

A composite image of deep space exploration. In the foreground, a blue spacecraft window frame is visible on the right. In the background, the International Space Station is seen in orbit above the Earth's horizon. The Moon is visible in the upper right, and the reddish surface of Mars is partially visible at the top right.

# Enabling Technologies for Deep Space Imaging

Government Video Expo 2018

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# Space Policy Directive-1

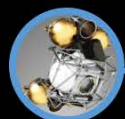


“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.

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.”

# GATEWAY

A spaceport for human and robotic exploration of 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.



## SAMPLE RETURN

Pristine samples robotically delivered to the Gateway for safe processing and return to Earth.

- **Cameras**

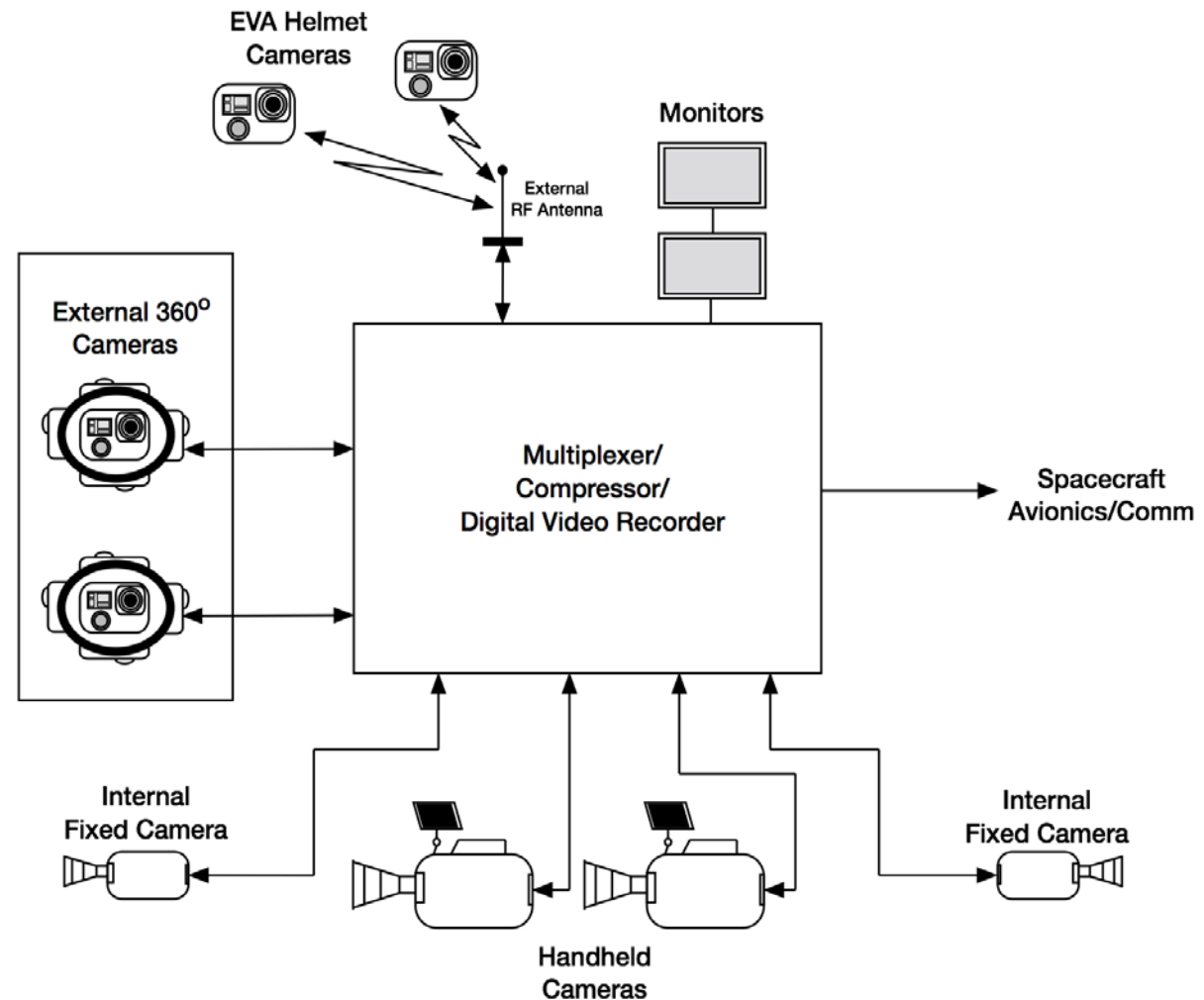
- HDTV
- Ultra-High Definition
- 8K
- 360° field-of-regard
  - Pixel pitch appears to be critical factor
- Radiation Tolerance

- **Compression**

- MPEG-4 h.264
- HEVC h.265
- Latency

- **Intelligent Systems**

- Situational awareness
- Spacecraft integrity



- **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
  - Could extract HD from wide field-of-view to create virtual pan/tilt/zoom
- But more pixels means more data to compress and higher bandwidth for streaming and file transfers
  - Mitigate with better, more efficient compression

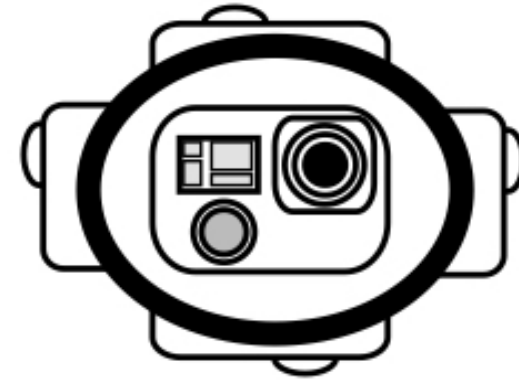
- **Environment**

- 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



- 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 UDP 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

- 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

- <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](https://youtu.be/lil_I_-7aOM)
  - VR 360° video shot inside Neutral Buoyancy Lab
- <https://youtu.be/7k2uKb9vCOI>
  - First 8K from space
  - Downloadable here, <https://images-assets.nasa.gov/video/First-8K-Video-from-Space/First-8K-Video-from-Space~orig.mp4>

