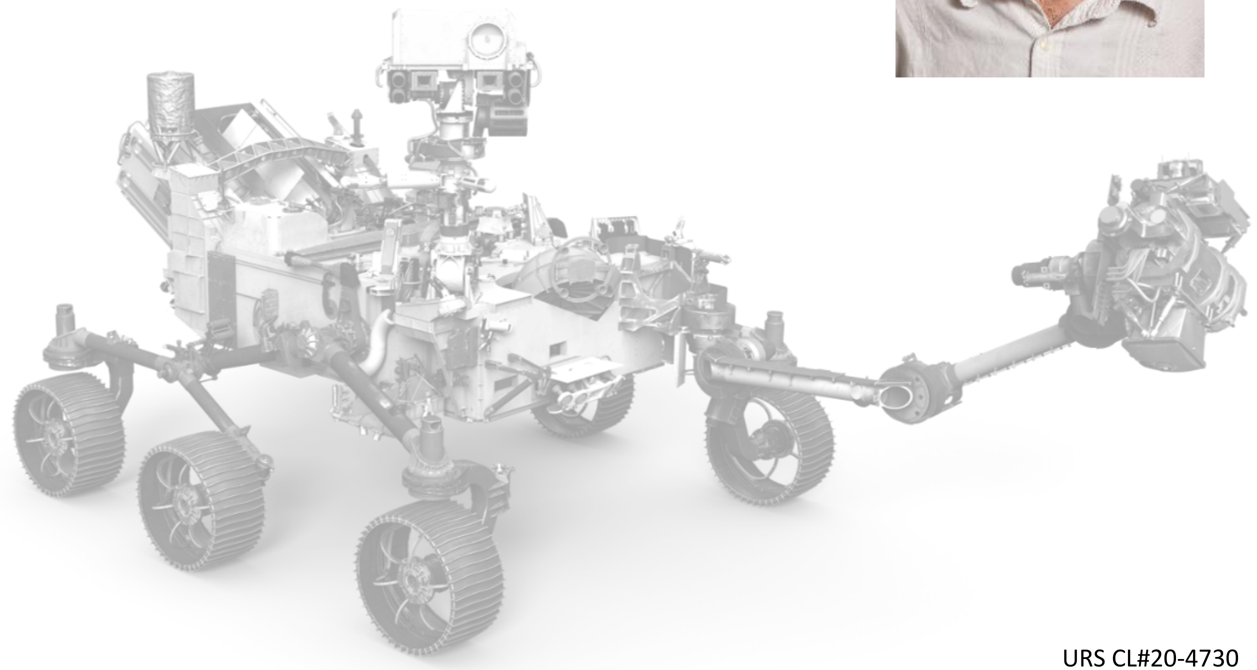
Jet Propulsion Laboratory
California Institute of Technology

MARS 2020

Dr. Justin I. Simon
Return Sample Scientist
NASA Johnson Space Center



URS CL#20-4730

Why do scientists explore Mars?

- Mars has geologic features similar to Earth.
- Water once flowed on Mars.
- We want to know if Mars could have once supported ancient life forms (and how we could live there).

Credit: NASA

How do scientists study planetary objects in our Solar System?

Put your answers in the chat.

Credit: NASA

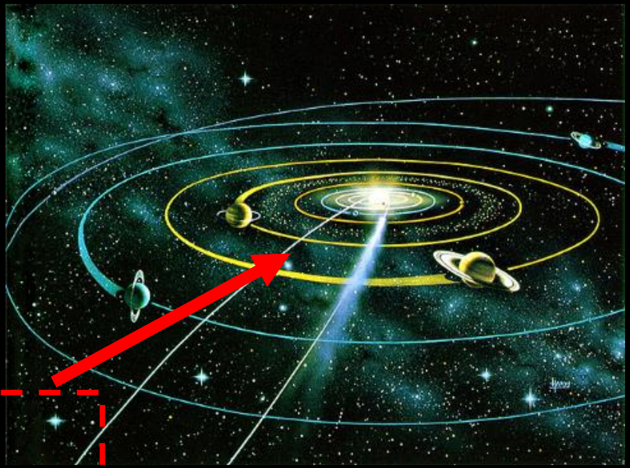
How do scientists study planetary objects in our Solar System?

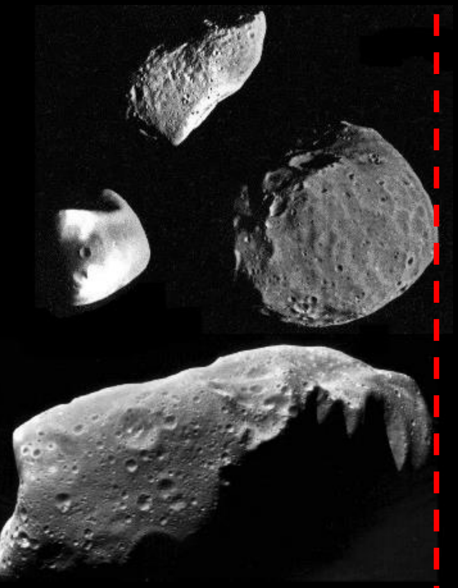
- Observations from telescopes on Earth
- Measurements from orbiters ('spacecraft')
- Measurements from robotic landers and rovers
- Collect and study meteorites
- Robotic geologists and astronauts collect and return samples

Credit: NASA

Where do meteorites come from?

Primitive meteorites come from
→ asteroid belt





Real images of asteroids

Credit: NASA

Martian meteorites are knocked off from the impact of these objects.

Which after floating around fall to Earth

Painting by Don Davis. Copyright SETI Institute, 1994

Meteorites fall lots of places on Earth, but we’ve had a lot of success finding dark rocks on light ice

Credit: NASA

Softball-sized carbonaceous chondrite (“protoplanetary disk sediment”)

Meteor Crater, Arizona

Images = Cascadia Meteorite Laboratory

Many martian meteorites have less clear ages… this one ranges from 0.2 to 1.3 billion years old

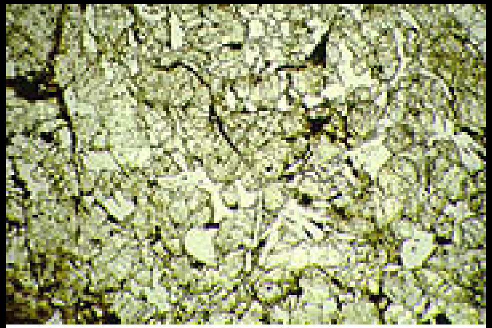
8 kg (17 lbs) martian meteorite found in Antarctica

Credit: NASA

Antarctic Martian Meteorite

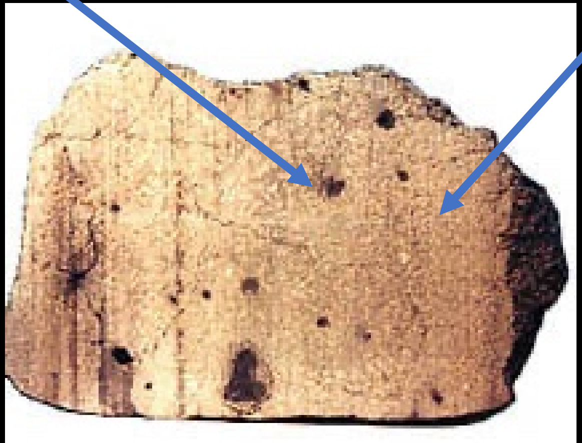
Each photomicrograph is 2.8 mm across.

“Sheared” black outer fusion crust from atmospheric entry



EETA79001 Lithology A

EETA79001 Lithology B



Cut surface

Mixture of primitive meteorite +/- sedimentary martian surface rock (and altered on Earth too before collection)

We have found many meteorites & learned a lot from them, but their travels to Earth can be pretty rough!

Credit: NASA

If we want more pristine rock samples we have to go get them…!

Credit: NASA

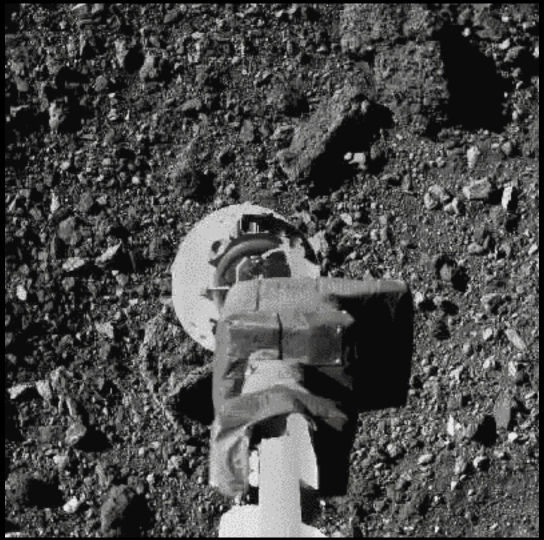
Apollo Missions to the Moon

Apollo 17, Dec. 1972

Credit: NASA

OSIRIS-REx
ASTEROID SAMPLE RETURN MISSION

This is an artist's rendition



This is real (Aug. 11th dress rehearsal ~ to our successful sample collection Oct. 21st, 2020)

Credit: NASA

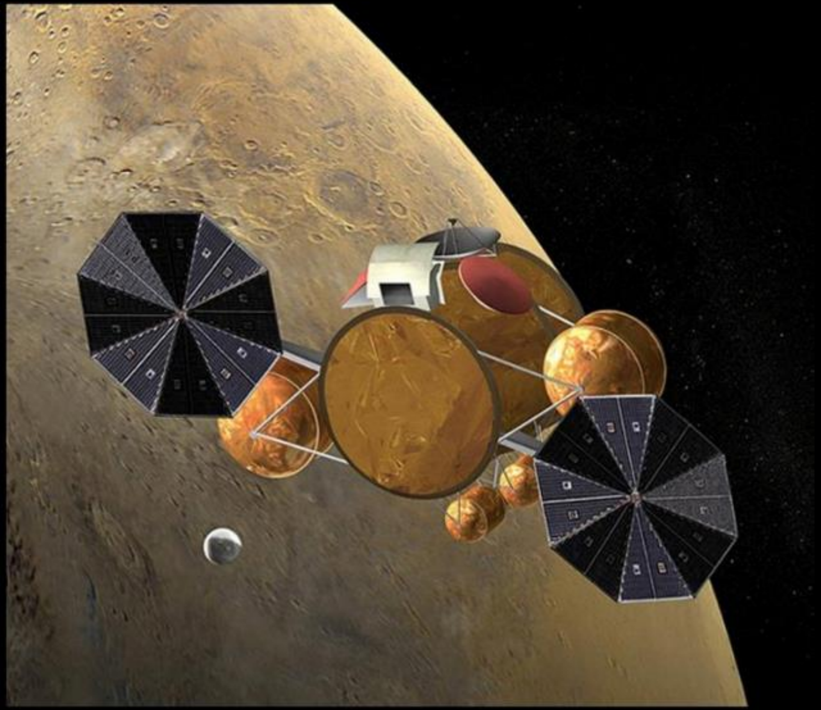
The Three-Mission Mars Sample Return Campaign

Sample Collection
(Mars 2020)

we are here

These are artists' renditions

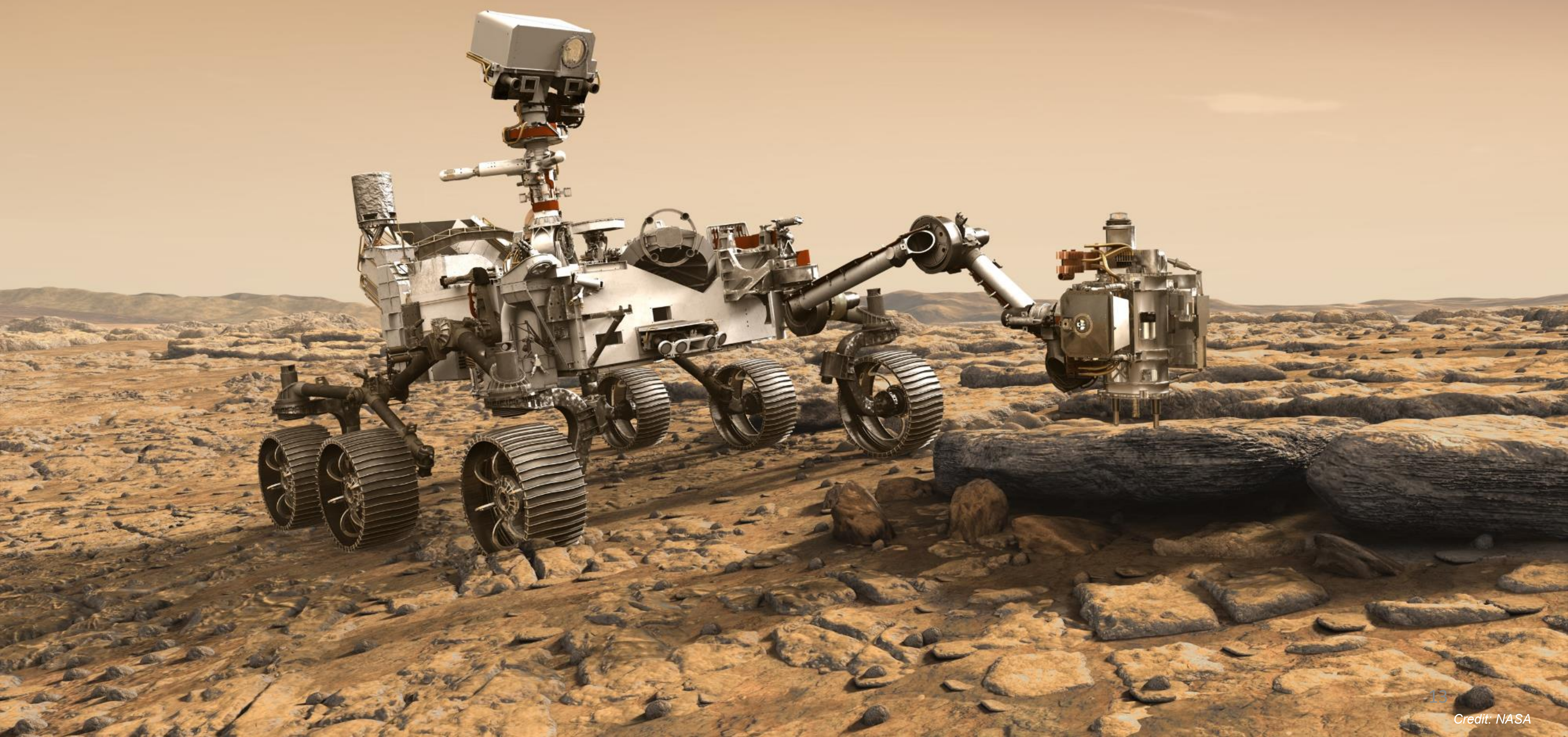
Mars Ascent Vehicle (MAV)
launches Orbiting Sample (OS)



Mars Orbiter captures OS and
brings it back to Earth

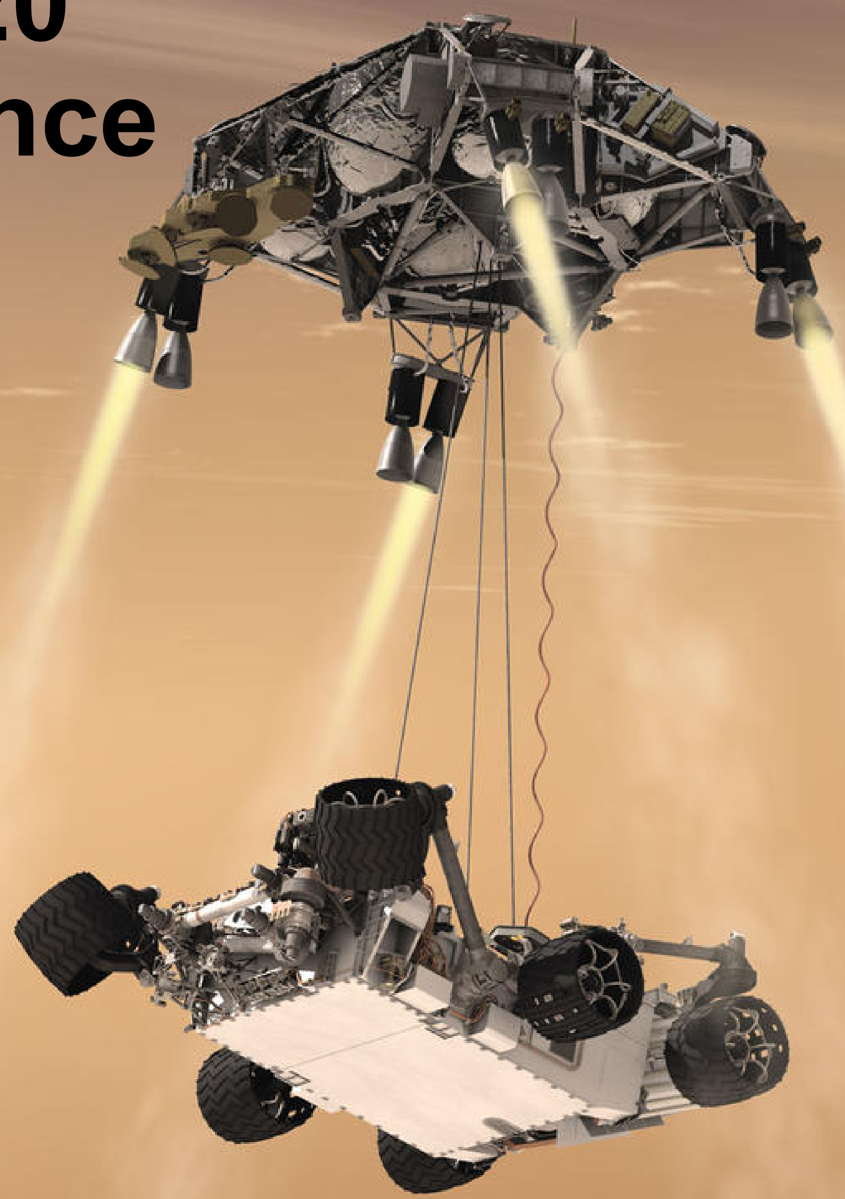
Credit: NASA

Introducing the Mars 2020 Rover Perseverance, our Scientific Adventure Begins



Credit: NASA

Mars 2020 Perseverance



GOALS:

