Lunar Communications in 21st Century

ANTONIO ABAD

CTO

October 2022

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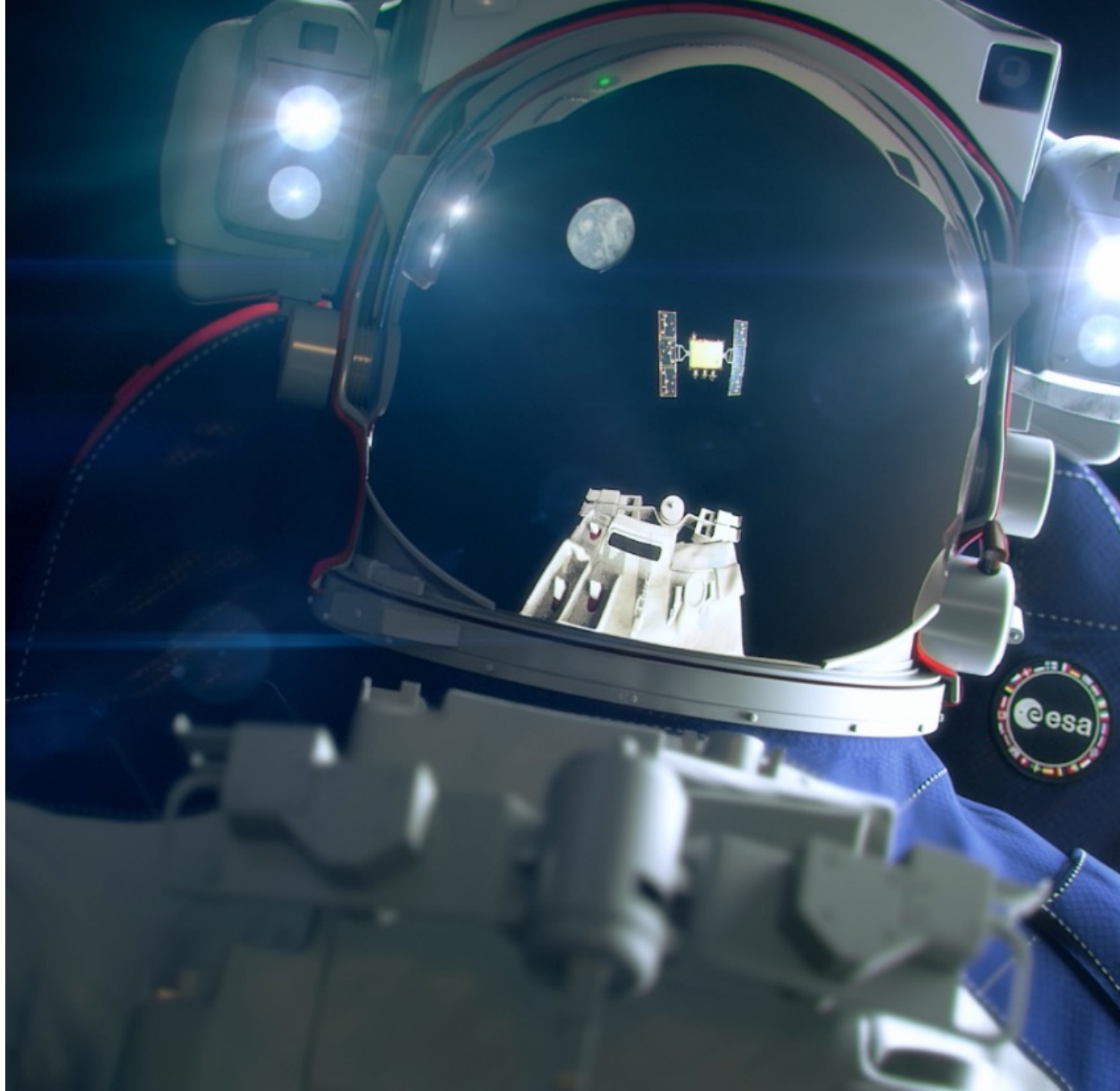
A Redeia company



THE MOON

EARTH SATELLITE

MEAN RADIUS: 1.737 KM

SURFACE GRAVITY: 1,62 M/S^2

ORBITAL PERIOD: 27,3 DAYS

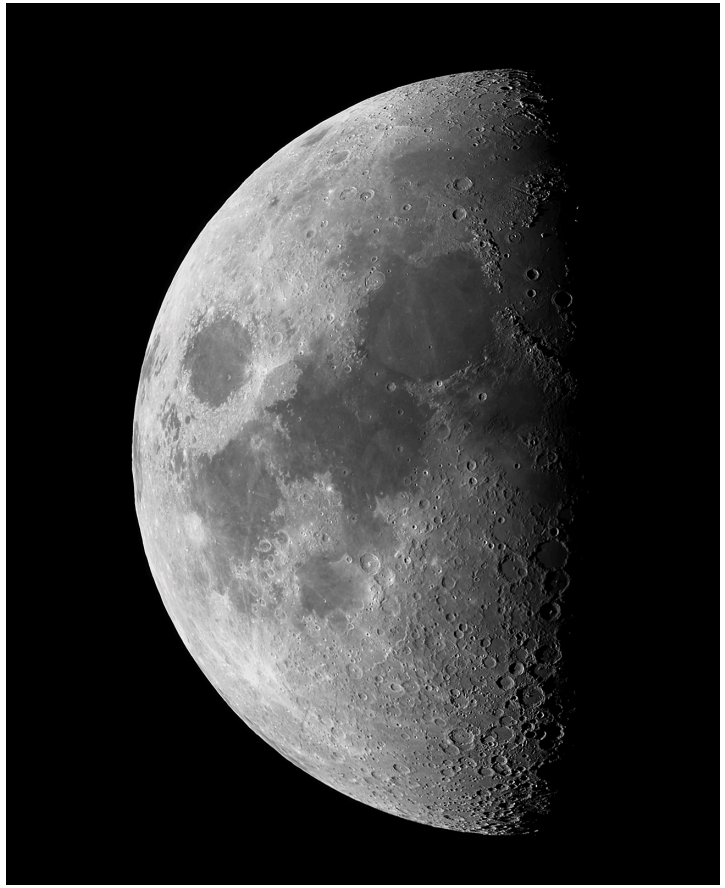
AVG. DISTANCE TO EARTH: 384.400 KM

MOONWALKERS: 12 (1969-1972)

HUMAN VISITORS: 24 (1968-1972)

ROBOTIC VISITS: 100+

LUNAR MISSIONS: 1959-today



WHY DID THE U.S. STOPPED GOING TO THE MOON?

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Vietnam War

WHY DID THE U.S. STOPPED GOING TO THE MOON?

Operating at the Edge of Capabilities

$30 Billions Cost

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Presidential Memorandum on 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."

—Excerpt, Space Policy Directive-1, December 11, 2017

In March 2019, the White House directed NASA to accelerate its plans to **return humans to the moon by 2024**

…4 years earlier than NASA had planned.

WHY DO WE WANT TO GET BACK TO THE MOON?

