Engineering In Action

Paving the Path for Human Space Exploration: The Challenges and Opportunities

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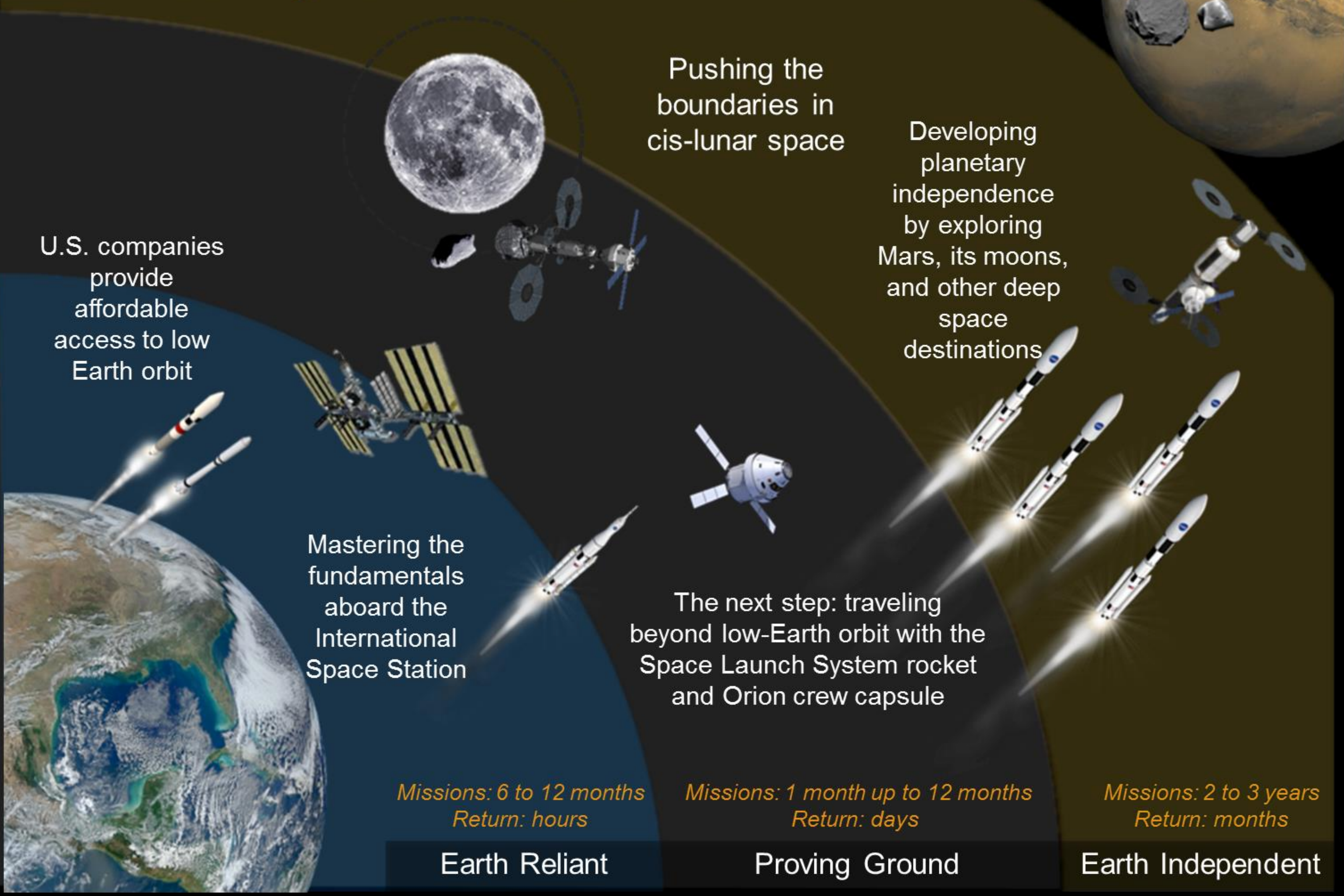
The Future of Human Space Exploration

NASA's Building Blocks to Mars

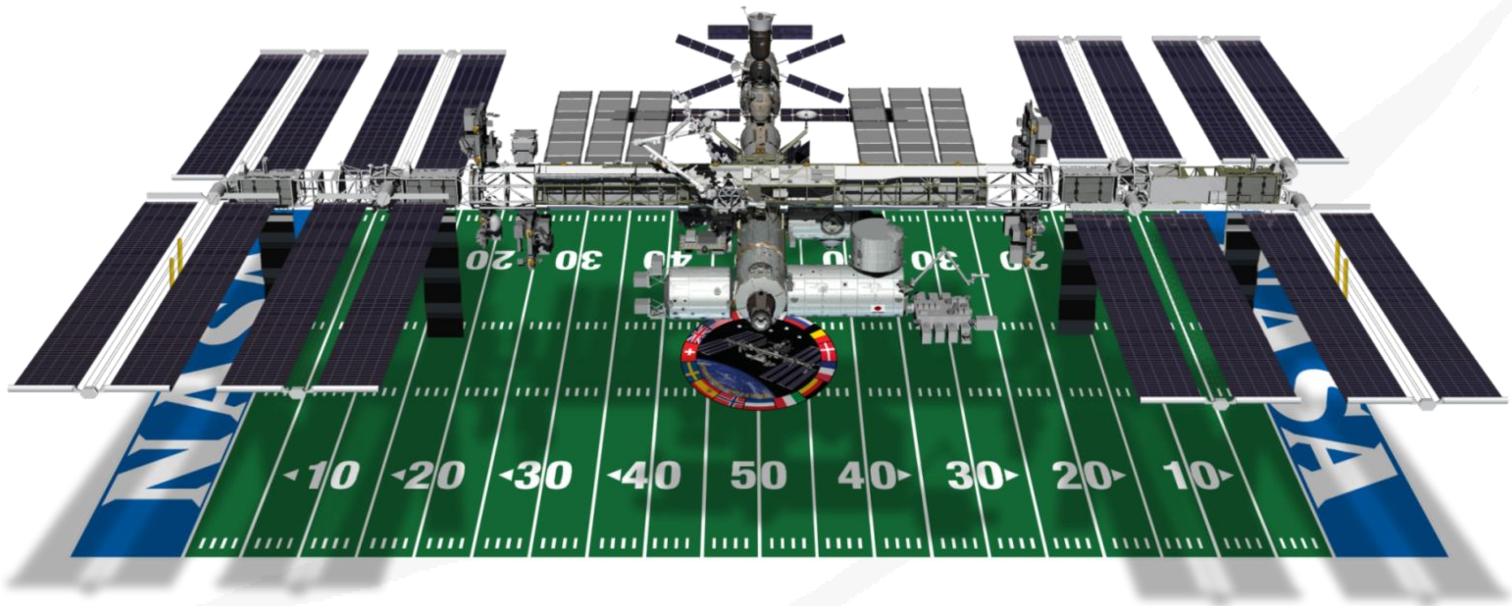


Human Spaceflight in Low Earth Orbit (LEO)

- **Low Earth Orbit (LEO) Challenges:**
  - Spacecraft design to endure harsh flight environments and maintain crew safety.
  - Mass and volume constraints.
  - Program budget constraints.
  - Fluctuating flight schedule(s).
  - Complex program level systems engineering.

45 MINUTES TO EARTH

AS BIG AS A FOOTBALL FIELD



5 Space Agencies Representing 15 Countries

Completion: ~1 million lb (~454,000 kg)

Velocity: 17,500 mph (28,100 kph)

Altitude: 220 miles (350 km) above Earth

Every day, station travels the equivalent distance to the moon and back seeing:

16 sunrises / 16 sunsets

24 hours a day

7 days a week

365 days a year

Requires Extensive Logistics & Maintenance

International Space Station

LIVING AND WORKING IN ORBIT
ON THE INTERNATIONAL SPACE STATION

Menu

CREWS HAVE EATEN ABOUT
25,000 MEALS
SINCE THE FIRST CREW IN 2000

APPROXIMATELY
SEVEN TONS
OF SUPPLIES SUPPORT **A CREW OF THREE** FOR ABOUT
SIX MONTHS

7 TONS

SPACEWALKING
ASTRONAUTS AND COSMONAUTS
HAVE SPENT MORE THAN **1,000 HOURS**
WORKING OUTSIDE THE STATION

MORE THAN **1,500 SCIENTIFIC INVESTIGATIONS**
PERFORMED ON THE INTERNATIONAL SPACE STATION

INTERNATIONAL SPACE STATION
BENEFITS FOR HUMANITY

ADVANCED
ROBOTIC SURGERY

CLEAN DRINKING WATER
FOR **PEOPLE LIVING FAR** FROM
WATER TREATMENT FACILITIES

REMOTE
MEDICAL DIAGNOSTICS

EDUCATIONAL EVENTS
42 MILLION STUDENTS REACHED

MICROGRAVITY AND LOW-EARTH ORBIT
RESEARCH LABORATORY
CONDUCTING EXPERIMENTS IN:

- HUMAN RESEARCH
- LIFE SCIENCES
- PHYSICAL SCIENCES
- EARTH SCIENCES
- ASTROPHYSICS
- TECHNOLOGY RESEARCH

ONE THING YOU CAN SAY ABOUT THE INTERNATIONAL SPACE STATION
IT'S BIG

LARGER THAN A
6-BEDROOM HOUSE

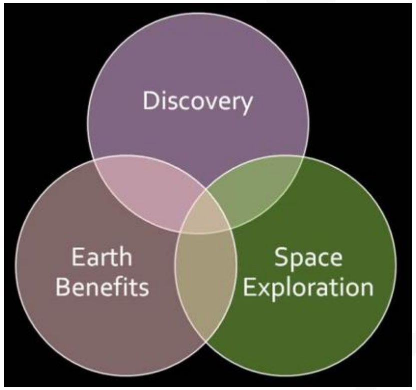
INTERNAL VOLUME OF A
BOEING 747

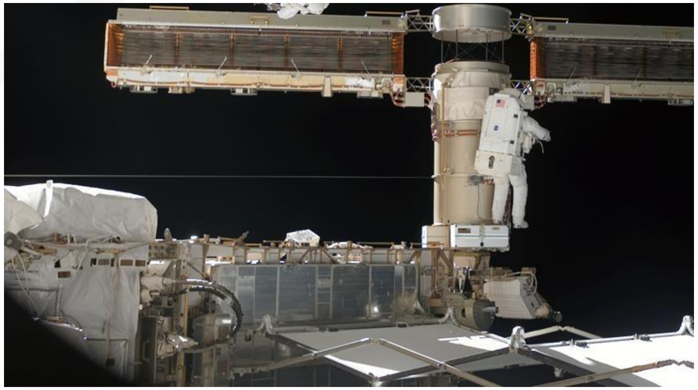
WEIGHS ALMOST A
MILLION POUNDS
(EQUIVALENT TO MORE THAN 320 AUTOMOBILES)

TRAVELS THE EQUIVALENT DISTANCE
TO THE MOON AND BACK
IN ABOUT A **DAY**

ISS Top Research Accomplishment

- **New Targeted Method of Chemotherapy Drug Delivery**
- **Robotic Assist for Brain Surgery**
- **Understanding Mechanisms of Osteoporosis and New Drug Treatments**
- **Developing Improved Vaccines**
- **Improving Eye Surgery with Space hardware**
- **43 Million Students and Counting Touched by ISS Education**





Low Earth Orbit Access

Commercial Cargo

Facilitate U.S. private industry development of safe, reliable, and cost effective <u>cargo</u> space transportation capabilities to low-Earth obit and the International Space Station.

- Two companies (SpaceX and Orbital Sciences) have successfully completed ISS cargo missions to date.

Commercial Crew

Commercial Crew Program (CCP) is an innovative partnership to help the aerospace industry in the United States develop space transportation systems that can safely launch humans to low-Earth orbit and to the International Space Station in a safe, reliable, and cost effective way.

- JSC Engineering provides technical insight/oversight, recommendations, and shared practices for safety and mission success.

BOEING

SPACEX DRAGON

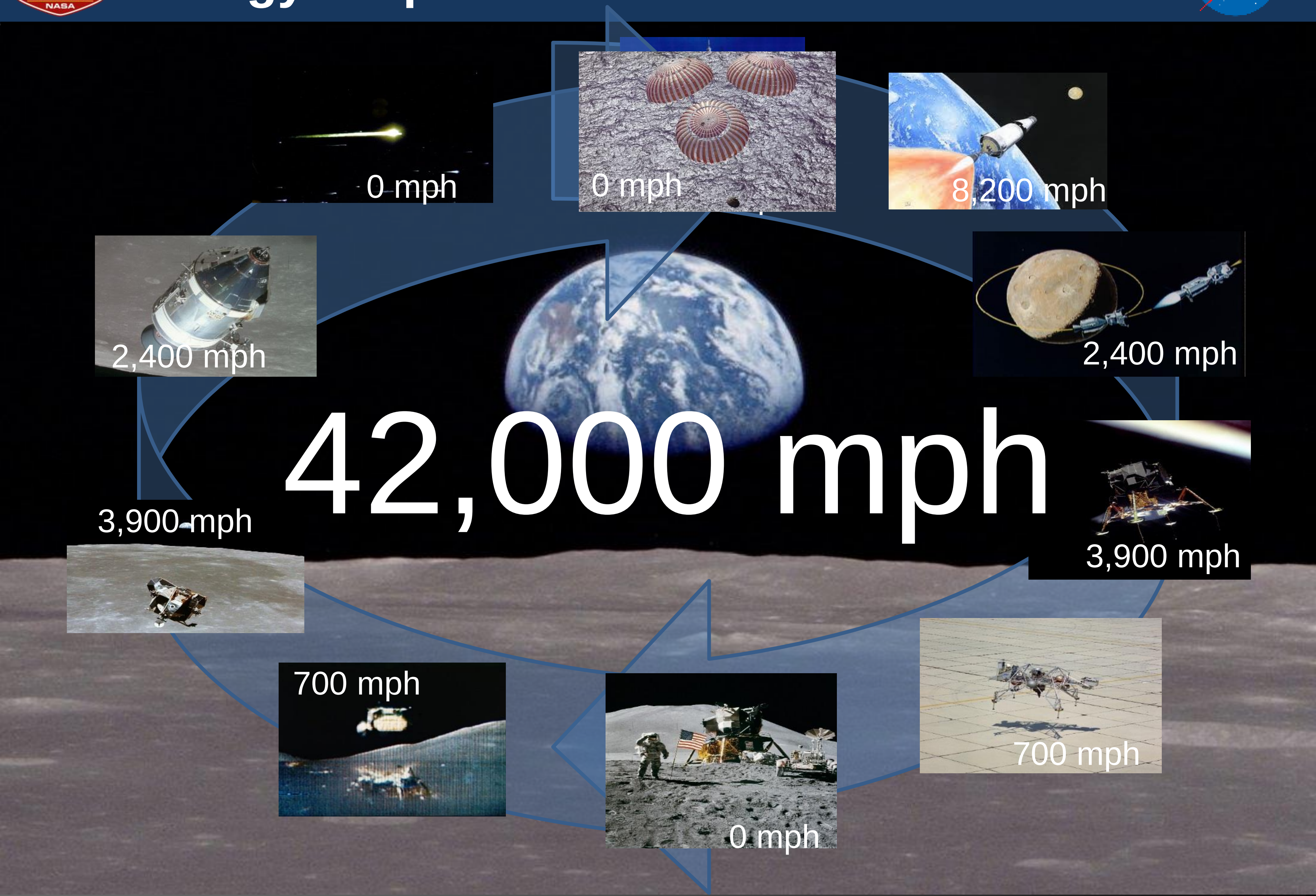
Beyond Earth Orbit *Crew safety complexity*

- **Beyond Earth Orbit (BEO) Challenges:**
  - Spacecraft design to endure harsh flight environments and maintain crew safety.
  - Spacecraft resupply for BEO missions not feasible.
  - Increased reliability due to harsh radiation environment.
  - Program budget constraints.
  - Fluctuating flight schedule(s).
  - Complex program level systems engineering.
  - Mass and volume constraints.

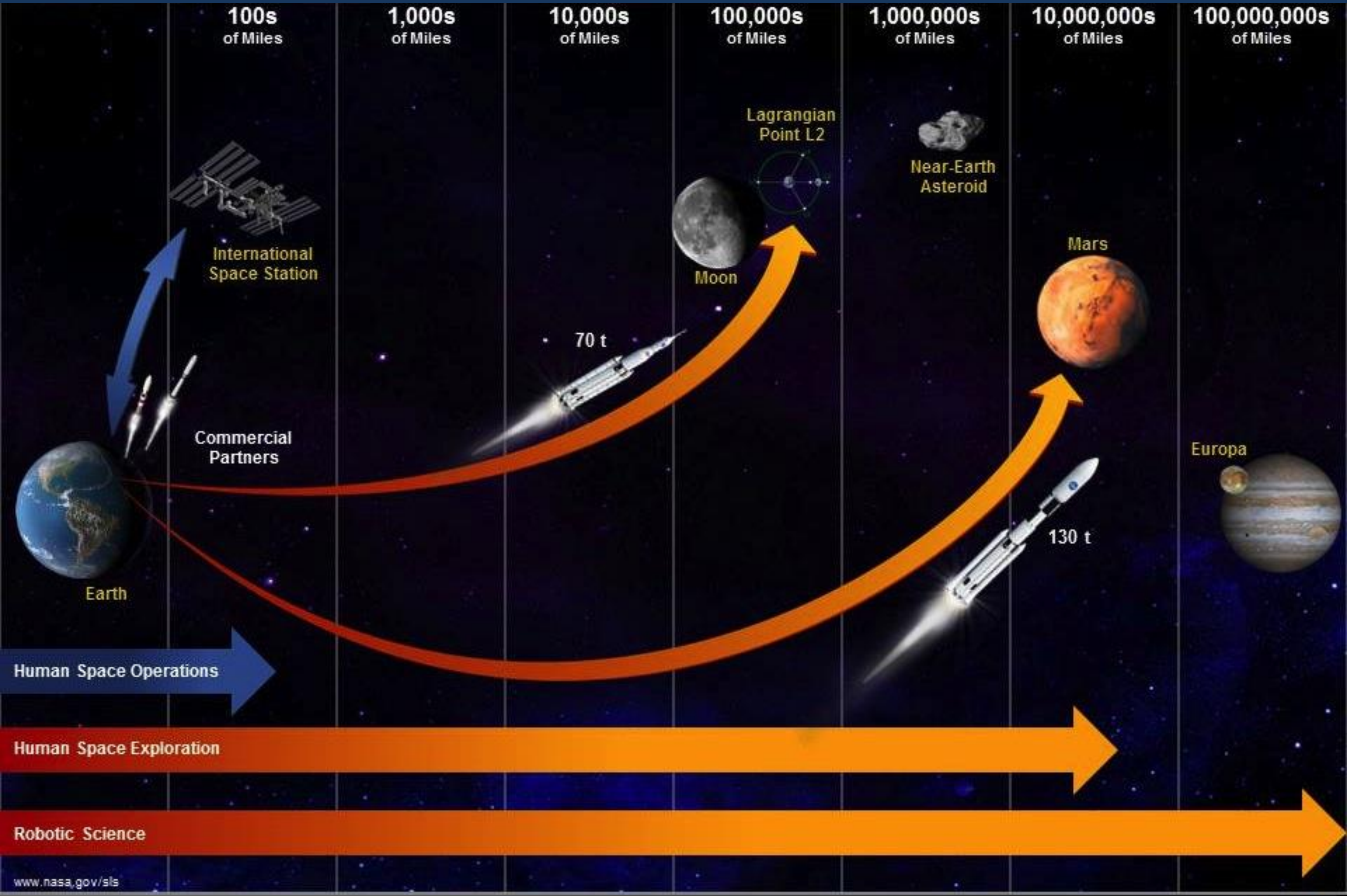
5 TO 11 DAYS TO EARTH


0 mph
0 mph
8,200 mph
2,400 mph
2,400 mph
3,900 mph
42,000 mph
3,900 mph
700 mph
0 mph
700 mph

