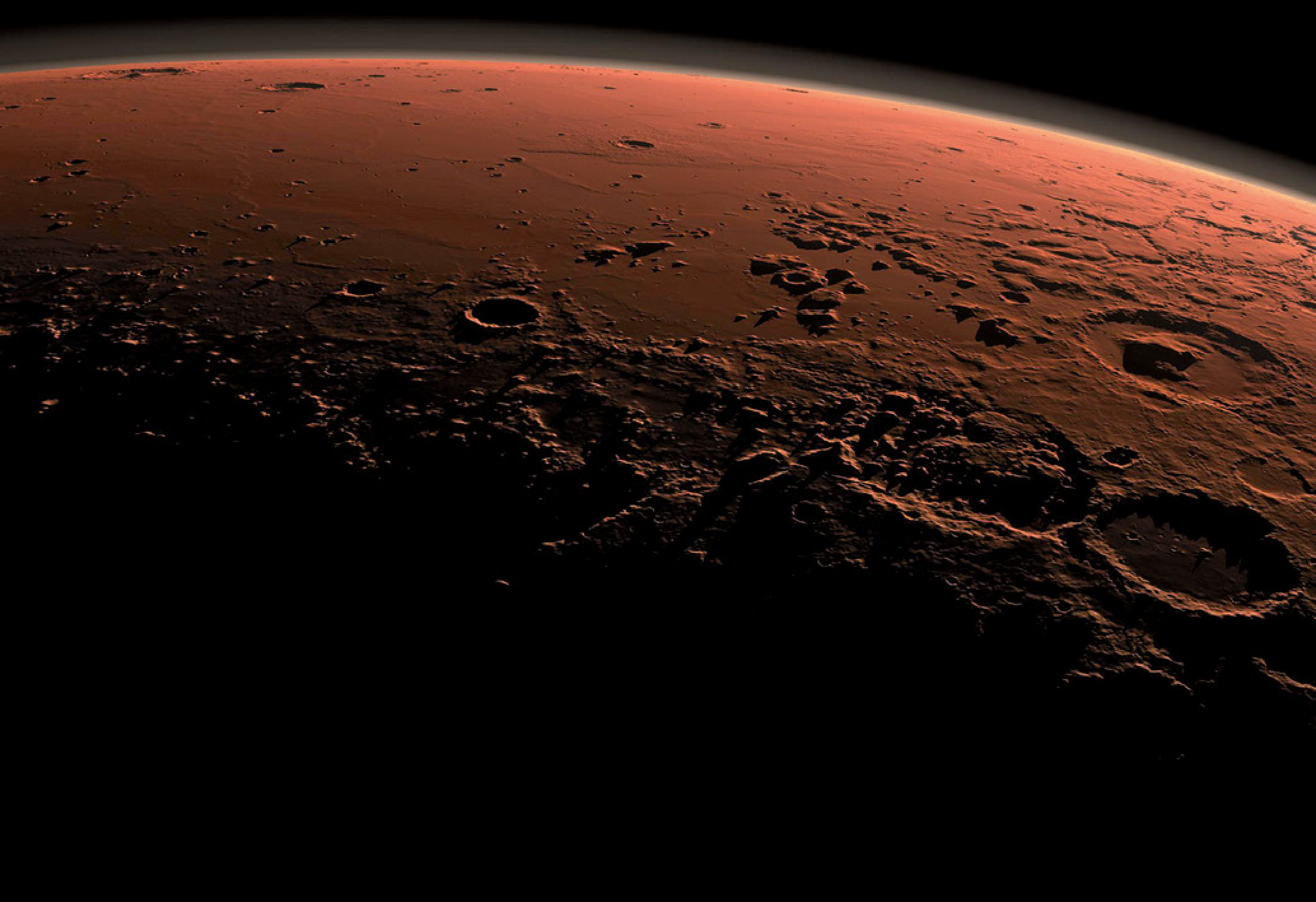

Research and development vehicle with redundant EtherCAT communication

NASA develops Modular Robot Vehicle

The Modular Robot Vehicle developed by NASA looks like a "roadster" at first glance, but can be more accurately defined as a robot. Having individual control of each steering and drive unit enables the MRV to travel in some very unorthodox modes.