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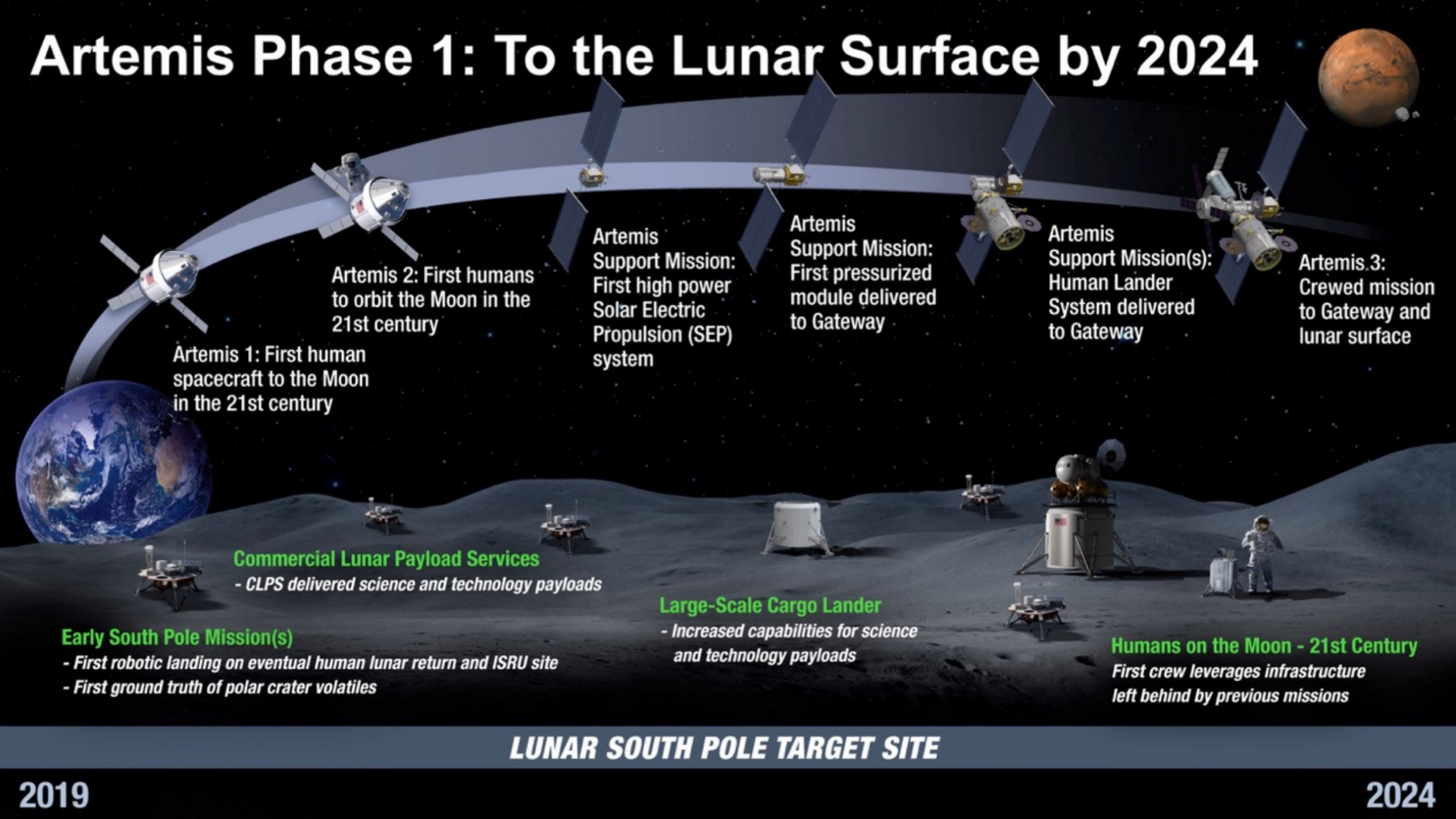
Live and work off world
Gateway to Mars and beyond
WHY DO WE WANT TO GET BACK TO THE MOON?
Scientific discoveries about our origins
International Cooperation in space
Expand activity & economy beyond Earth

WHAT DO WE EXPECT TO ACHIEVE?


Live and work in the Moon
Identify potential resources
Moon as sustained platform for science
Create commercial opportunities
International partnerships in space
Enable exploration to Mars
WHAT DO WE EXPECT TO ACHIEVE?

Artemis Phase 1: To the Lunar Surface by 2024



LUNAR SOUTH POLE TARGET SITE

2019 2024

ARTEMIS I

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport

1 LAUNCH
SLS and Orion lift off from pad 39B at Kennedy Space Center

2 JETTISON ROCKET BOOSTERS
Solid rocket boosters separate

3 JETTISON LAUNCH ABORT SYSTEM (LAS)
The LAS is no longer needed, Orion could safely abort

4 CORE STAGE MAIN ENGINE CUT OFF (MECO) and separation

5 ENTER EARTH ORBIT
Perform the perigee raise maneuver

6 EARTH ORBIT
Systems check and solar panel adjustments

7 TRANS LUNAR INJECTION (TLI) BURN
Burn lasts for approximately 20 minutes

8 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION
The ICPS has committed Orion to TLI

9 OUTBOUND TRANSIT
Requires several attitude maneuvers

10 OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS
As necessary adjust trajectory for Lunar flyby to DRO

11 OUTBOUND POWERED FLYBY (OPF)
62 miles from the Moon; targets DRO insertion

Heliocentric Disposal precludes re-contact

12 ORBIT INSERTION
Enter Distant Retrograde Orbit for next 6-23 days

13 DISTANT RETROGRADE ORBIT (DRO)
Orbit Maintenance burns and solar panel adjustments; 38,000 nmi from the surface of the Moon

14 DRO DEPARTURE
Leave DRO and start return to Earth

15 RETURN POWER FLY-BY (RPF)
RPF burn prep and return coast to Earth initiated

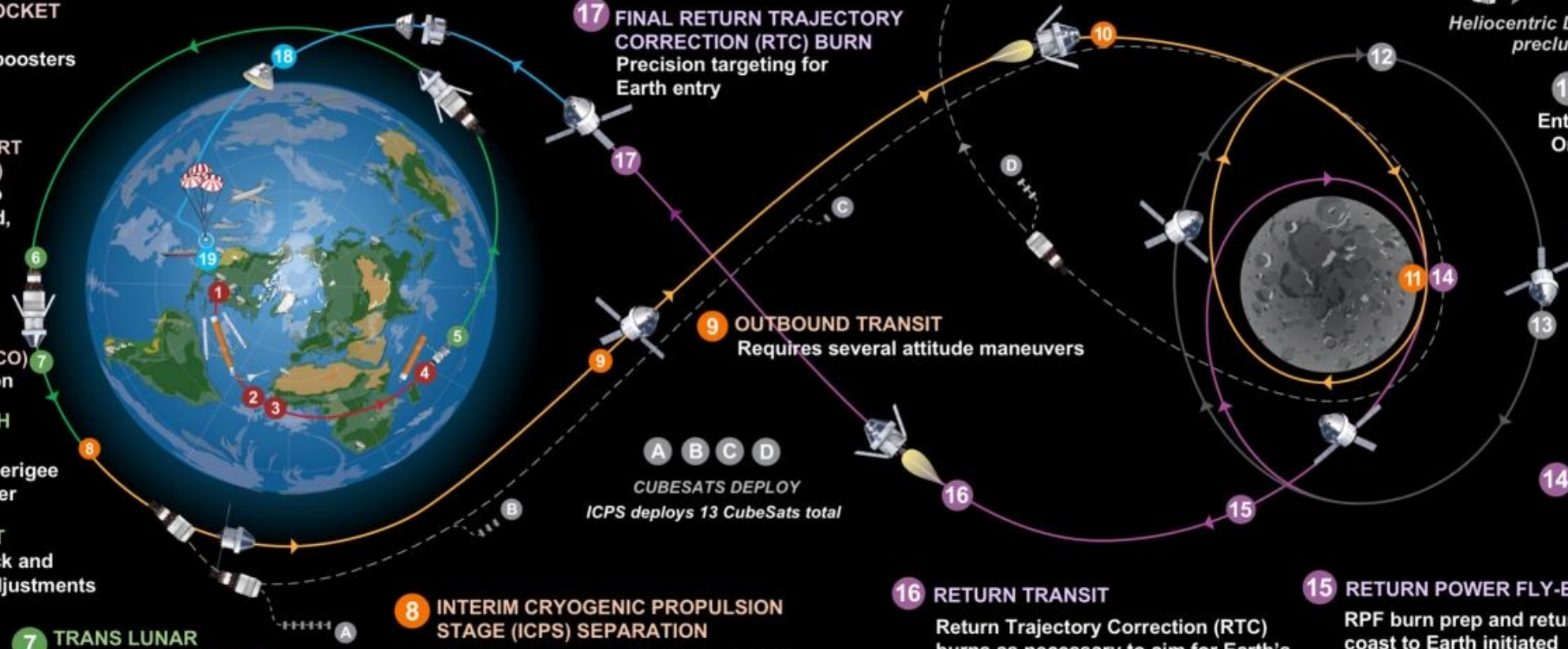
16 RETURN TRANSIT
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time 3-11 days

17 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN
Precision targeting for Earth entry

