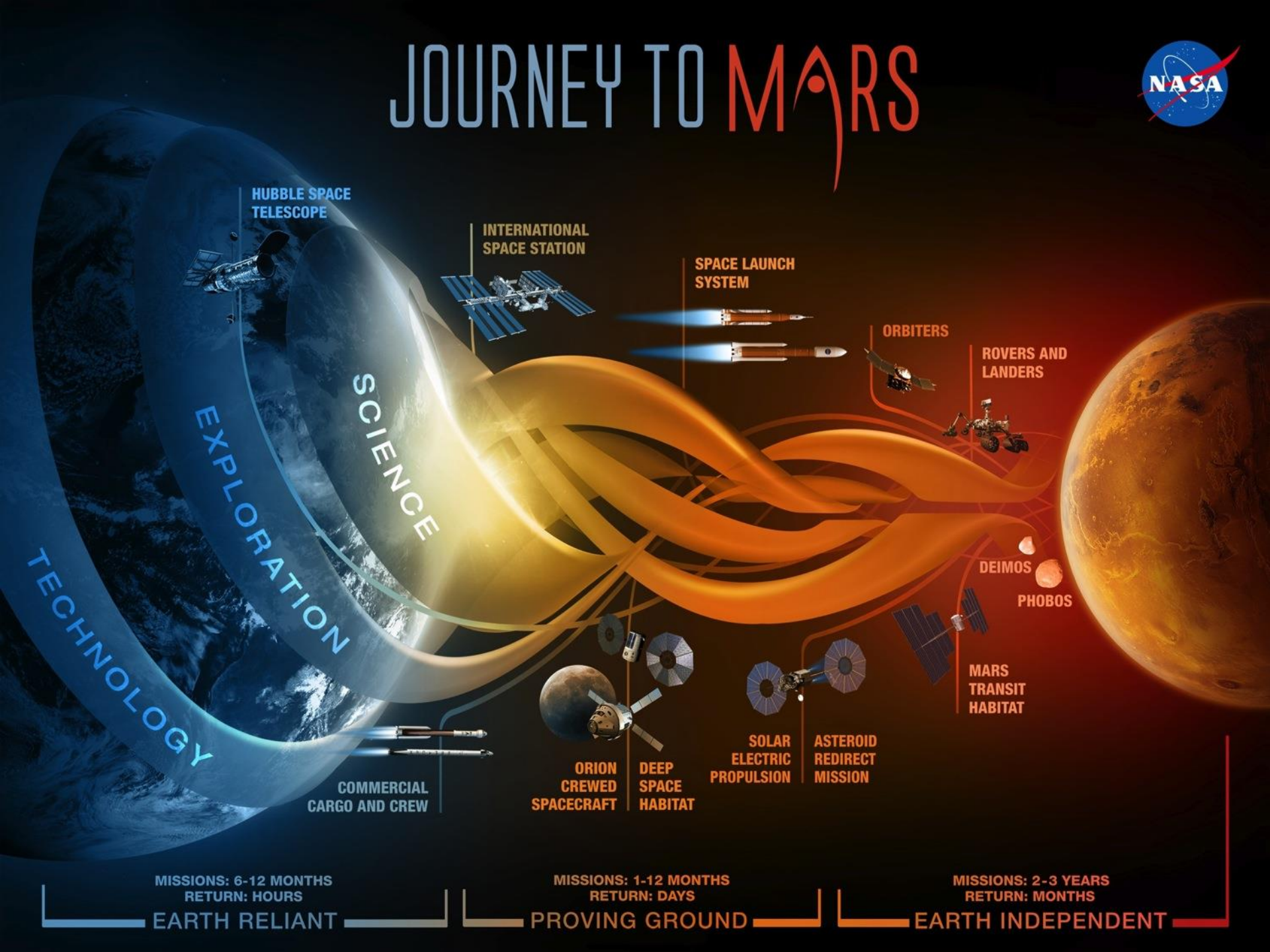
National Aeronautics and Space Administration

