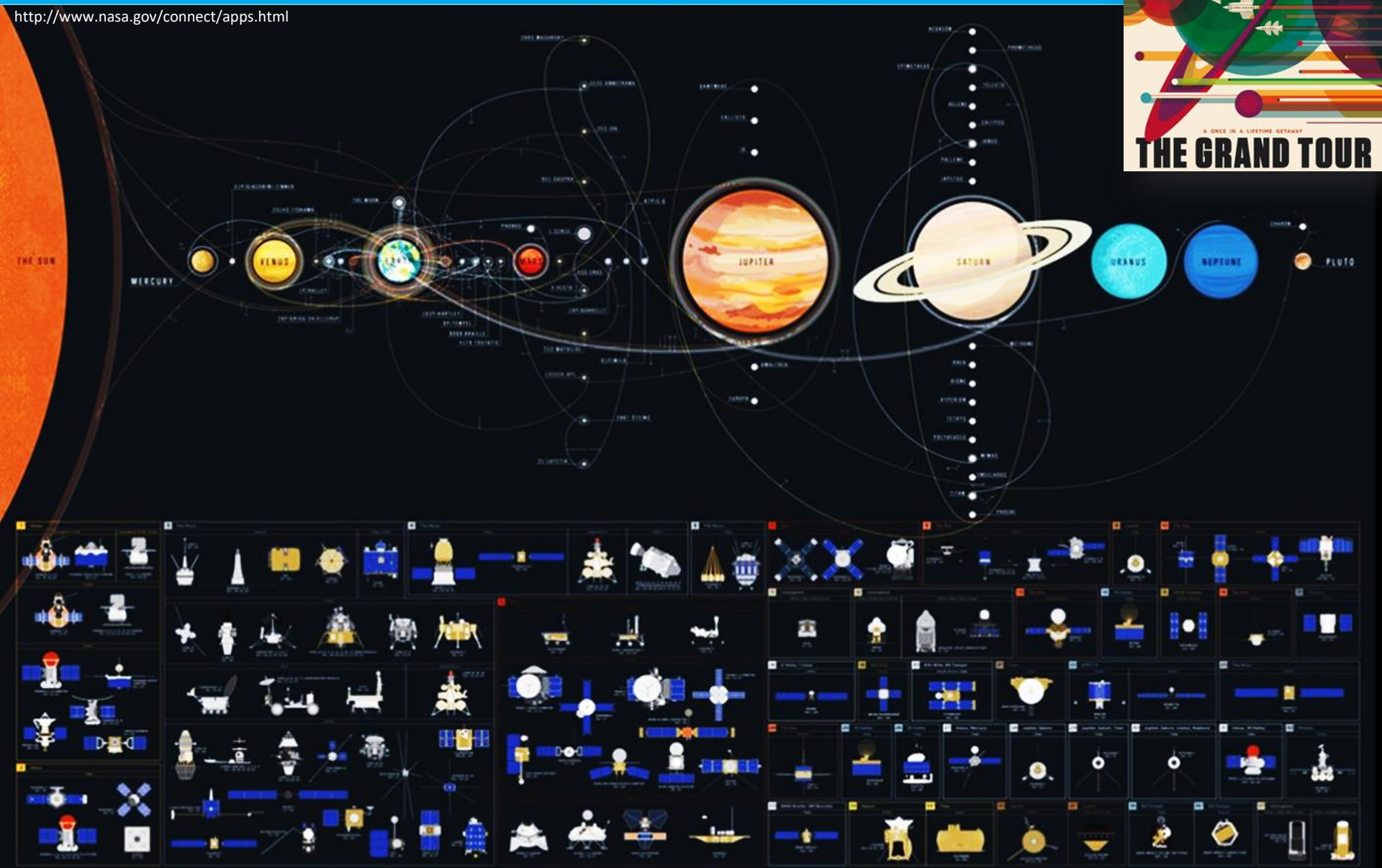
Space Communications and Navigation

Dr. Daniel Raible

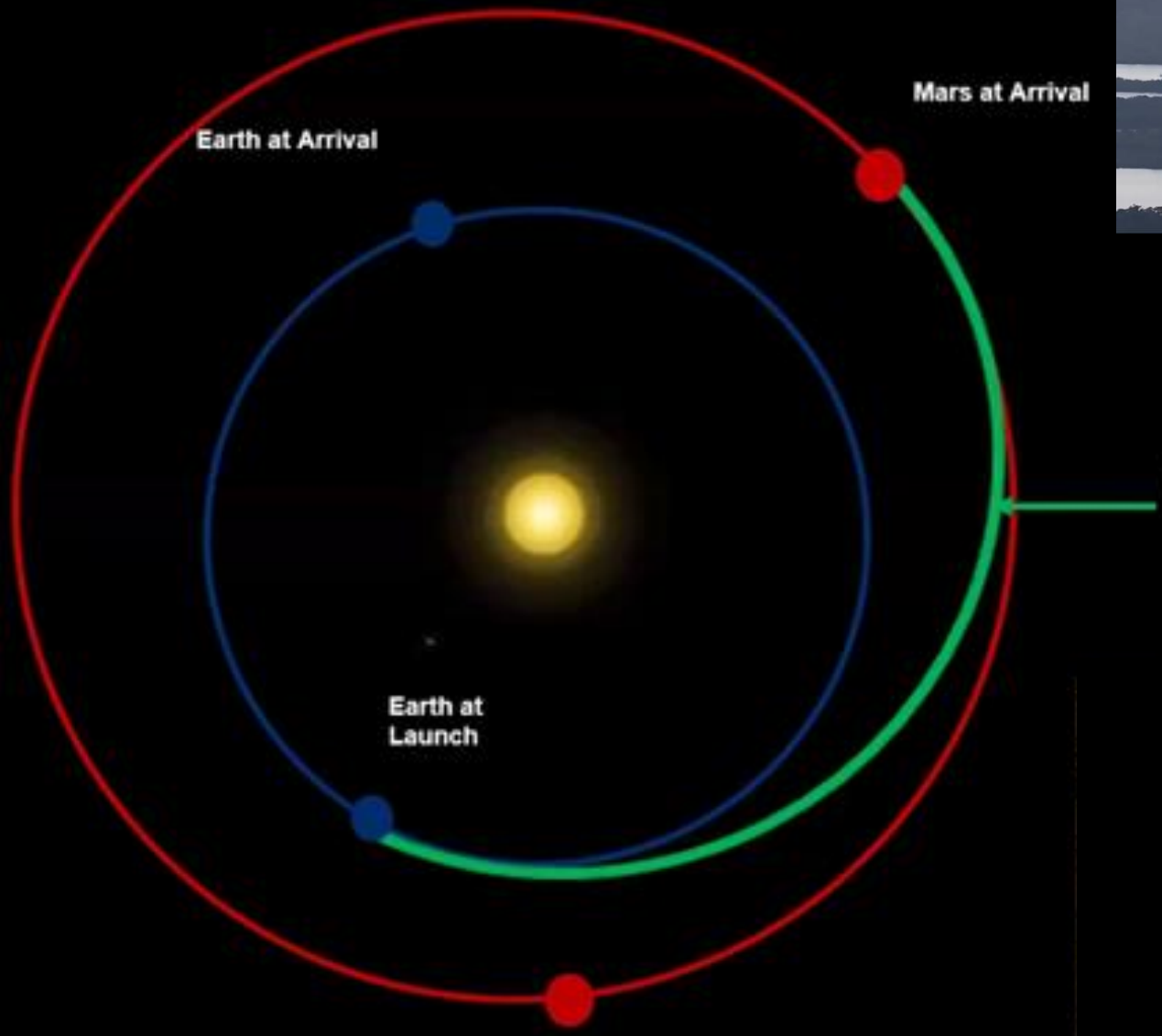
Our Cosmic Exploration

http://www.nasa.gov/connect/apps.html

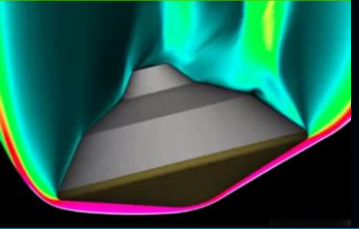


Going to Mars

July 2020 launch

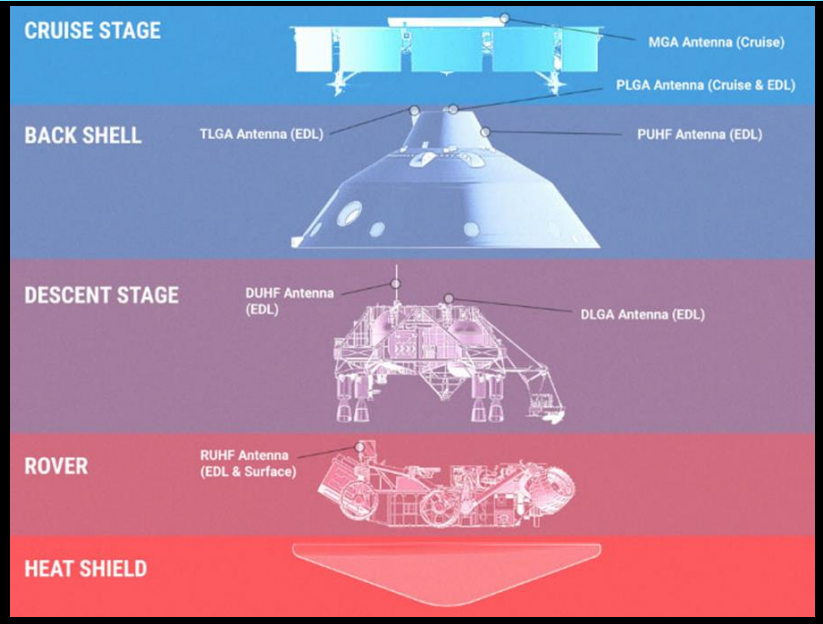