18 ENTRY INTERFACE (EI)
Enter Earth's atmosphere

19 SPLASHDOWN
Pacific Ocean landing within view of the U.S. Navy recovery ships

A B C D
CUBESATS DEPLOY
ICPS deploys 13 CubeSats total



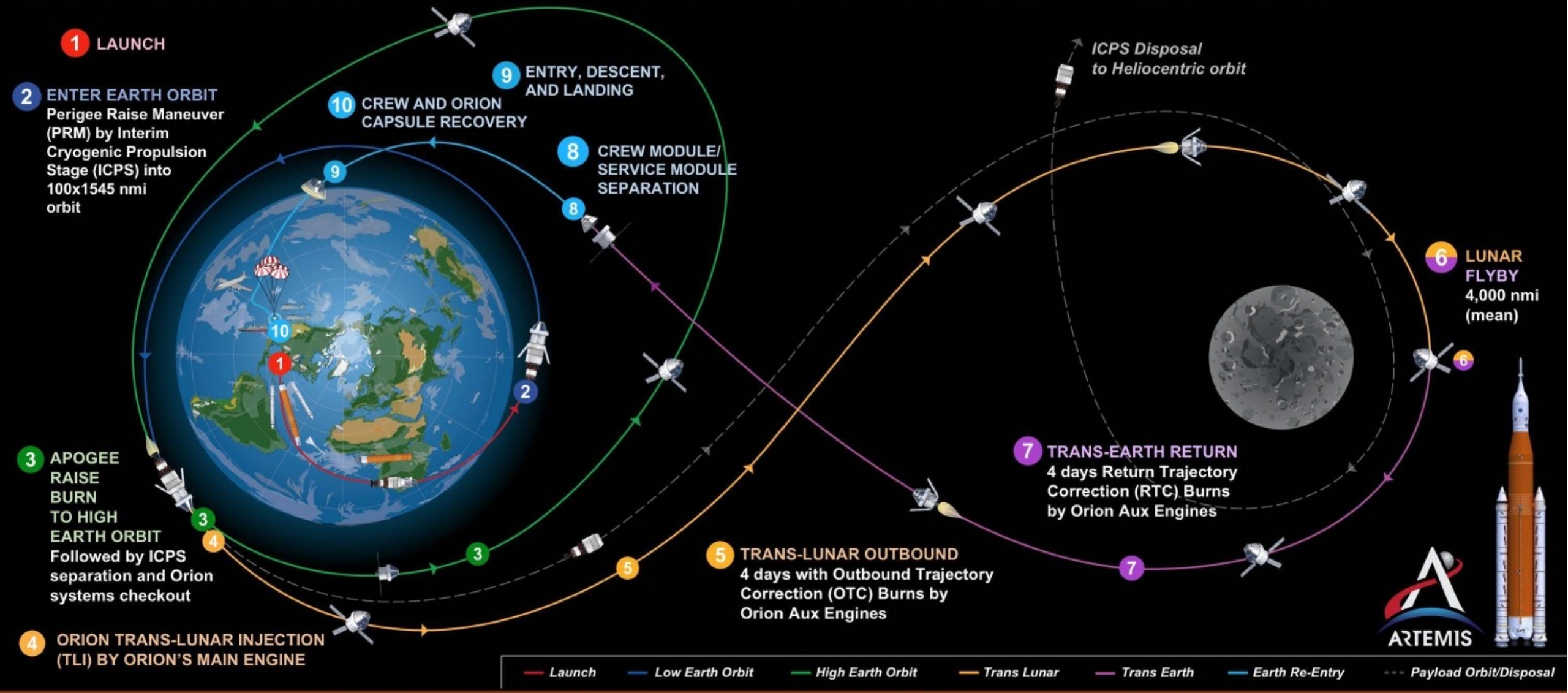
ARTEMIS

ARTEMIS I

Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

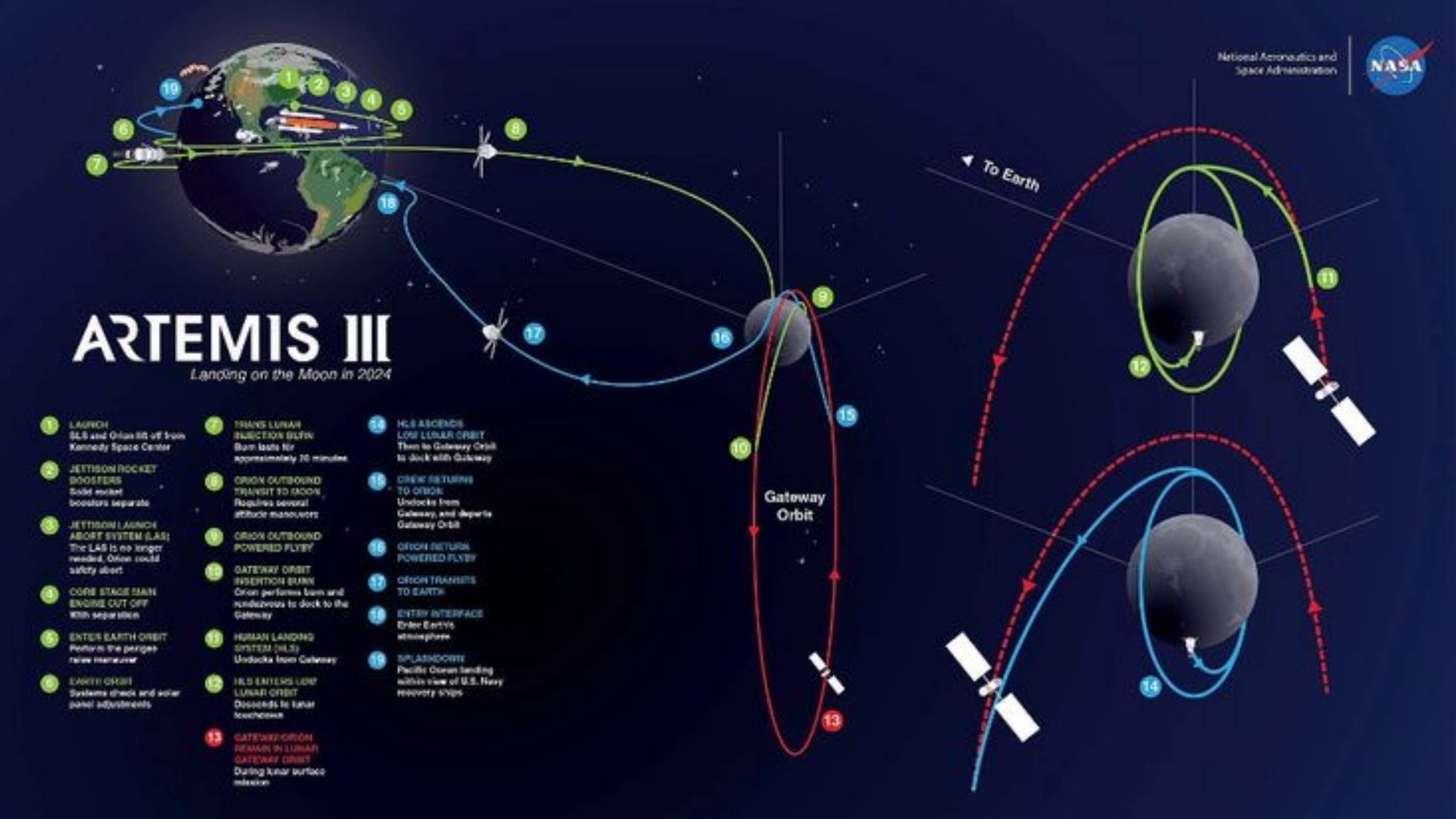
ARTEMIS II

Crewed Hybrid Free Return Trajectory, demonstrating crewed flight and spacecraft systems performance beyond Low Earth Orbit (LEO)

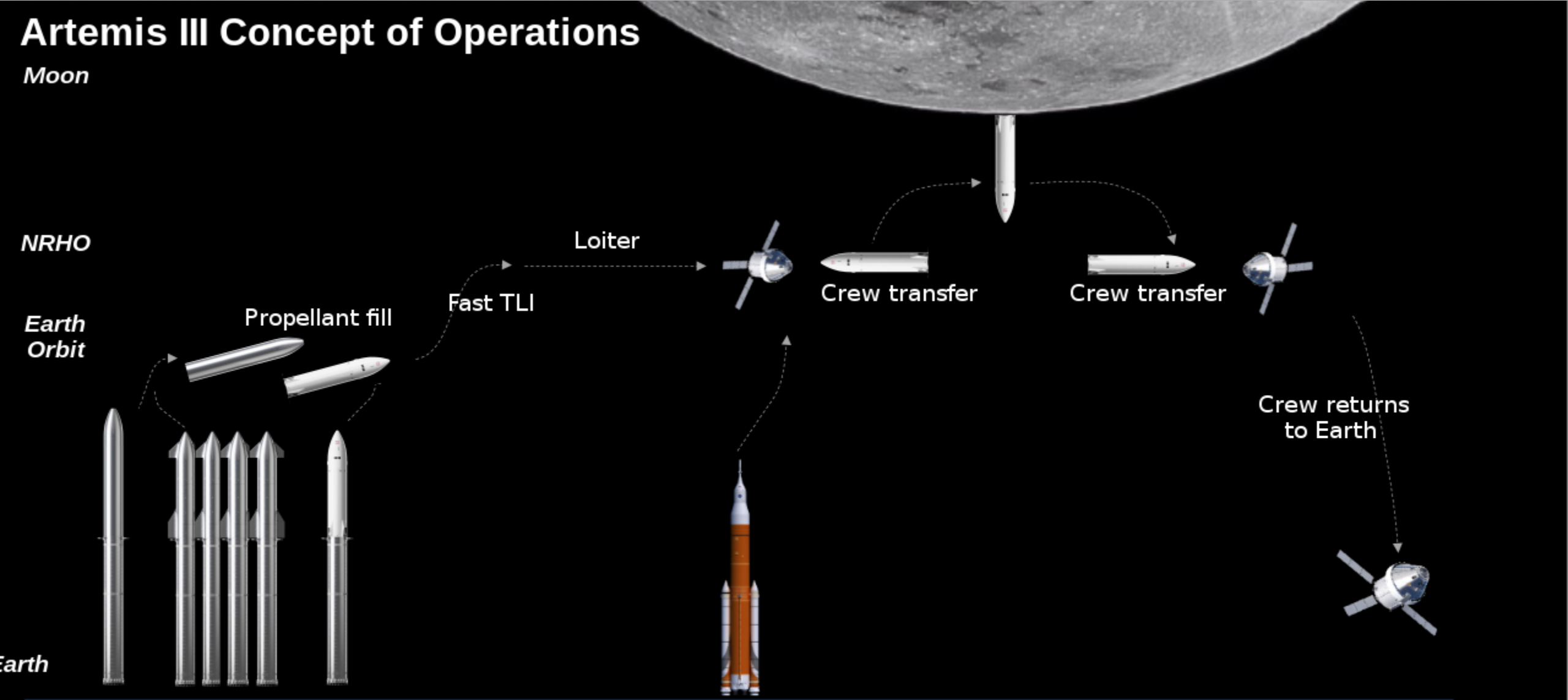


SLS Configuration (Block 1) with Human Rated ICPS | 15x1200 nmi (27.8x2222.4 km) insertion orbit | 28.5 deg inclination

