Mars Rover

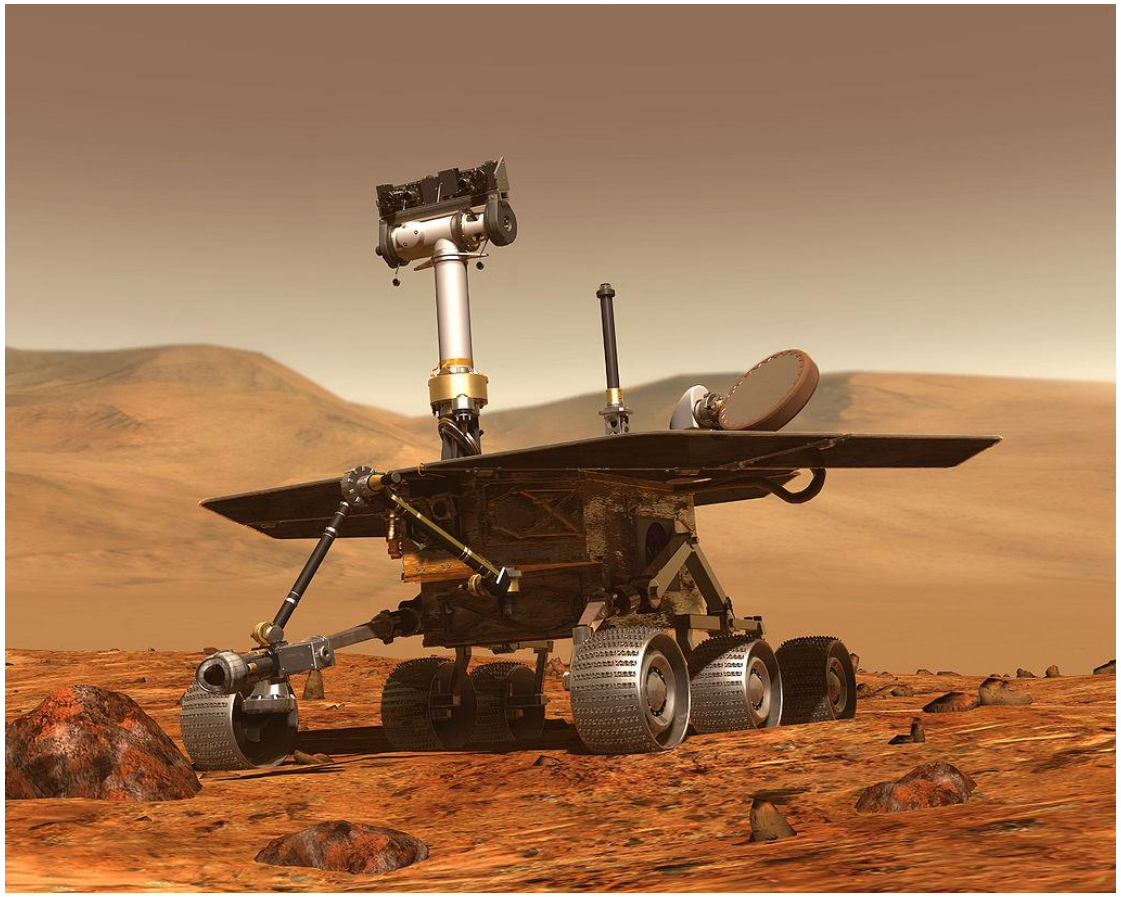
Robotic Hardware Systems

Content

- Definition
- Physical Design for various applications
- Locomotion System & Actuators
- Navigation System (Sensors) & Control
- Data Collection
- Data transmission
- Power Management

