Human Exploration & Operations Overview

William H. Gerstenmaier
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“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.”
“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
LEAD THE EXPLORATION OF SPACE WITH INTERNATIONAL & PRIVATE SECTOR PARTNERS

DEVELOP SPACE
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
NASA’s Open Architecture Develops Space

**ISS as a model**

- Soyuz & Progress (Roscosmos)
- H-II Transfer Vehicle (JAXA)
- Orion/European Service Module (ESA)

**INTERNATIONAL**

- Cygnus (Northup Grumman)
- Dragon (SpaceX)
- Dream Chaser (SNC)
- Dragon Crew (SpaceX)
- Starliner (Boeing)

**COMMERCIAL CARGO & CREW**

- Multiple providers expected in lunar orbit and on the surface

**Lunar Surface**
# Sustaining Leadership Through The Buildup of Mutually-enabling Exploration Capabilities

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<th>Year</th>
<th>Event Description</th>
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<td>2018</td>
<td><strong>ISS Exploration Systems Testing and development of LEO commercial market</strong></td>
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<td>2022</td>
<td><strong>Buildup and Operations of Gateway in Lunar Orbit</strong></td>
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<td>2030s and Beyond</td>
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**Continue NASA, American industry, and international partner utilization of**
- LEO commercially available capabilities
- Lunar orbit
- Lunar surface

**NASA and private development and demonstration of robotic 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 cis-lunar missions
- Gateway in lunar orbit
- Larger lunar landers progressing toward human-class landers
- Mars sample return

Late 2030s
- First human mission to Mars
- Human and robotic lunar surface operations
- Prep for Mars mission

Timelines are tentative and will be developed further in FY2019
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
- Balance Disorders
- Fluid Shifts
- Visual Alterations
- Bone Loss

Distance from Earth
- Need for “autonomous” medical care – cannot return home for treatment

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

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

Isolation and Confinement
- Behavior aspect of isolation
- Sleep disorders
Leveraging Space Station: Habitation Systems (1/2)

**Habitation Systems Elements**

**LIFE SUPPORT**
- Excursions from Earth are possible with artificially produced breathing air, drinking water and other conditions for survival.
  - Atmosphere Management
  - Waste Water Management

**ENVIRONMENTAL MONITORING**
- NASA living spaces are designed with controls and integrity that ensure the comfort and safety of inhabitants.
  - Pressure
  - O₂ & N₂
  - Moisture
  - Particles
  - Microbes
  - Chemicals
  - Sound

**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

**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

**TODAY**
- Space Station
- Deep Space

**FUTURE**
- ~50% O₂ Recovery from CO₂
- 90% H₂O Recovery
- < 6 mo mean time before failure (for some components)
- 75%+ O₂ Recovery from CO₂
- 98%+ H₂O Recovery
- >30 mo mean time before failure

- 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
- Smaller, efficient equipment
- Onboard medical capability
- Long-duration food system
Habitation Systems Elements

**RADIATION PROTECTION**

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

**FIRE SAFETY**

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

**LOGISTICS**

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

**CROSS-CUTTING**

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

**TODAY**

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**

- 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**

Large CO₂ Suppressant Tanks

- 2-cartridge mask
- Obsolete combustion prod. sensor
- Only depress/repress clean-up

**LOGISTICS**

- Manual scans, displaced items
- Disposable cotton clothing
- Packaging disposed
- Bag and discard

**CROSS-CUTTING**

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

**TODAY**

Leveraging Space Station: Habitation Systems (2/2)
What It Takes To Come Home Safely

Low Earth Return
- 3 hours
- 1,650°C
- 28,160 KPH
- 400 KM

Lunar Return
- 3 days
- 2,870°C
- 39,750 KPH
- 386,240 KM

Mars Return
- 9 months
- 3,425°C
- 43,130 KPH
- 62,764,420 KM
Commercial Crew – Boeing Starliner
Commercial Crew – SpaceX Dragon
EXPLORE LUNAR SURFACE TRANSPORTATION CAPABILITY

DEVELOP COMMERCIAL LUNAR PAYLOAD SERVICES (CLPS)

LUNAR CATALYST TIPPING POINT
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.

**GATEWAY SPECS**
- **4 Crew Members**
- **30-90 Day Crew Missions**
- **125 m³ 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.

**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.
Path To Lunar Surface

- LRO (2009)
- ISS - SUSTAINABLE LOW-EARTH CAPABILITY 2000 –
- ARTEMIS (2020)
- ORION SPACECRAFT
- POWER & PROPULSION ELEMENT 2022
- ORION CREWED EXPLORATION
- GATEWAY IN LUNAR ORBIT 2026
- SMALL COMMERCIAL LANDERS 2019 –
- MID-SIZE ROBOTIC LANDERS 2022
- ADVANCED EXPLORATION LANDER 2026
Questions?