AMD XILINX

CASE STUDY

NASA Rover Exploring Mars Using Adaptive Computing Technology from Xilinx

Perseverance Rover Uses FPGA-Based Hardware Acceleration from Xilinx for Image Processing and Navigation

AT A GLANCE:

The National Aeronautics and Space Administration (NASA) is the U.S. agency dedicated to space exploration. The organization operates 20 centers across the country which study the Earth, sun, and other planets in the solar system. It also works with partners from business and academia to conduct aeronautics-related research.

Industry: Aerospace & Defense
Head Office: Washington, D.C., USA
Established: 1958
Website: http://www.nasa.gov

Figure 1. Illustration of Perseverance Mars Rover
(Source: NASA/JPL-Caltech)

SUMMARY:

On February 18, 2021, the NASA Mars rover, Perseverance, made landfall on the surface of Mars, capping a near seven-month journey through space. Managed by the agency's Jet Propulsion Laboratory in California, the rover's mission is to seek out signs that the planet once supported life.

Aboard the rover are several instruments that are collecting and examining soil and rock samples. Many of these instruments, and the systems that help to navigate the unit, are powered by Xilinx FPGAs.

CHALLENGE:

Identifying chemical elements the size of a grain of salt is not an easy task, especially when the research robot being controlled is at least 35 million miles away. Yet, that is the challenge for scientists at NASA's Jet Propulsion Laboratory (JPL), the U.S. space agency that recently landed its fifth rover, Perseverance, on Mars. Armed with multiple test and measurement instruments and a small helicopter, Perseverance is studying the planet's Jezero Crater on a mission to find evidence that life once existed there.

Getting working research equipment safety delivered to Mars was a huge undertaking by itself. But keeping it operational and collecting valuable data samples for the duration of a multi-year mission amidst extreme temperatures and harsh atmospheric radiation is also daunting task for the JPL team.

SOLUTION:

A Xilinx radiation-hardened Virtex 5 (SIRF) FPGA brings computer vision and AI to a space exploration rover for the first time. The FPGA accelerates certain tasks, including image detection, matching, and rectification. It also analyzes and filters out useless data that it has captured before sending it to Earth.

One of many research instruments aboard the Perseverance rover is named PIXL (Planetary Instrument for X-ray Lithochemistry). This tool, powered by a Xilinx radiation-tolerant Virtex 4 FPGA, features an x-ray spectrometer and high-res imager to help identify chemicals in the Martian landscape.

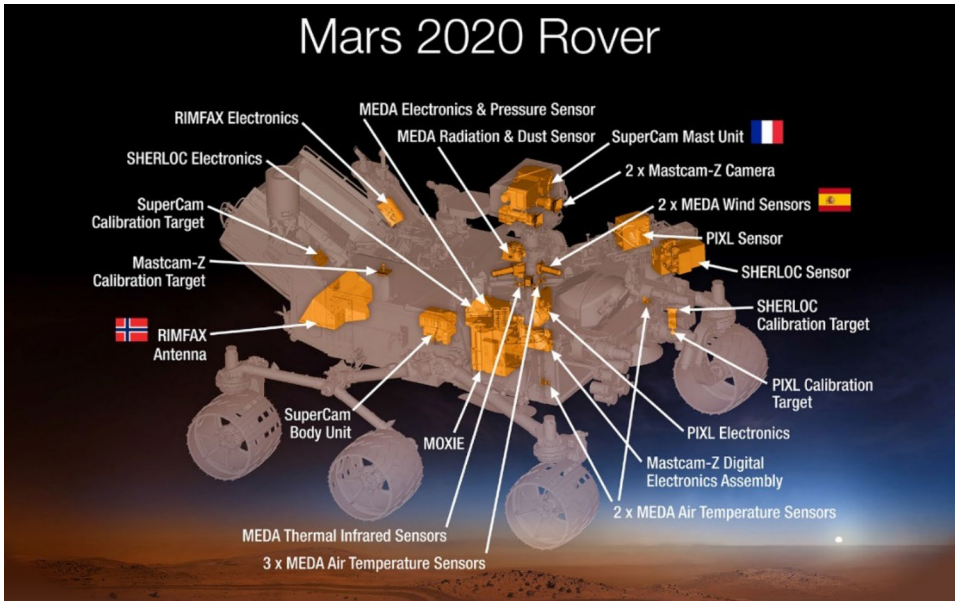


Figure 2. Xilinx Virtex FPGAs power many systems on the Mars Perseverance rover.
(Source: NASA/JPL-Caltech)

Xilinx Virtex II FPGAs are also used in Mastcam-Z, a 3D imaging system that captures detailed images and video of distant objects at high speed; Electra-lite, a UHF transceiver; and SHERLOC, an instrument used to detect minerals and organic molecules.