Deep Space Exploration Imagery

Technology Challenges

Rodney Grubbs
NASA Imagery Experts Program Manager

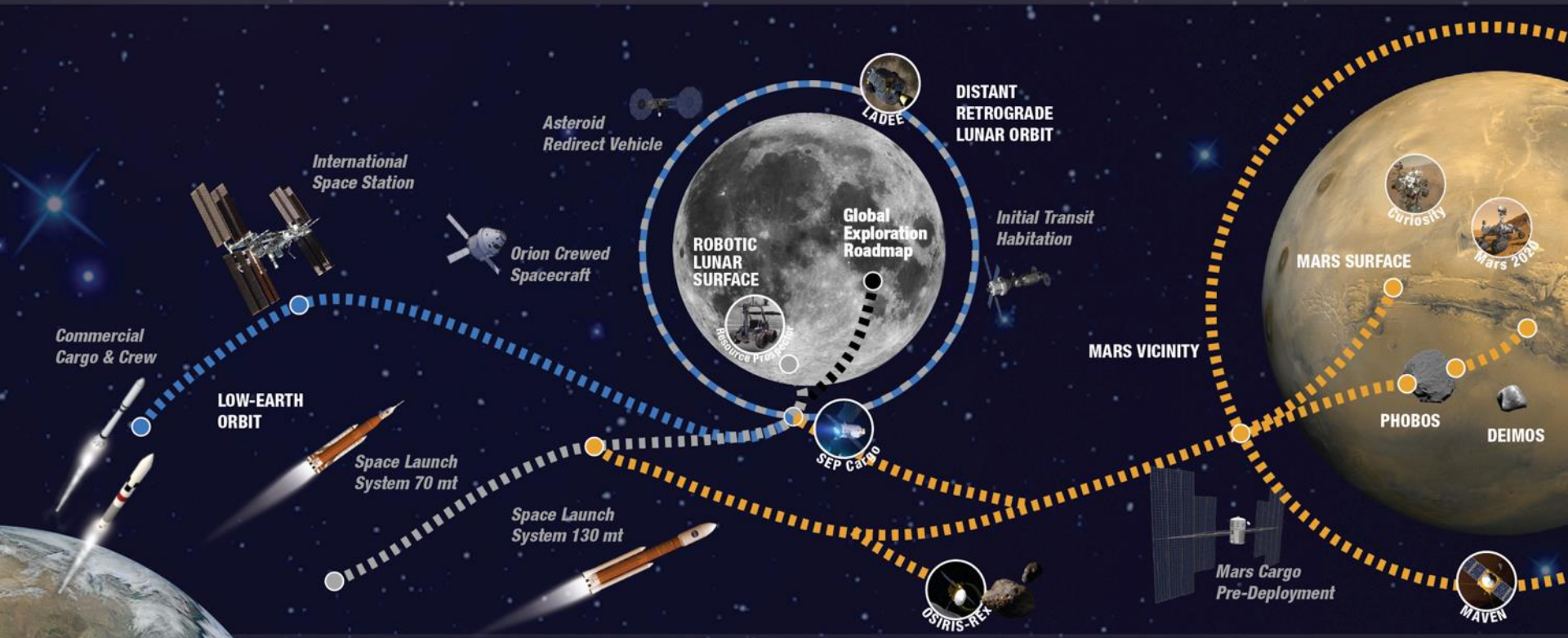
JOURNEY TO MARS



EVOLVABLE MARS CAMPAIGN

A Pioneering Approach to Exploration

EARTH RELIANT | PROVING GROUND | EARTH INDEPENDENT



THE TRADE SPACE

Across the Board | Solar Electric Propulsion • In-Situ Resource Utilization (ISRU) • Robotic Precursors • Human/Robotic Interactions • Partnership Coordination • Exploration and Science Activities

Cislunar Trades
- Deep-space testing and autonomous operations
- Extensibility to Mars
- Mars system staging/refurbishment point and trajectory analyses

Mars Vicinity Trades
- Split versus monolithic habitat
- Cargo pre-deployment
- Mars vicinity activities
- Entry descent and landing concepts
- Transportation technologies/trajectory analyses