"You should definitely buckle your seatbelt" was the advice from Mason Markee, one of the Mechanical Engineers from the NASA R&D team and driver for our test ride in the MRV (Modular Robotic Vehicle) developed by the space agency. The MRV is advancing NASA research on future vehicles that will be used on Earth and in space. We visited the Johnson Space Center in Houston to see the MRV and took turns riding in the passenger seat. The 2-seat, 4-wheeled vehicle looks like a "roadster" at first glance, but can be more accurately defined as a robot.

Each wheel and steering assembly of the MRV is referred to as an "e-corner" (to use NASA robot lingo) and each device in the e-corner is called a "joint". The controls for each wheel's propulsion, braking, and steering are controlled through a triple-redundant EtherCAT network. Having individual control of each steering and drive unit enables the MRV to travel in some very unorthodox modes, much like some of the NASA R&D team's other robotic vehicles.

"MRV is a research and development platform for our mobility robotics program. Future applications include a potential lunar or Martian exploration vehicle. In particular, the focus of this R&D is on safety, reliability, maneuverability, and human interfacing. The previous iteration of this vehicle, which ultimately led to the development of the MRV, was referred to as the Surface Exploration Vehicle (SEV)," explains Ryan Reed, NASA Engineer and host of our visit to Johnson Space Center. "Our goal was to design a vehicle that would have reliable, fail-safe operator control. The MRV is intended to seat up to two passengers in high speed travel, making safety a primary concern."

From afar, the MRV looks very much like a small open cart or roadster – albeit a high tech one with digital dash display, gold anodized parts, and even a place for your smartphone. It can drive in traditional modes, such as "two-wheel steering" and "four-wheel steering", both currently used by commercial vehicles. However, once Mason Markee of NASA pulled out of the driveway and onto the road in front of the building where the vehicles are stored, he shifted into "omnidirectional mode", (see figure 1) bringing sensations that can only be described as if you are sliding on ice. The direction the front of the vehicle is pointing has no correlation to where the vehicle is going. Control is deceptively simple, needing only the steering wheel and a joystick on the center console. The MRV is also capable of a "zero radius turn", similar to a high-end riding lawnmower. Mason was able to switch from one mode to another effortlessly and elegantly while going at around 15 mph, dodging into and out of parking areas, avoiding medians, and generally doing his best to impress his passenger. The drivers in traffic on the road near Johnson Space Center seemed accustomed to the strange sight of a car sliding in unusual patterns on the roadway.

"We had some experience with CAN, MIL-STD-1553, Ethernet, and LVDS controlling other robots. However, we wanted a network that would allow us to continue operating the robot with at least one failure, and the ability to transport enough data to maintain control of the vehicle at high speeds," said Reed. "After one of our teammates listened to an EtherCAT presentation at an ETG seminar we decided to try it based on the technical specifications. We set up a test bed and were quickly able to meet our requirements. The outcome was the MRV."

When asked which properties of EtherCAT were of most interest to the R&D group, Reed replied that "the high bandwidth provided proved a major benefit, and the cable redundancy feature was one the most intriguing characteristics for us. In testing this feature, we maintained control of the joints from our master computer after disconnecting a single connection. Using all commercial off-the-shelf (COTS) components on the master computer made setup easy." Reed continued, "Finally, radiation immunity of the ASIC was yet another interesting characteristic. While the MRV is strictly a terrestrial vehicle, we had the opportunity to test the ASICs after some other parts had completed their radiation testing. The ASICs did exceptionally well, and we are considering it for possible use on a future project."

