

Autonomy and the Gateway

Human-Robotic Systems and Operations



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NASA Autonomous Systems

Systems Capability Leadership Team

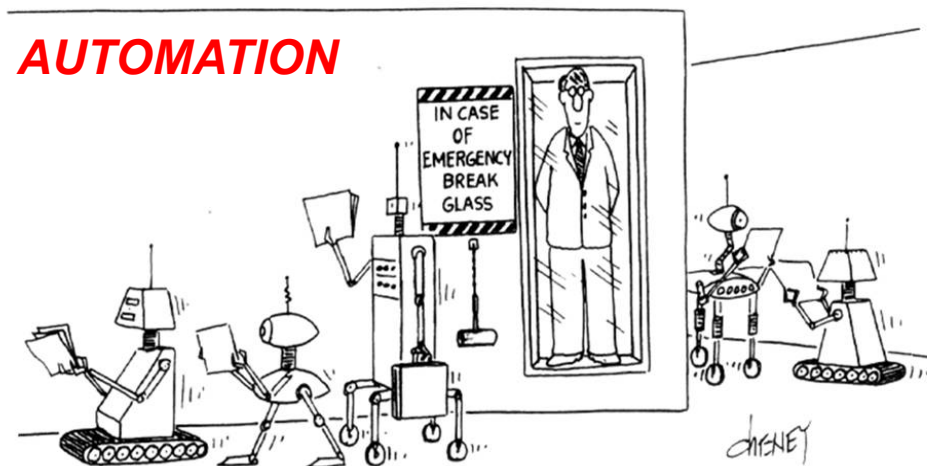
- Serve as a **community of practice** in autonomous systems
- **Identify barriers** that impact the development and infusion of autonomy capabilities into mission systems
- Identify and **assess the NASA workforce** and facilities needed to advance autonomous systems
- **Recommend research and development** in autonomous systems technology for NASA
- **Recommend investment/divestment** to improve the use of autonomous systems in aeronautics (ARMD), human exploration (HEOMD), science (SMD), and space technology (STMD)

Structure

- Lead: Terry Fong (STMD)
- Deputy: Danette Allen (LaRC)
- Members: Center SMEs, relevant CLT leads, Mission Directorate reps



What is Autonomy?



VS.

AUTONOMY
THE DESIRE TO BE
SELF DIRECTED



- **Autonomy** is the ability of a **system** to achieve goals while operating independently of external control (*NASA Technology Roadmaps, TA 4: Robotics and Autonomous Systems, 2015*).
- A **system** is the combination of **elements** that function together to produce the capability required to meet a need. The elements include all hardware, software, equipment, facilities, personnel, processes, and procedures needed for this purpose (*NASA Systems Engineering Handbook, NASA SP-2016-6105 Rev 2*).
- **Autonomy technology** consists of the elements and methods required to build, test, certify, and operate an autonomous system.

What is NOT Autonomy?

Autonomy is **NOT automation**, but often relies on automation

- Automation is the automatically-controlled operation of an apparatus, process, or system using a pre-planned set of instructions
- Most deep-space robotic missions use automation (command seq)

