLC-41
- Delta II –SLC-17A/B
- Delta IV – SLC-37

Harlingen, TX
- Atlas V and GX Mechanical Structures
- Payload Fairing Fabrication and Assembly
- Adapter Fabrication and Assembly

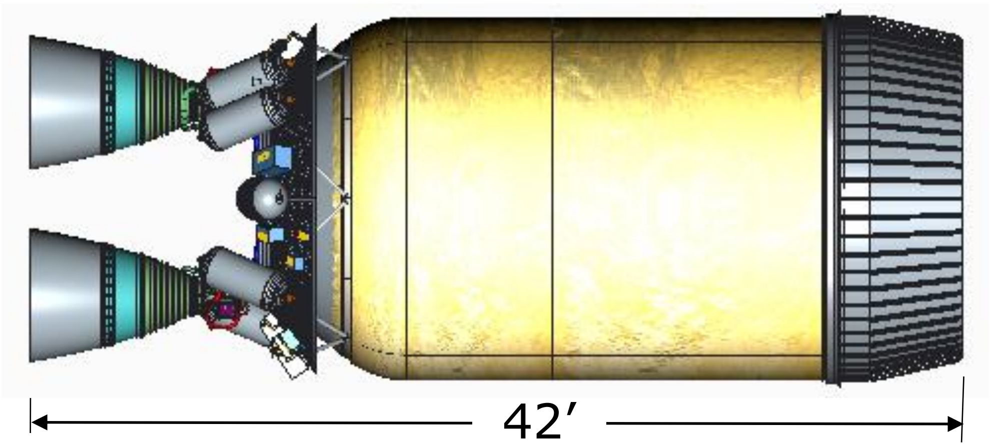
ACES, DCSS, Centaur Comparison



DCSS 5m
63 klb Propellant
201″ diameter
0.87 mass fraction



Centaur
46 klb Propellant
120″ diameter
0.90 mass fraction



ACES
110 klb Propellant
196″ diameter
~0.92 mass fraction

Advanced Common Evolved Stage (ACES)

