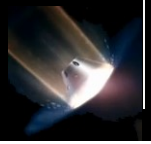


NASA's Adventures at Mars
Past, Present and Future

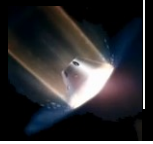
Presented by

Robin A. S. Beck

To

The Rotary Club of Castro Valley

July 6, 2021



Overview

- Who am I?
- Why go to Mars and not Venus?
- A little about Mars
- Past missions to Mars
- Current missions on Mars
- Future missions to Mars
- Q&A

Who is Your Speaker?

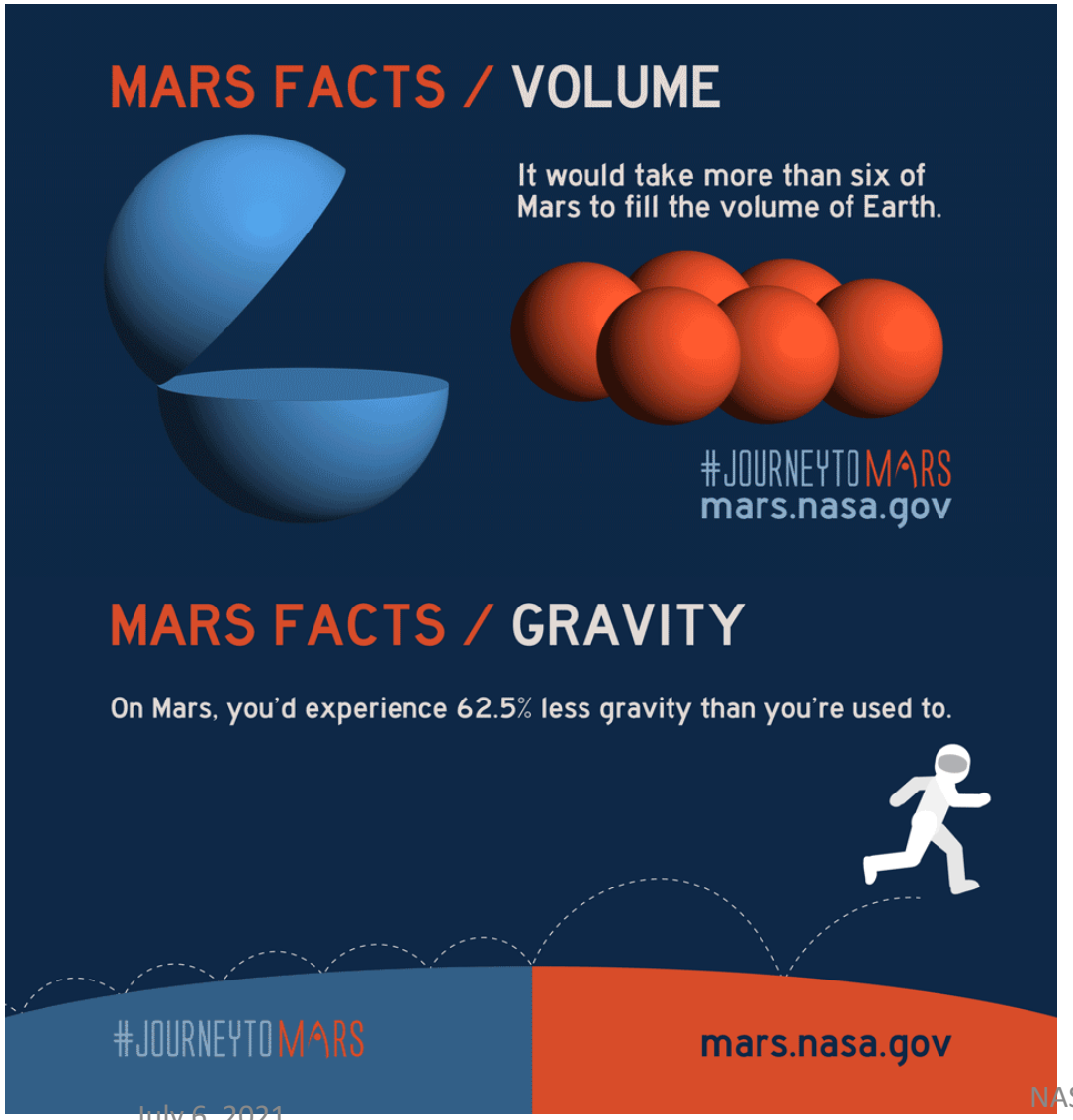
Robin A. S. Beck, PE

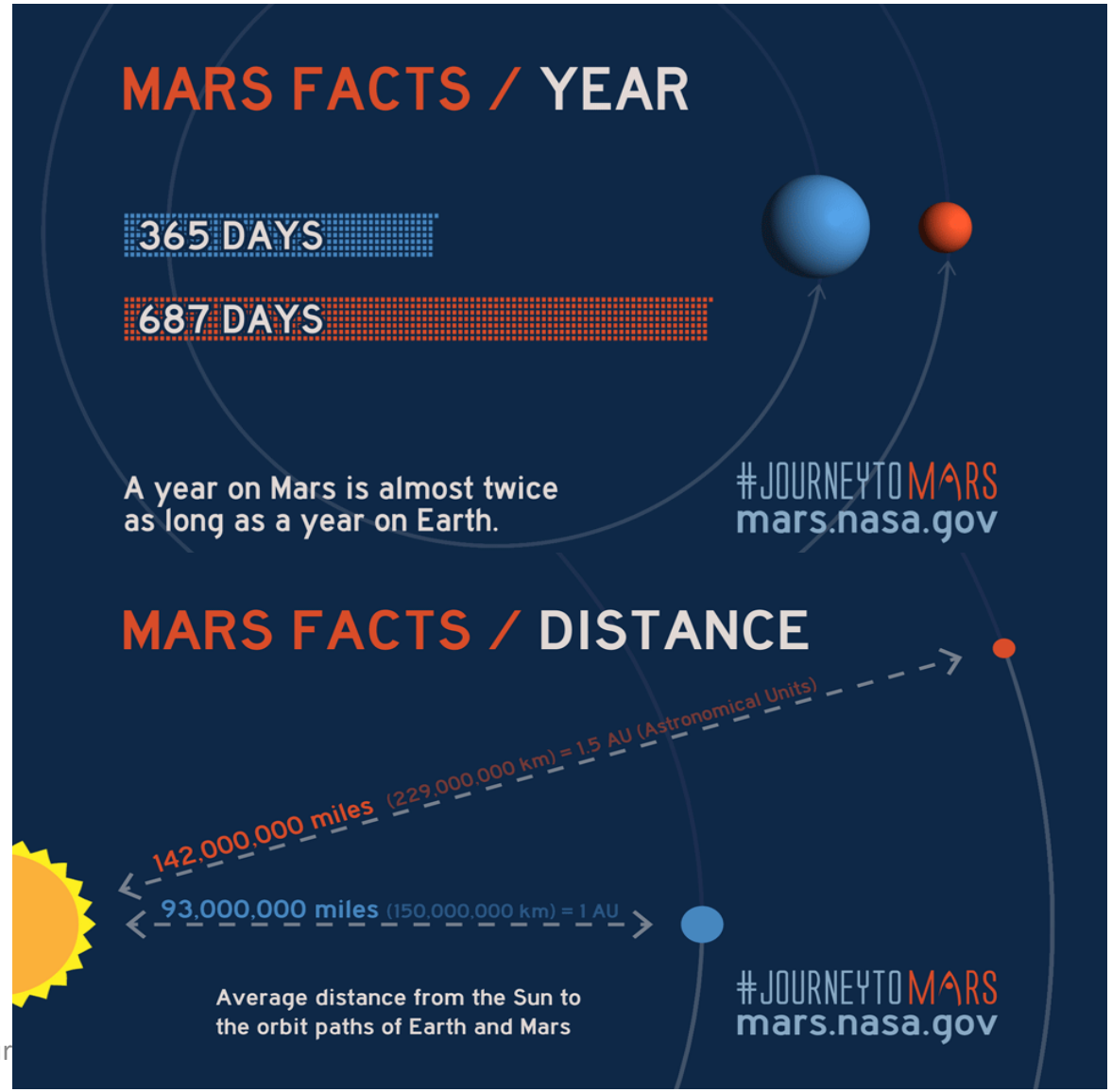
- Born and raised (and still live) in San Jose?
- Went away to college (to Santa Clara University and Stanford)
  - BS and MS in Mechanical Engineering
- Married my college sweetheart and we have 2 adult children and one grandson
- Worked most of my adult life in aerospace (with a short stint in semiconductor manufacturing), 14 years at NASA
- Expert in ablative materials for thermal protection systems (TPS)
- TPS Cognizant Engineer for Mars Science Laboratory, Mars 2020 and Mars Sample Return Lander missions