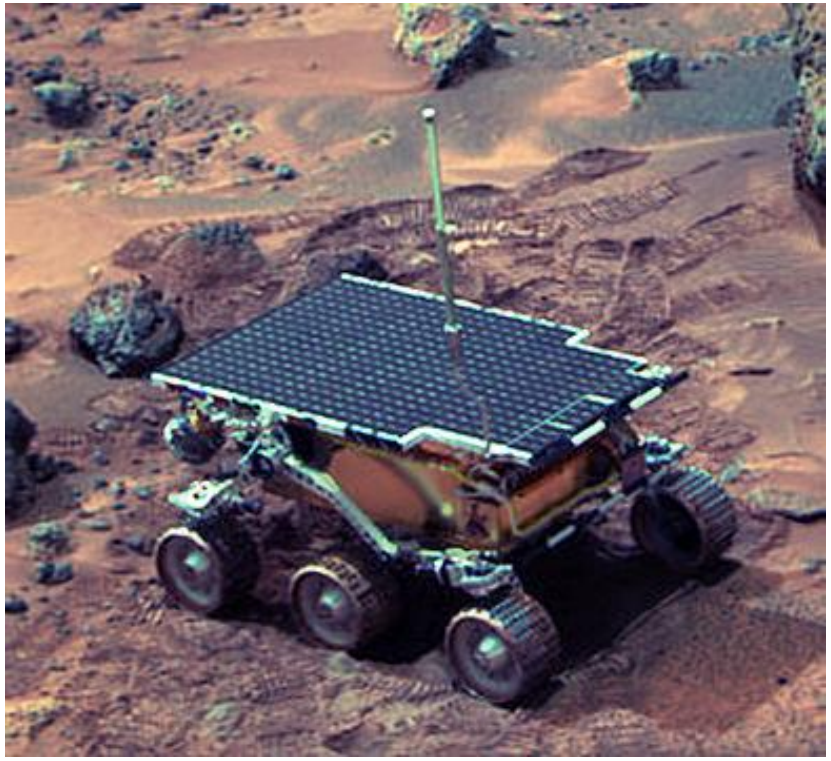
Definition

- A Mars rover is a motor vehicle that travels across the surface of the planet Mars upon arrival.
- Rovers have several advantages over stationary landers: they examine more territory, they can be directed to interesting features, they can place themselves in sunny positions to weather winter months, and they can advance the knowledge of how to perform very remote robotic vehicle control.
- As of February 2021, there have been five successful robotically operated Mars rovers, all managed by the Jet Propulsion Laboratory: Sojourner, Opportunity, Spirit, Curiosity, and Perseverance.
- The four science goals of NASA's long-term Mars Exploration Program are:
    1. Determine whether life ever arose on Mars
    2. Characterize the climate of Mars
    3. Characterize the geology of Mars
    4. Prepare for human exploration of Mars



Physical Design for various applications

- Sojourner is a robotic Mars rover that landed on July 4, 1997,[1] in the Ares Vallis region. Sojourner was operational on Mars for 92 sols (95 days).
- It had front and rear cameras and hardware to conduct several scientific experiments.



