Enabling Technologies for Deep Space Imaging

SpaceOps 2018

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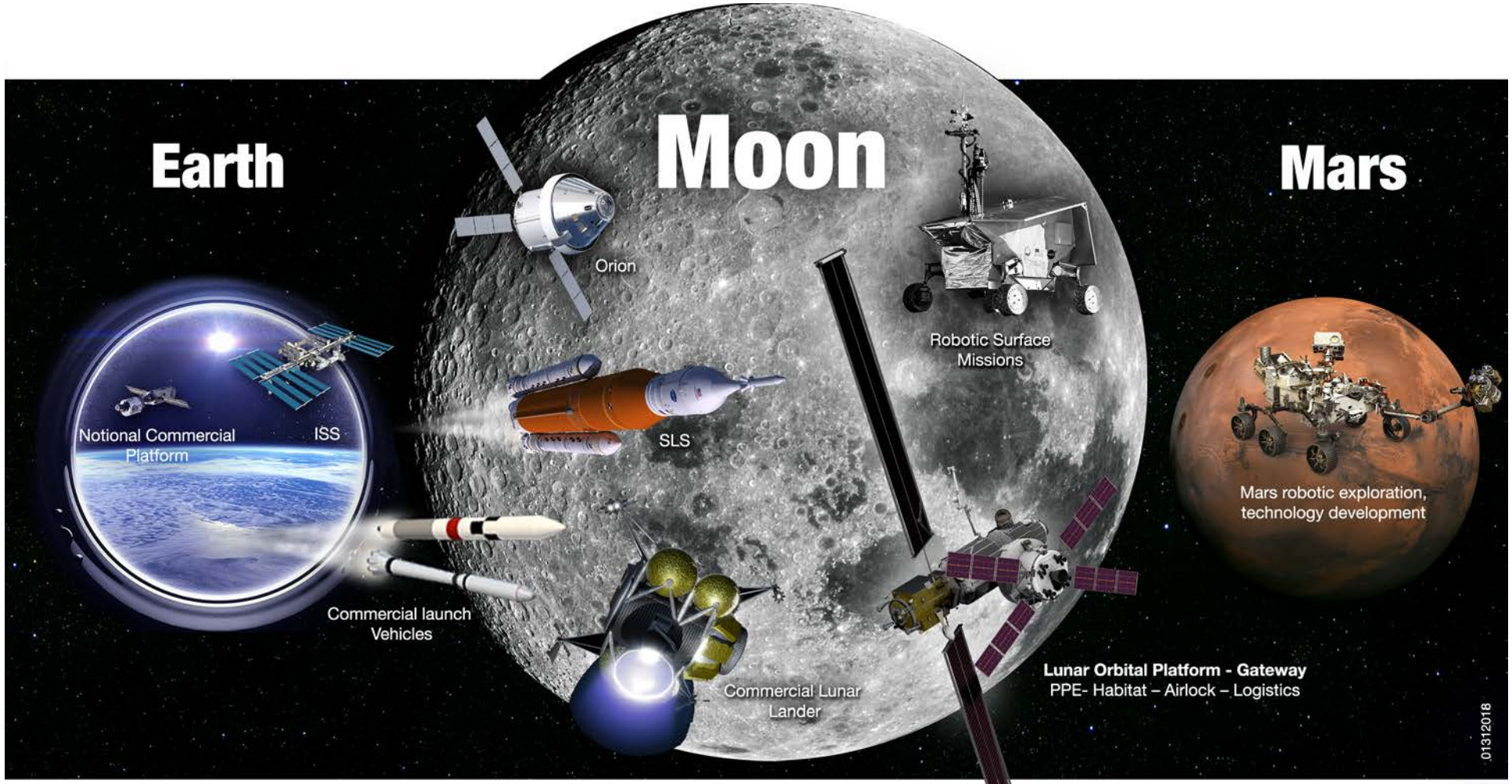
EXPLORATION CAMPAIGN

