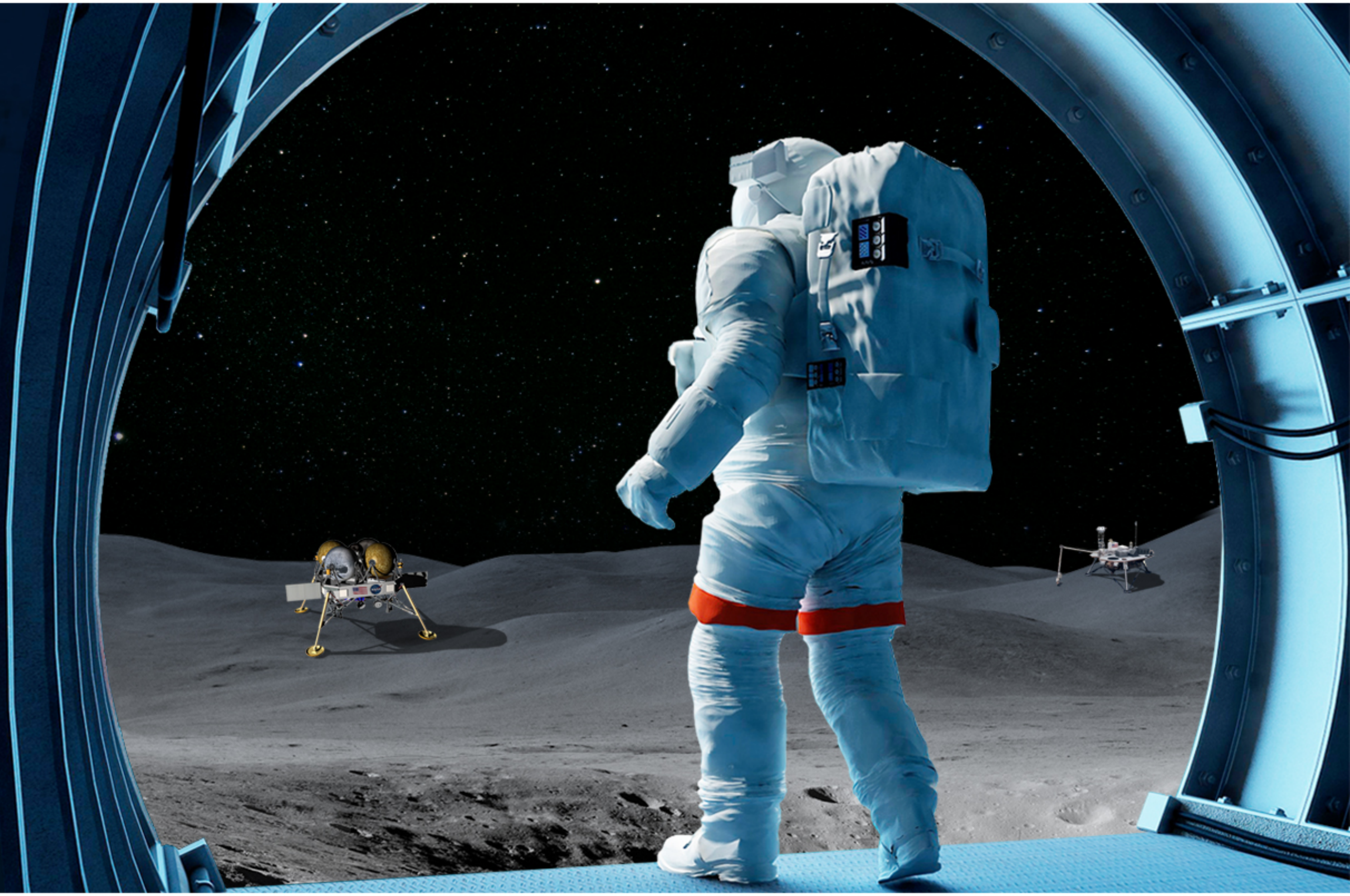
Human Exploration & Operations Overview

National Aeronautics and Space Administration



William H. Gerstenmaier

NAC HEO Committee Public Meeting

August 27, 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."

