RTI CUSTOMER SNAPSHOT

European Space Agency

HUMAN ROBOT INTERACTION LABORATORY

"We've been using RTI products for almost a decade. When we first started experimenting with manipulating a ground robot from the international space station, we quickly realized that pairing our haptic technology with DDS was the way to go to ensure reliable communications. Only DDS can give us the ultra-low latency and rapid data throughput that we need, so that our astronauts can interact with our ground robots across vast and unimaginable distances."

Dr. Thomas Krueger
Human Robot Interaction Laboratory, ESA

HIGHLIGHTS

- ESA uses Connext DDS for communication and video to demonstrate long-distance object control from aboard the International Space Station (ISS)
- RTI Connext DDS enabled developers to manage complex communications from ISS to the earthbound exploration robot, as part of ESA's Analog-1 project
- Using DDS enabled ESA to get active feedback from the robotic arm, while operating the gripper via remote control to work with the precision and dexterity of a human hand

ABOUT EUROPEAN SPACE AGENCY

The European Space Agency (ESA) is a leader in telerobotic development, which the agency considers vital for advancing space exploration. Hidden away in the picturesque, seaside town of Noordwijk in the Netherlands, ESA's Human Robot Interaction Laboratory develops pioneering haptic solutions using remotely controlled semi-autonomous robots. These robots offer opportunities for interactive discovery and research in places where it's impossible or impractical to send astronauts.

A telerobotic device provides visual and sensory data back to the person operating it and responds to the human controller's movements, which are communicated wirelessly. However, there are a number of significant challenges to building and deploying telerobotic systems for extraterrestrial missions – including system design, systems integration and long-distance communication. To help solve these challenges, ESA turned to RTI.

CHALLENGE

There are many environments that are too dangerous for people – and a faraway planet is at the top of that list. That's where robots come in. There are clear advantages to deploying robots to collect geological specimens under harsh conditions of zero gravity, subzero temperatures and zero oxygen. But to do it right, the robot needs to be part of a haptic control loop, which means that the astronaut interacts with the robot to not just guide it, but also experience the tactile sensations – through a joystick or data gloves – of everything the robot touches. Consequently, this system needs a low-latency control loop in order to perform accurate object manipulation. At the same time, this control loop generates a high volume of video and real-time telemetry data.

For everything to work as intended, communications must be near real-time and deterministic. For example, it's critical that telerobotics systems continue to operate effectively, even at times when the consistent performance of the communication link itself is not assured. A big challenge is that the communication link to the ISS is restricted to a predefined number of port and protocol combinations,

Figure 1. Astronaut Luca Parmitano controls the ground robot from aboard the ISS.

which is further complicated by the fact that the wireless IP addresses tend to switch constantly due to dynamic network changes. Another specific limitation is maximum bandwidth speed to the ISS, capped at four megabits per second, which nevertheless needs to accommodate two video streams, plus all the haptic and telemetry data. While the idea of a traffic jam in deep space may appear mildly ironic, it presents a serious challenge for telerobotic operation. Thanks to the Data Distribution Service™ (DDS) data connectivity standard, a solution was on the horizon.

SOLUTION

According to ESA, the decision to use RTI Connext DDS for the Analog-1 test project was an easy one. ESA had already used Connext DDS to build major parts of its Human Robot Interaction Lab infrastructure, which provided a strong foundation for the agency's initial telerobotics experiments back in 2014. Flashing forward, the Analog-1 test project of 2019 sought to better leverage the wealth of data generated by a ground robot. The project had multiple technical goals, chief among which was achieving the split-second latency needed for the communication link, so that the astronaut and the robot could truly work as one.

The agency created a real-time control loop between the space station and the robot using Connext DDS as the communication layer. This kind of communication requires a DIL (Disconnected, Intermittent or Lossy) communication link, which is characterized by extreme message latency and jitter. In this environment, the status needs to be continuously assessed and fed back into the control loop. In fact, when transmitting highly distributed communication (including augmented reality video) over challenging datalinks, the link status is an active part of the control algorithm. And for that, you need DDS technology. But not just any DDS technology, as Dr. Thomas Krueger of the Human Robot Interaction Laboratory points out.