Quick Comparisons of Our Neighbors

	VENUS	EARTH	MARS
Average Distance from Sun	67 million miles	93 million miles	142 million miles
Average Speed in Orbiting Sun	21.8 miles/second	18.5 miles/second	14.5 miles/second
Diameter	7520 miles	7,926 miles	4,220 miles
Tilt of Axis	177.3° (retrograde rotation	23.5°	25°
Length of Year	225 Earth Days	365.25 Days	687 Earth Days
Length of Day	243 Earth Days	23 hours 56 minutes	24 hours 37 minutes
Gravity	0.91 that of Earth	2.66 times that of Mars	0.375 that of Earth
Average Temperature	863 °F (Hot hot hot!)	57 °F	-81 °F
Atmosphere	Mostly carbon dioxide, a small amount of nitrogen	nitrogen, oxygen, argon, others	mostly carbon dioxide, some water vapor, nitrogen
Atmospheric Pressure (relative to Earth)	93 (Squish!)	1	1/100

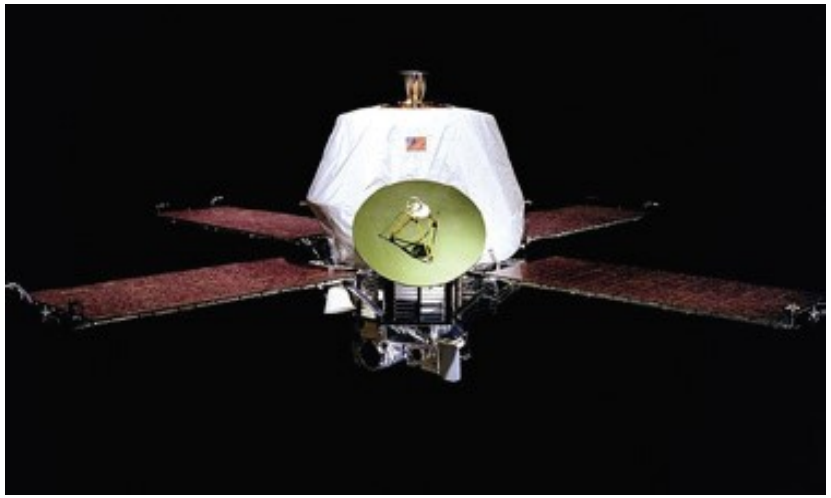
Mars Facts – 1


MARS FACTS / VOLUME
It would take more than six of Mars to fill the volume of Earth.
#JOURNEYTOMARS
mars.nasa.gov
MARS FACTS / GRAVITY
On Mars, you'd experience 62.5% less gravity than you're used to.
#JOURNEYTOMARS
mars.nasa.gov


MARS FACTS / YEAR
365 DAYS
687 DAYS
A year on Mars is almost twice as long as a year on Earth.
#JOURNEYTOMARS
mars.nasa.gov
MARS FACTS / DISTANCE
142,000,000 miles (229,000,000 km) = 1.5 AU (Astronomical Units)
93,000,000 miles (150,000,000 km) = 1 AU
Average distance from the Sun to the orbit paths of Earth and Mars
#JOURNEYTOMARS
mars.nasa.gov

NASA's Past Missions to Mars Mariner

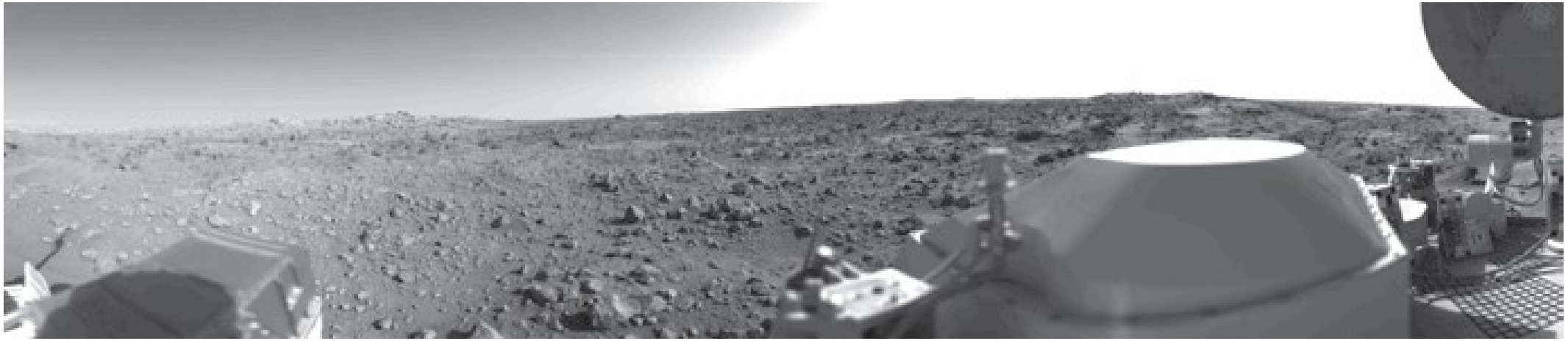
- Mariner 3 & 4 launched in 1964
  - Designed to carry out the first fly-bys of Mars (7/1965)
  - Mariner 4 collected the first close-up photographs of another planet, showing lunar-type impact craters
- Mariner 6 & 7 launched in 1969 as fly-bys
  - Designed to measure atmospheric composition, pressure, density and temperature
  - Also provided a precise measurement of the mass of Mars
  - Photomapped 10% of the surface
- Mariner 9 launched in May 1971 and became the first artificial satellite of Mars when it arrived and went into orbit.
  - It revealed a very different planet than expected — one that boasted gigantic volcanoes and a canyon stretching 3,000 miles across its surface.
  - More surprisingly, the relics of ancient riverbeds were carved in the landscape of this seemingly dry and dusty planet.
  - Photomapped 100% of the surface



NASA's Past Missions to Mars
Viking

- NASA's Viking Project found a place in history when it became the first U.S. mission to land a spacecraft (Viking 1) safely on the surface of Mars on July 20, 1976 and return images of the surface.
- Viking also obtained the first soil sample on another planet

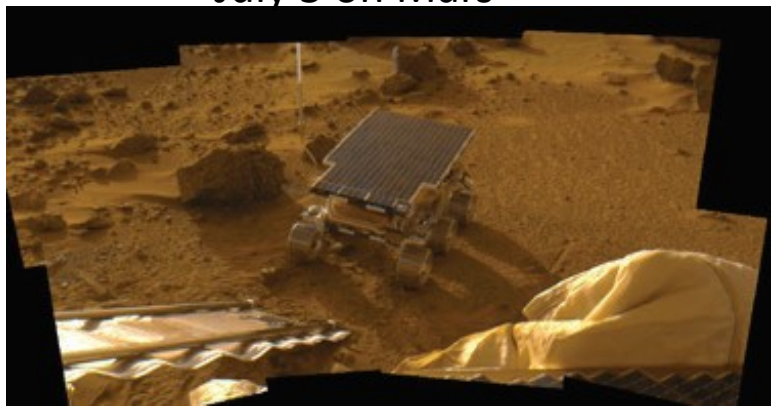
First panoramic view by Viking 1 from the surface of Mars



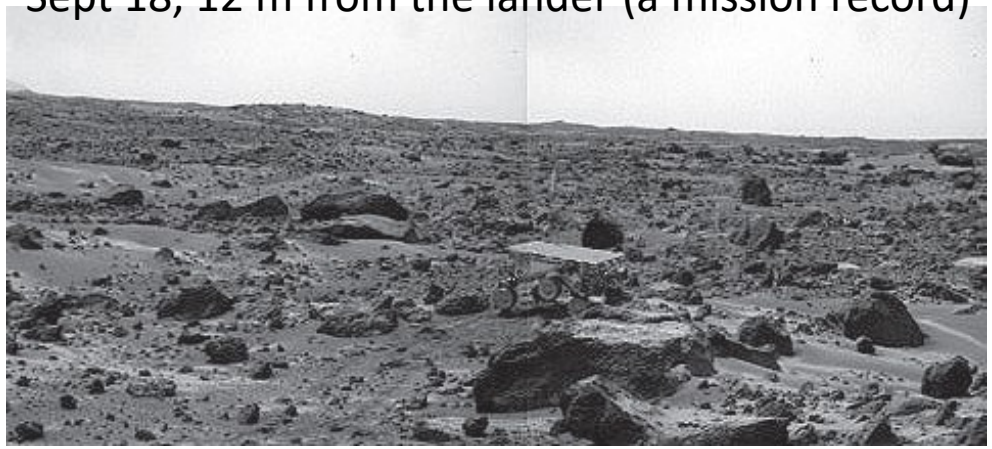
NASA's Past Missions to Mars Pathfinder

- Mars Pathfinder landed on July 4, 1997
- Designed as a technology demonstration of a new way to deliver an instrumented lander and the first-ever robotic rover (Sojourner) to the surface of Mars.
- Used an innovative method of directly entering the Martian atmosphere, assisted by a parachute to slow its descent through the thin Martian atmosphere and a giant system of airbags to cushion the impact.
- From landing until the final data transmission in September 1997, Mars Pathfinder returned 2.3 billion bits of information including more than 16,500 images from the lander and 550 images from the rover, as well as more than 15 chemical analyses of rocks and soil.
- Findings from instruments on both the lander and the rover suggest that Mars was at one time in its past warm and wet.

