Computer Human Interface Challenges in Space Exploration

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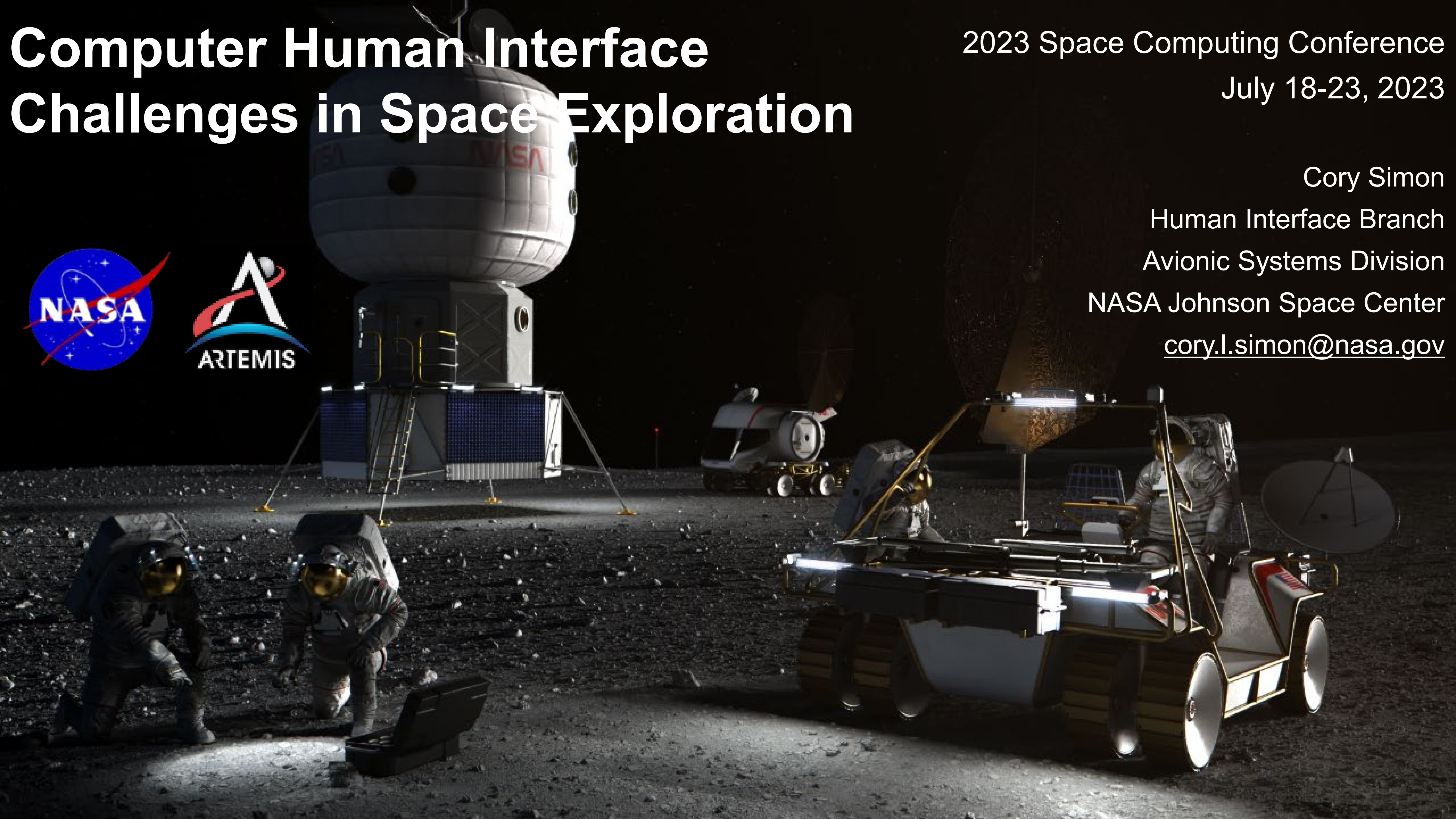