- Identify past environments capable of supporting microbial life
- Seek signs of possible past microbial life in those habitable environments
- Collect rock core and “soil” samples and store them on the martian surface
- Test oxygen production from the martian atmosphere

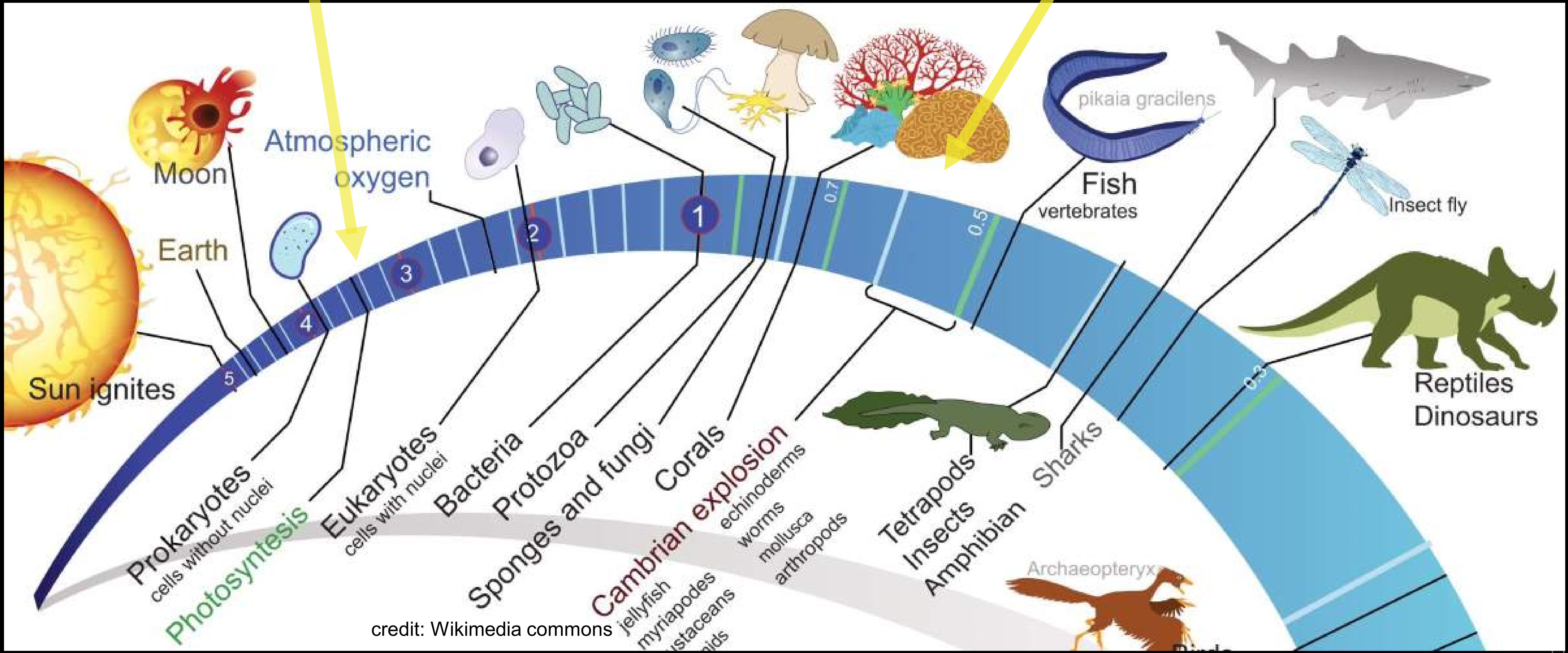
This is an artist’s rendition of a real event!

Credit: NASA

Terrestrial Biological Time Line

Mars climate change here

First Familiar "fossils"



credit: Wikimedia commons

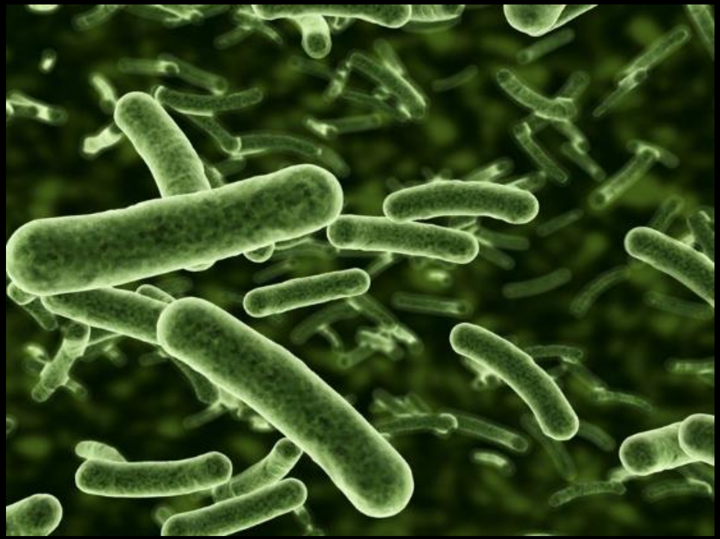
Modern Stromatolites: Shark Bay

BASIC NEEDS OF A LIVING ORGANISM

Water, energy, nutrients, and clement environment (e.g., reasonable temperature)

Likely geological places to find life:

- Near or in bodies of water
- Near volcanoes and other geothermal heat sources
- In partially melted subsurface ices



E. Coli on International Space Station

EVIDENCE OF PAST LIFE ON EARTH

Classic Fossils: Less than ~650 million years old

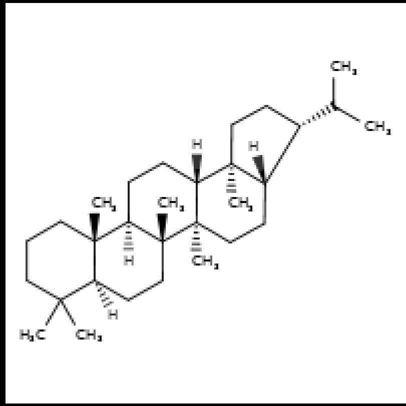
Microbial Biosignatures: up to 3.6 billion years old

On Mars we would be looking for evidence of past life... looking for evidence in data such as... (see next slide!)

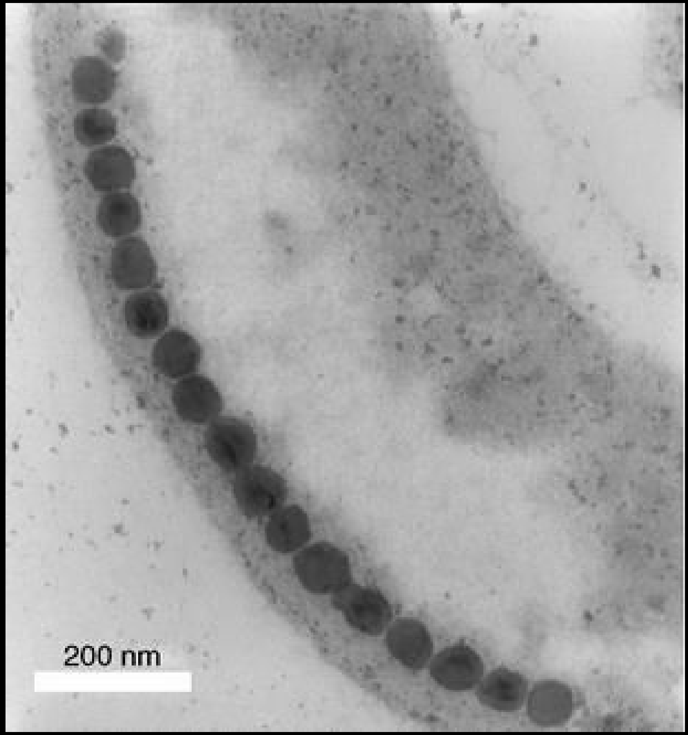
How might we detect ancient, possibly non-Earthlike life?

$^{13}C/^{12}C$
$^{18}O/^{16}O$

isotopes



organic molecules



biominerals

physical & chemical structures in rocks

Where should Mars 2020 go…?

4 Landing Site Selection Workshops
1st in 2014: many landing sites
2nd in 2015: >20 landing sites
3rd in 2017: 8 landing sites
4th in 2018: 3 final landing sites

ra	Site	Landing Site Scientific Selection Criteria											
		CHARACTERIZABLE GEOLOGIC SETTING & HISTORY		ANCIENT HABITABLE ENVIRONMENT		HIGH BIOSIGNATURE PRESERVATION POTENTIAL		ASTROBIOLOGICAL QUALITY OF RETURNED SAMPLES		PETROLOGICAL QUALITY OF RETURNED SAMPLES		AVERAGE	
		mode	average	mode	average	mode	average	mode	average	mode	average	mode	average
1	Jezero	5	4.9	5	4.7	5	4.4	5	4.4	5	4.3	5	4.5
2	Columbia Hills	5	4.7	5	4.3	5	4.3	3	3.8	5	4.1	4.6	4.2
3	NE Syrtis	5	4.7	5	3.8	3	3.3	5	3.8	5	4.8	4.6	4.1
4	Eberswalde	5	5.0	5	4.5	5	4.3	3	3.4	3	3.0	4.2	4.0
5	SW Melas	5	4.5	5	4.1	5	3.9	3	3.6	3	3.1	4.2	3.9
6	Nili Fossae Trough (N)	5	4.4	3	3.4	3	3.2	3	3.4	5	4.7	3.8	3.8
7	Nili Fossae Carbonate	5	4.2	3	3.4	3	3.2	3	3.2	5	4.3	3.8	3.7
8	Mawrth	5	4.3	3	3.7	3	2.9	3	3.4	5	3.9	3.8	3.6
9	Holden Crater	5	4.4	3	3.4	3	3.2	3	3.2	3	3.4	3.4	3.5
10	McLaughlin	3	3.6	3	3.9	3	3.0	3	3.5	3	3.5	3	3.5
11	Hypanis	3	3.8	3	3.6	3	3.1	3	3.0	3	2.8	3	3.2
12	Nili Fossae Trough (S)	3	3.8	3	2.9	3	2.6	3	2.9	3	3.9	3	3.2
13	Ladon Valles	3	3.8	3	3.3	3	3.1	3	2.7	3	2.7	3	3.1
14	E. Margaritifer	3	3.7	3	3.1	3	3.5	3	2.7	3	2.7	3	3.1
15	Coprates Chasma	5	4.1	3	2.7	3	2.3	3	2.5	3	3.7	3.4	3.1
16	Oyama Crater	3	3.3	3	3.2	3	2.8	3	2.7	3	3.1	3	3.0
17	Eridania	3	3.2	3	2.8	3	2.5	3	2.3	3	2.4	3	2.6
18	Nili Patera	5	4.6	3	2.4	3	2.5	1	1.4	3	2.2	3	2.6
19	Oxia Planum	3	3.0	3	2.4	1	2.1	1	2.1	3	2.7	2.2	2.5
20	Sabrina/Magong Crater	3	3.1	3	3.0	3	2.2	1	1.8	1	2.0	2.2	2.4
21	Hadriacus Palus	3	3.2	3	2.5	1	1.5	1	1.6	3	2.8	2.2	2.3

Top three landing sites…

4 Landing Site Selection Workshops
1st in 2014: many landing sites
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ra	Site	Landing Site Scientific Selection Criteria											
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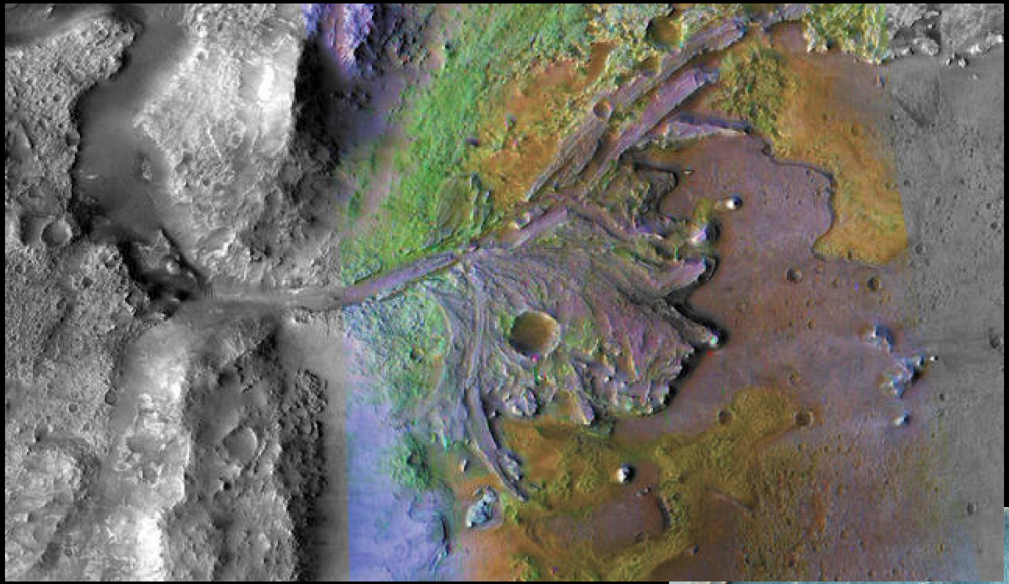
17	Eridania												
18	Nili Patera												
19	Oxia Planum												
20	Sabrina/Magong Crater												
21	Hadriacus Palus												

FINAL 3 LANDING SITE CHOICES

Choice 1: Jezero Crater

- Data indicates this area once had river channels and lakes filling the now "dry" crater.

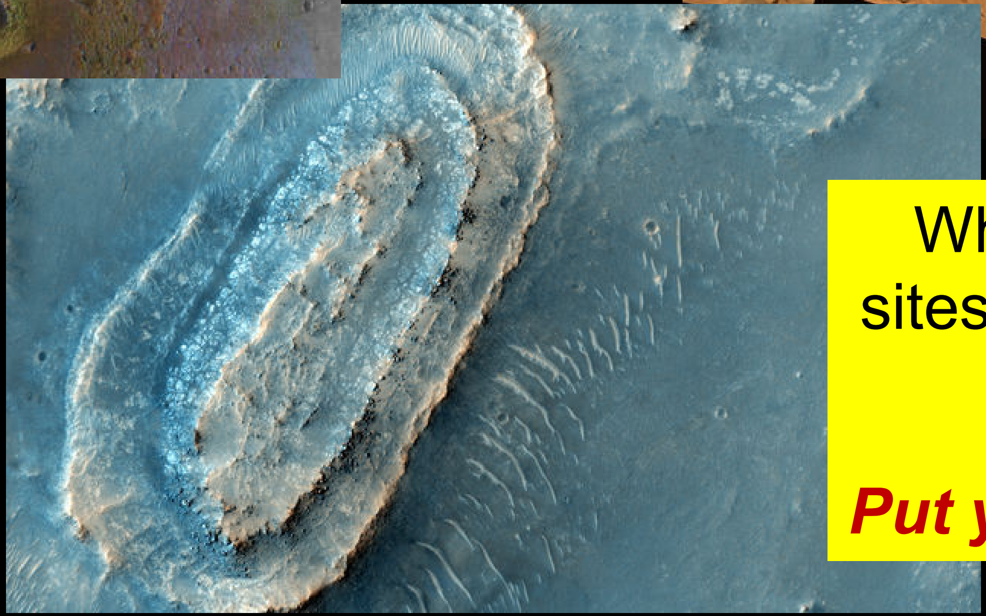


Choice 2: Columbia Hills, Gusev Crater

- Previously explored by the Mars Spirit Rover.
- Evidence of past hot springs.

Choice 3: NE Syrtis

- Associated with past volcanic activity.
- Evidence of past hot springs, surface ice melting, layered terrain.