July 5 on Mars

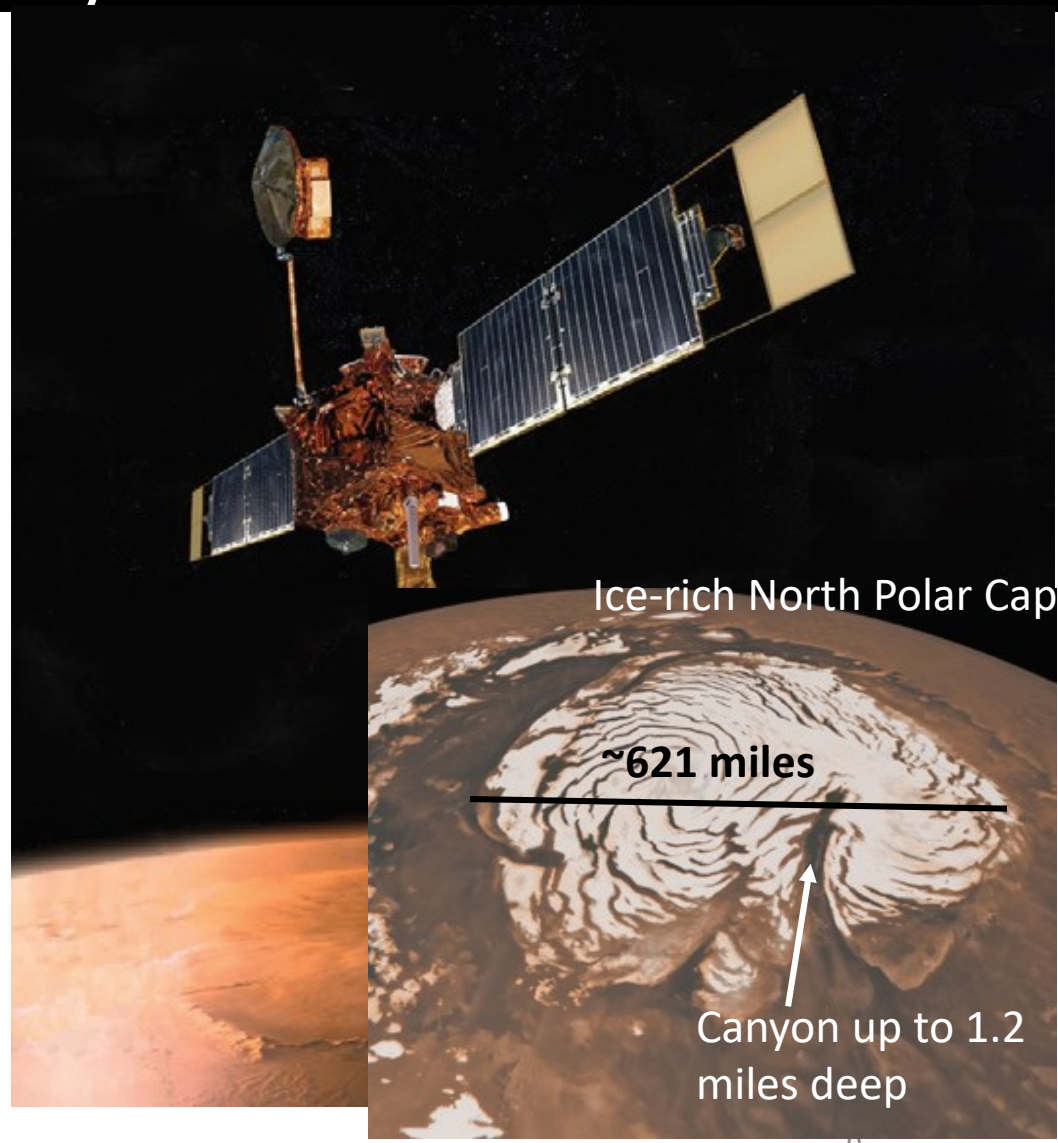


Sept 18, 12 m from the lander (a mission record)



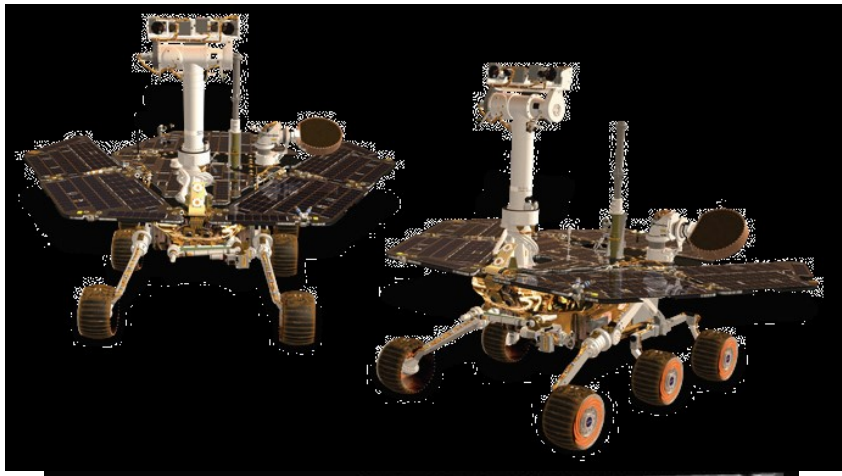
NASA's Past Missions to Mars
Mars Global Surveyor

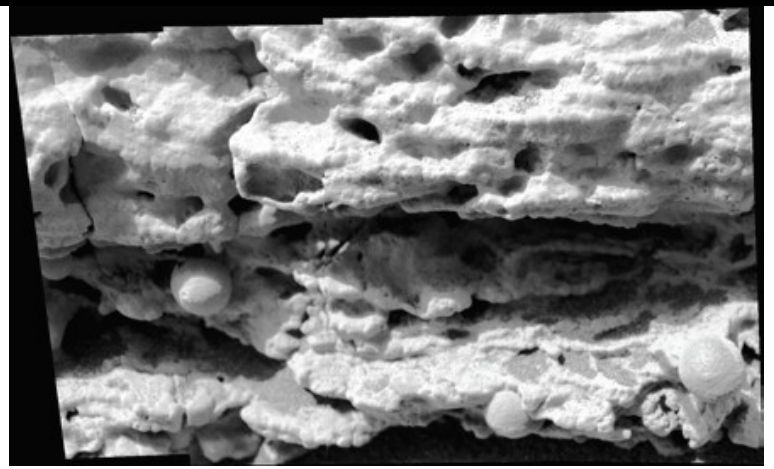
- Mars Global Surveyor began its prime mapping mission in March 1999 from a low-altitude, nearly polar orbit
- Mars Global Surveyor generated high-resolution images that document gullies and debris flows, suggesting that occasional sources of liquid water — similar to an aquifer — were once present at or near the surface of the planet
- Mars Global Surveyor last communicated with Earth on Nov. 2, 2006. Within 11 hours, depleted batteries likely left the spacecraft unable to control its orientation.