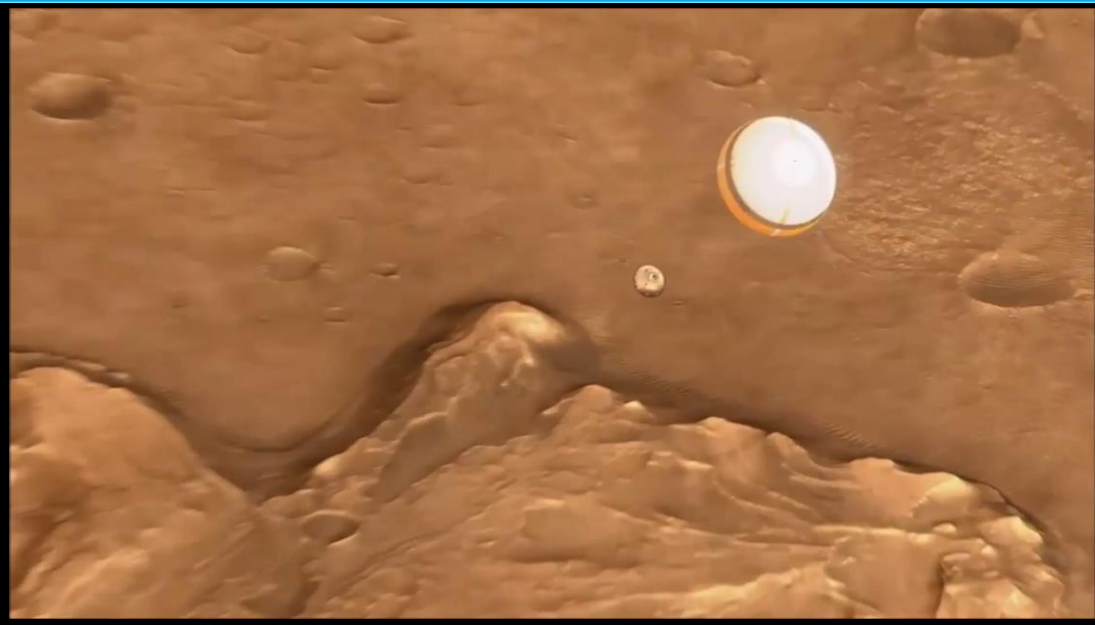
- Launch opportunity every 2 years (21 day window)
- Distance: 175 million kilometers
- Speed: 95,000 km/hr
- Trip length: 7 months
- Navigational course corrections (extreme precision required)
- Resolve spacecraft velocity to 0.1 mm/s and angle to 2.5 nano-radian (a 1 km landing zone)



