Human Exploration & Operations Overview

National Aeronautics and
Space Administration

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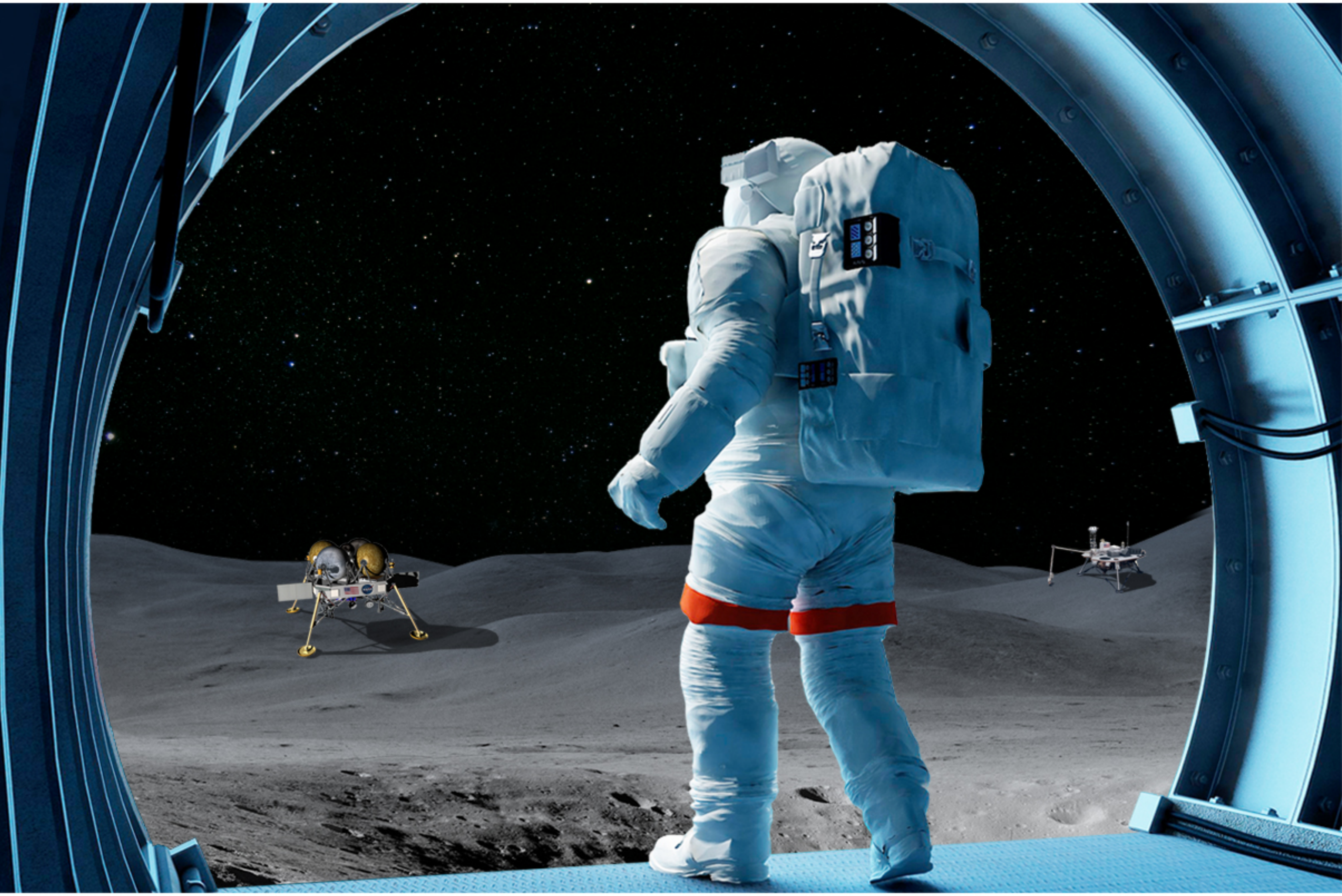
NAC Full Meeting
August 29, 2018



Space Policy Directive – 1

Reinvigorating America's Human Space Exploration Program

"Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.

Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations."

Space Policy Directive – 2

Streamlining Regulations on the Commercial Use of Space

"It is the policy of the executive branch to be prudent and responsible when spending taxpayer funds, and to recognize how government actions, including Federal regulations, affect private resources.

It is therefore important that regulations adopted and enforced by the executive branch promote economic growth; minimize uncertainty for taxpayers, investors, and private industry; protect national security, public-safety, and foreign policy interests; and encourage American leadership in space commerce."

Space Policy Directive – 3

National Space Traffic Management

"For decades, the United States has effectively reaped the benefits of operating in space to enhance our national security, civil, and commercial sectors. Our society now depends on space technologies and space-based capabilities for communications, navigation, weather forecasting, and much more.

Given the significance of space activities, the United States considers the continued unfettered access to and freedom to operate in space of vital interest to advance the security, economic prosperity, and scientific knowledge of the Nation."