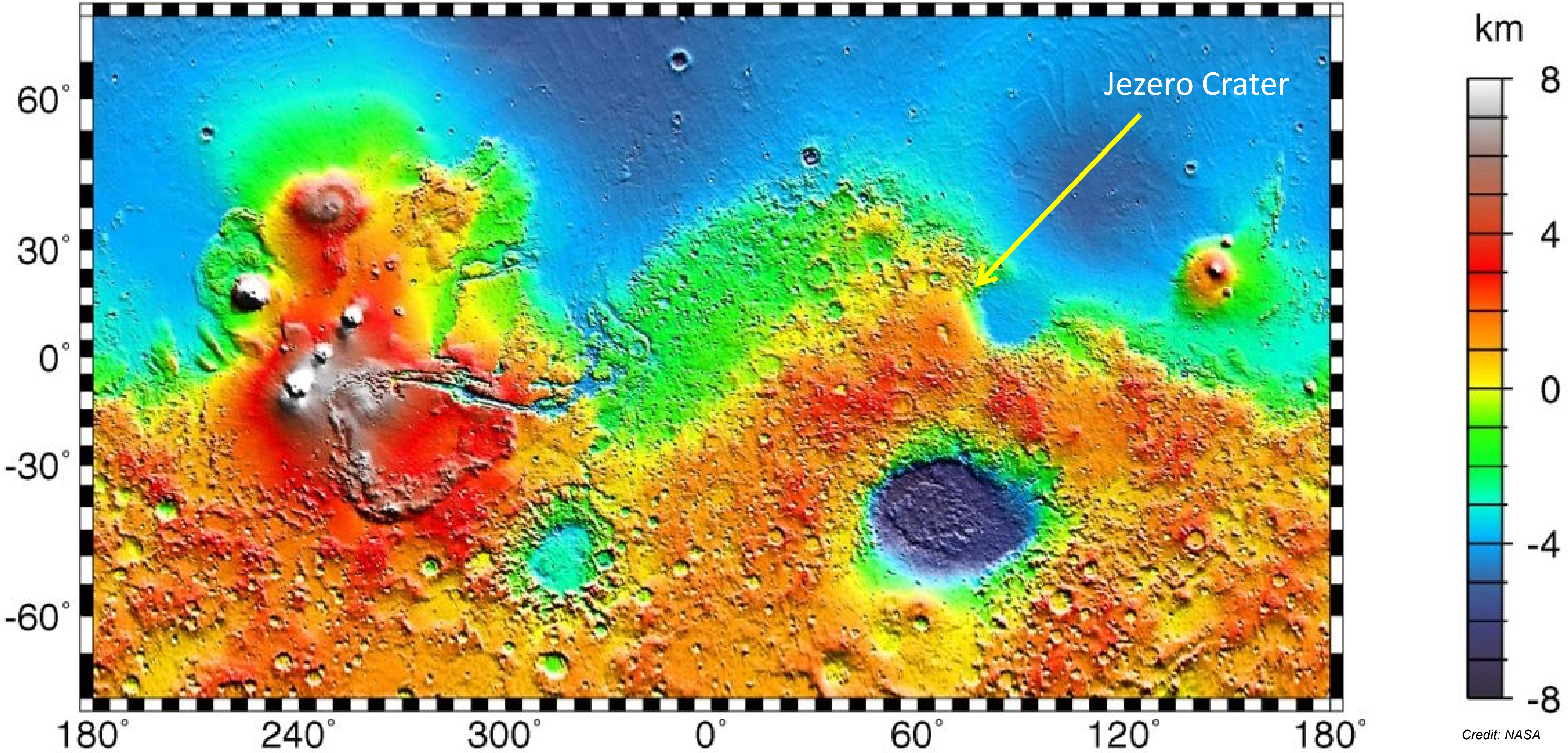


What makes each of these sites good landing sites for the Mars 2020 Rover?

Put your answers in the chat.

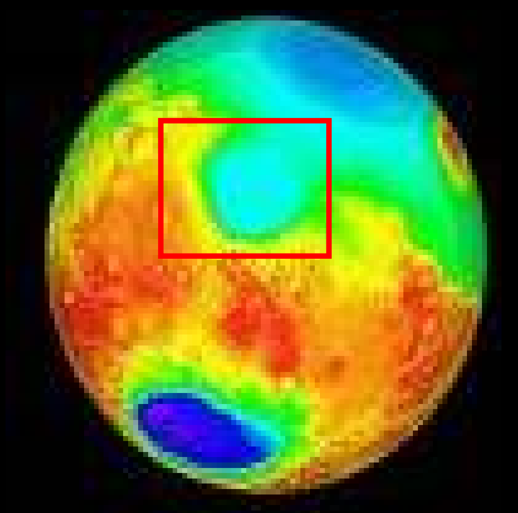
Credit: NASA

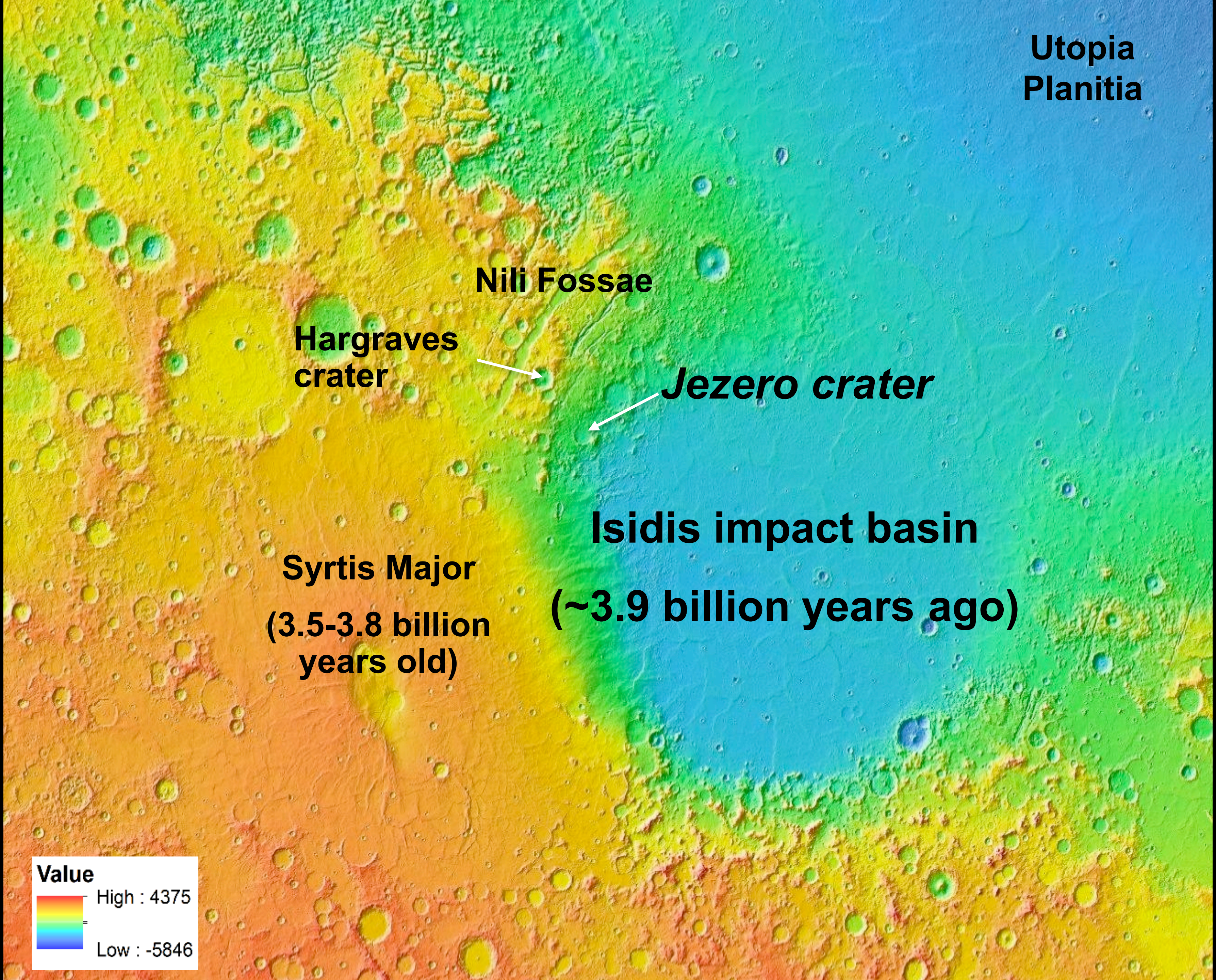
Perseverance Landing Site: Jezero Crater (winner)



