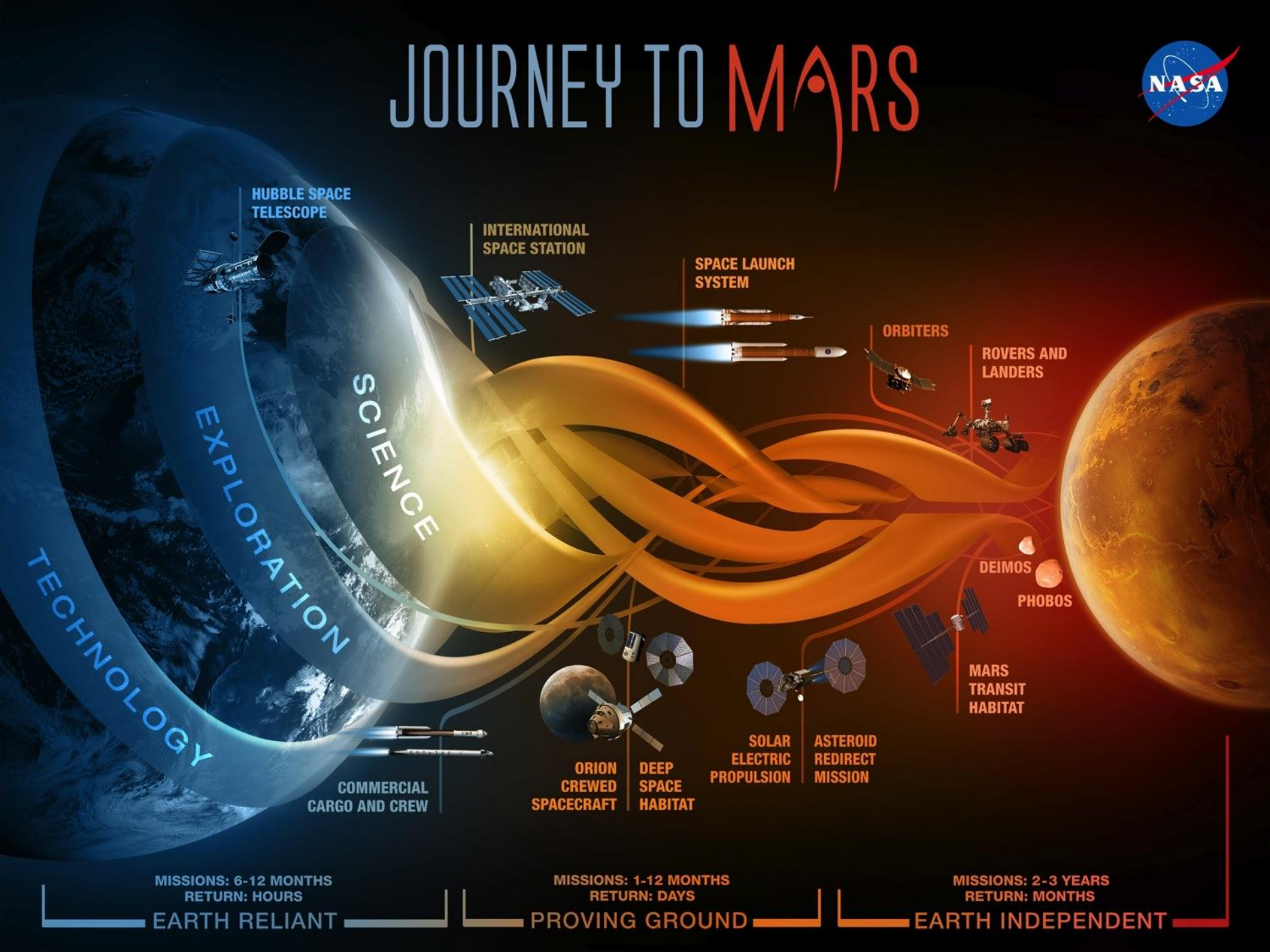
National Aeronautics and Space Administration

More & Better Pixels

How NASA plans to use HDR, 4K, VR and other technologies to take everyone along for the ride to Mars