Autonomy is **NOT artificial intelligence (AI)**, but may make use of AI methods

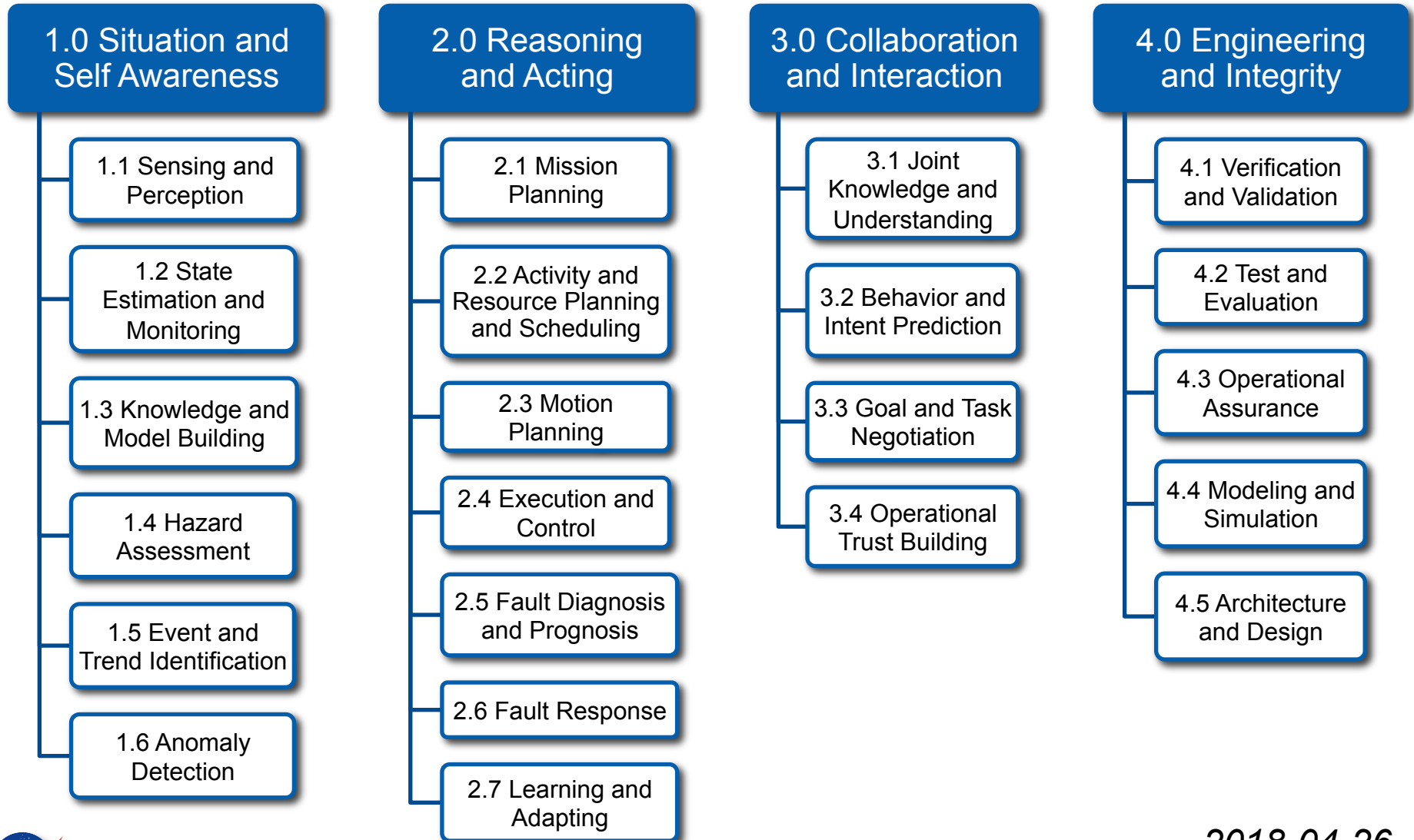
- Machine learning (deep learning, reinforcement learning, etc.)
- Perception (object recognition, speech recognition, vision, etc.)
- Search, probabilistic methods, classification, neural networks, etc.

Autonomy is **NOT necessarily about making machines “intelligent”, “smart”, or “unmanned”**

- Autonomy is about making systems independent and self-reliant
- Systems can include humans as an integral element (“human-system integration”, “human-autonomy teaming”, etc.)



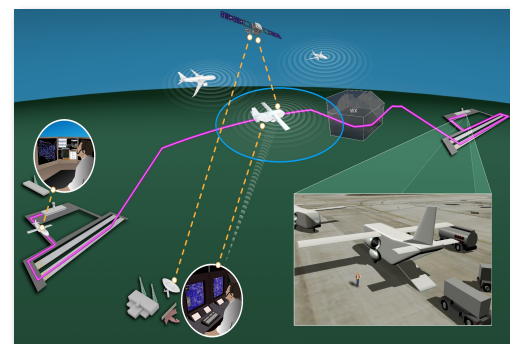
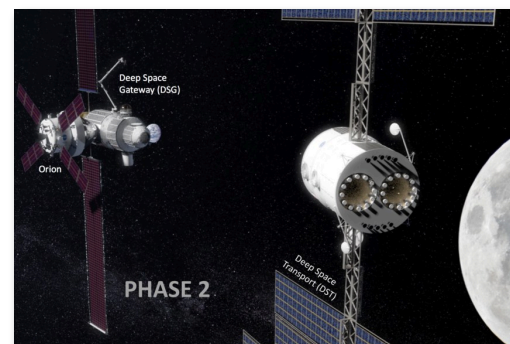
Autonomous Systems Taxonomy



Why autonomy?

