



# TIPPING POINT FLIGHT DEMONSTRATION – UNITED LAUNCH ALLIANCE

John G Reed  
ULA Chief Rocket Scientist



# 156 SUCCESSFUL LAUNCHES – ONE AT A TIME





# ULA ENABLES NASA'S EXPLORATION OF THE UNIVERSE

## MARS

- InSight
- MAVEN
- Mars Science Laboratory
- Phoenix
- Mars Reconnaissance Orbiter
- Opportunity
- Spirit
- 2001 Mars Odyssey
- Mars Polar Lander/Deep Space 2
- Mars Climate Orbiter
- Mars Pathfinder
- Mars Global Surveyor
- Mariner 4, 6, 7, 9

## VENUS

- Pioneer Venus Multiprobe
- Pioneer Venus Orbiter
- Mariner 2, 5, 10

## MERCURY

- MESSENGER
- Mariner 10

## THE MOON

- GRAIL
- LRO/LCROSS
- Explorer Program 35, 49
- Surveyor Program (6)
- Lunar Orbiter Program (5)
- Ranger Moon Probes (4)

## SUN-EARTH INTERPLANETARY SPACE

- Parker Solar Probe
- STEREO
- Genesis
- WMAP
- ACE
- SOHO
- WIND
- ISEE 3
- Pioneer 6, 7, 8, 9

## JUPITER

- Juno
- New Horizons
- Pioneer 10, 11

## GEOCENTRIC ORBITS

- ICESat-2
- GOES Program (4)
- JPSS-1
- TDRS Program (3)
- ISS Resupply (3)
- MMS
- SMAP
- EFT-1
- OCO2
- Landsat 8
- RBSP
- Suomi NPP
- Aquarius
- Solar Dynamics Observatory

## SATURN

- Cassini
- Pioneer 11

## COMETS & ASTEROIDS

- OSIRIS-REx
- Dawn
- Deep Impact
- CONTOUR
- Stardust
- Deep Space 1/SEDSAT-1
- NEAR

- Earth Observer
- ISEE 1, 2
- FUSE
- Polar
- Radarsat/Surfsat
- Geotail/DUVE
- EUVE
- Rosat
- COBE
- Exosat
- IRAS
- SMU
- Dynamics
- SMM

- IUE
- LAGEOS-1
- Cos-B
- SMS Program (2)
- TD-1A
- Landsat Program (6)
- ITOS Program (9)
- HEOS Program (2)
- ISIS Program (2)
- Biosat Program (3)
- ESSA Program (9)
- Ariel 1
- OSO Program (8)
- Nimbus Program (7)

- ECHO Program (2)
- TDRS Program (3)
- Terra
- CRRES
- GOES Program (14)
- NOAA Program (18)
- Solwind
- TIROS Program (10)
- TIROS-N
- HEAO Program (3)
- OAO Program (3)
- OGO Program (4)
- Explorer Program (29)
- Mercury Astronaut Program (4)

## LEGEND

- Atlas, Delta & Centaur Launches
- Science Missions
- Exploration Missions
- Weather Missions
- (X) Number of Launches