NASA's Past Missions to Mars
Mars Exploration Rovers

- In January 2004, two robotic geologists named Spirit and Opportunity landed on opposite sides of Mars.
- Special rock abrasion tools, never before sent to another planet, enabled scientists to peer beneath the dusty and weathered surfaces of rocks to examine their interiors.
- Spirit and Opportunity each found evidence for past wet conditions that possibly could have supported microbial life.
- Spirit lasted 20 times longer than its original design until its final communication to Earth in 2010 after traveling nearly 5 miles.
- Opportunity continued to operate until June 2018, traveling more than 28 miles

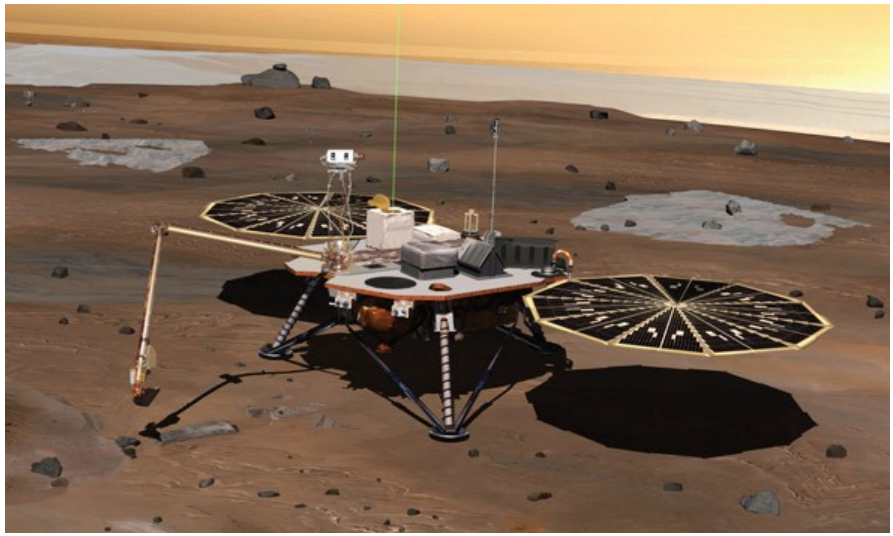




This close-up view of a target rock called "Last Chance" was acquired by the microscopic imager on the arm of Opportunity in 2004.

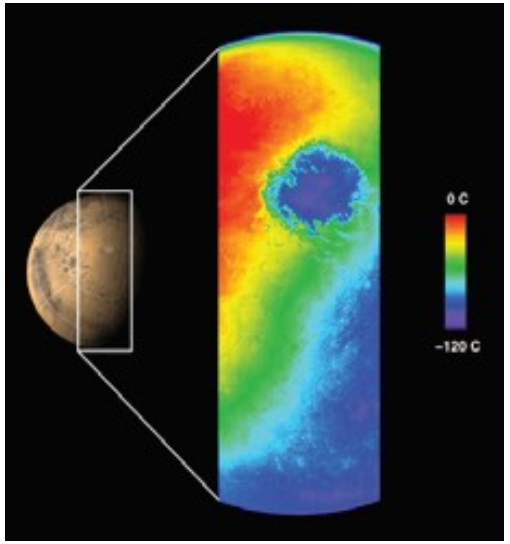
NASA's Past Missions to Mars
Phoenix

- The Phoenix lander studied its surroundings after landing on a Martian arctic plain on May 25, 2008
- During its mission, Phoenix dug into an ice-rich layer near the surface. It checked samples of soil and ice for evidence about whether the site was ever hospitable to life
- To analyze soil samples collected by its robotic arm, Phoenix carried tiny ovens and a portable laboratory. Selected samples were heated to release volatiles that were examined for their chemical composition and other characteristics
- In August 2008, Phoenix completed its three-month mission studying Martian ice, soil and atmosphere. The lander worked for two additional months before reduced sunlight caused energy to become insufficient to keep the lander functioning

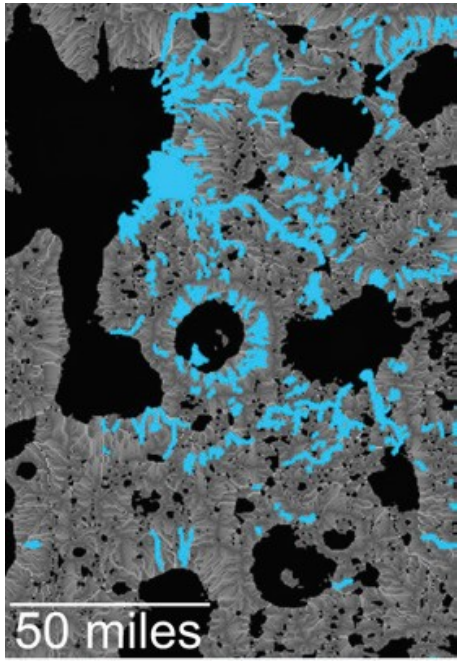


NASA's Current Missions at Mars
Mars Odyssey

- The 2001 Mars Odyssey mission is NASA's longest-lasting spacecraft at Mars.
  - Its mission includes making the first global map of the amount and distribution of chemical elements and minerals that make up the Martian surface
  - Images and other measurements from Mars Odyssey help identify potential landing sites for rovers and landers
  - The orbiter's extended operations continue today



The extremely cold, circular feature in blue is the carbon dioxide ice cap at the south pole of Mars at a temperature of about -120 °C (-184 °F).

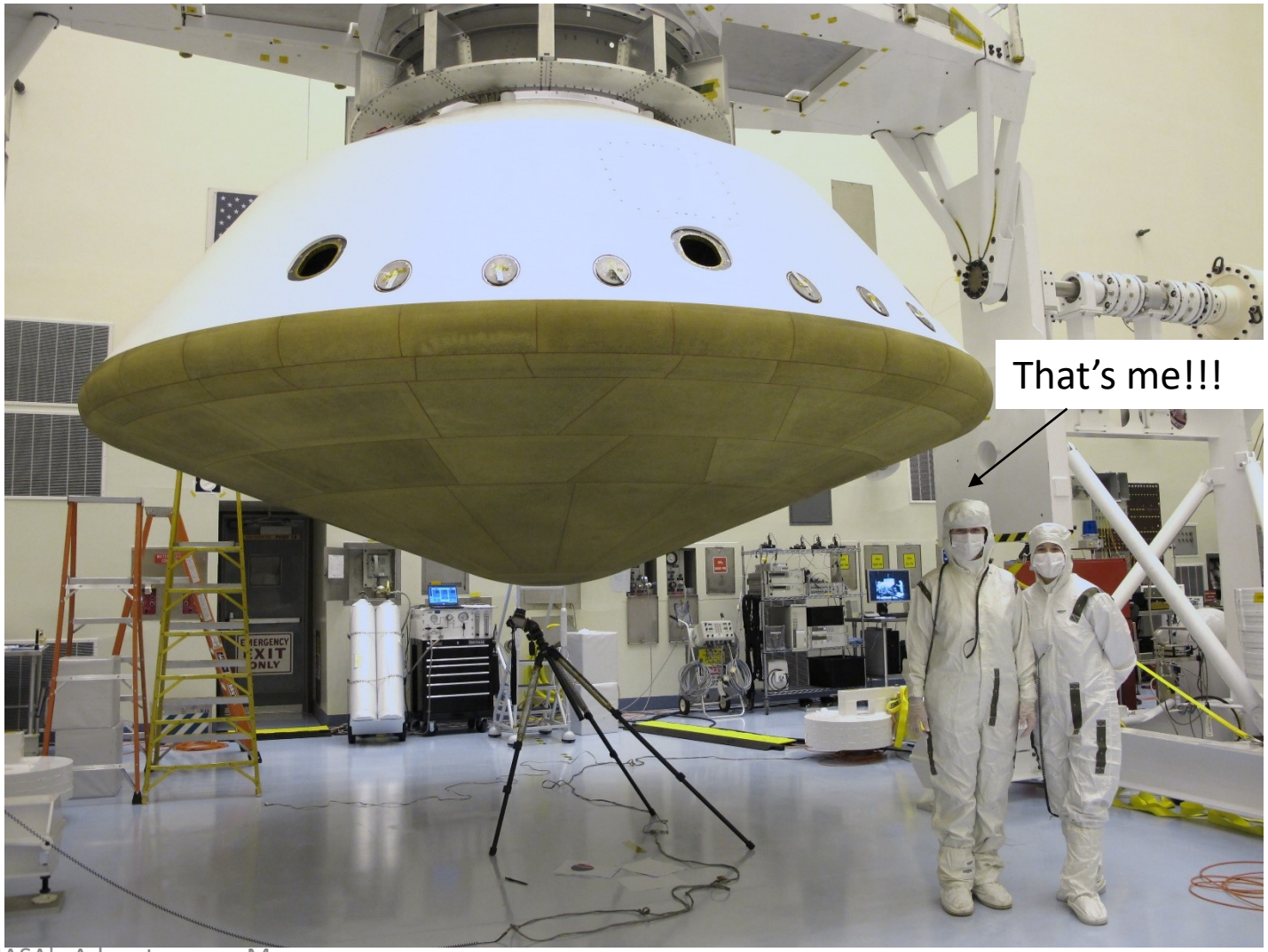


NASA's Current Missions at Mars
Mars Science Laboratory Curiosity - 1

- Curiosity was the largest and most capable rover ever sent to Mars when it landed in August 2012
- Body the size of Mini Cooper, wheel base of a Hummer
- Powered by a Radioisotope Thermoelectric Generator (RTG), a nuclear battery instead of solar panels
  - Can operate in any weather, any time of day
- So large, a new landing system was developed
- Heating so high, a new (for Mars) TPS material system was needed for the heatshield

