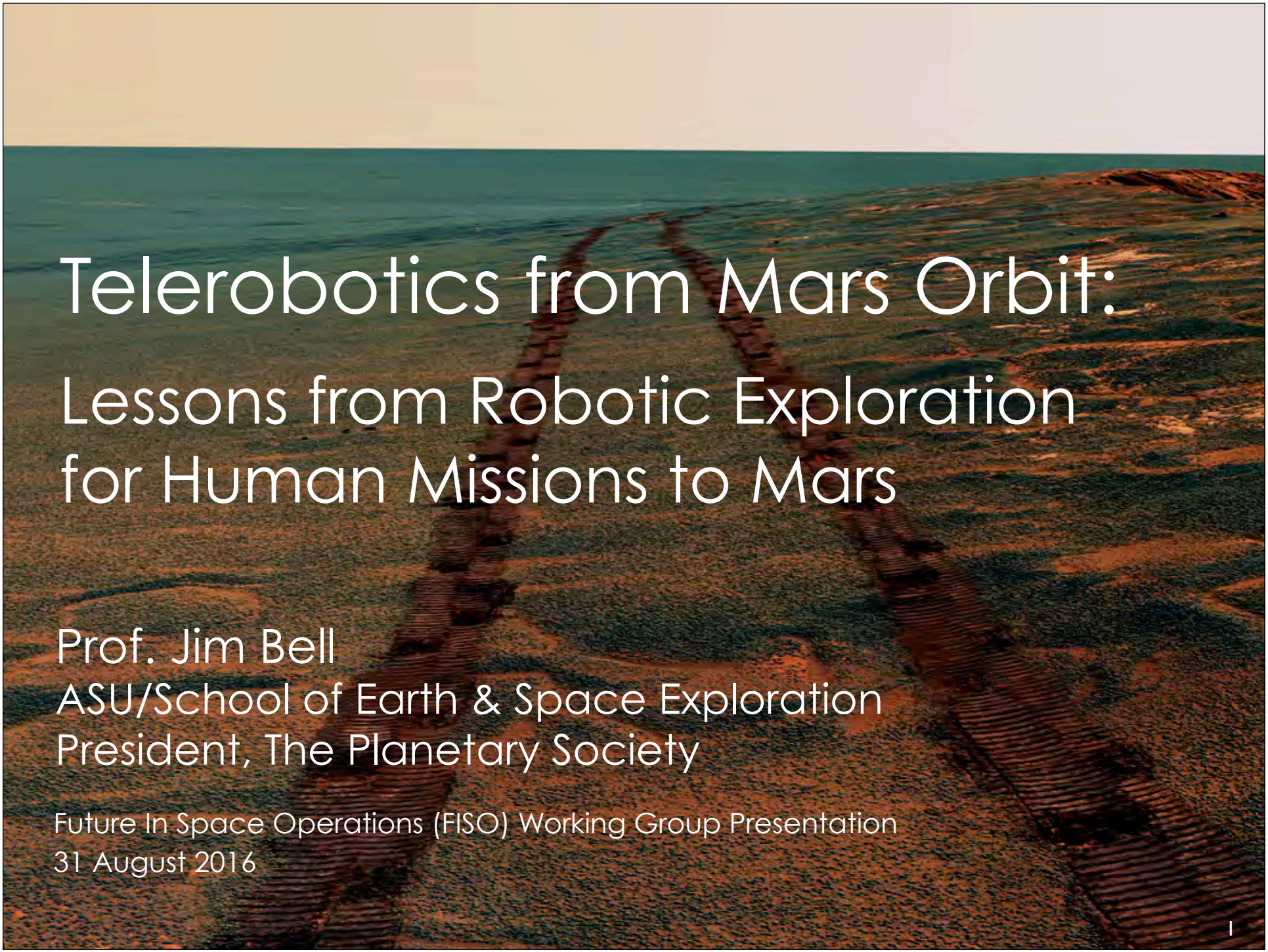
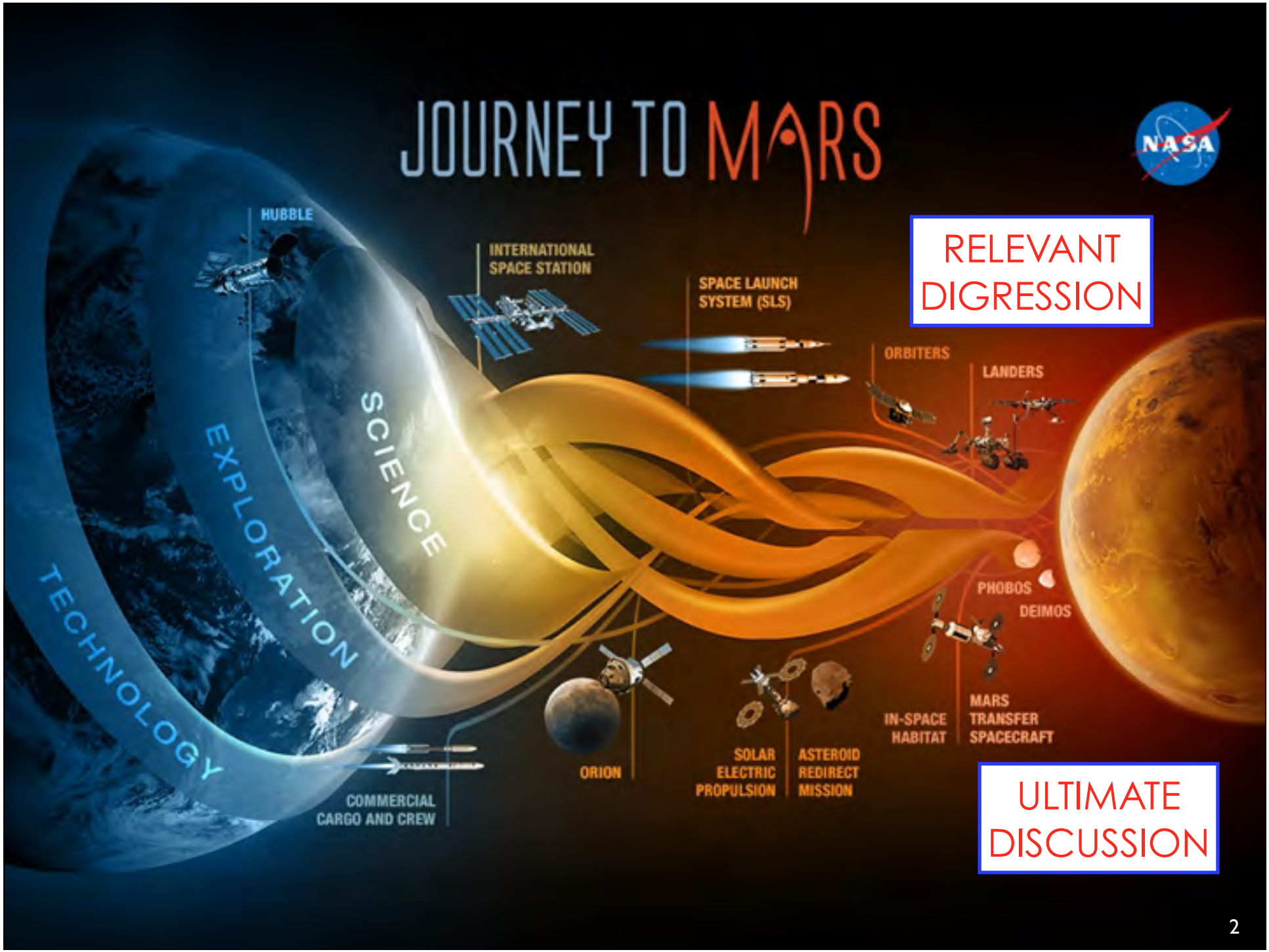


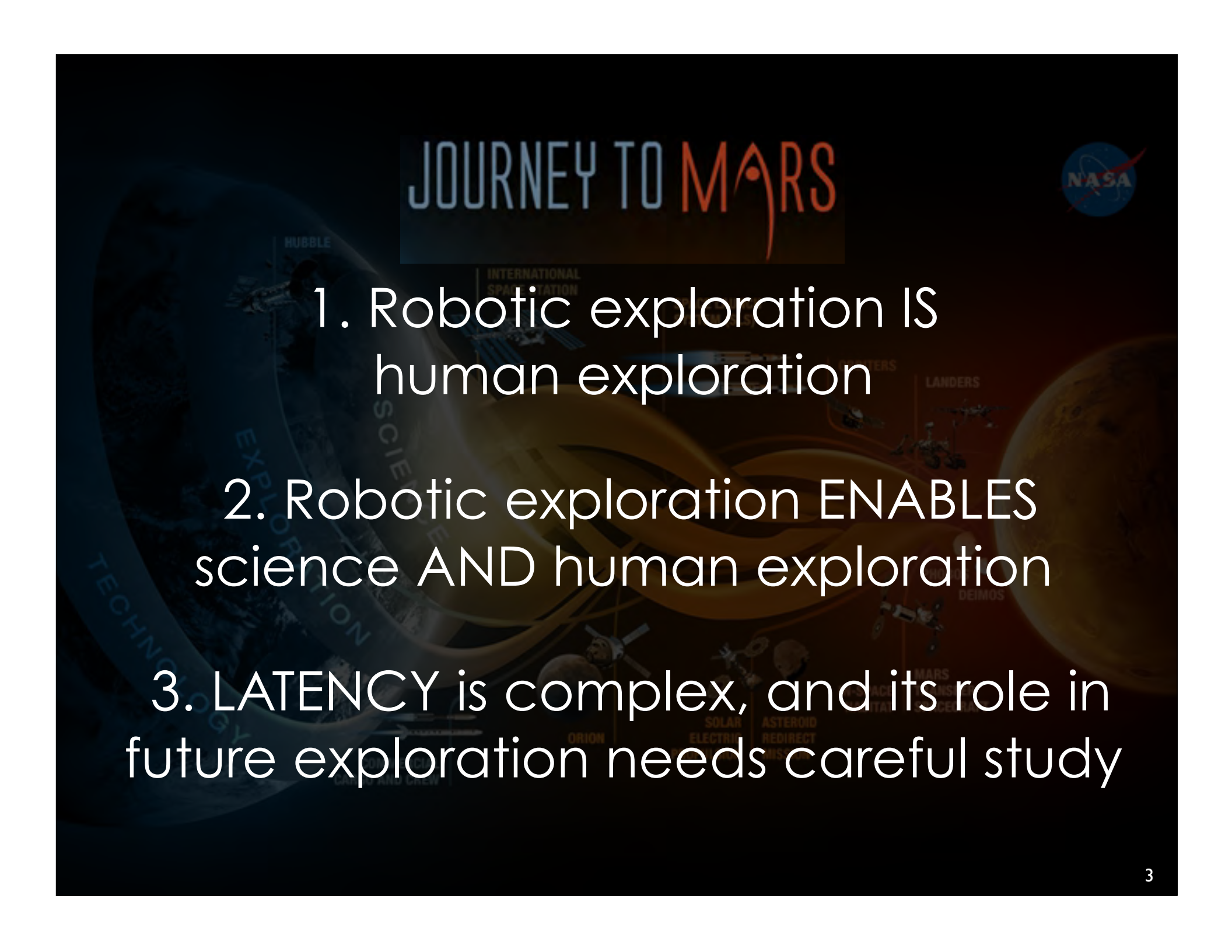
Telerobotics from Mars Orbit:

Lessons from Robotic Exploration for Human Missions to Mars

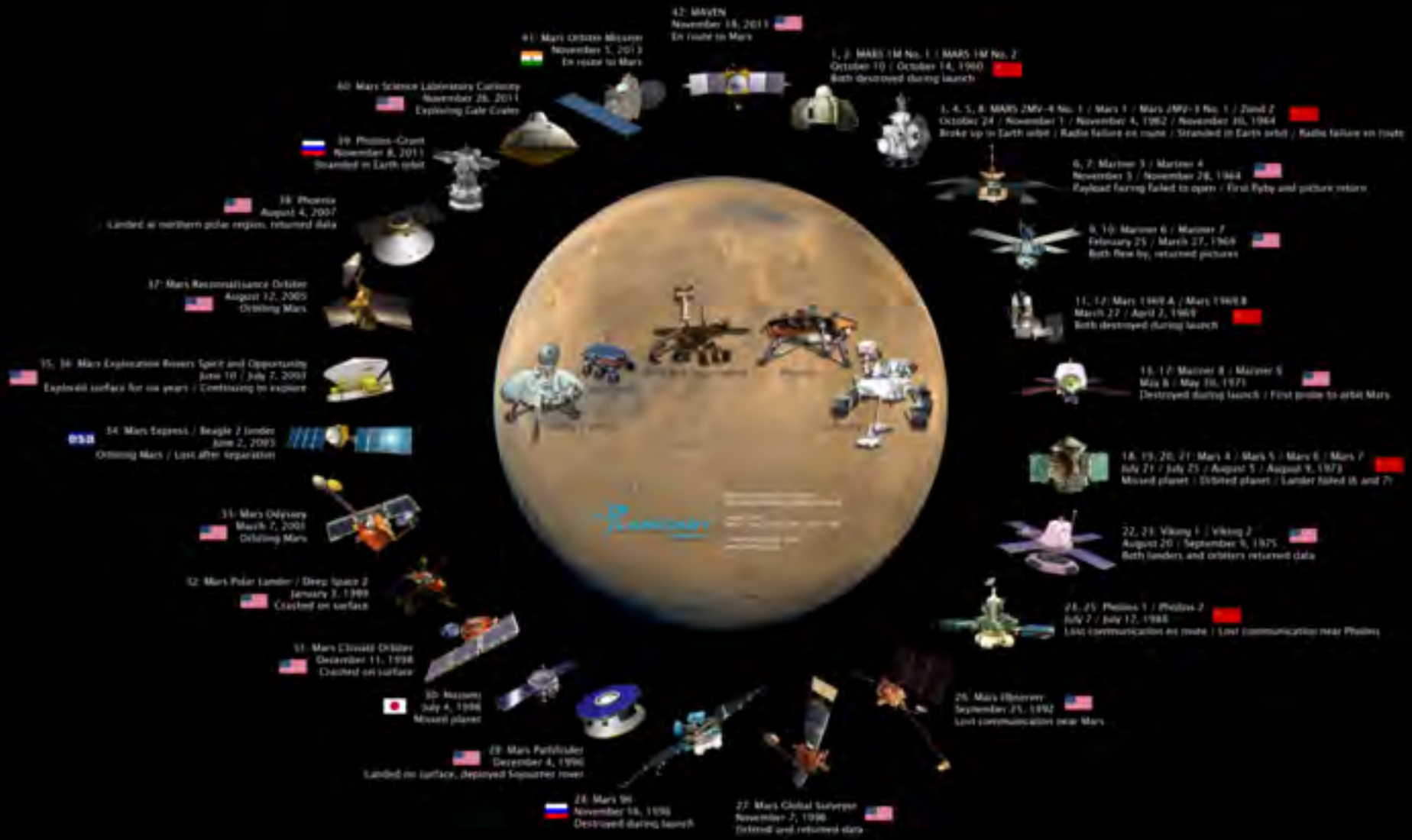
Prof. Jim Bell
ASU/School of Earth & Space Exploration
President, The Planetary Society

Future In Space Operations (FISO) Working Group Presentation
31 August 2016


JOURNEY TO MARS
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
RELEVANT DIGRESSION
ORBITERS
LANDERS
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
COMMERCIAL CARGO AND CREW
ULTIMATE DISCUSSION

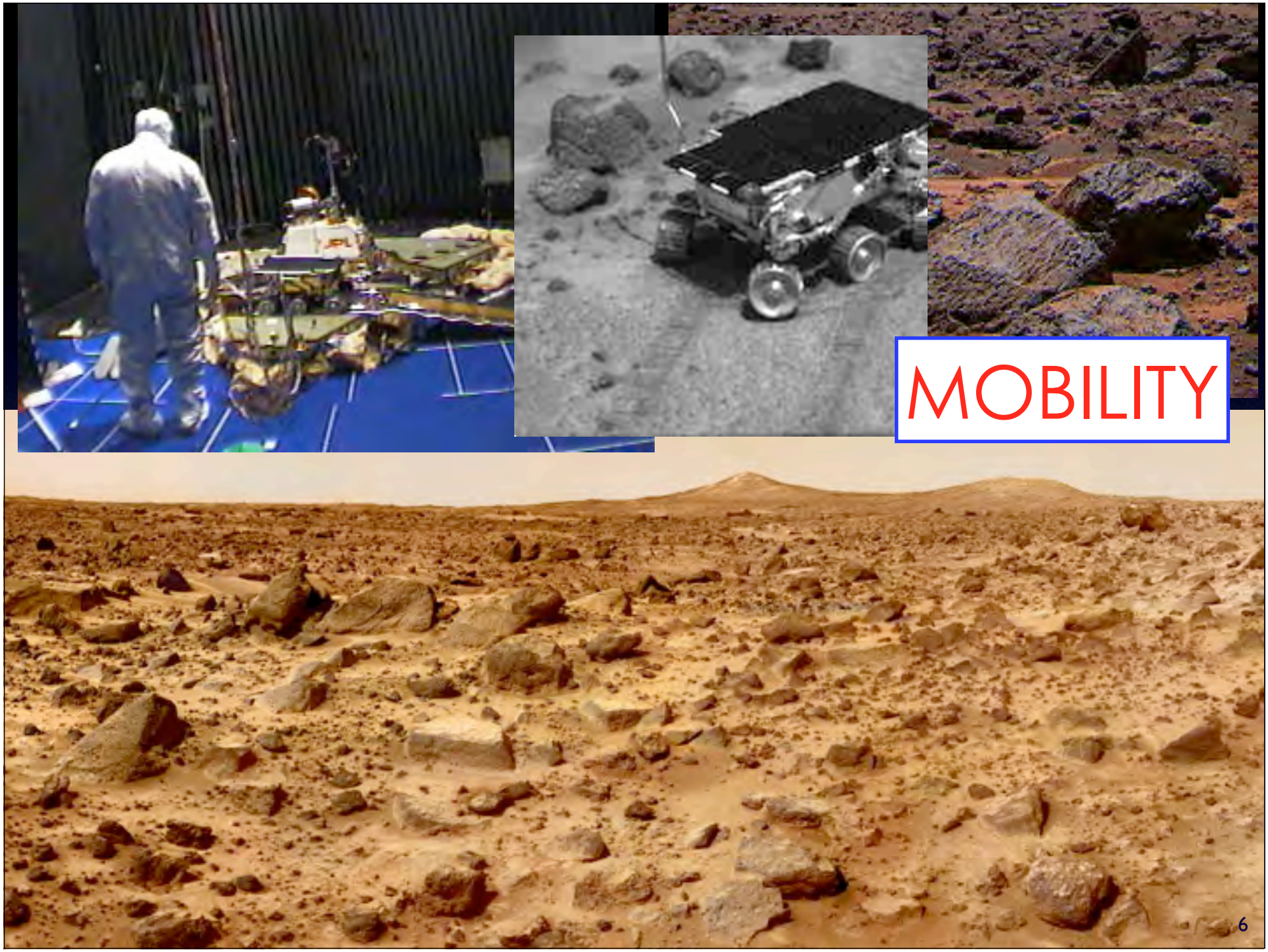

JOURNEY TO MARS
NASA
1. Robotic exploration IS human exploration
2. Robotic exploration ENABLES science AND human exploration
3. LATENCY is complex, and its role in future exploration needs careful study