4 astronauts | Mission duration: 10 Days | Re-entry speed: 24,500 mph (Mach 32)

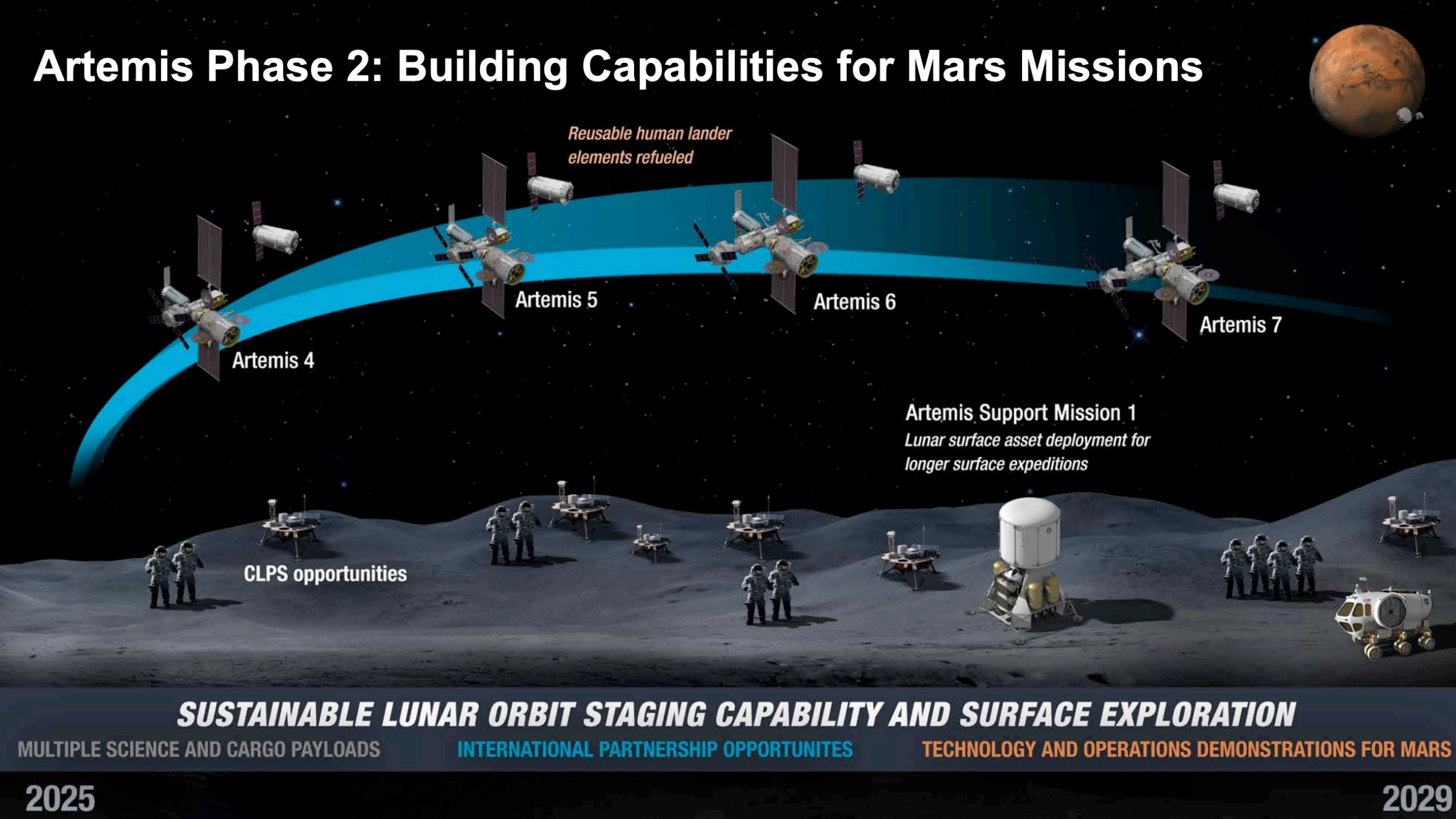

National Aeronautics and Space Administration
NASA
ARTEMIS III
Landing on the Moon in 2024
1 LAUNCH
SLS and Orion lift off from Kennedy Space Center
2 JETTISON ROCKET BOOSTERS
Solid rocket boosters separate
3 JETTISON LAUNCH ABORT SYSTEM (LAS)
The LAS is no longer needed, Orion could safely abort
4 CORE STAGE MAIN ENGINE CUT OFF
With separation
5 ENTER EARTH ORBIT
Perform the perigee raise maneuver
6 EARTH ORBIT
Systems check and solar panel adjustments
7 TRANS LUNAR INJECTION BURN
Burn lasts for approximately 30 minutes
8 ORION OUTBOUND TRANSIT TO MOON
Requires several attitude maneuvers
9 ORION OUTBOUND POWERED FLYBY
10 GATEWAY ORBIT INSERTION BURN
Orion performs burn and rendezvous to dock to the Gateway
11 HUMAN LANDING SYSTEM (HLS)
Undocks from Gateway
12 HLS ENTERS LOW LUNAR ORBIT
Descends to lunar touchdown
13 GATEWAY ORION REMAIN IN LUNAR GATEWAY ORBIT
During lunar surface mission
14 HLS ASCENDS LOW LUNAR ORBIT
Then to Gateway Orbit to dock with Gateway
15 CREW RETURNS TO ORION
Undocks from Gateway, and departs Gateway Orbit
16 ORION RETURN POWERED FLYBY
17 ORION TRANSITS TO EARTH
18 ENTRY INTERFACE
Enter Earth's atmosphere
19 SPLASHDOWN
Pacific Ocean landing within view of U.S. Navy recovery ships
To Earth
Gateway Orbit