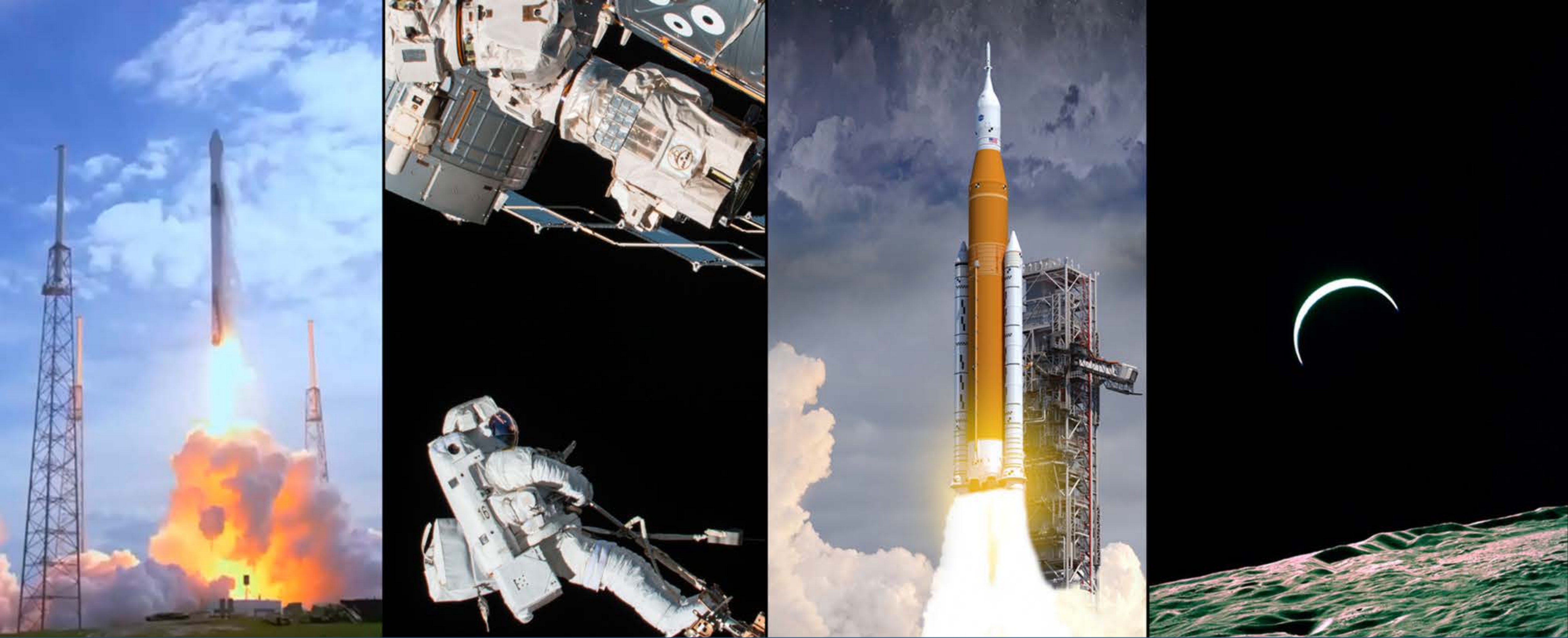
EXPLORE

ADVANCE
EXPLORATION
& SCIENCE

DEVELOP

DEVELOP
SPACE

LEAD THE EXPLORATION
OF SPACE WITH
INTERNATIONAL
& PRIVATE SECTOR
PARTNERS



STRATEGIC PRINCIPLES OF HUMAN SPACE EXPLORATION

Fiscal Realism | Commercial Partnerships | Scientific Exploration
Technology Pull and Push | Gradual Buildup of Capability
Architecture Openness and Resilience
Global Collaboration and Leadership | Continuity of Human Spaceflight

International Interoperability Standards

Draft Deep Space Interoperability System Standards
Posted for feedback on March 1, 2018

- Avionics
- Communications
- Environmental Control and Life Support Systems
- Power
- Rendezvous
- Robotics
- Thermal

www.InternationalDeepSpaceStandards.com

NASA's Open Architecture Develops Space

COMMERCIAL CARGO & CREW


Cygnus (Northup Grumman)


Dragon (SpaceX)


Dream Chaser (SNC)

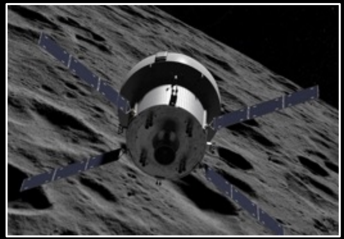

Dragon Crew (SpaceX)

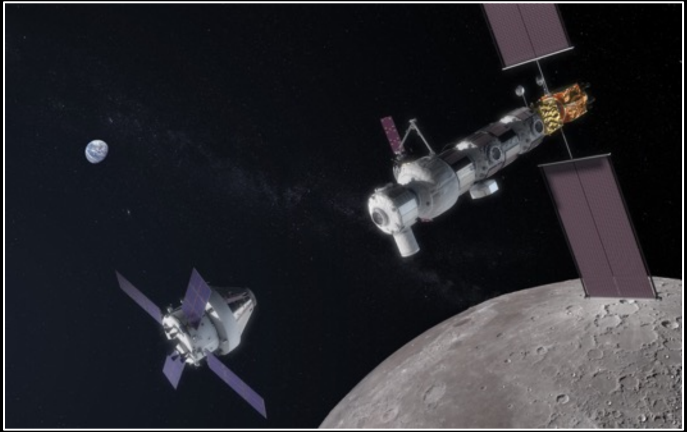

Starliner (Boeing)

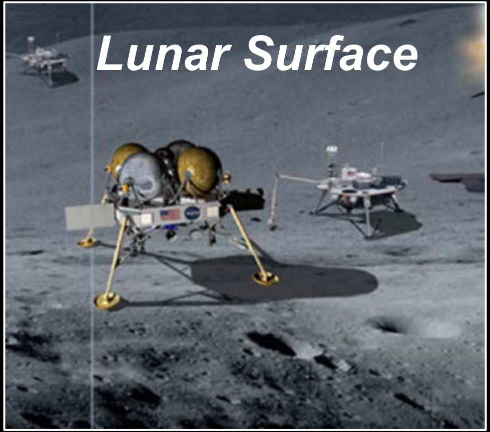
INTERNATIONAL


Soyuz & Progress (Roscosmos)