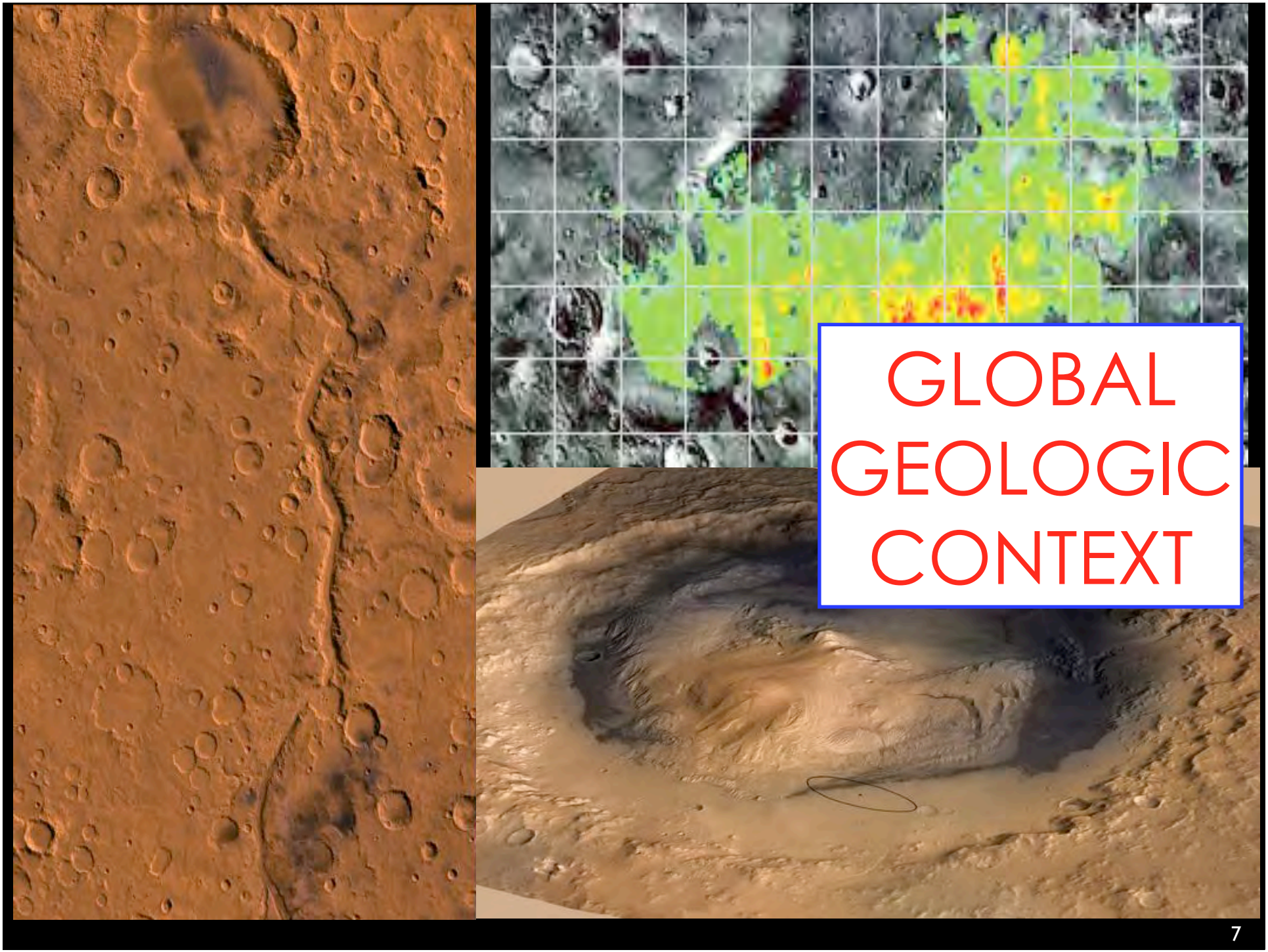
Mars Exploration Family Portrait



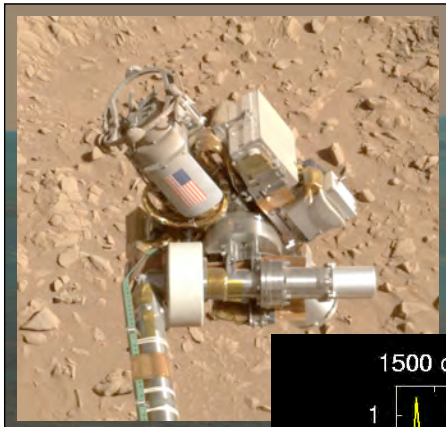
NASA / Roscosmos / JAXA / ESA / ISRO / Created by Jason Davis