## PLUTO & KUIPER BELT

- New Horizons

## OUTER PLANETS

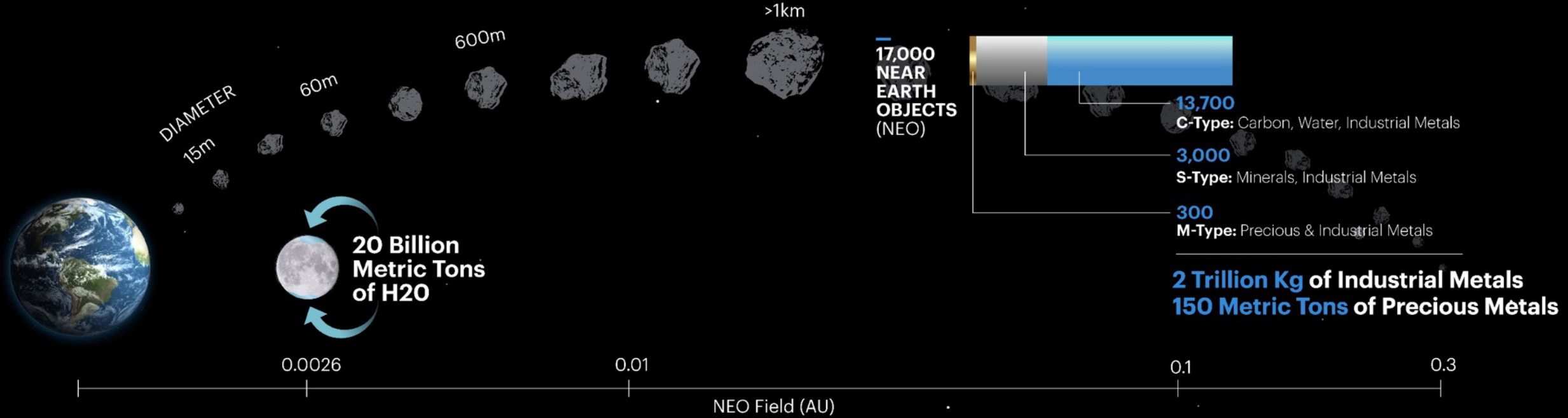
- Voyager 1
- Voyager 2

## UPCOMING

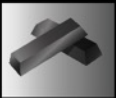
- Starliner
- Mars 2020
- Solar Orbiter
- Landsat 9
- Lucy
- JPSS-2



# CISLUNAR RESOURCES



**EARTH**



2 B

Industrial Production Metals (Kg)