Physical Design for various applications

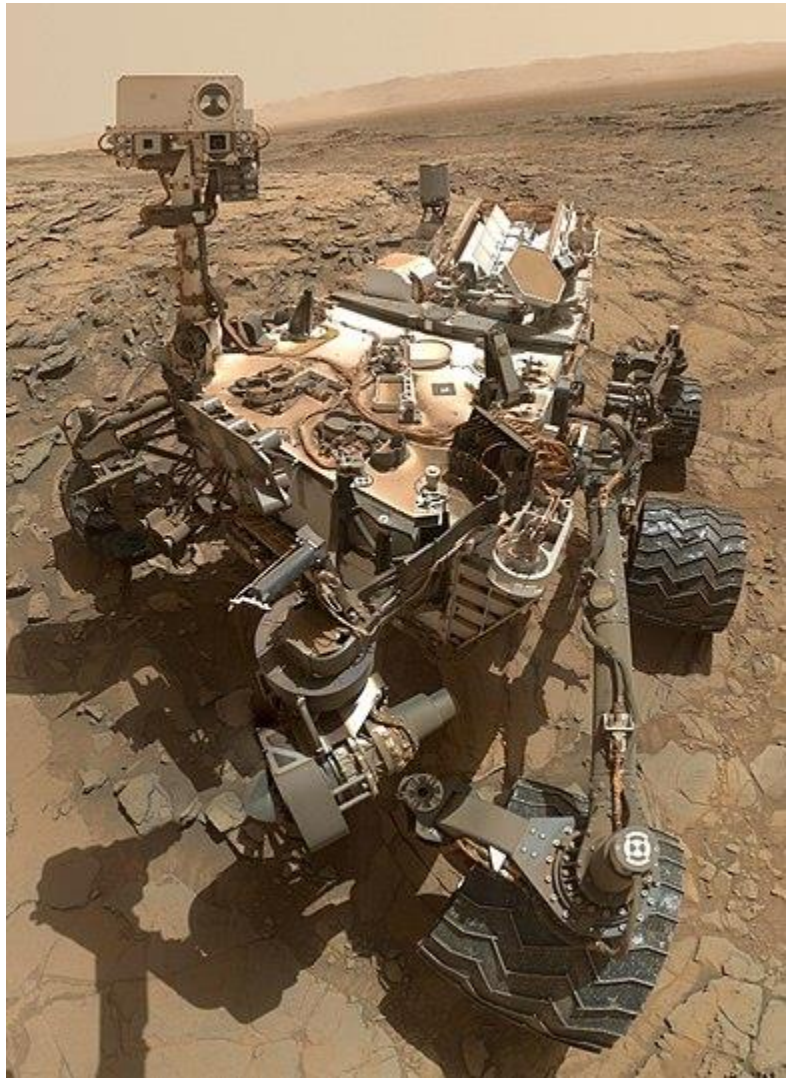
- Opportunity is a robotic rover that was active on Mars from 2004 until mid-2018.
- Opportunity was operational on Mars for 5110 sols (5250 days; 14 years, 136 days)
- Opportunity weighs around 185 kg and travels on six wheels powered by electrical energy supplied by solar panels.
- It is equipped with three pairs of cameras used for navigation and several scientific instruments: a panoramic camera located on a mast 1.5 meters high, a tool for abrading the surface of rocks carried by an articulated arm on which are located also an X-ray spectrometer, a Mössbauer spectrometer and a microscope camera. Finally, an infrared spectrometer is used for the analysis of rocks and the atmosphere.

Physical Design for various applications

- Spirit is a rover launched towards the planet Mars in 2003.
- The object which landed on Mars on January 4, 2004 in the Goussev crater was intended to study the geology of Mars and in particular to determine the role played by water in the history of the planet.
- Its mission, which was to last 90 days, officially ended in March 2010. This lifespan enabled it to cover 7.73 km (primary mission objective 600 meters) and to greatly exceed the assigned scientific objectives.
- Spirit weighs around 185 kg and travels on six wheels powered by electrical energy supplied by solar panels.
- It is equipped with three pairs of cameras used for navigation and several scientific instruments: a panoramic camera located on a mast 1.5 meters high, a tool for abrading the surface of rocks carried by an articulated arm on which are located also an X-ray spectrometer, a Mössbauer spectrometer and a microscope camera. Finally, an infrared spectrometer is used for the analysis of rocks and the atmosphere.