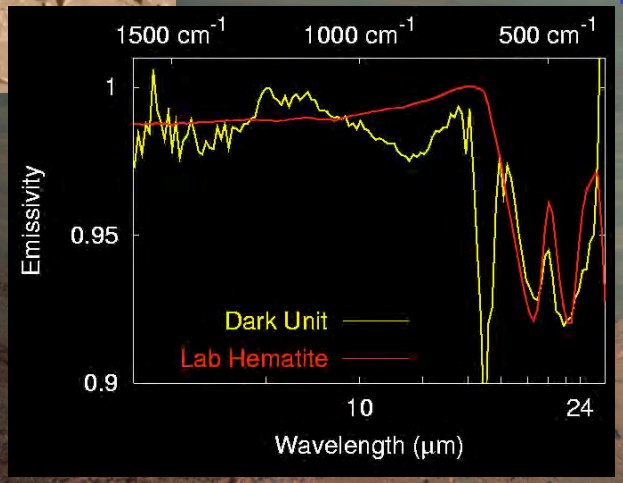

ASTROBIOLOGY

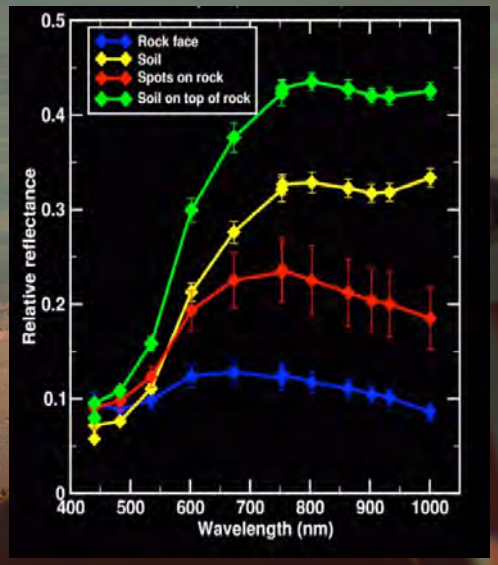

MOBILITY

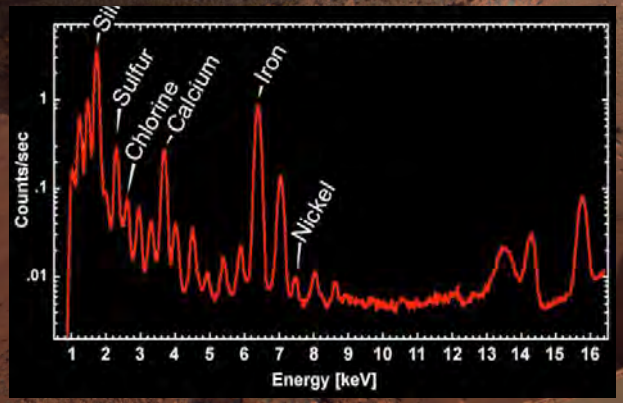

GLOBAL
GEOLOGIC
CONTEXT

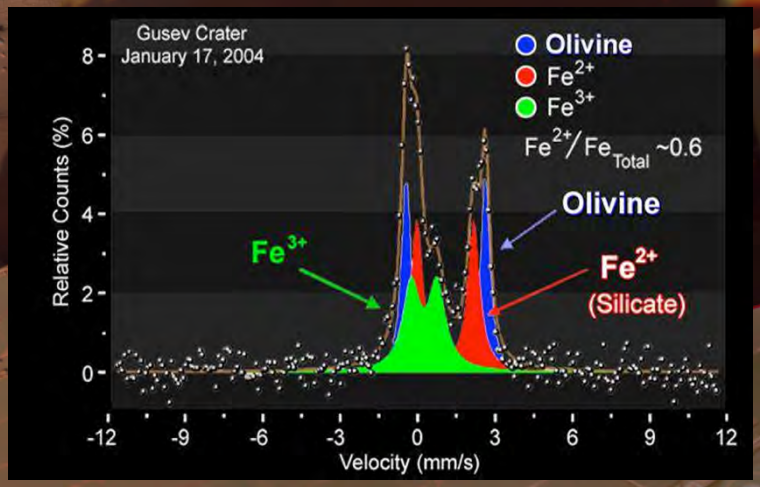
P.I.-LED SCIENCE

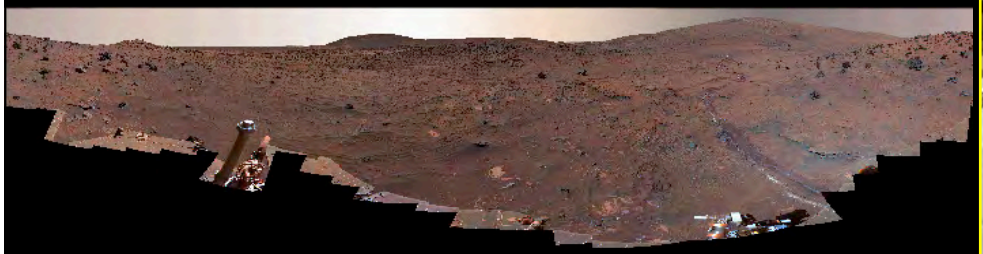


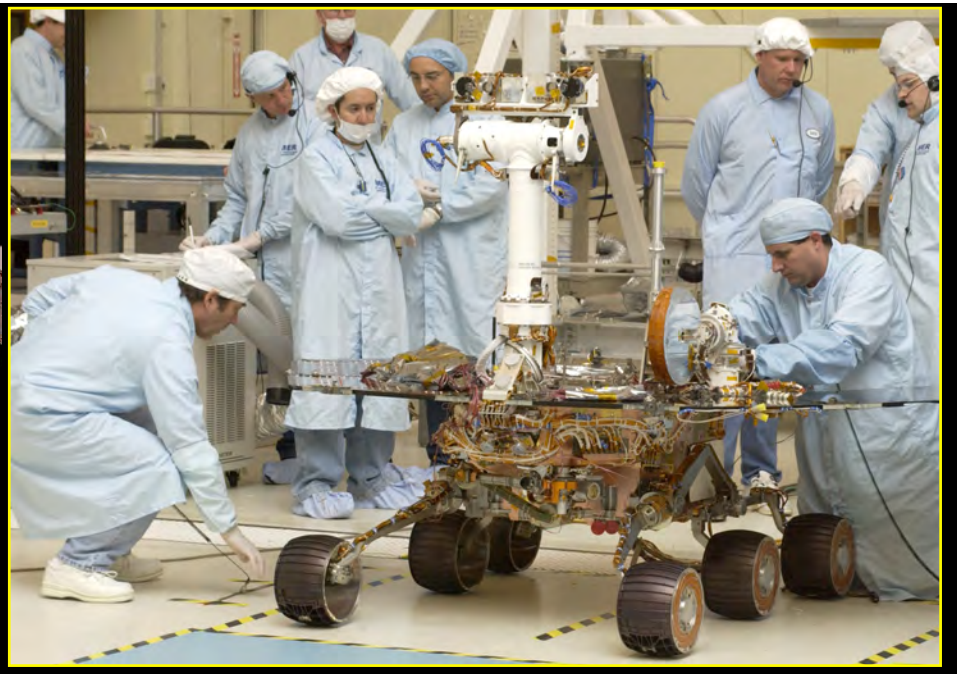




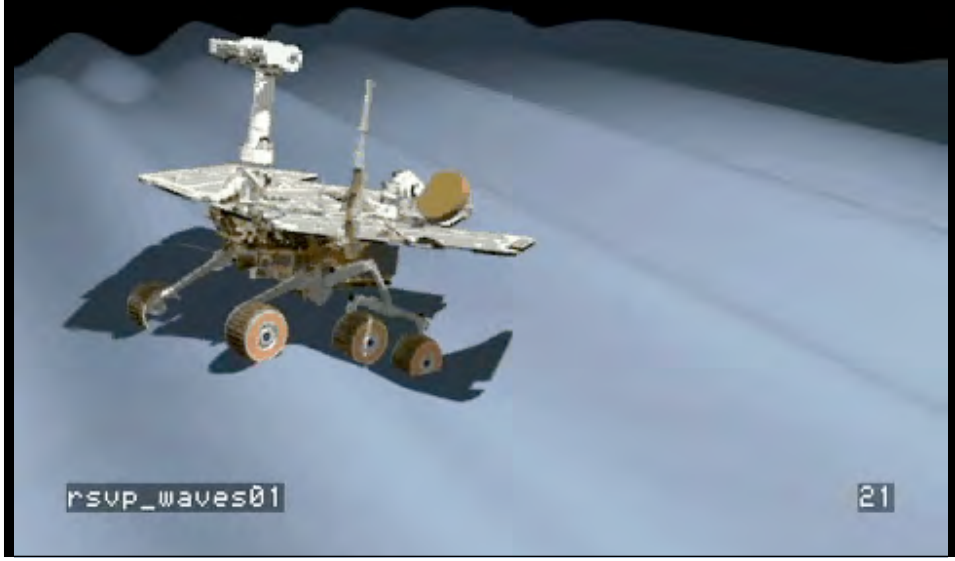


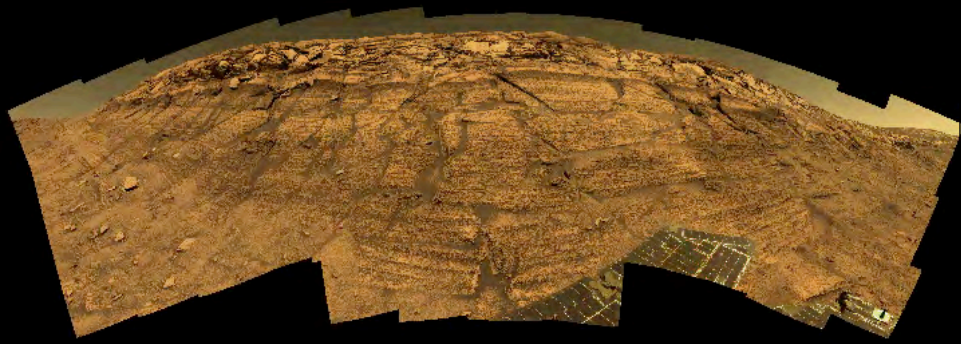


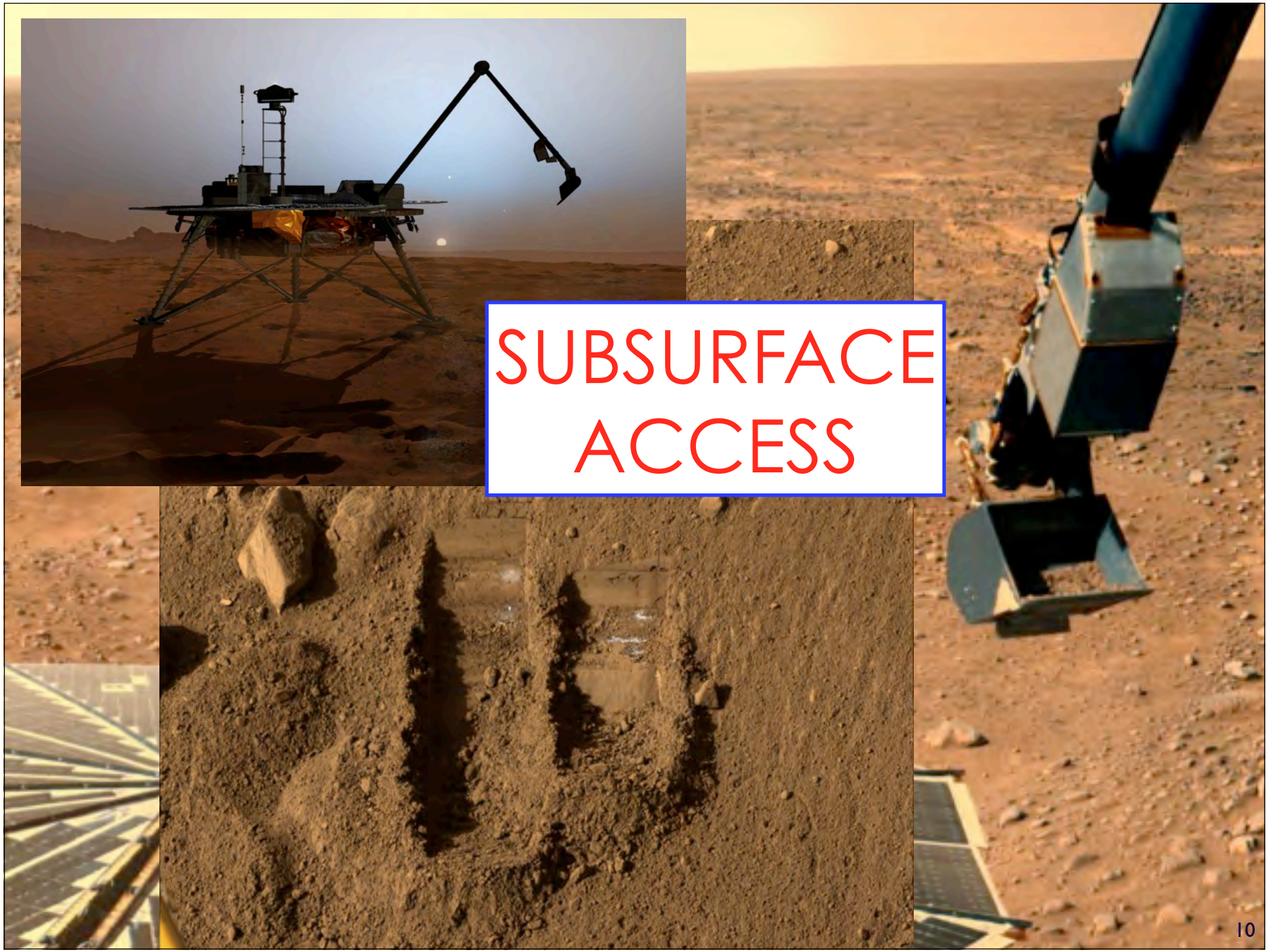


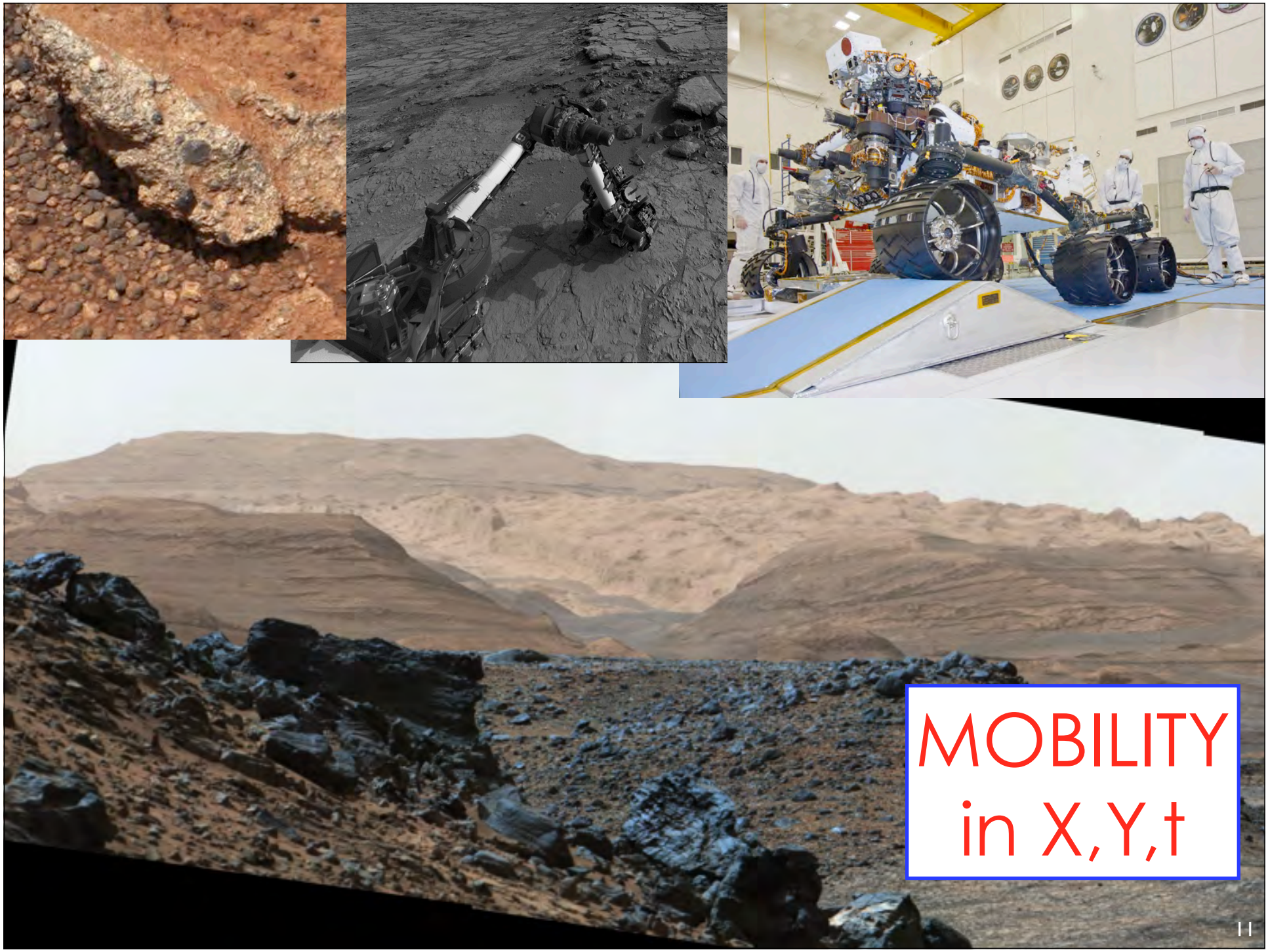


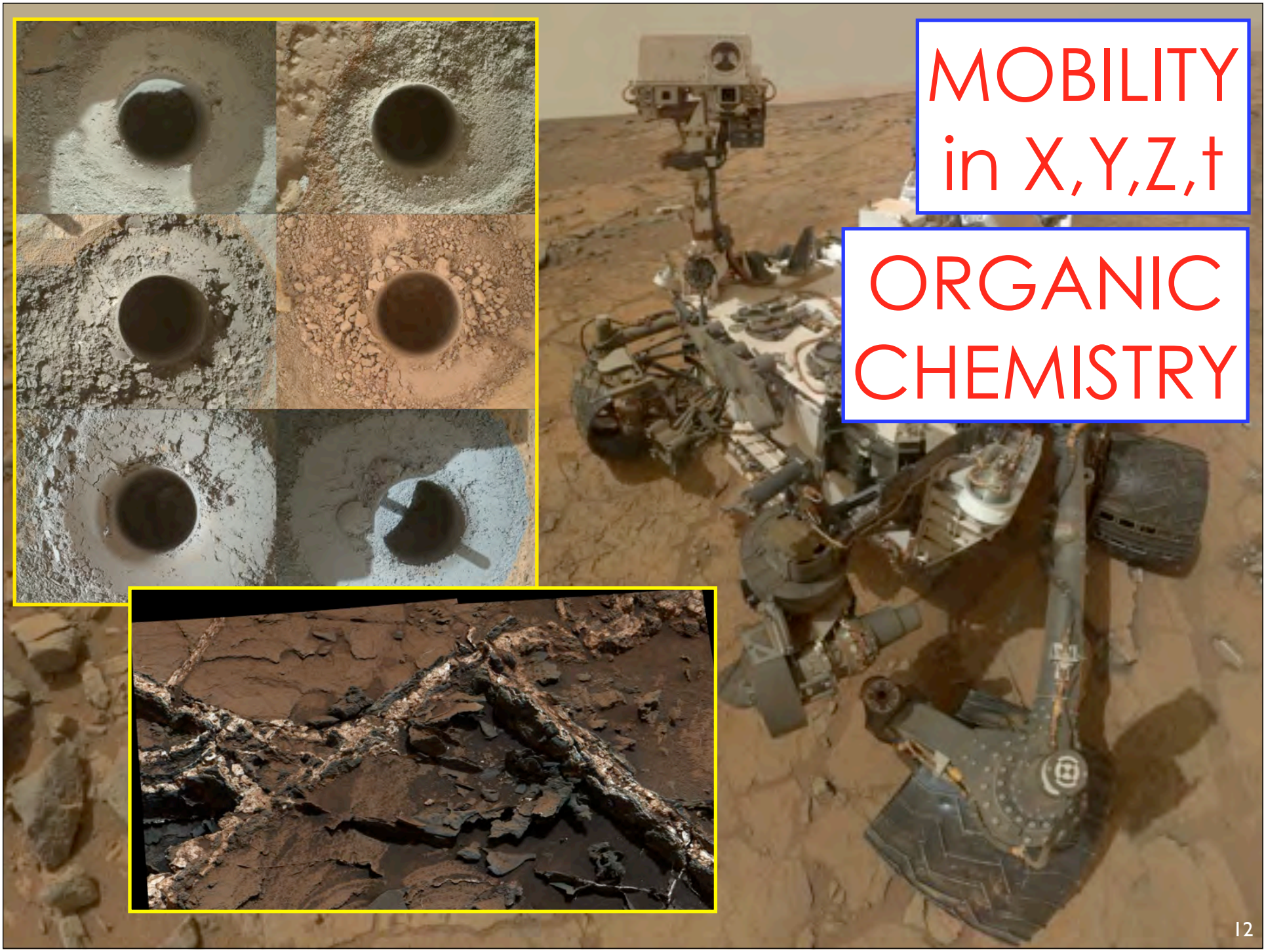
MOBILITY!!!