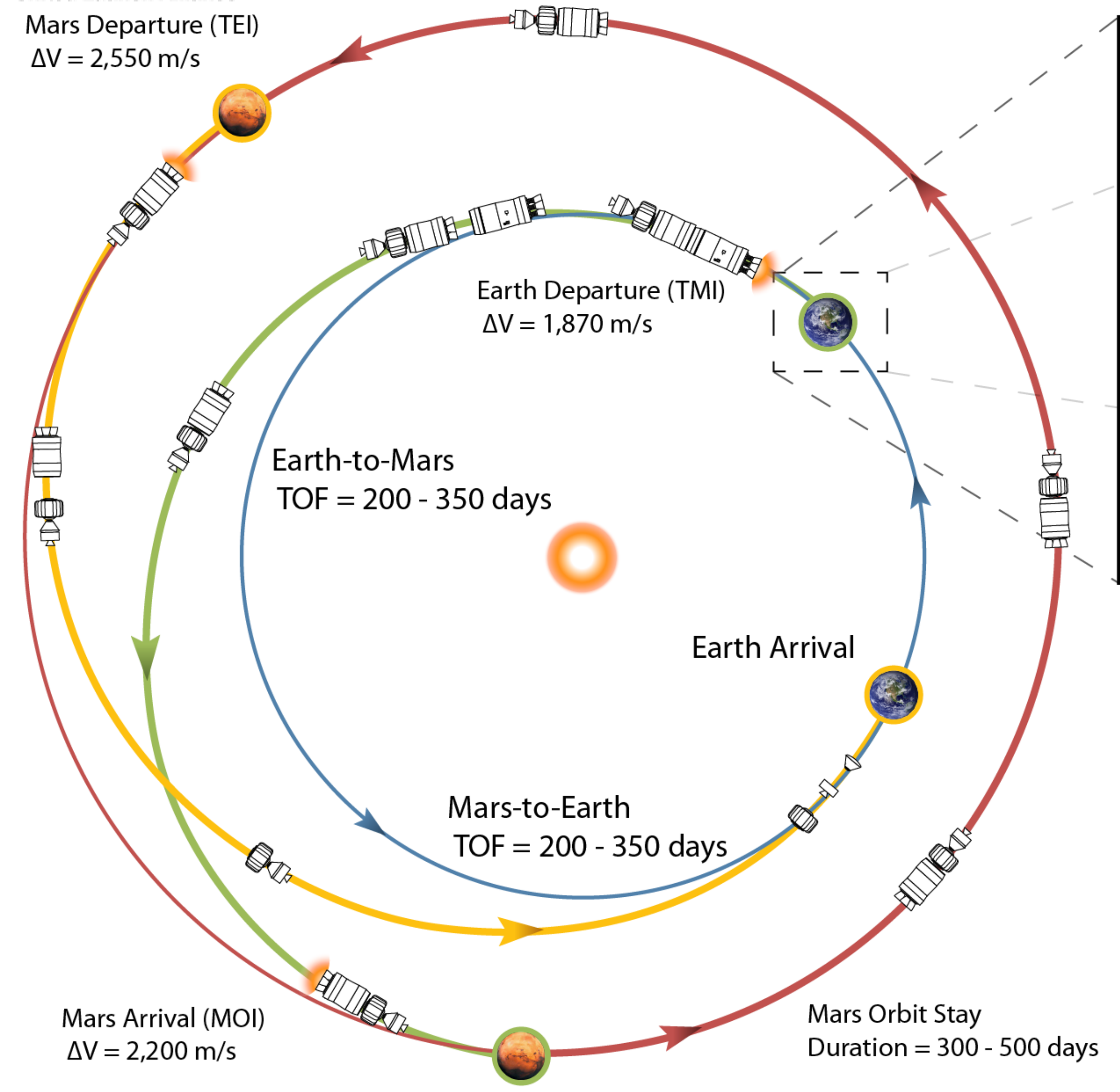
The Best of Centaur and Delta

- ❑ Mission Benefits
  - Reduced Cost
  - Increased Performance
  - Mission Flexibility
  - Improved Reliability

- ❑ Low Risk Evolution of:
  - Existing Atlas V and Delta IV Boosters
  - Existing 5.4M Payload Fairing
  - Familiar Stainless Steel Tank Structure
  - Common Avionics
  - Existing Fluid and Pneumatic Systems
  - Existing Flight Software
  - Existing RL10C Engine
  - Existing Launch Site with Minimal Modifications