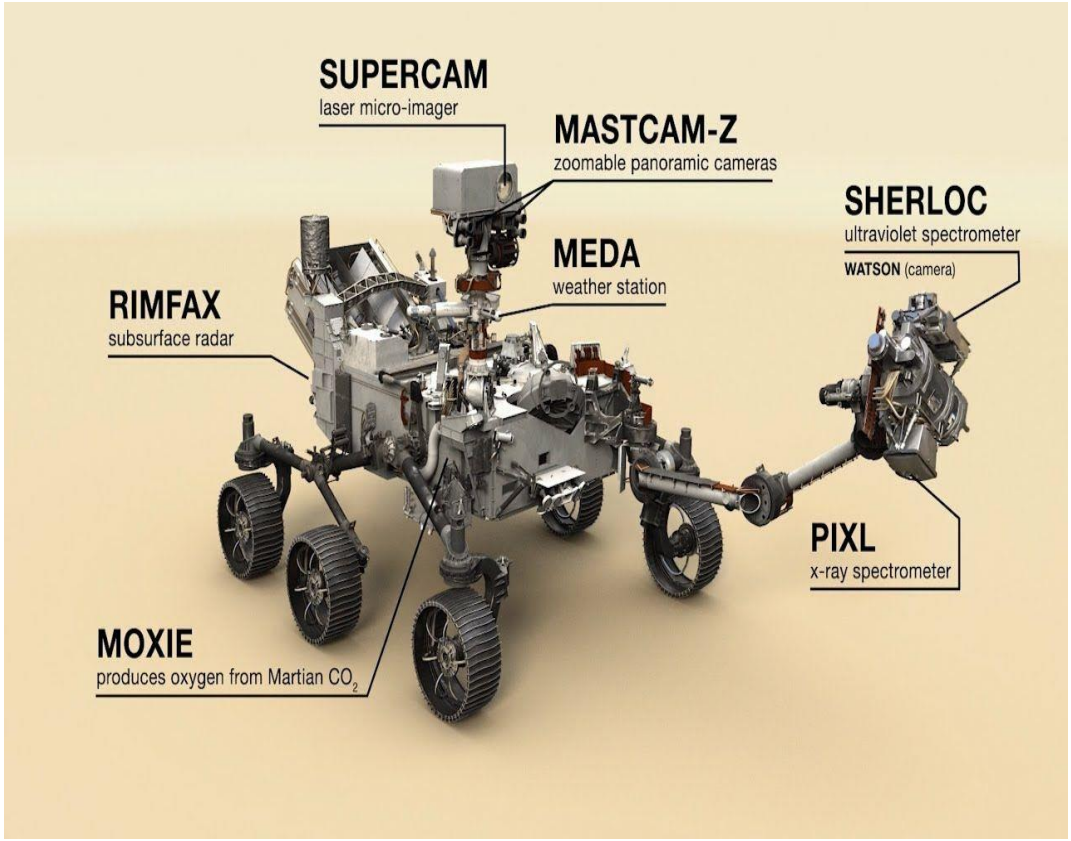
Physical Design for various applications

- Curiosity is a rover deployed to Aeolis Palus on Mars in 2012 via the Mars Science Laboratory mission.
- It is a particularly imposing machine with a mass of 899 kg .
- The main scientific goals of the MSL mission are to help determine whether Mars could ever have supported life, as well as determining the role of water, and to study the climate and geology of Mars
- Curiosity is 2.9 m long by 2.7 m wide by 2.2 m in height, including 6.8 kg of scientific instruments.
- In comparison to Pancam on the Mars Exploration Rovers, the MastCam-34 has 1.25× higher spatial resolution and the MastCam-100 has 3.67× higher spatial resolution