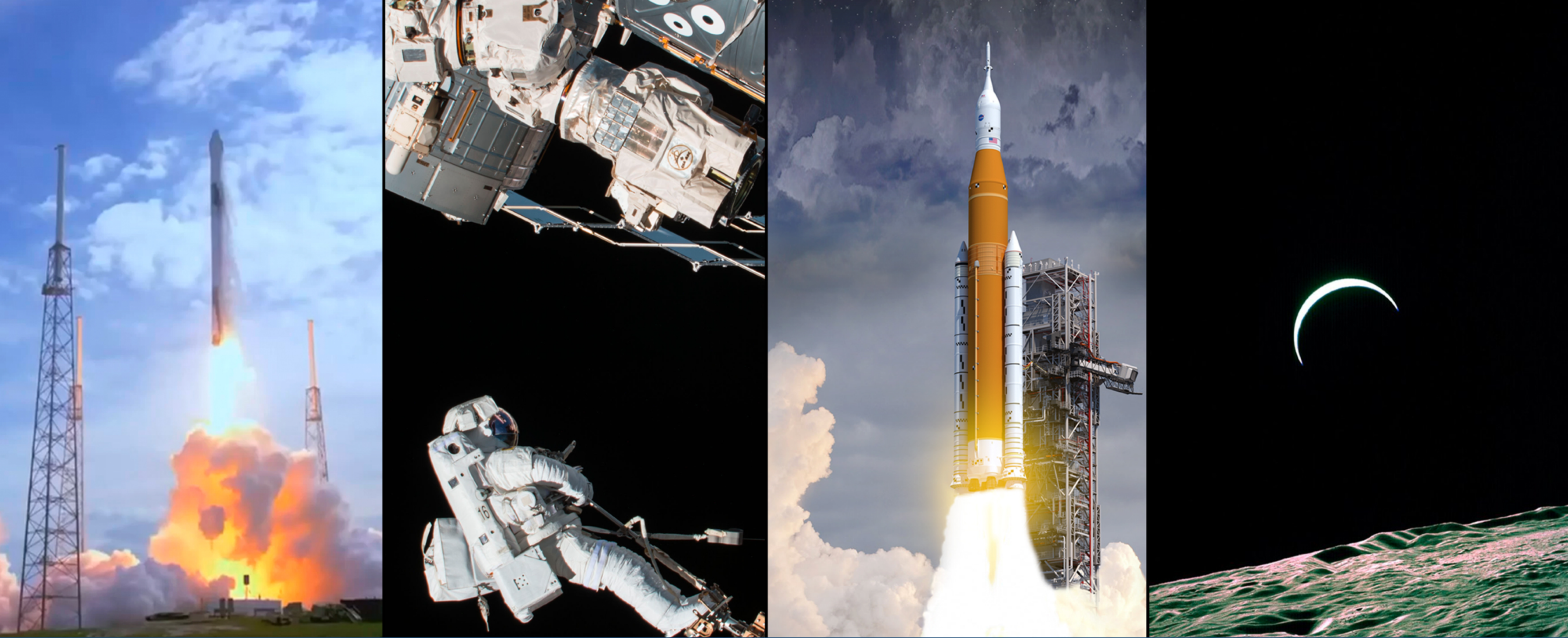
EXPLORE

ADVANCE
EXPLORATION
& SCIENCE

DEVELOP
SPACE

DEVELOP

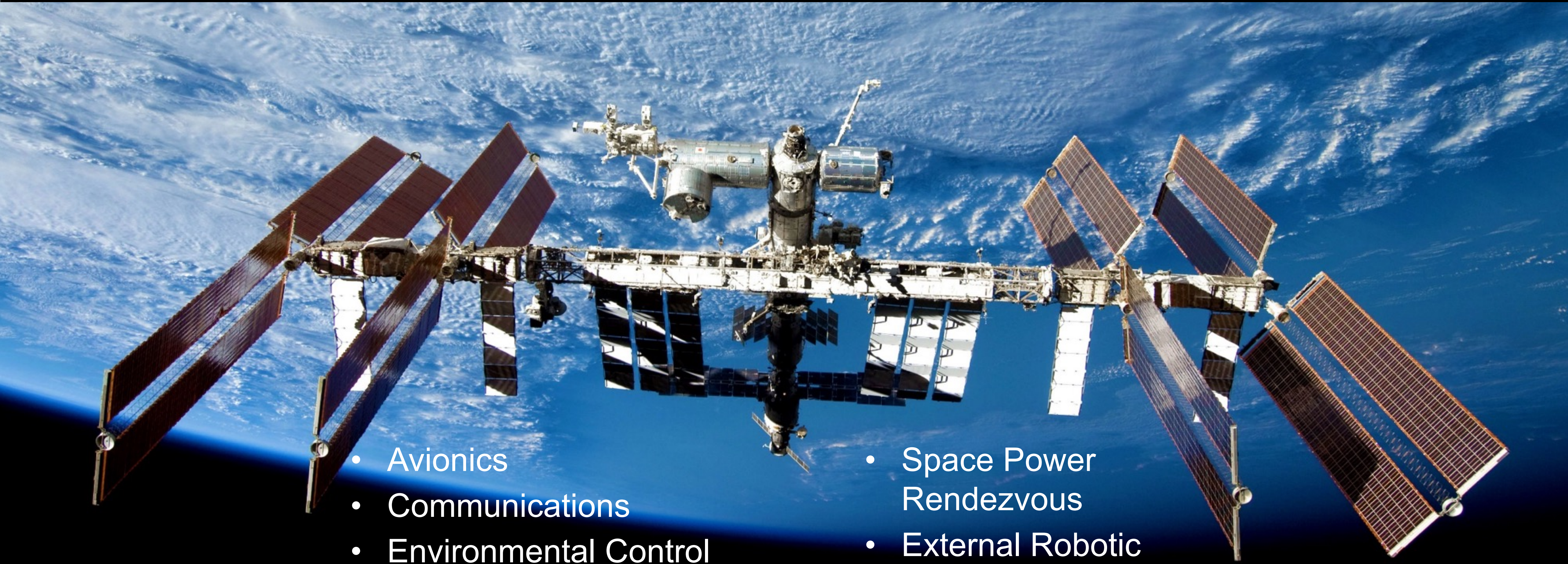
LEAD THE EXPLORATION
OF SPACE WITH
INTERNATIONAL
& PRIVATE SECTOR
PARTNERS



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



- Avionics
- Communications
- Environmental Control and Life Support System
- Interoperability
- Space Power Rendezvous
- External Robotic
- Thermal
- Docking

https://www.internationaldeepspacestandards.com

NASA's Open Architecture Develops Space

COMMERCIAL CARGO & CREW


Cygnus (Northup Grumman)


Dragon (SpaceX)


Dream Chaser (SNC)

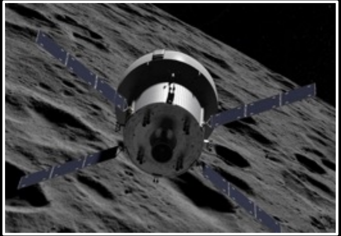

Dragon Crew (SpaceX)

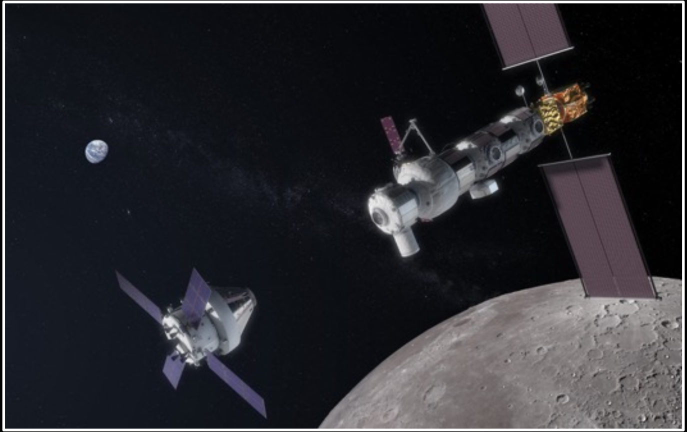
Starliner (Boeing)

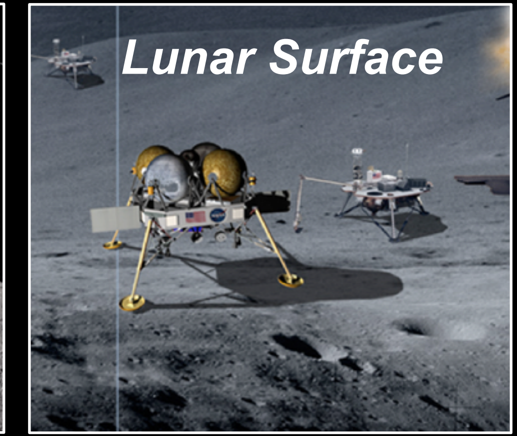
INTERNATIONAL


Soyuz & Progress (Roscosmos)


H-II Transfer Vehicle (JAXA)