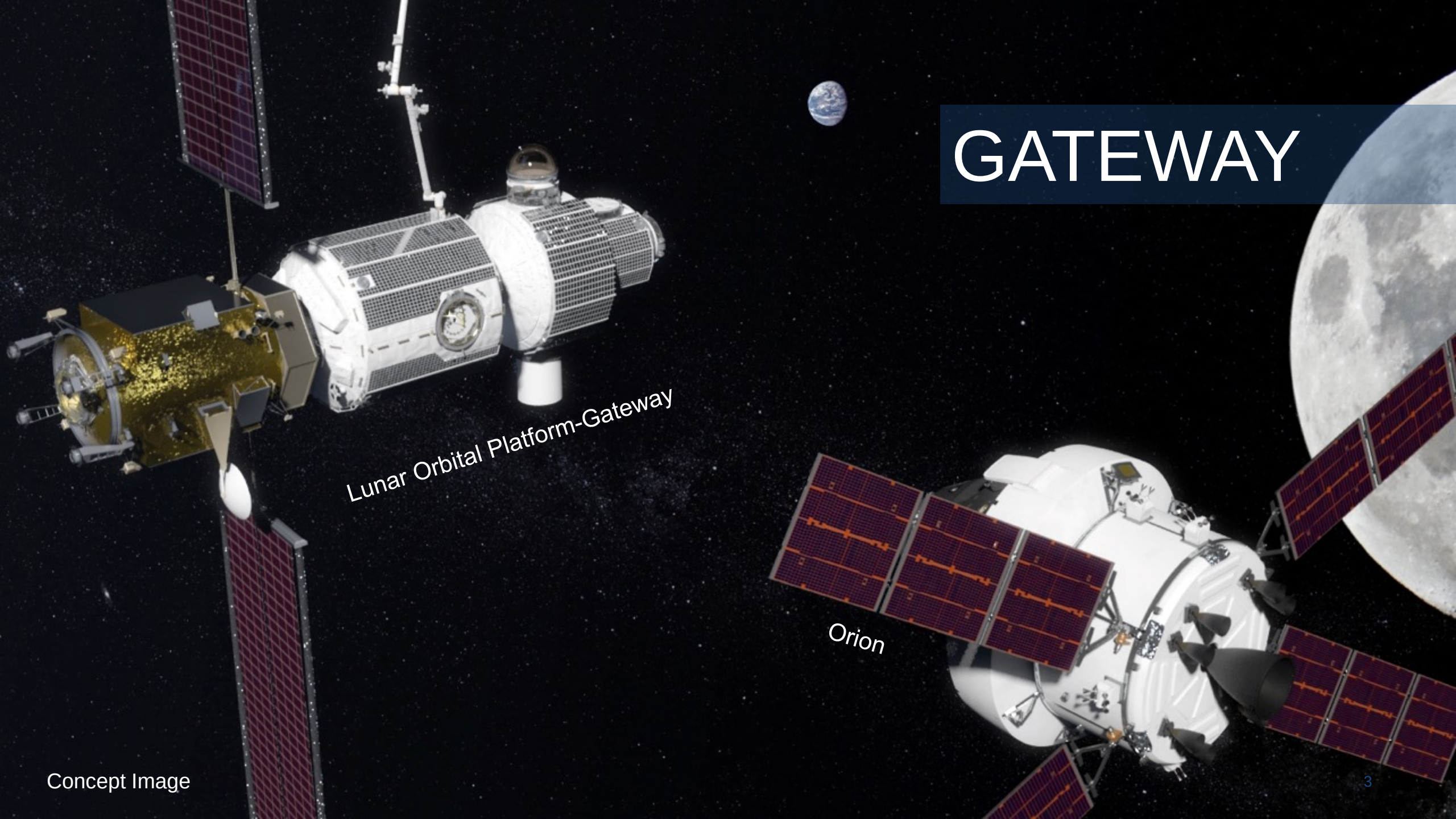


In LEO
Commercial & International partnerships

In Cislunar Space
A return to the moon for long-term exploration

On Mars
Research to inform future crewed missions

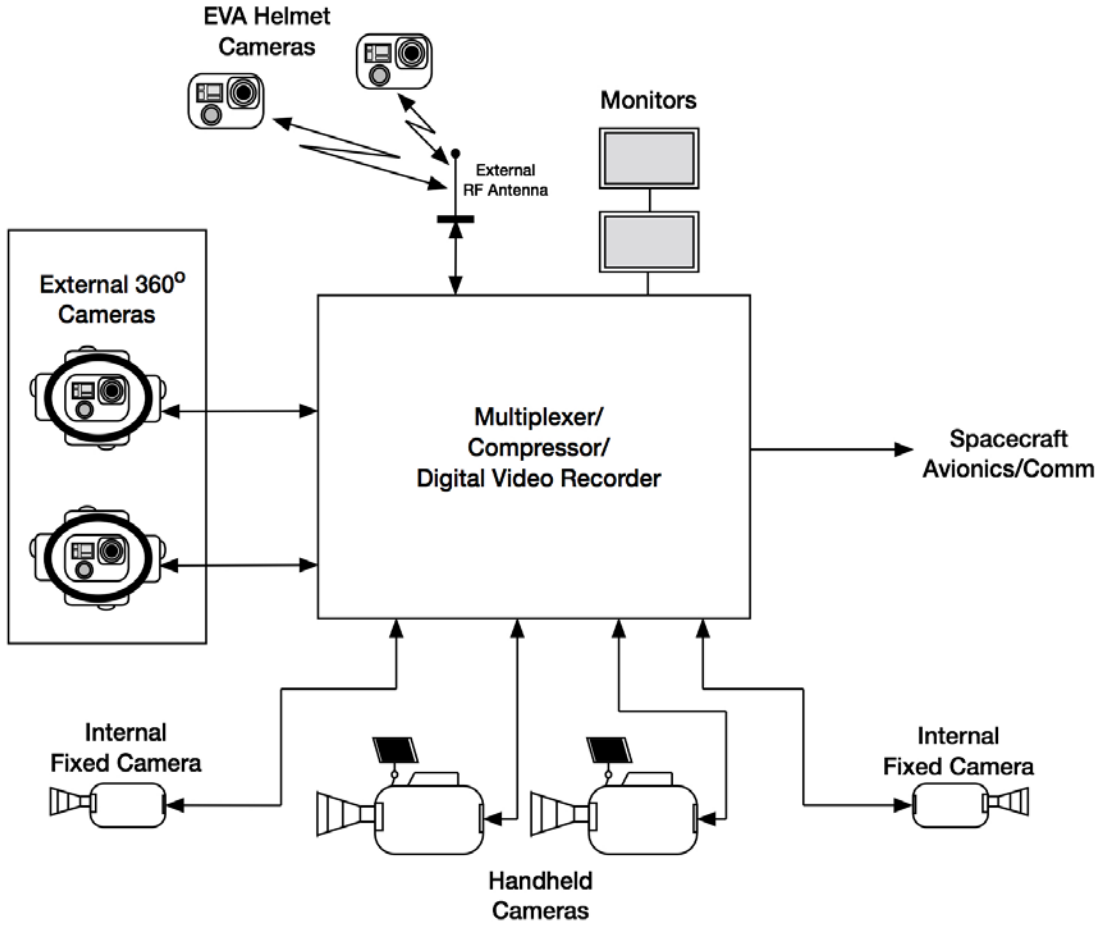
GATEWAY



Concept Image

Basic System Design and key technology challenges

- **Cameras**
  - HDTV
  - Ultra-High Definition
  - 8K
  - 360˚ field-of-regard
  - Radiation Tolerance
    - Pixel pitch appears to be critical factor
- **Compression**
  - MPEG-4 h.264
  - HEVC h.265
  - Latency
- **Intelligent Systems**
  - Situational awareness
  - Spacecraft integrity

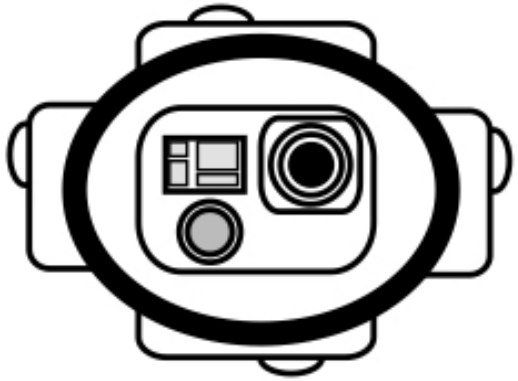


Cameras for Deep Space Applications

- **Resolution**
  - High Definition Television
    - 1280 x 720 or 1080 x 1920
    - Progressive scan preferred
  - Ultra-High definition
    - 2160 x 3840
    - Progressive Scan
    - Multiple frame rates of 25, 30, 50 and 60 are most common
  - 8K!
    - Being used already by Japanese Broadcaster NHK
  - Higher resolution allows for broad field-of-view to be used with little to no loss of detail
  - But more pixels means more data to compress and higher bandwidth for streaming and file transfers
    - Mitigate with better, more efficient compression
- **Environment**
  - Radiation
    - Ionizing radiation causes dead pixels
    - CMOS performs better than CCD
    - Very inconsistent experience with commercial cameras
    - Best to assume replacement every 12-18 months vs. trying to rad harden cameras

360˚ Field-of-Regard Camera systems

- Pan/Tilt systems for use in space are very bulky, heavy and expensive
  - Still limited with only one field-of-view at a time
  - Would not allow tracking of object in real-time
- New camera systems are available with a 360° field-of-regard with no moving parts
  - Would allow selected field-of-view by stitching imagery from up to three cameras at a time
  - Could allow multiple fields-of-view simultaneously from the same camera system
  - Dramatically reduces the mass required and should reduce the # of cameras needed to cover a large area
- Challenges
  - Real-time stitching requires high-performance Graphics Processing Units (GPU)
  - Placement of the stitching GPU system may need to be inside the vehicle, which means the live output of the 360° camera system would require up to a 12 Gbps link
  - Protecting the camera system from radiation damage
  - Containing the camera system for vacuum and thermal while still providing the 360° field-of-regard