"There is an open source version of DDS out there. But I prefer using Connext DDS, because it gives you a really good package of tools – especially a tool like Routing Service, which lets us filter and distribute data based on different Topics. This wound up working really well for us." Krueger says. "Thanks to the Connext DDS tools, we were able to build precisely what we needed."

Transmitting compressed video is now easier as well, as ESA is able to use the User Datagram Protocol (UDP) for keeping huge amounts of data in motion over unpredictable communication links. UDP is a far more reliable approach, because it runs in the transport layer on DDS and doesn't consume network resources. By contrast, this option is preferable to using a protocol like RTP, which lives at the application layer and can therefore impact application performance. ESA was further able to achieve DDS integration into Qt QML, which is the basis of ESA's user interface. Because a lot of components are simply C++ interfaces between QML and DDS, ESA's Human Robotic Interaction Laboratory now has the flexibility to extend these interfaces. In looking to the future, components can be quickly re-architected into subsequent projects and demos.

RESULTS

ESA's Analog-1 project was successfully concluded in November of 2019 with a two-hour space-to-ground test, during which ESA astronaut Luca Parmitano was able to use 'force-feedback' controls to operate a semi-autonomous exploration robot from aboard the ISS. And RTI Connext DDS was a crucial part of the effort, enabling ESA's developers to manage complex communications from ISS to the earthbound exploration robot in near real-time – a remarkable achievement, given the distance involved and the fact the control link was anything but direct.

Figure 2. The ESA ground robot collecting rock samples, controlled from space.

To illustrate this point, consider that communication needed to happen over a distance of approximately 160,000 kilometers and pass though the Tracking and Data Relay Satellite System (TDRSS) in geostationary orbit. From there, all communication also had to travel through equipment in White Sands, New Mexico and across transatlantic cable to reach Noordwijk and its corresponding infrastructure, resulting in a round-trip time of 850 milliseconds for all data. In any other situation, that kind of delay would tend to make direct control challenging, at best.

Despite these factors, Connext DDS enabled ESA to successfully achieve a robust and reliable communication and control link between the land-based rover and the ISS. In fact, the ability to exchange near real-time data not only enabled Luca to operate the ground robot, but also allowed him to simultaneously receive advice on a secondary communications link from a team of geological experts based at the European Astronaut Centre in Germany. The result was a successful simulation of a real-life surface exploration survey, and the integrity of the communication link was proven.

The success of the Analog-1 project resulted in two key technological benefits. First, ESA's Human Robot Interaction Laboratory was able to establish that the hardware and software it developed can reliably enable high-precision robotic control in weightless conditions. Second, the team was able to distribute data during the test across multiple operating systems using Connext DDS. The success of the initial project means that going forward, the communication portion won't impact performance, require configuration or otherwise burden the ESA network.

ABOUT RTI

Real-Time Innovations (RTI) is the largest software framework provider for smart machines and real-world systems. The company's RTI Connext® product enables intelligent architecture by sharing information in real time, making large applications work together as one.

With over 1,500 deployments, RTI software runs the largest power plants in North America, connects perception to control in vehicles, coordinates combat management on US Navy ships, drives a new generation of medical robotics, controls hyperloop and flying cars, and provides 24/7 medical intelligence for hospital patients and emergency victims.

RTI is the best in the world at connecting intelligent, distributed systems. These systems improve medical care, make our roads safer, improve energy use, and protect our freedom.

RTI is the leading vendor of products compliant with the Object Management Group® (OMG) Data Distribution Service™ (DDS) standard. RTI is privately held and headquartered in Sunnyvale, California with regional headquarters in Spain and Singapore.

Download a free 30-day trial of the latest, fully-functional Connext DDS software today: https://www.rti.com/downloads.

CORPORATE HEADQUARTERS
232 E. Java Drive, Sunnyvale, CA 94089
Telephone: +1 (408) 990-7400
Fax: +1 (408) 990-7402
info@rti.com

rti.com
rti_software
rtisoftware
company/rti
connextpodcast
rti_software