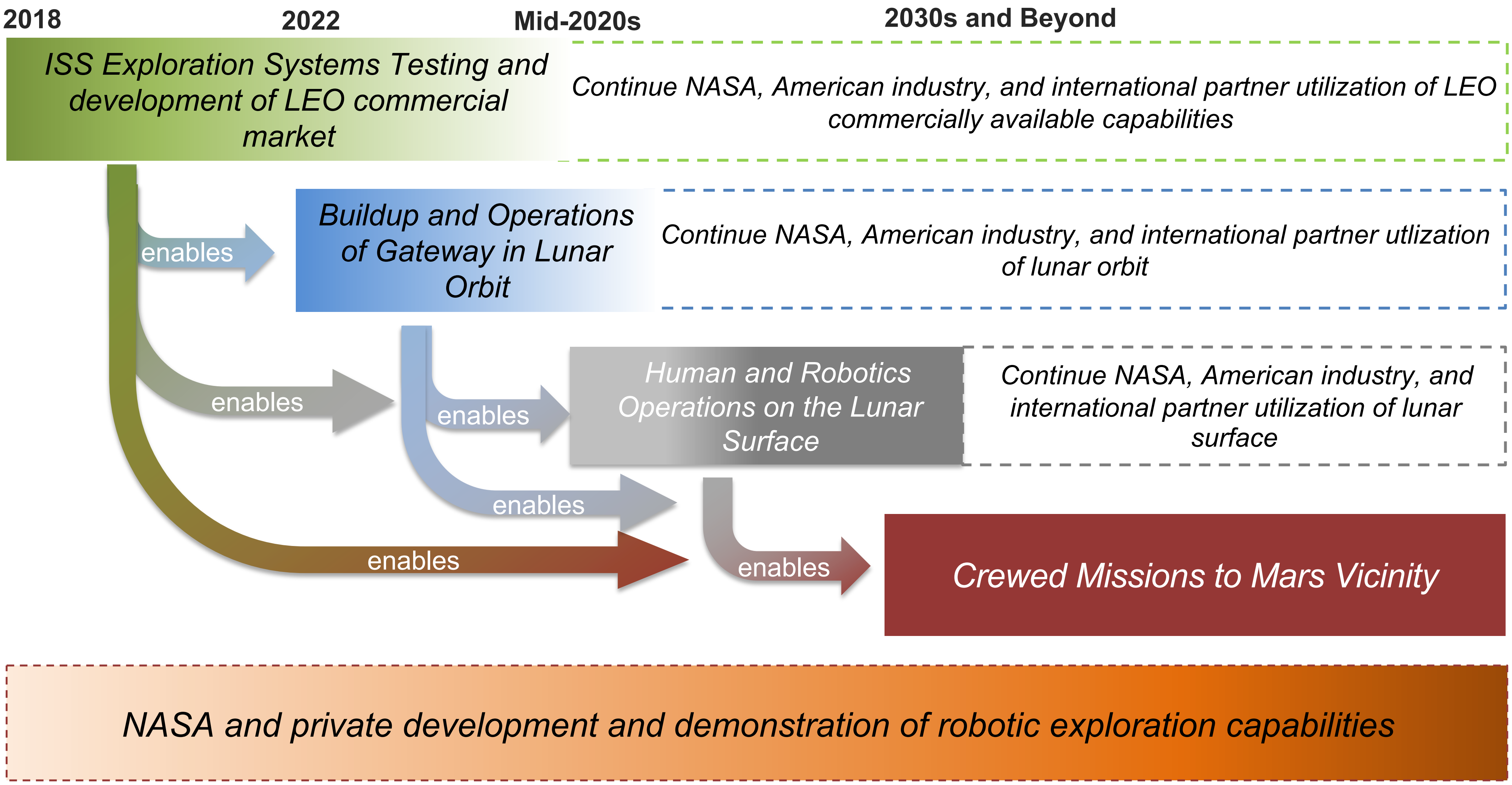

Orion/European Service Module (ESA)





Multiple providers expected in lunar orbit and on the surface

Sustaining Leadership Through The Buildup of Mutually-enabling Exploration Capabilities



Designing for Deep Space

A kilogram of mass delivered here	Adds this much initial architecture mass in LEO
LEO to Lunar Orbit	4.3 KG
LEO to Lunar Surface	7.5 KG
LEO to Lunar Orbit to Earth Surface	9.0 KG
Lunar Surface to Earth Surface	12.0 KG
LEO to Lunar Surface to Lunar Orbit	14.7 KG
LEO to Lunar Surface to Earth Surface	19.4 KG

LOW EARTH ORBIT

LUNAR ORBIT

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

Today (Space Station):
- ~50% O_2 Recovery from CO_2
- 90% H_2O Recovery
- < 6 mo mean time before failure (for some components)

Future (Deep Space):
- 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

Today (Space Station):
- Limited, crew-intensive on-board capability
- Reliance on sample return to Earth for analysis

Future (Deep Space):
- 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

Today (Space Station):
- Bulky fitness equipment
- Limited medical capability
- Frequent food system resupply

Future (Deep Space):
- 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

Today (Space Station):
- 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

Future (Deep Space):
- 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

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	FUTURE Deep Space
Node 2 crew quarters (CQ) with polyethylene reduce impacts of proton irradiation.	Solar particle event storm shelter, optimized position of on-board materials and CQ
Large multi-layer detectors & small pixel detectors – real-time dosimetry, environment monitoring, tracking, model validation & verification	Small distributed pixel detector systems – real-time dosimetry, environment monitoring, and tracking
Bulky gas-based detectors – real-time dosimetry	Small actively read-out detectors for crew – real-time dosimetry
Small solid-state crystal detectors – passive dosimetry (analyzed post-mission)	

FIRE SAFETY

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

Detection · Protection · Suppression · Cleanup

TODAY Space Station	FUTURE Deep Space
Large CO_2 Suppressant Tanks	Water Mist portable fire extinguisher
2-cartridge mask	Single Cartridge Mask
Obsolete combustion prod. sensor	Exploration combustion product monitor
Only depress/repress clean-up	Smoke eater

LOGISTICS

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

Tracking · Clothing · Packaging · Trash

TODAY Space Station	FUTURE Deep Space
Manual scans, displaced items	Automatic, autonomous RFID
Disposable cotton clothing	Long-wear clothing/laundry
Packaging disposed	Bags/foam repurposed w/3D printer
Bag and discard	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