H-II Transfer Vehicle (JAXA)

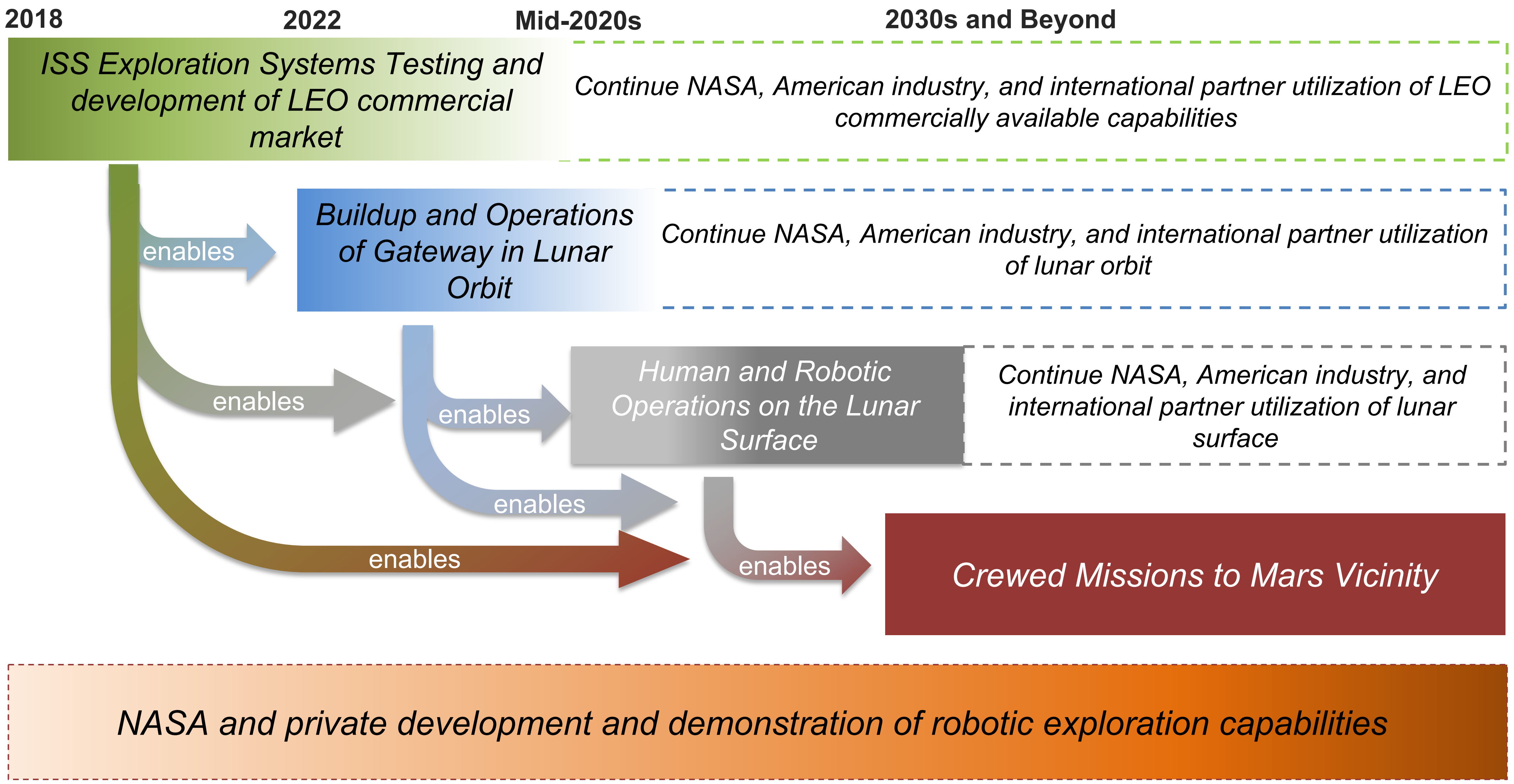

Orion/European Service Module (ESA)





Multiple providers expected in lunar orbit and on the surface

Sustaining Leadership Through The Buildup of Mutually-enabling Exploration Capabilities