Energy Required



Space Launch System (SLS) and Orion

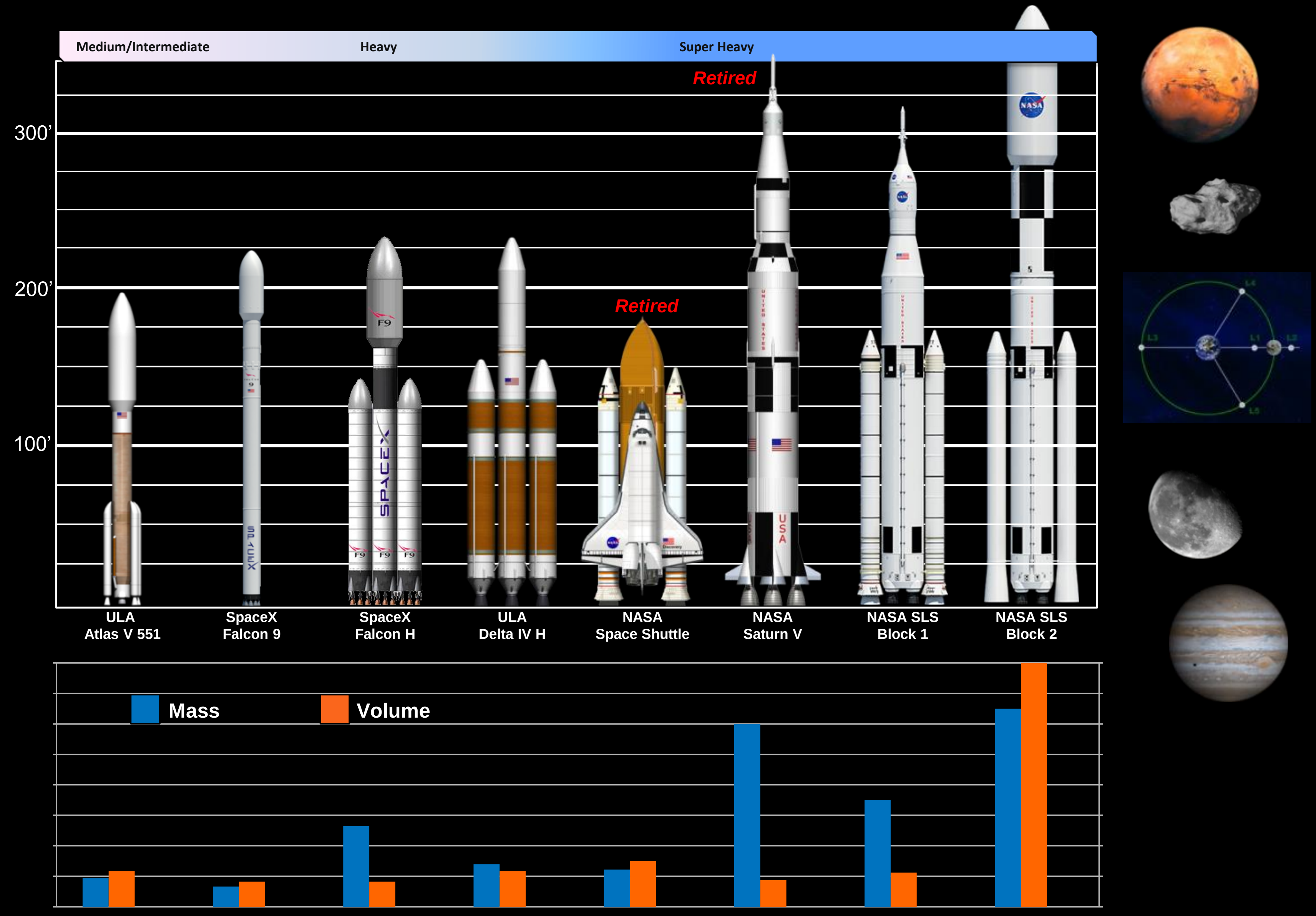


SLS Capabilities

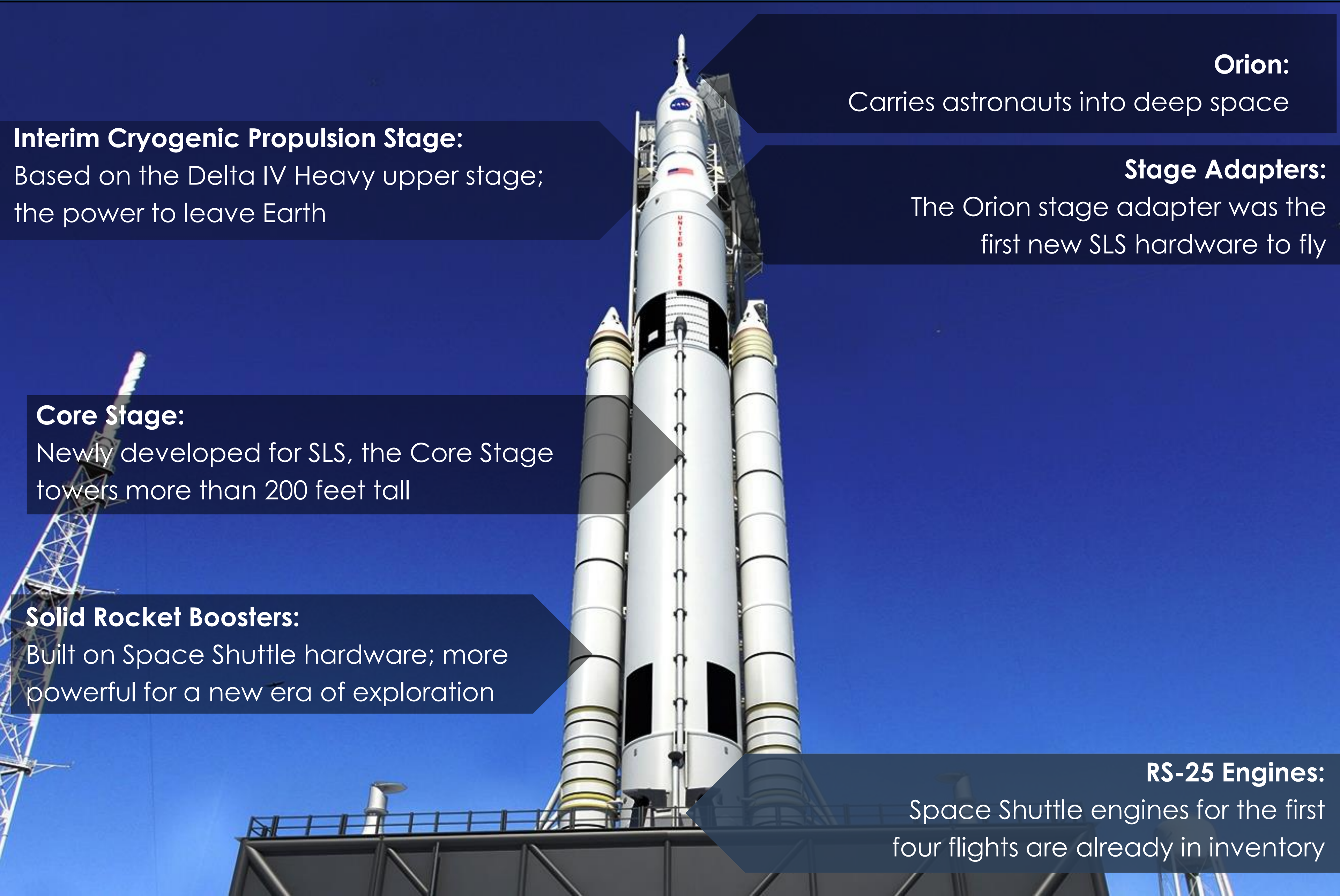
1) **SLS offers far greater mass and volume lift capability than any contemporary launch vehicle. This capability allows SLS to perform missions that no other vehicle can carry out, shorter travel times, and greater mission assurance. SLS is not designed to compete with industry launch vehicles, but to complement them by enabling new types of missions.**
2) **SLS enables human exploration and decadal-class science missions:**
   - Maintains reasonable number of launches per mission
   - Simplifies on-orbit operations
   - Maximizes mission reliability

5) **SLS investment can be leveraged for other missions:**
   - Deep Space Exploration
   - Planetary Landers
   - Human Habitats
   - Great Observatories
   - Space Solar Power
   - Outer Planet Missions
   - Department of Defense/NRO Payloads

Most Capable U.S. Launch Vehicle



The World's Most Powerful Rocket



Orion:
Carries astronauts into deep space

Interim Cryogenic Propulsion Stage:
Based on the Delta IV Heavy upper stage; the power to leave Earth