Entry, Descent and Landing

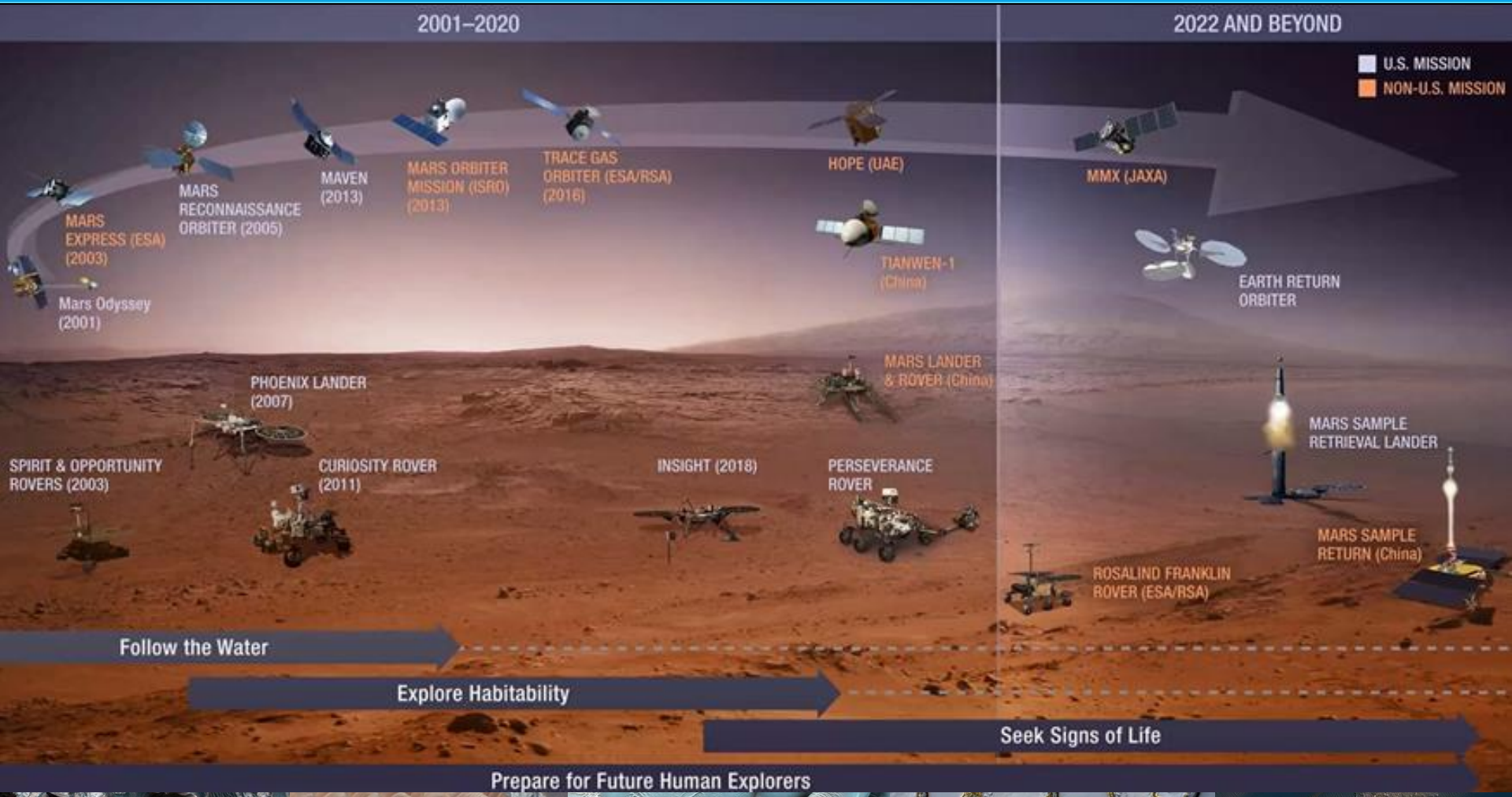
from 19,000 to 3 km/hr at touchdown





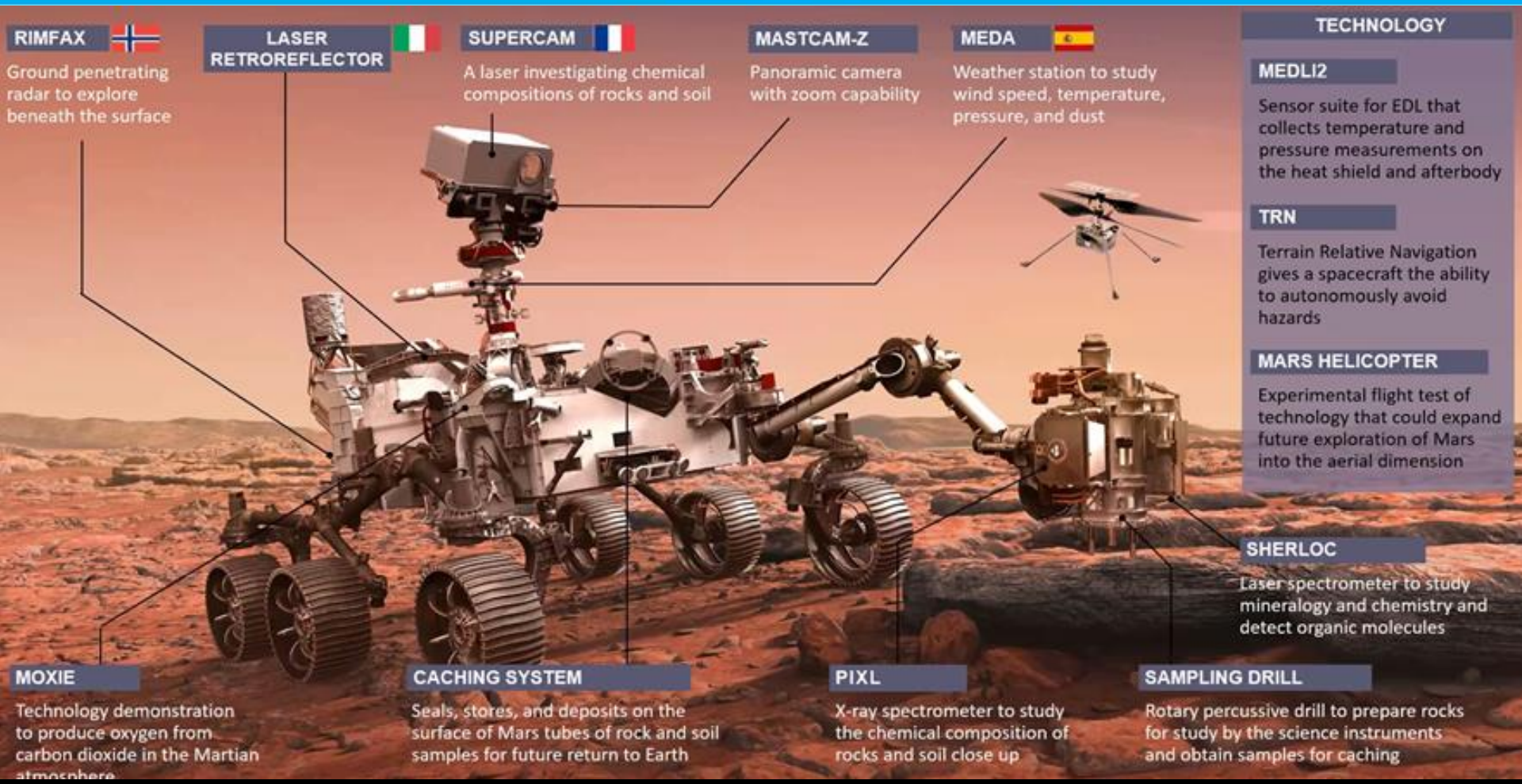
Mars Exploration Program

We've sent more hardware to Mars than any other planet



Instruments & Technology

Persevering Toward the Future



Searching for ancient life, gathering rocks and soil

Identifying resources to help pave the way for future human exploration

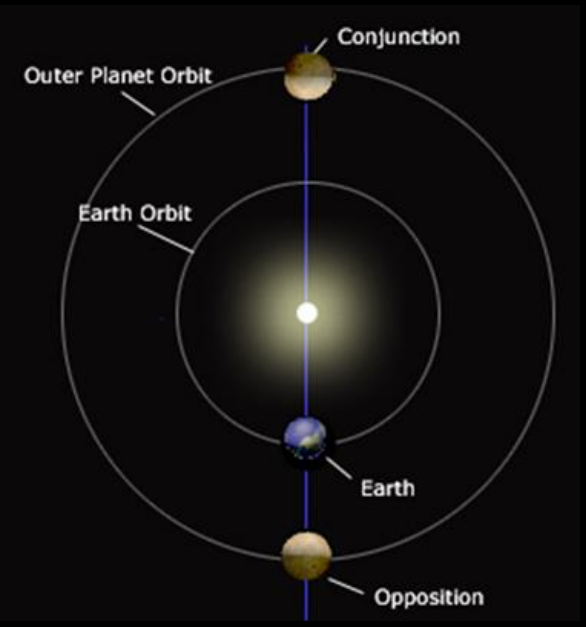
Generating a lot of data to transmit to Earth!