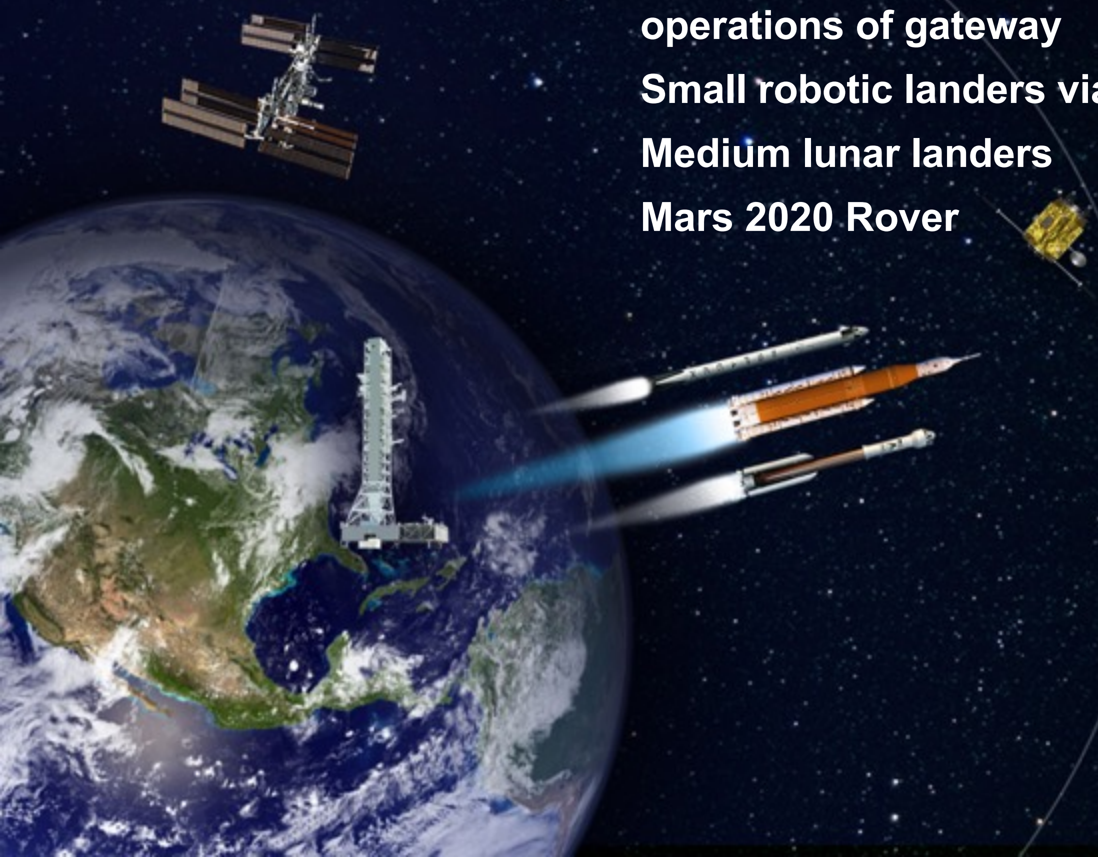
Expanding Human Presence In Partnership

Now

LEO commercial market

Technology and crew health advancements via ISS

Lunar discovery and exploration



Early 2020s

SLS/Orion

Buildup and Initial operations of gateway

Small robotic landers via CLPS

Medium lunar landers

Mars 2020 Rover

Late 2020s

SLS/Orion cislunar missions

Gateway in lunar orbit

Larger lunar landers progressing toward human-class landers

Mars sample return

Late 2030s

First human mission to Mars

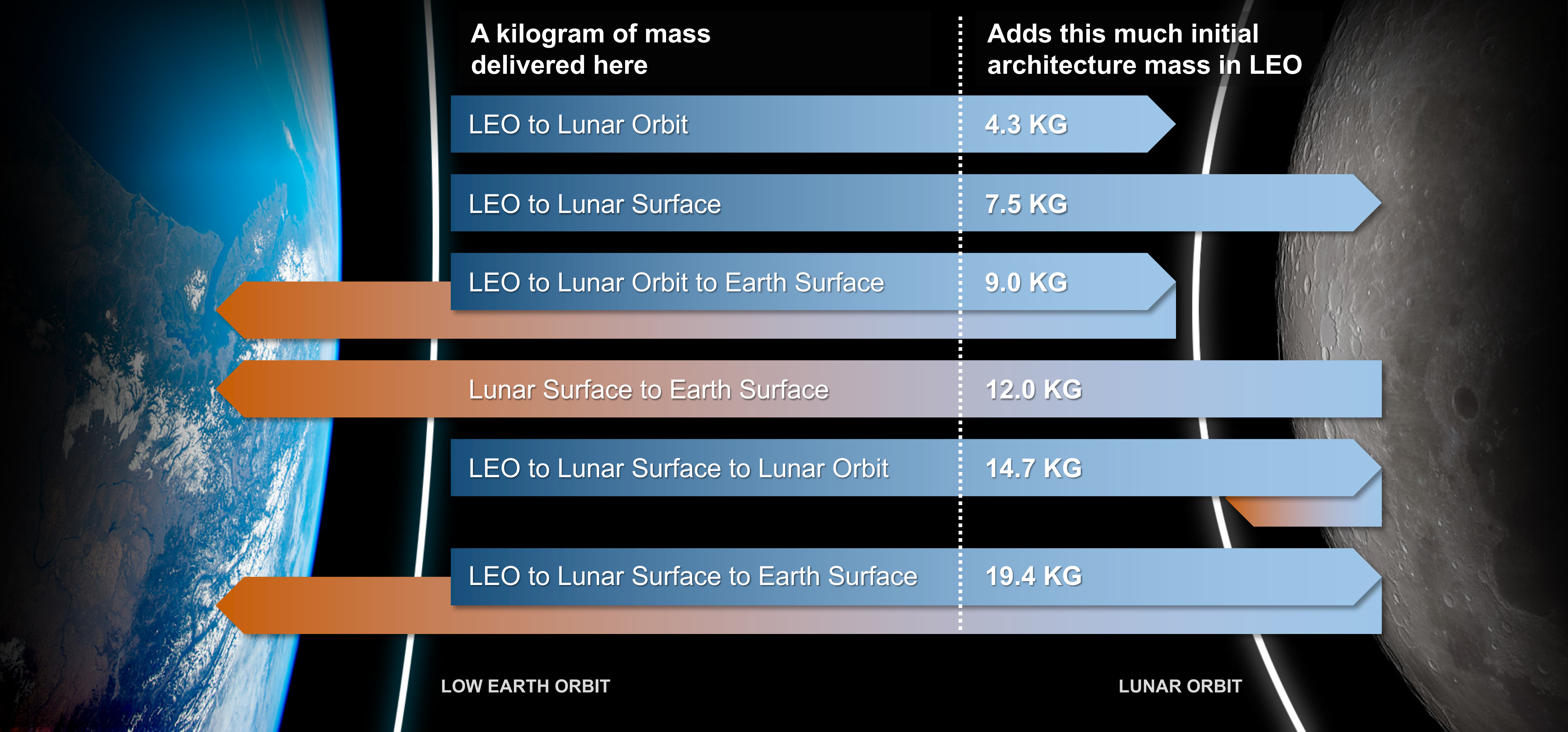
Early-2030s

Human and robotic lunar surface operations

Prep for Mars mission

Timelines are tentative and will be developed further in FY2019

Designing for Deep Space



Human Spaceflight Risks

Physiological Changes

- Cardiovascular Deconditioning
- Decreased Immune Function
- Muscle Atrophy
- Balance Disorders
- Fluid Shifts
- Visual Alterations
- Bone Loss