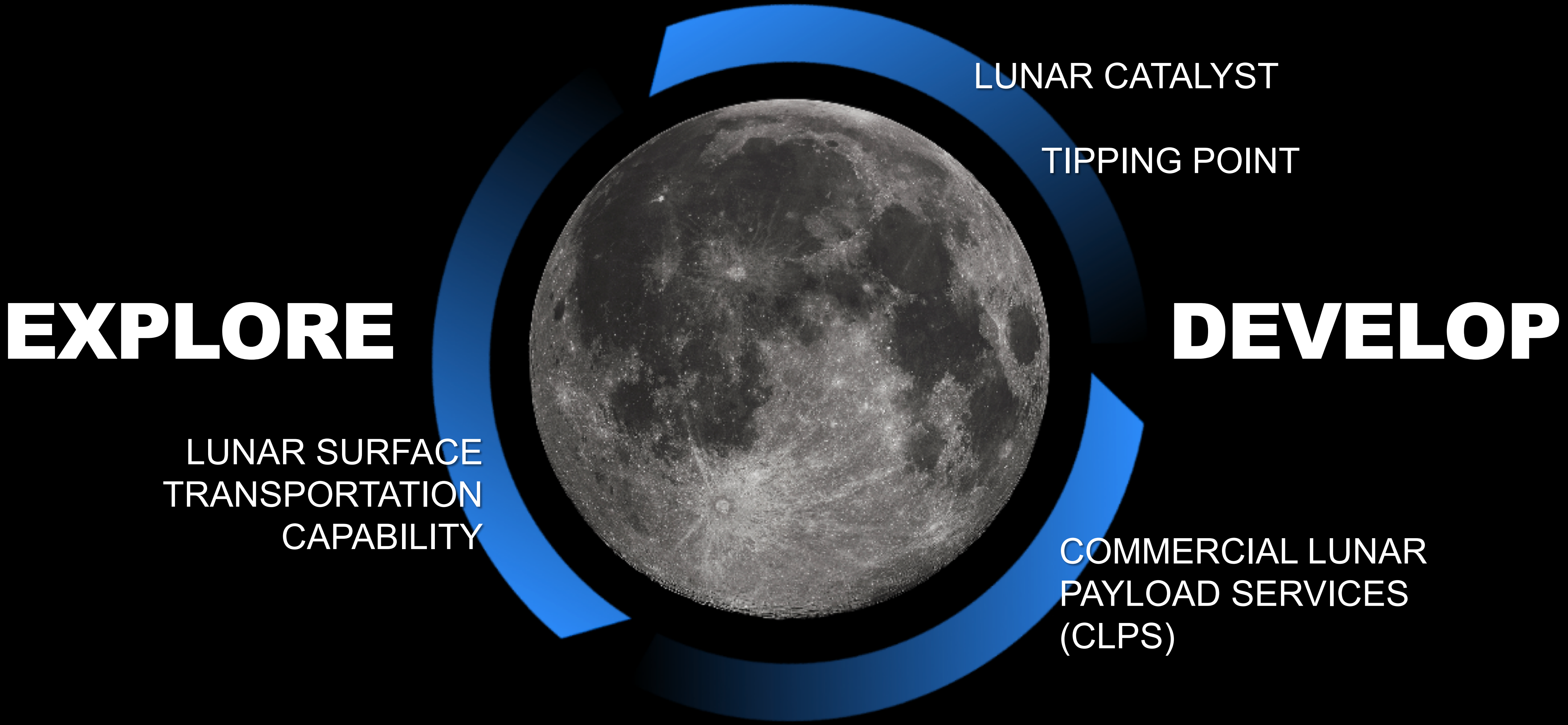
TODAY Space Station	FUTURE Deep Space
Minimal on-board autonomy	Ops independent of Earth & crew
Near-continuous ground-crew communications	Up to 40-minute comm delay
Some common interfaces, modules controlled separately	Widespread common interfaces, modules/systems integrated
	Manufacture replacement 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