Existing Systems Packaged into Larger More Capable Stage

Mars Orbit Mission



Mars Departure (TEI)
ΔV = 2,550 m/s

Earth Departure (TMI)
ΔV = 1,870 m/s

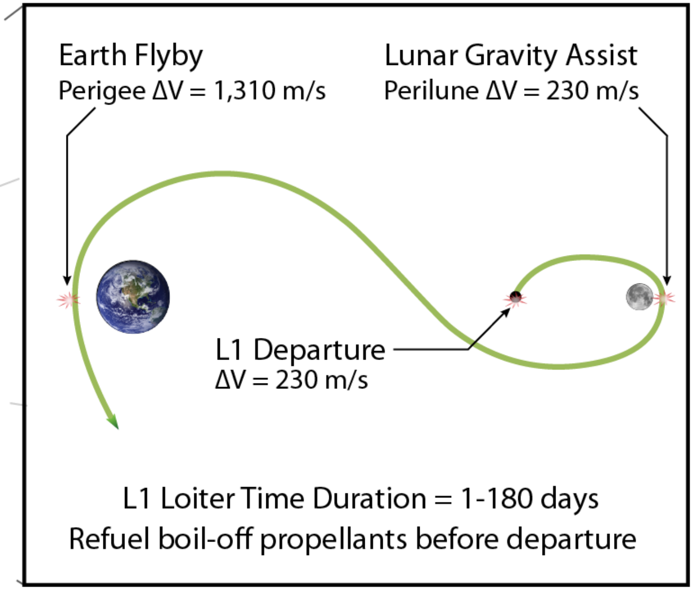
Earth-to-Mars
TOF = 200 - 350 days

Earth Arrival

Mars-to-Earth
TOF = 200 - 350 days

Mars Arrival (MOI)
ΔV = 2,200 m/s

Mars Orbit Stay
Duration = 300 - 500 days



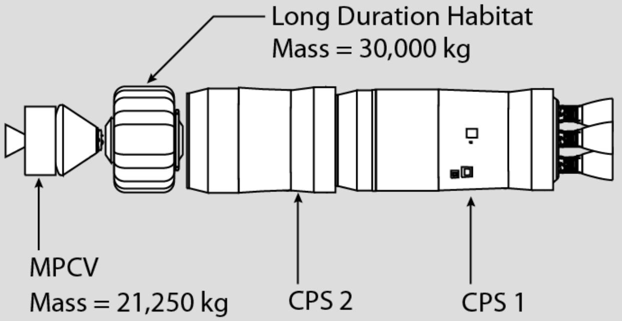
Earth Flyby
Perigee ΔV = 1,310 m/s

Lunar Gravity Assist
Perilune ΔV = 230 m/s

L1 Departure
ΔV = 230 m/s

L1 Loiter Time Duration = 1-180 days
Refuel boil-off propellants before departure

Vehicle Configuration



Long Duration Habitat
Mass = 30,000 kg

MPCV
Mass = 21,250 kg

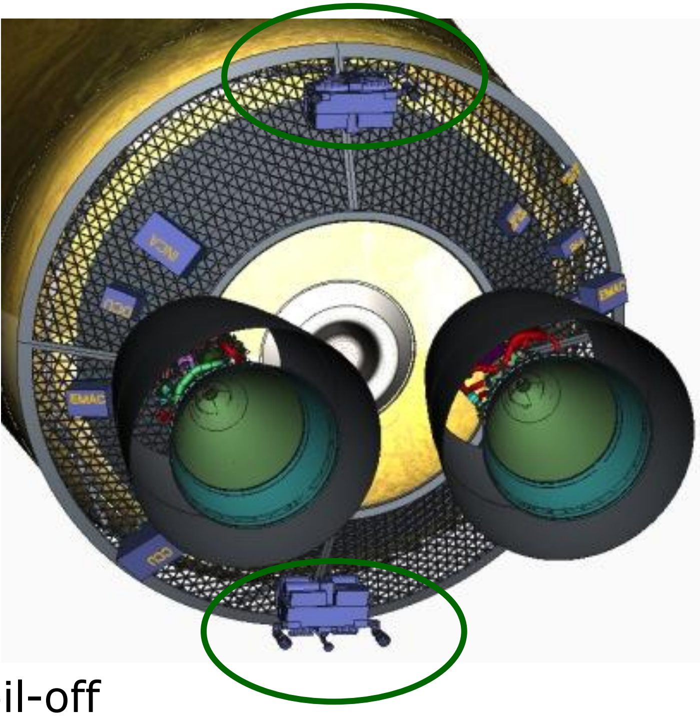
CPS 2

CPS 1

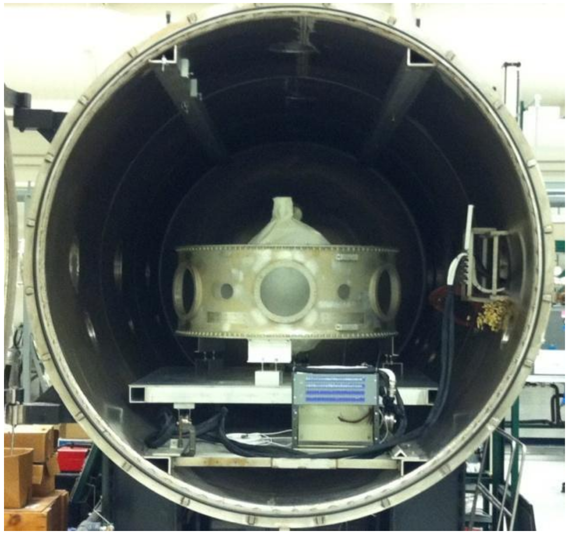
- 🟦 Earth
- 🟥 Mars
- ● Departure 1
- 🟩 Segment 1
- ● Arrival 1
- ● Departure 2
- 🟨 Segment 2
- ● Arrival 2

