National Aeronautics and Space Administration

Human Exploration & Operations Committee

Ms. Lynn Cline
Interim Chair
HEO NAC
(ESDMD/SOMD)
May 8 2024

HEO Committee Members

- Interim Chair
  - Ms. Lynn Cline
- Committee Members
  - Dr.Paul McConnaughey – New member
  - Mr. Jim Voss
  - Ms. Nancy Ann Budden
  - Dr. Pat Condon
  - Dr. George Sowers
  - Mr. Doug Ebersole
  - Mr. Michael Lopez-Alegria
  - Dr. Ellen Stofan

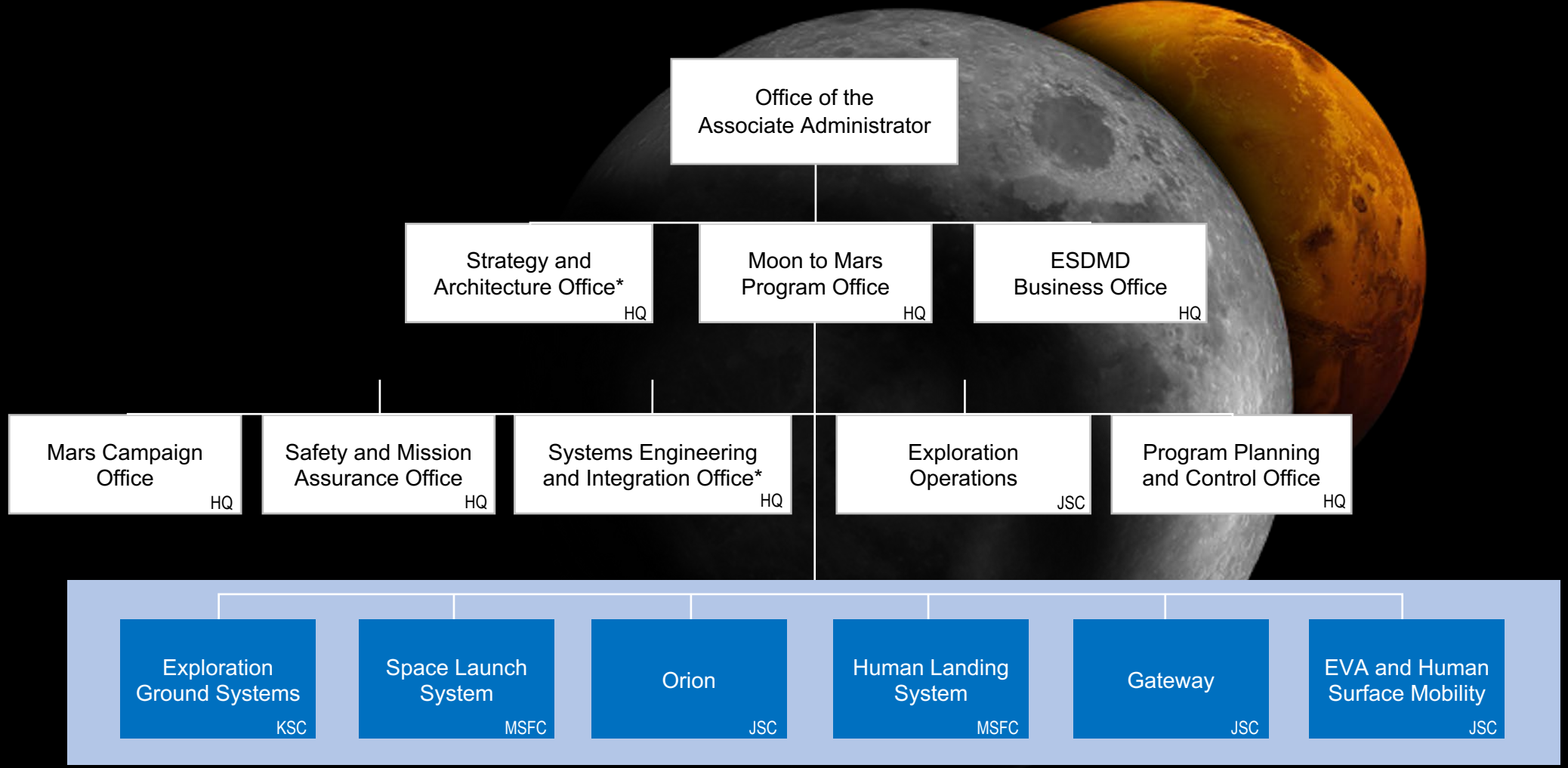
Human Exploration & Operations NAC

- Three Committee meetings were held since last report to the NAC
  - May 2023
  - Nov 2023
  - April 2024
- Meetings addressed:
  - Reorganization from Human Exploration and Operations Mission Directorate (HEOMD) into Explorations Systems Development Mission Directorate (ESDMD) and Space Operations Mission Directorate (SOMD).
  - Full range of ESDMD and SOMD programs
  - Areas of focus included Requirements Development, Systems Integration and Risk Management

National Aeronautics and Space Administration

Exploration Systems Development Mission Directorate Status

ESDMD Organization Chart



Exploration Systems Development Mission Directorate (ESDMD) Goals

Note: Mission Safety and Success are not listed as a goal because they are an inherent mandate

ESDMD Goals 2024-2025

Execute NASA's Artemis missions
Evolve a sustainable architecture to meet Moon to Mars objectives
Enable a national deep space transportation capability
Enhance affordability of all exploration systems
Expedite toward a yearly mission cadence

To accomplish these goals, we will continue to:

- Foster high standards of program and project management
- Balance funding profile, mission dates, and risks
- Lead international and commercial exploration partnerships
- Collaborate with centers to maintain highly skilled workforce & capabilities
- Communicate clear status and plans for all stakeholders