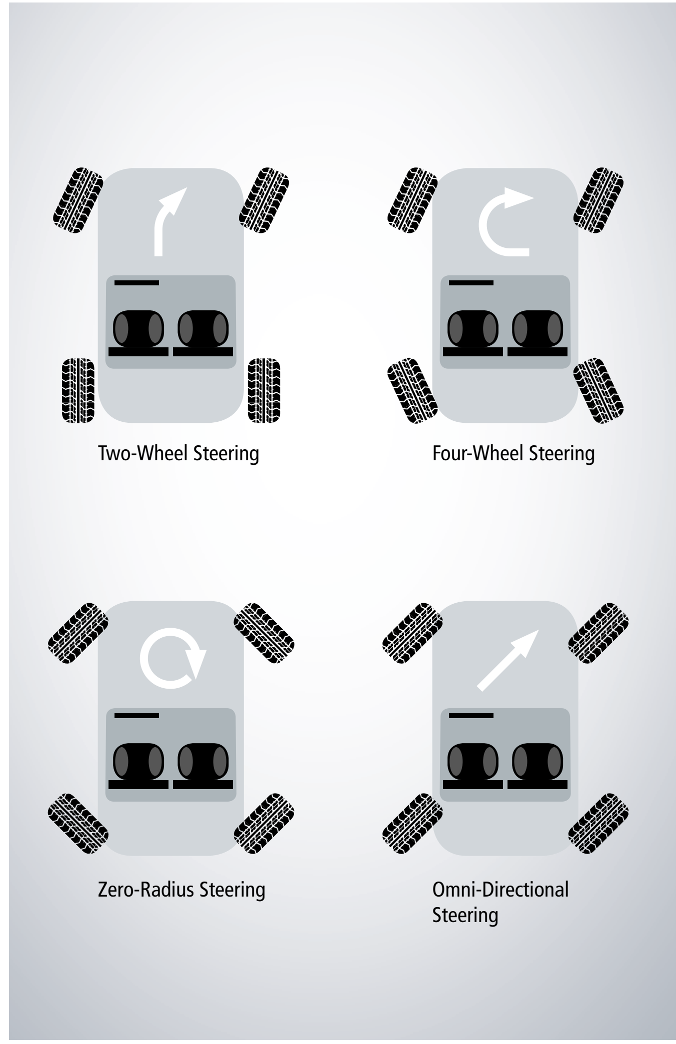

Figure 1: The MRV can drive in traditional modes, such as "two-wheel steering" and "four-wheel steering", but it can also be switched to "omnidirectional mode".

The redundancy scheme implemented in the MRV goes beyond what is typically used for cable redundancy in EtherCAT systems, however. Each of the joint's slaves has dual EtherCAT Slave Controller chips (Beckhoff ET1100 ASICs) (see figure 2). Each of the EtherCAT slave chips are connected to one of two completely independent EtherCAT networks from two separate masters with shared memory between them, which each utilize the cable redundancy feature. So each device has dual ESCs connected to two separate redundant cable networks and to two separate master controllers. When asked if the MRV project is a success, Reed stated, "Absolutely! With this being an R&D project, the work is never complete. However, the MRV has been functional for a few years now, and our drivers feel safe operating the vehicle. It has been a great R&D project for us to practice implementing safe, redundant and reliable robots. In fact, some of the other NASA project teams were impressed with our implementation and have adopted it in their systems."