Rodney Grubbs
NASA Imagery Experts Program Manager

JOURNEY TO MARS



MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT

MISSIONS: 1-12 MONTHS
RETURN: DAYS
PROVING GROUND

MISSIONS: 2-3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

Human Exploration of Mars is Hard

20-30 tons
Ability to land large payloads needed

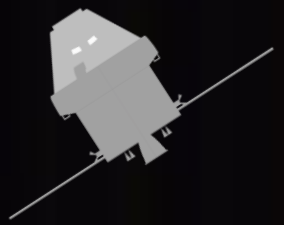
130 tons
Heavy-lift mass means **multiple** launches per mission

13.5 km/s Earth re-entry speed

800-1100 days away from Earth in micro gravity and high levels of radiation

Reliable in-space transportation:
Total continuous transportation power

Thin atmosphere and dusty conditions for surface operations.



44 minute max two-way communication delay
2-week blackout every 26 months when Earth and Mars are on opposite sides of the sun

20 tons of oxygen needed for ascent to orbit: In-Situ Resource Utilization (ISRU)

Some links while I'm talking

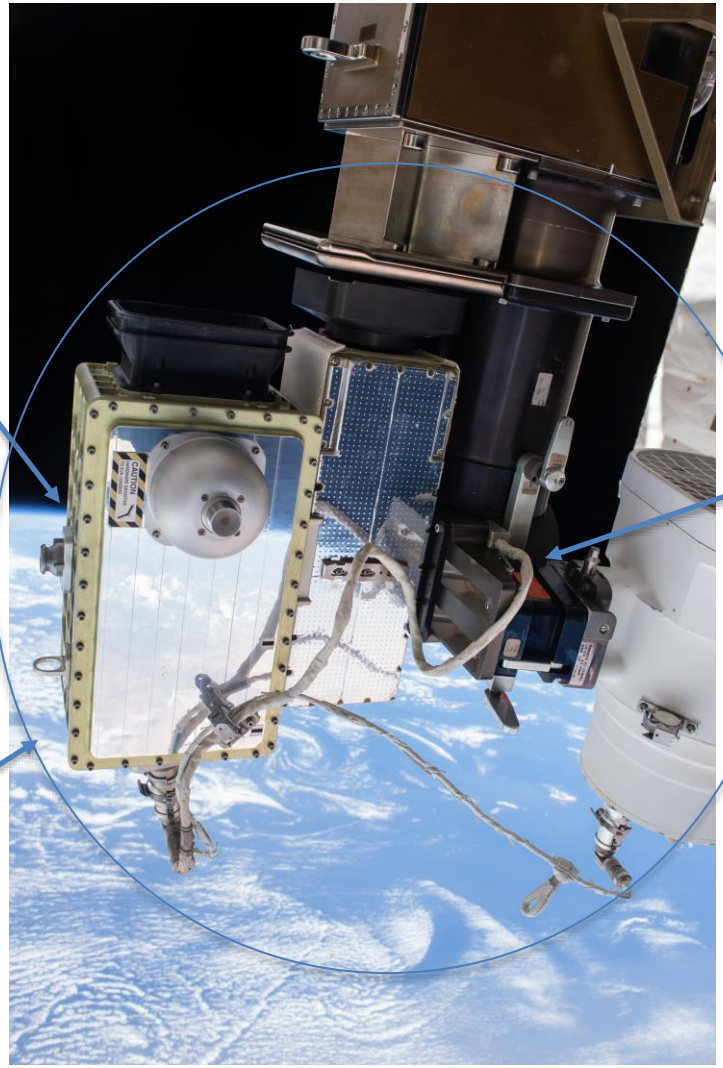
- https://www.youtube.com/results?search_query=NBL+VR
  - Or search "NBL VR" in YouTube
- https://www.youtube.com/watch?v=DhmdyQdu96M
  - Or search "Space Station Fisheye" in YouTube
- http://mars.jpl.nasa.gov/msl/multimedia/interactives/
  - Billion pixel VR from Mars
- https://www.youtube.com/watch?v=nPfcwT4Fcy8
  - Cool HDR/HFR of rocket motor test
- http://images.nasa.gov
  - Our new on-line imagery gallery
    - Downloadable video coming soon

How do evolving video technologies help us explore space?