Credit: NASA

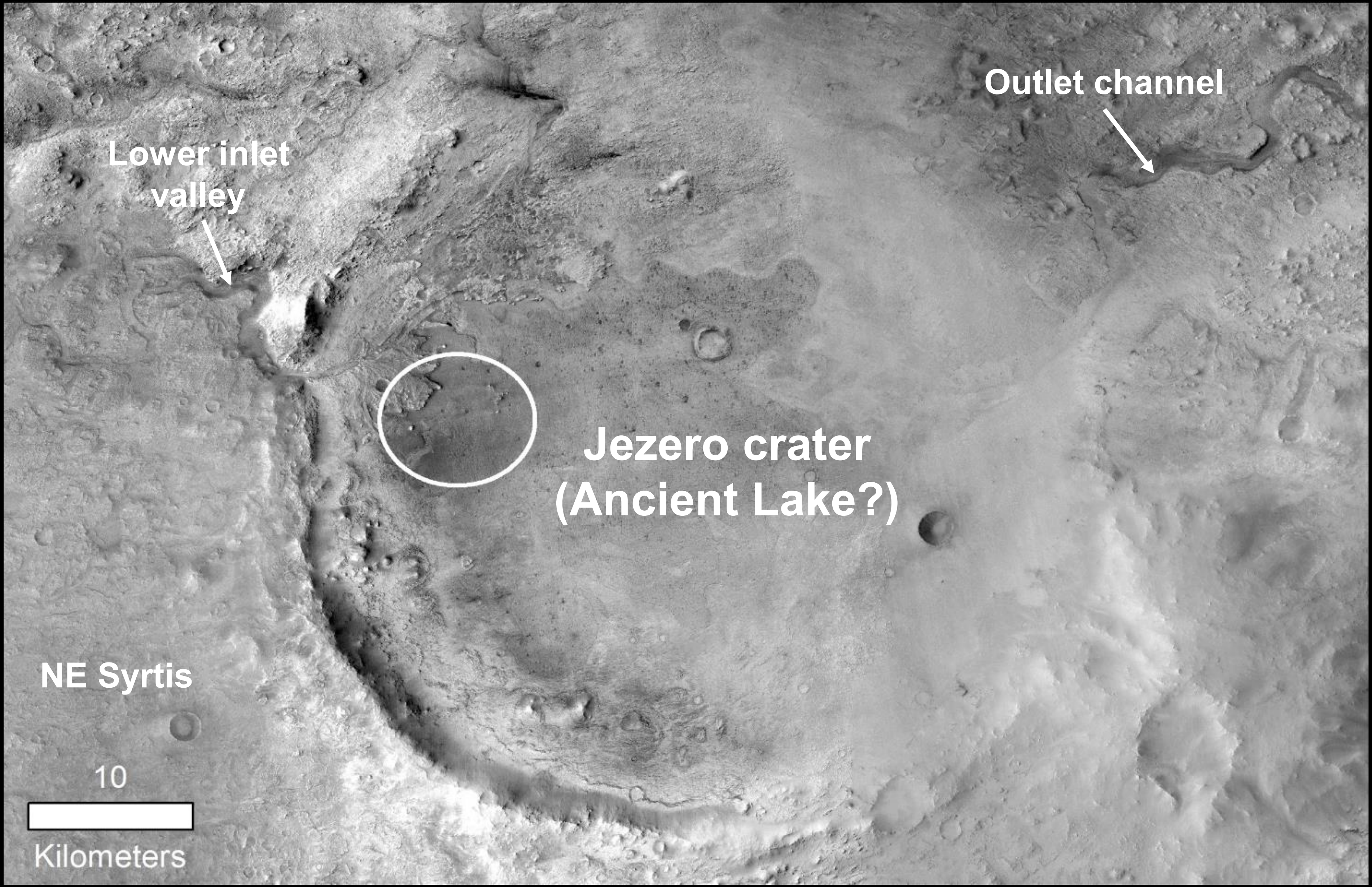
Jezero Crater Context





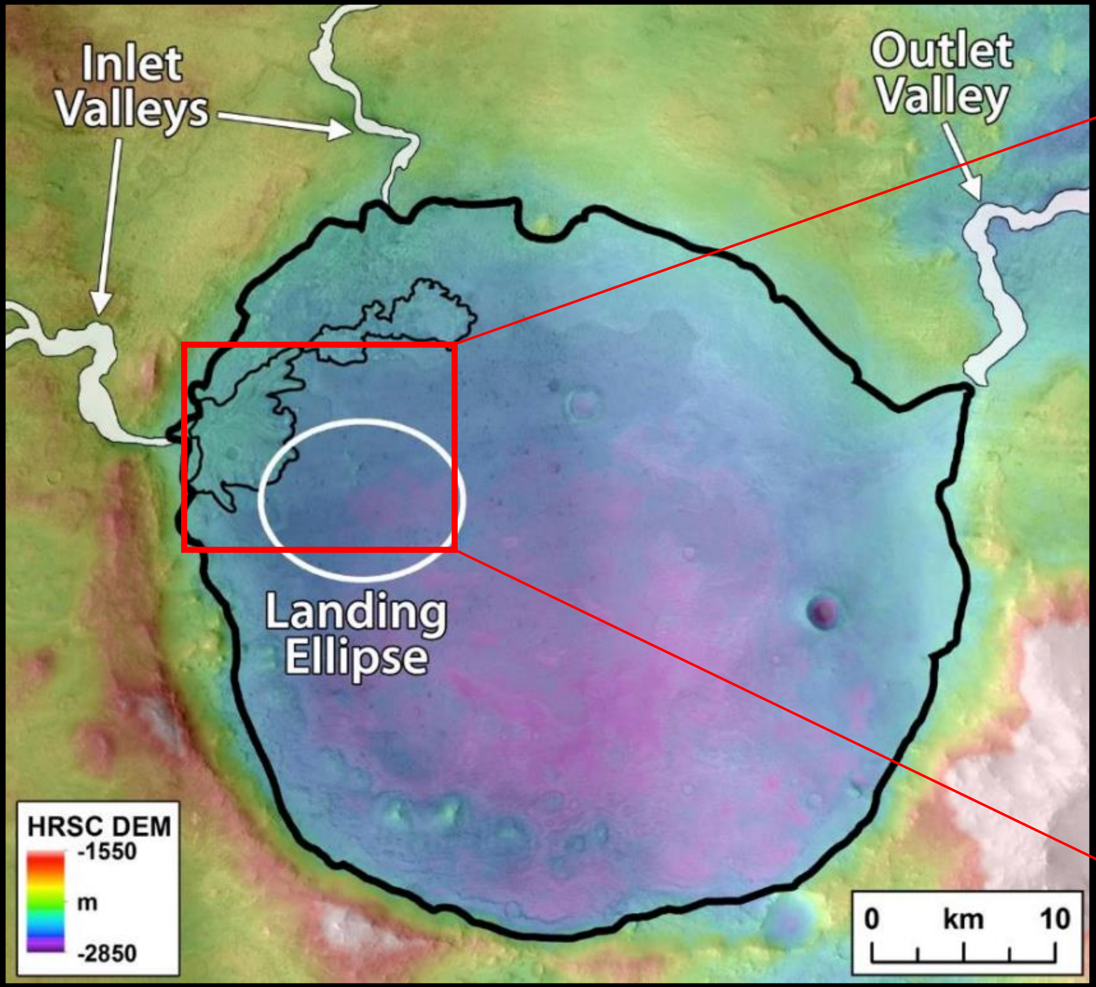
Credit: NASA

Anatomy of Jezero crater and its deposits

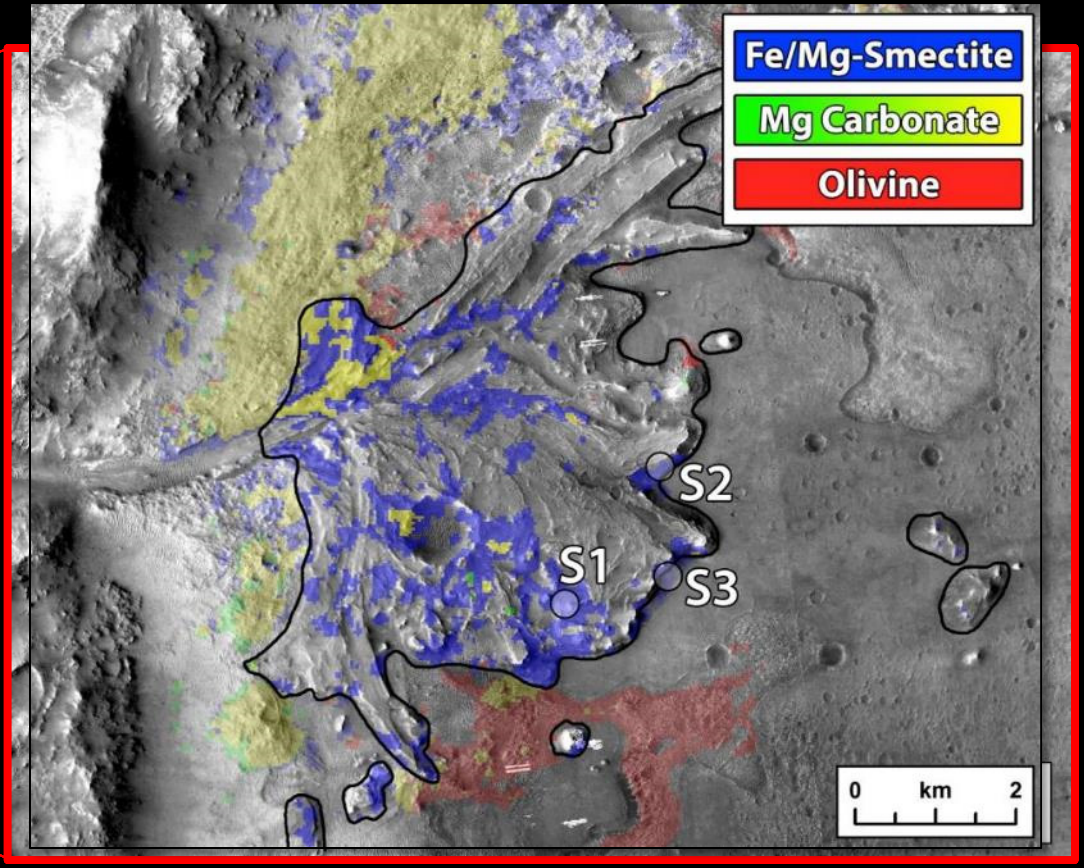


Credit: NASA

Delta Deposit Inside Jezero Crater



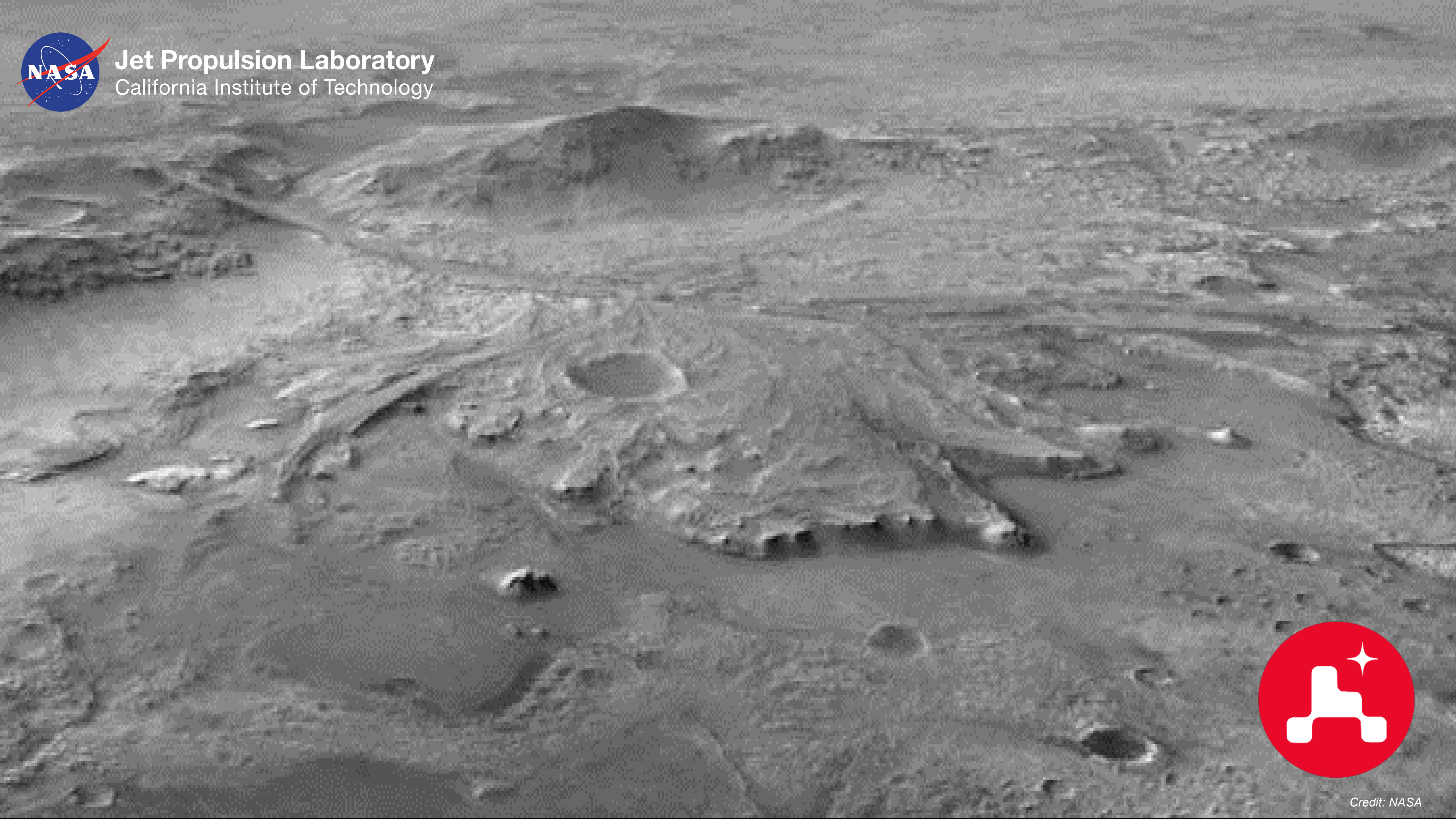
HRSC topography overlain on CTX mosaic



Modified from T. Goudge LSW3

Credit: NASA

Jet Propulsion Laboratory
California Institute of Technology

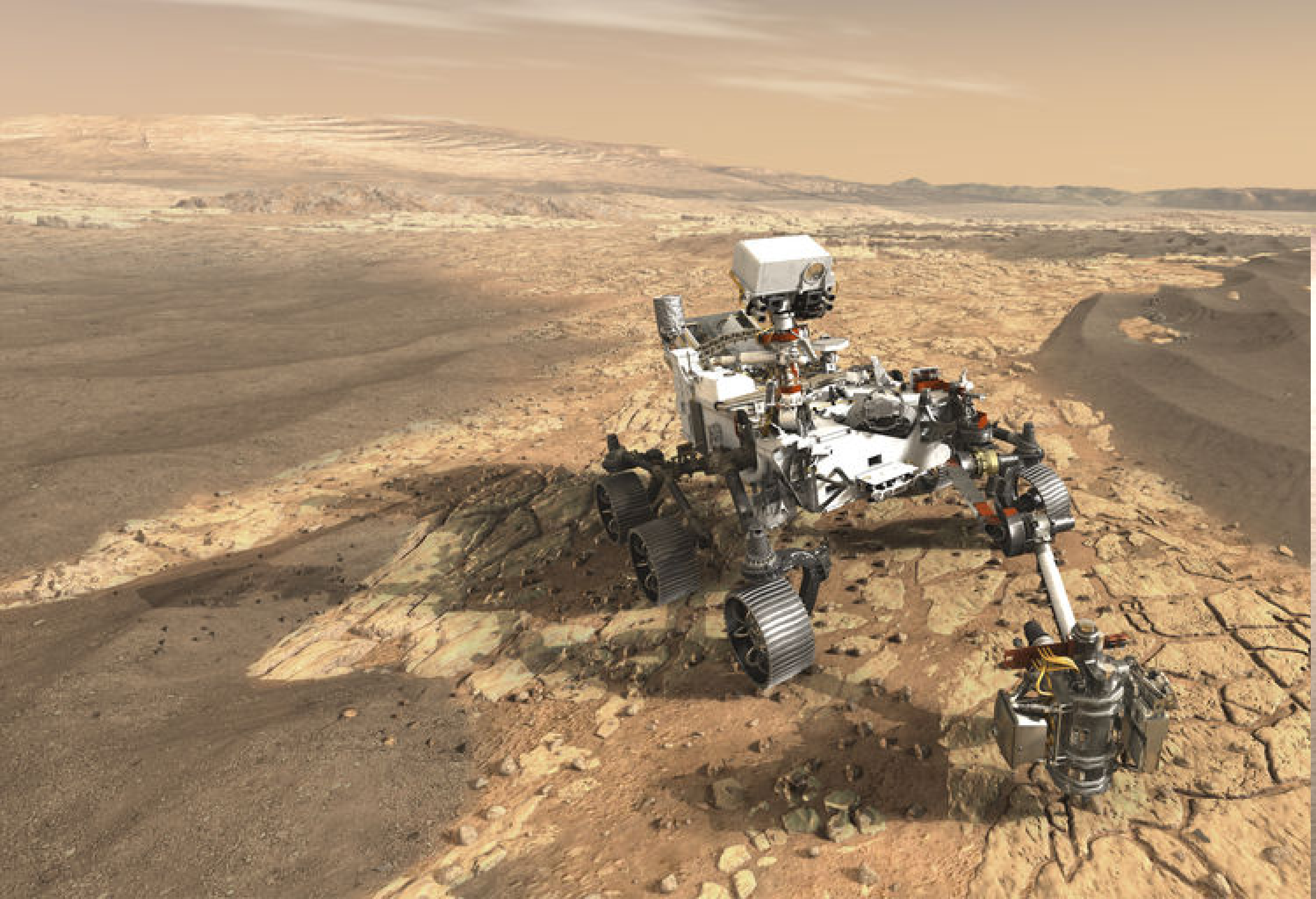


Credit: NASA

River deltas are environments teeming with microbial life

Alaska runoff, NOAA

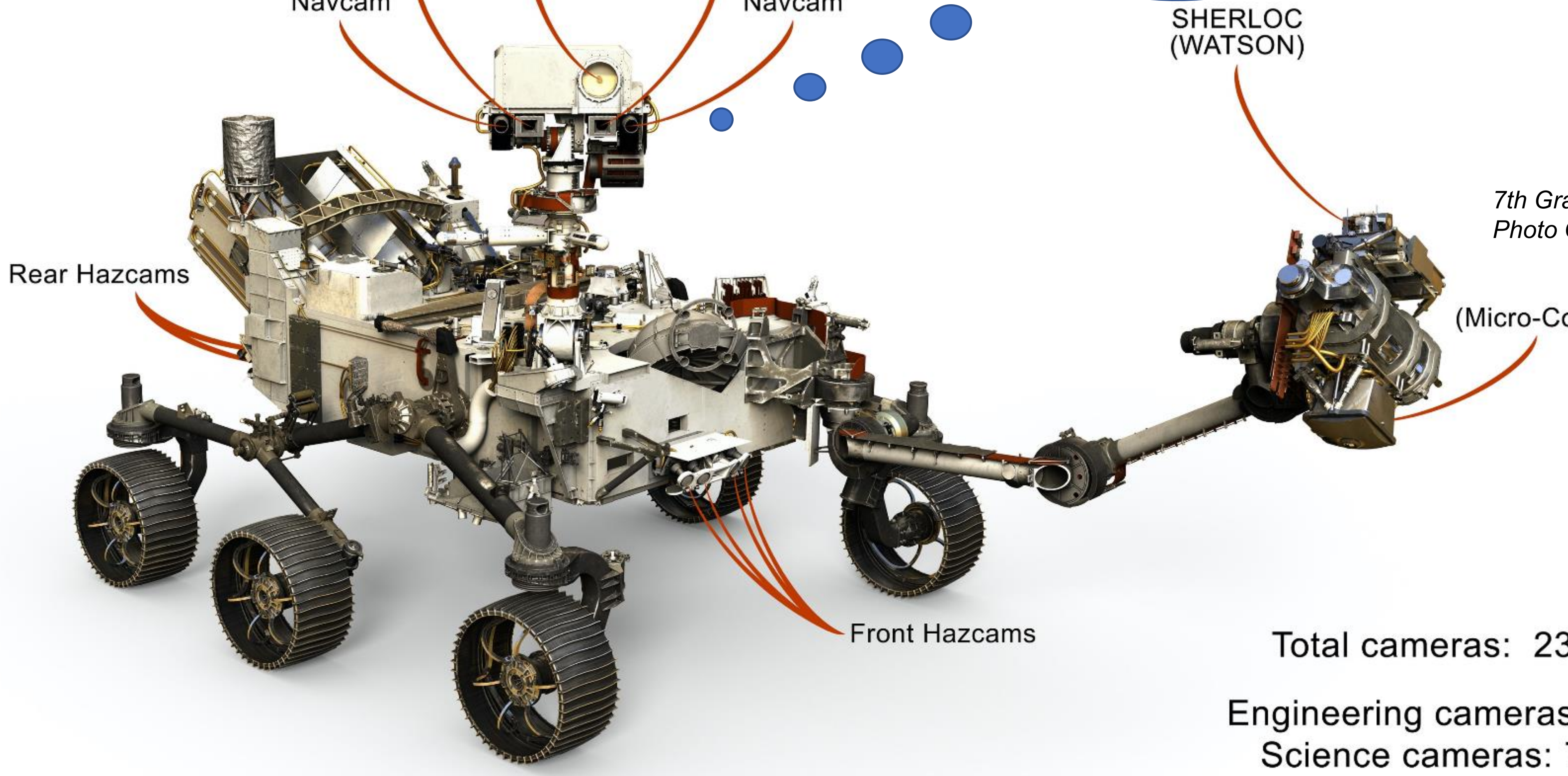
We launched July 30th, 2020; land on Mars Feb 18th, 2021; return samples 2026



