

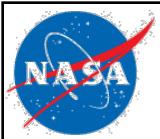
Humans and Robots to Mars Panel Discussion

AIAA Space 2018
Orlando, Florida

Hoppy Price

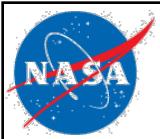
Jet Propulsion Laboratory
California Institute of Technology

September 18, 2018



Panelists

- Hoppy Price (NASA JPL), moderator
- Tim Cichan (Lockheed Martin)
- Mike Gernhardt (NASA JSC)
- Steve Hoffman (The Aerospace Corporation)
- Peter McGrath (Boeing)
- Tom Percy (NASA MSFC)

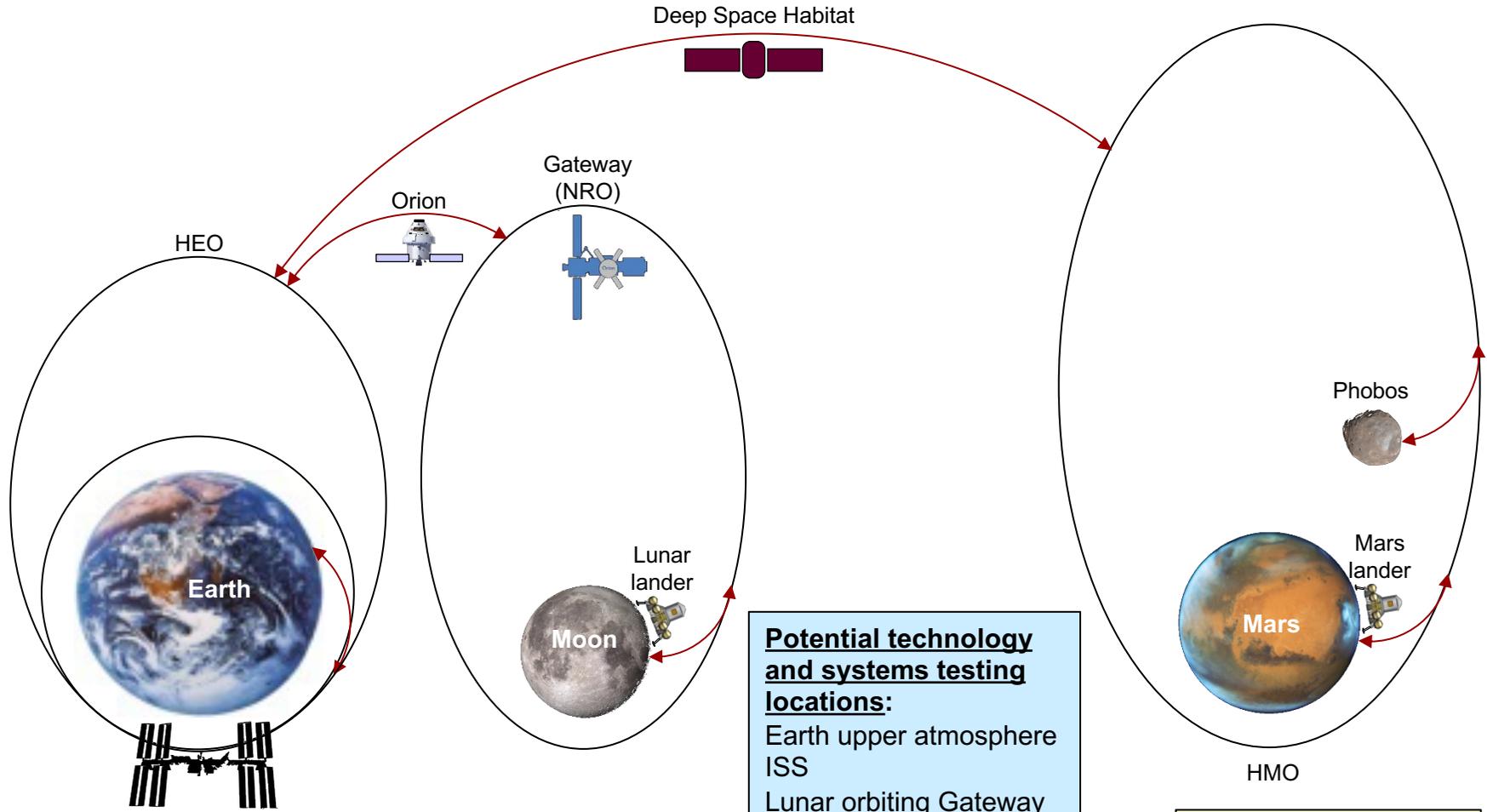


Panel Discussion Topics

- Human missions to Mars would require robotic precursors to qualify key technologies (e.g. EDL and ISRU) and to provide advanced data on landing sites and surface material properties
- Robotic vehicles would also be required in parallel with human vehicles to provide telecommunications relay, overhead reconnaissance, teleoperated access to extreme terrain and special regions, and surface element mobility, inspection, and maintenance. Robots would most likely be required for any mining of material for ISRU.
- Lunar mission precursors may be important for developing technologies, systems, and operations, and for retiring risks
- Missions to Phobos (and/or Deimos) might also be part of the human and robotic exploration strategy
- This panel will discuss the synergy and interaction between human and robotic vehicles and how they would need to be planned for in an integrated way