**NEAR EARTH OBJECTS**



2 T

**1,000 Years of Earth's Production of Industrial Metal**

+

**More than the World's Entire Gold/Silver/Platinum Reserves**

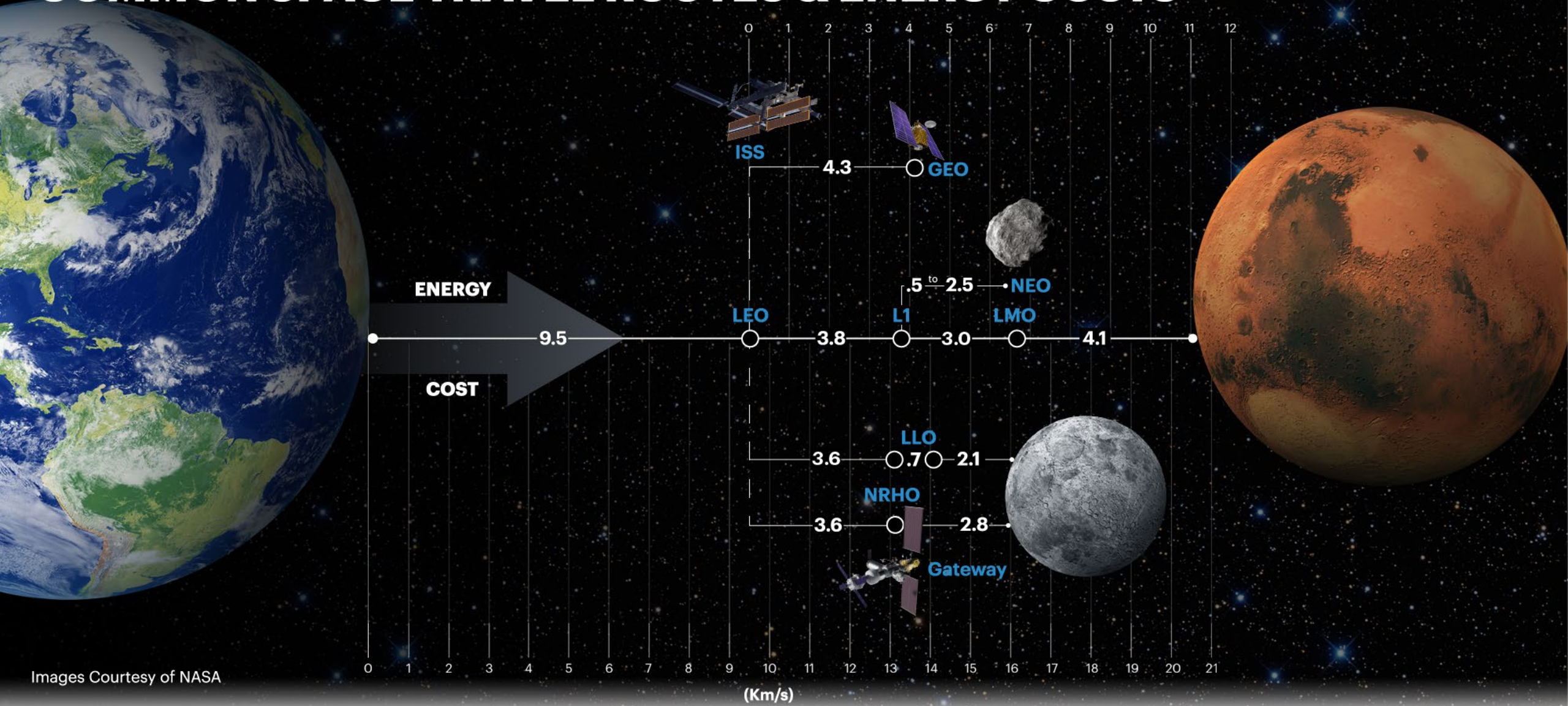
10

100

1,000



# COMMON SPACE TRAVEL ROUTES & ENERGY COSTS

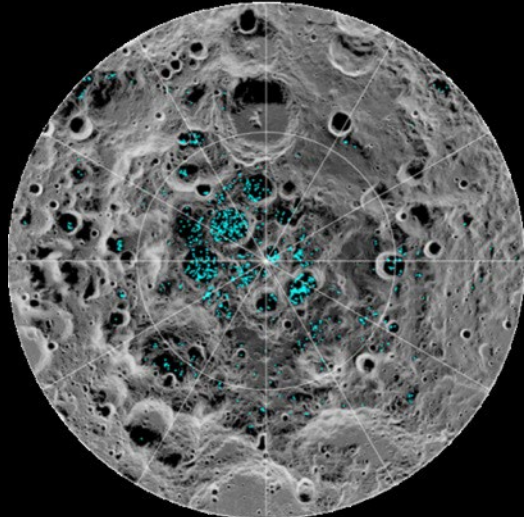
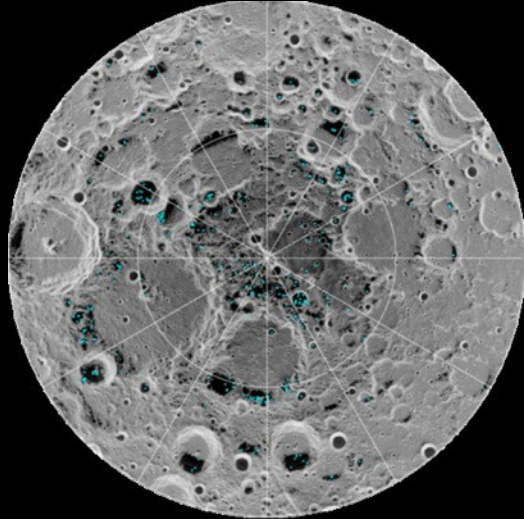


Images Courtesy of NASA

After LEO, Destinations are “Close” in Energy



# IN-SPACE PROPELLANT



## Harvesting H<sub>2</sub>O

1. In situ Thermal Mining
2. Dig and Process
3. Chemical Extraction

## Making Propellant

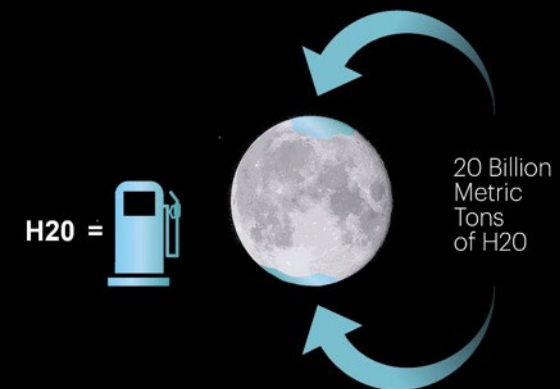
**Power:** Solar Panel, Nuclear Electrolysis