Credit: NASA

Mars 2020

I named the rover Perseverance
-Alex



7th Grade, Springfield, VA
Photo Credit: Joseph Rebello

Total cameras: 23

Engineering cameras: 9
Science cameras: 7
Entry, descent and landing cameras: 7

Credit: NASA

“Ingenuity” Helicopter

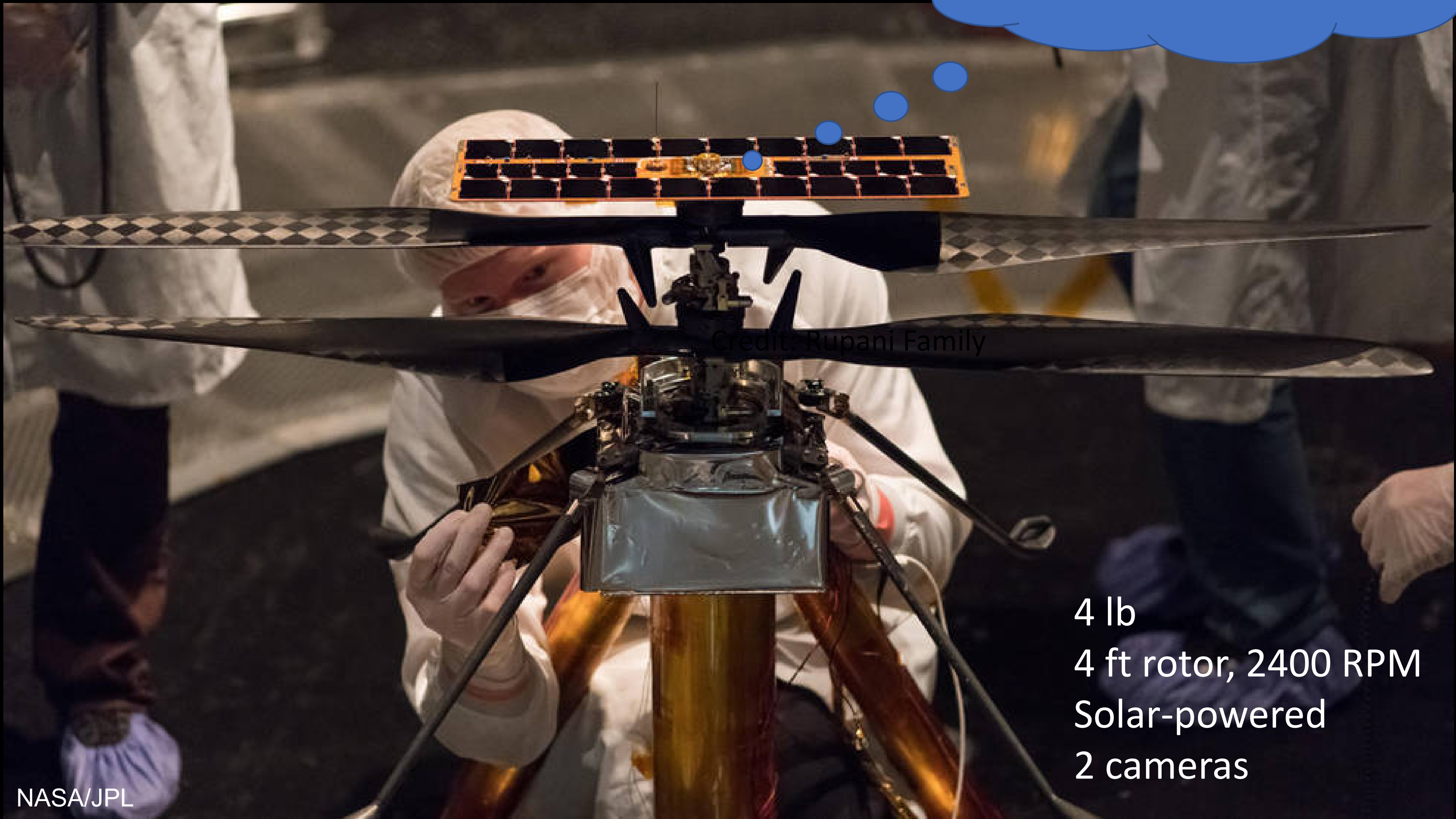
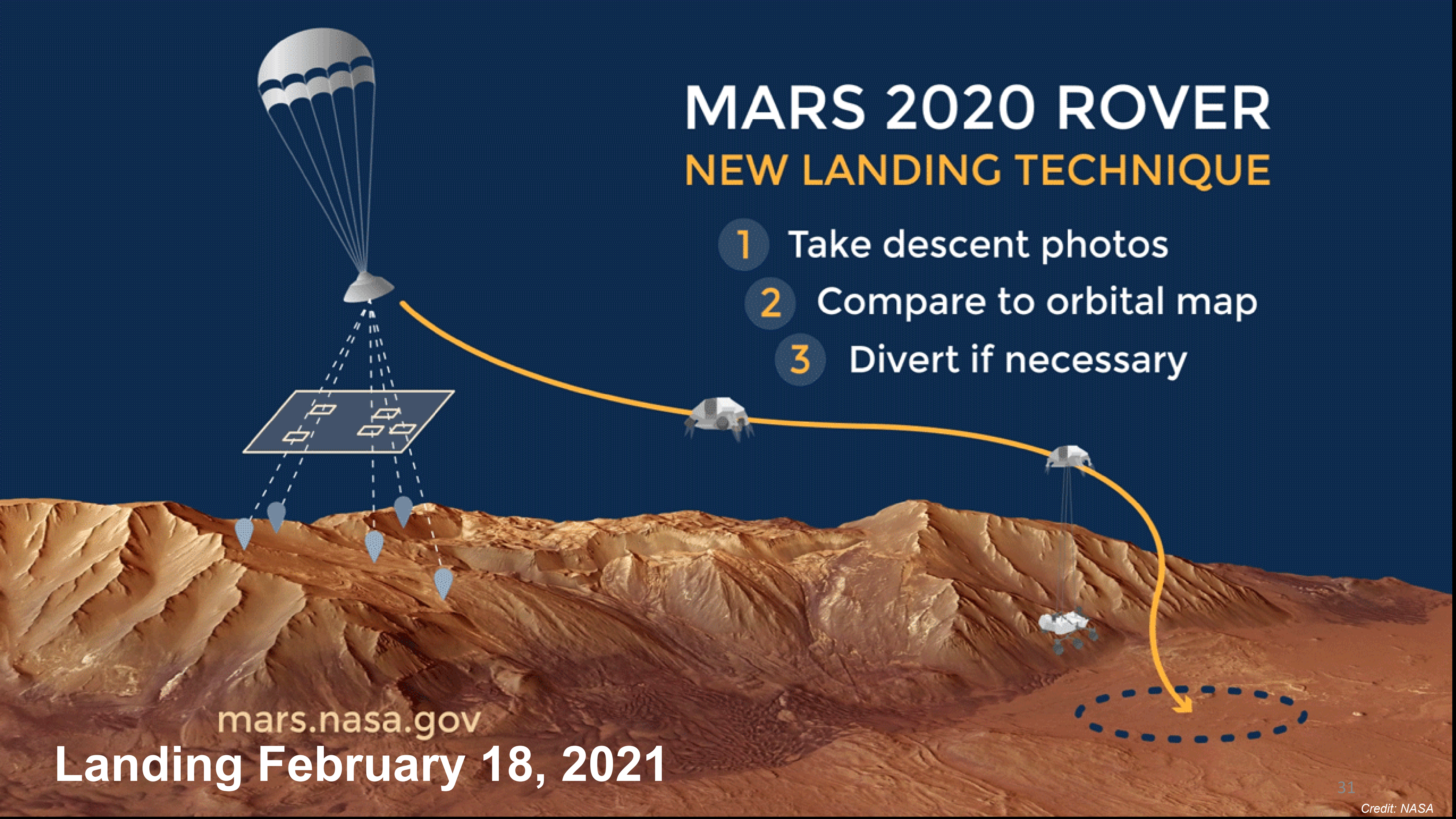


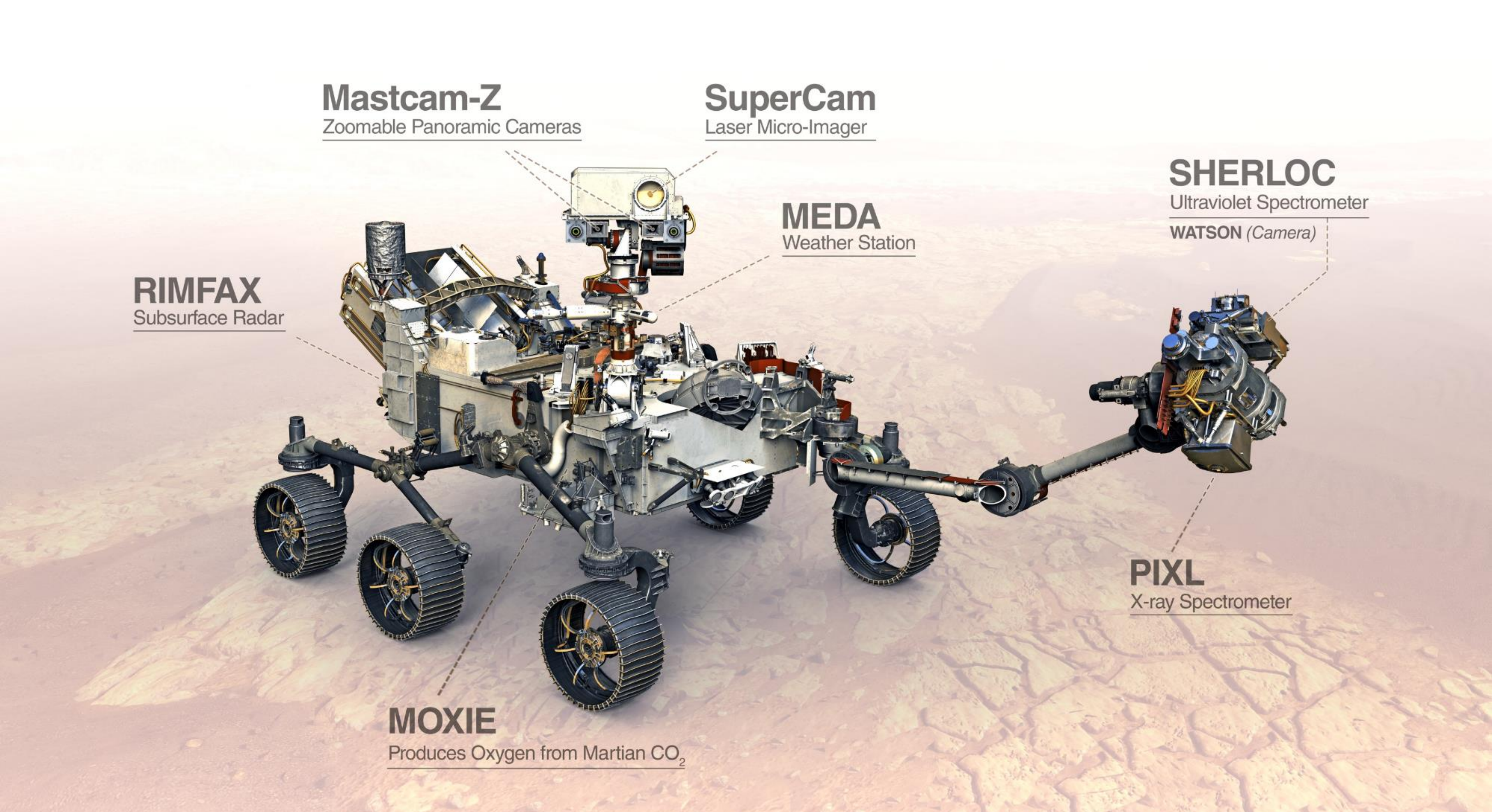
Image from NASA Article.
Image Credit: Rupani Family

Credit: NASA



Landing February 18, 2021

Credit: NASA


Mastcam-Z
Zoomable Panoramic Cameras
SuperCam
Laser Micro-Imager
SHERLOC
Ultraviolet Spectrometer
WATSON (Camera)
MEDA
Weather Station
RIMFAX
Subsurface Radar
PIXL
X-ray Spectrometer
MOXIE
Produces Oxygen from Martian CO_2

Credit: NASA

Mobility System

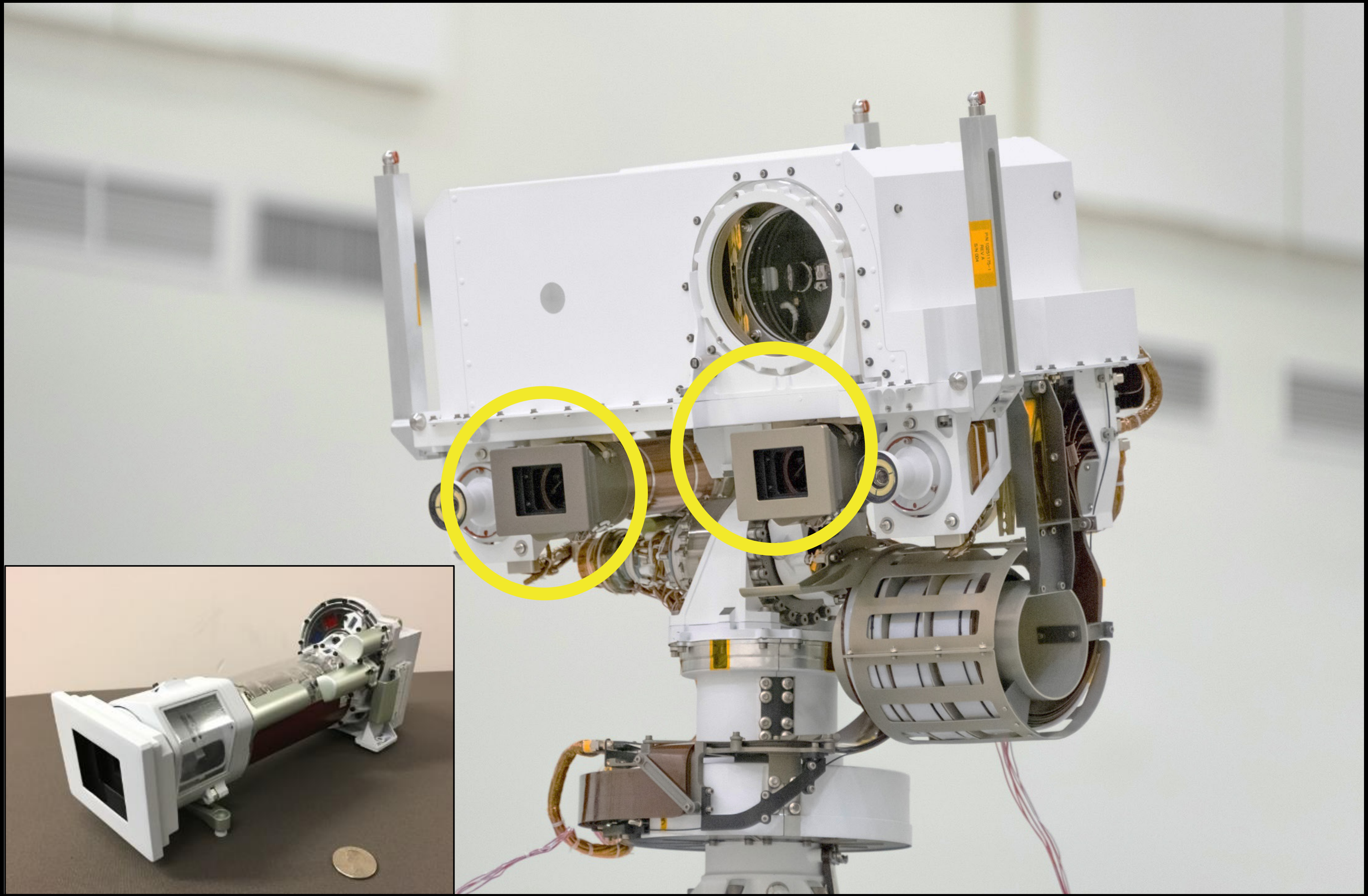
Perseverance is the fastest rover to date and we need this to have enough time to find and collect samples

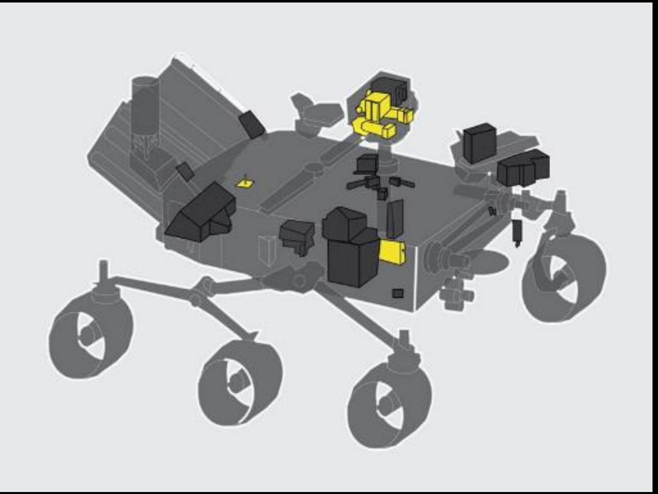
CURIOSITY

PERSEVERANCE

Credit: NASA

Mastcam-Z



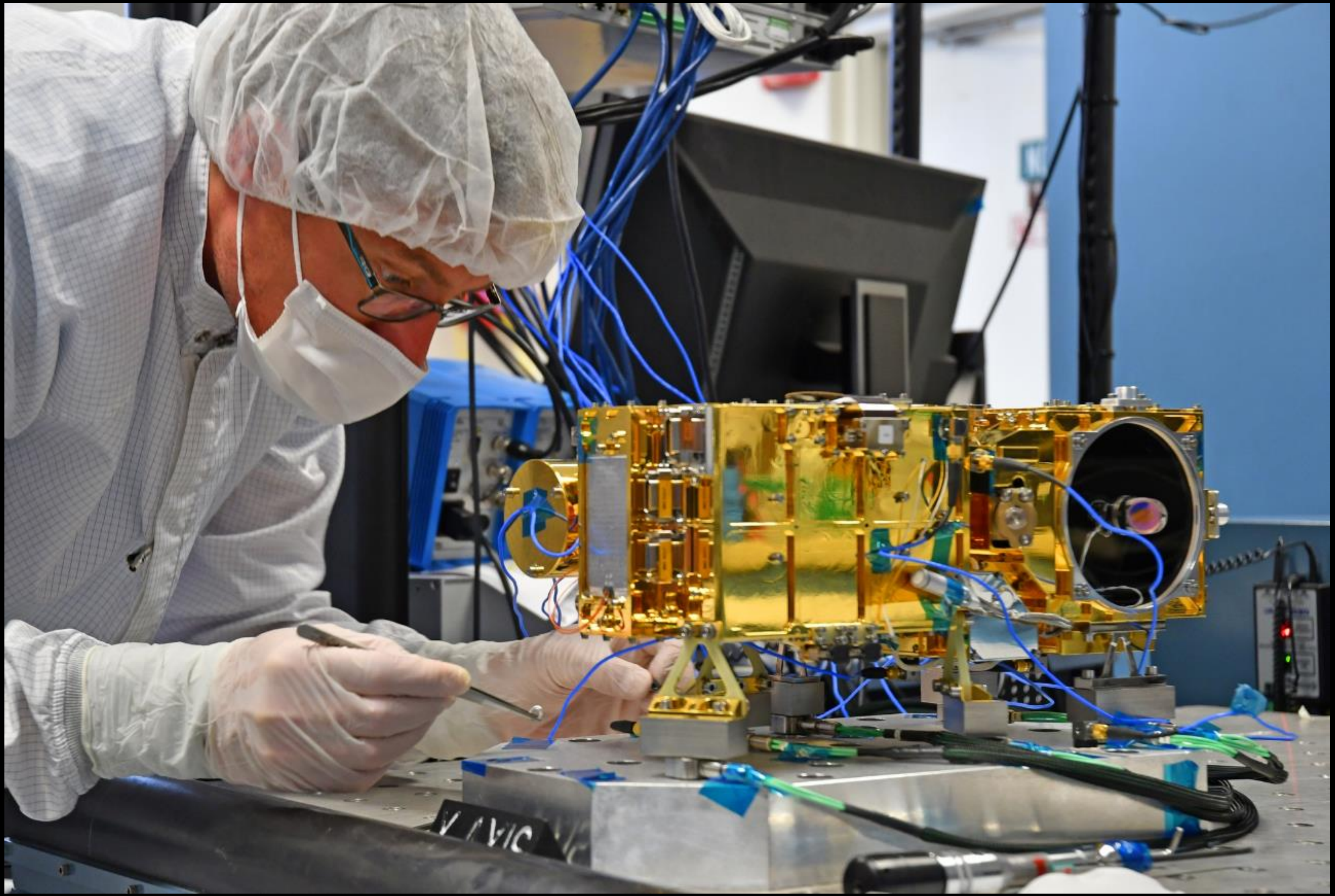


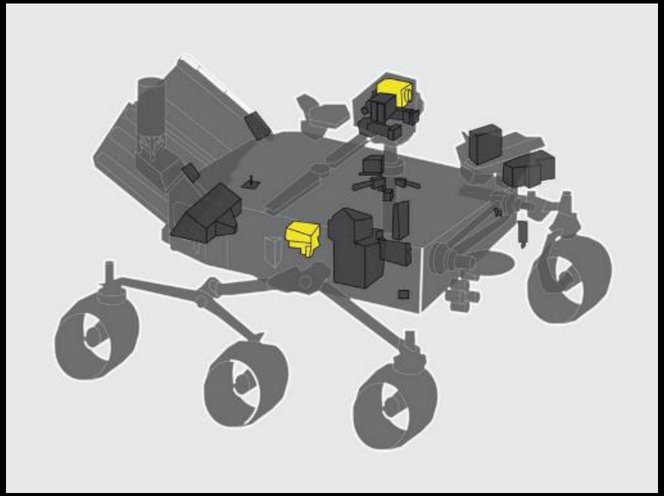
MAIN JOB:

Take high-definition video, panoramic color & 3D images of the surface & more!