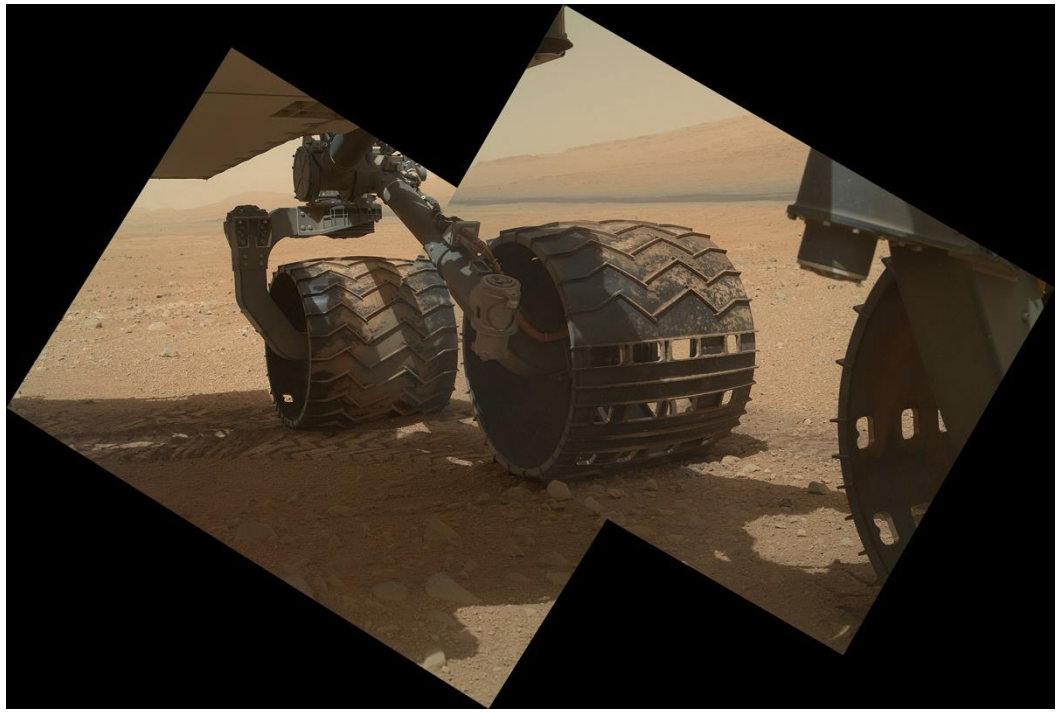
Physical Design for various applications

- Perseverance is a mobile robot designed to explore the Jezero crater which, about 3.6 billion years ago, housed a permanent lake and which retains traces of several river deltas.
- It landed on Mars on February 18, 2021
- Perseverance is a machine weighing more than a ton which has a sophisticated system for taking cores from Martian soil and a set of scientific instruments (cameras, spectrometers of various types) which are used to identify the most interesting, provide the context of the sample taken (geological characteristics, climatic conditions at the formation) and carry out a first chemical analysis
- The rover also carries a meteorological station (MEDA), a radar intended to probe the surface layers of the ground (RIMFAX).



Locomotion System & Actuators

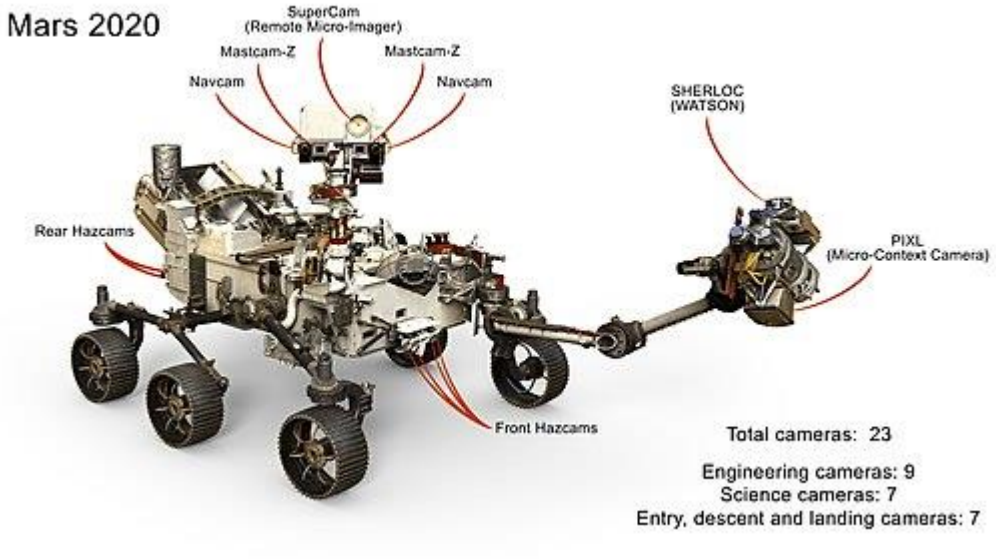
- Mars Rovers are usually equipped with wheels in a rocker-bogie suspension.
- The suspension system also served as landing gear for the vehicle
- Each wheel has cleats and is independently actuated and geared, providing for climbing in soft sand and scrambling over rocks.
- Each front and rear wheel can be independently steered, allowing the vehicle to turn in place as well as execute arcing turns.
- Each wheel has a pattern that helps it maintain traction but also leaves patterned tracks in the sandy surface of Mars. That pattern is used by on-board cameras to estimate the distance traveled.