Liquefaction

➔ LH<sub>2</sub> & LO<sub>2</sub>

**200 tons/yr** current in space propellant demand

**100 million years**  
@ current demand



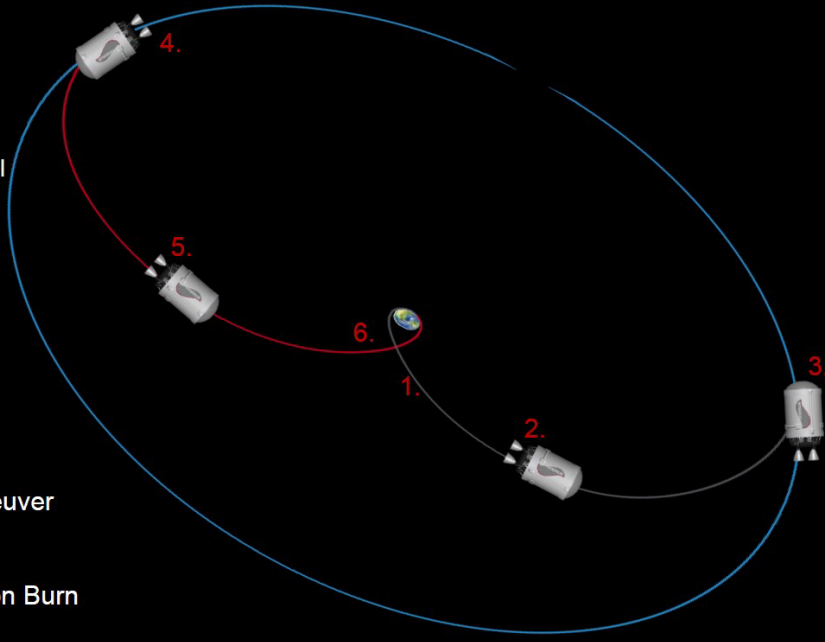
# TRADING TIME FOR FUEL

## CLASSIC TRANS-LUNAR INSERTION

- **Prompt**

- 3 to 5 Days Transit
- Ideal for Human Travel

1. TLI Insertion burn
2. Trajectory Correction Maneuver
3. NRHO Insertion Burn
4. NRHO Departure Burn
5. Trajectory Return Correction Burn
6. Earth orbit insertion Burn



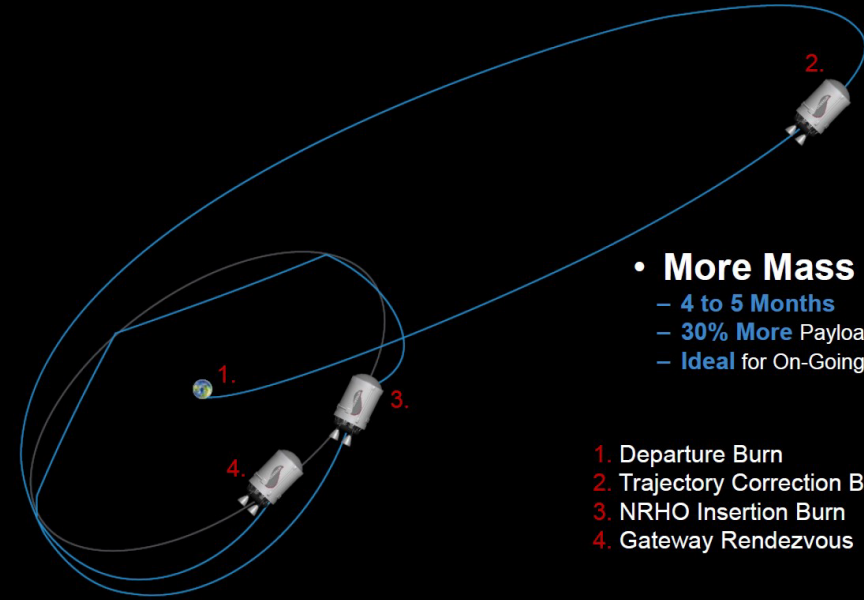
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## WEAK STABILITY BOUNDARY TRANSFER