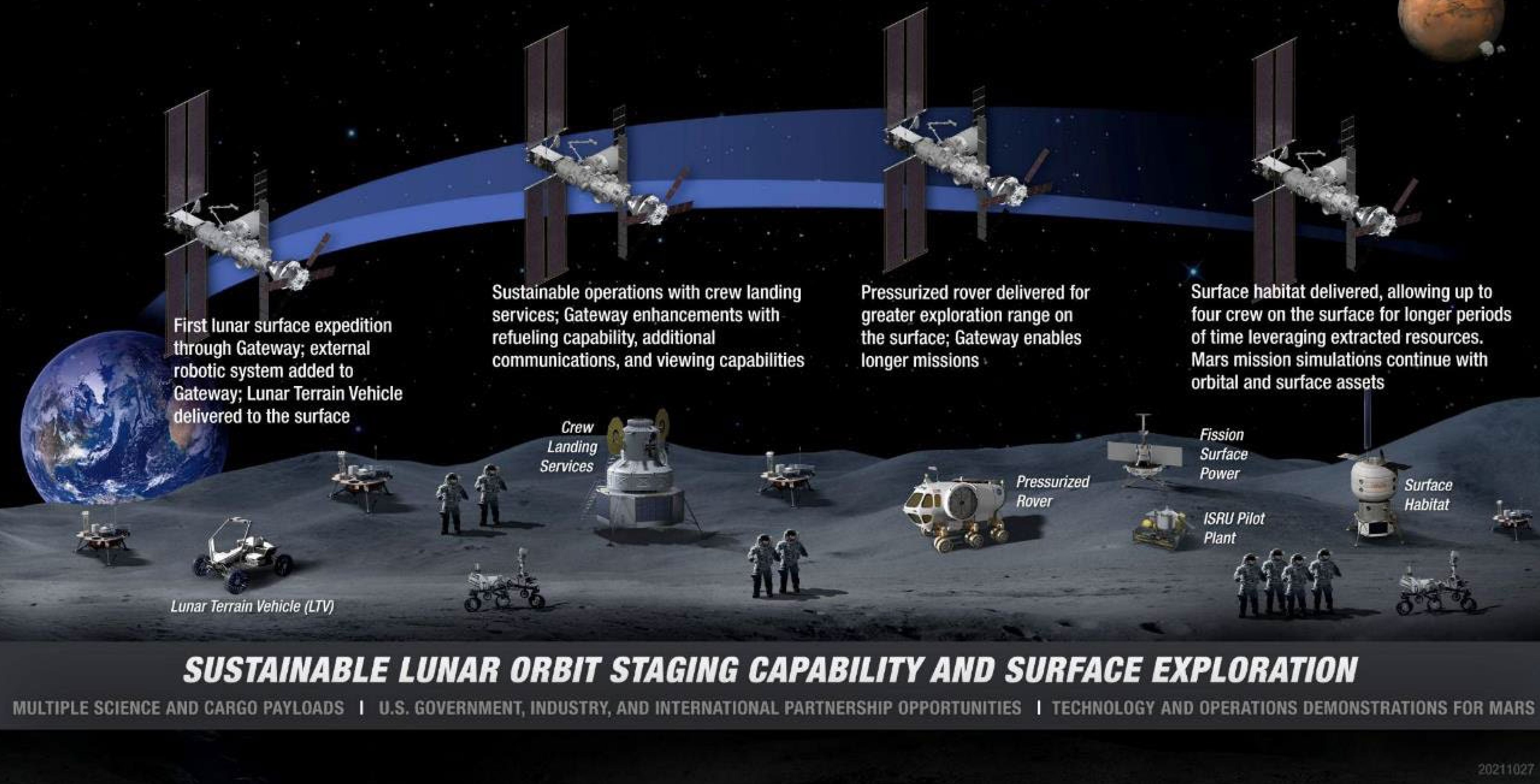
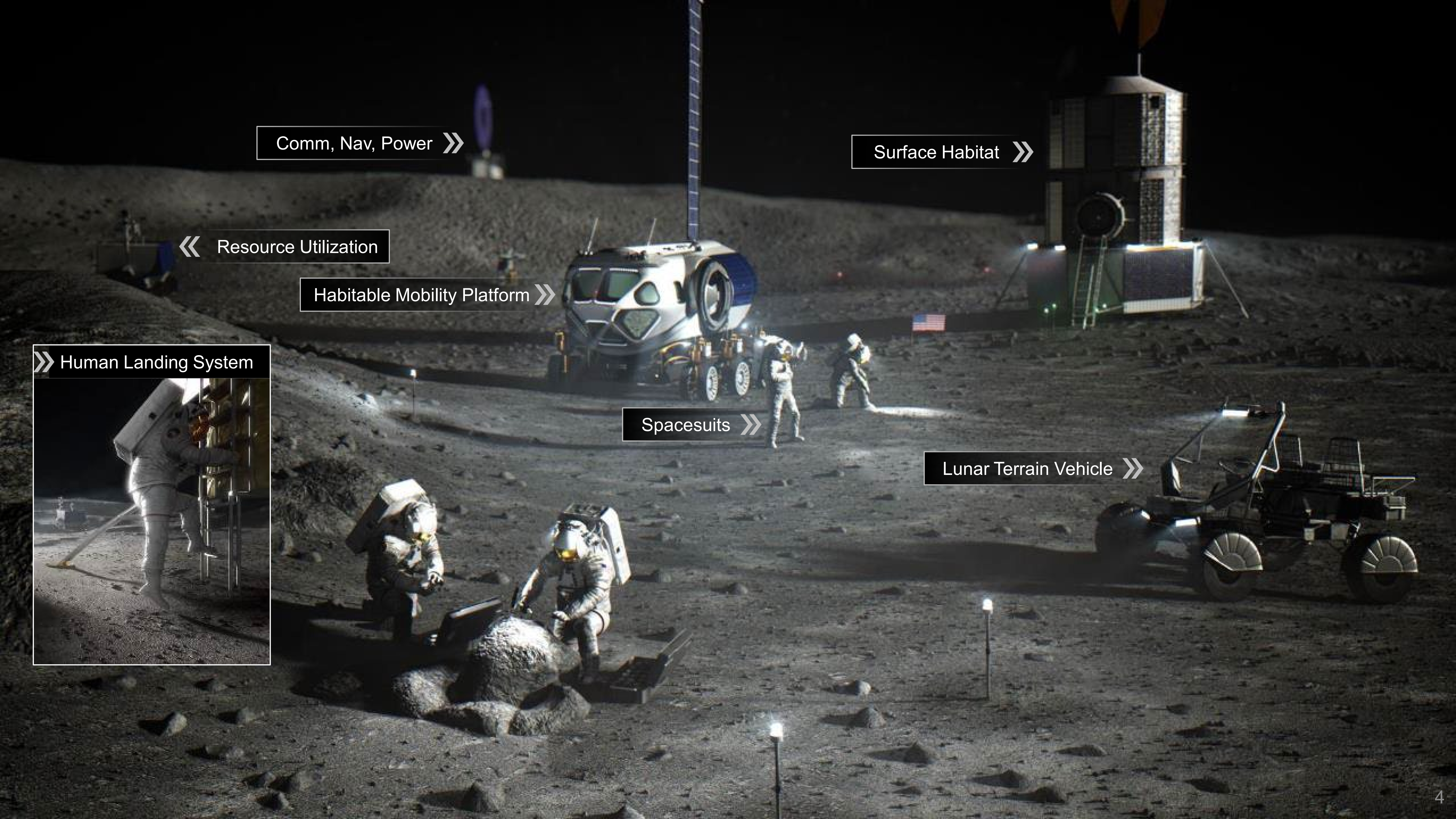