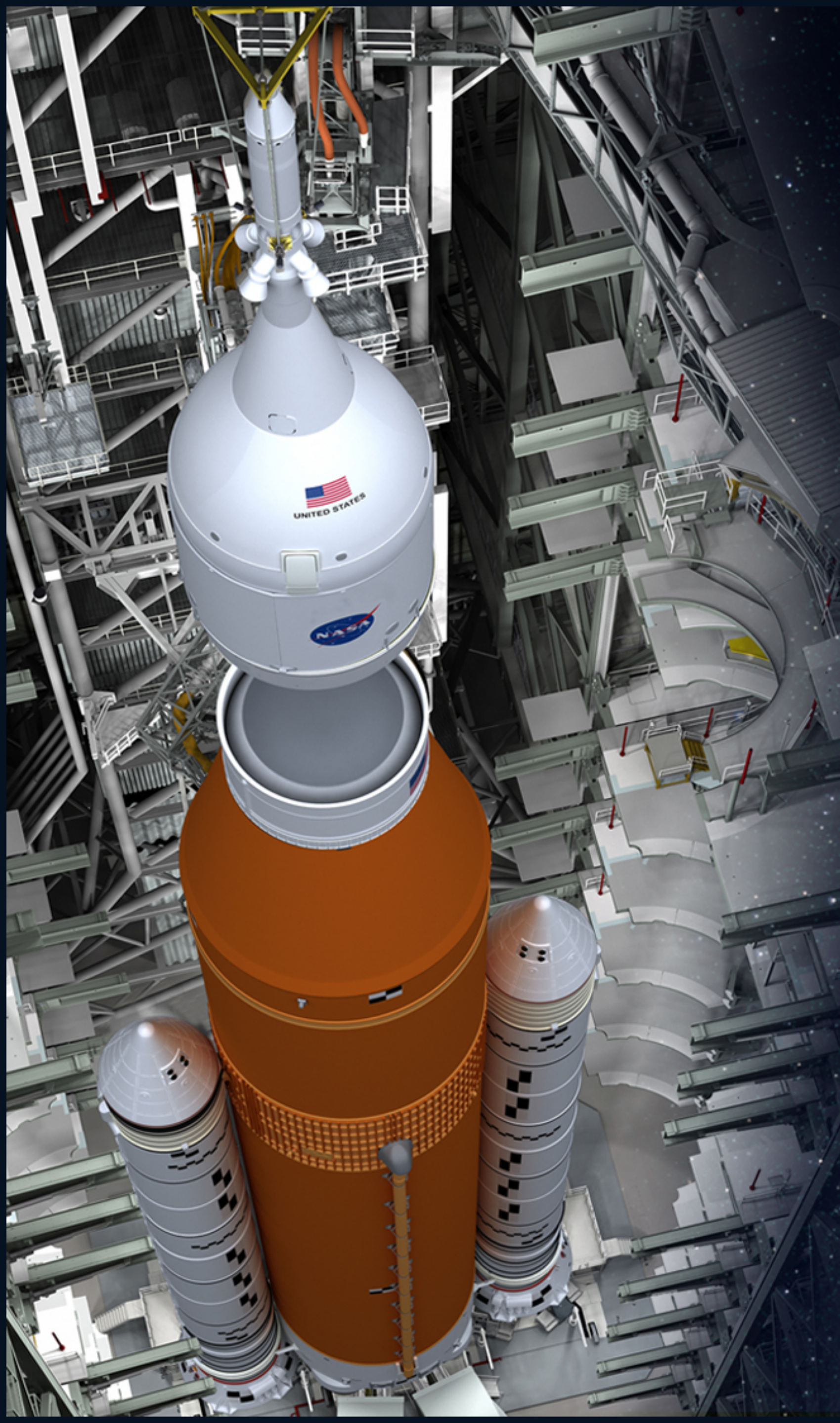
Commercial Crew – Boeing Starliner

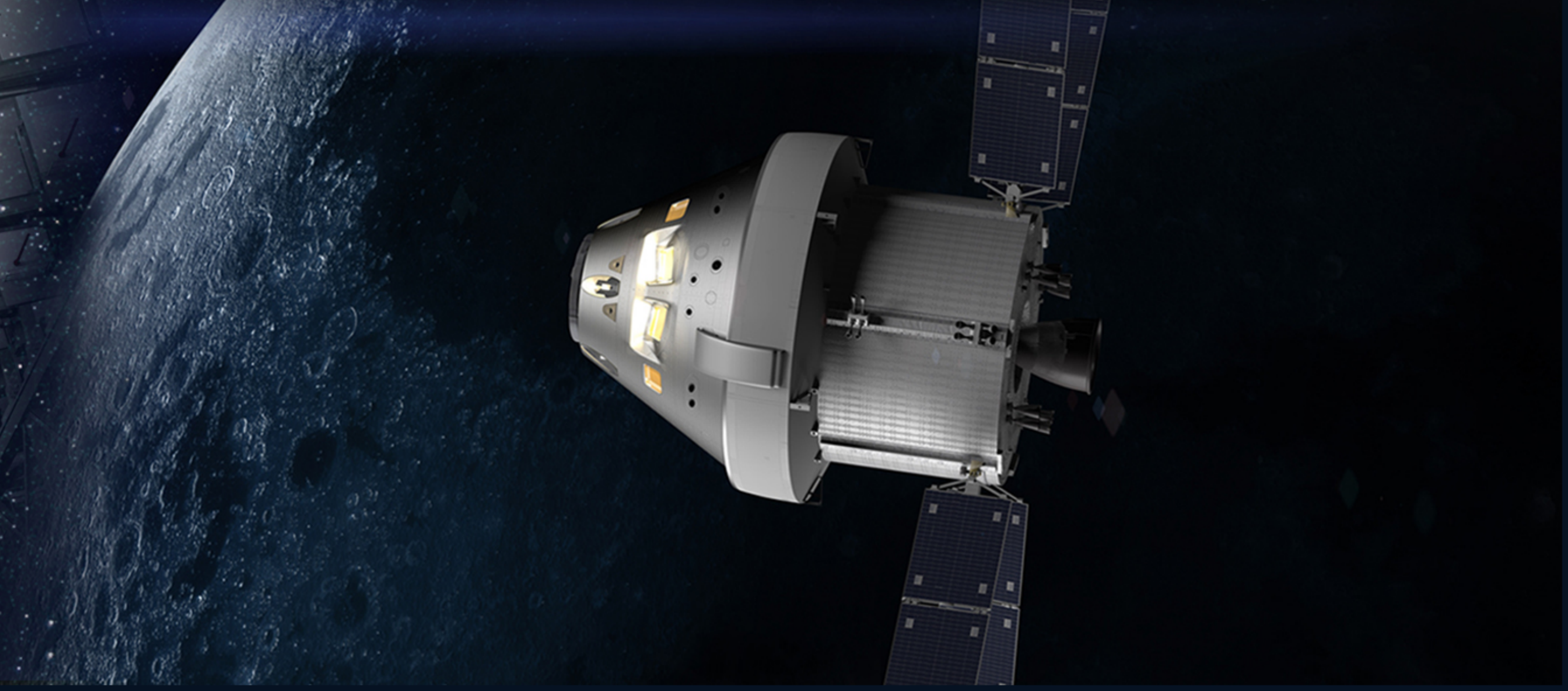
Commercial Crew – SpaceX Dragon


EXPLORE
DEVELOP
LUNAR CATALYST
TIPPING POINT
LUNAR SURFACE
TRANSPORTATION
CAPABILITY
COMMERCIAL LUNAR
PAYLOAD SERVICES
(CLPS)