Autonomy is needed ...

- When the cadence of decision making exceeds **communication constraints** (delays, bandwidth, and communication windows)
- When **time-critical decisions** (control, health, life-support, etc) must be made on-board the system, vehicle, etc.
- When decisions can be better made using **rich on-board data** compared to limited downlinked data (e.g., adaptive science)
- When local decisions **improve robustness** and **reduces complexity** of system architecture
- When autonomous decision making can **reduce system cost** or **improve performance**
- When **variability in training, proficiency**, etc. associated with manual control is unacceptable



Where can NASA use Autonomy?

EARTH LAUNCH AND LANDING SYSTEMS

- Launch Vehicles
- Launch Abort Systems
- Entry, Descent and Landing

EARTH ATMOSPHERIC SYSTEMS

- Unmanned Aerial Systems
- Vehicle Mission Safety
- Vehicle Performance Enhance
- Human-machine teaming
- National Airspace Management
- Distributed Large-scale Collaborative Systems

GROUND SYSTEMS

- Mission Operations
- Visualization and Interaction
- Robotic Inspection and Repair
- Propellant/Commodity Loading

ROBOTIC EARTH-ORBITING SYSTEMS

- Formation Flying
- Constellations and Swarms
- Rendezvous and Docking
- On-Orbit Servicing
- In-Space Assembly
- In-Space Manufacturing
- Instrument Data Analysis
- Sensor Web

HUMAN EARTH-ORBITING SYSTEMS

- Life Support
- Rendezvous and Docking
- On-Orbit Servicing
- Visualization and Interaction
- Robotic Assistants
- Mission and Data Analysis
- In-space Manufacturing
- In-space Assembly

ROBOTIC SPACE SYSTEMS

- Planetary Ascent Vehicles
- Rendezvous and Docking
- Entry, Descent & Landing
- In Situ Access
- Sample Collection
- Orbital Navigation
- Instrument Data Analysis
- In Situ Resource Utilization

HUMAN SPACE SYSTEMS

- Planetary Ascent Vehicles
- Life Support
- Rendezvous and Docking
- Entry, Descent & Landing
- Surface Transport
- Robotic Assistants
- Mission and Data Analysis
- In Situ Resource Utilization



Human Exploration

From Earth to the Moon and Mars

2020s

Now

Using the
International Space Station



Phase 0

Continue research and testing on ISS to solve exploration challenges. Evaluate potential for lunar resources. Develop standards.

Operating in the Lunar
Vicinity (proving ground)



Phase 1

Begin missions in cislunar space. Build Deep Space Gateway. Initiate assembly of Deep Space Transport.