NASA's Current Missions at Mars
Mars Science Laboratory Curiosity - 2

- MSL was the first spacecraft to fly a tiled heatshield to Mars
- The material is Phenolic Impregnated Carbon Ablator (PICA)
- PICA was invented at NASA Ames Research Center



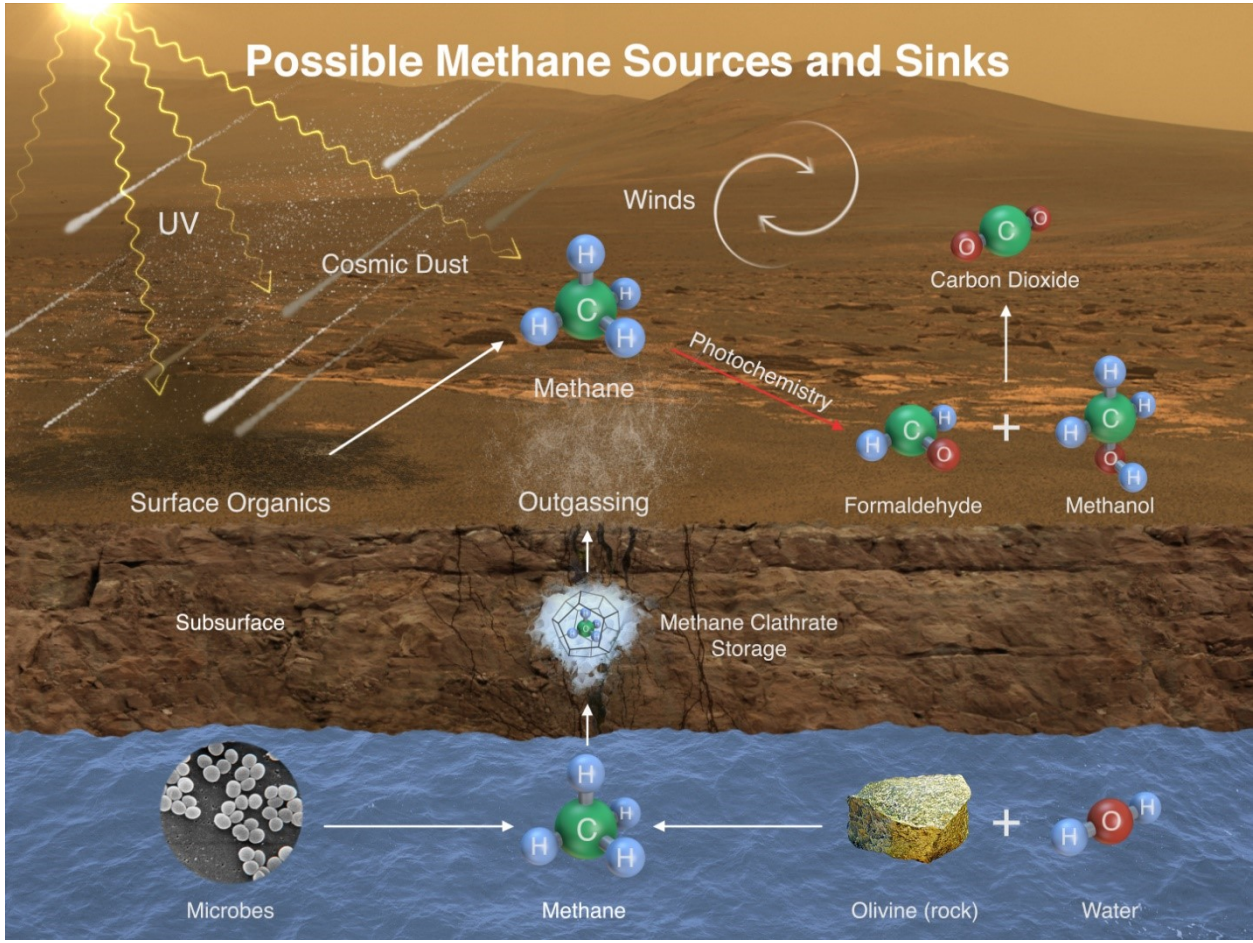
NASA's Current Missions at Mars
Mars Science Laboratory Curiosity - 3

- MSL's entry, descent and landing described as the seven minutes of terror

7 minutes of terror video goes here

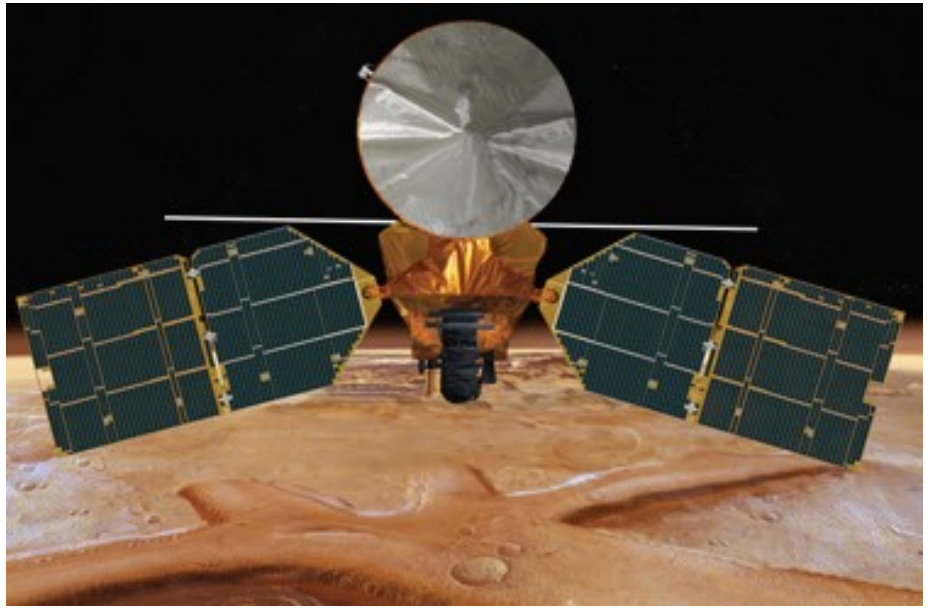
NASA's Current Missions at Mars
Mars Science Laboratory Curiosity - 4

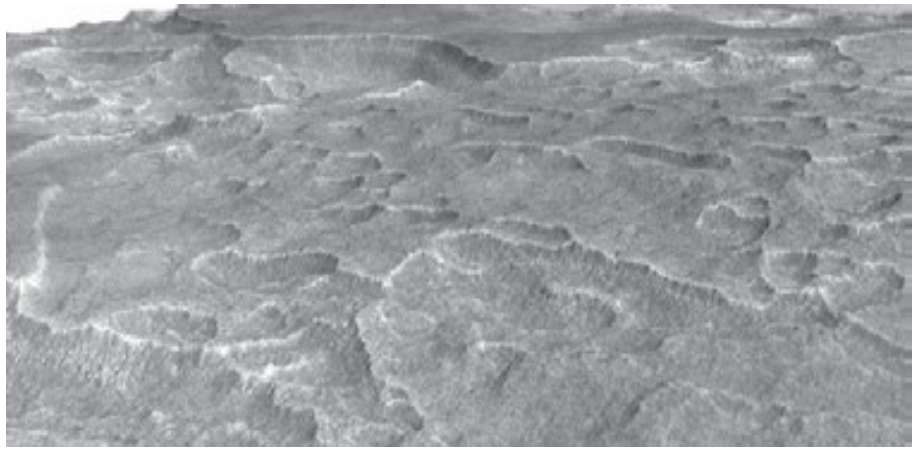
- Curiosity carried the biggest, most advanced instruments for scientific studies ever sent to the Martian surface
- Early in its mission, Curiosity found chemical and mineral evidence of past habitable environments on Mars.
- Curiosity has detected fluctuations in methane concentration in the atmosphere, implying both outgassing and photochemistry of methane may occur on modern Mars
- Curiosity has been on Mars for 3168 sols (3256 days), has traveled nearly 16 miles and is still going strong