- **More Mass**

- 4 to 5 Months
- 30% More Payload
- Ideal for On-Going Cargo and Logistics

1. Departure Burn
2. Trajectory Correction Burn
3. NRHO Insertion Burn
4. Gateway Rendezvous



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# ULA'S TIPPING POINT



ULA's **Tipping Point Flight Demonstration** is an on-orbit flight **experiment** that will demonstrate **new and innovative technologies** in the following cryogenic fluid management areas:

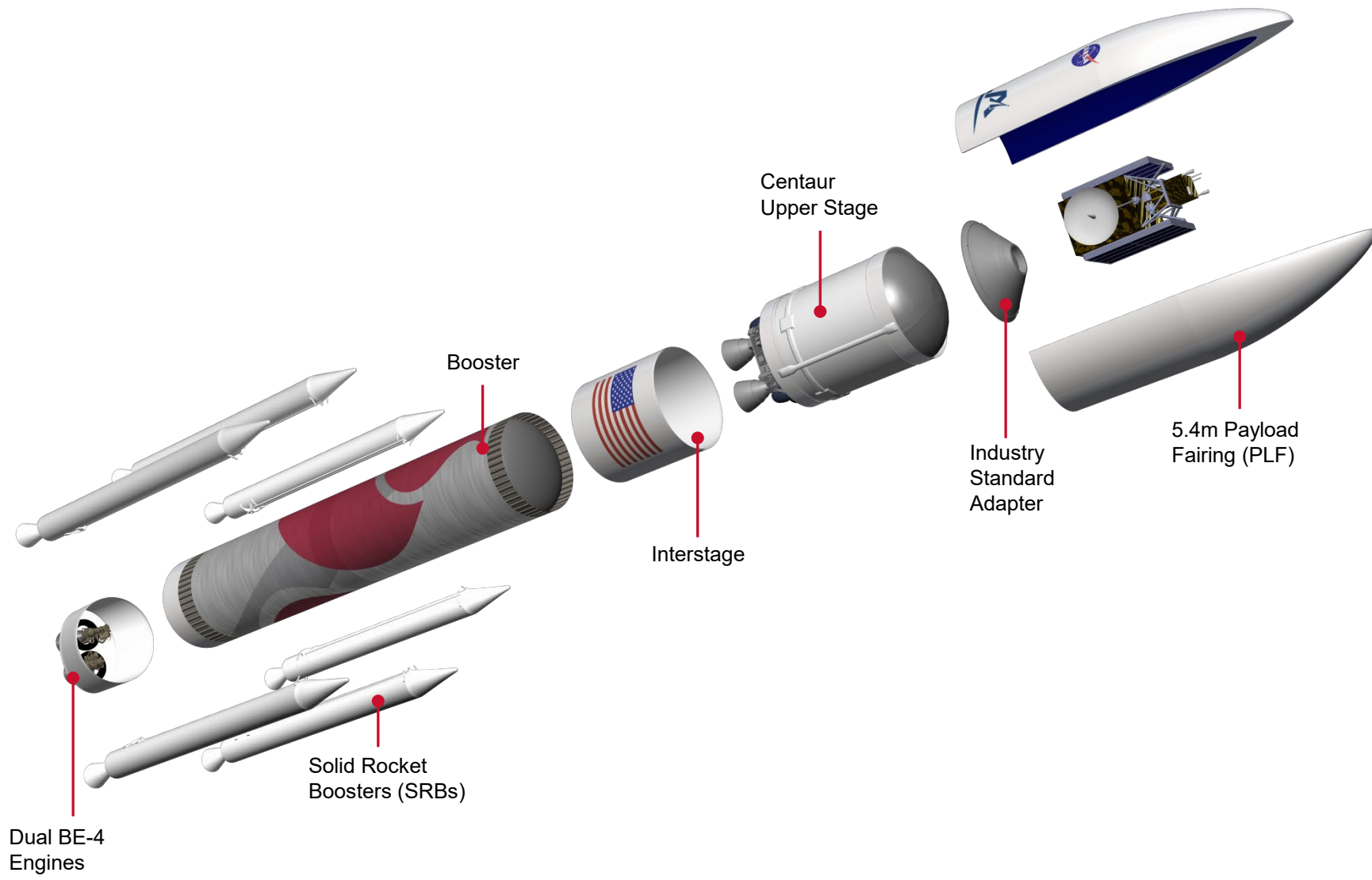
- Propellant tank-to-tank transfer
- Propellant pressure control
- Passive thermal control