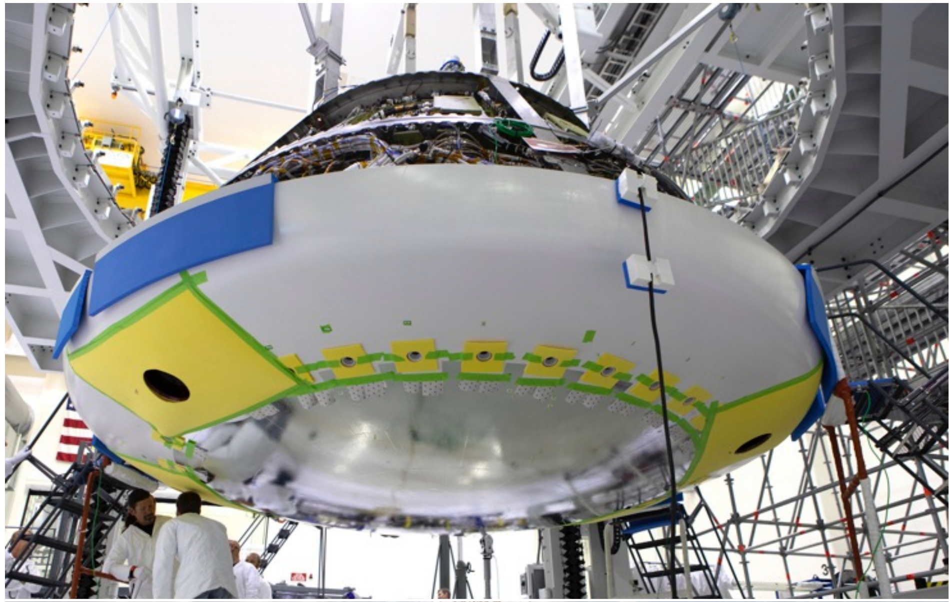
Deep Space Exploration System

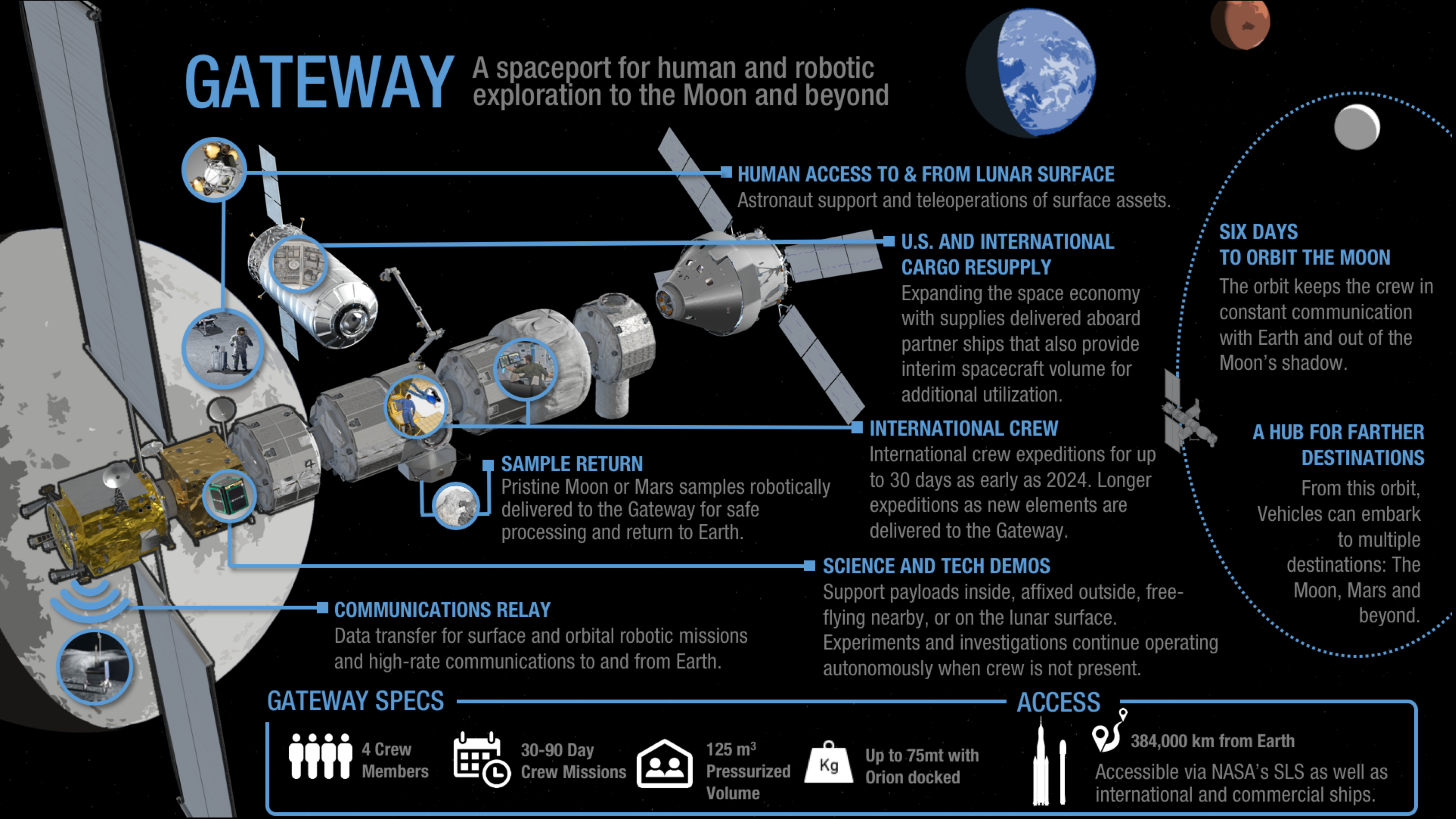
NASA's Deep Space Exploration System, including SLS, Orion, and modernized ground support facilities at Kennedy Space Center, is an asset that belongs to the American people. It is foundational to extending human presence into the solar system.