NASA's Current Missions at Mars
Mars Reconnaissance Orbiter

- Mars Reconnaissance Orbiter (MRO) launched in August 2005 and carried the most powerful camera ever flown on a planetary exploration mission for homing in on details of Martian terrain, spotting objects as small as a dinner plate
- MRO is also the first installment of an "interplanetary Internet" — the first link in a communications bridge back to Earth.
- The large silver circular feature above the spacecraft bus is the high-gain antenna, the spacecraft's main means of communicating with both Earth and other spacecraft
- The long, thin pole behind the bus is the Shallow Subsurface Radar (SHARAD) antenna. The large instrument (covered in black thermal blanketing) in the center is the High Resolution Imaging Science Experiment (HiRISE) camera.
- This shows scalloped depressions in Mars' Utopia Planitia region, one of the area's distinctive textures that prompted researchers to check for underground ice.
- More than 600 MRO overhead passes provided data for determining that about as much water as the volume of Lake Superior lies in a thick layer beneath a portion of this region





NASA's Current Missions at Mars
MAVEN

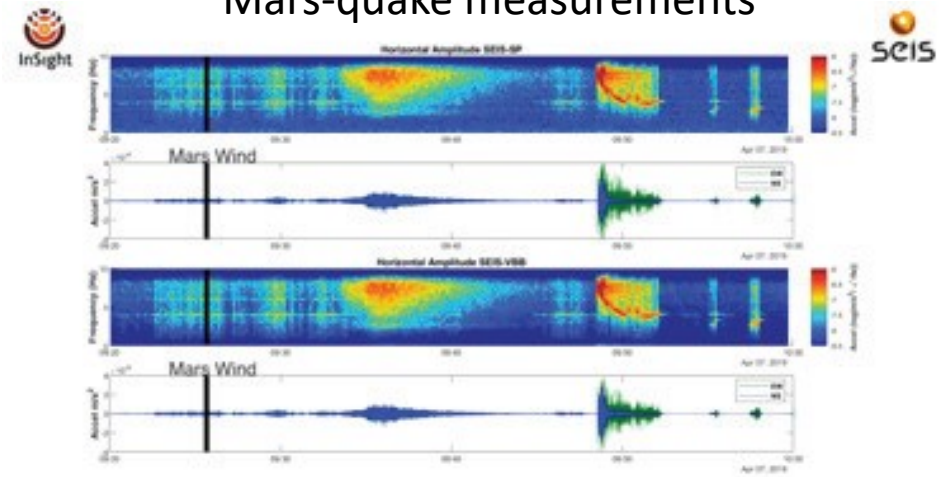
- Mars Atmospheric and Volatile EvolutioN (MAVEN), launched in November 2013 is obtaining critical measurements of the Martian atmosphere to help understand dramatic climate change on the Red Planet over its history.
- MAVEN was the first spacecraft ever to make direct measurements of the Martian atmosphere
- MAVEN carries an Electra UHF radio designed for communicating with robots on the surface, relaying data between Mars rovers or landers and Earth.

NASA's Current Missions at Mars
InSight

- The InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission placed a single geophysical lander on Mars in November 2018 to study its deep interior
- It is designed to address one of the most fundamental issues of planetary science: understanding the processes that shaped the rocky planets of the inner solar system (including Earth) more than four billion years ago