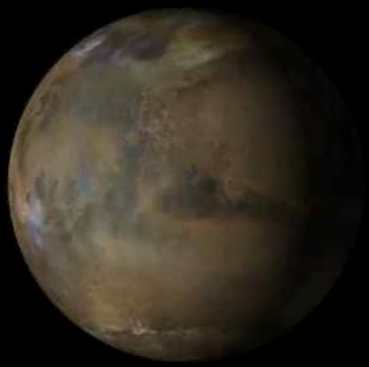
Communications Challenges

Mars is very far from Earth

- It takes about 5 to 20 minutes for a radio signal to travel the distance between Mars and Earth, depending on planet positions
- -90C temperatures at night and dust & radiation storms require rugged electronics
- Limited power and processing on rover
- Solar conjunction events cause planned outages
- Space and Earth weather can cause unplanned outages
- Everything is in motion - orbits , rotations and rover!

Watching a Martian sunset





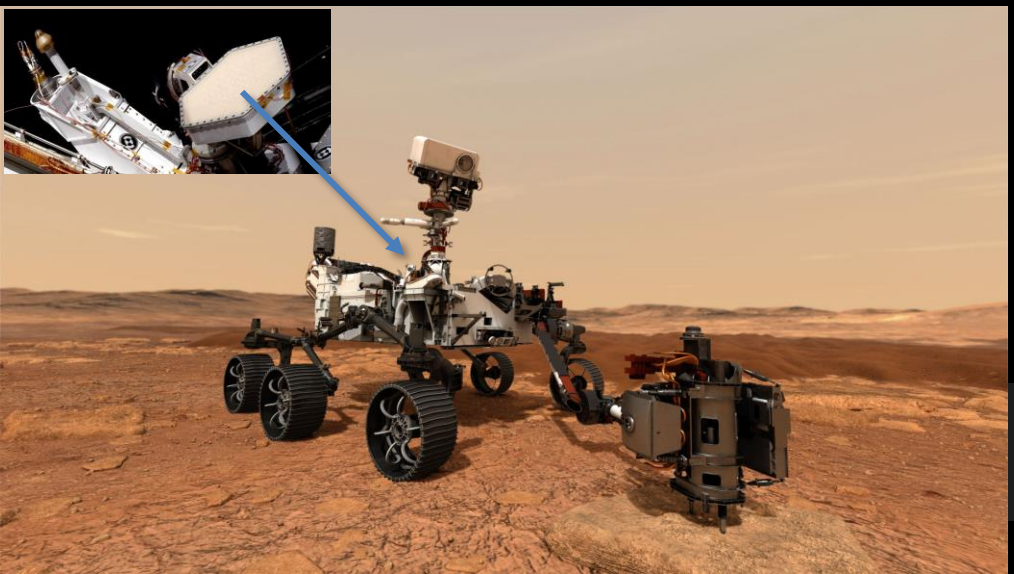
May 28

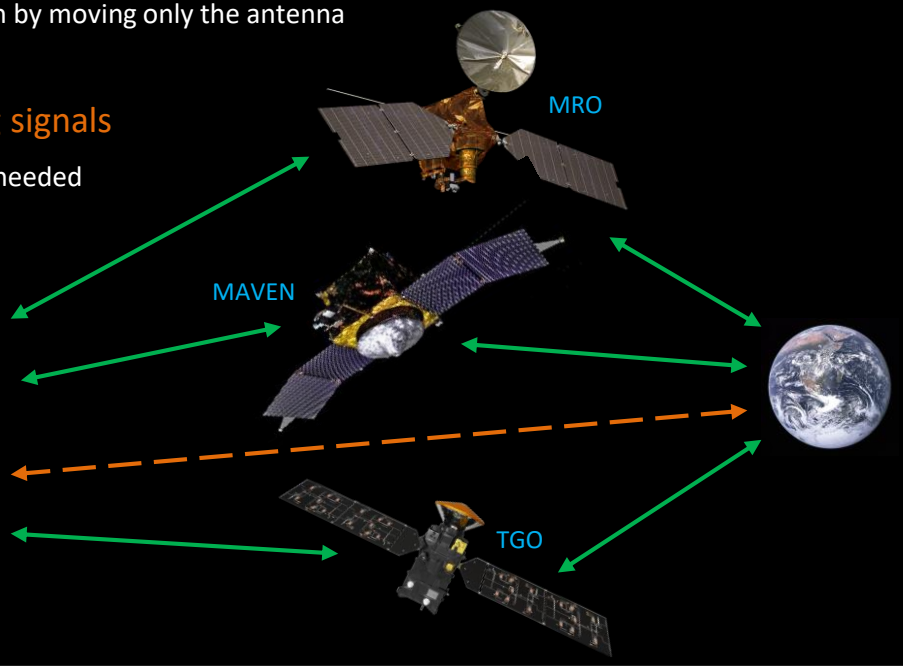
July 1

Perseverance

Three forms of Communications

- Ultra-High Frequency (UHF) antenna with transmission speeds of 2 megabits per second to an orbiting relay spacecraft
  - Orbiters use their much larger antennas and transmitters to relay data across the long-distance link back to Earth
  - 99.9% of science data is communicated through this antenna to passing orbiters, including NASA's MAVEN and Mars Reconnaissance Orbiter, as well as the European Space Agency's Trace Gas Orbiter
  - Orbiters will only be viewable for around 8 minutes per day, so data is recorded for storage until transmission
- Alternate X-Band high-gain antenna will be used to transmit data directly to Earth at 160-500 bits per second
  - Steerable beam so rover doesn't need to change position to talk to Earth by moving only the antenna
  - Routinely used to send commands to the rover each morning on Mars
- Lastly an X-Band low-gain antenna primarily used for receiving signals
  - Provides operational flexibility and backup options just in case they are needed