Space Radiation

- Acute in-flight Effects
- Long-term cancer risk
- Cardiovascular

Distance from Earth

Need for “autonomous” medical care –cannot return home for treatment

Hostile Environment

- Vehicle Design
- Environmental - Air levels
- Toxic exposure - Water, food

Isolation and Confinement

- Behavior aspect of isolation
- Sleep disorders

Leveraging Space Station: Habitation Systems (1/2)

Habitation Systems Elements		TODAY Space Station	FUTURE Deep Space
LIFE SUPPORT	Excursions from Earth are possible with artificially produced breathing air, drinking water and other conditions for survival. Atmosphere Management; Water Management; Waste Management	~50% O_2 Recovery from CO_2 90% H_2O Recovery < 6 mo mean time before failure (for some components)	75%+ O_2 Recovery from CO_2 98%+ H_2O Recovery >30 mo mean time before failure
ENVIRONMENTAL MONITORING	NASA living spaces are designed with controls and integrity that ensure the comfort and safety of inhabitants. Pressure O_2 & N_2; Moisture; Particles; Microbes; Chemicals; Sound	Limited, crew-intensive on-board capability Reliance on sample return to Earth for analysis	On-board analysis capability with no sample return Identify and quantify species and organisms in air & water
CREW HEALTH	Astronauts are provided tools to perform successfully while preserving their well-being and long-term health. Monitoring; Exercise; Diagnostics; Treatment; Food Storage & Management	Bulky fitness equipment Limited medical capability Frequent food system resupply	Smaller, efficient equipment Onboard medical capability Long-duration food system
EVA: EXTRA-VEHICULAR ACTIVITY	Long-term exploration depends on the ability to physically investigate the unknown for resources and knowledge. Mobility; Life Support; Science and Exploration	Upper body high mobility for limited sizing range Low interval between maintenance, contamination sensitive, and consumables limit EVA time Construction and repair focused tools; excessive inventory of unique tools	Full body mobility for expanded sizing range Increased time between maintenance cycles, contamination resistant system, 25% increase in EVA time Geological sampling and surveying equipment; common generic tool kit

Leveraging Space Station: Habitation Systems (2/2)

Habitation Systems Elements

TODAY Space Station | **FUTURE** Deep Space

RADIATION PROTECTION

During each journey, radiation from the sun and other sources poses a significant threat to humans and spacecraft.

Monitoring, Tracking, Modeling, Mitigation

Today – Space Station
- Node 2 crew quarters (CQ) with polyethylene reduce impacts of proton irradiation.
- Large multi-layer detectors & small pixel detectors – real-time dosimetry, environment monitoring, tracking, model validation & verification
- Bulky gas-based detectors – real-time dosimetry
- Small solid-state crystal detectors – passive dosimetry (analyzed post-mission)

Future – Deep Space
- Solar particle event storm shelter, optimized position of on-board materials and CQ
- Small distributed pixel detector systems – real-time dosimetry, environment monitoring, and tracking
- Small actively read-out detectors for crew – real-time dosimetry

FIRE SAFETY

Throughout every mission, NASA is committed to minimizing critical risks to human safety.

Detection, Protection, Suppression, Cleanup

Today – Space Station
- Large CO_2 Suppressant Tanks
- 2-cartridge mask
- Obsolete combustion prod. sensor
- Only depress/repress clean-up

Future – Deep Space
- Water Mist portable fire extinguisher
- Single Cartridge Mask
- Exploration combustion product monitor
- Smoke eater

LOGISTICS

Sustainable living outside of Earth requires explorers to reduce, recycle, reuse, and repurpose materials.

Tracking, Clothing, Packaging, Trash

Today – Space Station
- Manual scans, displaced items
- Disposable cotton clothing
- Packaging disposed
- Bag and discard

Future – Deep Space
- Automatic, autonomous RFID
- Long-wear clothing/laundry
- Bags/foam repurposed w/3D printer
- Resource recovery, then disposal

CROSS-CUTTING

Powerful, efficient, and safe launch systems will protect and deliver crews and materials across new horizons.

Robotics, Power, Communication, Docking, Avionics, Autonomy & Software, Thermal, Materials

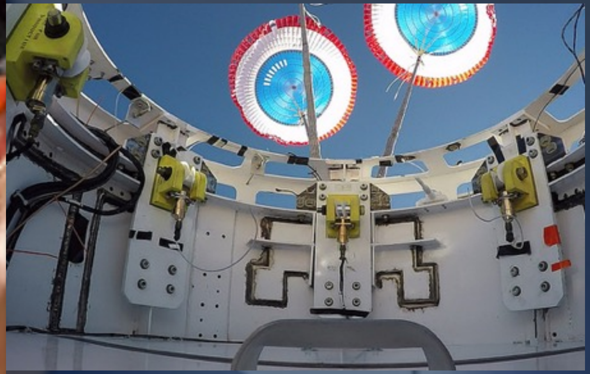
Today – Space Station
- Minimal on-board autonomy
- Near-continuous ground-crew communications
- Some common interfaces, modules controlled separately