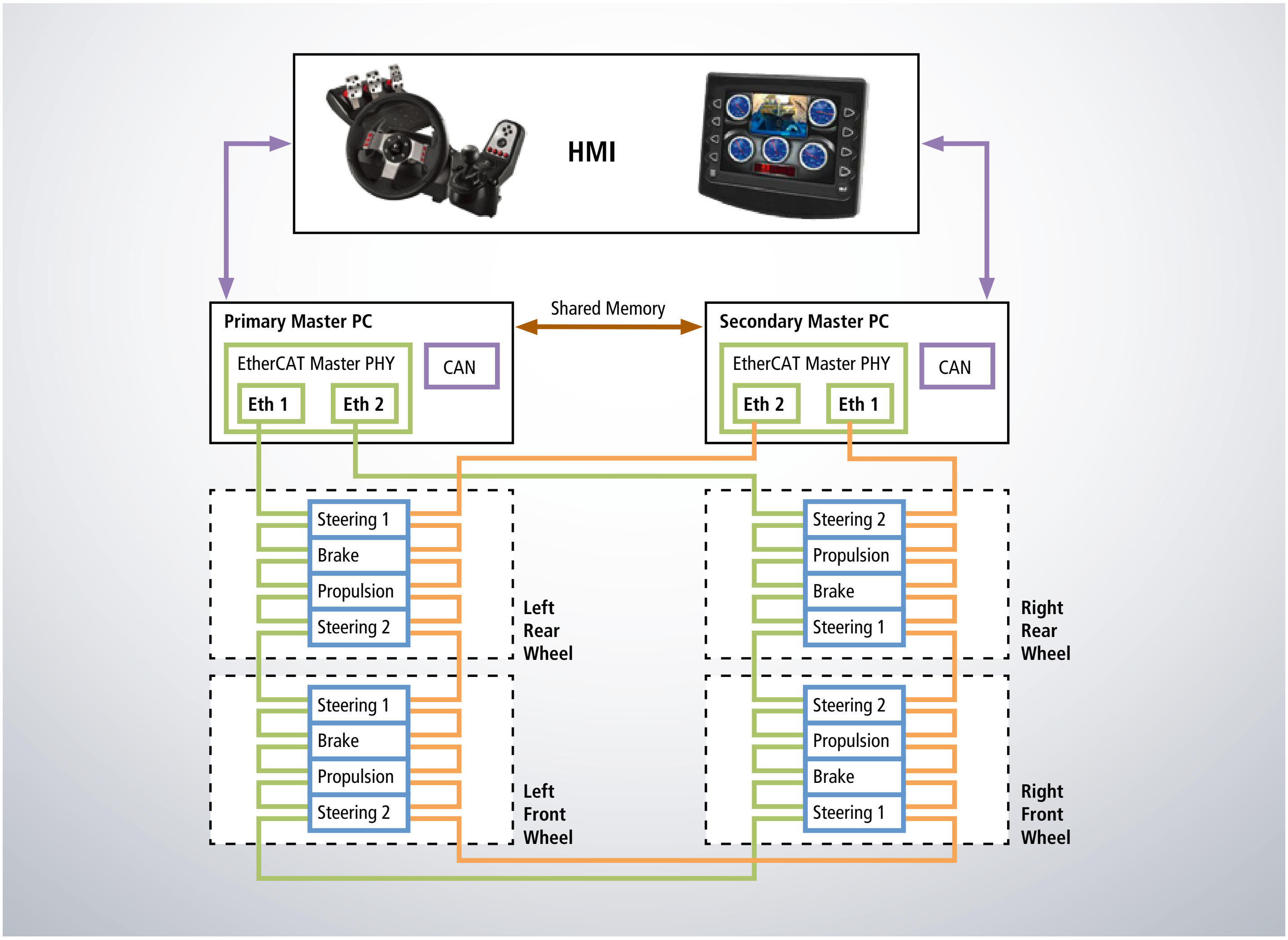

Figure 2: The controls of the MRV for each wheel's propulsion, braking, and steering are controlled through a triple-redundant EtherCAT network.

Case in point, the ARGOS (Active Response Gravity Offload Simulator), which simulates the reduced gravity of lunar or Martian environments is already using EtherCAT, and the Wearable Robotics team is exploring EtherCAT as a networking solution for human exoskeleton robotics. So wherever advanced equipment and devices happen to be in the solar system, EtherCAT keeps the data moving.

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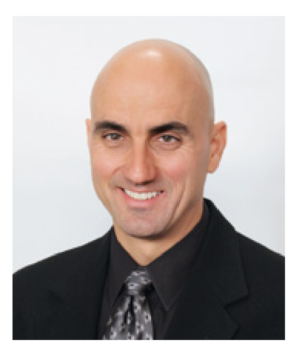

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