After 2030
Leaving the Earth-Moon System
and Reaching Mars Orbit



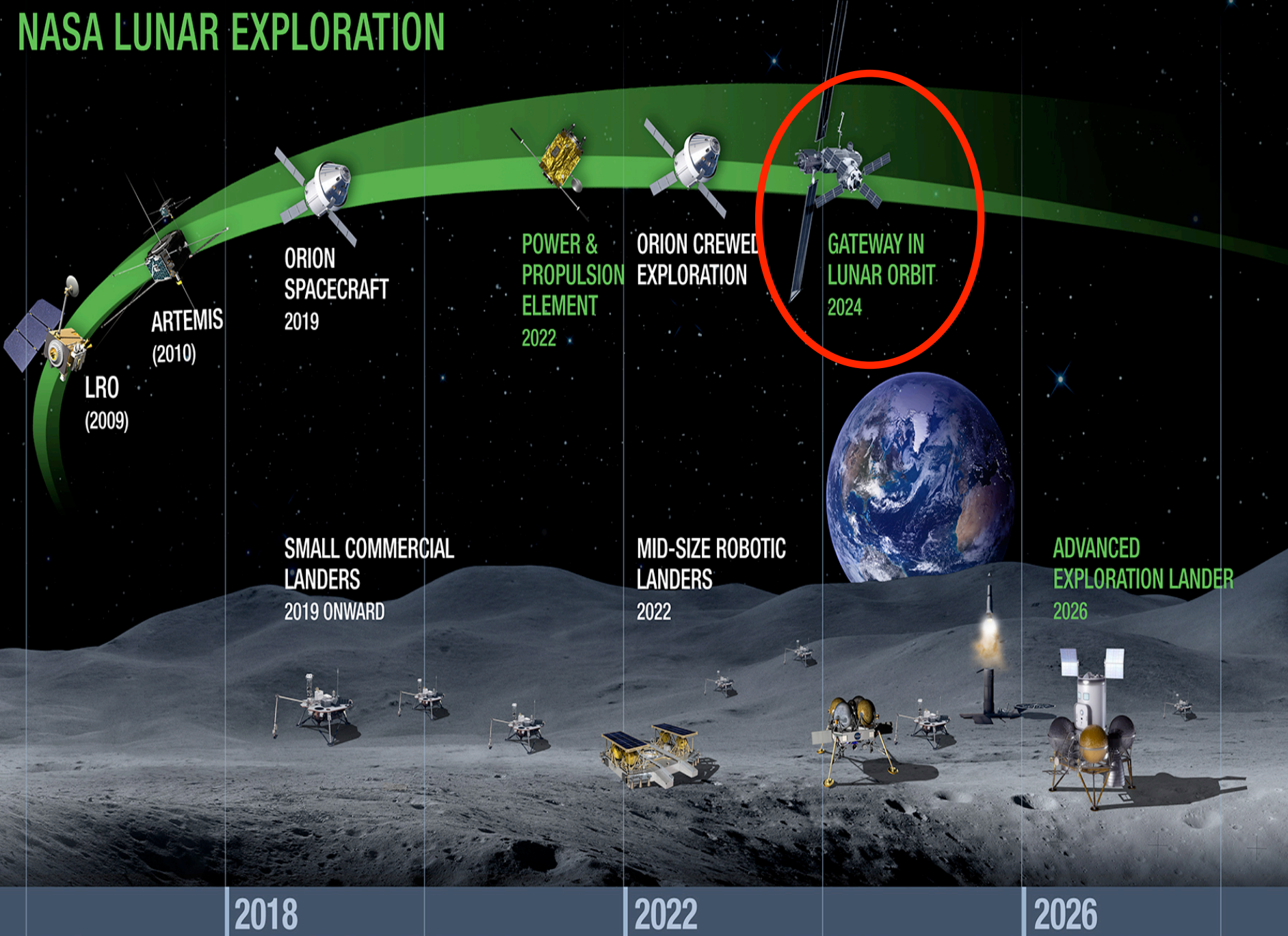
Phase 2

Complete Deep Space Transport and conduct yearlong Mars simulation mission.

Phases 3 and 4

Begin sustained crew expeditions to Martian system and surface of Mars.

NASA LUNAR EXPLORATION



LRO
(2009)

ARTEMIS
(2010)