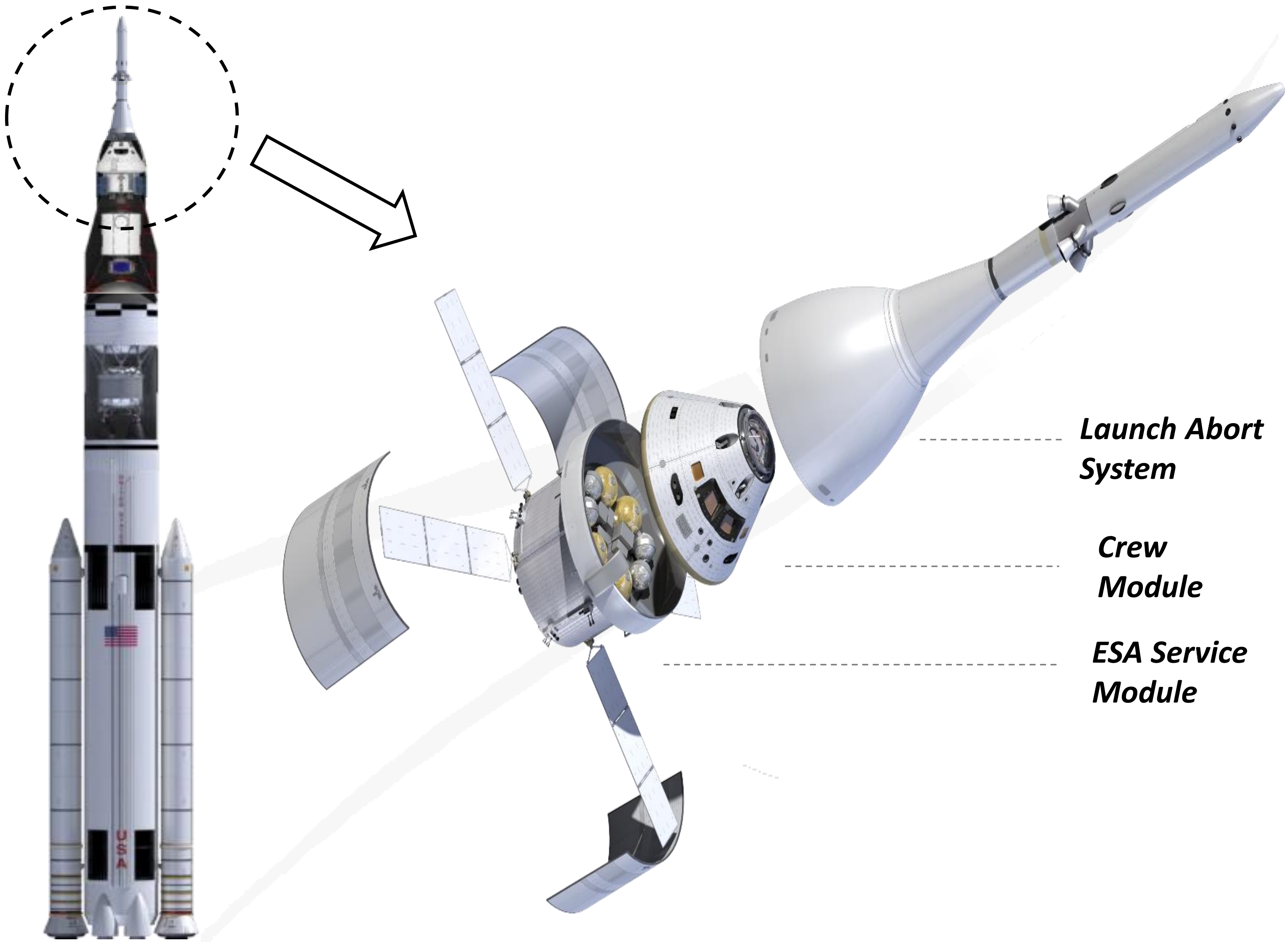
Stage Adapters:
The Orion stage adapter was the first new SLS hardware to fly

Core Stage:
Newly developed for SLS, the Core Stage towers more than 200 feet tall

Solid Rocket Boosters:
Built on Space Shuttle hardware; more powerful for a new era of exploration

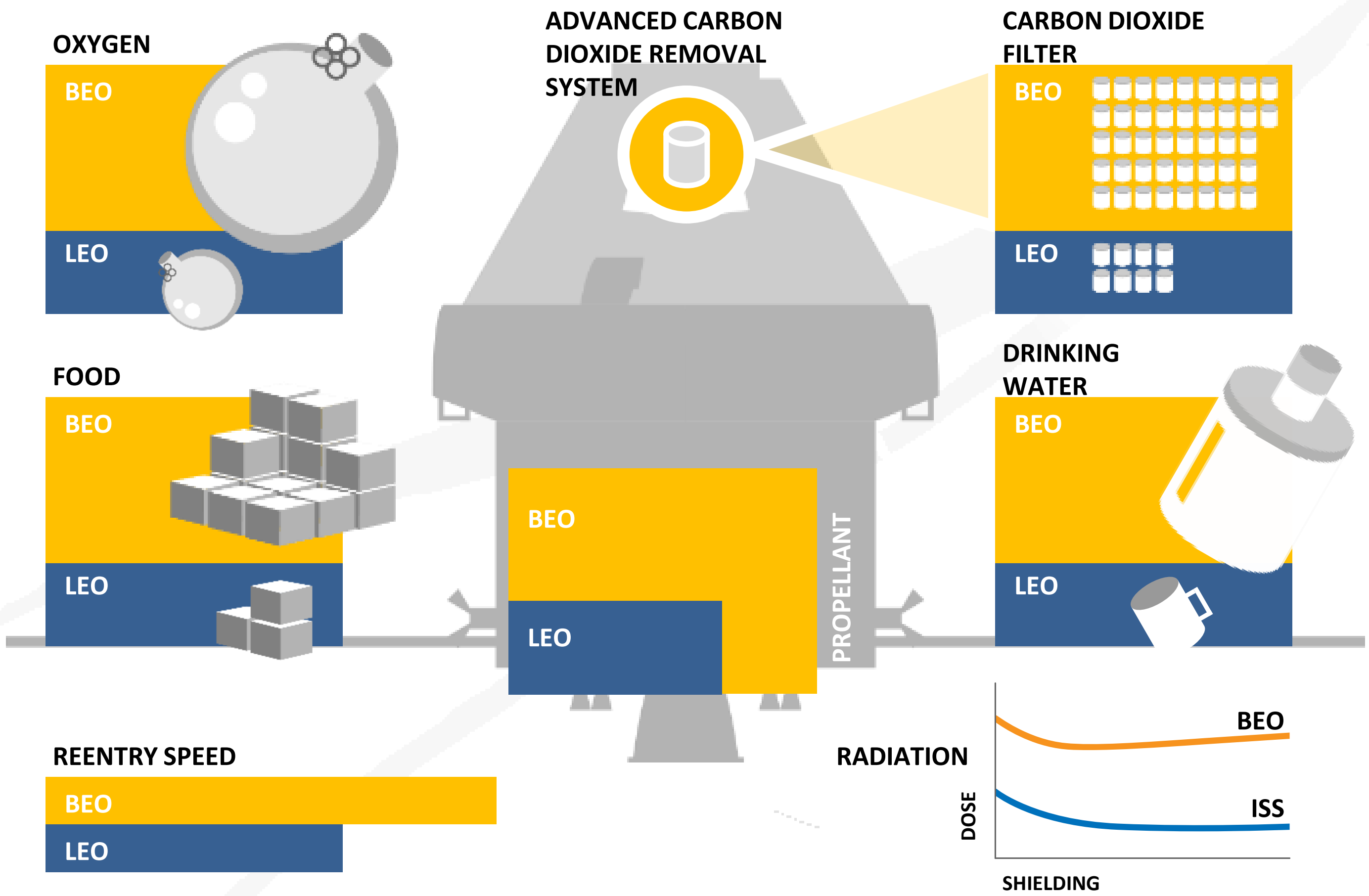
RS-25 Engines:
Space Shuttle engines for the first four flights are already in inventory