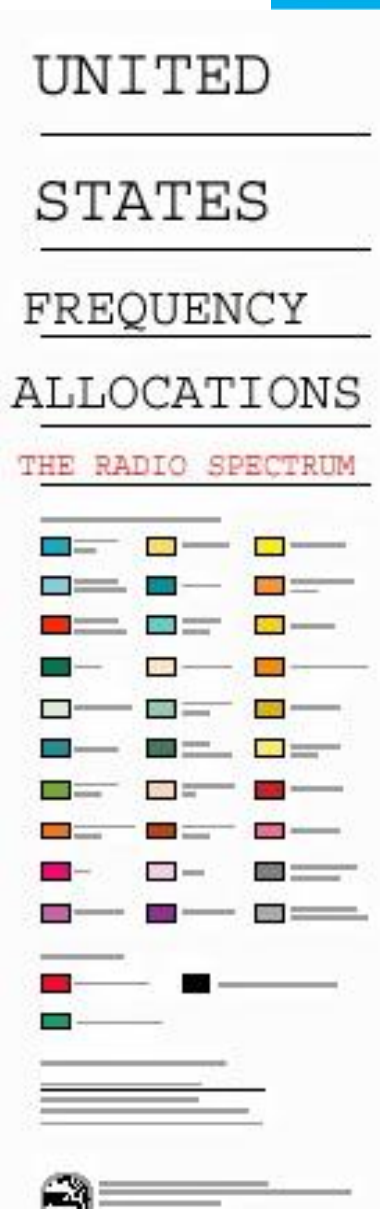


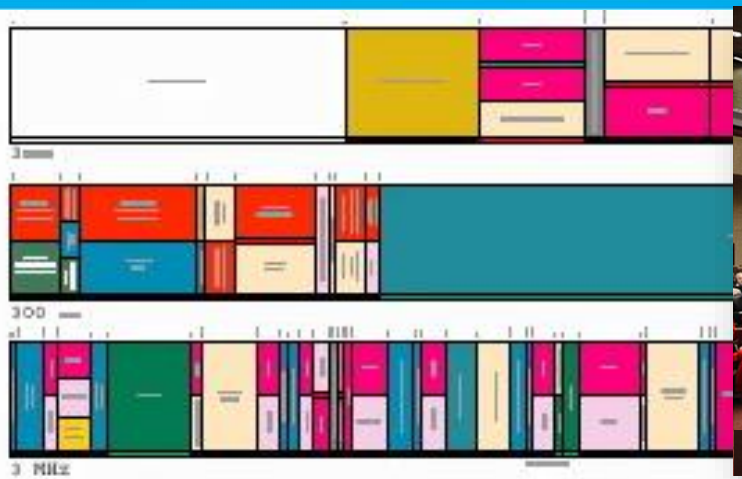


Mars Relay Network	UHF	X-BAND [HIGH GAIN]	X-BAND [LOW GAIN]
DATA SPEED	2 Mbps	160-500 bit/sec	10 bit/sec
	about 400 MHz	7 – 8 GHz	