Compression & Transmission protocols

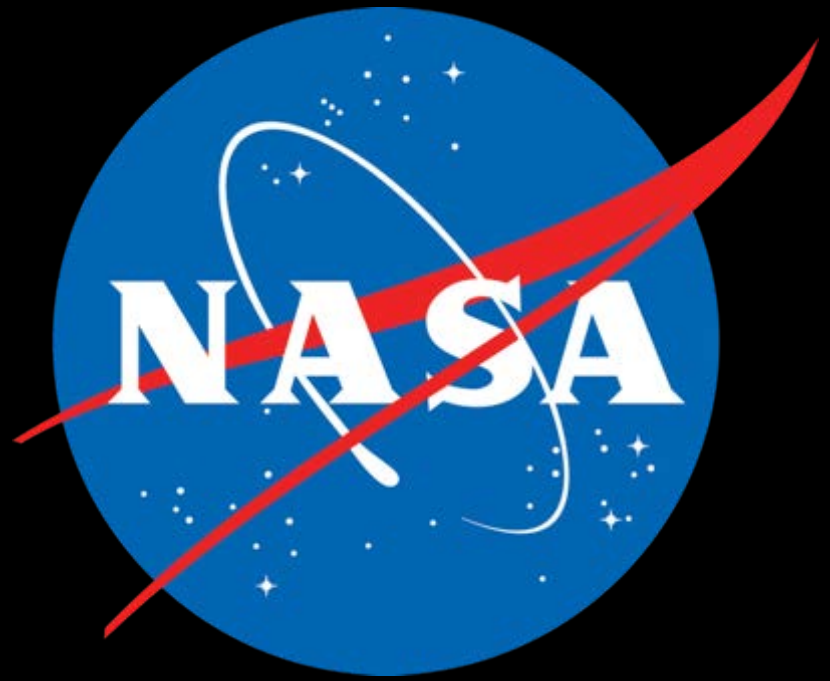
- HDTV raw uncompressed is 1.5 Gbps
- UHD can be up to 12 Gbps depending on frame rate
- MPEG-4 part 10 (also referred to as h.264) compression has been in use on the ISS for several years
  - ~ 8 Mbps commonly used for live HDTV downlinks
- High Efficiency Video Coding (HEVC, or h.265) is successor to h.264 and offers much better performance
  - Allows encoding of UHD at low bit rates
  - Used for Live UHD downlink demonstration from the ISS @ National Association of Broadcasters 2017 Expo
  - Could provide same quality HDTV @ much lower bitrates than h.264 (2-3 Mbps vs. 8 Mbps)
- Both h.264 and h.265 commonly use MPEG-2 Transport Streams for distribution over internet protocol networks (either UPD or RTP)
  - Works well with high performance TCP/IP networks and most commercial encoders/decoders
  - Sensitive to jitter and packet loss
    - Results in frozen or degraded image on screen because decoder doesn't have all the data
  - For live streaming over disruptive networks, use of Delay Tolerant Networking may mitigate issues
    - CCSDS Motion Imagery & Applications and Delay Tolerant Networking Working Groups currently looking into options for streaming over disruptive networks
- CCSDS Motion Imagery & Applications Working Group also investigating using Real Time Protocols without an MPEG-2 Transport Stream as an alternative distribution method

Intelligent Systems

- Concepts of Operation for the Gateway assume long periods of time when the spacecraft is uncrewed
- Mars mission concepts also include spacecraft placed in orbit or on the surface ahead of crew arrival
- Imagery systems with intelligent systems could be useful for vehicle integrity assurance and confirmation of other sensors
  - Heat detection using InfraRed or Near InfraRed capable systems could be used in conjunction with fire detection sensors
  - Motion detection software analyzing the imagery could be used to flag controllers or crew that something has changed in or around the spacecraft, or that something hit the spacecraft
  - Using photogrammetry the integrity of the spacecraft could be monitored
    - Requires characterization of the system
    - Imagery would be aware of the normal edges or shape of the spacecraft in the field-of-view
  - Using facial recognition or color recognition could enable the imaging system to automatically keep track of each crew member's location
    - Could be critical during an emergency to verify all crew members have evacuated
  - Proper metadata for each camera system will allow controllers and crew to precisely monitor spacecraft integrity and performance, as well as distances between objects of vehicles during rendezvous
    - x/y/z axis of field-of-view
    - Camera location
    - Timing

Links

- **https://images.nasa.gov/**
  - NASA's primary imagery gallery
- **On Amazon Prime TV, search for "Live ISS UHD downlink" to view the UHD live downlink demonstration from NAB 2017**
- **https://archive.org/details/NASA-Ultra-High-Definition**
  - Downloadable 4K videos
- **https://youtu.be/rgBKFEeXfww**
  - Music video featuring ISS 4K imagery & updated rendition of "Sounds of Silence"
- **https://youtu.be/lil_I_-7aOM**
  - VR 360° video shot inside Neutral Buoyancy Lab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