Technologies developed from this prototype flight demonstration will enable a **significant leap forward in space exploration capabilities**

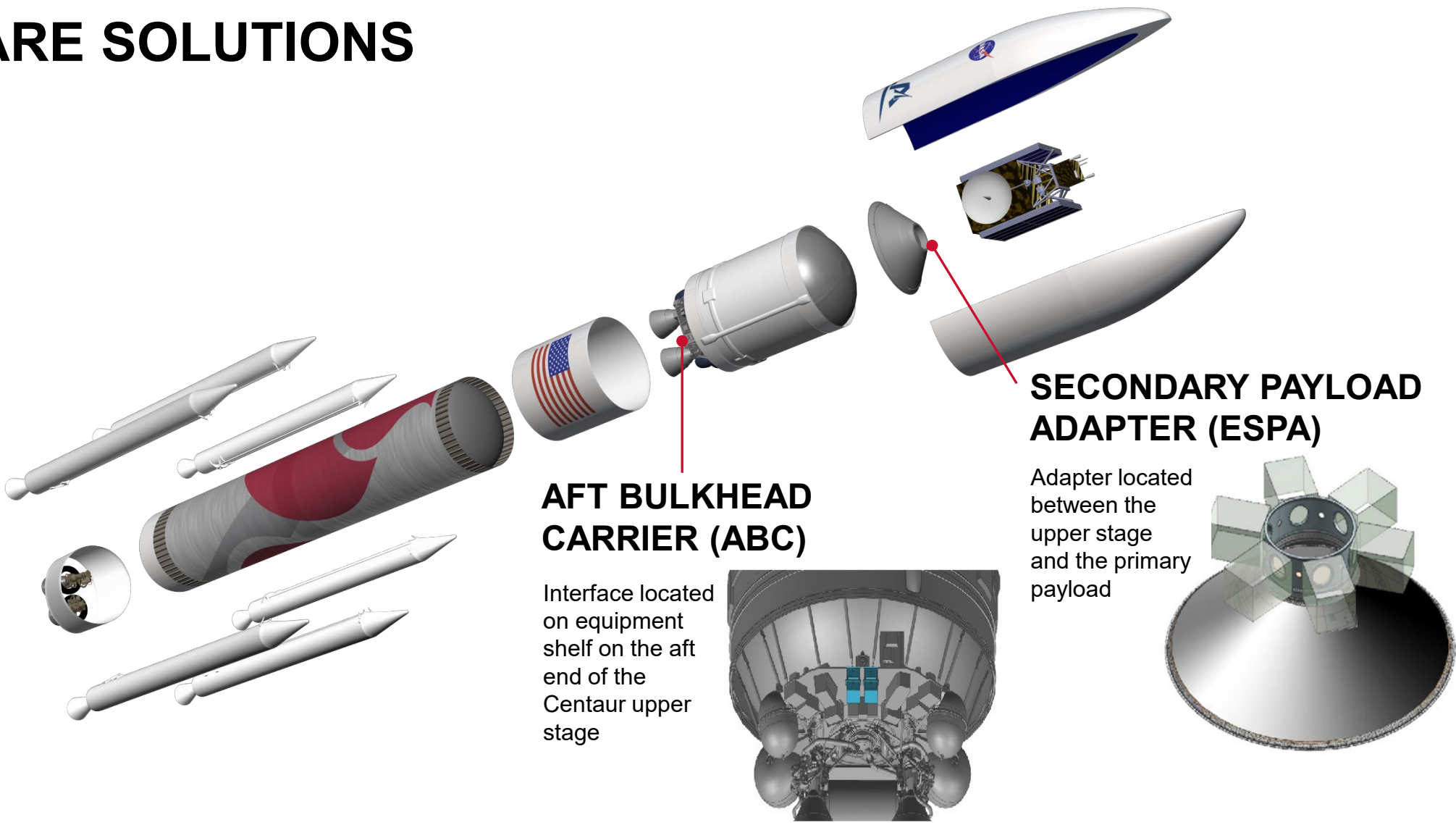
The experiment will fly as a **rideshare mission on Vulcan Centaur** in 2025.