Moon to Mars Manifest—FY2025 President's Budget Request

FY	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
ESDMD			**Artemis II** (Sep. 2025) Crewed Flight SLS Block 1/ Orion/ML1	**Artemis III** (Sep. 2026) Crewed Flight SLS Block 1/ Orion/ML1; HLS Crewed Lunar Demo; xEVA Surface Suits; *HLS Uncrewed Lunar Demo*; *Gateway PPE/HALO Launch*	*Gateway PPE/HALO Arrival in NRHO*	**Artemis IV** (Sep. 2028) Crewed Flight SLS Block 1B/ Orion/ML2; I-Hab to Gateway; Gateway Logistics Services; Sustaining HLS Crewed Lunar Demo; xEVA Surface Suits; *Sustaining HLS Uncrewed Lunar Demo*		**Artemis V** (Mar. 2030) Crewed Flight SLS Block 1B/ Orion/ML2; ESPRIT to Gateway; Sustaining HLS Crewed Lunar Demo; xEVA Surface Suits; LTV	**Artemis VI** (Mar. 2031) Crewed Flight SLS Block 1B/ Orion/ML2; Airlock to Gateway; Gateway Logistics Services; Gateway External Robotics System; TBD Sustaining HLS Services; xEVA Surface Suits	**Artemis VII** (Mar. 2032) Crewed Flight SLS Block 1B/ Orion/ML2; Gateway Operations; TBD Sustaining HLS Services; xEVA Surface Suits; Pressurized Rover
SOMD	DSN Upgrades (DLEU) **Completed** DSS-36 [Canberra]	**Completed** DSS-24 [Goldstone]	DSS-34 [Canberra] DSS-56 [Madrid]		Lunar Communications Relay and Navigation Services (LCRNS)–Increment Alpha	Lunar Exploration Ground Sites 1-3 DSS-54 [Madrid] Increment Bravo	Increment Charlie	Ongoing Science, Human Research Program, and Technology Development in LEO (ISS transition to CLD)		
SMD CLPS Flights Outlined	LRO; Mars 2020:	ESCAPADE; **Attempted** TO 2-AB **Completed** TO 2-IM; TO 19D	TO 20A: VIPER; HERMES ready for integration; ESA Lunar Pathfinder delivered for launch; AVATAR (Artemis II); TO PRIME-1 Lunar Trailblazer; TO CP-11	Artemis III Surface Science Instruments; MMX (MEGANE/ P-Sampler); TO CS-3&4; TO CP-12	LRO continued ops; TO CS-06; TO CP-21; TO CP-22	Artemis IV Surface Science Instruments; TO CS-6; TO CP-31	Rosalind Franklin Mission (RFM) Launch, Landing; TO CP-41; TO CP-42; TO CP-51; TO CP-52; TO CP-61; TO CP-62	Artemis V Surface Science Instruments; Artemis LTV Science Instruments	Artemis VI Surface Science Instruments	Artemis VII Surface Science Instruments
STMD	MOXIE; MEDA; DSOC	CFM SpaceX TP Flight Demo	Surface Robotic Scouts (CADRE); TO PRIME-1: Drill; Nokia LTE/4G Comm; IM Deployable Hopper; CFM ULA TP Flight Demo; PPE SEP qual. environ. complete; CFM Eta Space TP Flight Demo	CFM Lockheed Martin TP Flight Demo; NEP Concept Design	DRACO Demonstration	TO LIFT-1: Lunar Surface Power Demo (i.e., RFC, VSAT, Wireless Charging); Lunar Surface Scaled Construction Demo 1; ISRU Pilot Excavator; ISRU Subscale Demo	SEP qual. complete			Fission Surface Power demo delivered for launch; TO LIFT-2: Lunar Surface Scaled Construction Demo 2; Autonomous Robotics Demo; Deployable Hopper 2; ISRU Subscale Demo 2

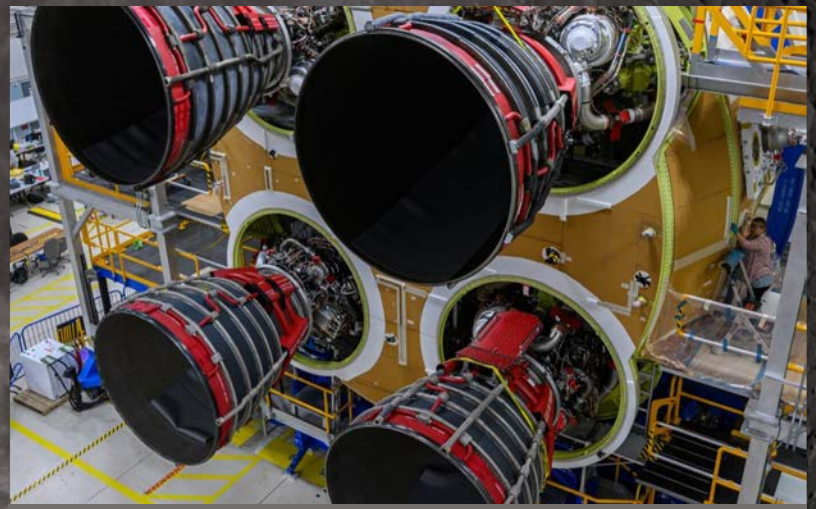
Icons are representative only, and may not reflect final configurations, not to scale | Icons represent the fiscal year in which an event occurs | Based on FY 2025 President's budget request

Presentation Version: 040824

Artemis II Progress

January 24, 2024—In preparation for the Artemis II crewed mission, EGS teams begin installation of four emergency egress baskets at Launch Complex 39B

The Artemis II crew stand on the crew access arm of the mobile launcher at Launch Pad 39B as part of an integrated ground systems test



Artemis II core stage with installed engines undergoing final outfitting

Artemis II Orion stage adapter with docking target and diaphragm installed

Artemis II booster motor segments receive "worm" logotype in the Rotation, Processing and Surge Facility at Kennedy Space Center

Starship Human Landing System Progress

March 14, 2024—Starship third integrated test flight. Credit: SpaceX

March 14, 2024—For the second time, all 33 Raptor engines on the Super Heavy Booster started up successfully and completed a full-duration burn during ascent. Credit: SpaceX