ORION
SPACECRAFT
2019

POWER &
PROPULSION
ELEMENT
2022

ORION CREWED
EXPLORATION

GATEWAY IN
LUNAR ORBIT
2024

SMALL COMMERCIAL
LANDERS
2019 ONWARD

MID-SIZE ROBOTIC
LANDERS
2022

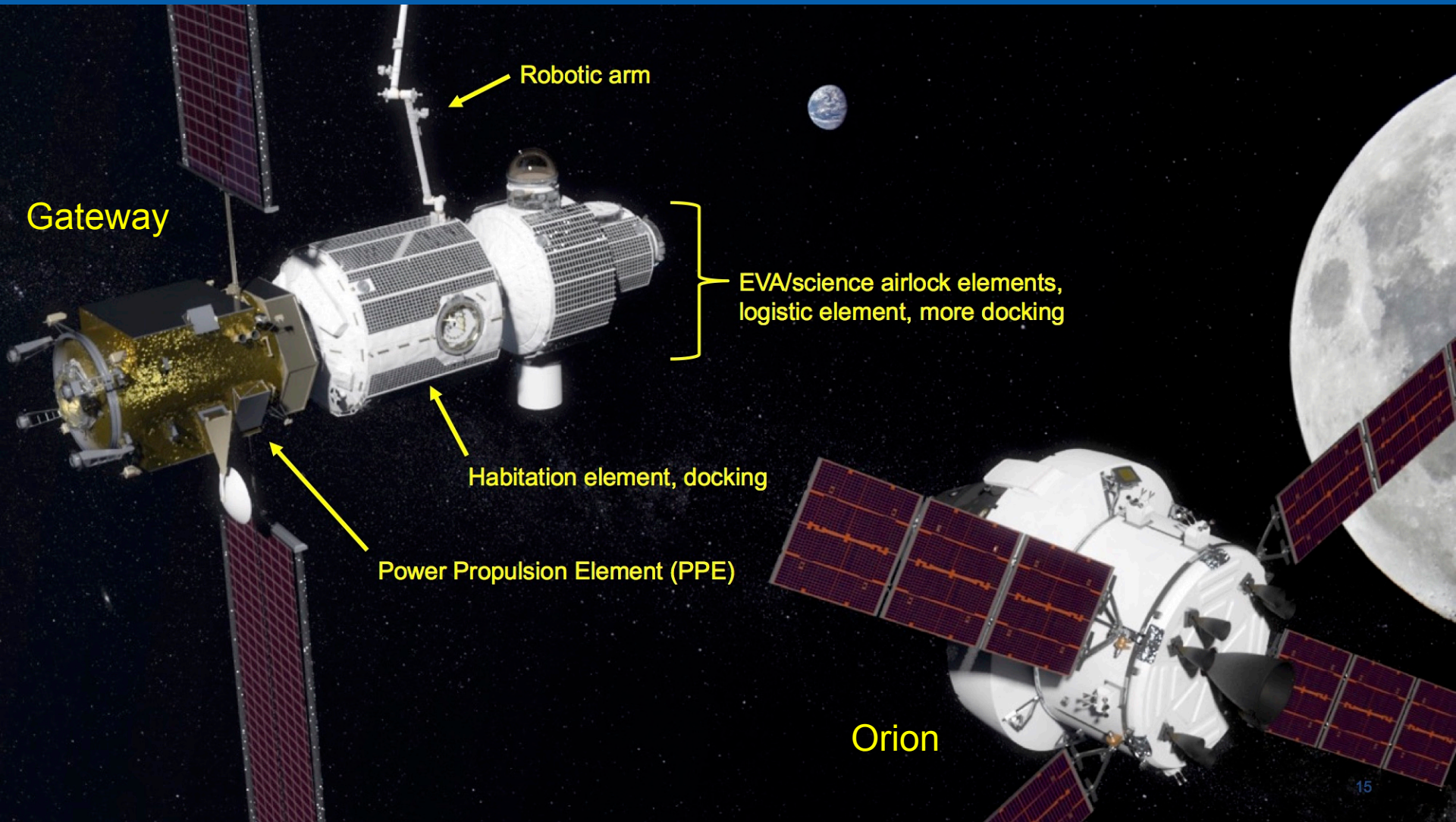
ADVANCED
EXPLORATION LANDER
2026

2018

2022

2026

Gateway Initial Configuration (Notional)



Gateway Initial Elements

Power and Propulsion Element (PPE)

- **First gateway capability** targeted for launch readiness in **2022**
- Power to gateway and externally accommodated elements
- Attitude control, orbit maintenance, and potential uncrewed orbit change
- Communications with Earth, space-to-space communications, and radio frequency relay capability

Habitation

- Provides habitable volume & short-duration crew life support
- Can be docked to the PPE, other elements, and visiting vehicles
- Offers attach points for external robotics, external science payloads, etc.
- Accommodations for crew exercise, science/utilization and stowage

Logistics

- Deliver cargo and supplies to enable extended crew mission durations
- Support science utilization, exploration technology demonstrations, potential commercial utilization



GATEWAY DEVELOPMENT

Establishing leadership in deep space and preparing for exploration into the solar system



FOUNDATIONAL GATEWAY CAPABILITIES

2022 2023 2024+



50 kW-class Power & Propulsion Element Habitation and Utilization Logistics and Robotic Arm Airlock

These foundational gateway capabilities can support multiple U.S. and international partner objectives in cislunar space and beyond.