Artemis III Concept of Operations

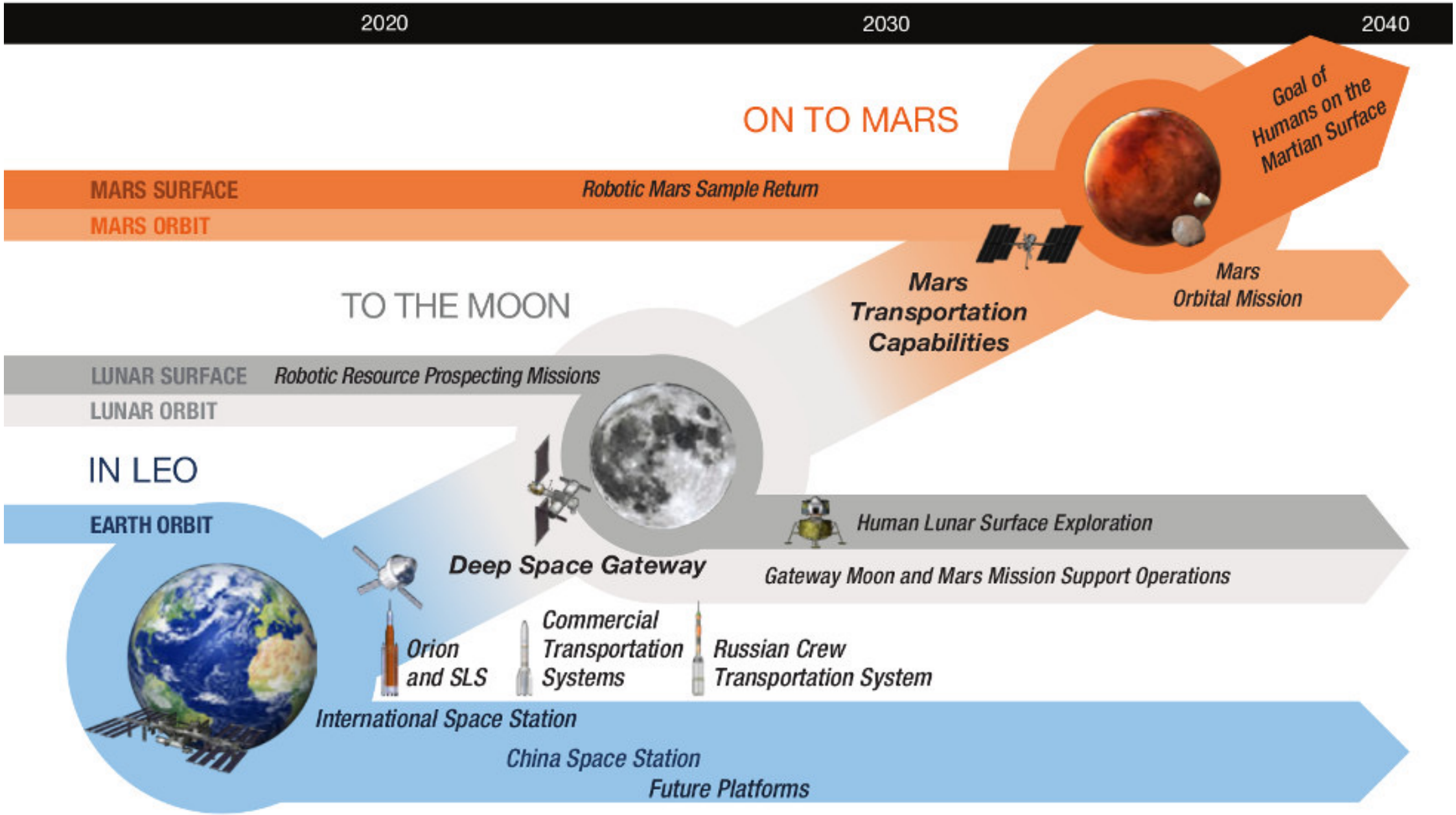


Propellant aggregation	HLS Starship launches	Extended loiter if needed	Orion launch	Variable Stay on the Moon	Crew returns to Orion