Human Exploration Destinations and Transit Segments



Potential technology and systems testing locations:
 Earth upper atmosphere
 ISS
 Lunar orbiting Gateway
 Lunar surface
 High Mars Orbit
 Phobos
 Martian surface

Acronyms:
 HEO = High Earth Orbit
 HMO = High Mars Orbit
 ISS = International Space Station
 NRO = Near Rectilinear Orbit
 LEO = Low Earth Orbit



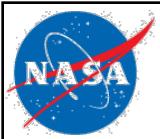
Robotic Mars Exploration Missions

MARS MISSIONS

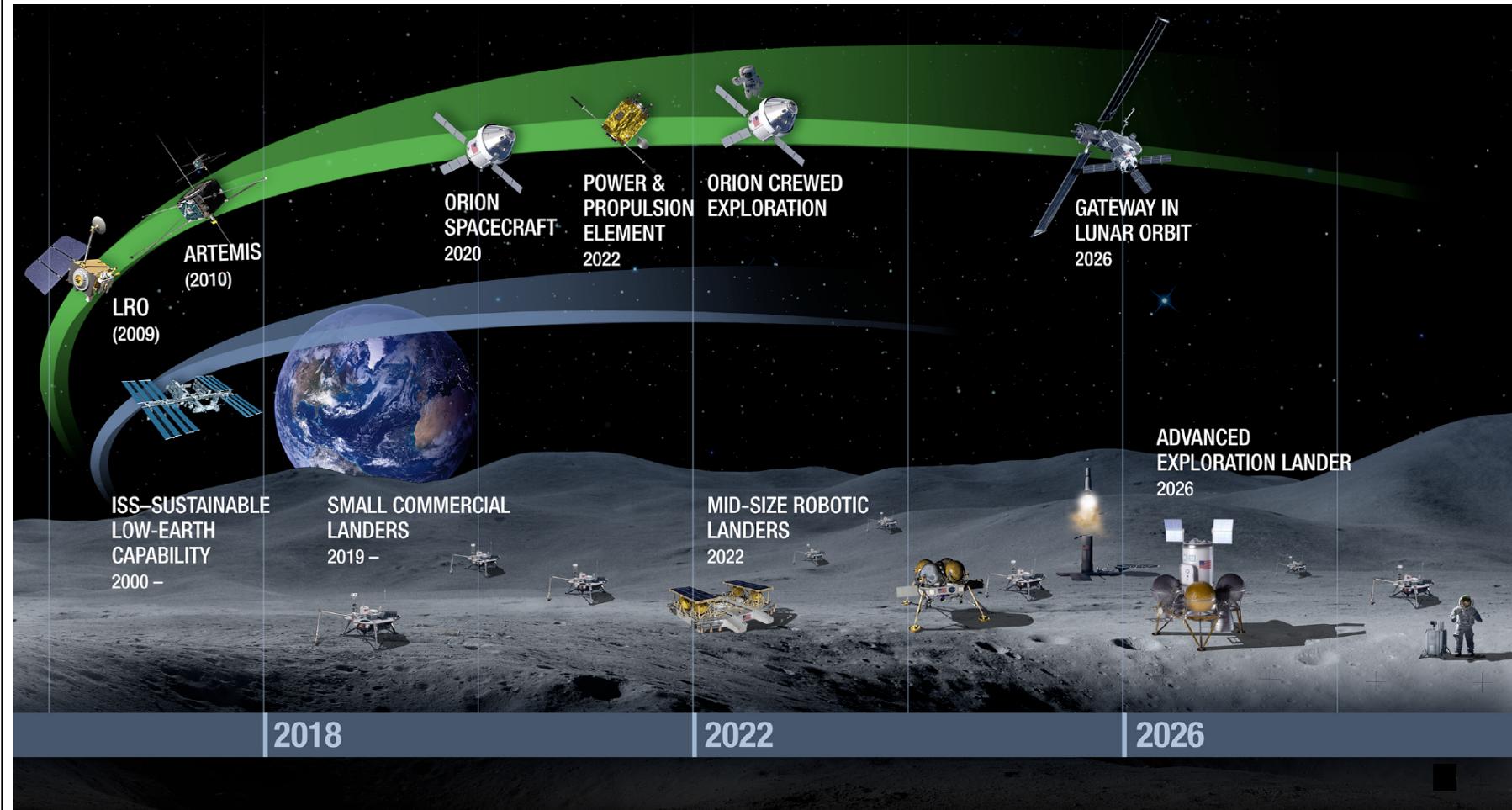
OPERATIONAL 2001–2017

2018 AND BEYOND





Notional Path to Lunar Surface





Robotic Missions to Support Crewed Missions

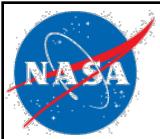
- Robotic precursor and support missions would be an integral part of a humans to Mars effort
 - Fill Strategic Knowledge Gaps (SKGs)
 - Qualify technologies to TRL 7
 - Provide key support to crewed missions
- Program system engineering, planning, and costing of these robotic missions would be important in developing a comprehensive go-forward plan for human exploration