Outline

- NASA's Artemis Campaign
- Flight Crew's Changing Role in Human Spaceflight
- Computer Human Interface Domains
- New Missions, Unique Technology Challenges
- Reaching Toward Mars
- Connecting with NASA

NASA's Artemis Campaign





Comm, Nav, Power
Surface Habitat
Resource Utilization
Habitable Mobility Platform
Human Landing System
Spacesuits
Lunar Terrain Vehicle

Flight Crew’s Changing Role in Human Spaceflight

Traditional Role

- Test Pilot, monitor spacecraft and nav
- Control core and payload systems
- Caution and Warning (C&W) interaction
- Audio and text communication

Current Role

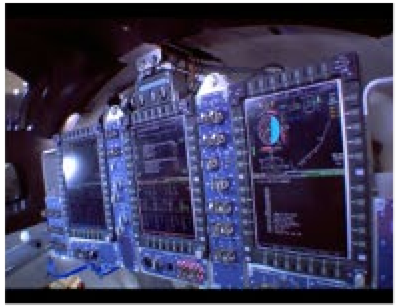
- Electronic procedures and checklists
- Video conferencing and public outreach
- Maintenance, inventory, stowage ops
- Telerobotics and telemedicine

Future Role

- Autonomy mgmt, collaborative planning
- Real time training and remote coaching
- Multi-spacecraft and robotics management
- Doctor, scientist, inspirational proxy

Gemini Cockpit Electromechanical

Shuttle CRT Cockpit



Orion Glass Cockpit

Tablet in use ISS

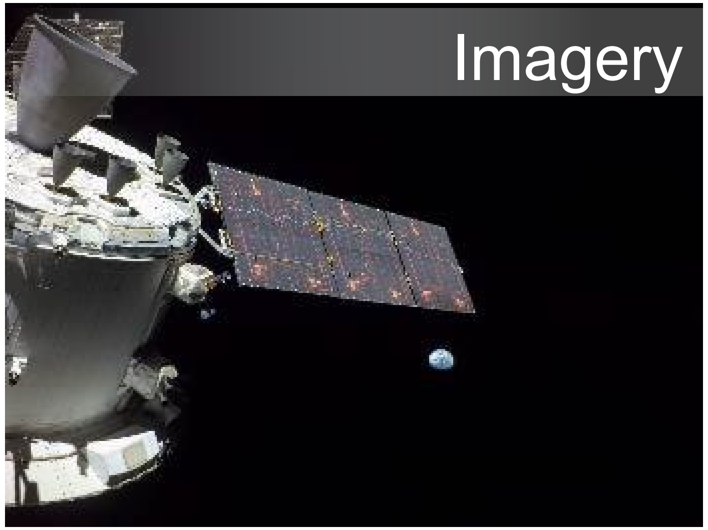
Hololens Demo ISS

EVA HUD Prototyping

Multi-vehicle Lunar missions require special attention to information and interaction

- **Information availability among mission actors: Crew, Mission Control, Vehicles, Automation, Robotics**
- **Natural and consistent human interfaces; Lowering the barrier between humans, information, and systems**
- **Public engagement expectations have increased significantly – real time video, shared experiences, access to crew**

Computer Human Interface Domains



New Missions, Unique Technology Challenges

Foundational Challenges for Spacecraft Computer Human Interfaces

- **Lack of radiation-tolerant electronics drives architectures, designs, performance, and risk**
- **Spacecraft CHI avionics hardware is unique**
  - Humans in space are unique, require systems that are not needed for satellites
  - Needs are not fully met by space-rated parts development to date

Deep Space Crew Display Challenges

Driving Use Cases

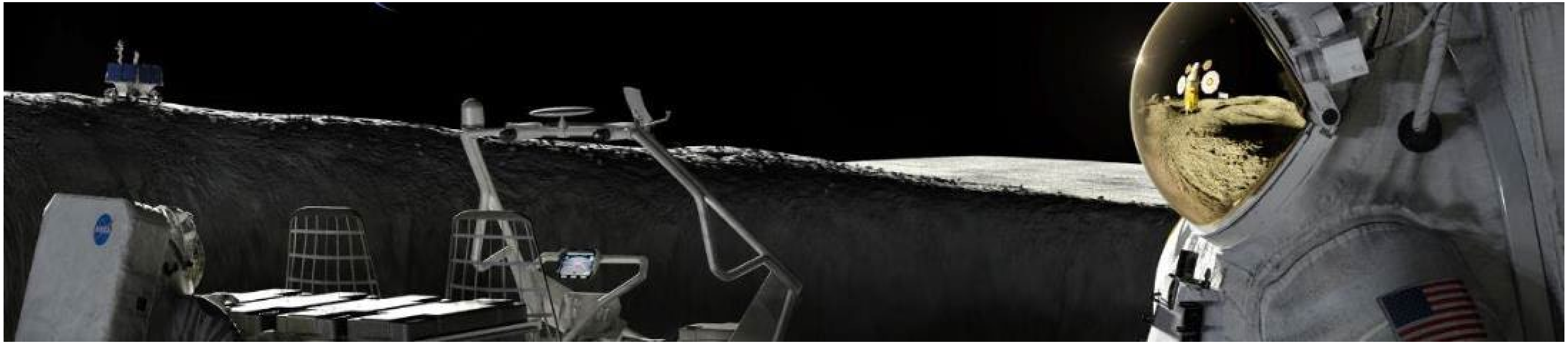
- Enable crew to reliably perform safety-critical and time-sensitive tasks