- VR/360 degree camera systems offer advantages due to lack of moving parts
  - Allows pan/tilt function
  - How to get live video off a system with small sized unit?
  - Autonomous/Smart technology to be self-aware?
  - Buffer video?
- High Dynamic Range
  - Color negative film has long been the choice for imaging dynamic events with high contrast (such as engine firings, rocket launches)
  - HDR offers a digital equivalent of film
- High Frame Rate
  - High speed film cameras are still in use to capture dynamic events where events happen quickly
  - HFR offers a digital equivalent of film
- UHD, 6K, 8K
  - Engine tests, spacecraft surveys, rocket launches all require high spatial resolution for analysis purposes
  - Again, digital equivalent of film

New ISS External HDTV Camera

HDTV Camera housing attached to original NTSC Camera/pan-tilt unit



Pan/Tilt mechanism

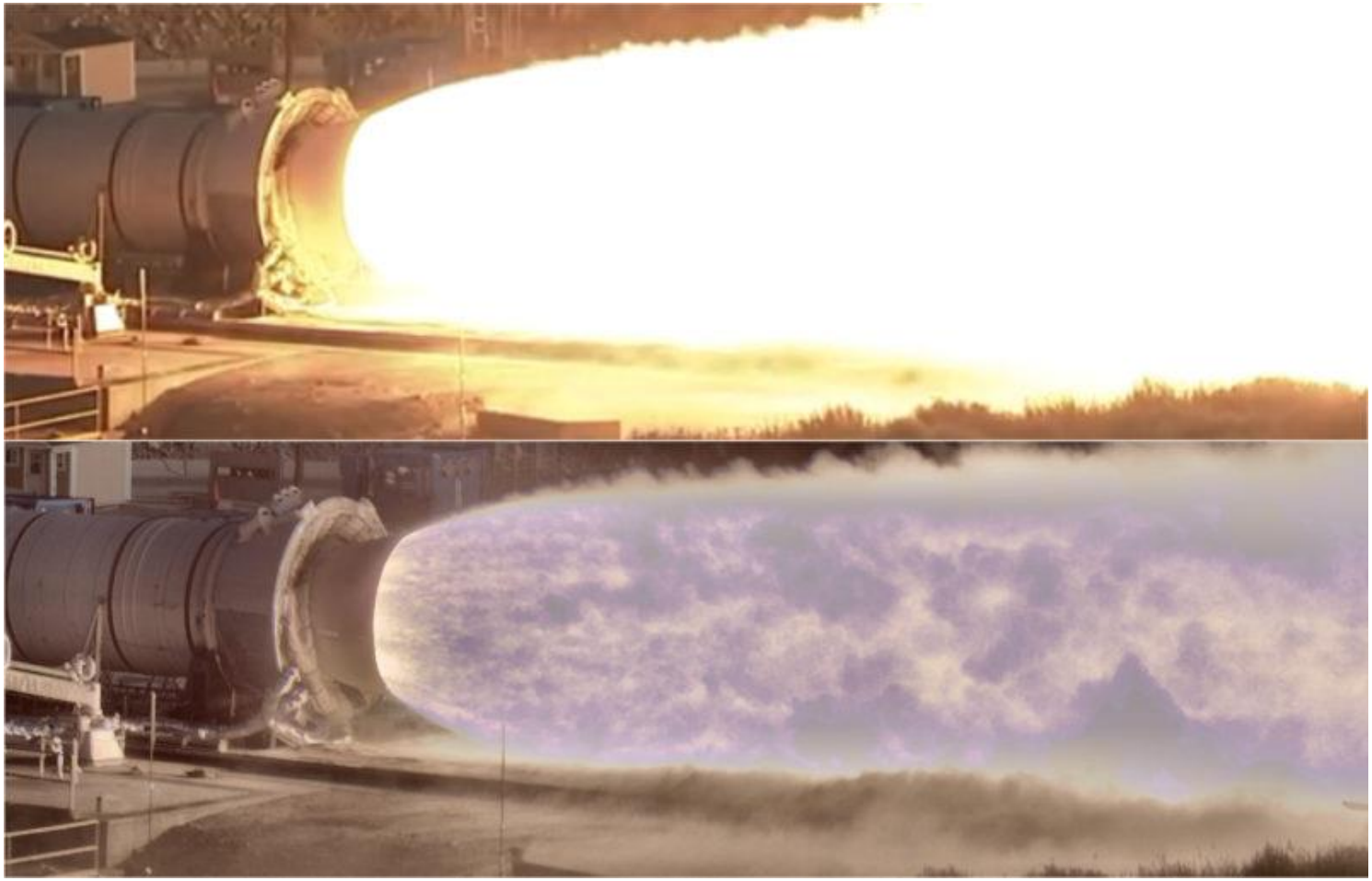
This is a lot of mass just to have a point-able camera!