The Orion Spacecraft



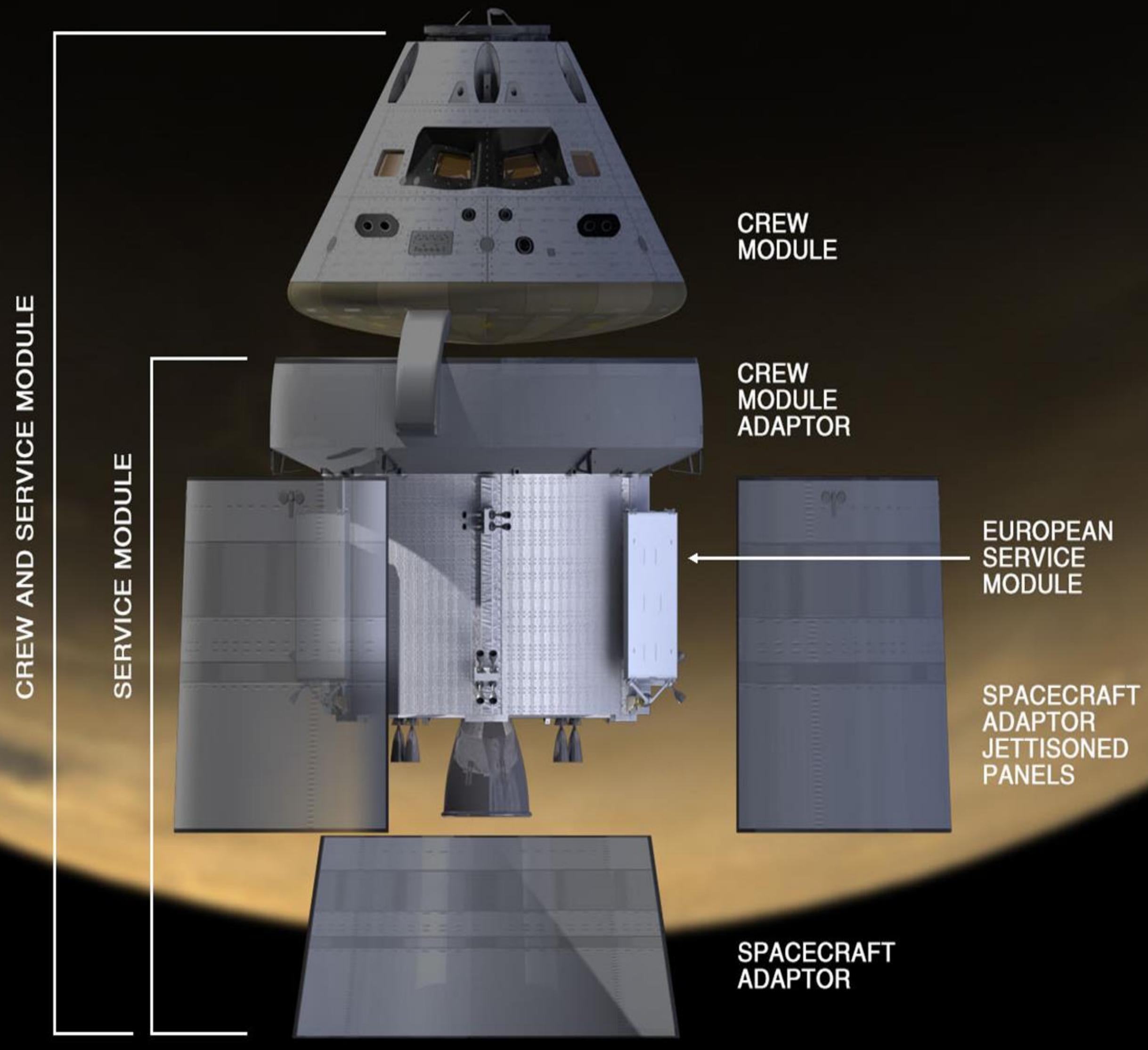
Orion Built for the Future

Orion is built for going Beyond Earth Orbit



LEO: Low Earth Orbit
BEO: Beyond Earth Orbit

ESA's Contribution to Orion



European Service Module

Service Module (SM) Functions & Configuration

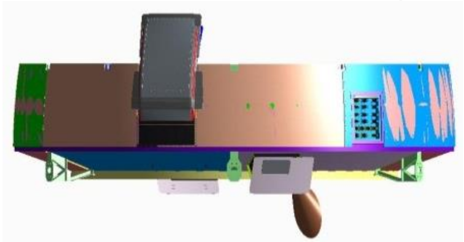
The SM, comprised of two subcomponents the Crew Module Adapter (CMA) and the European Service Module (ESM), provides services to the CM in the form of propulsion, consumables storage, heat rejection and power generation.

- Provide in-space translational delta-V capability to transfer the vehicle Provide orbital maintenance and attitude control
- Provide high altitude ascent abort propulsion after LAS jettison
- Provide consumables to support in-space habitable environment while attached to the CM (Water, O_2, and N_2 storage)
- Provide power generation and storage required for in-space flight
- Provide primary thermal control while mated with CM

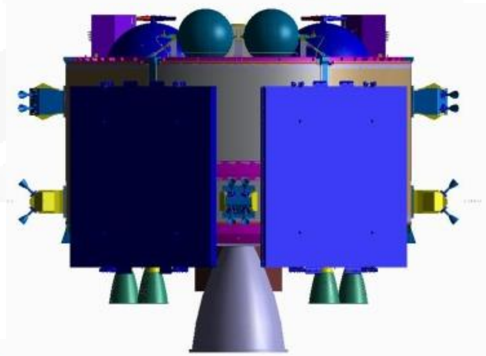
Spacecraft Adapter (SA/SAJ) Functions

- Provide structural connection to the launch vehicle from ground operations through orbital injection
- Provide protection for SM components from atmospheric loads and heating during first stage flight

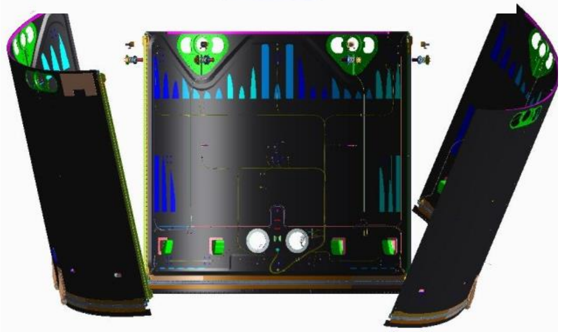
Crew Module Adapter (CMA)



European Service Module (ESM)

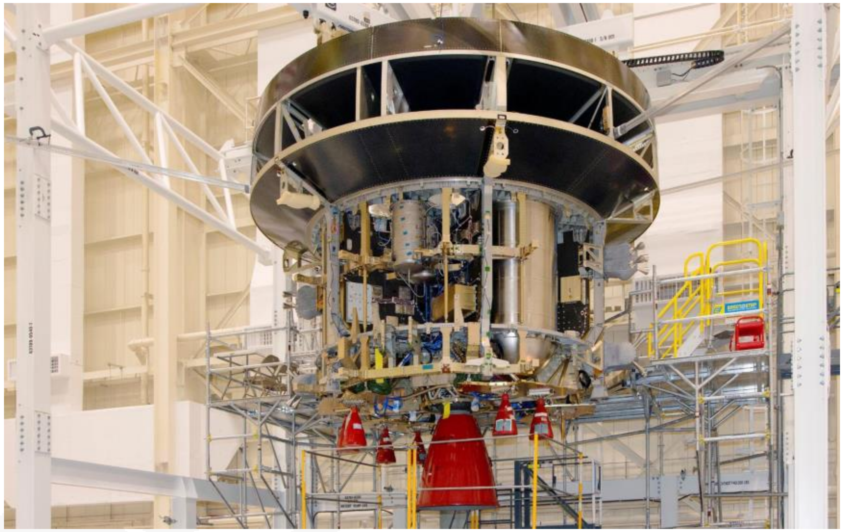


SA Jettisoned (SAJ)



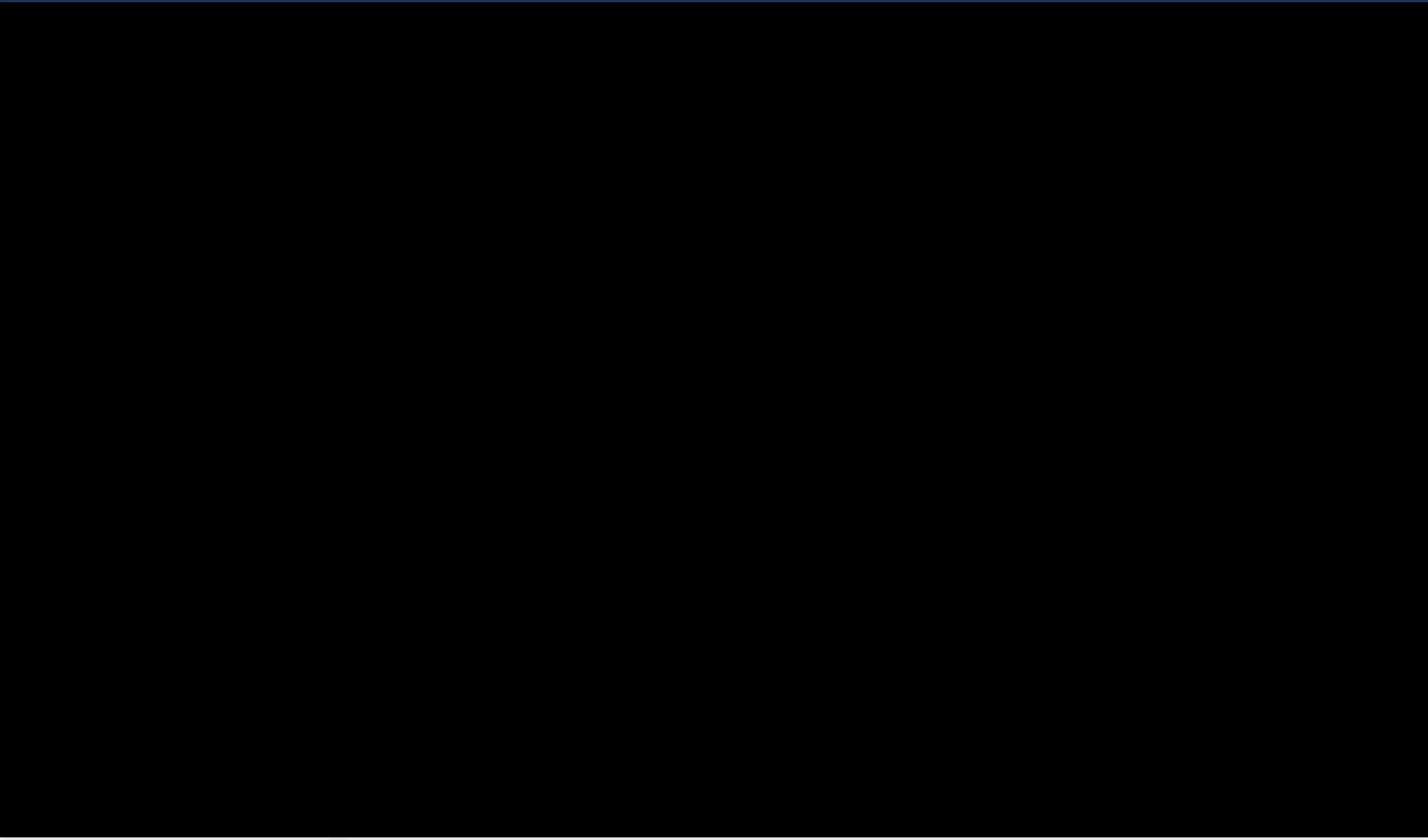
Spacecraft Adapter (SA)

European Service Module



- **ESA's Contributions to Orion:**
  - ESA is providing Orion's service module for Exploration Mission-1, when the spacecraft will launch atop the SLS rocket and venture 40,000 miles beyond the moon.
  - The ESA-provided service module, built by Airbus Defense and Space, is the spacecraft's powerhouse and will supply it with in-space propulsion, power, thermal control and air and water for crew when they are aboard.
  - For the first time, NASA will use a European-built system as a critical element to power an American spacecraft, extending our international cooperation from the space station into deep space.
  - NASA's work with ESA expands an already strong partnership and ensures continued international collaboration on the journey to Mars.