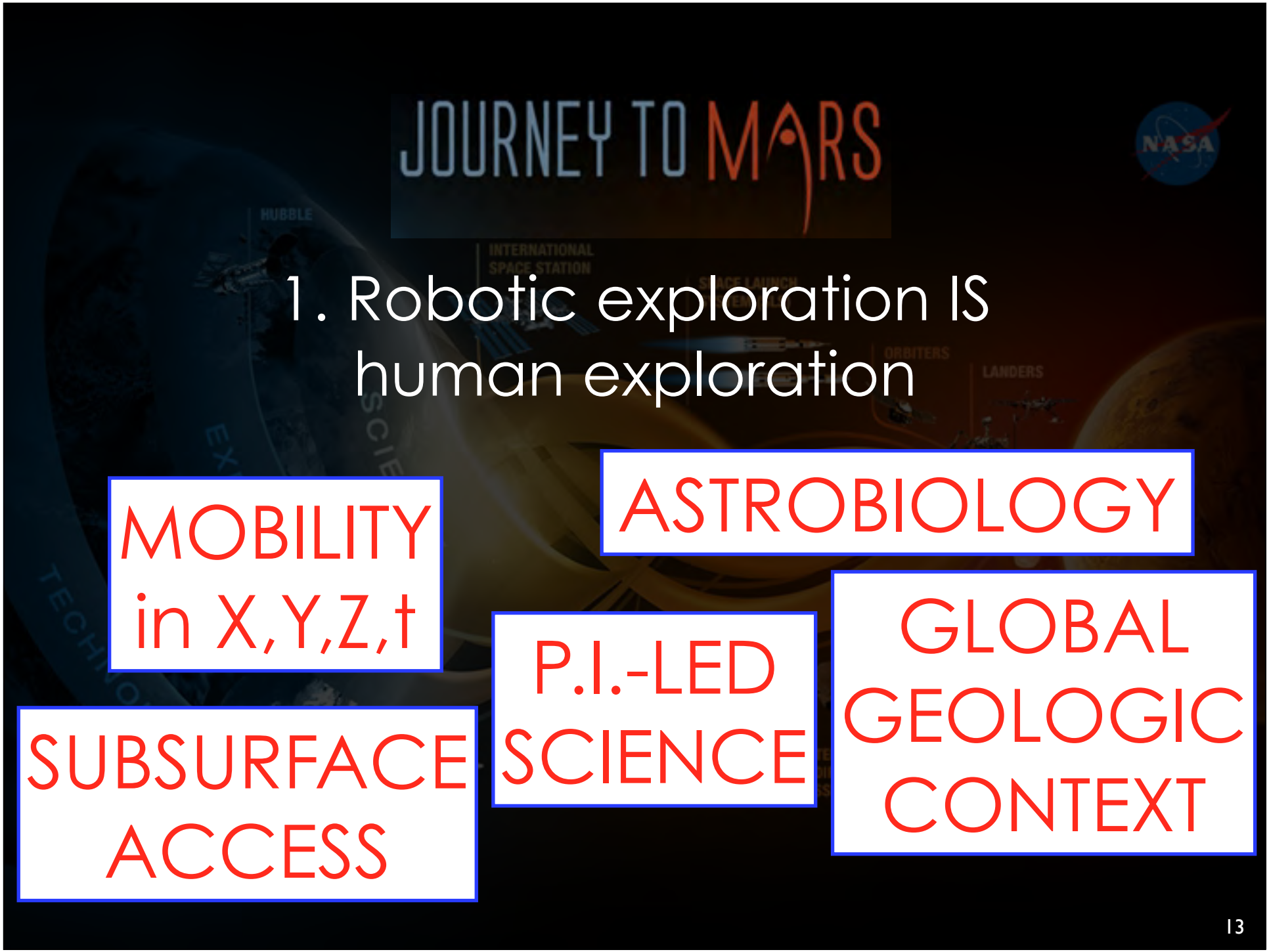





SUBSURFACE
ACCESS


MOBILITY
in X,Y,t


MOBILITY
in X,Y,Z,t
ORGANIC
CHEMISTRY



1. Robotic exploration IS human exploration

MOBILITY in X,Y,Z,t

ASTROBIOLOGY

P.I.-LED SCIENCE

GLOBAL GEOLOGIC CONTEXT

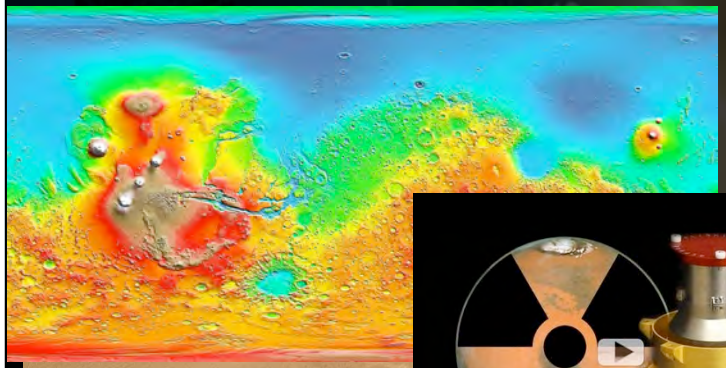
SUBSURFACE ACCESS

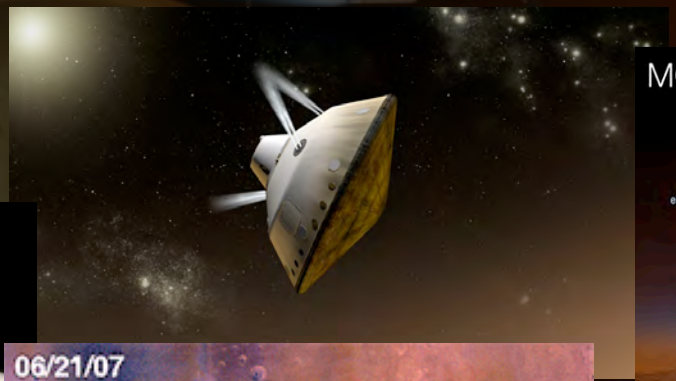
JOURNEY TO MARS

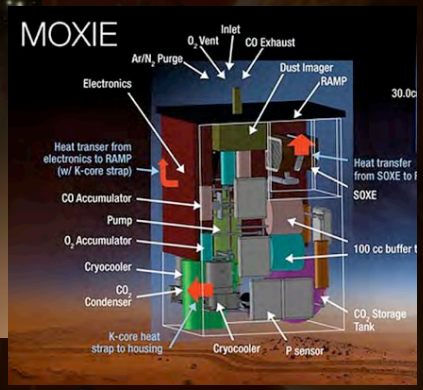
2. Robotic exploration ENABLES SCIENCE and human exploration

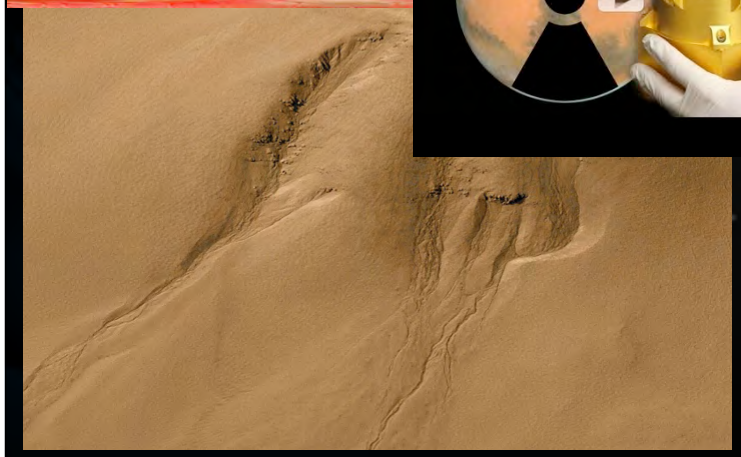
JOURNEY TO MARS

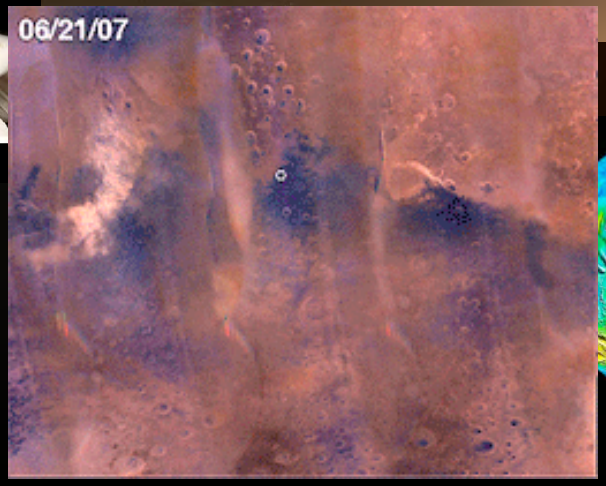
2. Robotic exploration ENABLES science AND HUMAN EXPLORATION