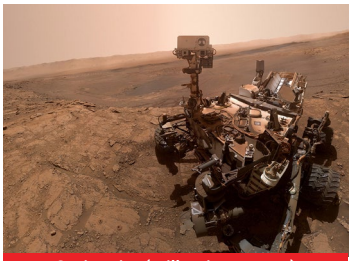
Additionally, Virtex II was instrumental in a radar-based sensor that provided range and velocity measurements to guide Perseverance to a safe landing on Mars.

All the Virtex FPGAs used on Perseverance are either radiation-tolerant or radiation-hardened by design.

Xilinx FPGAs have been part of satellites and space exploration for more than 20 years and have been an integral part of NASA's Mars rover missions, including Spirit, Opportunity, and Curiosity.

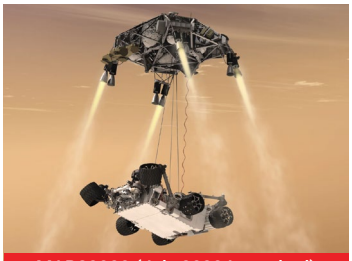
Spirit & Opportunity (now retired)

Lander: XQVR4000XL – Control Pyrotechnics that control various stages of maneuver for landing
Rover: XQVR1000 – Motor Control Board (wheels, steering, arms, cameras)



Curiousity (still going strong)

Instruments:
MAHLI (Imager – XQR2V3000), ChemCam (Remote sensing instruments – XQ2V1000), Electra-Lite (Communications – XQR2V3000) and MALIN (Processor – XQR2V3000)



MARS2020 (July 2020 Launched)

Hardware Accelerator (Vision Compute Element):
XQR5VFX130 used to accelerate certain stereo and visual tasks like image rectification, filtering, detection and matching

Figure 3. From Spirit to Perseverance, Xilinx FPGAs have been part of NASA rover missions.
(Source: NASA/JPL-Caltech)

RESULT:

The Mars Perseverance rover is already starting to send data back to Earth, with early tests showing that the chemical composition of some rocks are similar to igneous rocks on Earth. The mission is scheduled to collect Martian soil and rock samples that could be delivered to Earth within 10 years and is planning to include the first flight of a helicopter outside the Earth's atmosphere.

For future missions, Xilinx recently introduced an industry-first space-grade 20nm FPGA solution, named Kintex® UltraScale™. The radiation-tolerant device features true, unlimited on-orbit reconfiguration, and a 10X DSP compute increase for processing intensive algorithms that will allow high-performance edge inference in space.

ADDITIONAL RESOURCES: Learn More about the Perseverance Mission
Learn More About Xilinx's space-grade FPGAs

Corporate Headquarters
Xilinx, Inc.
2100 Logic Drive
San Jose, CA 95124
USA
Tel: 408-559-7778
www.xilinx.com

Xilinx Europe
One Logic Drive
Citywest Business Campus
Saggart, County Dublin
Ireland
Tel: +353-1-464-0311
www.xilinx.com

Japan
Xilinx K.K.
Art Village Osaki Central Tower 4F
1-2-2 Osaki, Shinagawa-ku
Tokyo 141-0032 Japan
Tel: +81-3-6744-7777
japan.xilinx.com

Asia Pacific Pte. Ltd.
Xilinx, Asia Pacific
5 Changi Business Park
Singapore 486040
Tel: +65-6407-3000
www.xilinx.com

India
Meenakshi Tech Park
Block A, B, C, 8th & 13th floors,
Meenakshi Tech Park, Survey No. 39
Gachibowli(V), Seri Lingampally (M),
Hyderabad -500 084
Tel: +91-40-6721-4747
www.xilinx.com