Key Challenges

- Pixel Technologies: NASA is wrapping up a study of the radiation tolerance of various pixel technologies (Bautista, Ryder, Garrett)
  - Need to couple best performing pixel tech with driving electronics, processing, and multi-layer software mitigations
- Space Suit Displays: NASA has investigated usability, hardware, and software under Joint AR Project (Mitra, Krygier, Miller)
  - Projection optics on curved helmet bubble remains very challenging
  - Development needed on very low power/processing rendering software
  - Radiation performance characterization of projection technologies is still needed

Display Performance Targets

- NASA-STD-3001 Vol 2, Human Factors, Habitability, and Environmental Health, specifies visual display parameters (Table 10.4-2)
- Display performance requirements vary by how the display is used



Deep Space Audio System Challenges

Driving Use Cases

- Audio systems provide voice communications and alarms – safety-critical time-sensitive functions

Key Challenges

- Industry/market gap: radiation-tolerant audio system with spacecraft network interfaces are not easily available or quickly developed

Performance Targets

- Continuous G.729 or G.711 encoding, decoding, and teleconferencing
- NASA-STD-3001 Vol 2: ensure 90% word recognition using ANSI/ASA S3.2-2009, Method for Measuring the Intelligibility of Speech (10.5.3.7 Speech Intelligibility)

Deep Space IT Infrastructure Challenges

Driving Use Cases

- Basic IT devices: servers, routers/switches, wireless access points, laptops, tablets…
- Functions: portable device communication, network services, data storage, software updates

Key Challenges

- Very little empirical data on the reliability of modern IT devices in the Lunar radiation environment
  - Artemis I Callisto payload included an iPad (Lockheed Martin/Jones)
  - Two generations of HPE Spaceborne Computer have flown on ISS in low Earth orbit (Hewlett Packard)
- ISS heritage and commercial software depend on modern network services and operating systems (Windows, Windows Server, Linux, iPad OS, etc.)

Performance Targets

- Standards-based, general purpose/multi-use, expandable, virtual machine support, highly reliable
- Support frequent updates - patching, software updates, new features, and unanticipated operational needs

Radiation Tolerance Performance Targets

- **Lack of radiation-tolerant electronics drives architectures, designs, performance, and risk**
- **RT Design Goal 1: Destructive Single Event Effects (SEEs) Immunity**
  - Up to Linear Energy Transfer (LET) of 60 MeV-cm2/mg
  - SEE characterization of performance, failure modes
- **RT Design Goal 2: Non-destructive SEE Immunity**
  - Minimize probability and duration of down time
- **RT Design Goal 3: Total Ionizing Dose (TID) Tolerance**
  - 100Krads(Si), TNID and ELDRs considered
  - TID characterization of performance, failure modes

Reference Mission Profiles

Lunar Mission Description *Displays, Audio are needed during crewed periods*	**Example Spacecraft**
30 days in Lunar orbit *Crewed for full mission*	Orion
15 years in Lunar orbit *Crewed for 30 days annually*	Gateway
10 years on Lunar surface *Crewed for 20 days annually*	Lunar Rover
10 years in Lunar orbit *Crewed for 20 days annually, transported to/from Lunar Surface*	Space Suit
3 months in Lunar orbit *Crewed for 20 days on Lunar surface*	Lunar Lander

Key References

- Cross-Program Design Specification for Natural Environments (DSNE)
- Space System Verification Approach Based on MEAL and Mission Risk Posture (2018 Gonzalez et al)

Reaching Toward Mars

Communication latency drives Earth-independent operations

New roles for crew, new needs for information and interaction, new technology demands

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