March 14, 2024—Starship third integrated test flight. Credit: SpaceX

Starship Human Landing System docking system qualification test

Starship Human Landing System elevator astronaut testing

Artemis III Progress

AxEMU spacesuit
during testing

Astronauts Victor Glover and Christina Koch practice runs on a
Starship elevator mockup in the Neutral Buoyancy Laboratory

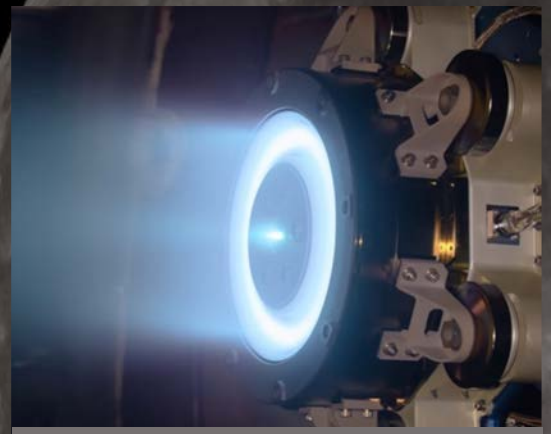
Spacesuit and hardware tests on the simulated lunar
terrain on the Neutral Buoyancy Laboratory (NBL) pool floor

The Joint Extravehicular Activity and Human Surface Mobility Program Test Team (JETT) testing tools and spacesuits in a rock
yard at NASA's Johnson Space Center, simulating the uneven terrain of the lunar surface, in preparation for Moonwalks

Spacesuit and EVA hardware testing in the NBL

Gateway Initial Capability Progress

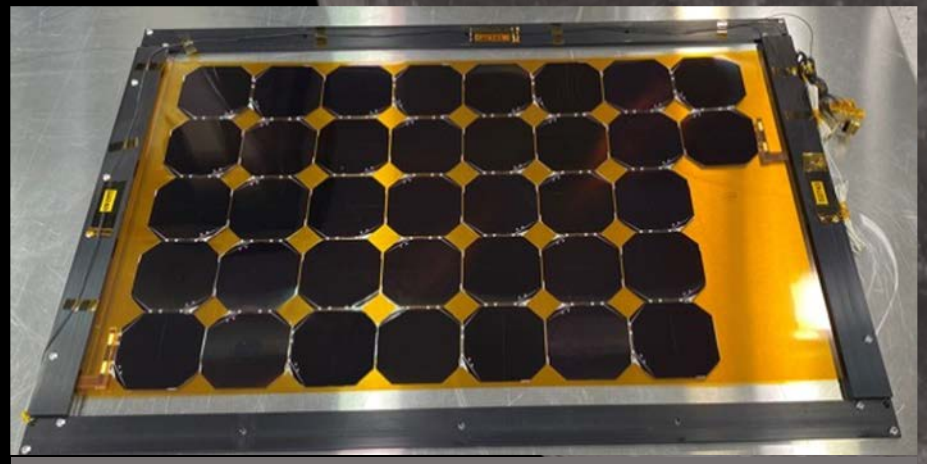
PPE Roll Out Solar Array (ROSA) Boom



Power and Propulsion Element 12-kilowatt Solar Electric Propulsion Test

Gateway advanced electric propulsion system qualification thruster

Engineers at Thales Alenia Space Italia gently guide HALO from its welding platform to an integration test stand.



Power and Propulsion Element (PPE) Solar Array Power Module

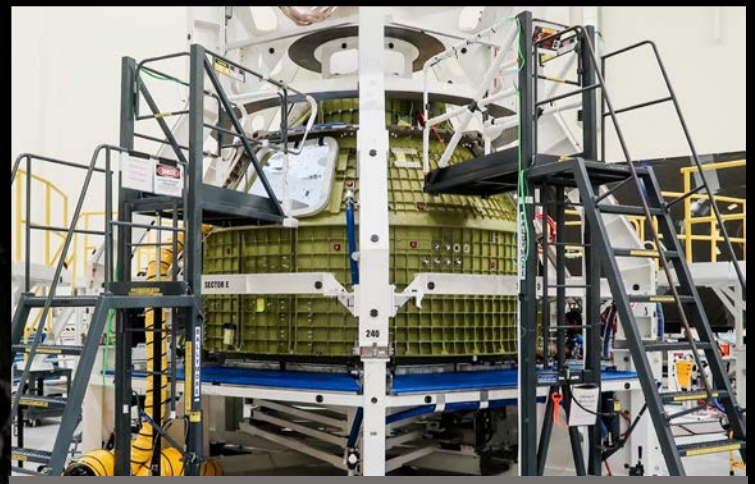
Power and Propulsion Element central cylinder testing at Maxar

Habitation and Logistics Outpost after completion of final welds in Turin, Italy

Artemis IV Progress

ML-2 truss work

Artemis IV payload adapter engineering development unit ready for evaluation

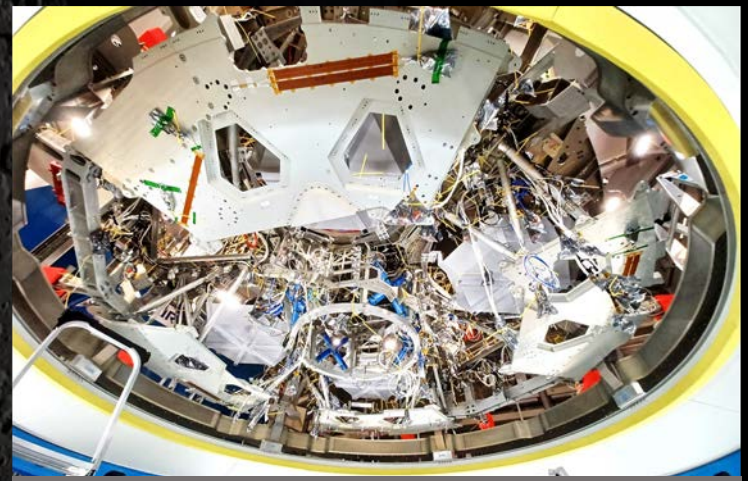


Artemis IV Crew Module Pressure Vessel at Kennedy Space Center

ML-2 tower module

Artemis IV universal stage adapter development test article at Marshall for testing