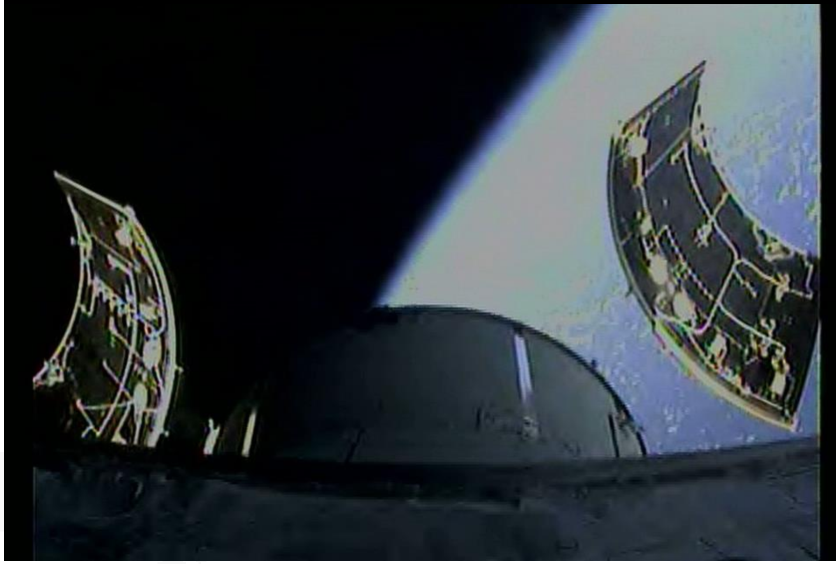
Trial by Fire



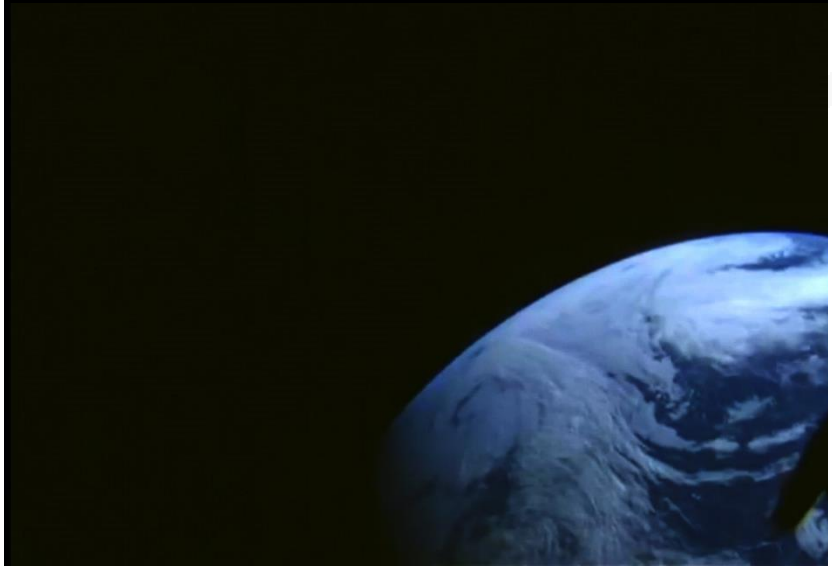
Orion EFT-1 December 5, 2014

LIFTOFF! Orion Begins New Era in Space Exploration!

Fairing Panel Jettison Complete



View of Earth from On-board Orion

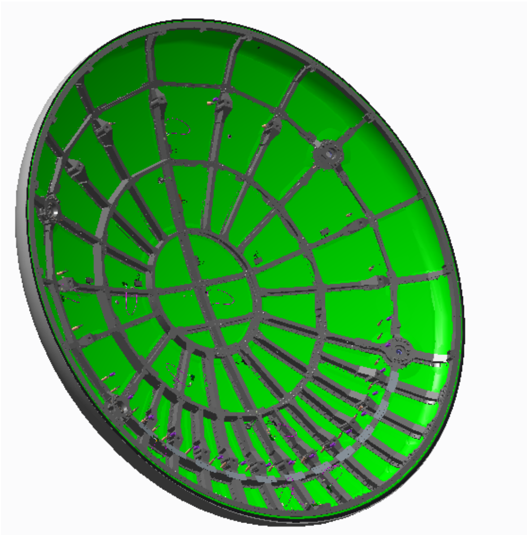


Orion Splashdown in Pacific Ocean

What is necessary for successful Human Space Craft development?

- **Design complexity**
  - Systems Engineering and Integration
  - Natural Environments
  - Induced Environments
- **Mass**
- **Budget**
- **Safety**
- **Reliability**
- **Example**
  - Orion Heat Shield

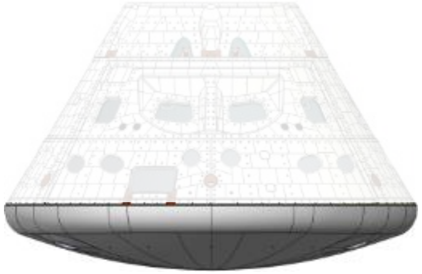
Orion Heat Shield Technology Development

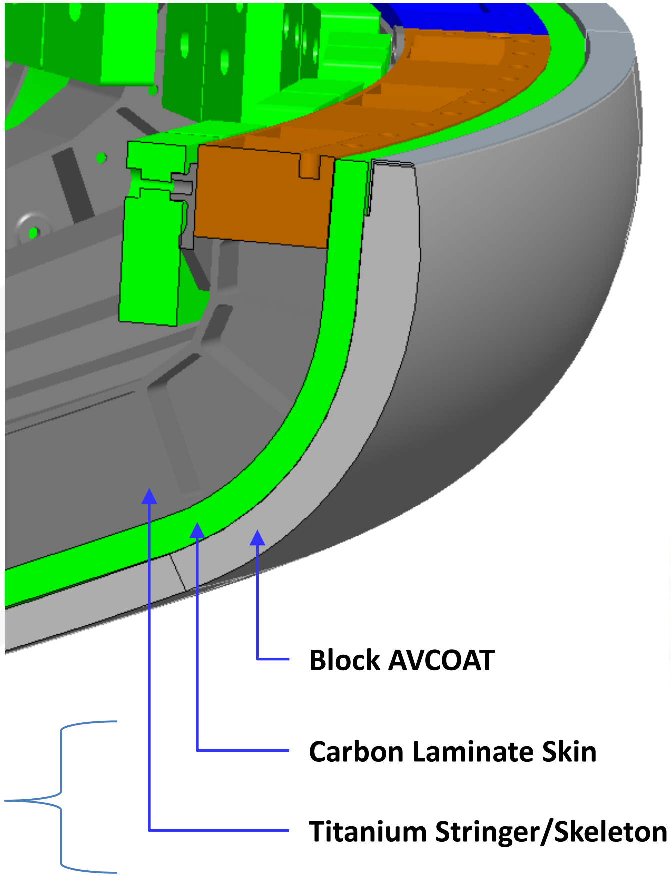


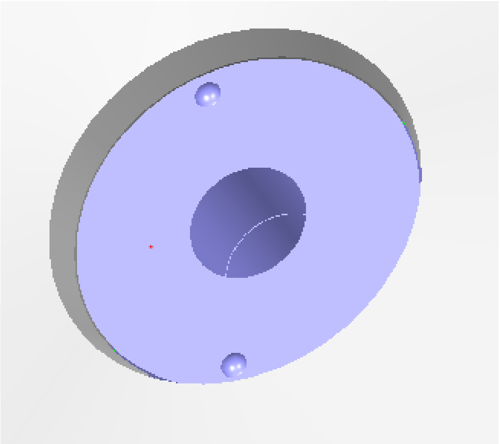
Titanium Stringer/Skeleton

Carbon Laminate Skin
(EFT1 Shown)

