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NASA's Mars Rover Curiosity Powered by Wind River

Could Mars Have Ever Hosted Life? Robot Explorer Seeks Answer

On August 6, 2012, NASA made an enormous advancement in space exploration when it landed the Mars Science Laboratory rover Curiosity in the Gale Crater on Mars. Curiosity is the most technologically advanced autonomous robotic spacecraft and geologist set ever to be deployed by any space venture. It's on a groundbreaking mission to determine whether Mars is or has ever been capable of supporting life and to assess its habitability for future human missions.

The VxWorks® real-time operating system (RTOS) plays a central role in this historic mission. VxWorks provides the core operating system of the spacecraft control system — from the second the rocket left Earth on November 26, 2011, until the end of the mission. NASA's Jet Propulsion Laboratory (JPL), the lead U.S. center for robotic exploration of the solar system, has used VxWorks as the mission-critical OS brain for more than two decades. The total cost of the Curiosity project is approximately $2.5 billion and represents eight years of passion and work, so the stakes are high, and a fail-proof, resilient RTOS was a core requirement.

Curiosity is much larger than other rovers — approximately the size of a Mini Cooper automobile. It carries 10 times more scientific instruments than the previous Mars Exploration rovers, Spirit and Opportunity. Curiosity is more durable and explores a larger area than previous rovers. It's expected to cover 12 miles or more during its planned two-year mission.

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> *— Mike Deliman, Senior Member of Technical Staff, Wind River*

NASA

Industry
Space exploration

Solutions
- VxWorks
- Wind River Workbench
- Wind River Professional Services

Results
- Developed and tested the most technologically advanced autonomous robotic spacecraft ever launched
- Directed complicated, risky maneuvers necessary for the mission's success, including a historically challenging landing on Mars
- Compressed development cycles by reducing the need for training and reusing existing code libraries from previous missions
- Lowered testing and qualification costs by reducing the complexity of test systems

THE CHALLENGE

The long journey to Mars through the harsh environment of space presented the Curiosity navigation team with an extensive list of challenges to get the craft safely to its destination. Now that it has landed, the craft must run various science packages to gather and process samples and photographs from the environment and transmit the data back to Earth.

To date, the most impressive accomplishment was completing a more precise, complex landing than any previous mission — within a 12.4-mile radius. The landing sequences, called "EDL" for "entry, descent, and landing," presented the most action-packed operations aside from the initial launch.

Because Curiosity is the biggest, most capable Mars rover yet, it required a new type of landing to reach the ground safely. In the EDL, referred to as the "seven minutes of terror," the craft had to slow down from more than 13,000 miles an hour to zero. It had to hit the atmosphere at precisely the right angle, endure extreme heat, open and detach from its parachute, fire rocket engines to slow the descent, drop down on four cables, lock its wheels in place, and cut the cables at touchdown.

"Wind River's VxWorks helped manage the terror in the seven minutes of EDL, making this incredible feat possible," explains Mike Deliman, senior member of the technical staff at Wind River®. "The role VxWorks plays during the landing process is similar to the role it plays in the autonomous devices we use every day without knowing it's there."

Another hair-raising challenge before EDL was performing trajectory correction maneuvers. This is the precise science of adjusting the craft so it lands in the correct location. Again, VxWorks was at the helm.

"VxWorks directs the Deep Space Network's giant antennae that capture radio signals from the craft and help determine its current location and trajectory," Deliman says. "Prior to the landing, engineers used this data to adjust the craft's course so it would land on target."

These are only a few examples of the many critical operations Curiosity must perform to successfully complete its mission. One of the largest challenges is that given the extremely cost- and time-intensive process of putting a spacecraft such as Curiosity on the surface of Mars, there's no tolerance for failure.

THE SOLUTION

With a long record of success with VxWorks on more than 20 missions, NASA JPL decided to deploy VxWorks once again when it began its work on Curiosity. The engineering team used Wind River Workbench for development and debugging.

Early in the project, JPL also turned to Wind River Professional Services for accelerating the integration of VxWorks and optimizing the use of VxWorks in critical areas. Now that Curiosity is out of the lab and onto the surface of Mars, VxWorks, running on BAE Systems' radiation-hardened RAD750 processor, continues to play a critical role. It performs complex, mission-critical tasks, such as trajectory, descent and ground operations control, data collection, and Mars-to-Earth communication relay.

The key functionalities of Curiosity can be divided into two categories. First, there are avionics functions, or everything necessary to keep the craft in flight and on course — such as the rockets and the motors that run the wheels. Second, there are science packages, responsible for gathering and processing environmental and photographic samples using tools such as spectrometers, drills, and cameras.

"Wind River's VxWorks is the software platform that controls the execution of all of Curiosity's functions — from managing avionics to collecting science data and sending the experimental results back to JPL on Earth using satellite telemetry," Deliman says. "To use the human body as an analogy to this rover, VxWorks is the core operating system for the brain, the avionics are the body, and the science packages are the eyes, ears, nose, and taste buds."

THE RESULT

The most significant results to date are the successful launch and landing of Curiosity, the world's technologically advanced autonomous robotic spacecraft. At each challenge, VxWorks has risen to perform its duties as the brains of the craft's operations.

NASA JPL's familiarity with Wind River products compressed development cycles by reducing the need for training and enabling the reuse of well-tested existing code libraries. VxWorks provides a stable programming interface and compatibility with standards such as POSIX, which reduced JPL's need to extend and maintain OS integration layers. This reduced the complexity of test systems, which translates into savings.
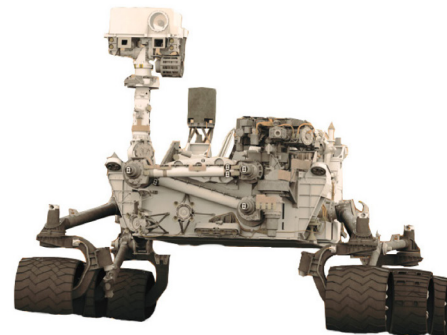
Prior to using commercial off-the-shelf (COTS) solutions for hardware and software, each robotic mission required custom hardware to be created along with custom programming tools. This reduced the ability to reuse anything from previous missions and reduced the effectiveness of applying "lessons learned" to new missions.

FUTURE PLANS

For more than 20 years, Wind River has provided reliable technology to NASA JPL for space exploration in the Mars Exploration Rover program and the Stardust Project, among other missions. Wind River technology has successfully powered countless space exploration products.

"The successful landing of Curiosity was an incredible feat," Deliman says. "It means we can make highly accurate deliveries to Mars or other planets or moons and perhaps some day even deliver supplies to Mars."

"Wind River is proud of NASA JPL for its incredible achievements over the past two decades of exploring our solar system," he adds. "We feel extremely fortunate to have worked with such excellent and passionate engineering teams who constantly enlighten the way we think about our world and our universe. We look forward to continuing to help NASA make fantastic missions possible."

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