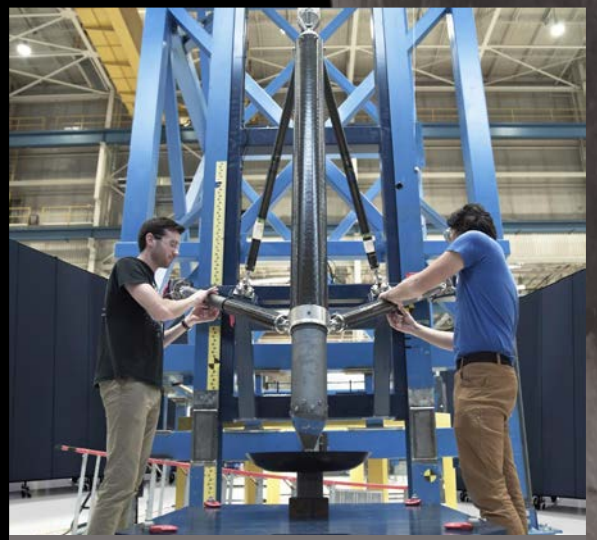
Artemis IV engine section in progress



Artemis IV European Service Module in Bremen, Germany

Blue Moon Human Landing System Progress

A Blue Origin technician conducts a vacuum chamber fit check for a fuel cell at Blue Origin's facility in West Texas.



Blue Origin conducted a drop test of the Blue Moon MK1 cargo lander leg to provide engineers with data to correlate design models for dynamic loads analysis.

Blue Origin's BE-7 team conducted a successful Thrust Chamber Assembly test at NASA Marshall Space Flight Center.

Hardware for Blue Origin's New Glenn second stage, which will refuel the cislunar transporter as part of Blue Origin's Artemis V architecture, is being manufactured at Blue Origin's production facility in Cape Canaveral, FL.

The first and second stages of New Glenn's test vehicle mated for the first time enabled Blue Origin to exercise their tooling and stage interfaces in preparation for the first launch.

Blue Origin's New Glenn rocket upended on its launch pad for the first time. The rocket's first stage underwent three tanking tests in preparation for its first launch.

Dual Tank Cryo Fluid Management Test Article. Credit: Blue Origin

New Glenn test article on Blue Origin's launch pad at LC-36

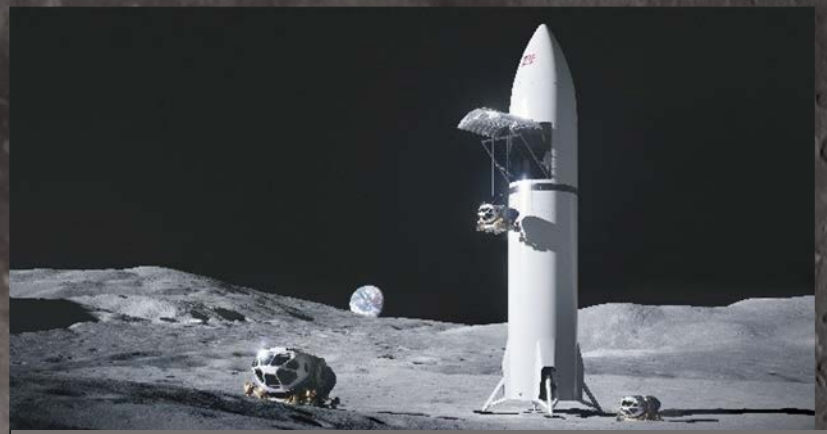
Beyond Artemis V Progress

NASA Administrator Bill Nelson, left, and Japan's Minister of Education, Culture, Sports, Science and Technology Masahito Moriyama, hold signed copies of an historic agreement between the U.S. and Japan. Under the agreement, Japan will design, develop, and operate a pressurized rover for crewed and uncrewed exploration on the Moon. NASA will provide the launch and delivery of the rover to the Moon as well as two Japanese astronaut missions to the lunar surface.

The European Service Module 6 structure ahead of shipment to the Airbus Integration Hall in Bremen, Germany

BOLE DM-1 Booster Segment complete for Artemis IX

Artist's concept of a pressurized rover. Credit: JAXA/Toyota



Early conceptual renderings of cargo variants of human lunar landing systems from NASA's providers SpaceX, left, and Blue Origin, right. Both industry teams have been given authority to begin design work to provide large cargo landers capable of offloading 15 metric tons of cargo, such as a pressurized rover, on the Moon's surface. (SpaceX and Blue Origin)