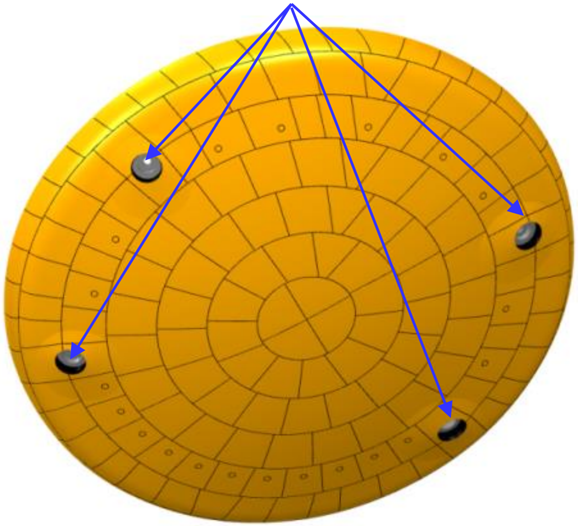
Carrier Structure







Compression Pads, 4 Locations

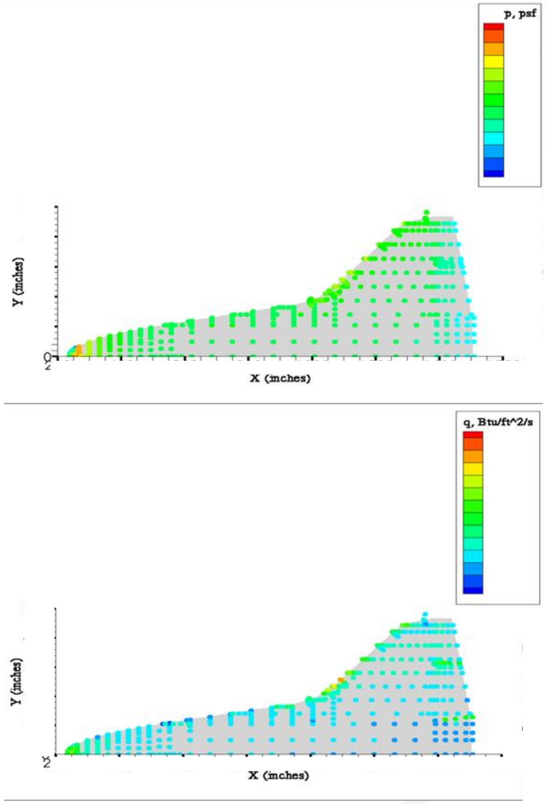


Block AVCOAT

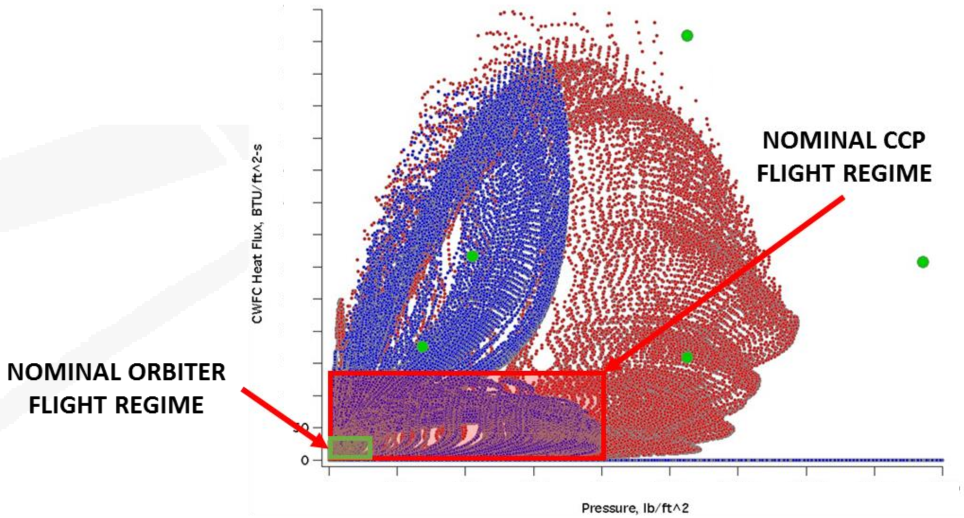
Induced Environment for Re-entry

Relative Risk of TPS Failure – Environment Differences

Orbiter Reentry



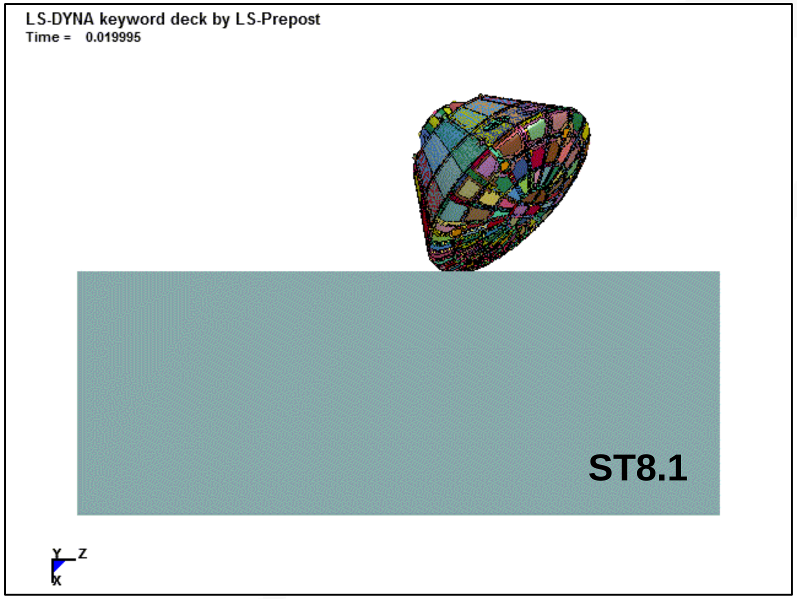
Orion Reentry



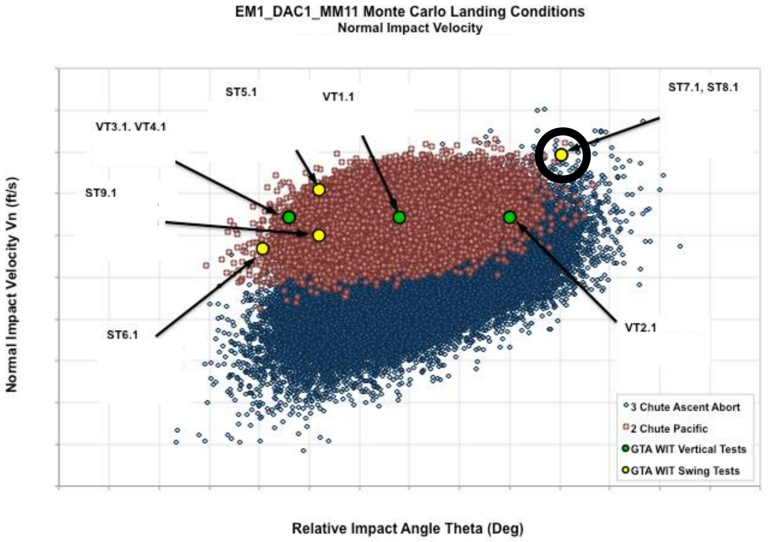
Orion Reentry Environments more severe than Orbiter and CCP - Increased Risk

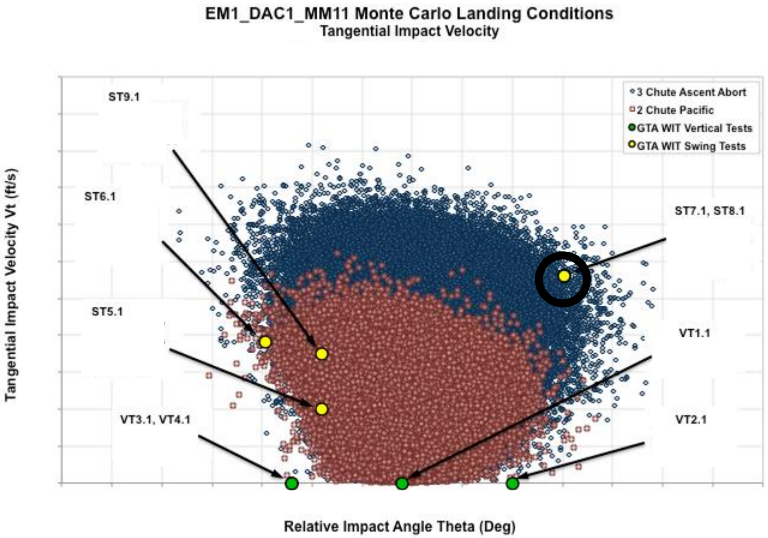
Natural Environment

- **ST8.1 Characteristics**
  - 3-chute ascent abort (with 30° roll)
  - Steep theta with moderate to high Vt
  - High Vn (for three chutes)
  - Low x-axis loads
  - Highest z-axis loads