Artemis Phase 2: Building Capabilities for Mars Missions

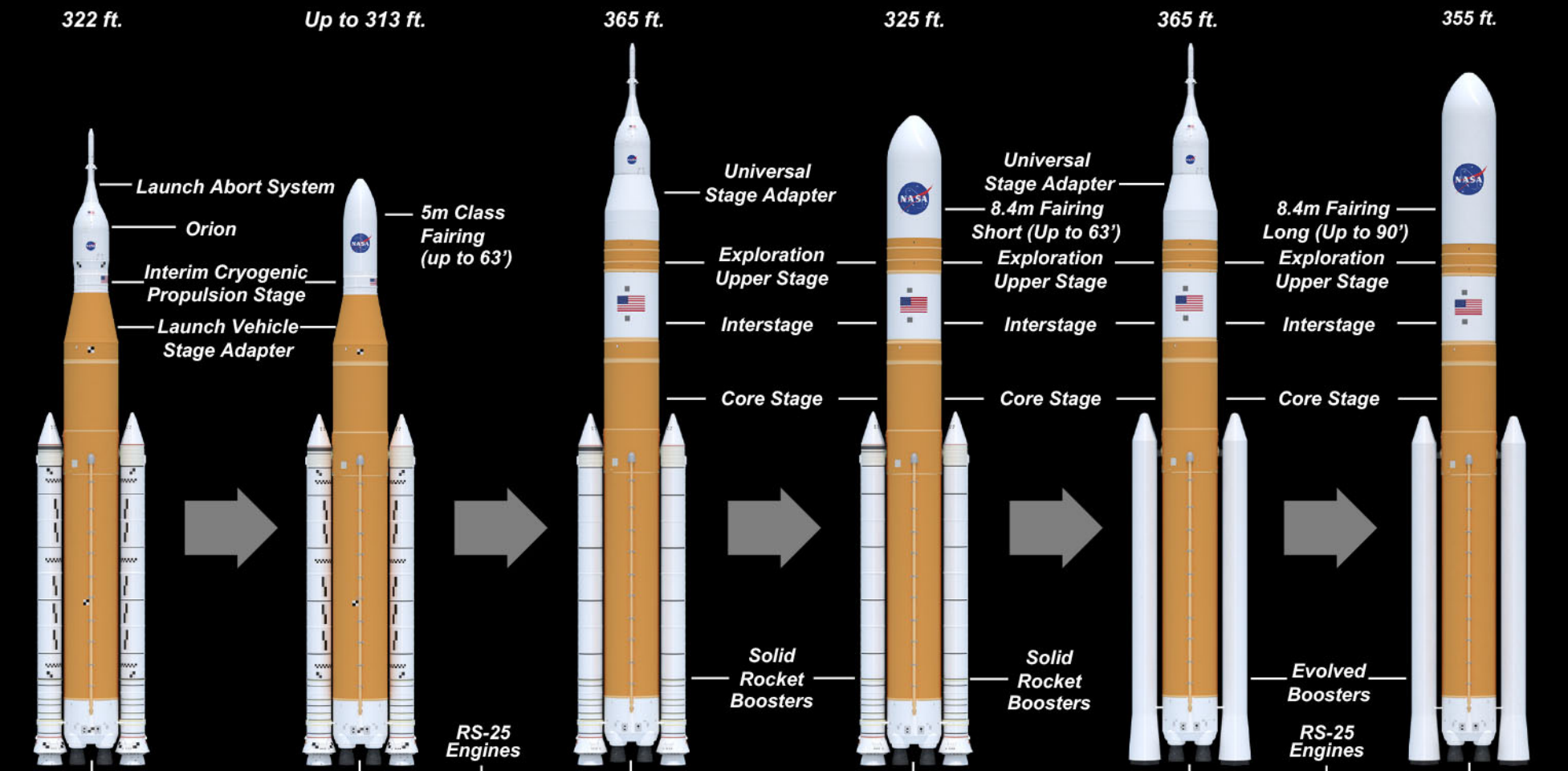


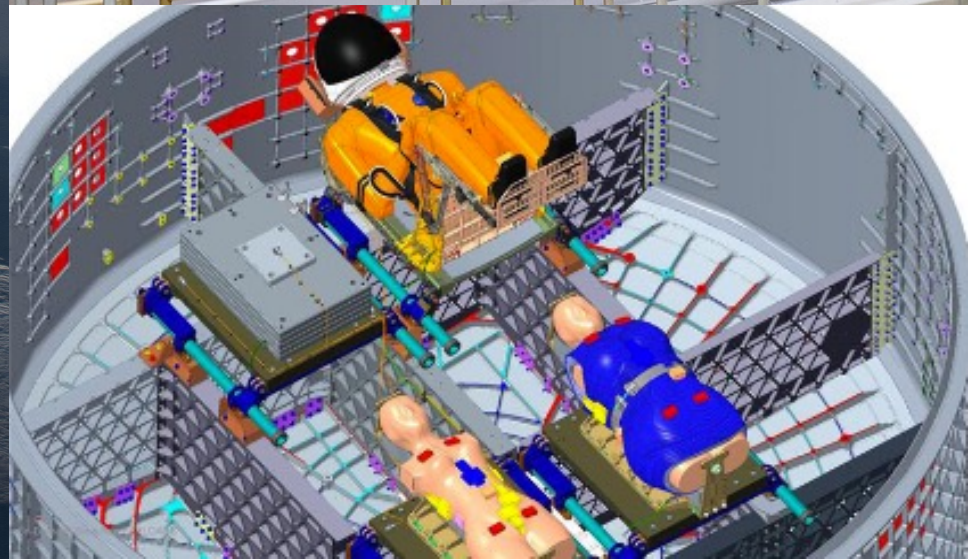
The Global Exploration Roadmap



SLS EVOLVABILITY

FOUNDATION FOR A GENERATION OF DEEP SPACE EXPLORATION

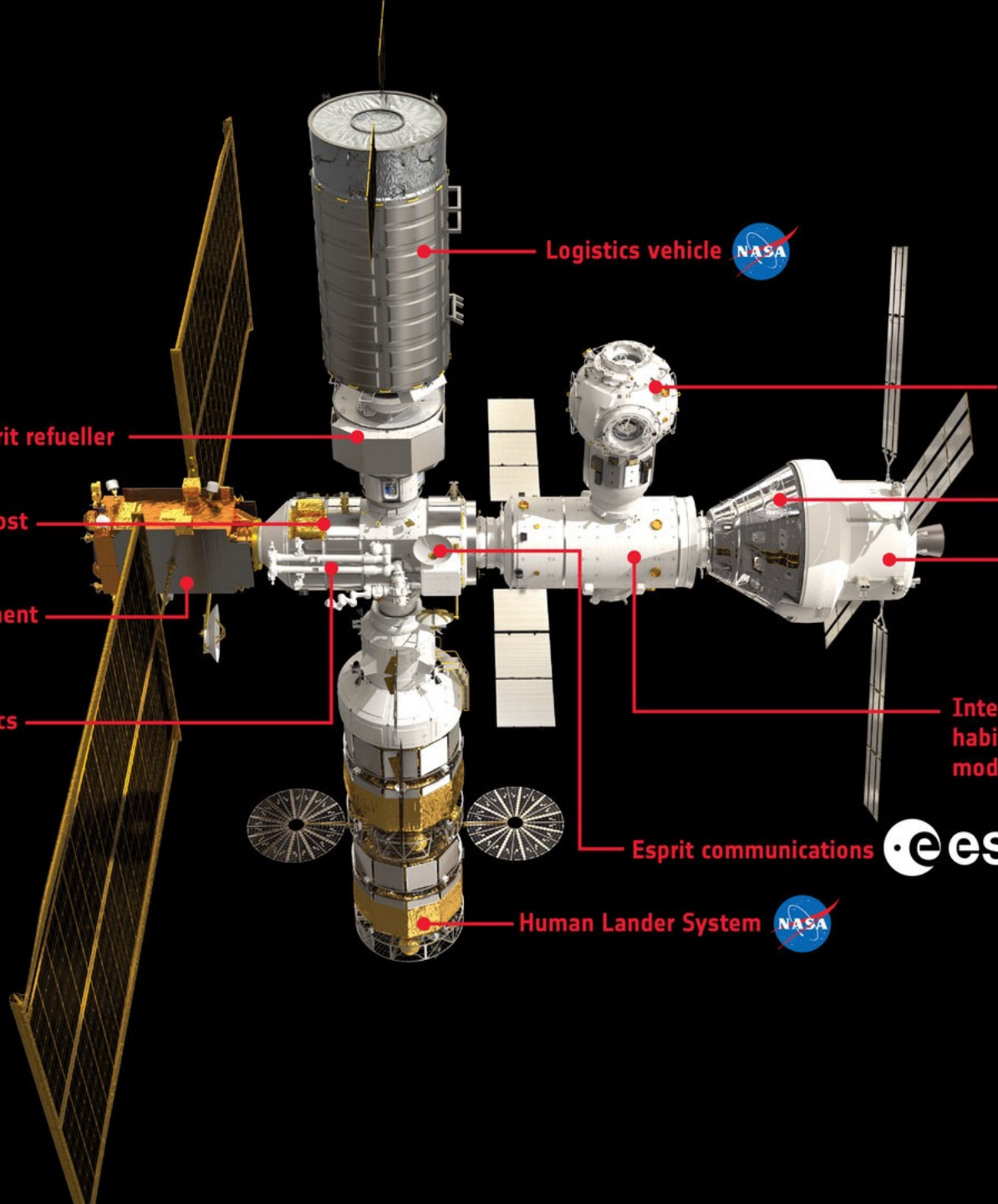





Ken Kremer
spaceupclose.com
NASA


NASA

GATEWAY



Logistics vehicle

Crew airlock

Esprit refueller

Orion capsule

Habitation and Logistics Outpost

European Service Module

Power and Propulsion Element

Robotics

International habitation module

Esprit communications

Human Lander System

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→ LUNAR MISSIONS

- Return
- Orbiter
- Lander
- Lander and mobility
- Human mission

- European Space Agency
- Canada
- China
- Germany
- India
- Israel
- Japan
- Russia
- South Korea
- United Kingdom
- United States of America

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NEXT TEN YEARS:

250+ missions

$100B of investment

A COMON INFRASTRUCTRE TO LUNAR MISSIONS

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- **Development of lunar missions** has been focused in the past **towards robotic, habitat and transportation technologies**
- Every individual mission was planning its **own custom solution for communication** and navigation what is **inefficient** and leads to **complex** and **costly** solutions
- Despite the wide variety of lunar missions planned, **no common global lunar communication and navigation infrastructure** was available
- Potential **optimization and centralization of the communication** and navigation needs of lunar missions would **allow for changing** the paradigm of **operations, design and cost** of exploration missions
- Additionally **outsourcing the communications services**, would stimulate **new business models**, encouraging further **private investment** and ultimately easing the **sustainability** of the lunar economy

The **interest and benefits** to maximizing the synergies between lunar navigation and communication needs, through the provision of a **common lunar orbital infrastructure** for both services, has become **apparent to all the international agencies involved**

ADVANTAGES OF A COMMON LUNAR COMMUNICATIONS INFRASTRUCTURE

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- Full lunar visibility
- Smaller and standardized Lunar Terminals (>8x power reduction)
- Higher autonomy of operations
- Higher service availability
- Real time services
- Operational cost savings
- Higher data throughput (>8x more data)
- Back up/Redundancy in the communications link

DRIVERS FOR LUNAR COMMUNICATIONS INFRASTRUCTURE

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- Interoperability due to the international footprint of large initiatives, like the Lunar Gateway
- Symmetric communications (forward/return), especially for future crewed missions
- Higher data rates, for new scenarios like remote medical support to astronauts
- Space internetworking across Earth network, relay network and Lunar orbit/surface network
- Security protection for the end-to-end Lunar communications paths
- Surface communications

LUNAR COMMUNICATIONS USER SCENARIOS CLASSIFICATION

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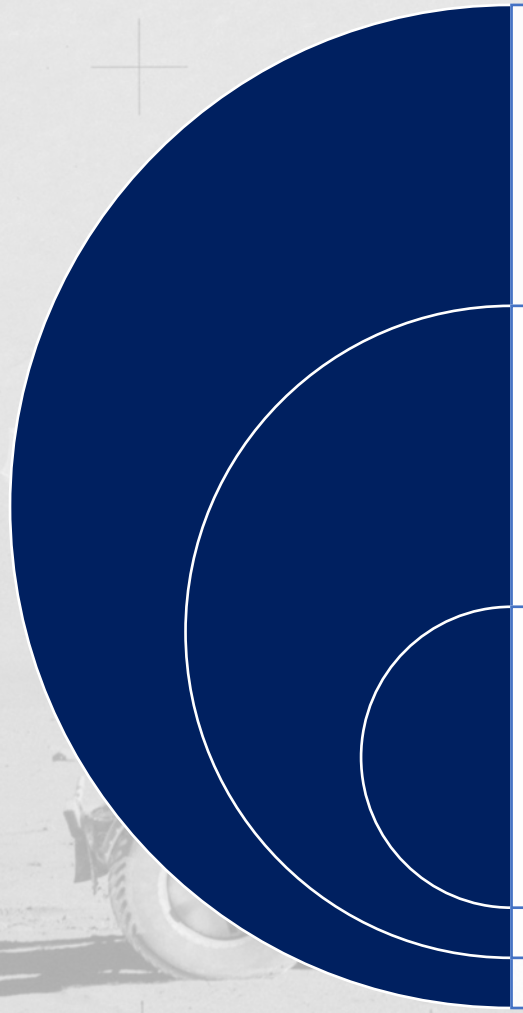
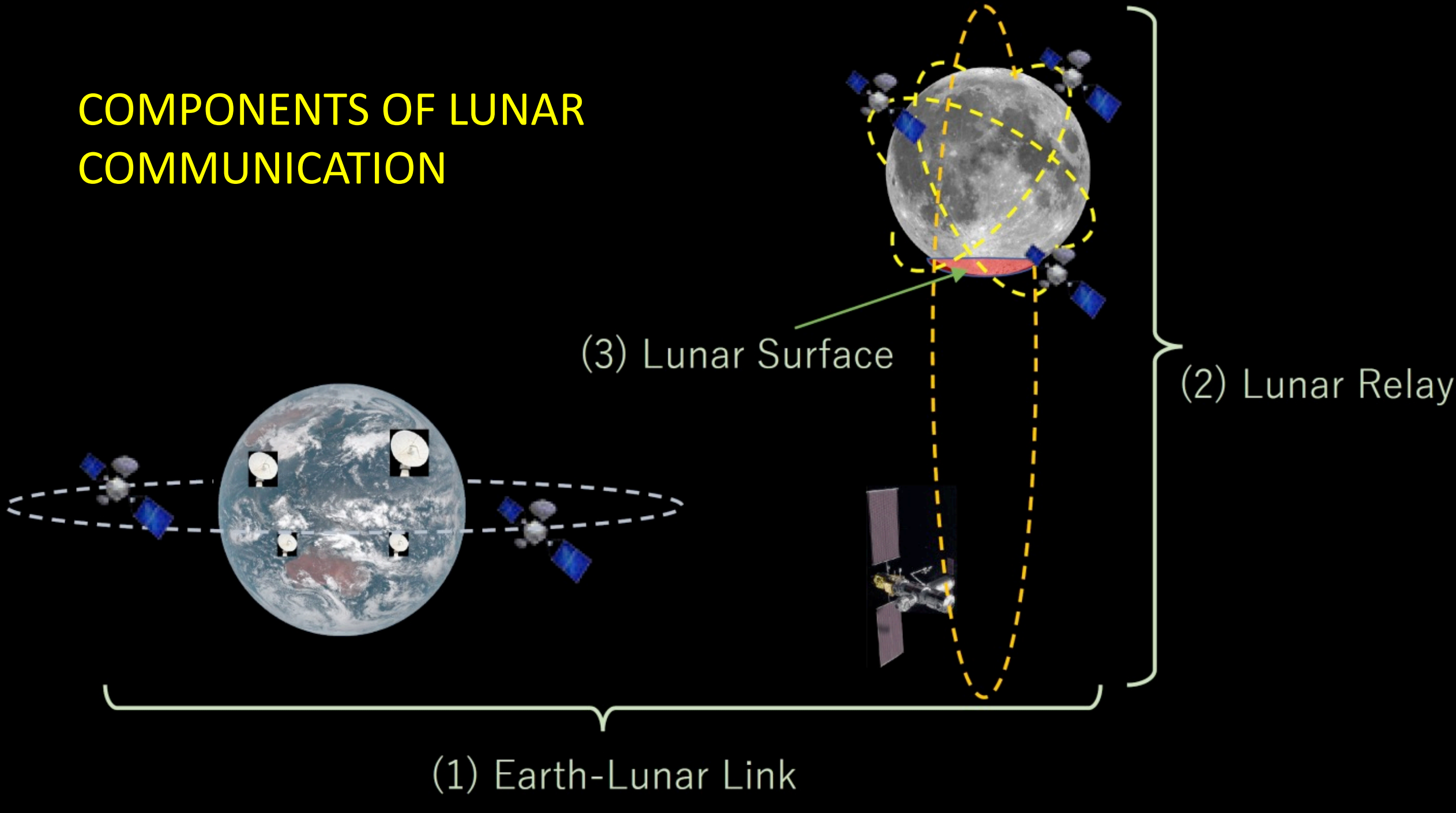