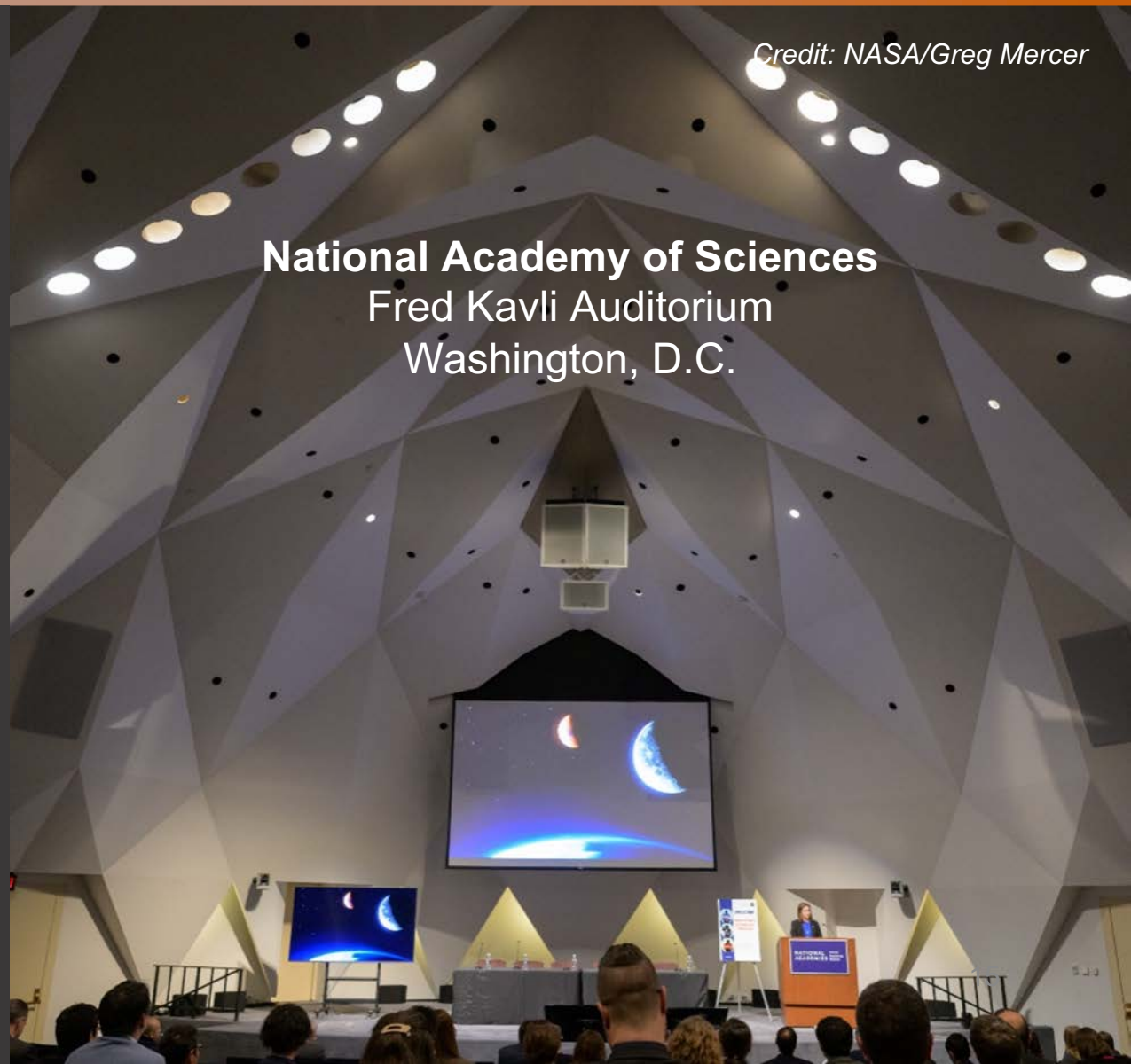
2024 Architecture Workshops

February 20–22 – Washington, DC

The workshops remain a great forum for **receiving feedback** from stakeholders and **answering questions**.

Key discussion areas included next steps in the process for **technology and systems definitions**.

NASA continues to engage **partners of all types**: emerging and established space agencies, small and large companies, and academia and the science community.



Subscribe to Updates

Subscribe to the Moon to Mars Architecture email list at the link below:

https://socialforms.nasa.gov/Architecture-Updates

Credit: NASA

For NAC ESDMD Recommendation

Title of Recommendation: Endorsement of the Agency-Wide Approach to the Moon to Mars Architecture

Recommendation: The Committee acknowledges and applauds the effort taken in the development of the Moon-to-Mars Architecture. Ensuring alignment across all the Mission Directorates, engaging a broad community for input and establishing an iterative process is a sound approach. As written, the Moon-to-Mars Architecture Definition Document clearly embraces its purpose to translate the broad objectives into functions and use cases that can be allocated to executable programs and projects. The Committee embraces the effort as a best practice that will serve the program well as it allocates available funds into prioritized programs and projects. The Committee recommends the Architecture Definition Document serve as a consistent guidepost for development of "Shall Statements" for follow-on contracted activity with industry partners.

Major Reason for Recommendation: To ensure the efficient application of the value of the Architecture Definition Document when contracting with industry partners to minimize program risk and any potential of requirements shortfalls.

Consequences of No Action on the Recommendation: If the Architecture Definition Document is not applied consistently going forward across all program participants, the program risks losing important linkages throughout the program which could result in inefficient implementation, costly engineering change proposals, and schedule disconnects.

For NAC ESDMD Recommendation

Title of Recommendation: Lunar Lander Services schedule and risk assessment

Recommendation: Lunar Lander Services suppliers should provide detailed schedule plans to NASA and complete risk assessment to NASA

Major Reason for Recommendation: Apollo history shows that development of a Lunar Lander will be the pacing item for human mission to the moon. The Artemis Campaign is designated to fit inside a budget and schedule constraint. Without accurate planning for schedules and proper risk understanding accurate planning and maintaining schedules is is highly unlikely.

Consequences of No Action on the Recommendation: If not implemented, the Artemis program will most likely have significant cost overruns and missions will not be planned most effectively.

ESDMD Findings

Title of Finding: Increased Emphasis on Systems Engineering and Integration (SEI) and risk management for Artemis.

Finding: The complexity of the Artemis missions dramatically increases for Artemis 2 and beyond. Each mission involves many elements and interfaces. Successfully executing these missions will require an increased emphasis in SEI as well as risk management at the enterprise level and within each program element.

ESDMD Findings

Title of Finding: Increase importance of science in both the lunar and Mars missions.