CAPABILITIES

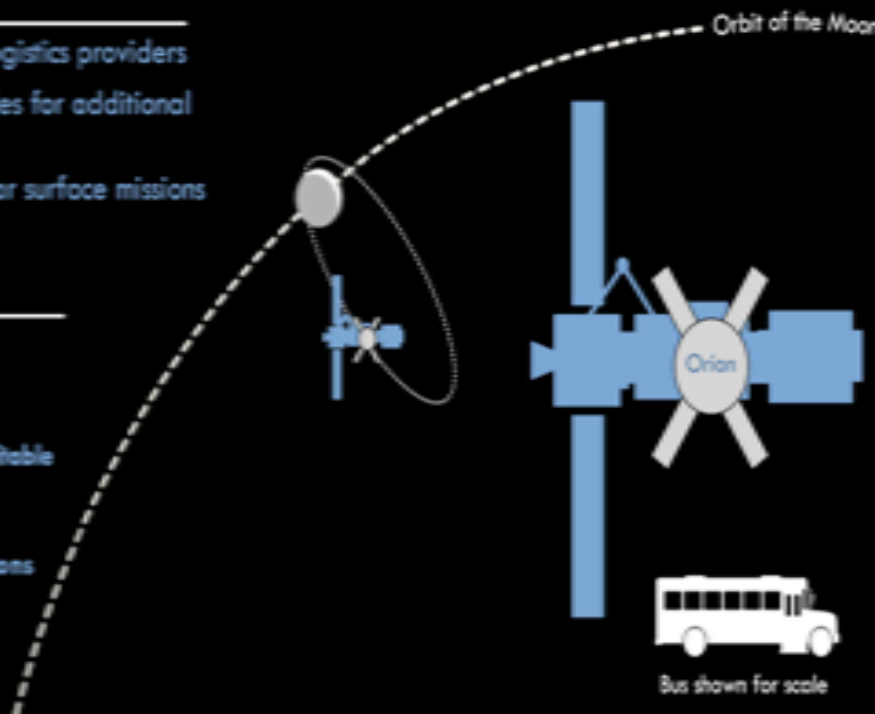
- Supports exploration, science, and commercial activities in cislunar space and beyond
- Includes international and U.S. commercial development of elements and systems
- Provides options to transfer between cislunar orbits when uncrewed
- External robotic arm for berthing, science, exterior payloads, and inspections

OPPORTUNITIES

- Logistics flights and logistics providers
- Use of logistics modules for additional available volume
- Ability to support lunar surface missions

INITIAL SCOPE

- 4 Crew Members
- At least 55 m³ Habitable Volume
- 30 Day Crew Missions
- Up to 75mt with Orion docked



Gateway Initial Scope

Crewed Missions

- 4 astronauts for 30 days
- Crew transit to/from Gateway using Orion
- Mission ops will likely be quite similar to ISS
- 55+ m³ habitable volume (ISS has 388 m³ habitable volume)
- May involve a variety of science and technology demo activities
- Likely high-bandwidth continuous communications with limited delay (10-30 sec round-trip)

Uncrewed Missions

- 92% of the year
- Will need a hybrid of ISS and robotic mission ops
- External and internal (tbd) robotics
- May involve a variety of science and technology demo activities
- Likely intermittent, high-bandwidth communications with limited delay (10-30 sec round-trip)



Gateway Utilization

Commercial

- Developing overall commercialization strategy
- RFI on commercial uses of a gateway (early Summer 2018)

International

- Developing strategy to involve international, ISS and non-ISS partners
- ESA could make major contributions: transportation and infrastructure

Science and Research

- Identifying potential science opportunities
- Assessing how gateway infrastructure can support future investigations
- Considering findings from Gateway science workshop (Feb 2018)

Technology

- **Evolve** initial capabilities or **enable** new capabilities for exploration
- Stimulate the development of commercial capabilities for cislunar space
- Evaluating **Gateway Technology Utilization RFI** (closed June 11)



Autonomous Crew Medical Operations

Tech Demo Concept:

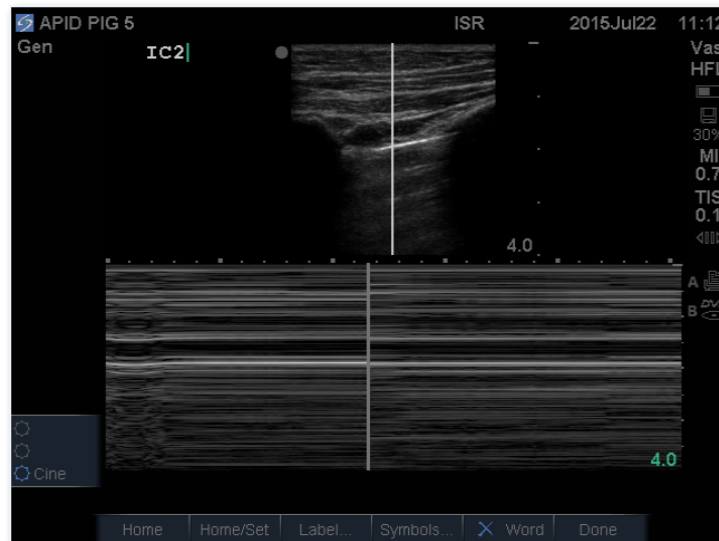
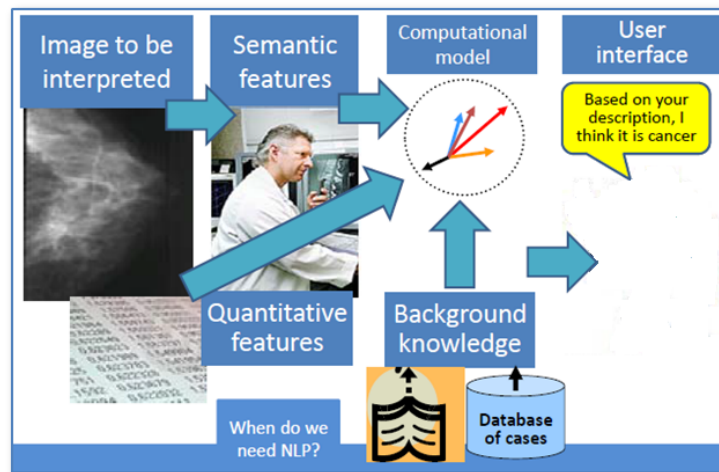
- Astronaut performs ultrasound self-exam and diagnosis without assistance from mission control. Requires decision support software for planning, conducting, and analyzing medical data.

Relevance:

- Will enable better contingency (loss of comm) robustness for crew health
- Will enable greater crew independence for deep-space missions

Gateway Requirements:

- Requires medical device data, vehicle data and crew self scheduling to be integrated
- Infusion of HRP Exploration Medical Capability, GCD AMO, and AES ASO technology



pulmonary ultrasound



Autonomous Crew In-Flight Maintenance

Tech Demo Concept:

- Astronaut performs inspection and repair of exercise equipment (as an example subsystem) without assistance from ground. Requires decision support software for planning, conducting, and execution of IFM procedures.

Relevance:

- Will enable better contingency (loss of comm) robustness for IFM
- Will enable greater crew independence from ground control for deep-space missions

Gateway Requirements:

- Requires equipment device data, vehicle data and crew self scheduling to be integrated
- Infusion of AES ASO technology



Exercise treadmill servicing



Carbon Dioxide Removal Assembly maintenance

IVA Payload Support Robot

Tech Demo Concept:

- IVA robot autonomously conducts IVA payload operations independent of crew and/or during uncrewed periods. Could be limited to specific “work area” and tasks.
- Example: robot initiates an experiment, periodically monitors and manipulates, perform shutdown, etc.

Relevance:

- Manage payloads without crew
- SBIR development could evolve into Gateway payload

Gateway Requirements:

- IVA robots need to be integrated into Gateway communications, power, and data systems
- Infusion of autonomous caretaking tech from AES ASO, AES LR, and GCD ISAAC (proposed) projects



*MANTIS arm concept
(Tethers Unlimited)*



IVA Caretaking Robot

Tech Demo Concept:

- IVA robot autonomously performs habitat caretaking independent of crew and/or during uncrewed periods
- Examples: (1) prepare for crew ingress after uncrewed period, (2) isolate & respond to anomaly, (3) routine monitoring

Relevance:

- Provides capability to ready the Gateway for crew arrival. Similarly, robotic systems may be used to “clean up” after crew.

Gateway Requirements:

- IVA robots need to be integrated into Gateway communications, power, and data systems
- Supports infusion of autonomous IVA caretaking tech from AES ASO, AES LR, GCD ISAAC (proposed), and STRI “SmartHabs” projects



*Astrobee free-flying robot
(under development)*



Questions?