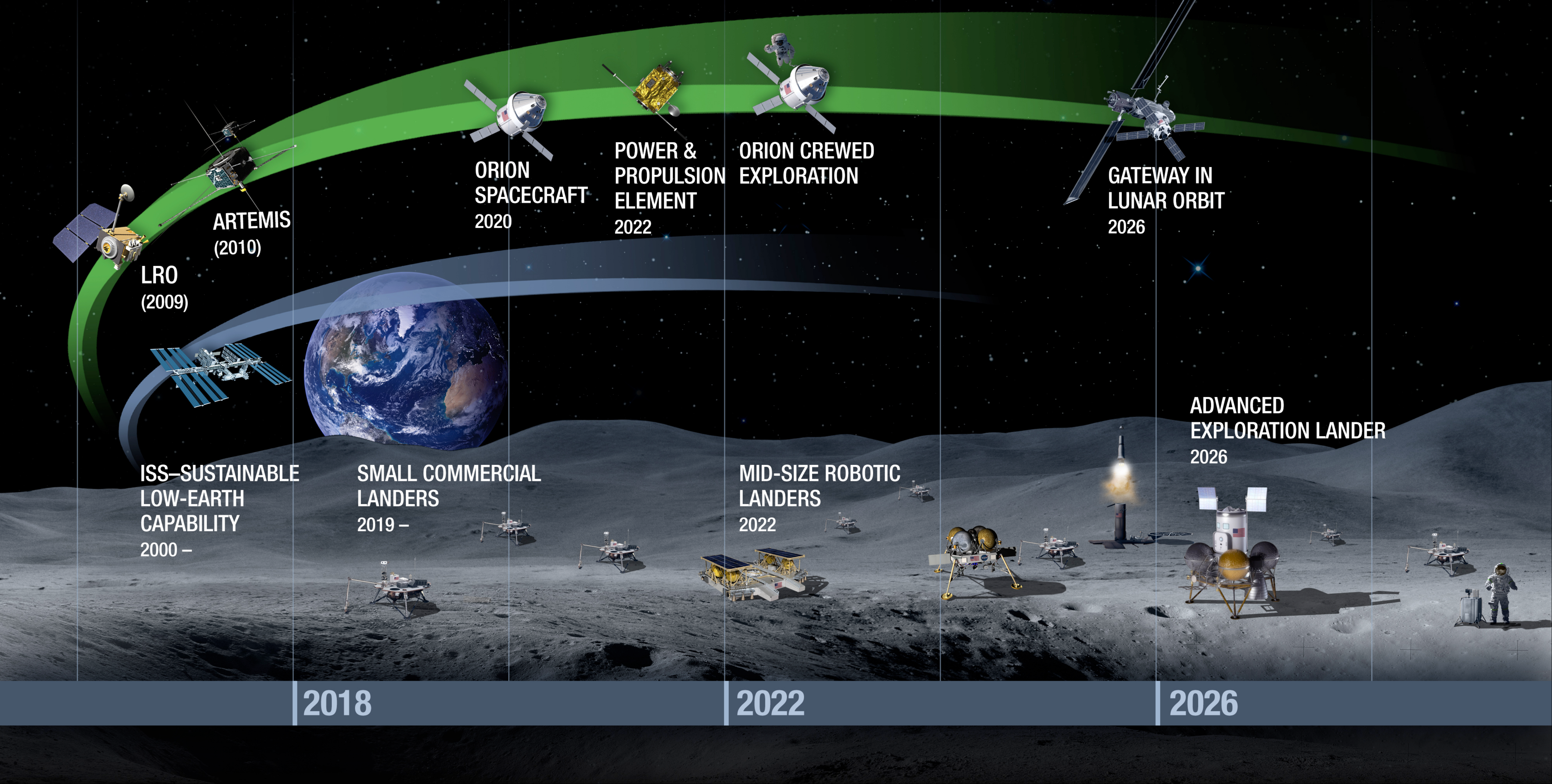


Deep Space Exploration System

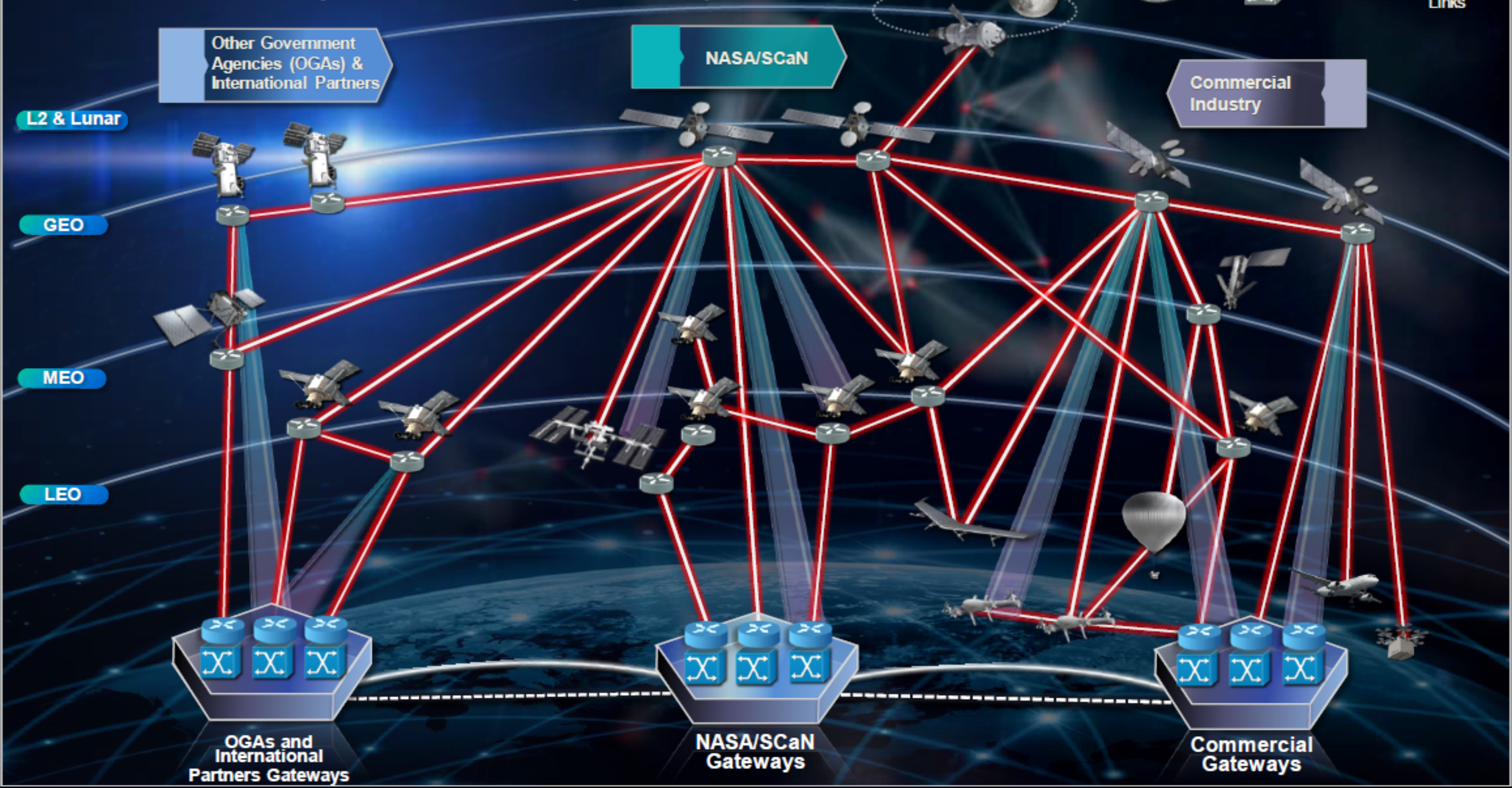



GATEWAY
A spaceport for human and robotic exploration to the Moon and beyond
HUMAN ACCESS TO & FROM LUNAR SURFACE
Astronaut support and teleoperations of surface assets.
U.S. AND INTERNATIONAL CARGO RESUPPLY
Expanding the space economy with supplies delivered aboard partner ships that also provide interim 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 m³ Pressurized Volume
Kg
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



Our Vision Fully Connected Interoperable Space Assets



Technology Development & Demonstration Timeline

Technology

2019 | 2019-2021 | 2022

Demonstrations

2019 | 2019 | 2021 | 2022

200 Gbps Demo

- 100 Gbps user terminal and 100 Gbps low cost ground station
- Space technologies based on commercial off the shelf (COTS) products
- CubeSat-sized, low size, weight and power (SWAP) user terminal, user-site installable ground station

LCRD Optical Relay Demo

- 1.244 Gbps optical relay two ground stations (2019)
- Routing of optical signals in a hybrid environment (RF/optical)