Future – Deep Space
- Ops independent of Earth & crew
- Up to 40-minute comm delay
- Widespread common interfaces, modules/systems integrated
- Manufacture replacement parts in space

What It Takes To Come Home Safely

LOW EARTH RETURN	LUNAR RETURN	MARS RETURN
3 HOURS	3 DAYS	9 MONTHS
1,650°C	2,870°C	3,425°C
28,160 KPH	39,750 KPH	43,130 KPH
400 KM	386,240 KM	62,764,420 KM

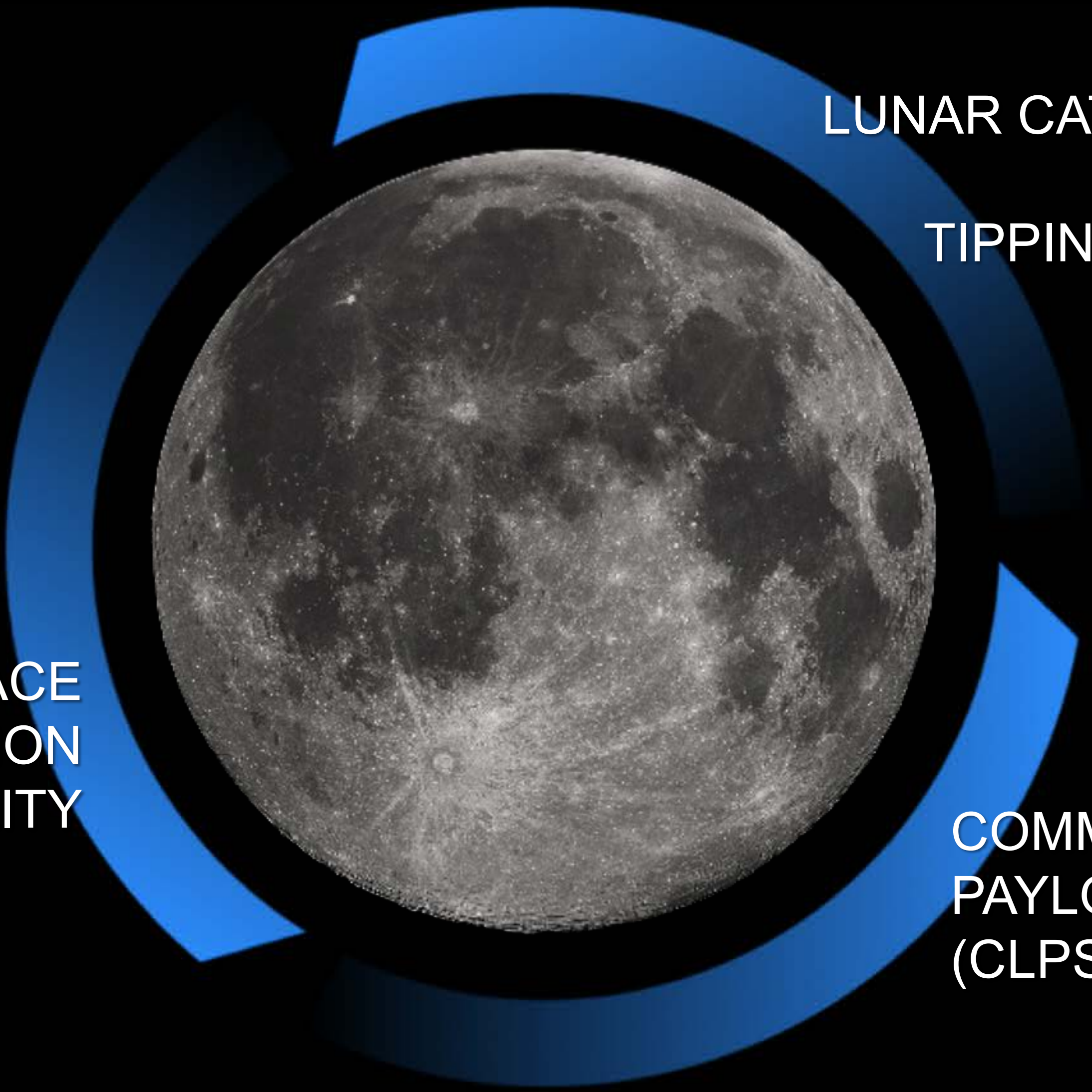
Commercial Crew – Boeing Starliner



Commercial Crew – SpaceX Dragon