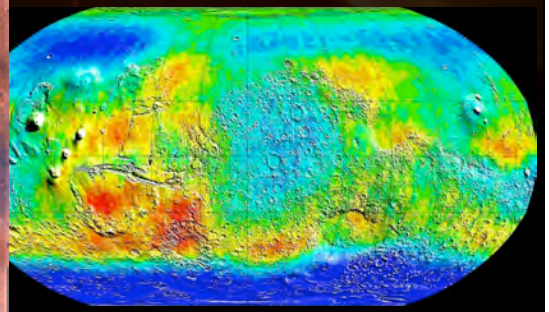








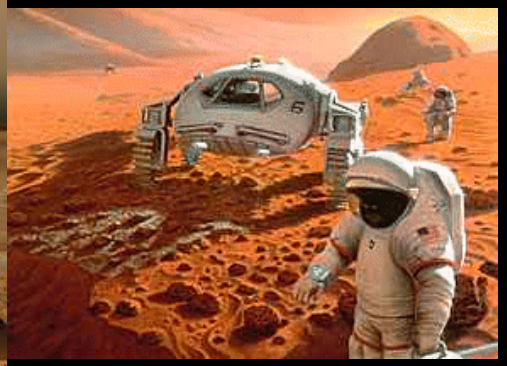


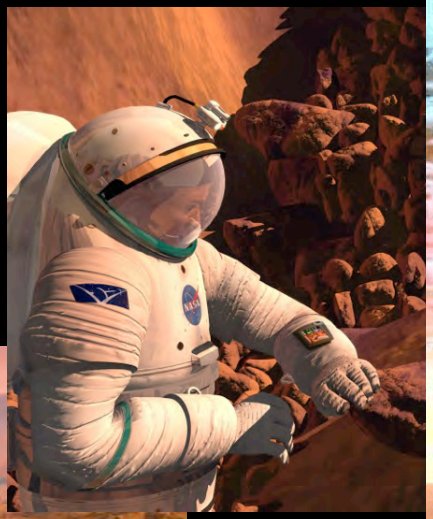


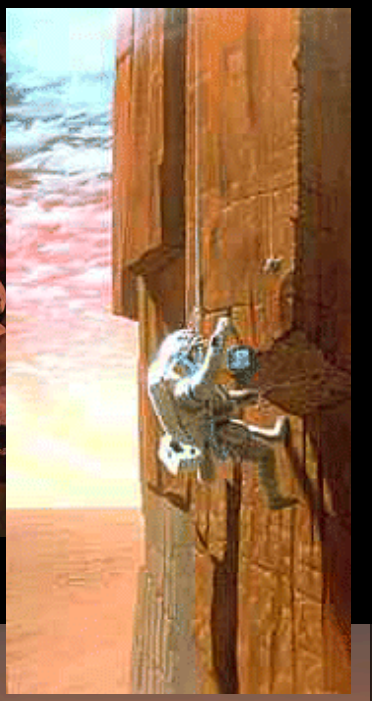
JOURNEY TO MARS

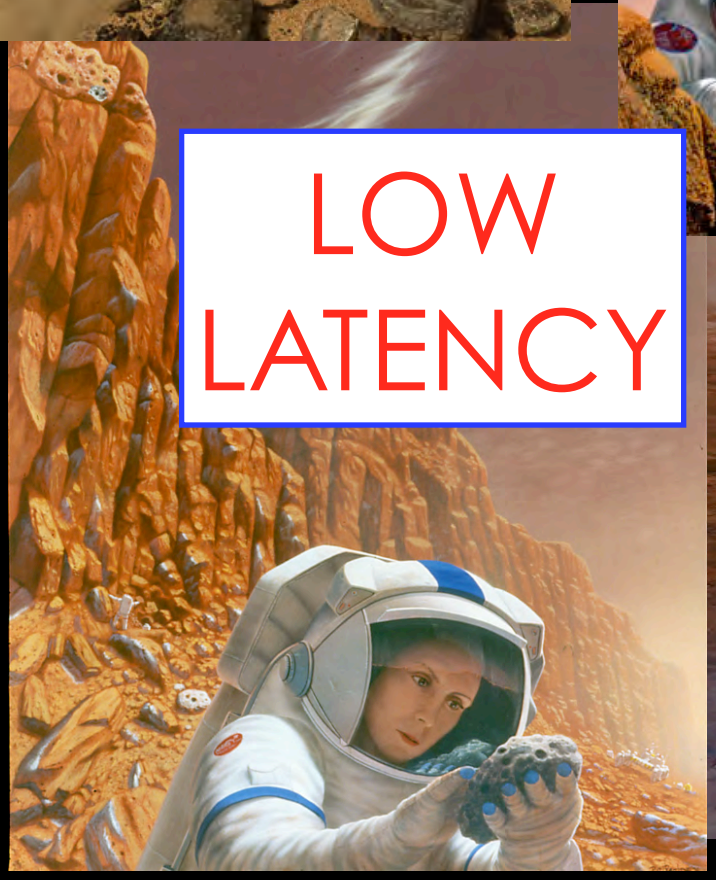
3. LATENCY is complex, and its role in future exploration needs careful study

"...the unfortunate truth is that most things our rovers can do in a perfect sol a human explorer could do in less than a minute."
- Steve Squyres, *Roving Mars*