HDR Example

RED EPIC HDR 6 mode illustrating dual exposure, A Frame

RED EPIC HDR 6 mode illustrating dual exposure, X Frame

HDR and HFR for engineering



Great write-up about this technology
http://petapixel.com/2016/08/06/nasa-rocket-test-shot-incredible-new-hdr-high-speed-camera/

Challenges for Imagery Architecture 1/2

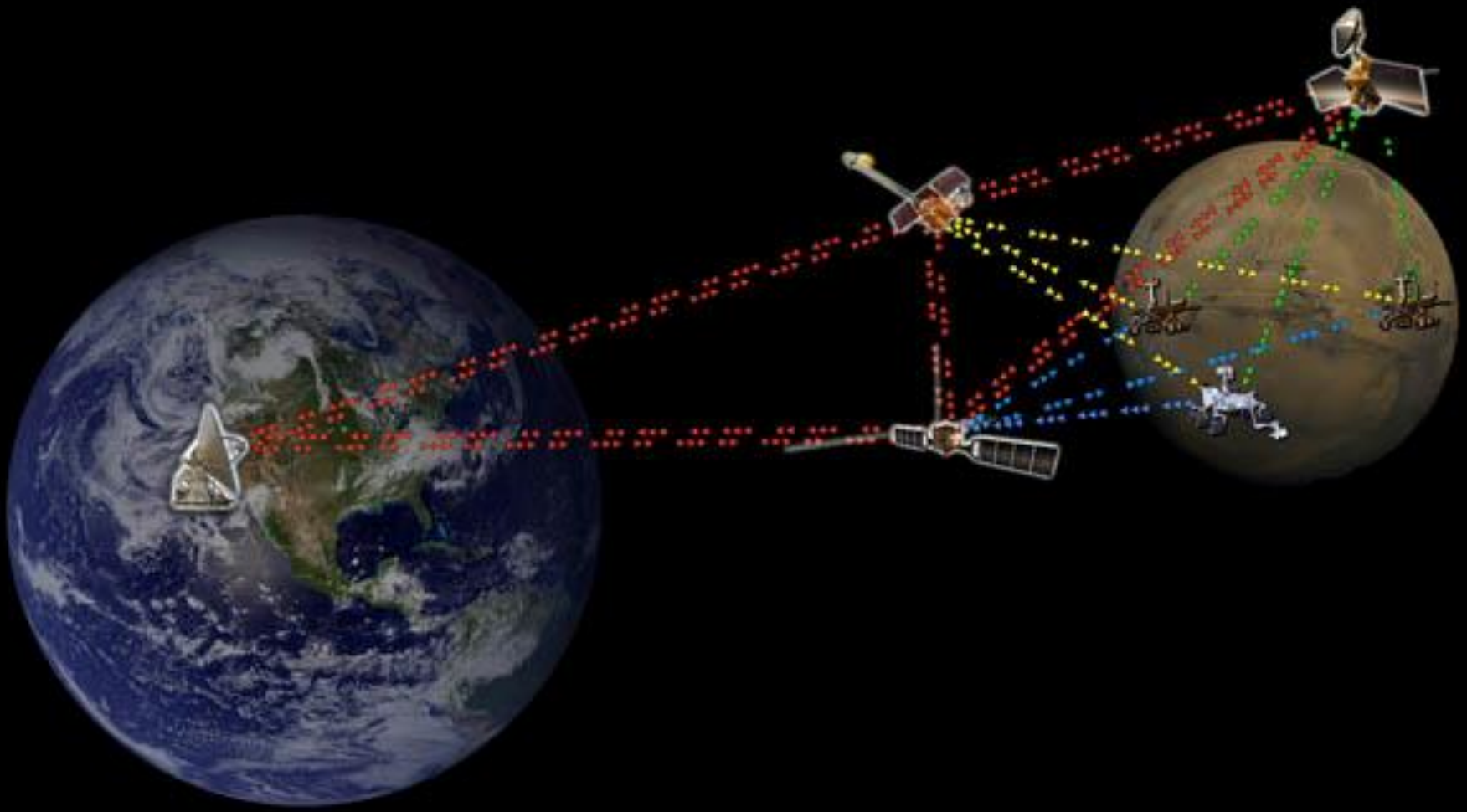
- Radiation
  - Limited experience beyond low Earth Orbit
    - Hi-res cameras on ISS have been highly susceptible to ionizing radiation damage to sensors
      - Some cameras can have 7-10 pixels damaged per day
    - CMOS less susceptible than CCD
      - Some sensors self anneal
      - In-camera pixel correction has been successful
    - Japanese Space Agency had an HD camera on a Moon probe (Selene) that did not suffer as much damage as expected
  - Can also cause latch-ups or damage recorded data
  - Can cause damage/colorization to coatings on glass
- Vacuum
  - Heat dissipation is a problem since fans are not practical
    - One workaround is to put cameras in a sealed container filled with nitrogen at 1 atmospheric pressure
  - Anything with exposed moving parts must work in a vacuum!
- Temperature fluctuations
  - Exposed hardware is subject to rapid heating or cooling
  - Known to cause leakage in exposed lens housings
  - Can cause moving parts to seize