Animation by Greg Vassilakos, NASA LaRC - STC



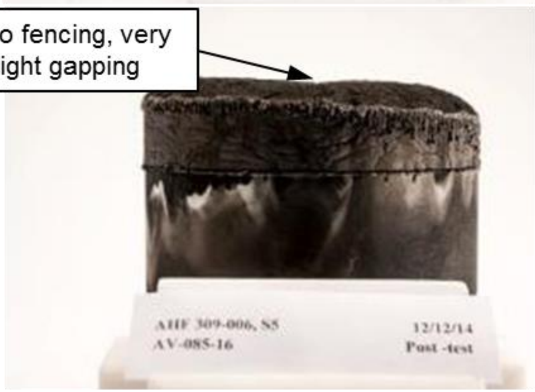


Thermal Assessment – Gap Filler

RTV560 with 5 pbw PMBs

High Heat flux

No fencing, very slight gapping

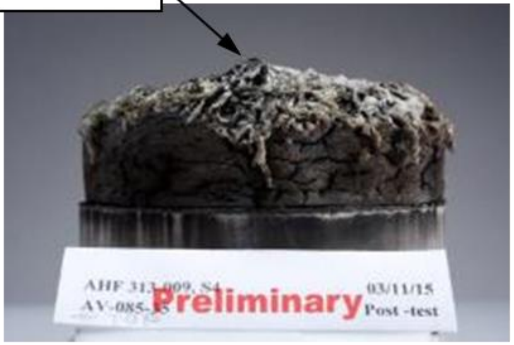


Low-med Heat

3-4 mm fence

Low Heat flux

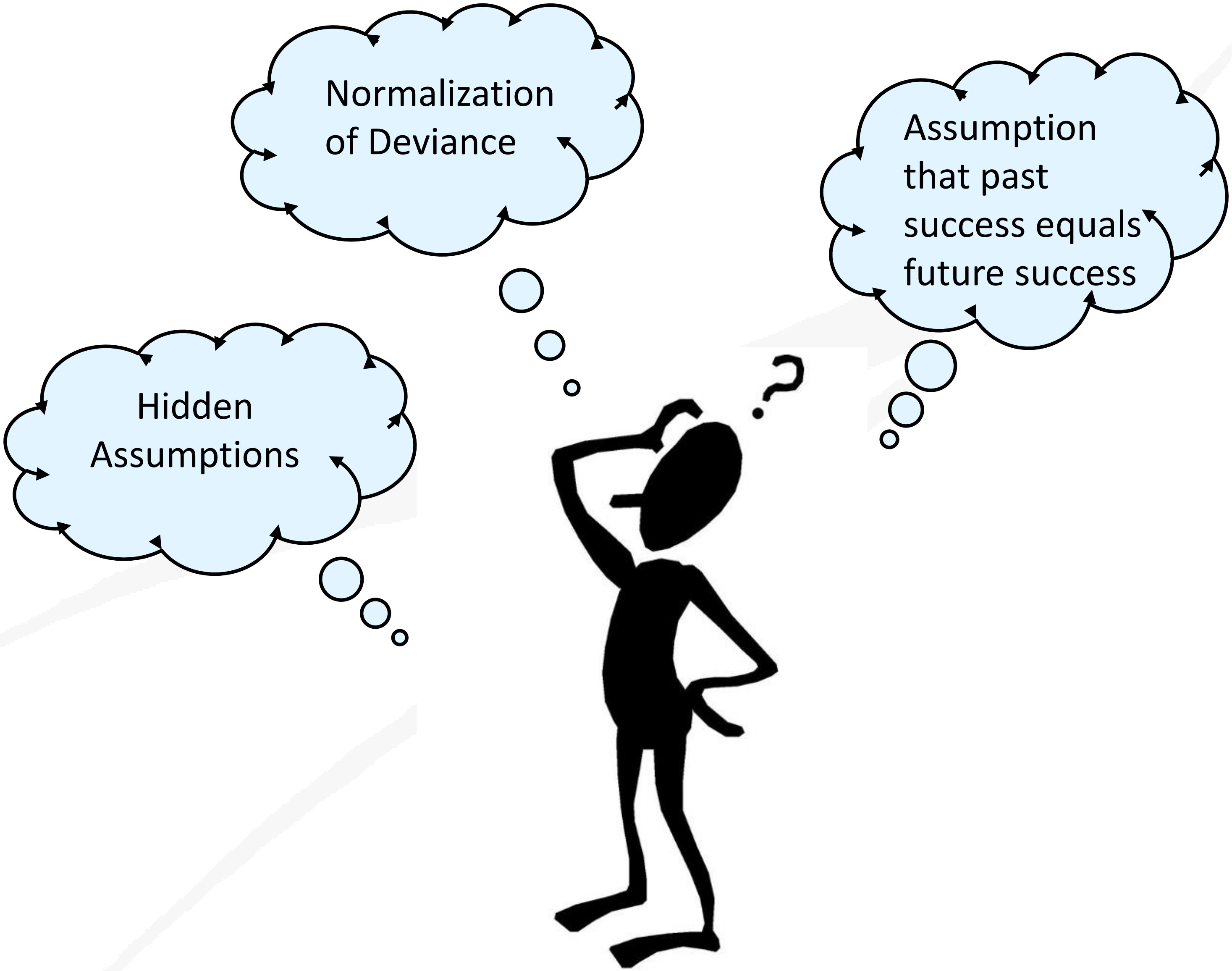
2-3 mm fence



- RTV560+pmb performance is in-family with RTV560
- Gap-Filler thermal performance is successful across test range
- Upcoming tests: 40 models including stag and wedge models over the next three months.

Safety

Human Nature



Opportunities

Spaceflight is hard, but the benefits are vast

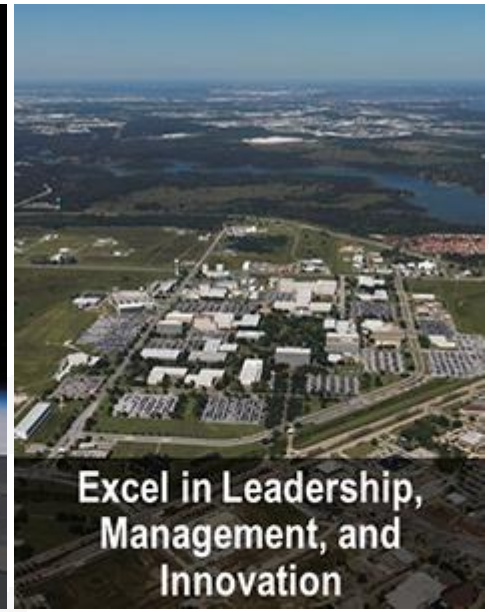
- **Real technical and medical benefits for life on earth as a direct result of space research**
- **Technical solutions invented for spaceflight that transfer to life on earth**
- **International cooperation**
- **Science, Technology and Engineering Education**
- **Benefits of exploration – new discoveries and new knowledge**
- **http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20130009008.pdf**

Questions

Back Up Charts

NASA Johnson Space Center

Leading Human Space Exploration



Engineering

Flight Operations

Astromaterials Research & Exploration Science

Exploration, Integration, and Science

International Space Station Program

Orion Multi-Purpose Crew Vehicle Program

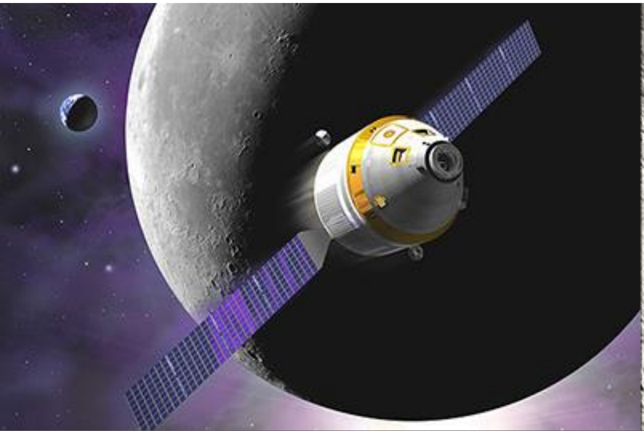
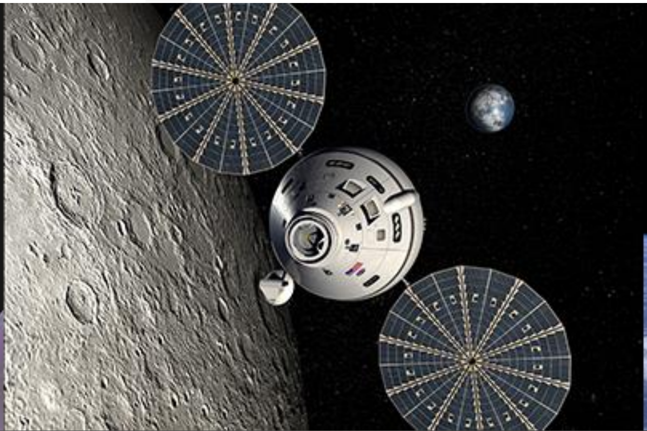
Commercial Crew & Cargo Program

Safety & Mission Assurance

Human Health & Performance

Orion Has Been Shaped By Its History

- **Built for Beyond Earth Orbit (BEO)**
- **Synergistic with the Commercial Crew Program strategy**
- **Adapted to Significant Policy/Strategic Changes since Inception**
- **Orion/SLS combination is critical to extending human presence beyond low earth orbit**


Mars Challenges

Technology Focus for Staying Healthy

Life Support

- High reliability systems
- O_2 recovery and reducing logistics
- Water recovery loop closure
- Solid waste volume reduction and resource recovery
- Store nutritionally-adequate food for years

Space Suits

- Low mass suit and power pack
- Lower torso mobility
- Enhanced dexterity
- Compatible with Mars environment
- Increase information system capabilities
- In-situ suit repair

Microgravity Countermeasures

- Exercise equipment for muscle and cardiovascular atrophy, and bone loss
- Low-mass, rapid deploy, low-maintenance systems

Autonomous Medicine

- Advanced medical diagnosis, prognosis and treatment capabilities
- In-situ analysis of biomedical samples

Environmental Control

- In-flight analysis capabilities
- Rapid detection and mitigation of environmental hazards
- Detect contaminants introduced via surface activities
- Automated recovery
- Fire suppression

Mars Challenges

Technology Focus for Transportation

Access to Space

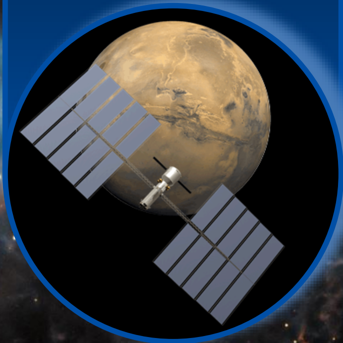
- Space Launch System heavy lift for large mass and volume
- Orion crew vehicle for crew delivery to and return from deep space

Chemical Propulsion

- O_2/Hydrocarbon (CH_4) propulsion for in-space transit, landing and ascent
- Integrated main and reaction control propulsion systems
- Ability to maintain cryogenic fluids for long durations

Advanced Propulsion

- Advanced capabilities to improve mass delivery and trip time
- Under investigation
  - Solar Electric
  - Advanced Chemical
  - Nuclear Thermal
  - Nuclear Electric



In-Situ Resource Utilization

- Production of O_2 from the atmosphere for Mars ascent
- Production of life-support consumables
- Construction of surface infrastructure from local resources

Entry, Descent, Landing & Ascent

- Hypersonic inflatable or deployable decelerators
- Supersonic retro-propulsion
- Precision landing
- Plume blast mitigation
- High-speed Earth re-entry
- Occupant protection

Mars Challenges

Technology Focus for Working in Space

Humans & Robots Working Together

- Human/machine coordination to improve productivity & reduce risk
- Robots performing routine tasks (inspection, logistics)
- Robotic Explorers (reconnaissance and risk reduction)

Autonomous Operations

- Independent, self-reliant crew can operate with up to 40 minute time delay
- Highly automated vehicle operable by minimal crew
- MCC automation (strategic/analysis role)
- Automated rendezvous & docking

In-Flight Maintenance

- Component-based design for maintainability & reliability
- Vehicle-wide diagnostics, prognostics & recovery
- In-space repair & manufacturing

Exploration Mobility

- Routine surface exploration
- Maximize time spent and distance traveled
- Minimize "time to get out the door"
- Environmental protection including dust abatement

Power Generation

- Production of high, continuous, latitude independent power for crew operations
- Mobile power systems for robust exploration