The Mars Curiosity Rover Wheels and Legs

Navigation System (Sensors) & Control

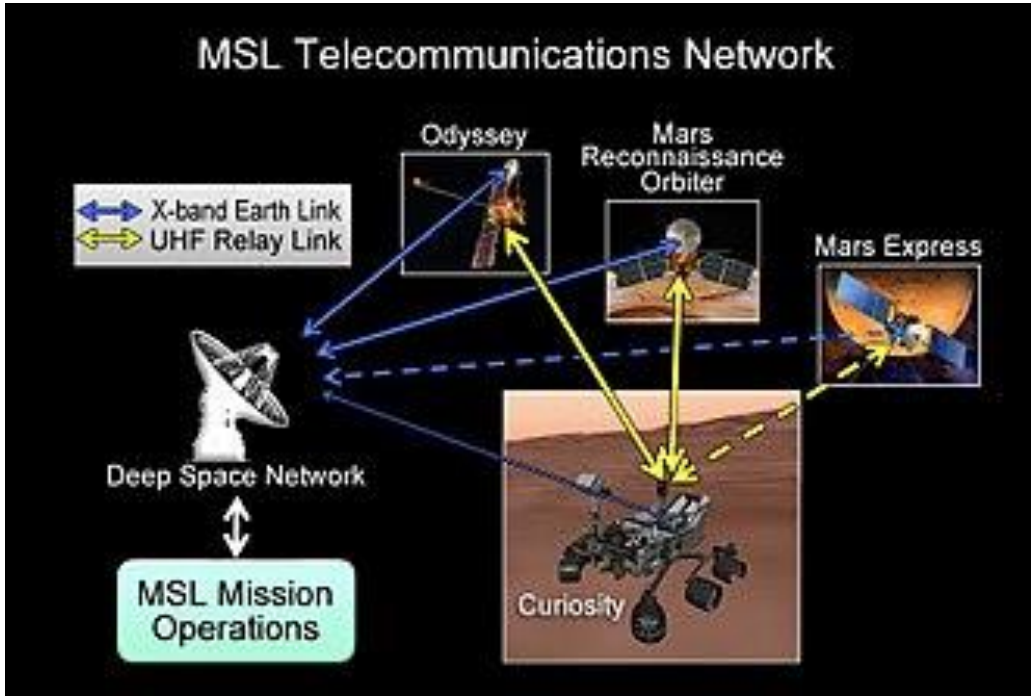
- The curiosity rover has two pairs of black and white navigation cameras mounted on the mast to support ground navigation. The cameras have a 45° angle of view and use visible light to capture stereoscopic 3-D imagery.
- The MastCam system provides multiple spectra and true-color imaging with two cameras.
- The two identical on-board rover computers, called Rover Compute Element (RCE) contain radiation hardened memory to tolerate the extreme radiation from space and to safeguard against power-off cycles. The computers run the VxWorks real-time operating system (RTOS)
- Curiosity RCE computers use the RAD750 Central processing unit (CPU), which is a successor to the RAD6000 CPU of the Mars Exploration Rovers.
- The rover has an inertial measurement unit (IMU) that provides 3-axis information on its position, which is used in rover navigation. The rover's computers are constantly self-monitoring to keep the rover operational, such as by regulating the rover's temperature. Activities such as taking pictures, driving, and operating the instruments are performed in a command sequence that is sent from the flight team to the rover.