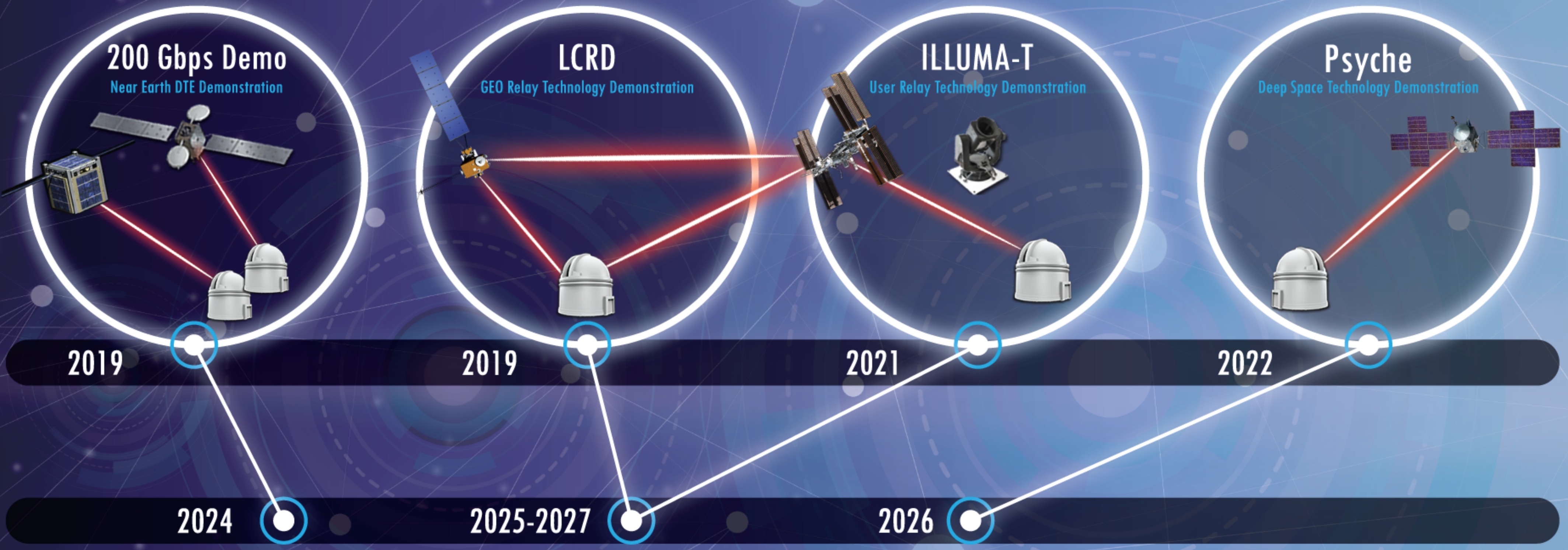
ILLUMA-T User Relay

- 1.244 Gpbs user terminal
- LEO satellite acquisition and tracking in a GEO relay system-(LCRD)
- Space Station ⟷ LCRD ⟷ Earth

Discovery Psyche Demo

- Space user terminal 125 Mbps at 40 Mkm range
- 5-meter optical ground station
- Deep space optical link

Operational Timeline



Near Earth DTE Operational Services

Initially two SCaN operated ground stations; other added incrementally

- Scheduling
- Ground data buffering and routing
- Cognitive algorithms

Relay Operational Services

Reuses LCRD and adds two more GEO relay node to the network

- Based on LCRD design
- Augments near earth DTE network
- Cognitive networking in operations

Deep Space Operational Services

Adds deep space class terminals to the architecture

- Based on first generation terminals
- Ready to support missions starting in 2026

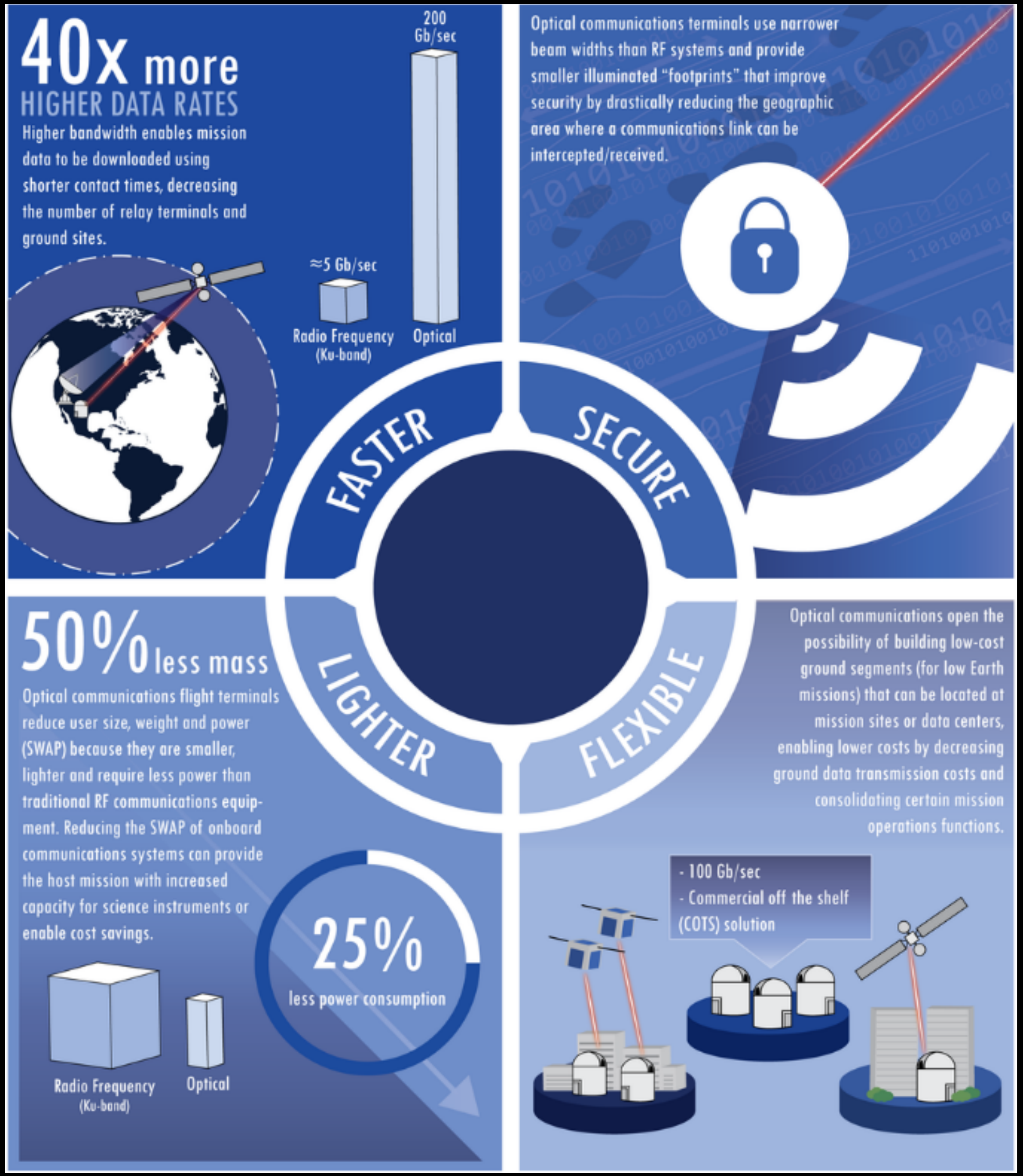
Optical Communications Benefits

Faster: Higher data rates can enable increased data volume for missions that have been able to generate far more data than they could downlink, or enable new "high definition" instruments that collect larger volumes of data. *It's not that the data is traveling faster with optical communications compared to radio communications. Instead, higher data rate links will enable mission data to be downloaded using shorter contact times, resulting in the use of less onboard spacecraft power and requiring fewer relay terminals and ground sites to support missions. Therefore, the process is sped up.*

Secure: Optical communications terminals use narrower beam widths than radio frequency (RF) systems. They provide smaller illuminated "footprints" that improve security by drastically reducing the geographic area where a communications link can be intercepted/received.

Lighter: Optical communications flight terminals reduce user Size, Weight, and Power (SWAP) because they are smaller, lighter and require less power than traditional RF communications equipment. Reducing the SWAP of onboard communications systems can provide the host mission with increased capacity for science instruments or enable cost savings.

Flexible: Optical communications open the possibility of building low-cost ground segments (for low Earth missions) that can be located at mission sites or data centers, enabling lower costs by decreasing ground data transmission costs and consolidating certain mission operations functions



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Questions?