| Notional Set of Robotic Precursors and Support Missions | Notional Proj. Start | Notional Launch Date | Comments |
|--|-----------------------------|-----------------------------|---|
| Commercial lunar lander | 2020 | 2023 | Currently under study by private companies |
| Commercial lunar prospector | 2020 | 2024 | Could be a commercial/NASA collaboration |
| Mars Sample Return | 2020 | 2026 | Currently under study |
| Mars EDL Tech Demo | 2022 | 2026 | Sub-scale SRP lander (Earth atmosphere and/or Mars testing) |
| Phobos precursor lander | 2023 | 2028 | To characterize surface conditions and dust parameters |
| Phobos reconnaissance orbiter | 2023 | 2028 | Phobos orbit or flybys from Mars orbit |
| Phobos telecom orbiter | 2026 | 2031 | Leading or trailing in Phobos orbit |
| Mars ISRU robotic precursor | 2026 | 2031 | LOX from atmosphere and/or H2O from a Martian source |
| Teleoperated Mars rover(s) | 2027 | 2033 | Extreme terrain for cliffs and caves? Sterilized for special regions? |
| H2M Hi Res imaging orbiter | 2030 | 2035 | For landing site selection and continuing mission support |
| H2M relay orbiters | 2030 | 2035 | More advanced than Electra. Could tie in with relay orbiters. |



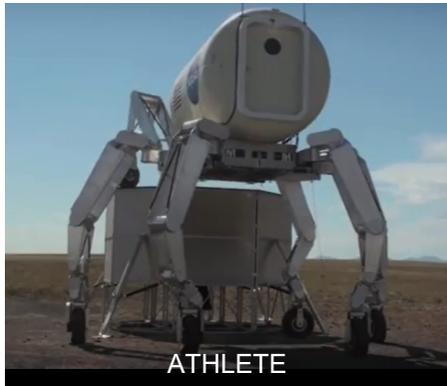
Robotic Precursor Mission Concepts

- Mars Sample Return
 - Sample Return Lander is under study to retrieve Mars 2020 samples and launch them to Mars orbit with a small MAV
 - Mars Sample Return orbiter is being studied by ESA
 - Earth Entry Vehicle is being studied by NASA
- Entry, Descent, and Landing demo mission
 - Would demonstrate a Supersonic Retro-Propulsion (SRP) EDL system that would be scalable for feed-forward to crewed Mars landers and cargo deliveries of at least 20 t
- ISRU demo mission(s)
 - Would follow-up on MOXIE to demonstrate LOX production and storage and/or breathing oxygen for crews
 - There could potentially be pathfinder missions to mine water from hydrated minerals or near-surface ice and process it into useful products (e.g. propellants, drinking water)



Robotic Vehicle Concepts to Support Human Missions

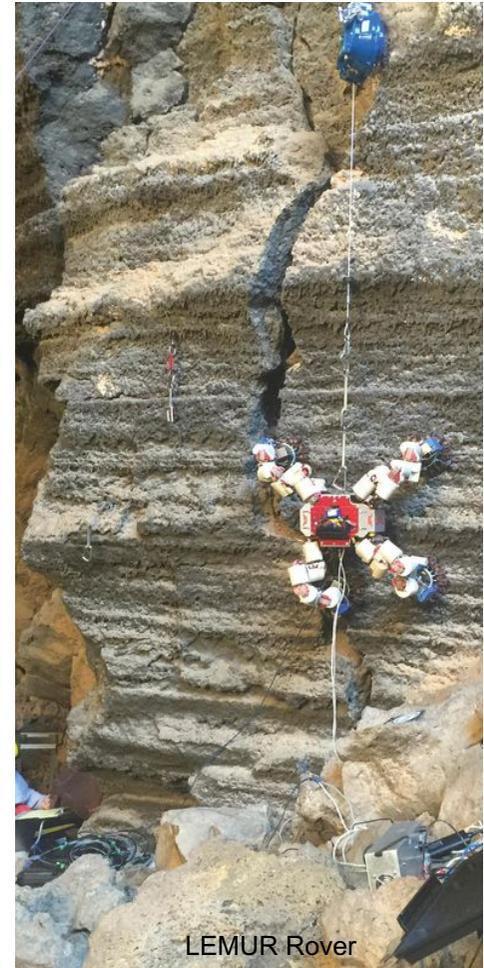
- ATHLETE type vehicles to relocate large elements
- Tractor type vehicles for digging and moving regolith
- Moderate to deep drilling systems
- Fine manipulator rovers to configure crew transfer tunnels, ISRU connections, troubleshooting and contingency deployment of arrays and radiators, perform inspections and repairs
- Telecom relay rovers
- Teleoperated sterilized rovers for special regions
- Extreme terrain exploration rovers (cliffs, caves)



ATHLETE



DuAxel Rover



LEMUR Rover