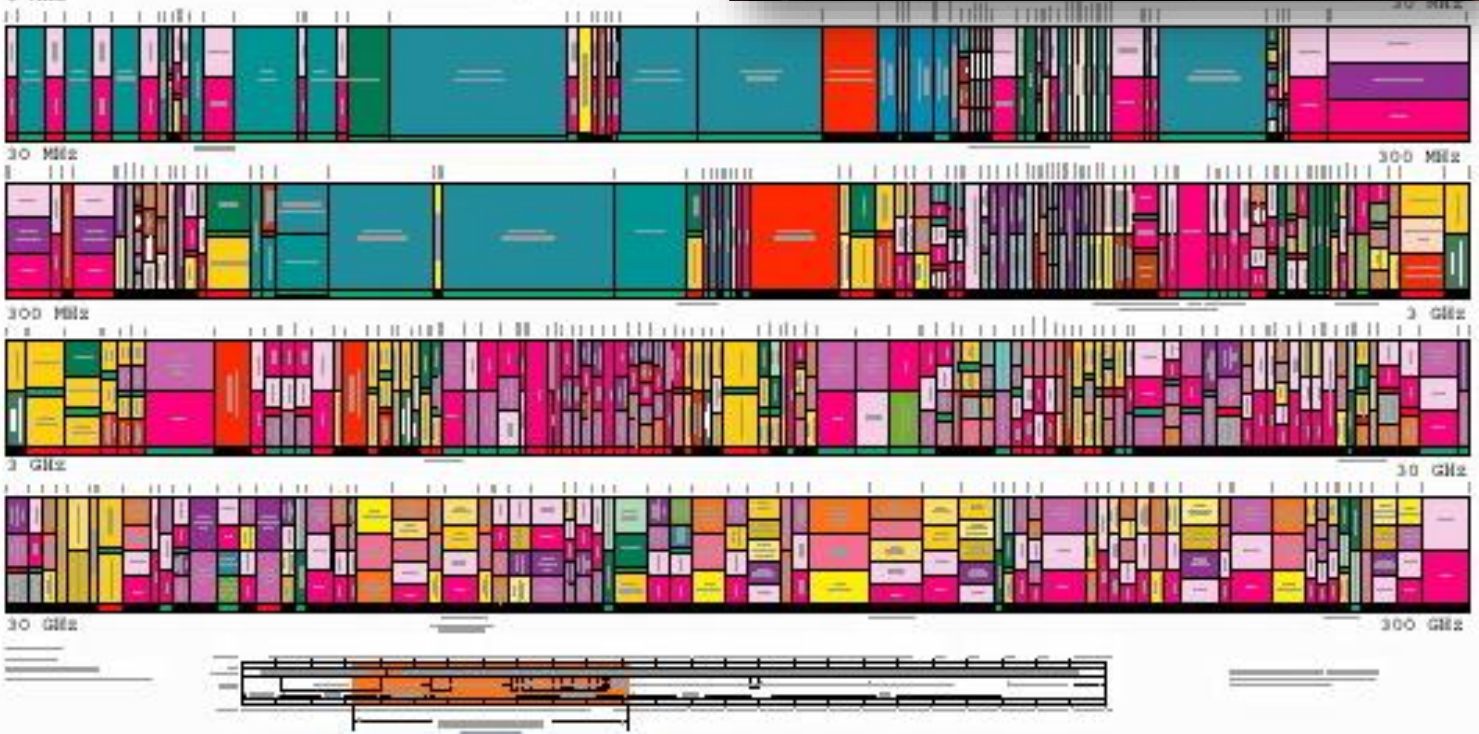
Allocated Radio Frequencies

in contention with all worldwide users





NASA Spectrum Management at Work in Geneva



Featuring a Helicopter Demonstration

Ingenuity - First Powered Flight on Another Planet

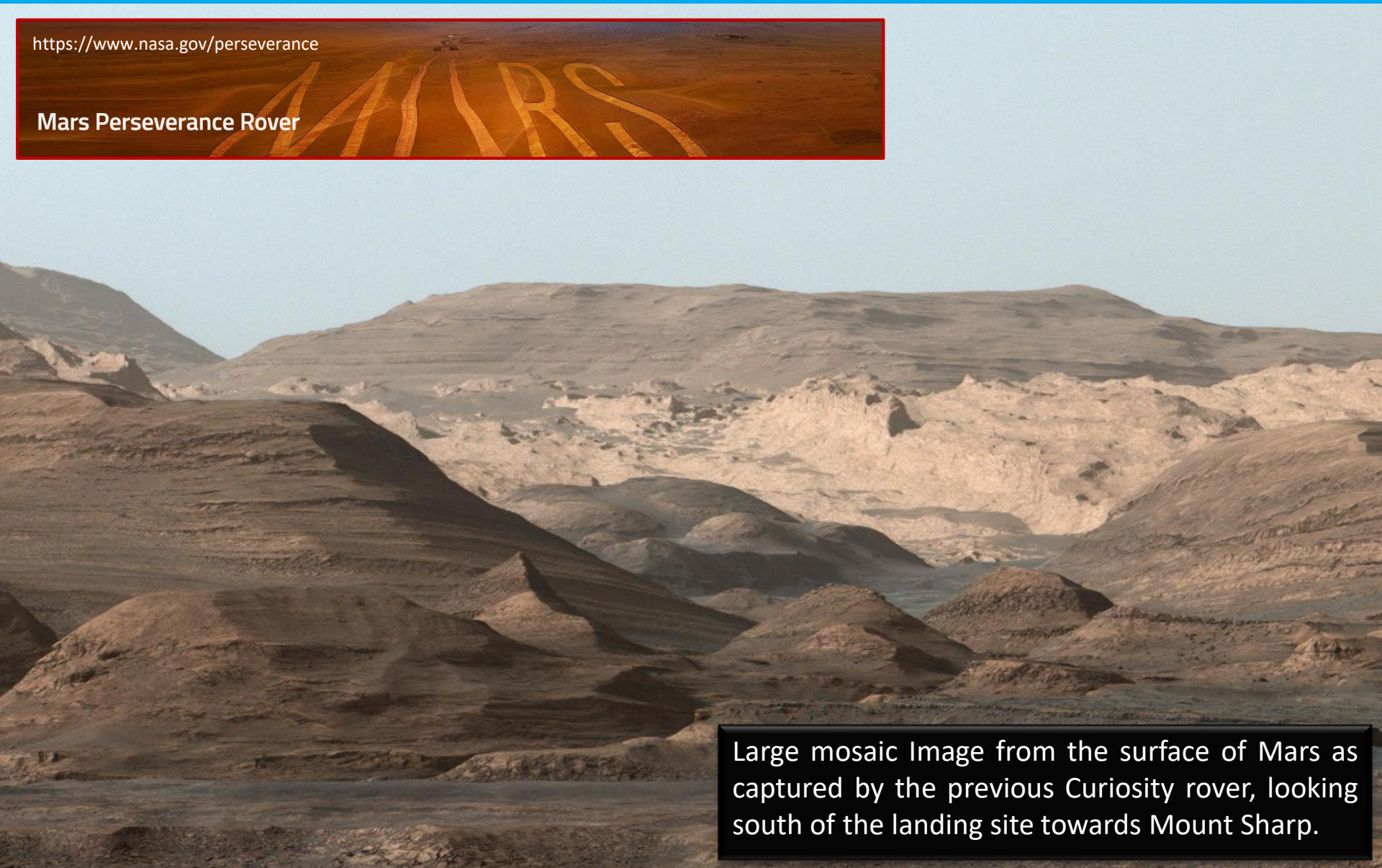
Offers reach, range and resolution to the mission, and creates a small communications network on the surface

Perseverance

Anticipating an Enormous Amount of Data Return

https://www.nasa.gov/perseverance

Mars Perseverance Rover

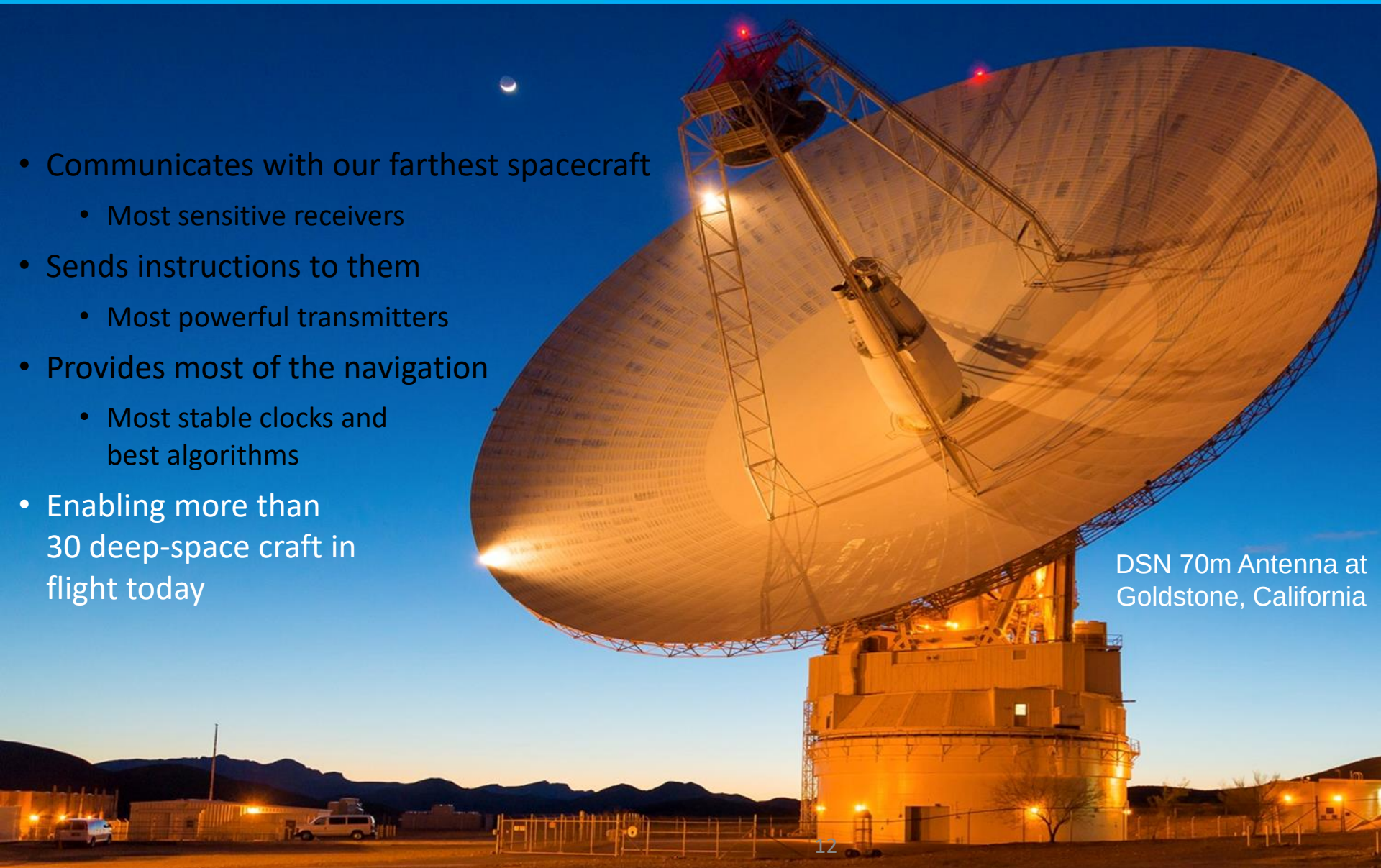


Large mosaic Image from the surface of Mars as captured by the previous Curiosity rover, looking south of the landing site towards Mount Sharp.