EXPLORE

LUNAR SURFACE
TRANSPORTATION
CAPABILITY

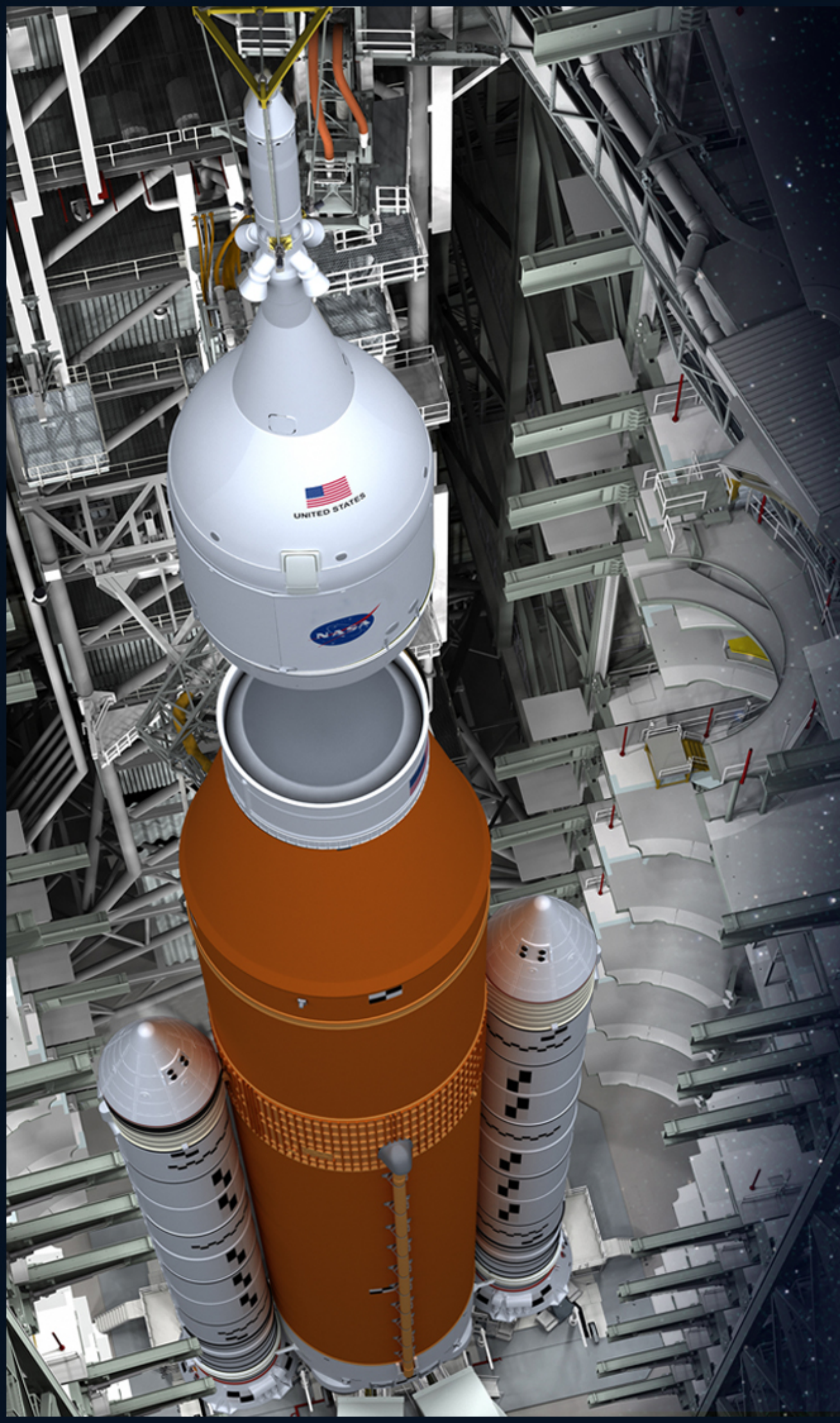


DEVELOP

LUNAR CATALYST

TIPPING POINT

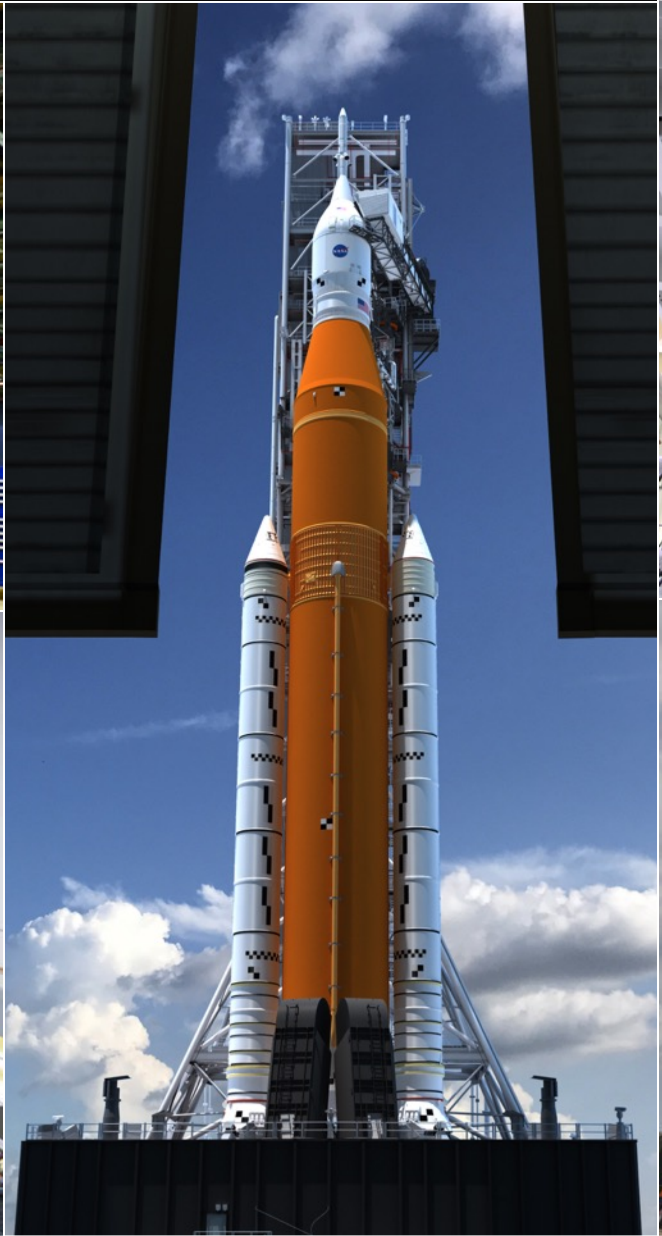
COMMERCIAL LUNAR
PAYLOAD SERVICES
(CLPS)



Deep Space Exploration System

NASA's Deep Space Exploration System, including SLS, Orion, and modernized ground support facilities at Kennedy Space Center, is an asset that belongs to the American people. It is foundational to extending human presence into the solar system.