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
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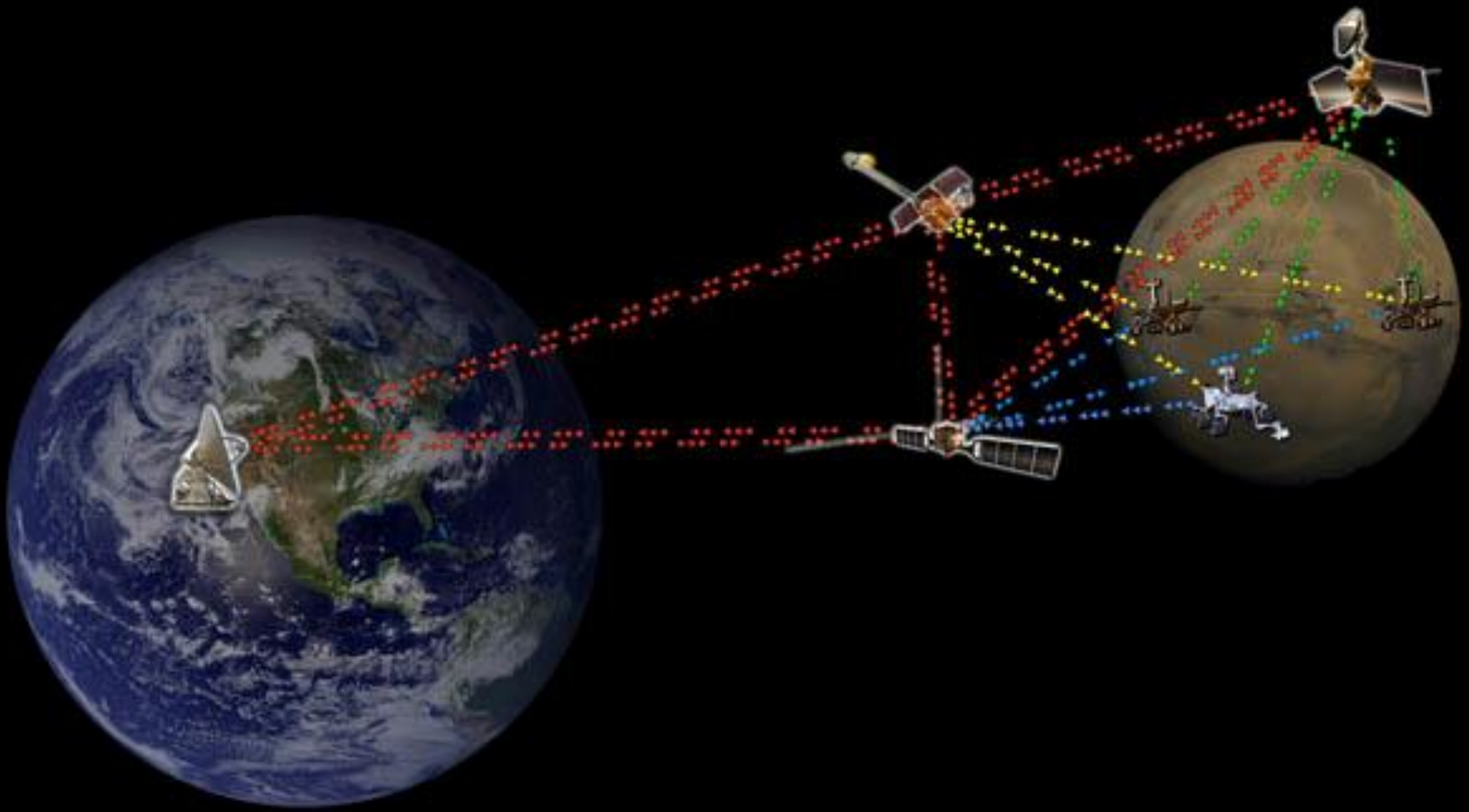
Challenges for Imagery Architecture 2/2

- 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
- 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?
- 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


RED

One more thing….

- 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"
- 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

Pioneering Space - Goals

"Fifty years after the creation of NASA, our goal is no longer just a destination to reach. Our goal is the capacity for people to work and learn and operate and live safely beyond the Earth for extended periods of time, ultimately in ways that are more sustainable and even indefinite. And in fulfilling this task, we will not only extend humanity's reach in space -- we will strengthen America's leadership here on Earth."

- President Obama - April, 2010

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.