Nikon
B
A
NASA


CSA ASC
asc-csa.gc.ca

Challenges for Imagery Architecture 2/2

- Bandwidth constraints
  - Conventional RF transmission takes power and large antennas
  - Optical offers far more bandwidth in bursts but has problems with availability, aiming of antennas
  - Video requires orders of magnitude more bandwidth than all other communications
- Link integrity
  - Conventional two-way IP connections are not practical due to breaks in links and latency between nodes
- Command & Control
  - Ground commanding of remote cameras, encoders and related systems typically requires two-way communications
    - Latency can be an issue for pin-point aiming, focus, etc.



Mitigations, Ideas & Unknowns

- Still a lot of debate about “radiation hardened” camera sensors
  - Efforts have been expensive with “hit-or-miss” results
  - Commercial Panasonic 3DA1 is by far the best performing camera flown to date--nobody knows why
  - JAXA’s Selene camera performed very well, maybe because it was shielded by fuel tanks
- Need smart systems that can re-boot themselves if latch-ups occur
  - FPGA’s to update software and capabilities for long duration missions
- Detachable/Throw-away camera systems for third-person views, inspections, emergency scenarios
  - Would require power, encoder, and transmission system included with camera system
- Need more efficient encoding
  - HEVC currently requires significant CPU/GPU, large footprint hardware with high power consumption
  - Variable frame rate?
  - Automated scene dependent encoder for efficiency?
- Automated/smart technologies to be self-aware, adjust to environment
- The International Space Station is an excellent laboratory for testing technologies
- The ideal system weighs nothing, generates no heat, and takes up no volume….
  - Light, small footprint, and low power are key
  - Made from unobtainium


RED

Some Final Thoughts….

- Imagery is important for engineering and operations and that cannot be compromised, but…
- …NASA is open to new ideas for sharing our experiences with the American public (and the world)
- The Space Act that created NASA requires the Agency to share its activities with the public, because the public paid for it
  - What if the tax-payer didn't pay for all of it?
- Unique partnerships are possible
  - IMAX films
  - Time's coverage of Commander Kelly's "Year in Space"
  - The NASA UHD Channel via Harmonic
  - Red camera for the ISS National Lab
- Maybe we could do something that isn't quite NASCAR-like, more like PBS, where commercial enterprises help NASA with its mission but does help take everyone else along for the ride

Our Purpose

Expand human presence into the solar system and to the surface of Mars to advance exploration, science, innovation, benefits to humanity, and international collaboration.

Every decision made is made with this purpose in mind.

It requires sustainable exploration.

To us, that means affordable and continuous.