Finding: The committee recognizes the partnership with the Science Mission Directorate. We see more complementary requirements in the lunar and Mars programs. We applaud that the mission directorates are working so well together

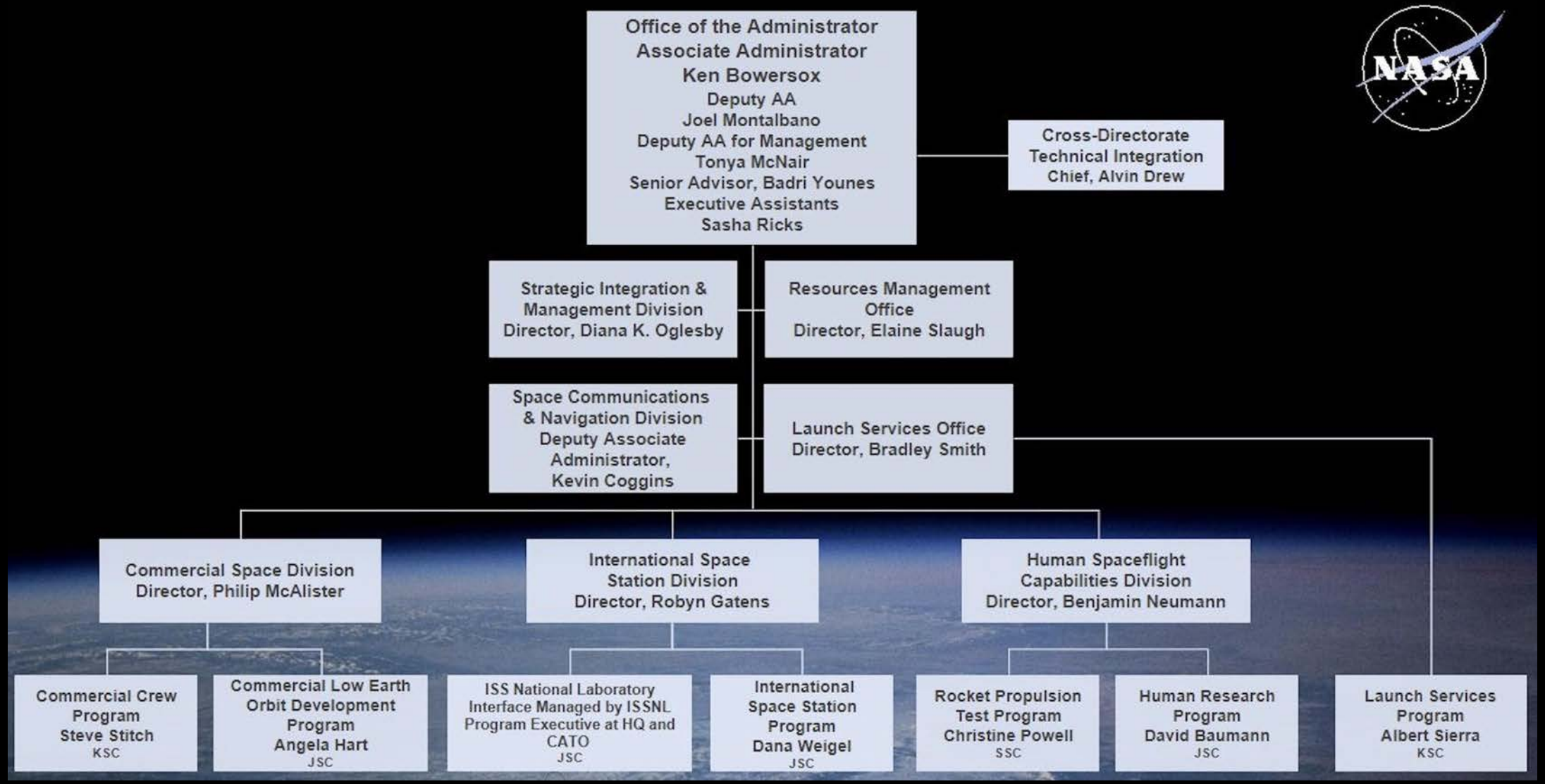
Finding - Budget Allocation

•The FY 24 appropriations for NASA's Exploration Development Programs establishes only the top line budget in law, with the allocations by program elements in the accompanying report. The HEO committee strongly supports this approach. This approach allows for more flexibility and effective financial and risk management of this integrated program. The HEO Committee finds that NASA should continue to work with Congress to continue this approach in future budgets.

National Aeronautics and Space Administration

Space Operations Mission Directorate Status

SOMD Organizational Chart



SOMD OVERARCHING STRATEGY

- **Maintains a safe and sustained human presence in LEO**
- **Provides *mission-critical* support to NASA and non-NASA customer missions**
  - Continues providing space communication and navigation services to missions and developing capabilities to ensure lunar communication and navigation support for Artemis system needs
  - Continues providing launch and test services
  - Continues providing training and readiness to support crew health and safety and mission success
  - Continues researching and developing capabilities to safeguard our astronaut explorers
- **Continues research to advance discoveries that benefit life on Earth and support Exploration**
  - Continues support of ISS operations and research
- **Supports development of an American-led space infrastructure and commercial economy in LEO**
- **Implements ISS End of Life activities**

Low-Earth Orbit Transition: ISS to Commercial Destinations

FY 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032

International Space Station (ISS) Operations

U.S. Deorbit Vehicle Development — *Delivery* — *Deorbit*

Commercial LEO Destinations (CLDs) Development — CLD Operations

Phase 1: Early Design Maturation | *Phase 2: Certification & Services*

Continue valuable science and research on ISS through end of life

Develop U.S. Deorbit Vehicle to safely deorbit ISS at end of useful life

Balancing 3 Priorities

Partner with U.S. commercial space industry to develop and deploy commercial destinations to ensure American access to LEO

SOMD Summary

SUMMARY

- The budget includes $4.4 billion for Space Operations to enable sustained human exploration missions, scientific discovery, advanced operations in our solar system, and inspiration of the next generation of STEM leaders
  - Stimulating growth of the low-Earth orbit economy by developing commercial space stations
  - Providing for critical operations, infrastructure, communication, launch, and testing services indispensable to the Nation's access to and use of space
  - Supporting research and technology development, including research to enable human health and performance in future human exploration missions