Back on Earth - The Deep Space Network (DSN)

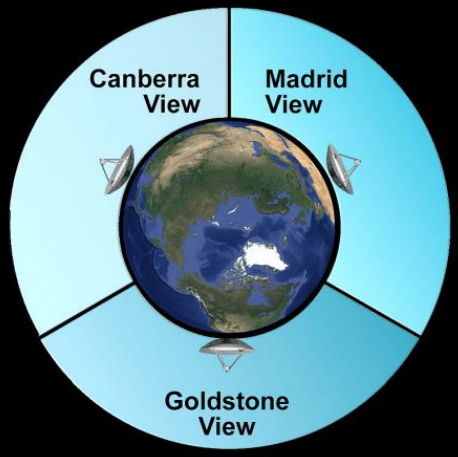
NASA's Connection to the Moon, Planets, & Beyond

- Communicates with our farthest spacecraft
  - Most sensitive receivers
- Sends instructions to them
  - Most powerful transmitters
- Provides most of the navigation
  - Most stable clocks and best algorithms
- Enabling more than 30 deep-space craft in flight today



DSN 70m Antenna at Goldstone, California

Deep Space Network (DSN)

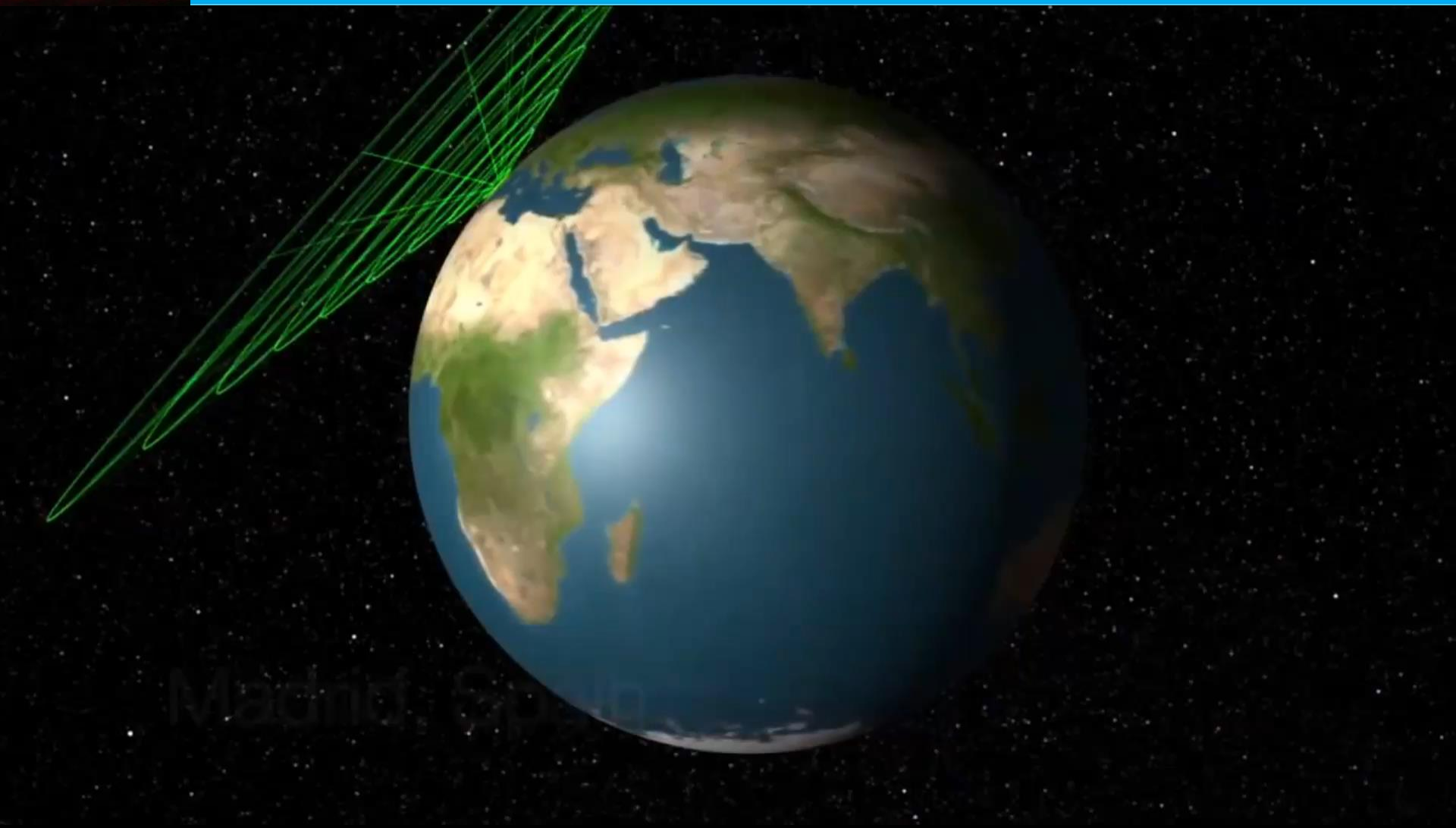


Goldstone, CA
35.30 deg N. Latitude
116.9 deg W. Longitude

Madrid, Spain
40.4 deg N. Latitude
3.70 deg W. Longitude

Canberra, Australia
35.30 deg S. Latitude
149.1 deg E. Longitude

Deep Space Network Complexes

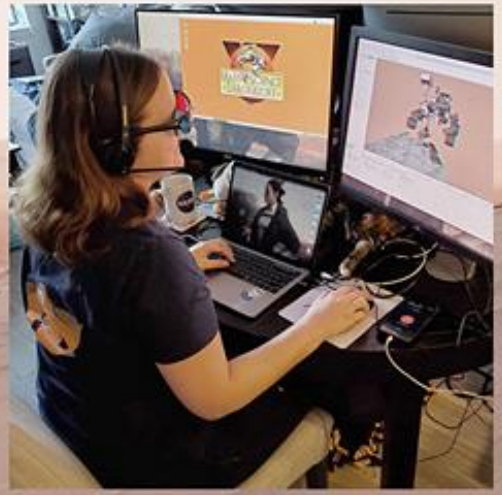


JPL Space Flight Operations Facility (SFOF)

Control Room Operating 24/7 for 40 years in Pasadena, CA

The SFOF has monitored and controlled all interplanetary and deep space exploration for NASA and other international space agencies since 1963. The facility also acted as a backup communications facility for Apollo missions.