Credit: NASA

SuperCam



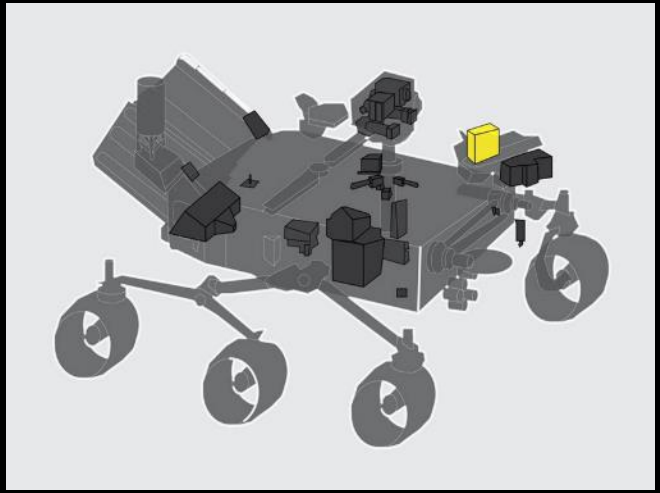


MAIN JOB:

Identify the chemical composition of the rocks and soils including their atomic & molecular makeup.

Credit: NASA

Planetary Instrument for X-ray Lithochemistry (PIXL)

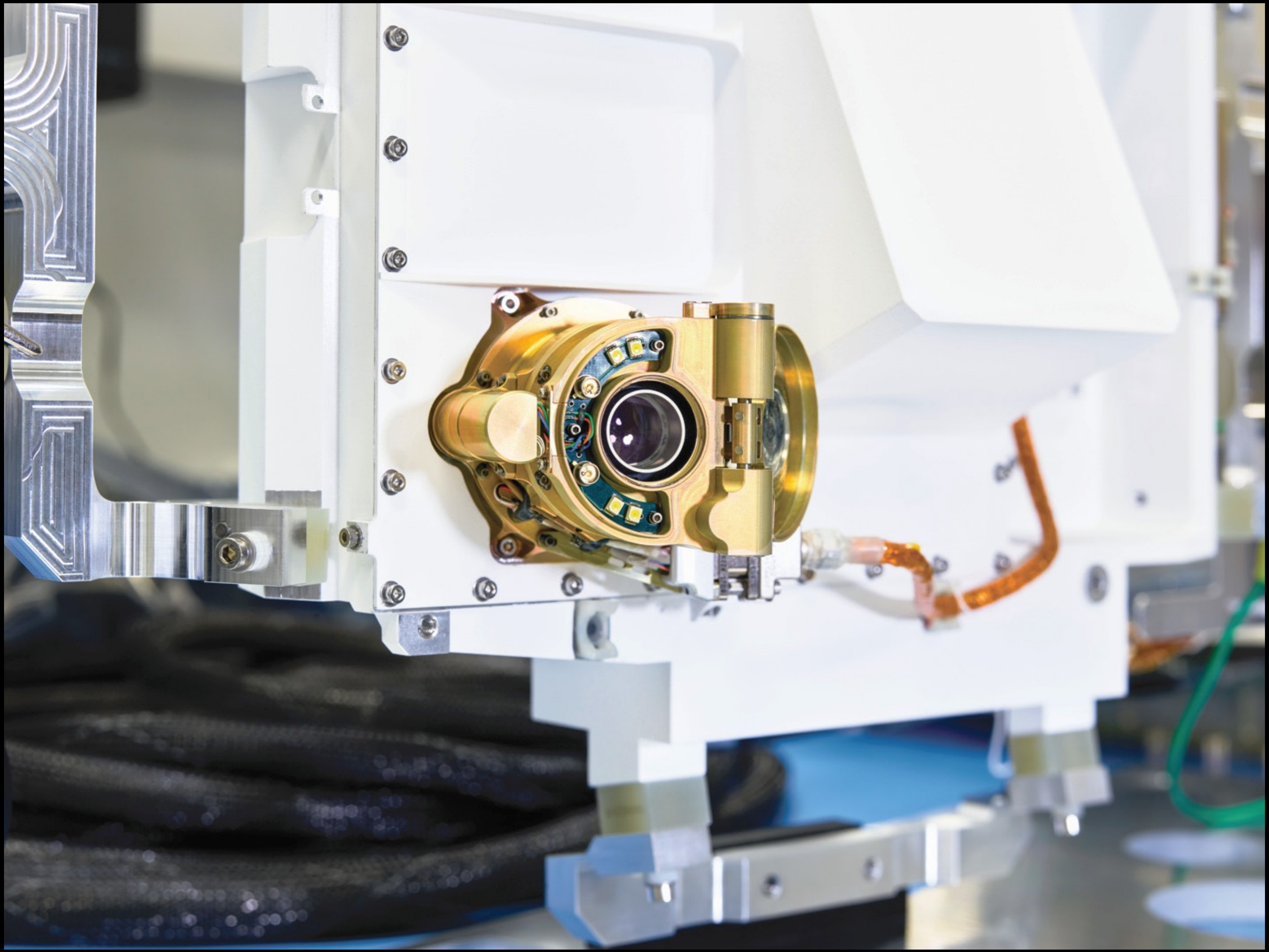


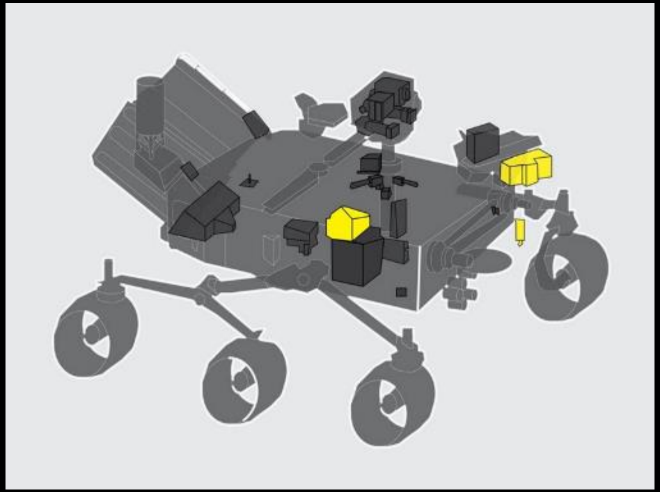
MAIN JOB:

Measure the chemical makeup of rocks at a very fine scale. (sub-mm scales)

Credit: NASA

Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals (SHERLOC)



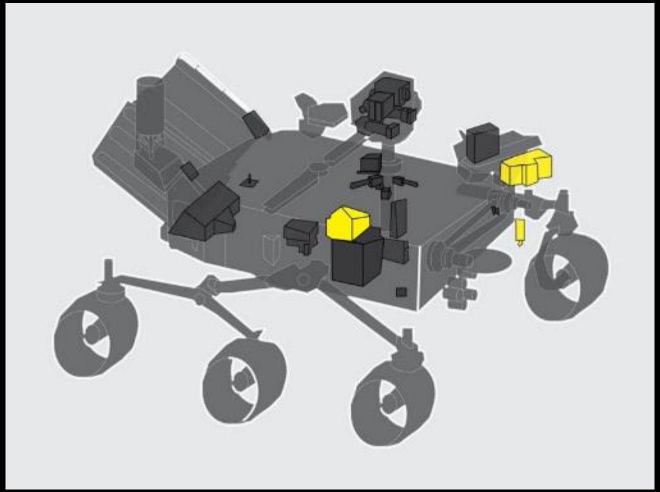


MAIN JOB:

Fine-scale detection of minerals, organic molecules, and potential biosignatures.

Credit: NASA

Wide Angle Topographic Sensor for Operations and eNgineering (WATSON)

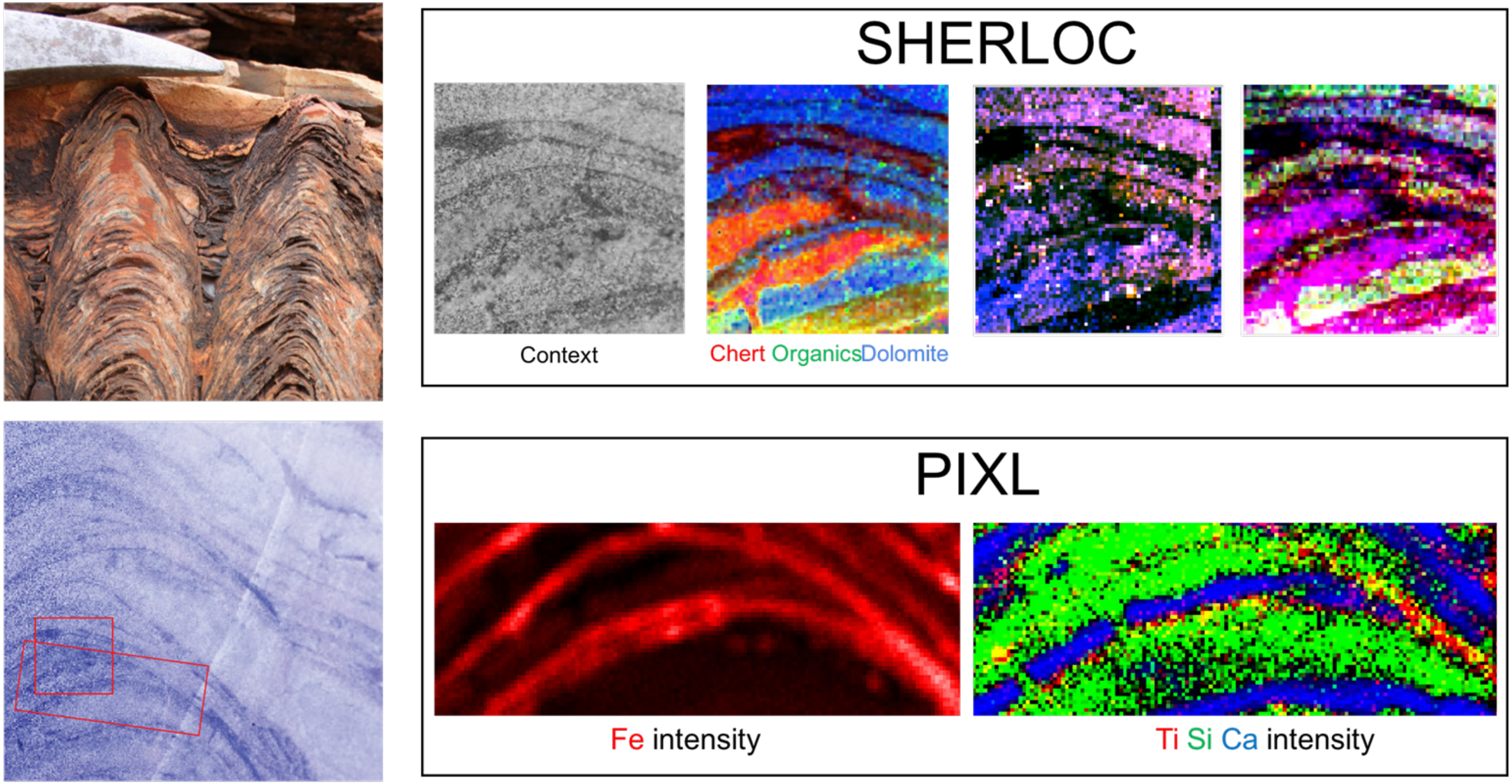


MAIN JOB:

Camera that will take close-up pictures of rock textures. Will work closely with the SHERLOC instrument.

Credit: NASA

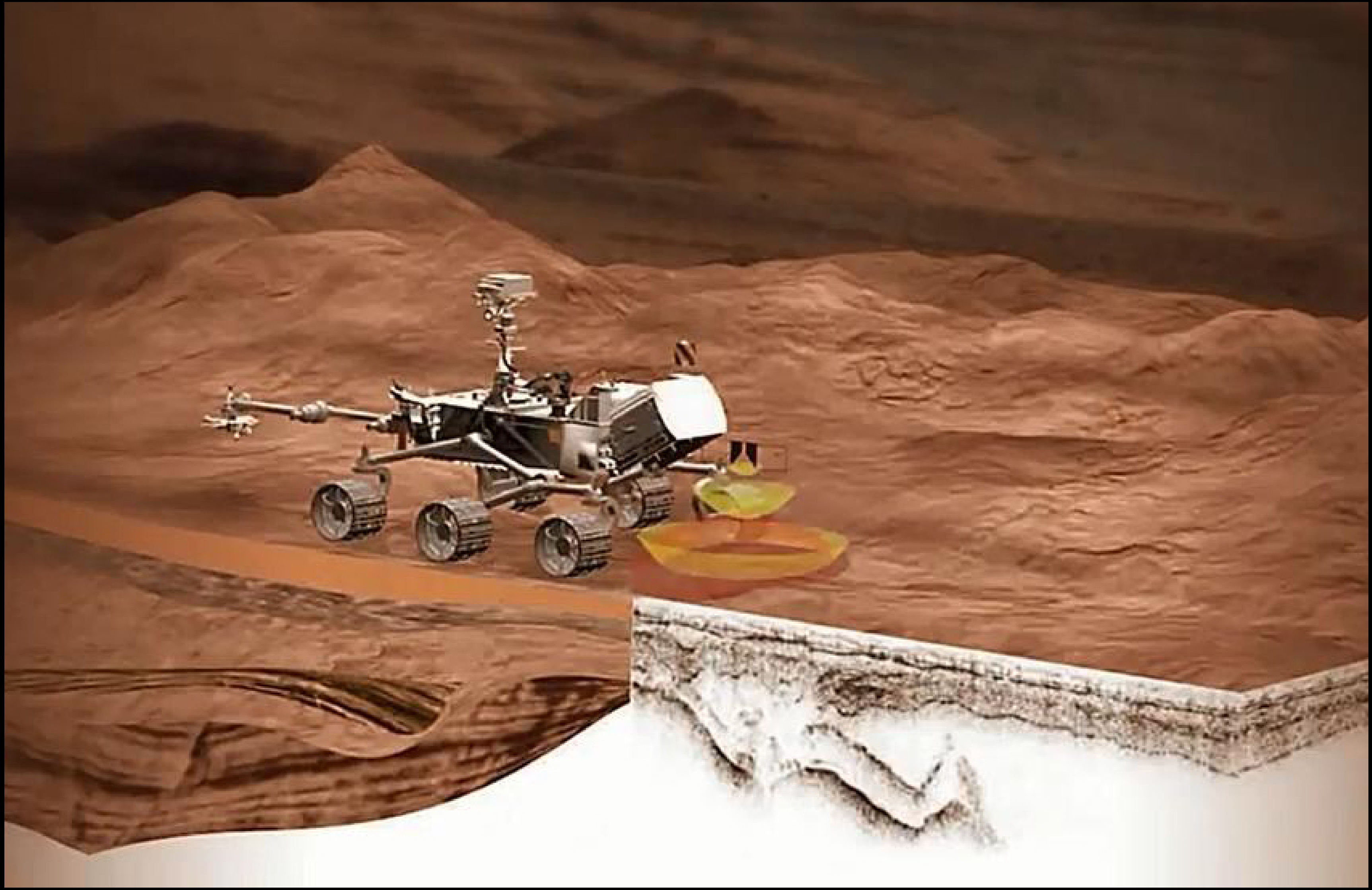
SHERLOC, WATSON, and PIXL Work Together

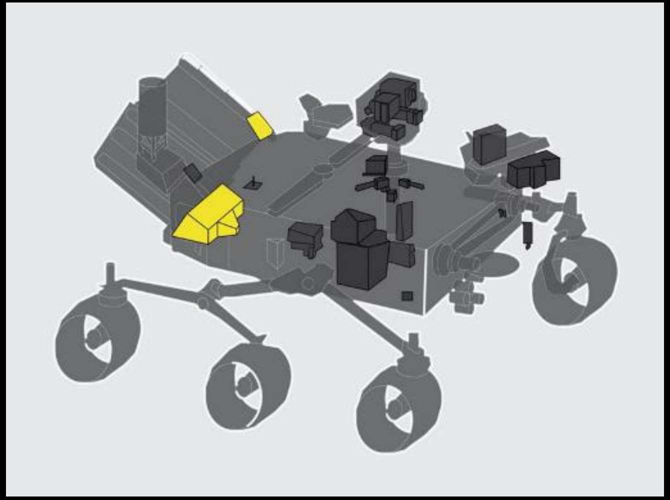


2.72 Ga Stromatolites (Fortescue Gp., Western Australia)
Above: outcrop. Below: cut slab

Credit: NASA

Radar Imager for Mars' Subsurface Experiment (RIMFAX)