# VULCAN CENTAUR

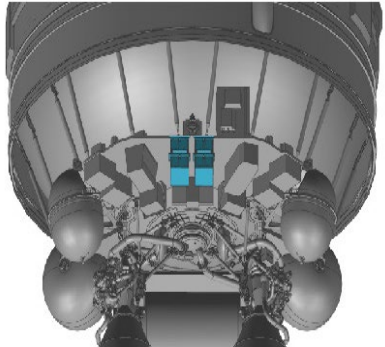


# VULCAN CENTAUR // RIDESHARE SOLUTIONS



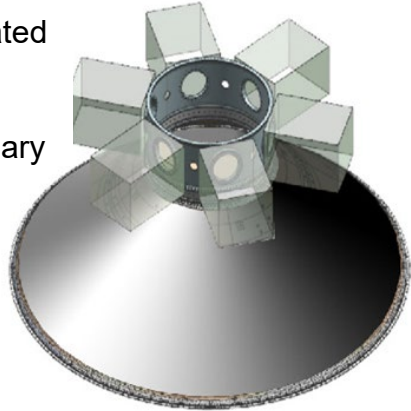
## AFT BULKHEAD CARRIER (ABC)

Interface located on equipment shelf on the aft end of the Centaur upper stage



## SECONDARY PAYLOAD ADAPTER (ESPA)

Adapter located between the upper stage and the primary payload





# EXPERIMENT OBJECTIVES

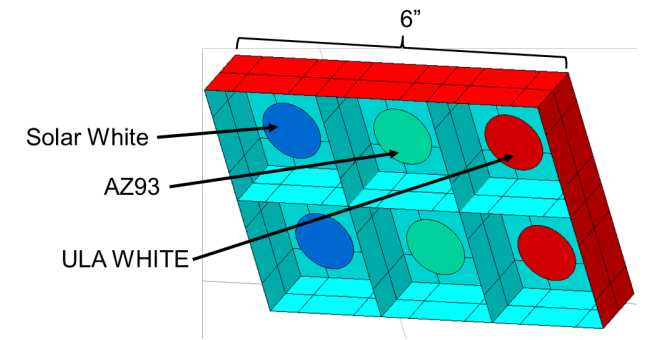
The flight experiment will demonstrate the **transfer of liquid hydrogen (LH2)** from one vessel to another while minimizing propellant mass loss and maintaining pressure control

The flight experiment will also demonstrate performance of the **Solar White** passive thermal control technology

- Solar White is a low absorptivity coating developed by NASA Kennedy Space Center

## Experiment Objectives

- Transfer LH2 into experiment auxiliary tank
- Maintain pressure control of LH2 system
- Collect temperature data to characterize Solar White solar absorptivity
- Isolate experiment
  - From Centaur flight systems during primary mission and during disposal operations



**Solar White Coupon Experiment**



Solar White on Al 7075 disk - NASA

# VULCAN CENTAUR // TECHNOLOGY ADVANCEMENT



**Advancement of  
Cryogenic Fluid  
Management  
Technologies**

**Completion of ULA's Tipping Point Flight Experiment will demonstrate new and innovative Cryogenic Fluid Management technologies, directly leading to increased capabilities, NASA knowledge and value for our space launch customers**



# QUESTIONS

**THANK  
YOU**