Deep Space Exploration System



GATEWAY

A spaceport for human and robotic exploration to the Moon and beyond

HUMAN ACCESS TO & FROM LUNAR SURFACE
Astronaut support and teleoperations of surface assets.

U.S. AND INTERNATIONAL CARGO RESUPPLY
Expanding the space economy with supplies delivered aboard partner ships that also provide interim spacecraft volume for additional utilization.

INTERNATIONAL CREW
International crew expeditions for up to 30 days as early as 2024. Longer expeditions as new elements are delivered to the Gateway.

SAMPLE RETURN
Pristine Moon or Mars samples robotically delivered to the Gateway for safe processing and return to Earth.

SCIENCE AND TECH DEMOS
Support payloads inside, affixed outside, free-flying nearby, or on the lunar surface. Experiments and investigations continue operating autonomously when crew is not present.

COMMUNICATIONS RELAY
Data transfer for surface and orbital robotic missions and high-rate communications to and from Earth.

SIX DAYS TO ORBIT THE MOON
The orbit keeps the crew in constant communication with Earth and out of the Moon's shadow.

A HUB FOR FARTHER DESTINATIONS
From this orbit, Vehicles can embark to multiple destinations: The Moon, Mars and beyond.

GATEWAY SPECS

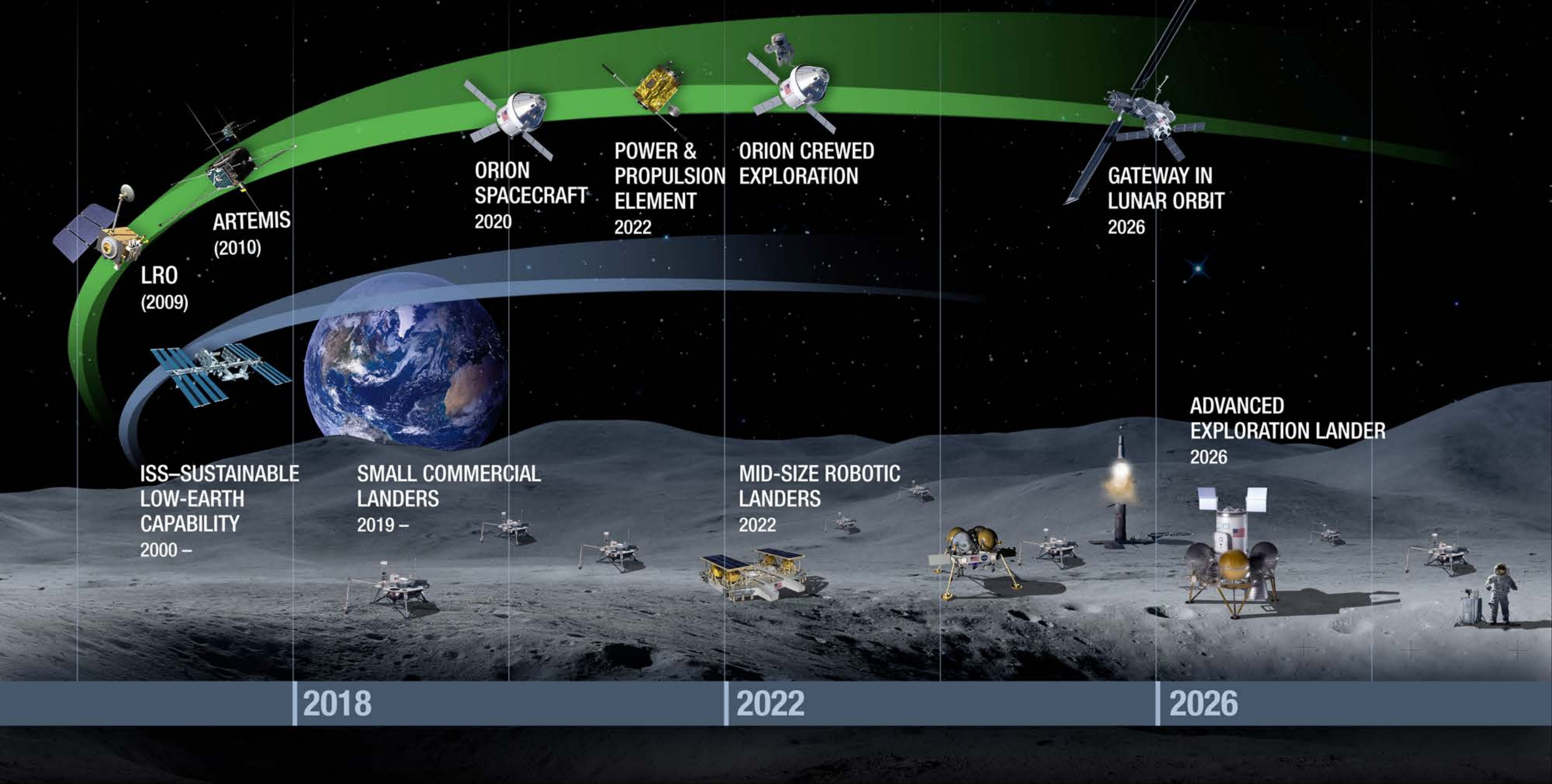
- 4 Crew Members
- 30-90 Day Crew Missions
- 125 m^3 Pressurized Volume
- Up to 75mt with Orion docked

ACCESS

384,000 km from Earth

Accessible via NASA's SLS as well as international and commercial ships.

Path To Lunar Surface



Questions?