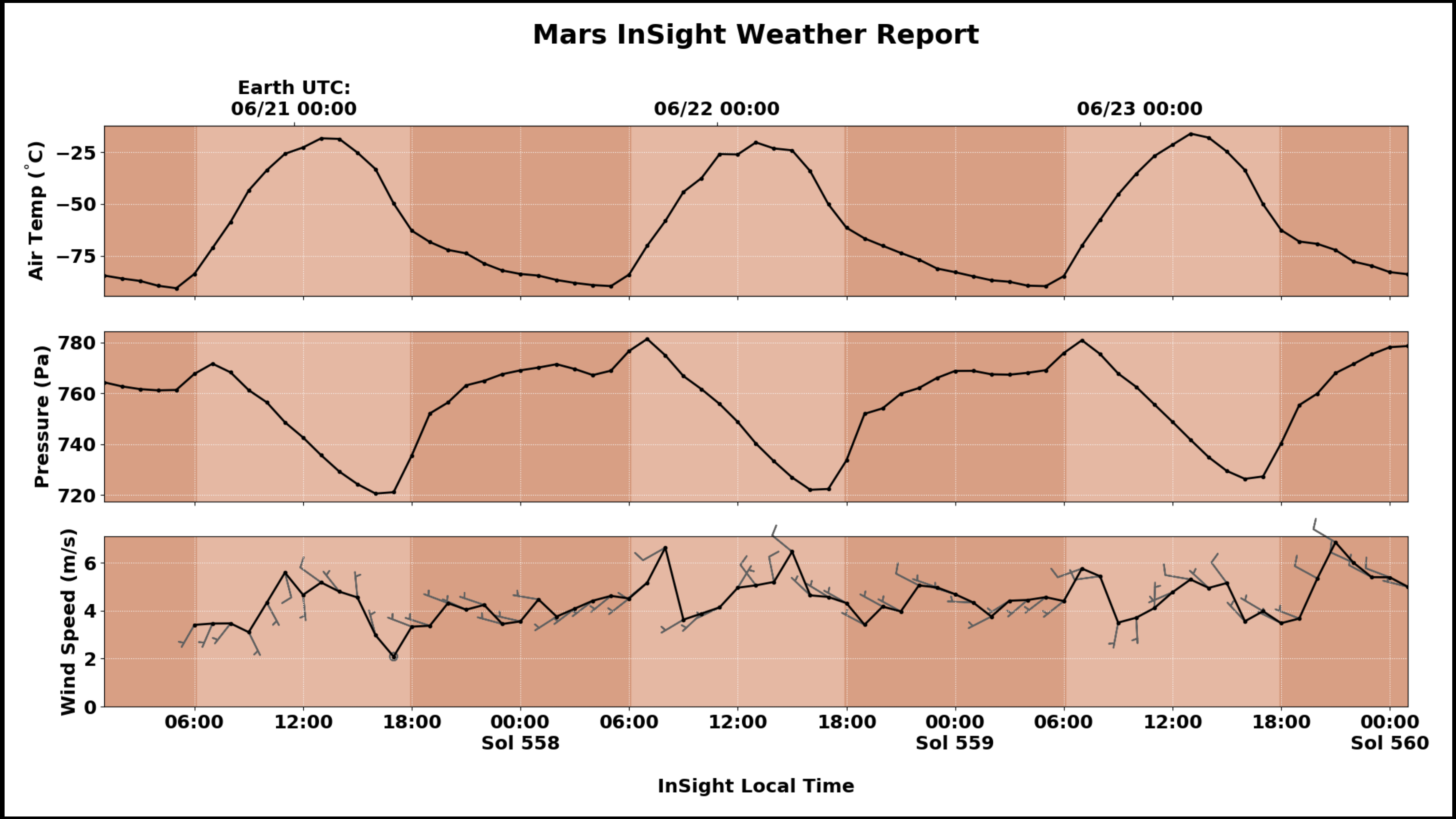


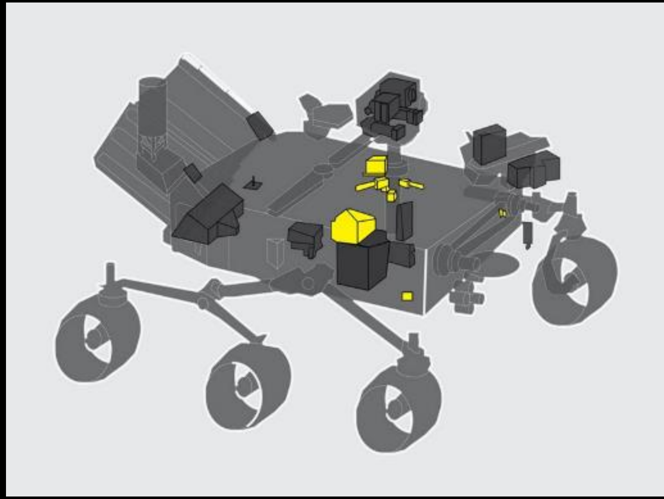
MAIN JOB:

To see geologic features under the surface with ground-penetrating radar.

Credit: NASA

Mars Environmental Dynamics Analyzer (MEDA)



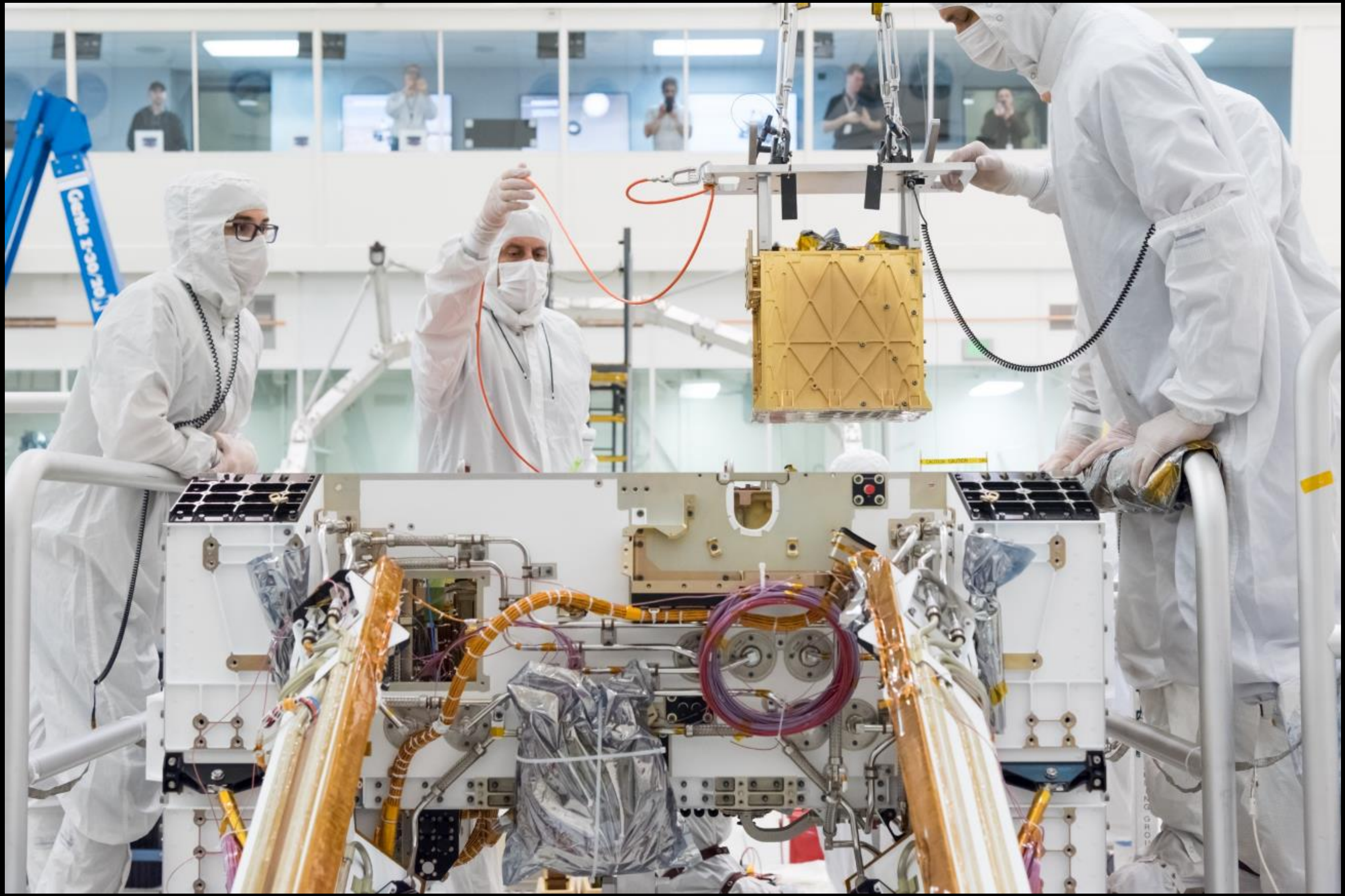


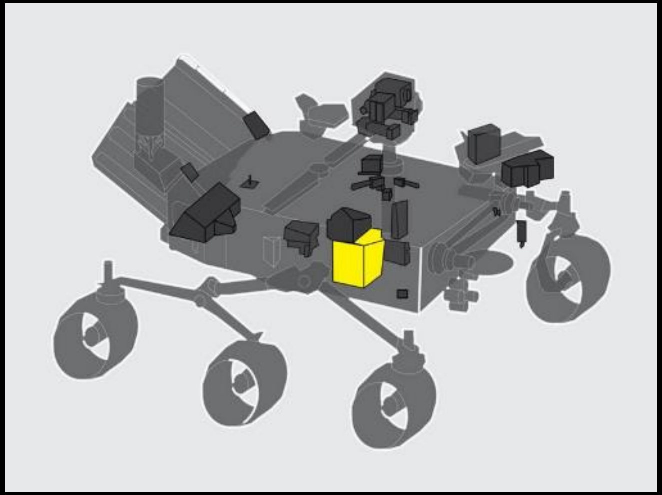
MAIN JOB:

To measure weather (such as wind speed & direction, temperature, humidity) and monitor dust in the atmosphere.

Credit: NASA

Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE)

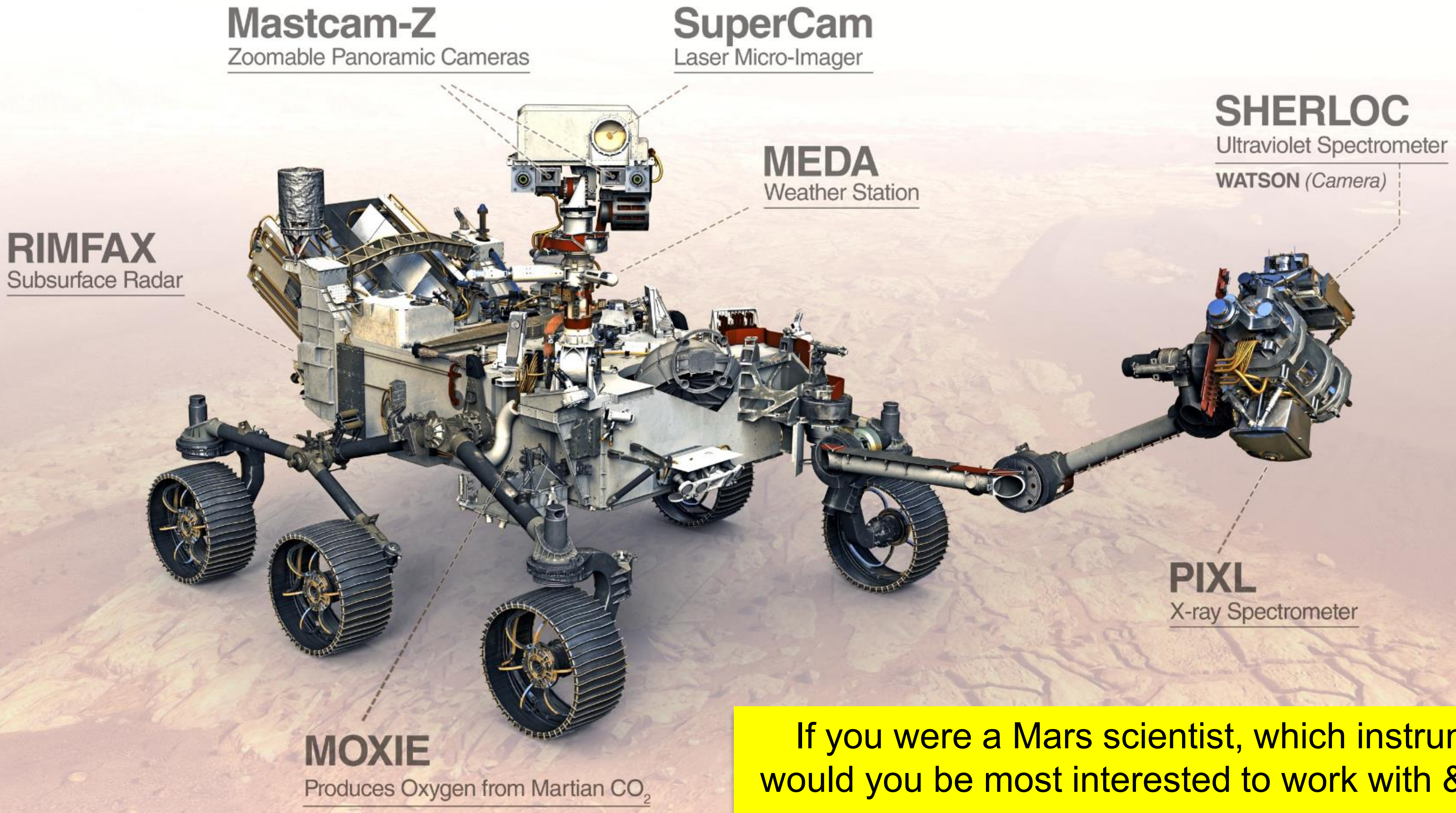




MAIN JOB:

To produce oxygen from the Martian carbon-dioxide atmosphere.