TRANSPORTATION	• Lunar Transfer Vehicle and Earth Return
	  ○ Transfer from Earth to Moon
	  ○ Transfer from Moon to Earth
	  ○ Transfer from LLO to Gateway
	• Lander Vehicle
	• Ascender Vehicle
	• Rendevous and Docking

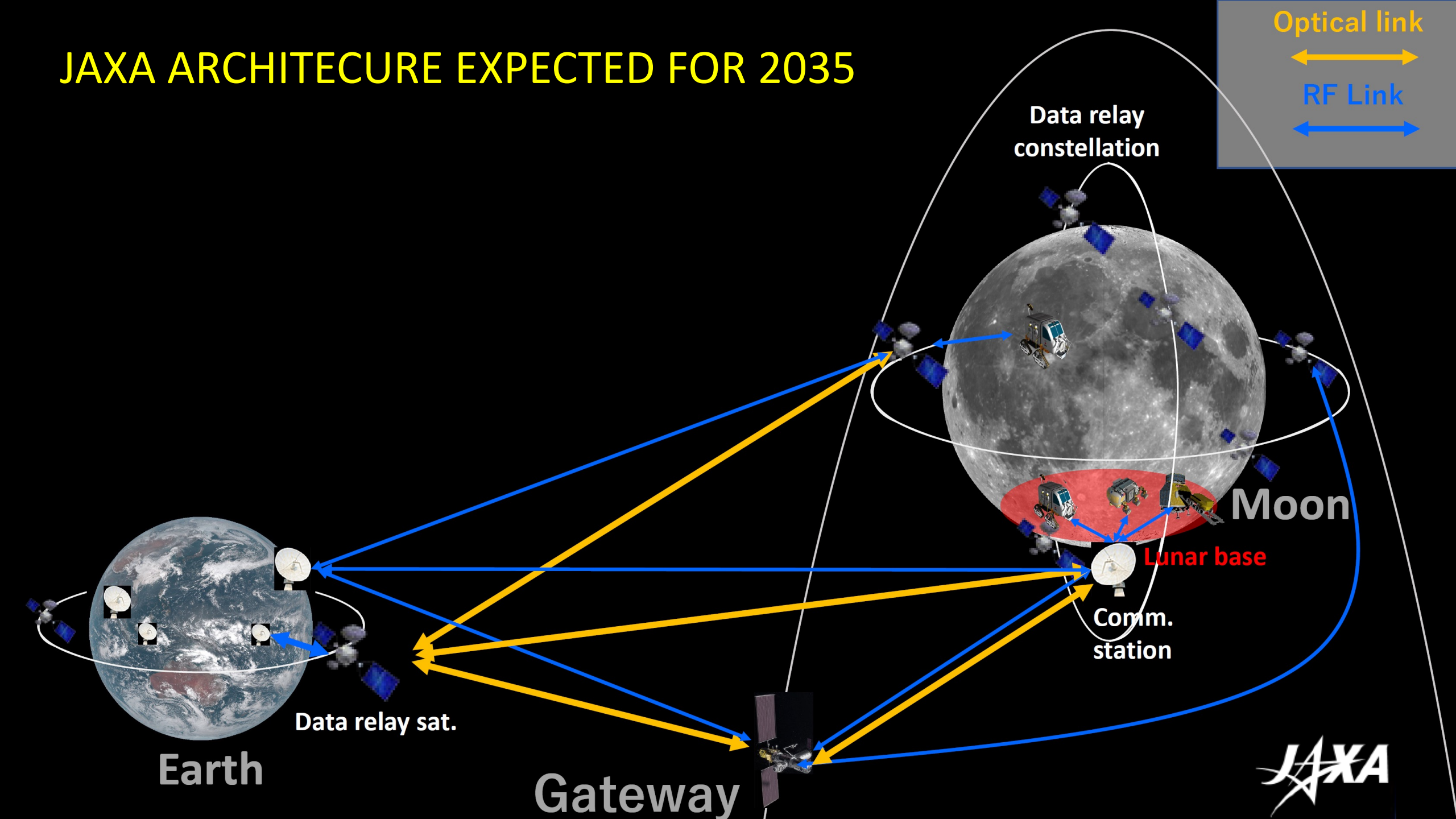
ORBIT	

SURFACE	• Rover/Mobile Platform
	  ○ Unmanned autonomous
	  ○ Unmanned tele-operated
	  ○ Manned/Pressurised Rover
	• Static Platforms-Infrastructures
	  ○ Unmanned
	  ○ Habitat/Manned Lander

COMPONENTS OF LUNAR COMMUNICATION



JAXA ARCHITECURE EXPECTED FOR 2035



CHANGE OF PARADIGM TO "NEW" COMMERCIAL SPACE

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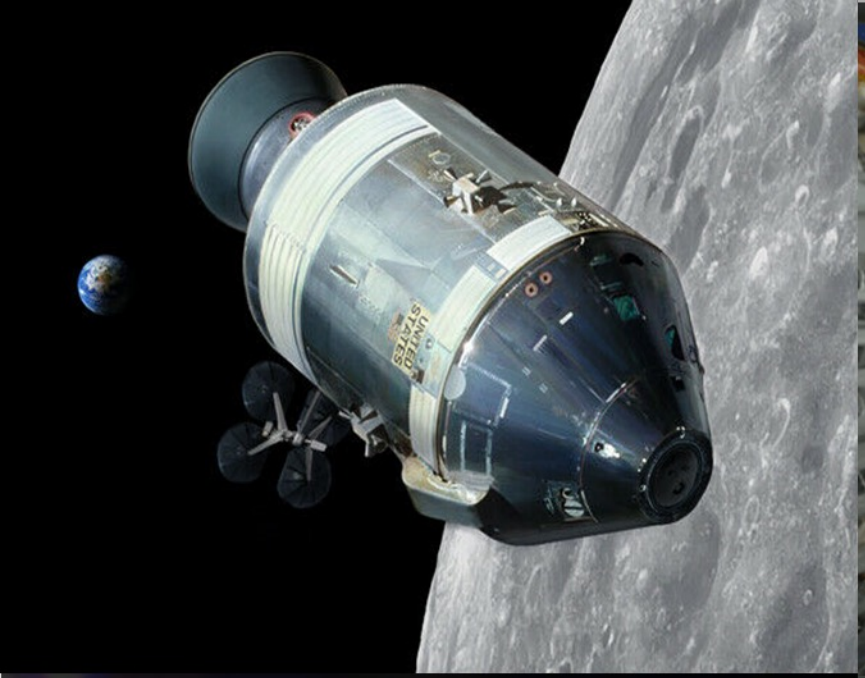
Program Characteristic	Early Space Age Approach	Commercial – Oriented Approach
Owner	NASA	Industry
Contract Fee-Type	Cost Plus	Fixed Price
Contract Management	Prime Contractor	Public-Private Partnership
Customer(s)	NASA	Government and Non- government
Funding for Capability Demonstration	NASA procures capability	NASA provides investment via milestone payments
NASA´s Role in Capability Development	NASA defines "what" and "how"	NASA defines "what" industry defines "how"
Requirements Definition	NASA defines detailed requirements	NASA defines top-level capabilities needed
Cost Structure	NASA incurs total cost	NASA and Industry share cost

Martin, G. (2017). NASA. NewSpace: The Emerging Commercial Space Industry ISU MSS 2017.