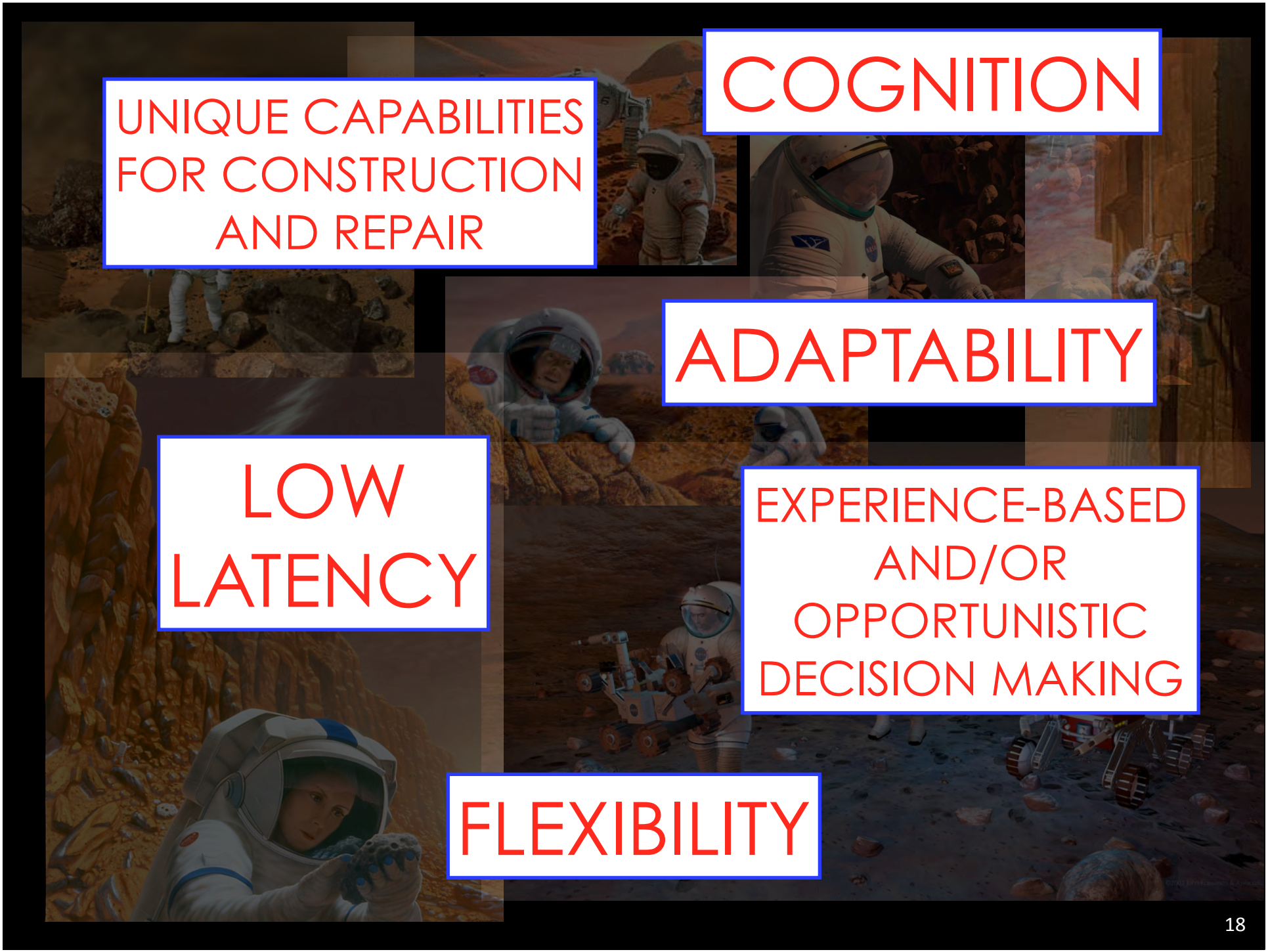




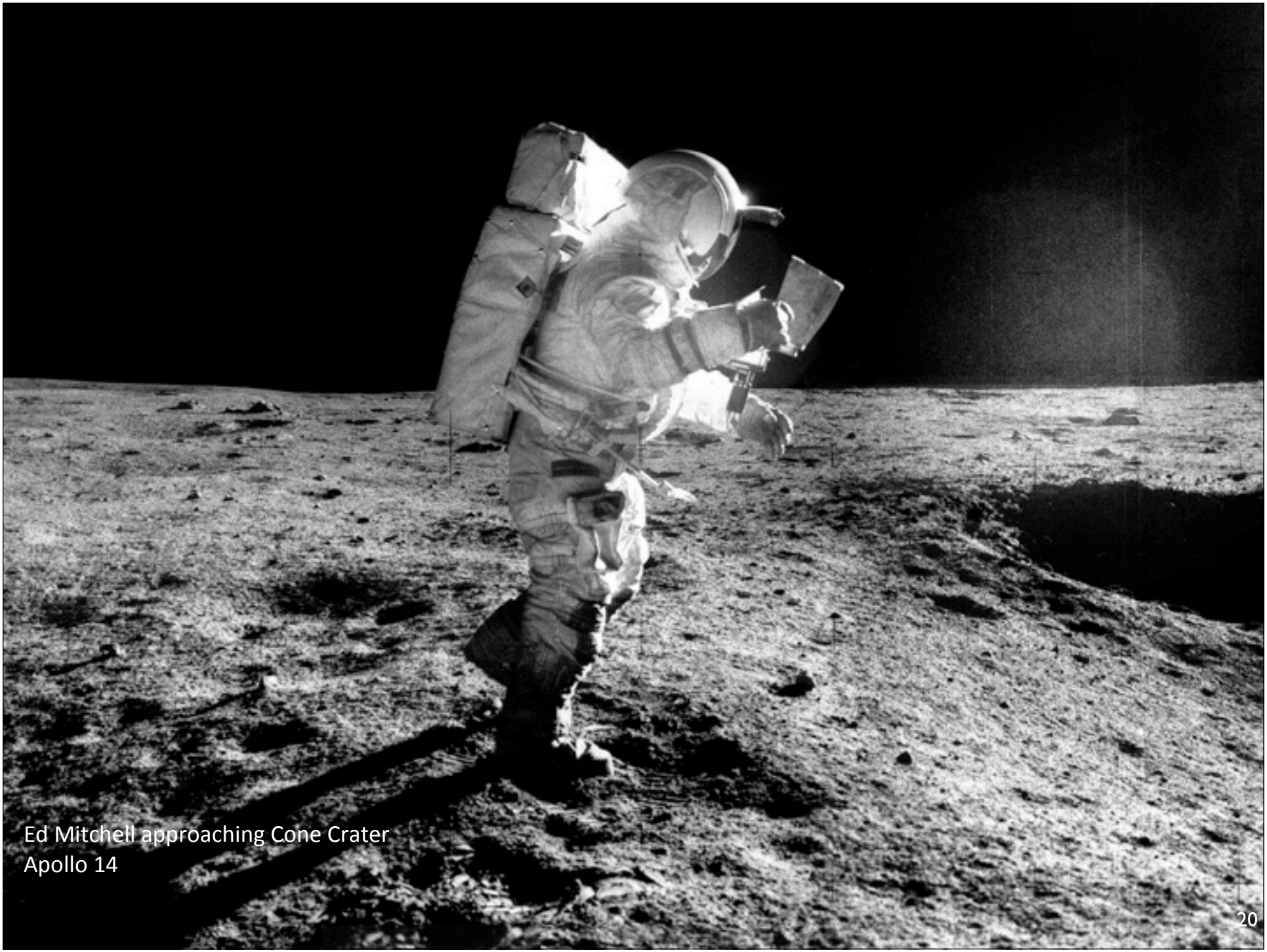




LOW LATENCY

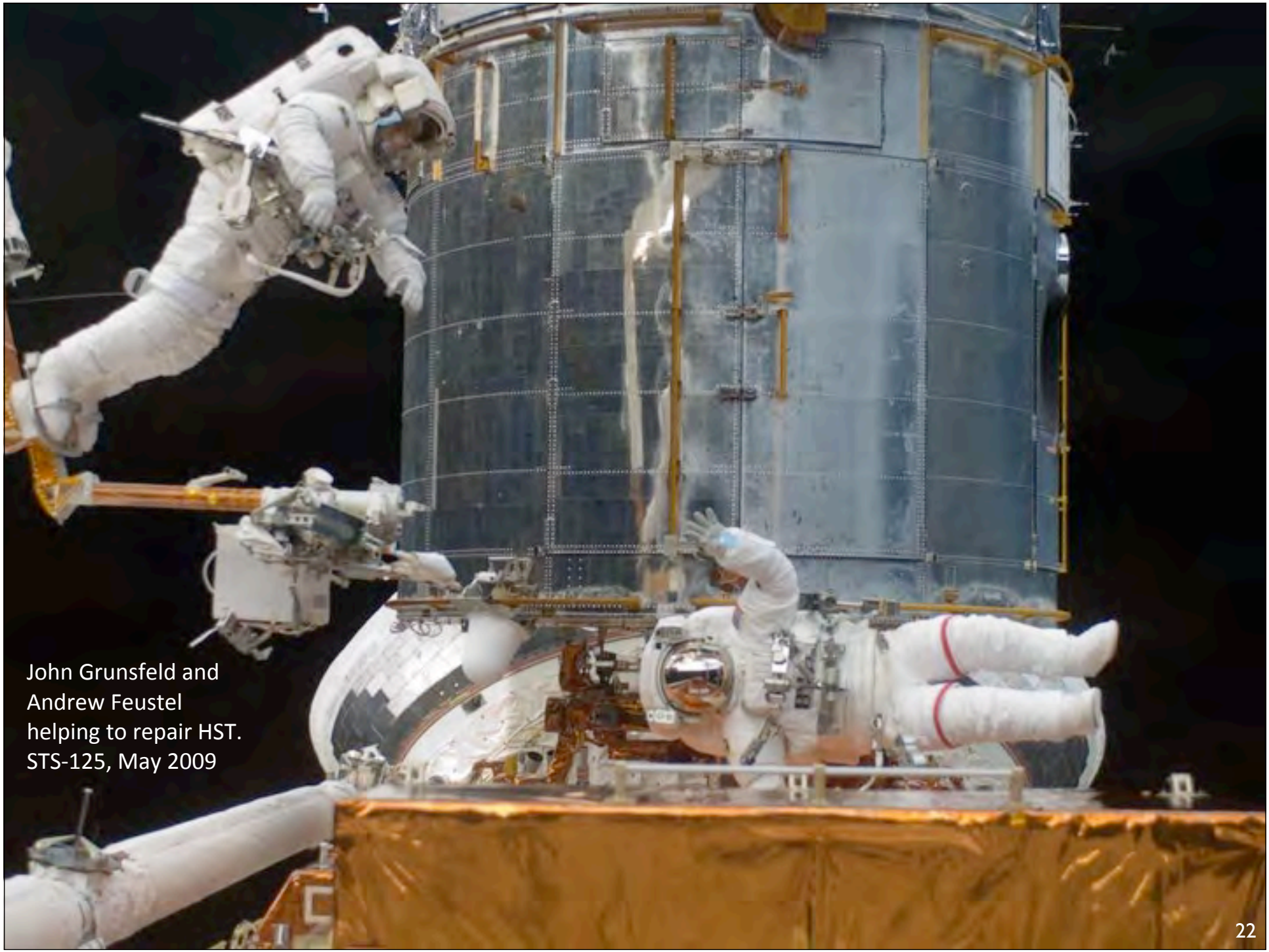

UNIQUE CAPABILITIES FOR CONSTRUCTION AND REPAIR
COGNITION
ADAPTABILITY
LOW LATENCY
EXPERIENCE-BASED AND/OR OPPORTUNISTIC DECISION MAKING
FLEXIBILITY


BUT LATENCY
IS COMPLEX

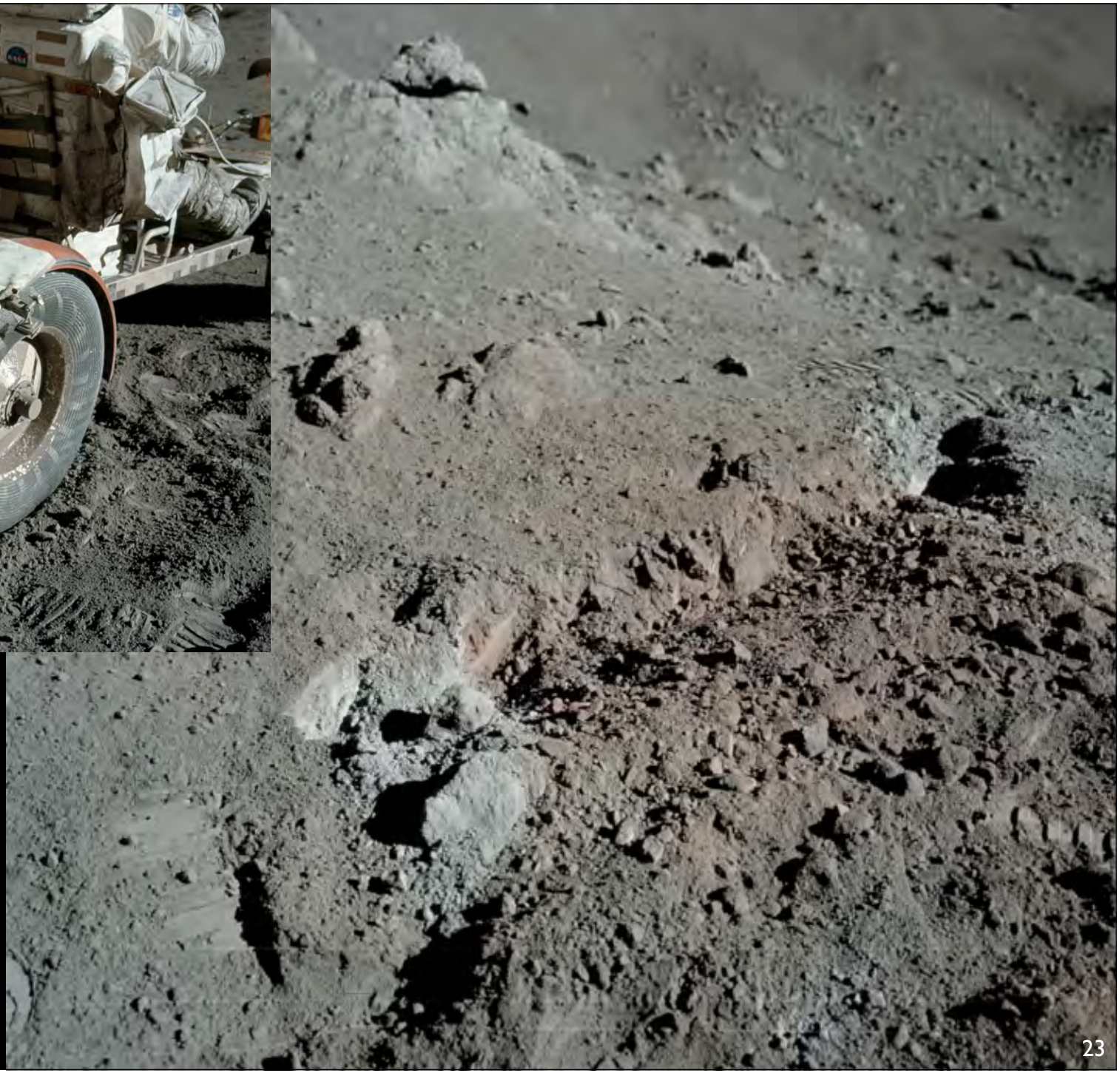


Ed Mitchell approaching Cone Crater
Apollo 14

Charlie Duke sampling rock-shielded materials
Apollo 16



John Grunsfeld and
Andrew Feustel
helping to repair HST.
STS-125, May 2009



Improvised rover repair by Gene Cernan and Jack Schmitt helps enable the discovery of orange soil near Shorty crater.
Apollo 17

Acta Astronautica 66 (2010) 70–73

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Crew on the ISS: Creativity or determinism?

Sergey K. Krikalev, Alexander Yu. Kalery, Igor V. Sorokin*

S.P. Korolev Rocket and Space Corporation Energia (RSC Energia), 4A, Lenin Street, Korolev City, Moscow region 141070, Russia