Credit: NASA

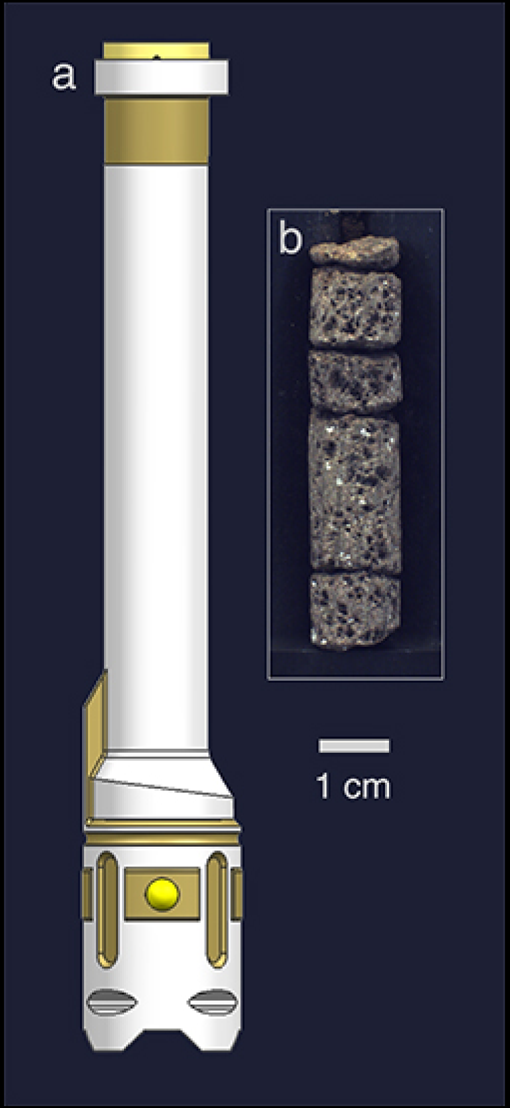


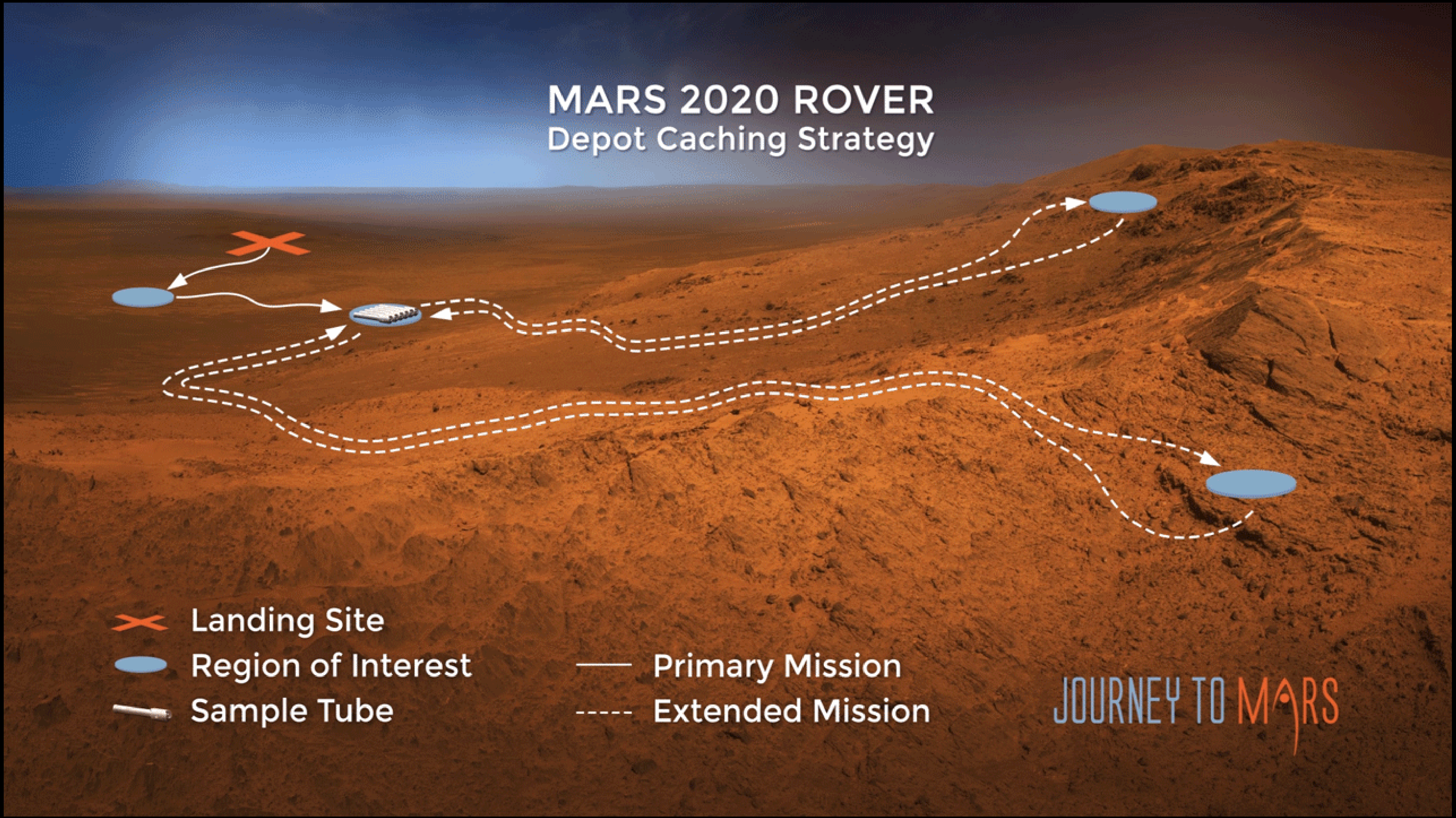
Credit: NASA

If you were a Mars scientist, which instrument would you be most interested to work with & <u>why</u>?

Put your answers in the chat.

Sampling and Caching



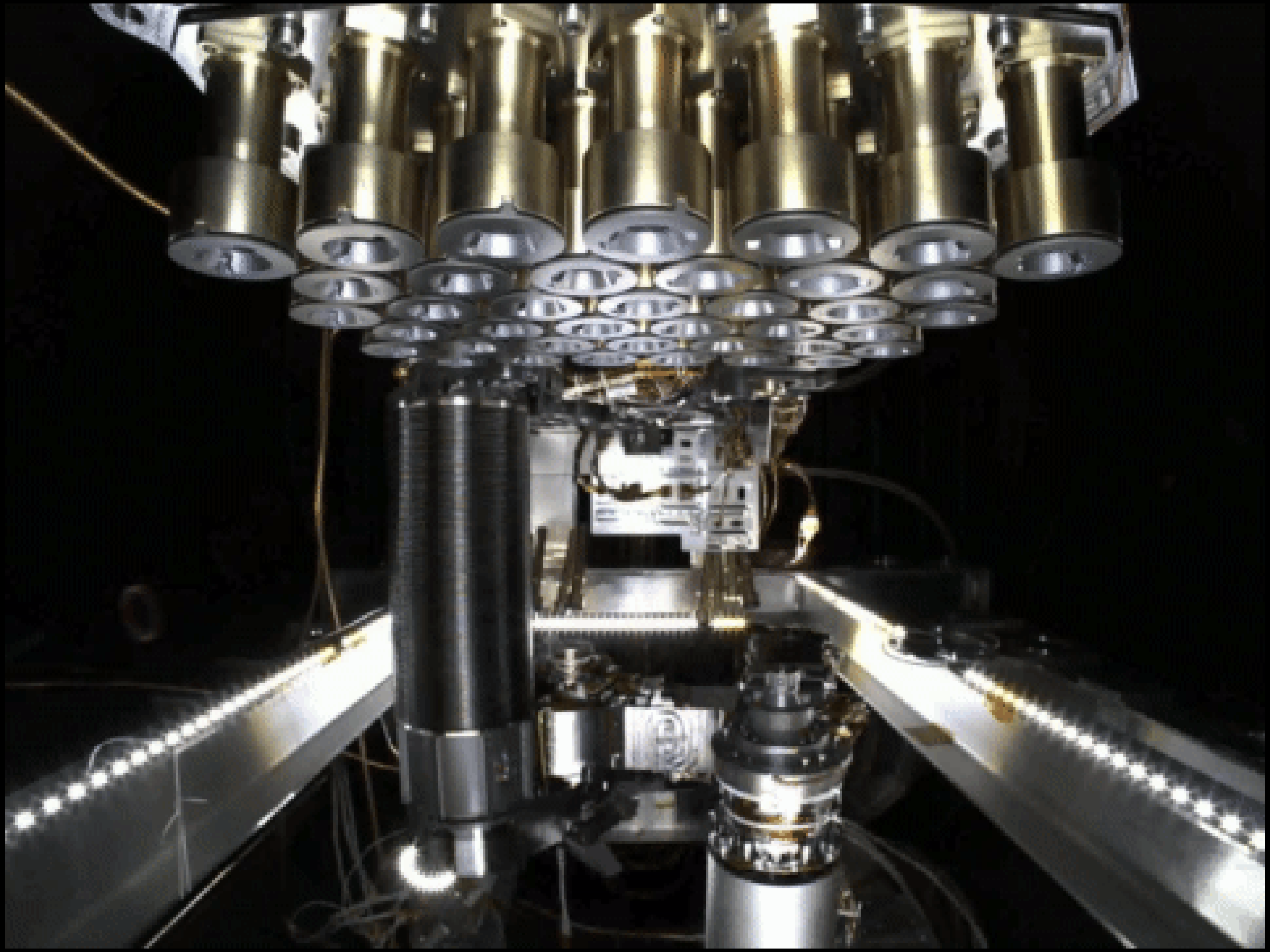


Credit: NASA

SCS (& Friends) Family Portrait

URS CL#20-4730

Credit: NASA



Flight sample tube handling during TVAC testing

Rover will drill core samples to be returned to Earth

Credit: NASA

These extraterrestrial samples are curated by NASA. But studied by scientists all over the world!

Credit: NASA

https://mars.nasa.gov/resources/25473/perseverance-arrives-at-mars-feb-18-2021-mission-trailer/

Fun Fact: Well-known “secret”

Jezero crater

A rover traverse outside the Jezero to Midway would allow us explore much of the 3rd landing site.

Choice 3: NE Syrtis

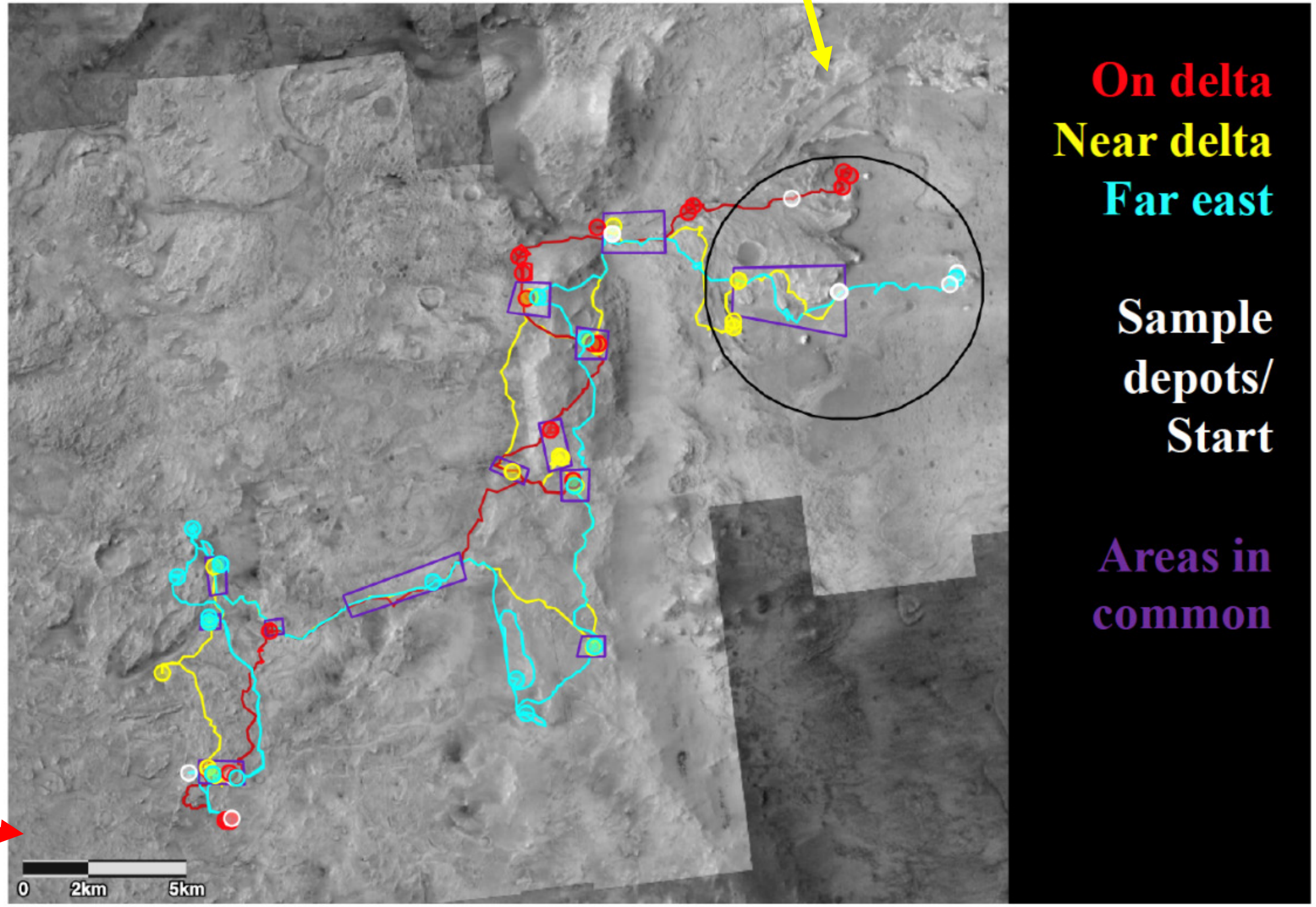
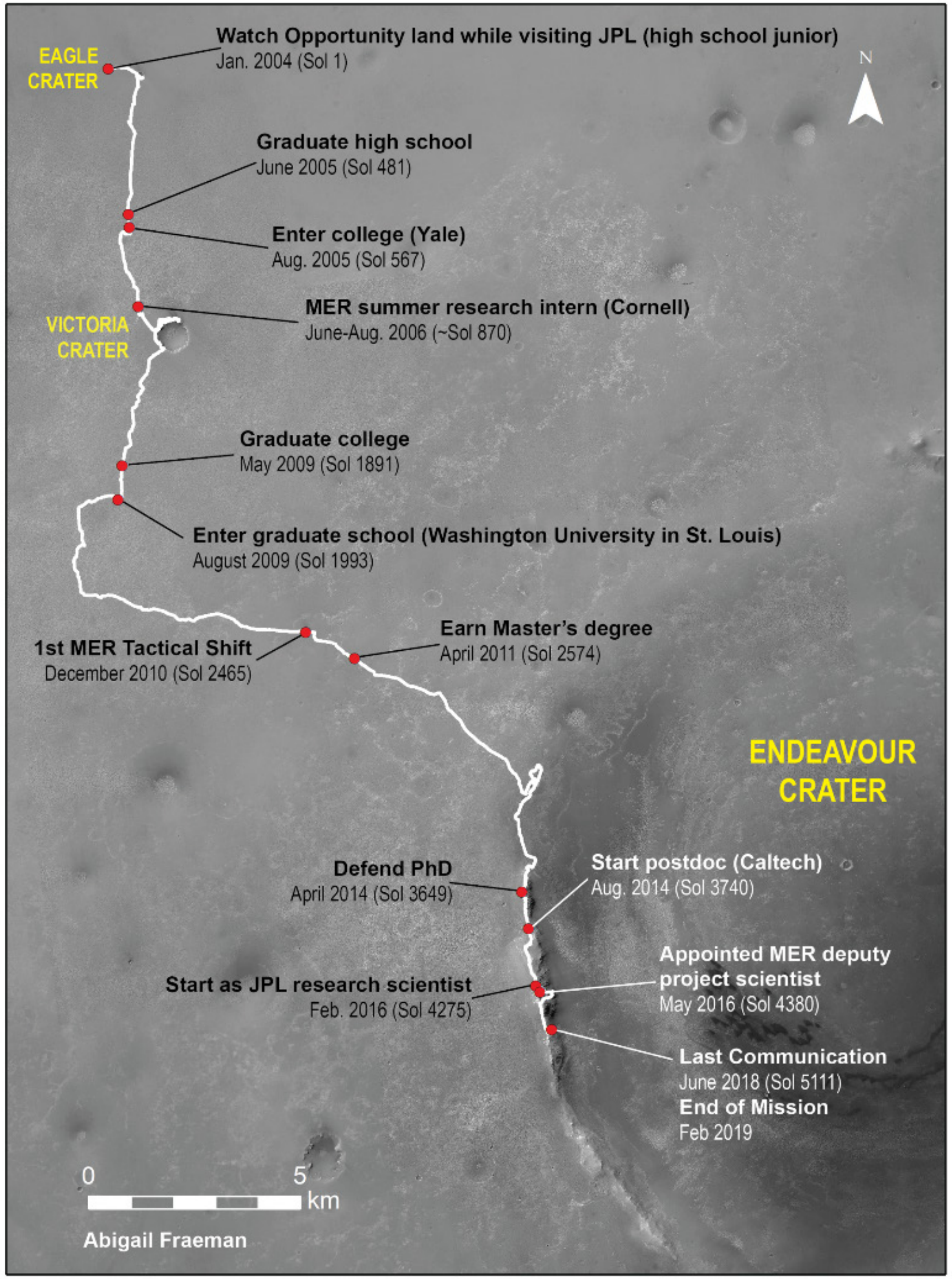


Figure 1: Region and suggested extended mission rover paths outside Jezero crater. Color coding indicate 3 paths that afford high priority science and sampling objectives in Nili Planum. After exiting

Credit: NASA

Fun Fact: Career path of Dr. Abigail Fraeman from high school to Deputy Project Scientist (MER Mission)



Credit: NASA