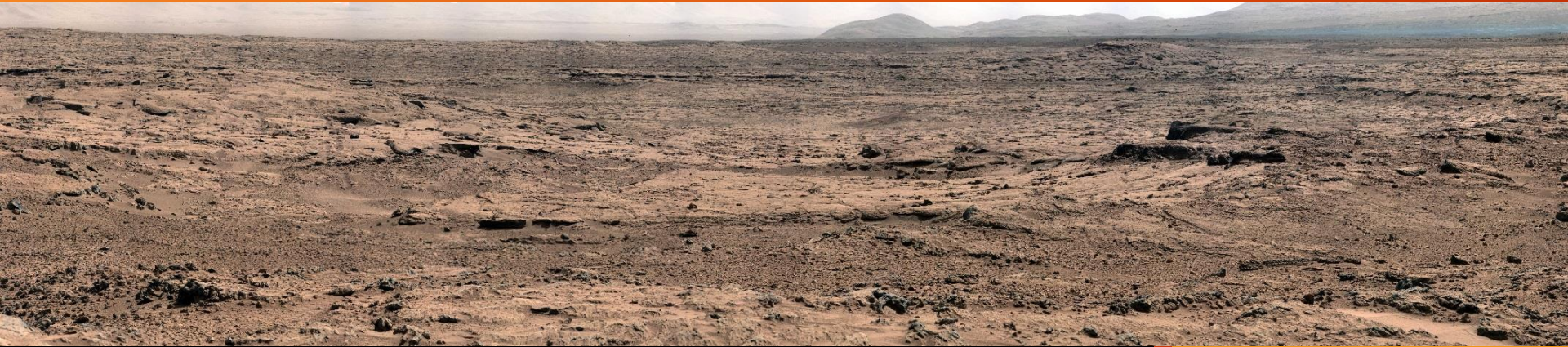




Emerging Technologies for Human Mars Exploration

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Human Explorers on Mars

have different needs than rovers

2



Power



Life Support



Health Care



Shelter



Communication



Earth Return

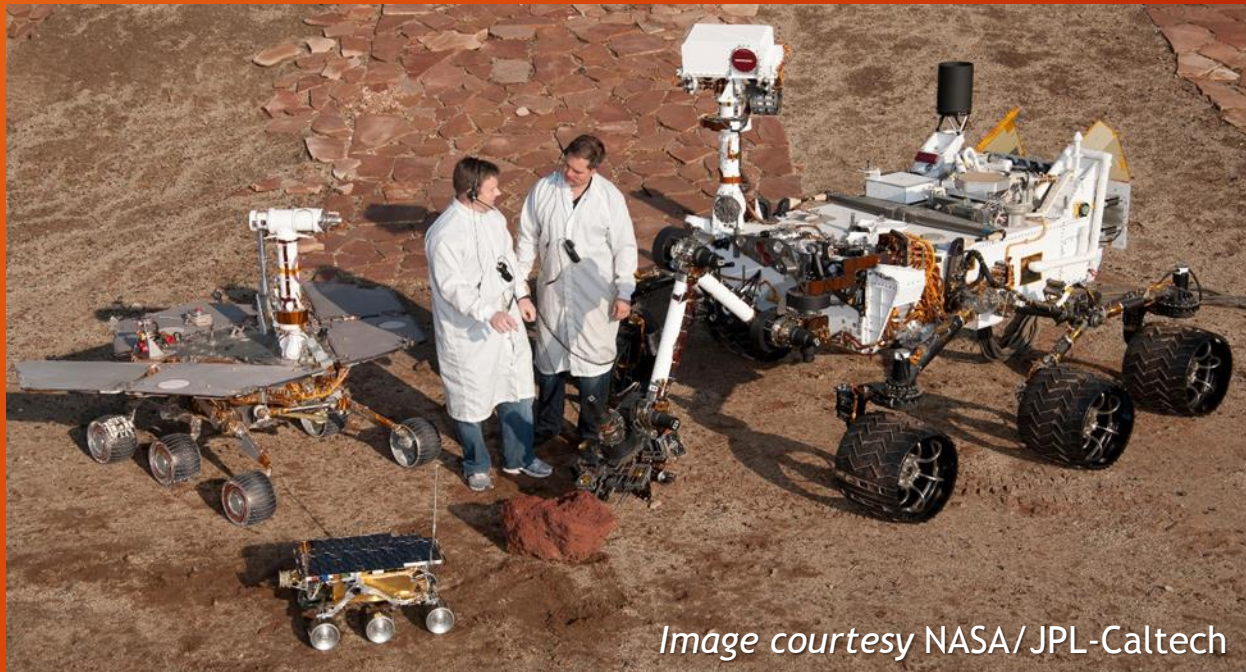


Image courtesy NASA/JPL-Caltech



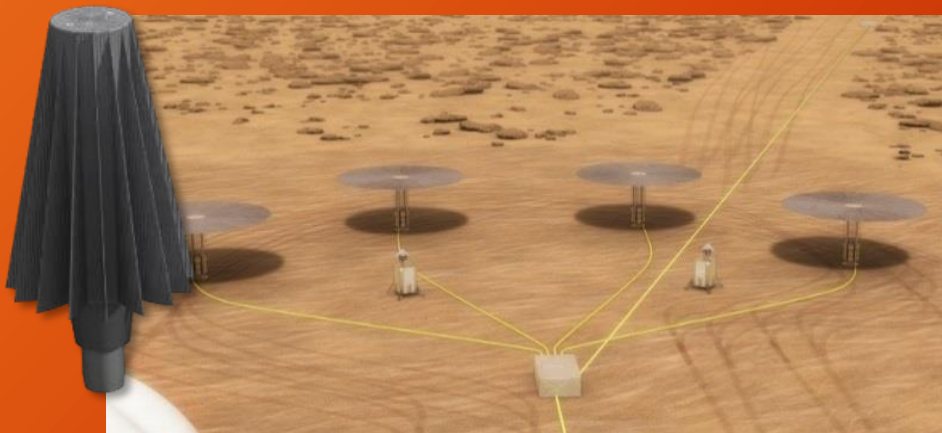
Humans *need a lot more power!*



3

Rovers can hibernate...humans cannot

- Mars rovers need less than 25 Watts (W) keep-alive power
 - Less than 650 W at peak loads
- Human explorers may need as much as 40 *kiloWatts* (kW) for 300+ day surface missions
 - As much as 25 kW keep-alive power
 - Apollo missions were ~4 kW for 3 days



- Kilopower Fission Power
- High density energy storage
- Robotic power connections



Humans *need Life Support Systems!*



4

Rovers don't need food, oxygen, water, bathrooms, or spacesuits

- Closed-loop life support systems
- Advanced water/air monitoring
- Advanced waste management
- Extended shelf-life food systems
- New planetary spacesuits





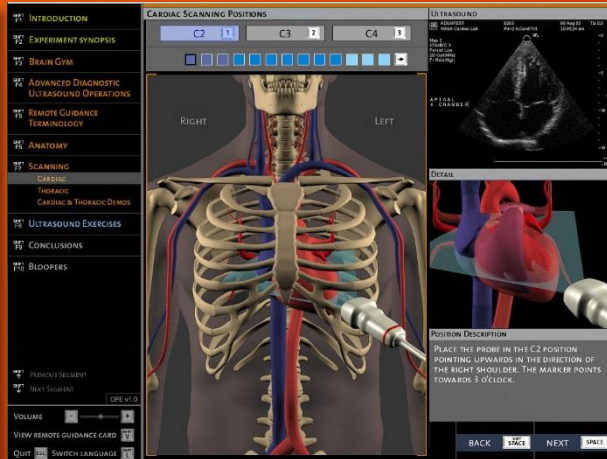
Humans *need Health Care!*



5

Rovers don't get sick

- Space radiation protection
- Reduced gravity countermeasures
- Autonomous medicine + non-physician training
- In situ sample analysis, health monitoring





Humans *need to come inside!*



6

Rovers don't mind living outside

- Reduced pressure
 - Temperature extremes
 - Months-long dust storms
 - Radiation
-
- Long-duration habitats
 - Pressurized Rovers





Humans *need to connect with loved ones!*



7

Isolation doesn't bother a rover

- Up to 44 minutes delay between asking a question and getting an answer!
 - Mars ground station will only be able to talk to Earth ~12 hours per Martian day
 - Curiosity's data rate direct-to-Earth is ~500 to 32,000 bits per second (bps)
 - Human missions will need >300 megabits per second (Mbps)
-