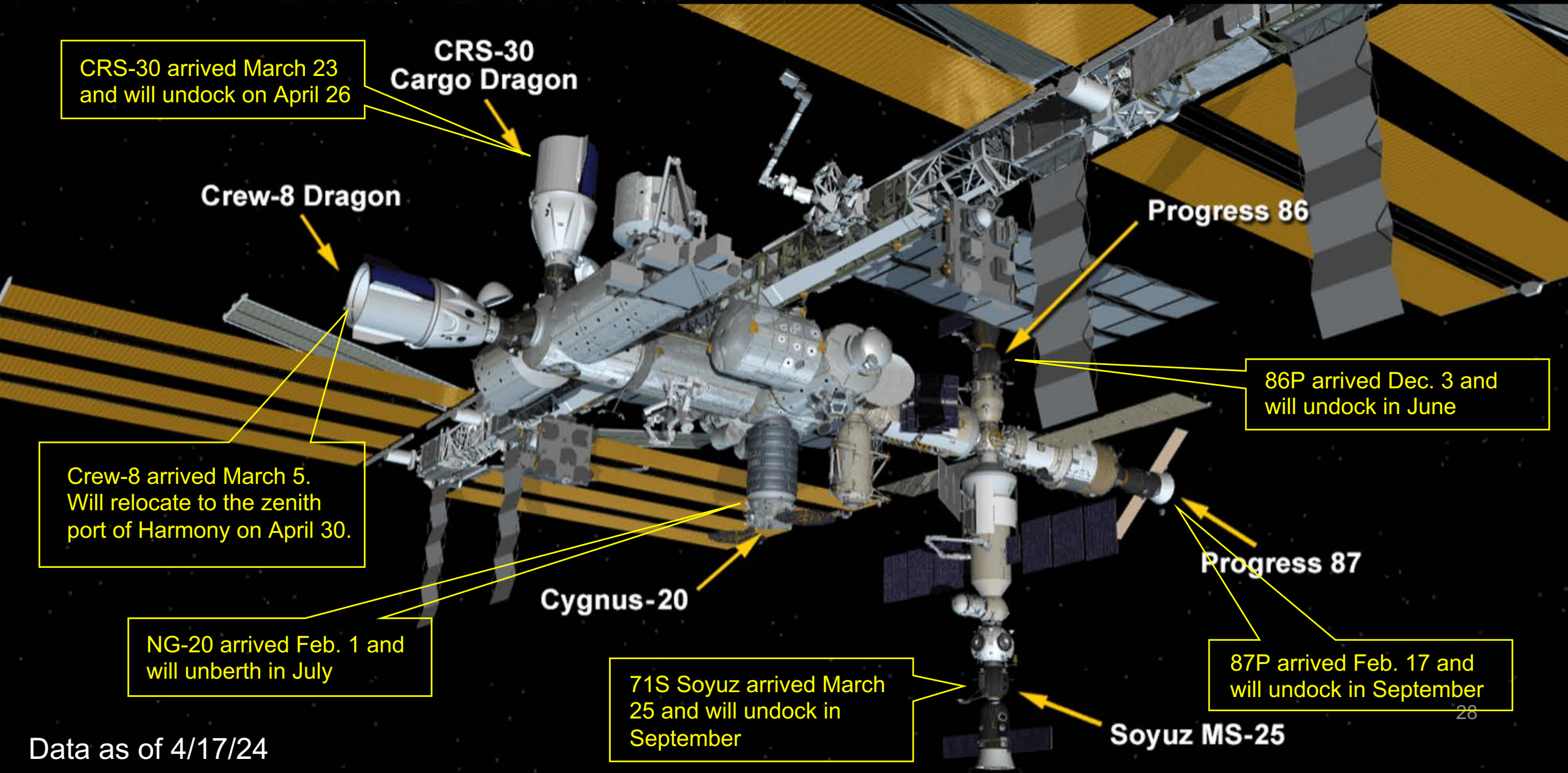
For More Information on Station Benefits for Humanity, see International Space Station Benefits for Humanity (nasa.gov)
For More Information on SOMD FY 2025 Budget, see NASA FY 2025 Budget Request (nasa.gov)

Increment 71 Overview

- Soyuz 70S Undock
- SpaceX CRS-30 Undock
- SpaceX Crew-8 Relocate (Enables CFT docking)
- RS EVA 62
- Boeing Crew Flight Test (CFT)
- Progress 86 Undock
- Progress 88 Launch/Dock
- US EVAs (RFG, ERDC R&R, IROSA prep)
- Northrop Grumman CRS-20 Unberth
- Northrop Grumman CRS-21 Launch
- Progress 87P Undock
- Progress 89P Launch/Dock
- SpaceX Crew-9 Launch/Dock
- SpaceX Crew-8 Undock
- Soyuz 72S Launch/Dock
- Soyuz 71S Undock

Flight Engineers Alexander Grebenkin (Roscosmos) Tracy Caldwell-Dyson (NASA), Michael Barratt (NASA), Nikolai Chub (Roscosmos), Matt Dominick (NASA), Commander Oleg Kononenko (Roscosmos), Jeanette Epps (NASA) .

Current Configuration



Data as of 4/17/24

ISS National Lab Status (CASIS)

- **Continuing to see more demand than resources available**
- **Igniting Innovations Solicitation full proposals have been received, selections will be announced Summer 2024**
- **Registration open for ISS Research and Development Conference in Boston, MA July 30th – August 1st**
  - Early bird registration is open
- **Relaunched Upward Magazine**
  - www.issnationallab.org/upward
- **National Laboratory in LEO**
  - ISS continuing to work on formal action from National Space Council to develop strategy for future National Lab in LEO
  - Internal NASA workshop to define strategy planned for May 6th and 7th
  - Groups from Federal Workshops have been meeting throughout the year to explore opportunities and programs for collaborative LEO research