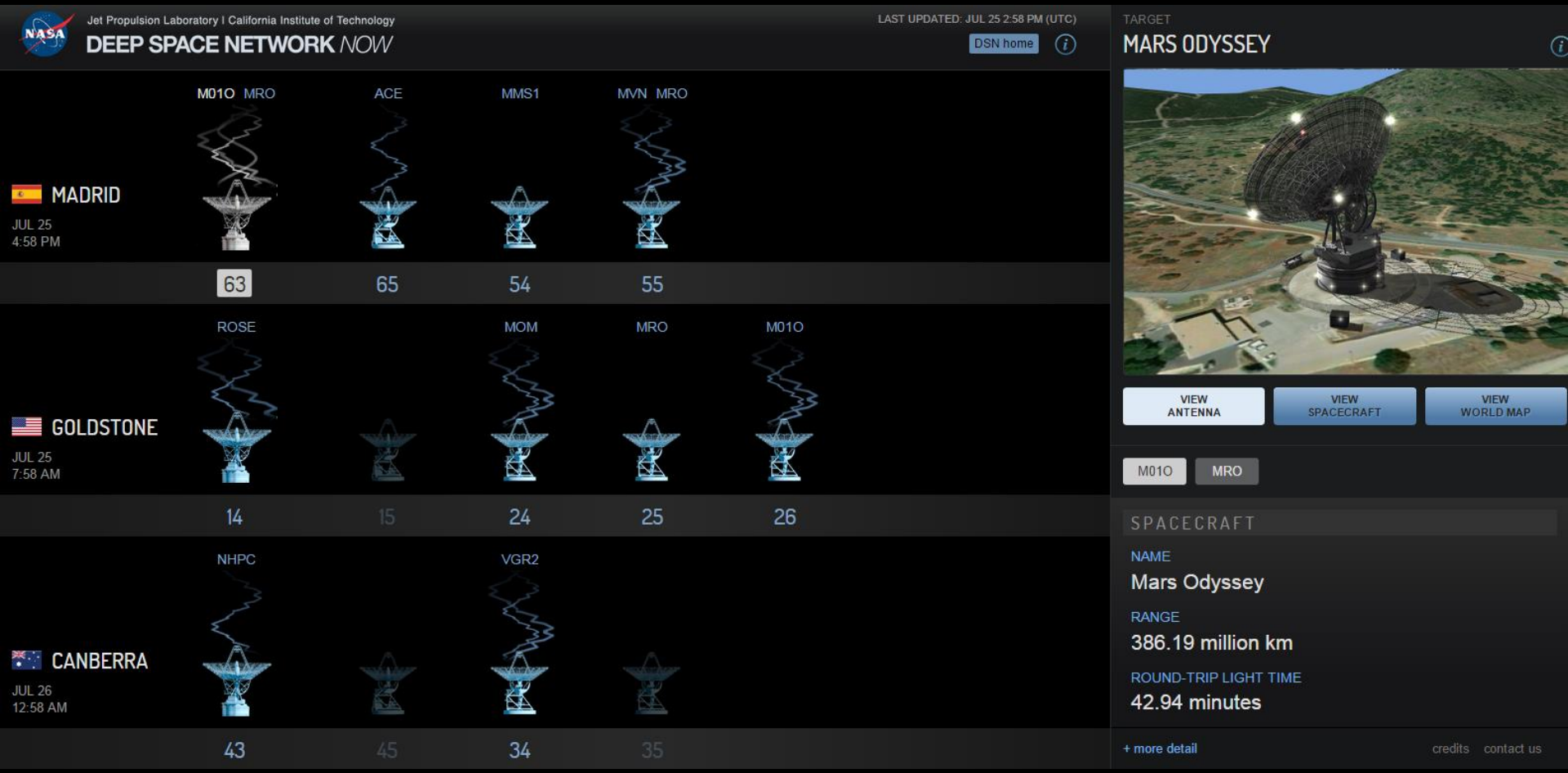
COVID-19: Operating a Mars Rover From Home



March 20, 2020, the first day the entire NASA Curiosity Mars rover mission team worked remotely from home.

Watch Live Status of the DSN

https://eyes.nasa.gov/dsn/dsn.html

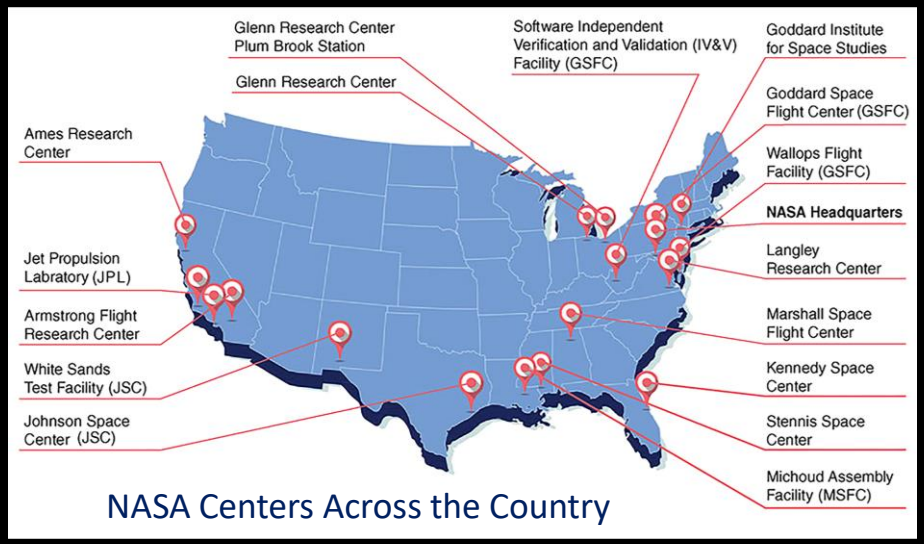


Ways to Participate

- Small Business Innovation Research Program
  - H9.01 - Long Range Optical Telecommunications
  - H9.03 - Flight Dynamics and Navigation Technology
  - H9.05 - Transformational Communications Technology
  - H9.07 - Cognitive Communications subtopic
  - H6.22 - Neuromorphic Processing subtopic
- NASA Contracting and Agreement Mechanisms
  - Space Act Agreement – Non-Reimbursable (no transfer of funds)
  - Space Act Agreement – Reimbursable (NASA receives funding)
  - Cooperative Agreement – 50/50 cost share for joint research
  - Contract – Payment for R&D activities
- Academic Collaborations
  - Faculty fellowships
  - Intern programs (LERCIP, USRP, GSRP)
  - Postdoctoral research
- Informal Discussions
  - Technical Workshops, e.g. Cognitive Communications for Aerospace Applications
  - Communications Division – Distinguished Technical Lecture Series
  - Project-level discussions

Internships https://intern.nasa.gov/

- Internships are available from high school to graduate level
- Most interns receive a stipend award
- Interns are selected and placed for fall, spring and summer sessions
- Applications may be made to specific projects at Center locations, or Agency-wide



NASA Centers Across the Country

Thank you for your kind attention!