Cameras on the Perseverance Rover

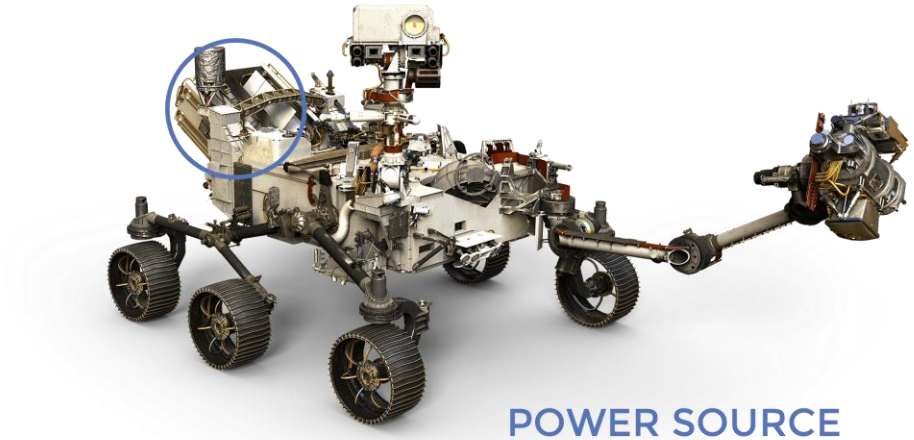
Data Collection and Transmission

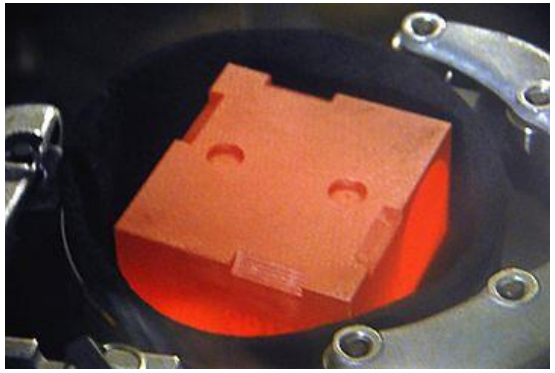
- Curiosity is equipped with significant telecommunication redundancy by several means: an X band transmitter and receiver that can communicate directly with Earth, and an Ultra high frequency (UHF) Electra-Lite software-defined radio for communicating with Mars orbiters
- Telecommunication included a small deep space transponder on the descent stage and a solid-state power amplifier on the rover for X-band.
- The rover also has two UHF radios, the signals of which orbiting relay satellites are capable of relaying back to Earth. Signals between Earth and Mars take an average of 14 minutes, 6 seconds.
- Jet Propulsion Laboratory (JPL) is the central data distribution hub where selected data products are provided to remote science operations sites as needed.
- At landing, telemetry was monitored by three orbiters, depending on their dynamic location: the 2001 Mars Odyssey, Mars Reconnaissance Orbiter and ESA's Mars Express satellite.



Power Management

- Sojourner has solar panels and a non-rechargeable battery, which allowed limited nocturnal operations. Once the batteries were depleted, it could only operate during the day. The batteries are lithium-thionyl chloride (LiSOCl2) and could provide 150 watt-hours. The batteries also allowed the health of the rover to be checked while enclosed in the cruise stage while en route to Mars.
- Spirit functioned until it got stuck in 2009 and ceased communications in 2010, while Opportunity was able to stay operational for 5111 sols after landing, maintaining its power and key systems through continual recharging of its batteries using solar power
- Curiosity and Perseverance are powered by a radioisotope thermoelectric generator (RTG) (generators that produce electricity from the decay of radioactive isotopes). Heat given off by the decay of this isotope is converted into electric voltage by thermocouples, providing constant power during all seasons and through the day and night.
- The electrical output from the MMRTG charges two rechargeable lithium-ion batteries. This enables the power subsystem to meet peak power demands of rover activities when the demand temporarily exceeds the generator's steady output level. Each battery has a capacity of about 42 ampere hours.





Radioisotope pellet within a graphite shell that fuels the generator