- **High-rate communications to support precision landing, high definition video, etc.**
 - **More autonomy to mitigate delay problem**





Humans *want to return home!*

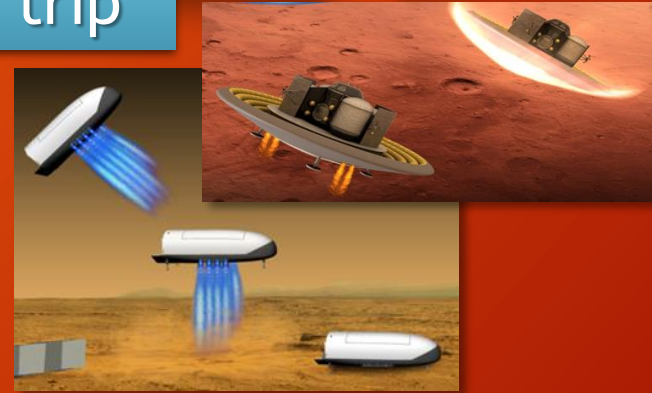


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Rovers are resigned to a one-way trip

Humans need a soft landing *on Mars*

- Curiosity (~1 metric ton) is the largest payload ever landed
- Crewed Mars lander payloads ~20 to 40 metric tons!



- Rigid Mid Lift-to-Drag-Ratio (L/D) Lifting Body
- Hypersonic Inflatable Aerodynamic Decelerator (HIAD)
- Liquid Oxygen/Methane propulsion + cryogenic propellant management



Humans need a boost *off* of Mars

- Requires 7+ kg of propellant for every 1 kg of Mars ascent payload
- In Situ Resource Utilization -return propellant from Martian resources
- Common ascent/descent propulsion
- Orion for Earth re-entry



Humans Have Different Needs... and Different Capabilities

“I'm a robot guy,

but I'm actually a very strong supporter of human spaceflight. I believe that the most successful exploration is going to be carried out by humans, not by robots.

What Spirit and Opportunity have done in 5-1/2 years on Mars, you and I could have done in a good week.

Humans have a way to deal with surprises, to improvise, to change their plans on the spot. All you've got to do is look at the latest Hubble mission to see that.”

--Dr. Steve Squyres

*lead scientist for the Mars Exploration Rover Project
professor at Cornell University*





Key Take-Aways

Emerging Technologies for Mars

10



Power



Life Support



Health Care



Shelter



Communication



Earth Return

- Human Mars explorers will have different needs than robotic explorers
- Human Mars exploration can leverage many emerging technologies
 - Opportunities to test these technologies on the International Space Station or in cis Lunar space



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Questions?

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