ESA MOONLIGHT INITIATIVE:
LUNAR COMUNICATION AND NAVIGATION SERVICES

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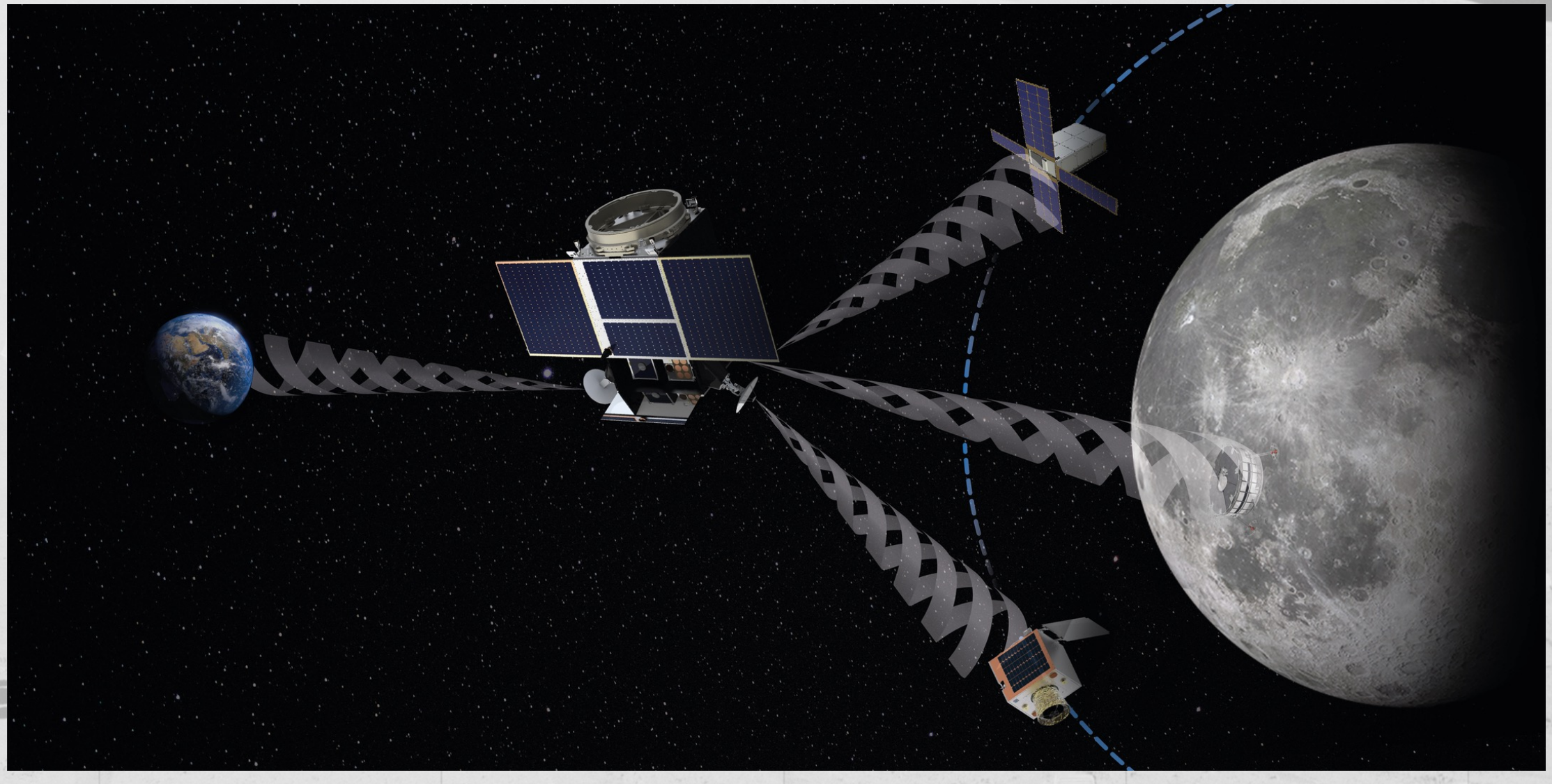


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Aitken
Coordinate System: Planetographic, +East, -180 - 180
Control Network: LOLA 2011
Northernmost Latitude -14.3 °
Southernmost Latitude -18.58 °
Easternmost Longitude 175.19 °
Westernmost Longitude 170.73 °
Diameter 129.69 KM
Center Latitude -16.44 °
Center Longi
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UNITED
STATES

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NASA


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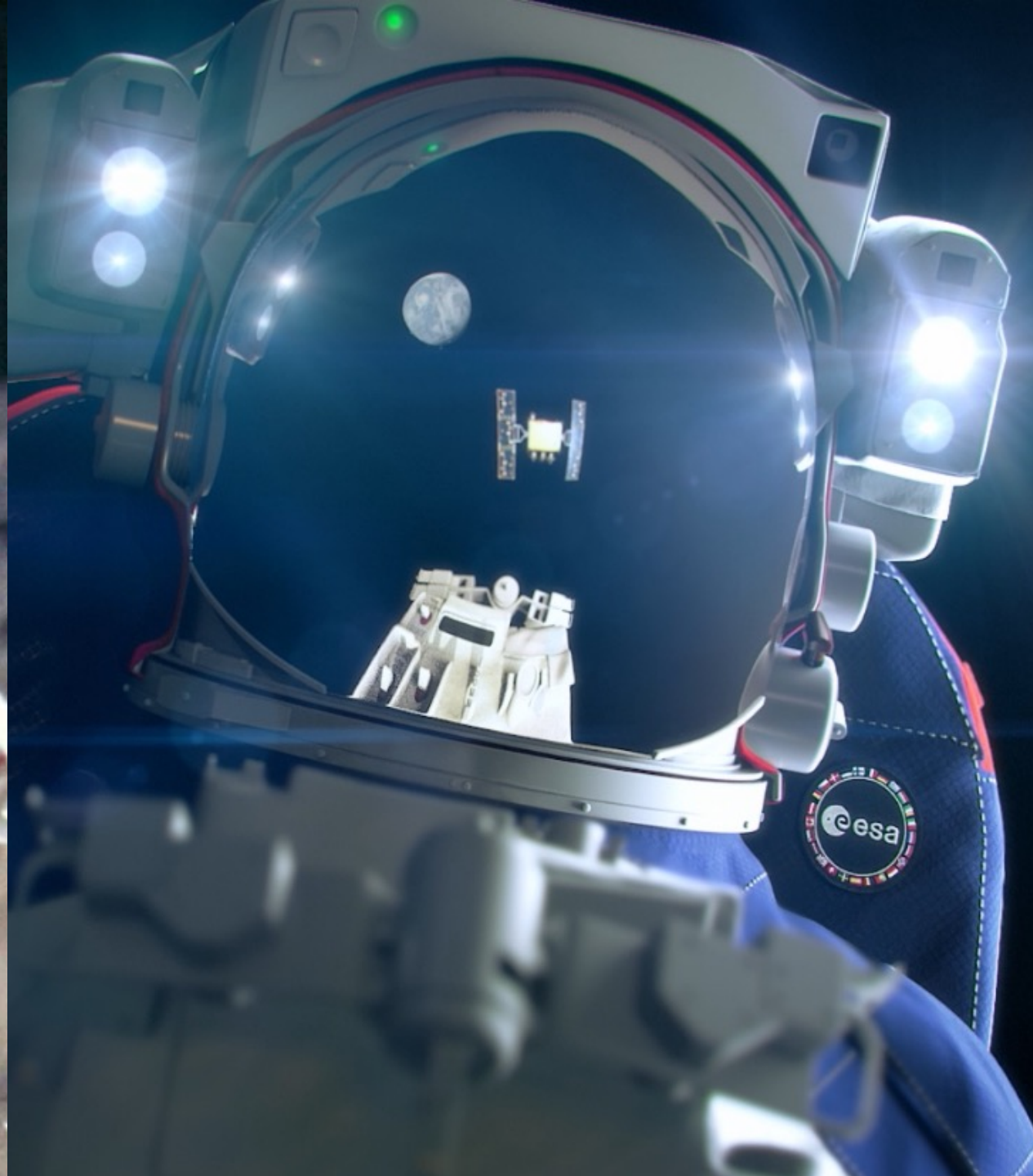
E. ALDRIN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