Integrated Vehicle Fluids - IVF

- ❑ **Auxiliary Power Unit**
  - – Eliminates He, N2H4, Large Batteries
- ❑ **Provides enhanced mission flexibility**
  - – Power for long duration missions
  - – “Unlimited” Tank Pressurization Cycles, Main Engine Burns
  - – Increased RCS impulse capability
    - Mid course corrections
- ❑ **Development status**
  - – Key elements in prototype testing
  - – Integrated brass board ground test 4th Q 2013
- ❑ **Power to payload**
  - – Enroute and while on lunar surface using ACES boil-off



Cryo Propellant Storage & Transfer
Ongoing risk Reduction



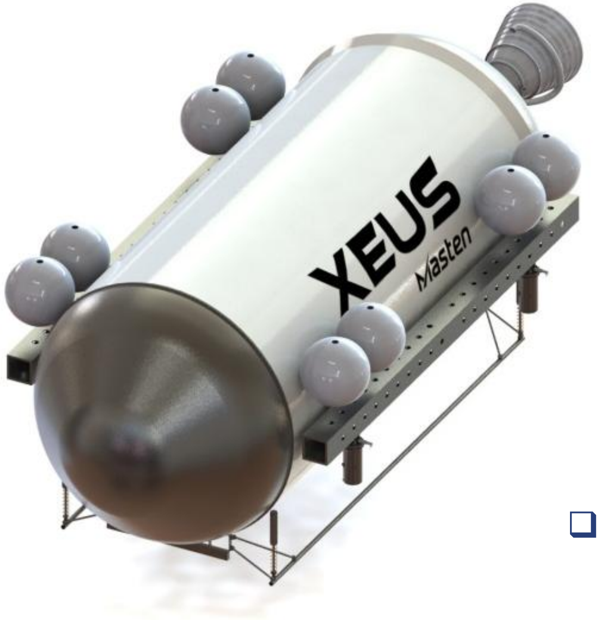
- ❑ CRYOTE Ground Test Article 1
  - Testing Jan 2012 (LN2)
  - Sub scale (2.5’ dia)
  - Demonstrate: no vent fill, vapor cooling, thermodynamic vent system

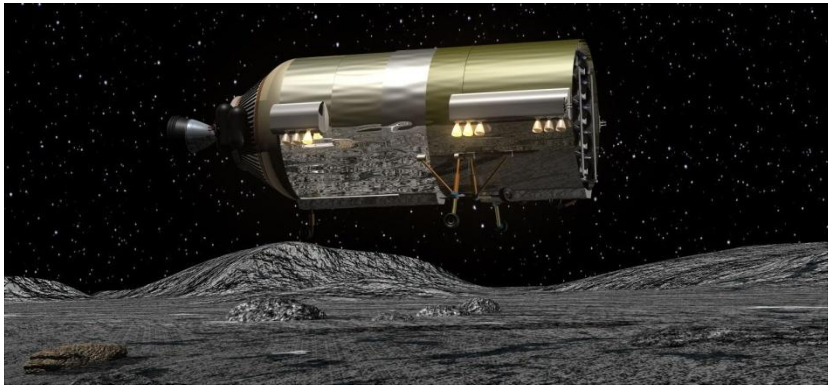
- ❑ CRYOTE Ground Test Article 2
  - Testing Dec 2012 (LN2)
  - Sub scale (2.5’ dia)
  - Demonstrate: enhanced no vent fill, vapor cooling, thermodynamic vent system

- ❑ CRYOTE Ground Test Article 3
  - Testing 1Q 2014 (LN2 & LH2)
  - Full Scale (10’ dia)
  - Demonstrate <0.1%/day boil-off equivalent

- ❑ Engaged with NASA’s Cryo Propellant Storage and Transfer program

XEUS
eXperimental Enhanced Upper Stage





- ❑ Mission kit to enable ACES/CPS to support lunar surface access
  - – Affordable
    - • Development of kit, not entire stage
  - – Large surface payloads (15 mT with SLS)
  - – Combine existing upper stage and vertical take off vertical landing technology
- ❑ Full scale terrestrial technology demonstrator
  - – Distributed propulsion, control, impingement, slosh