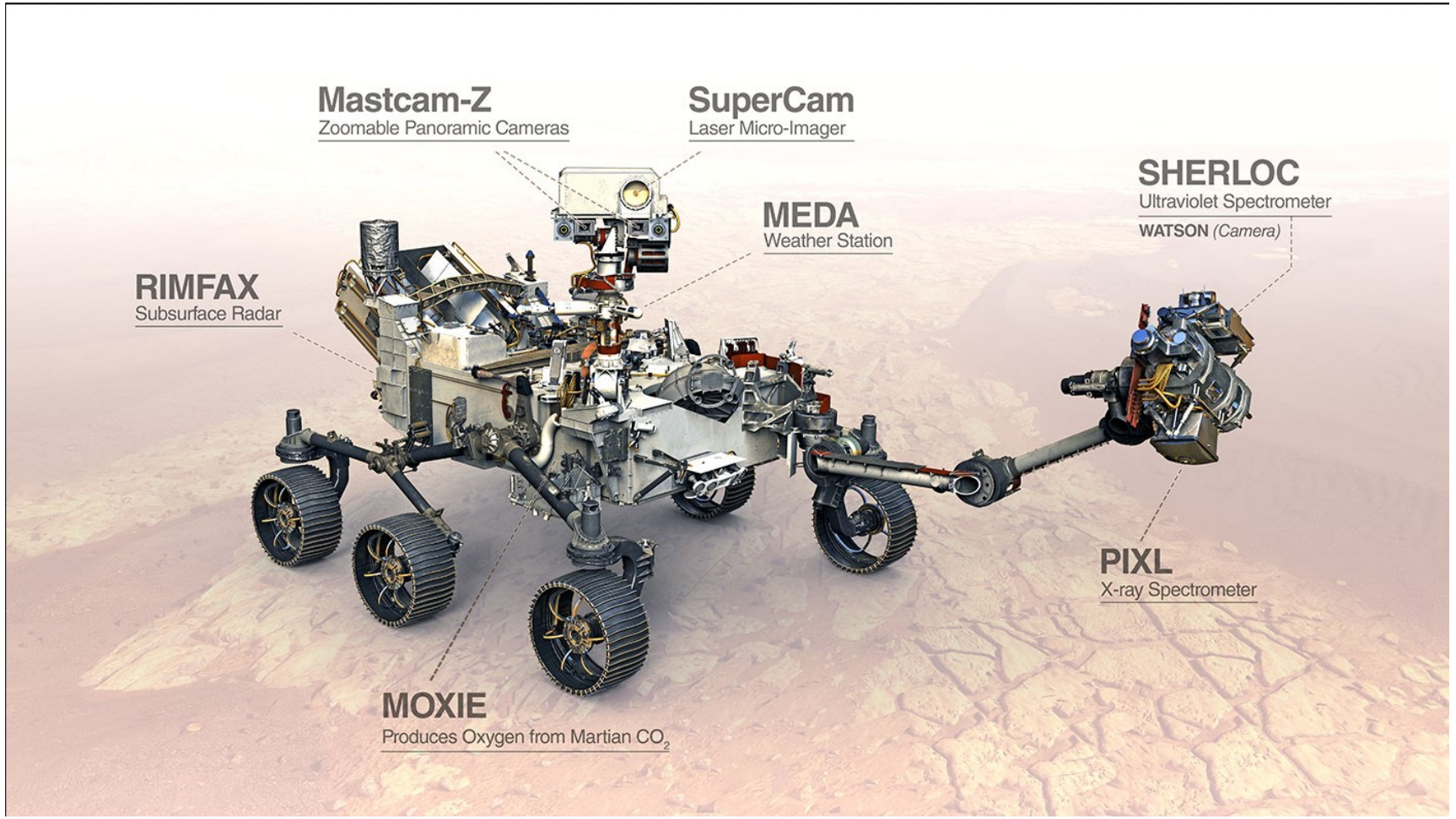
Insight deploying equip video goes here

Mars-quake measurements



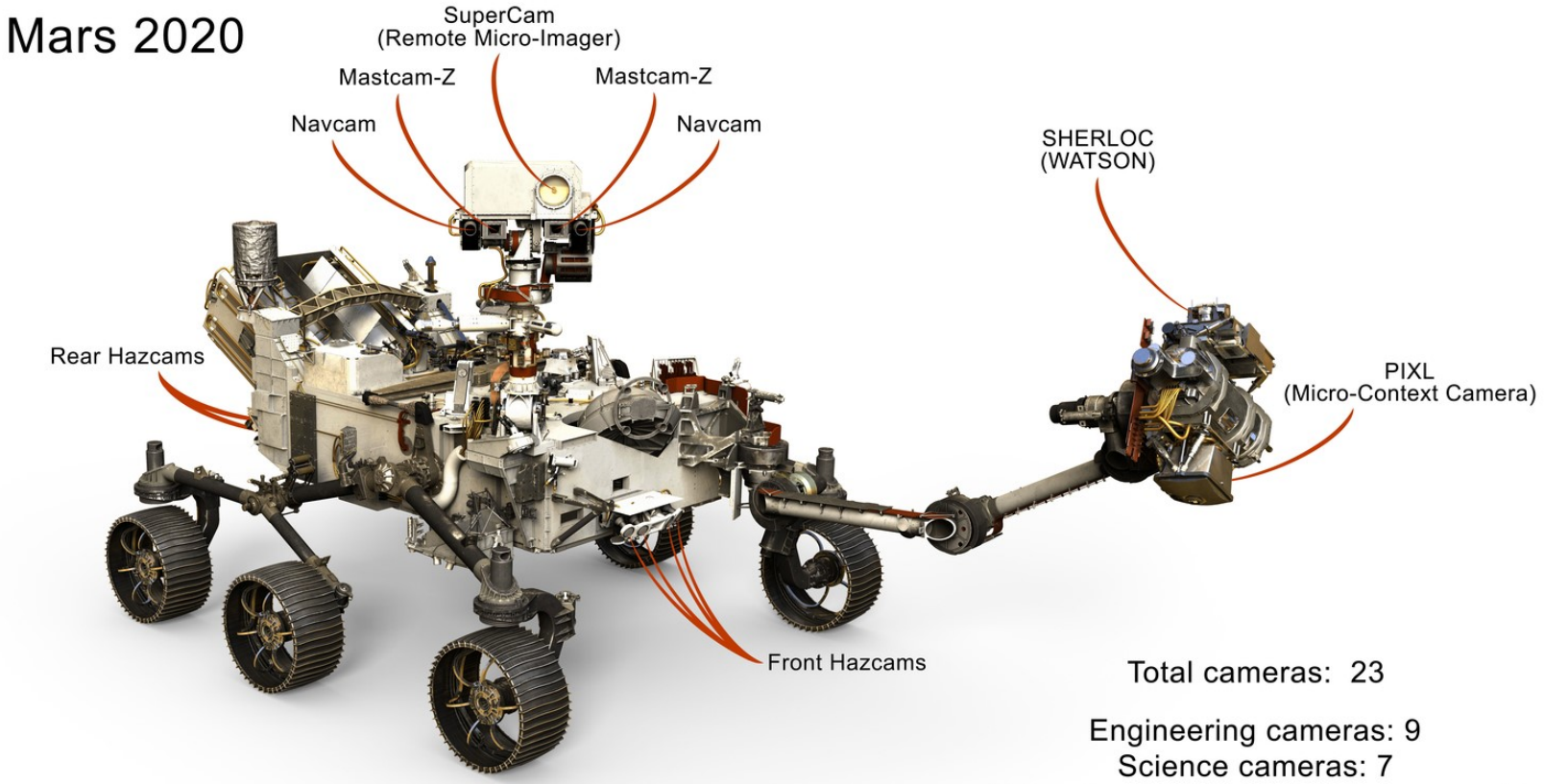
NASA's Current Missions at Mars
Mars 2020 Perseverance - 1

Science Instruments on Board



NASA's Current Missions at Mars
Mars 2020 Perseverance - 2

Cameras on Board



Total cameras: 23

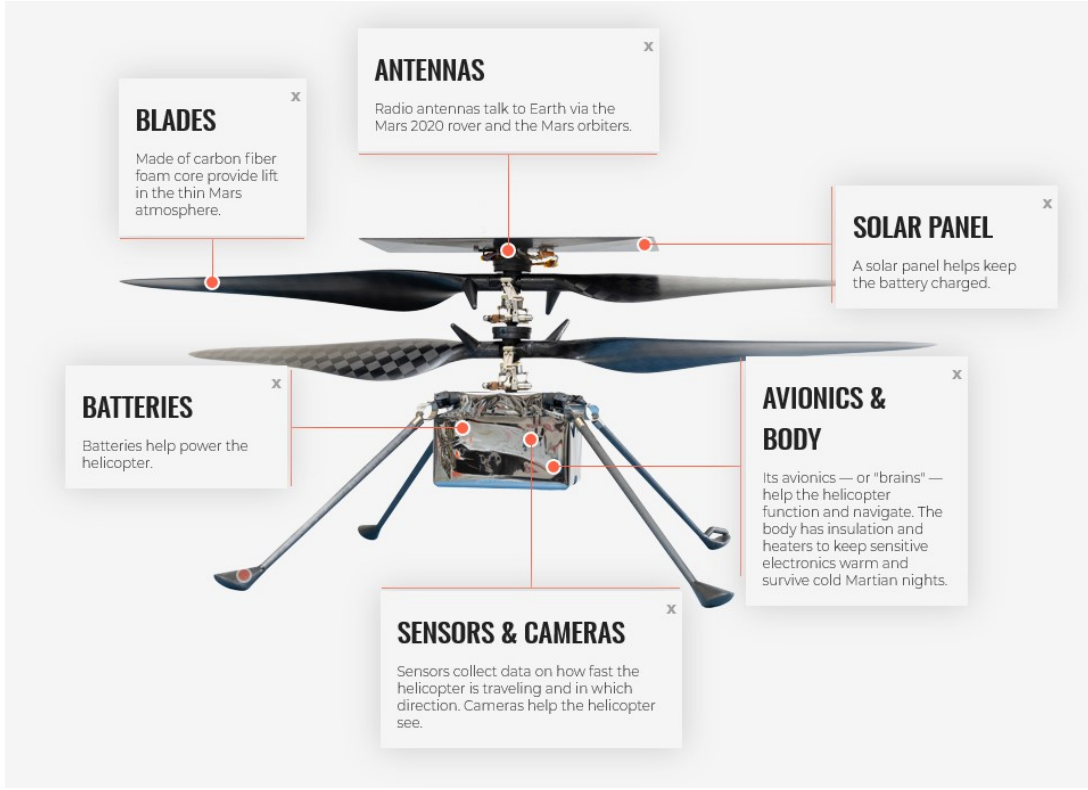
Engineering cameras: 9
Science cameras: 7
Entry, descent and landing cameras: 7

NASA's Current Missions at Mars
Mars 2020 Perseverance - 3

- The Mars 2020 Perseverance rover, which landed on Mars in February 2020, is based on the Curiosity rover and its proven landing system (with a little extra)
  - Added Terrain Relative Navigation (TRN) for autonomous hazard avoidance
  - Added a ton of cameras (up-look at the parachute (3), down-look at the descent stage, up-look from the descent stage)
  - https://www.youtube.com/watch?v=ZbTJ_YCTDLI
  - https://www.youtube.com/watch?v=uKxYMRfKAEs
- The mission addresses high-priority science goals for Mars exploration including key questions about the potential for life on Mars, focusing on signs of past microbial life itself
- The rover will collect and cache samples for a future return to earth mission to retrieve

NASA's Current Missions at Mars
Mars 2020 Ingenuity

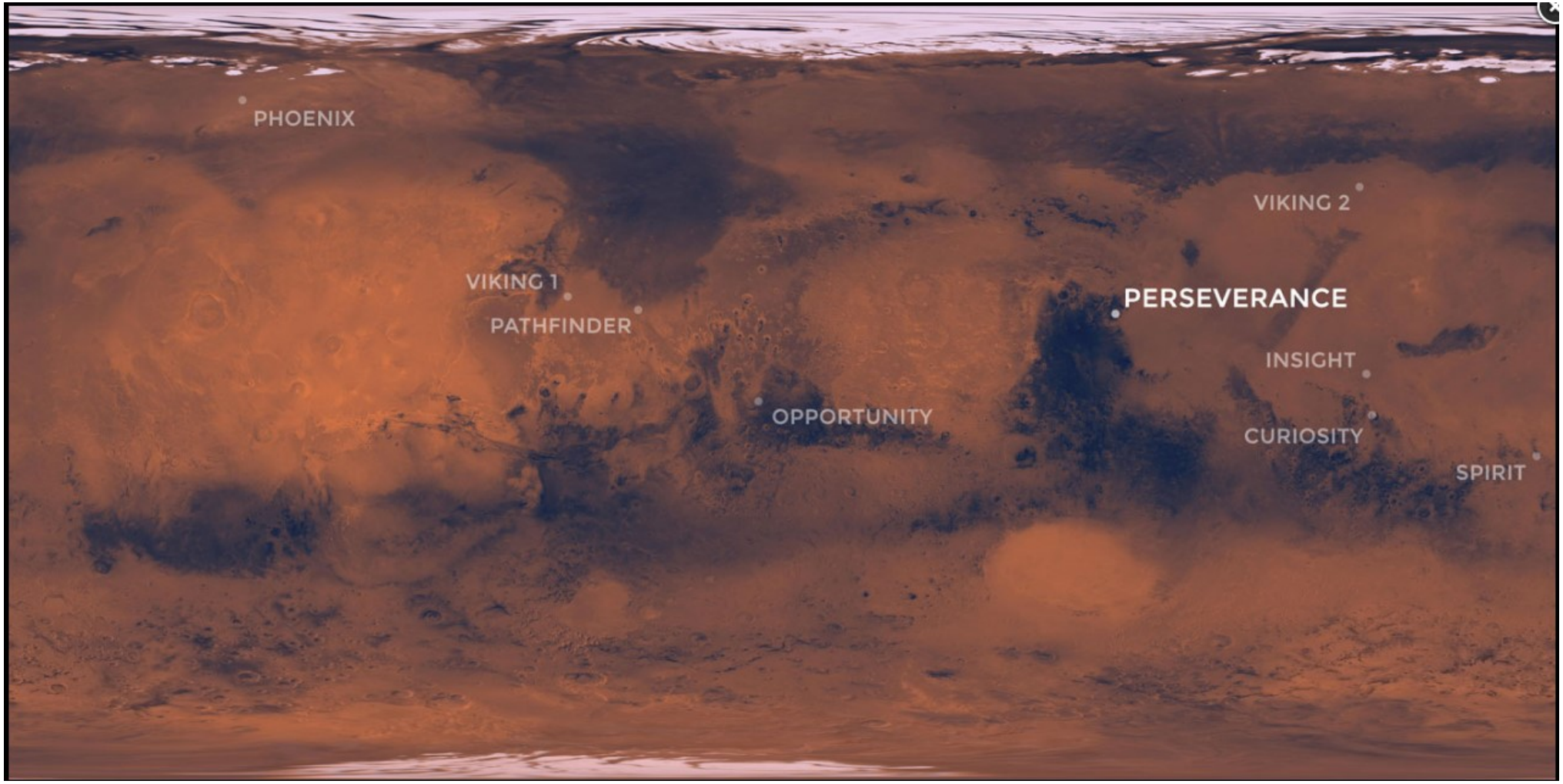
- A Mars helicopter, Ingenuity, is a small, autonomous rotorcraft that flew under the belly of Perseverance to demonstrate the viability and potential of heavier-than-air vehicles on the Red Planet.
- More than 1,500 individual pieces of carbon fiber, flight-grade aluminum, silicon, copper, foil, and foam went into Ingenuity, which became the first aircraft to attempt powered flight on another planet
- Ingenuity has flown 8 times so far