CCP Flight Accomplishments

CCP is proud to be leading a new chapter in human spaceflight

SPACEX

Demo-1
Launched 03/02/19
Landed 03/08/19

BOEING

OFT
Launched 12/20/19
Landed 12/22/19

SPACEX

Demo-2
Launched 05/30/20
Landed 08/02/20

SPACEX

Crew 1
Launched 11/15/20
Landed 05/02/21

SPACEX

Crew 2
Launched 04/23/21
Landed 11/09/21

SPACEX

Crew 3
Launched 11/10/21
Landed 05/06/22

SPACEX

Crew 4
Launched 04/27/22
Landed 10/14/22

BOEING

OFT-2
Launched 05/19/22
Landed 05/25/22

SPACEX

Crew 5
Launched 10/5/22
Landed 3/12/23

SPACEX

Crew 6
Launched 3/2/23
Landed 9/4/24

SPACEX

Crew 7
Launched 8/25/23
Landed 3/12/2024

SPACEX

Crew 8
Launched 3/4/2024
On Orbit

BOEING

CFT
Launch NET 5/6/2024

SPACEX

Crew 9
Launch NET Mid-Aug 2024

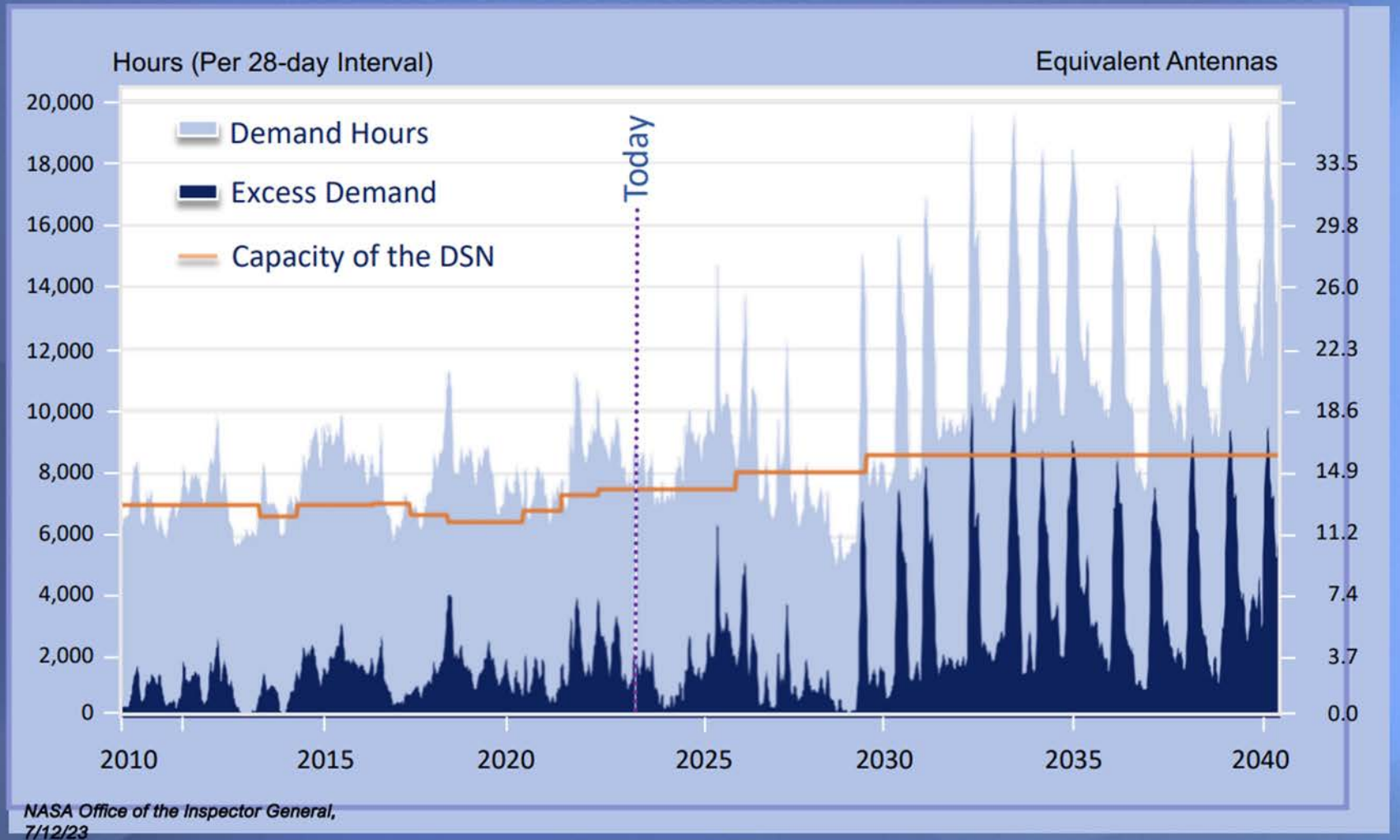
Summary

- CCP continues to facilitate the development and certification of U.S. industry-based crew transportation systems
- SpaceX continuing to provide routine crewed missions to the International Space Station
- Boeing is making progress toward final readiness for crewed flight
- CCP is beginning a more robust engagement with the Comm LEO Program, including integrating the crew transportation requirements into the overall CLD requirements.
  - Announced seven U.S companies the agency will partner through its second Collaborations for Commercial Space Capabilities (CCSC-2)

Go Boeing CFT!

Commercial LEO Destinations
Funded Partners

DSN Challenge: Growing User Needs



NASA Office of the Inspector General, 7/12/23

For NAC SOMD Recommendation

Title of Recommendation: Shortfall in NASA Deep Space Communications Network

Recommendation: NASA needs to emphasize the requirements for expansion and sustainment of the Deep Space Network (DSN). NASA needs to immediately complete plans for and fund the expansion of the capability of the DSN.

Major Reasons for the Recommendation: The DSN capabilities may not be able to support the expected cis-lunar, Lagrange, and deep space missions of the future unless steps are taken to expand capabilities. These infrastructure items have long lead time requirements and need to be addressed immediately. Resources, especially appropriations, need to be a high priority. The committee is unsure if Launar Exploration Ground Sites (LEGS) will provide enough relief to the DSN to allow all the missions to be supported.

Consequences of No Action on the Recommendation: Without increased capabilities, lack of communications capability will stifle the plans that US and its allies have developed for deep space operations.

For NAC Findings - SOMD

Title: Commercial LEO gap Finding

Finding: It is extremely important not to have a gap in US LEO presence. Ensuring no gap requires close monitoring of the progress of the Commercial Low Earth Orbit Destinations (CLDs) Program in relation to the planned 2030 deorbit date of the ISS and careful planning of the transition.