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Flight control flexibility

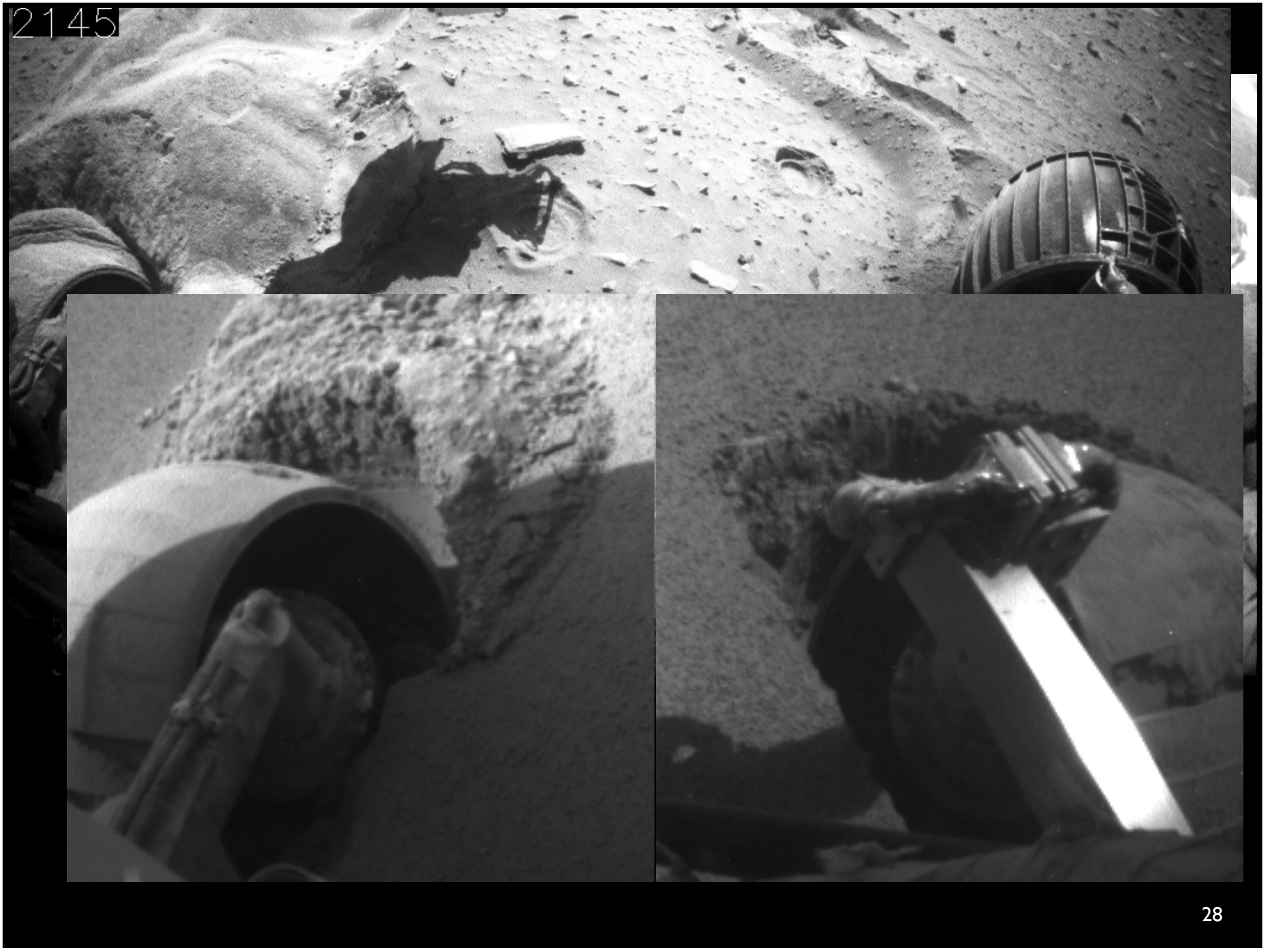
ABSTRACT

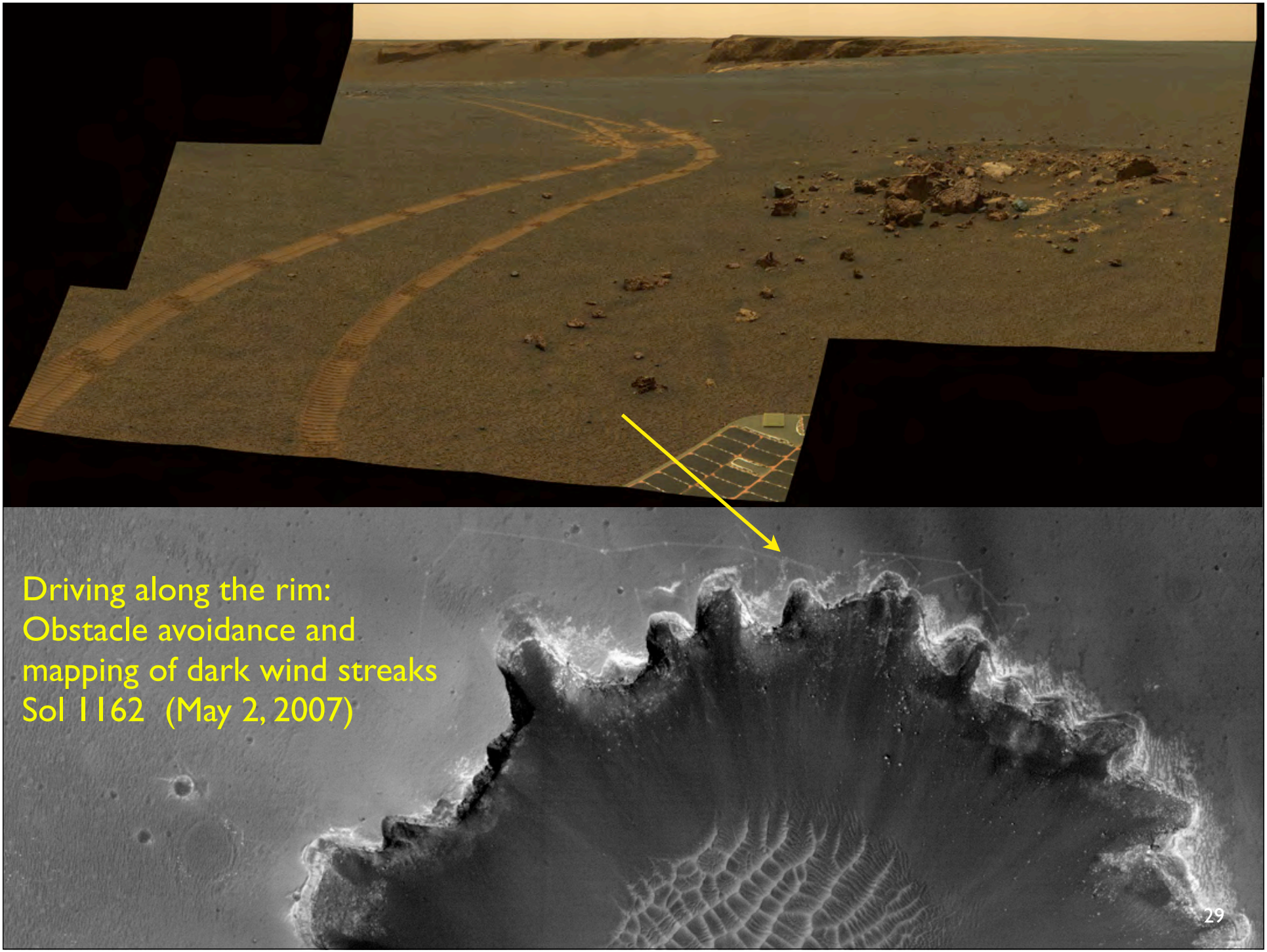
Analyzing the experience of human flights to the *Mir* space station in 1986–2000 and to the ISS in 2000–2008, as well as *Space Shuttle* missions we can define structural and organizational tendencies in human missions to space and mission support. The tendency to the increased determinism in flight operations leads to lower flexibility of the "Crew-Mission Control Center" link in case of contingency. We justify the necessity to reduce the centralization of the control process and to hand over some mission control centers (MCC) authority to the International Space Station (ISS) crew. We conclude that human missions to the Moon and Mars where crew actions will be independent to a high degree will be impossible without resolution of this issue. Creativity and determinism should be properly balanced.


HUMANS
ORBITING MARS
THE PLANETARY SOCIETY
March 31–April 1, 2015
Washington, D.C.
2015


HOW TO BEST DEPLOY LOW LATENCY FOR TELEROBOTICS?

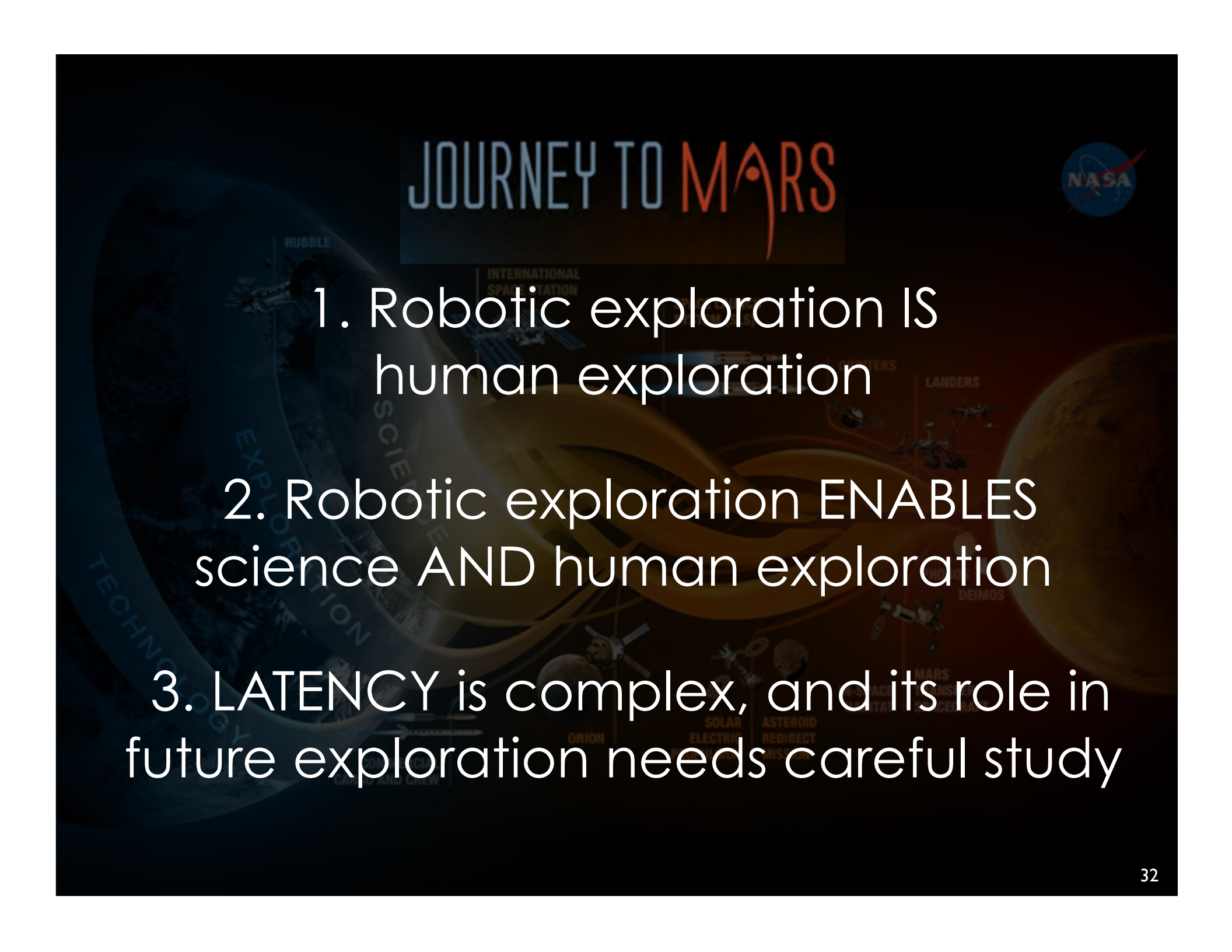
First 12 drill holes in
Gale Crater (through sol 1261)...


2145


Driving along the rim:
Obstacle avoidance and
mapping of dark wind streaks
Sol 1162 (May 2, 2007)

Important Drivers

- Is there added science and/or exploration value that telerobotic operations from Mars orbit provides, given the risks that the crew will be exposed to?
- If so, what specific attributes does low-latency provide that is worth that risk, versus just living with the current delay in communications?
- If not, are there technological advances or innovations that *could* provide that added value, helping to focus current/future development work?


JOURNEY TO MARS
NASA
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