https://www.youtube.com/watch?list=PLTiv_XWHnOZpzQKYC6nLf6M9AuBbng_O8&v=y5niGi4k9vQ&feature=emb_imp_woyt

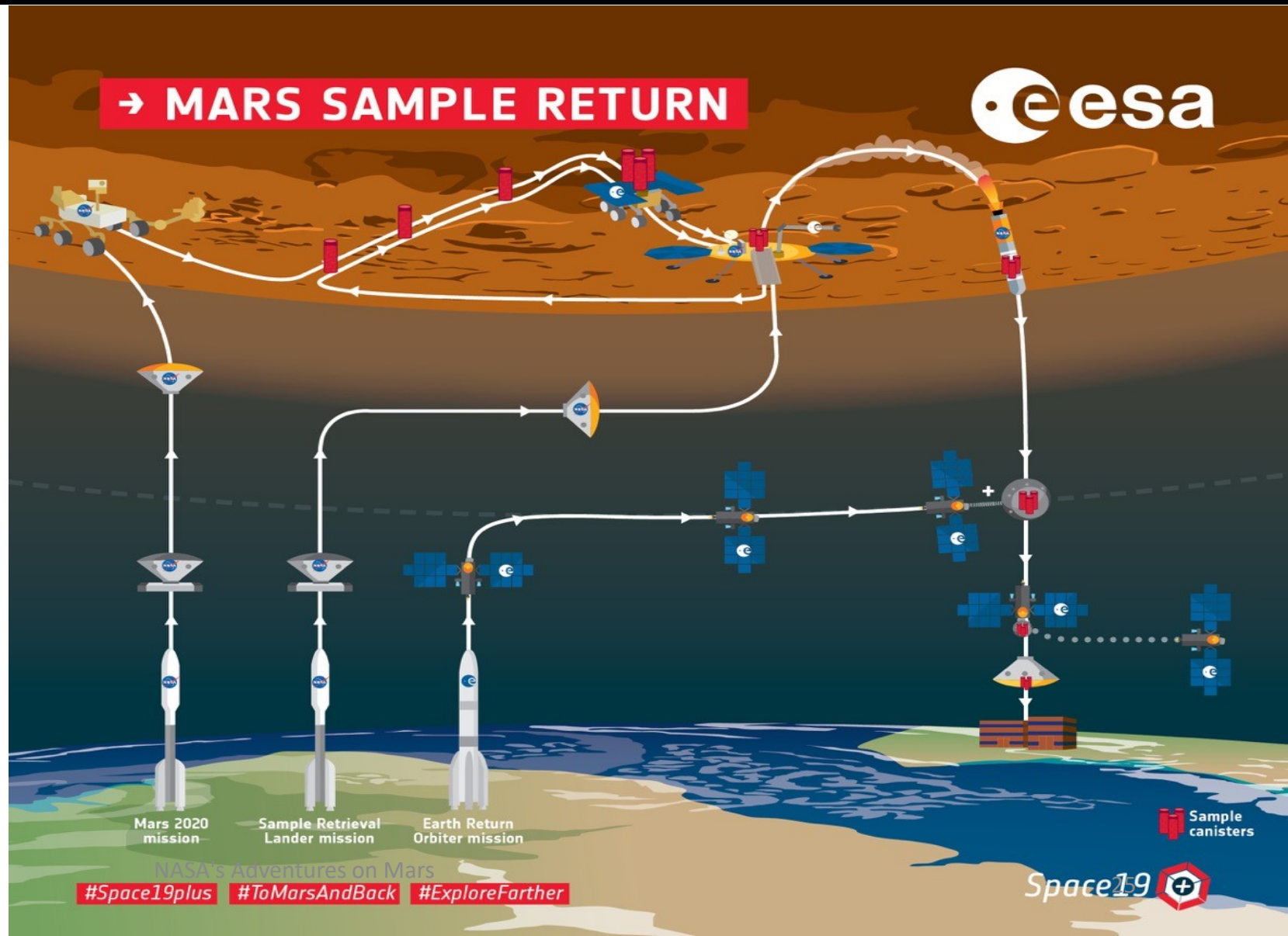
NASA's Missions to Mars Locations

Where everything landed



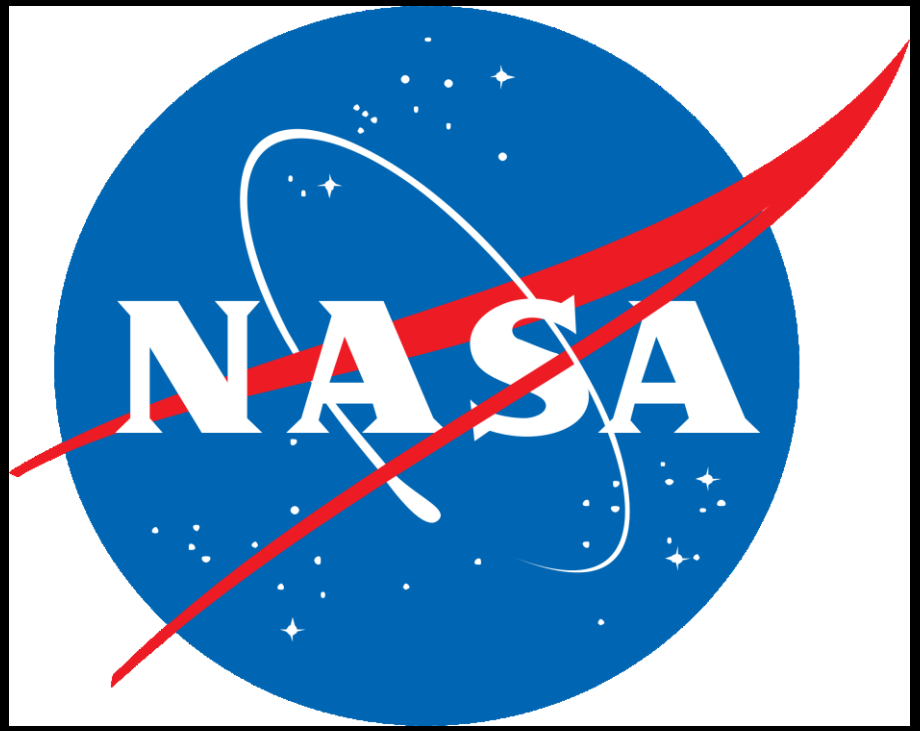
NASA's Future Missions to Mars
Mars Sample Return Campaign

- This is a multi-year, multi-agency, multi-center concept
- Mars2020 is the first step of this mission, gather (rock and soil) samples using its drill, store samples in tubes
- SRL will land a fetch rover and the Mars ascent vehicle (MAV)
- On the surface, the fetch rover will collect the tubes and place them in the MAV
- MAV will deposit samples to the Earth Return Orbiter (ERO)
- ERO will decontaminate, then place samples in the Earth Entry Vehicle (EEV) for return to Earth.



Questions?

National Aeronautics and Space Administration



Ames Research Center
Entry Systems and Technology Division