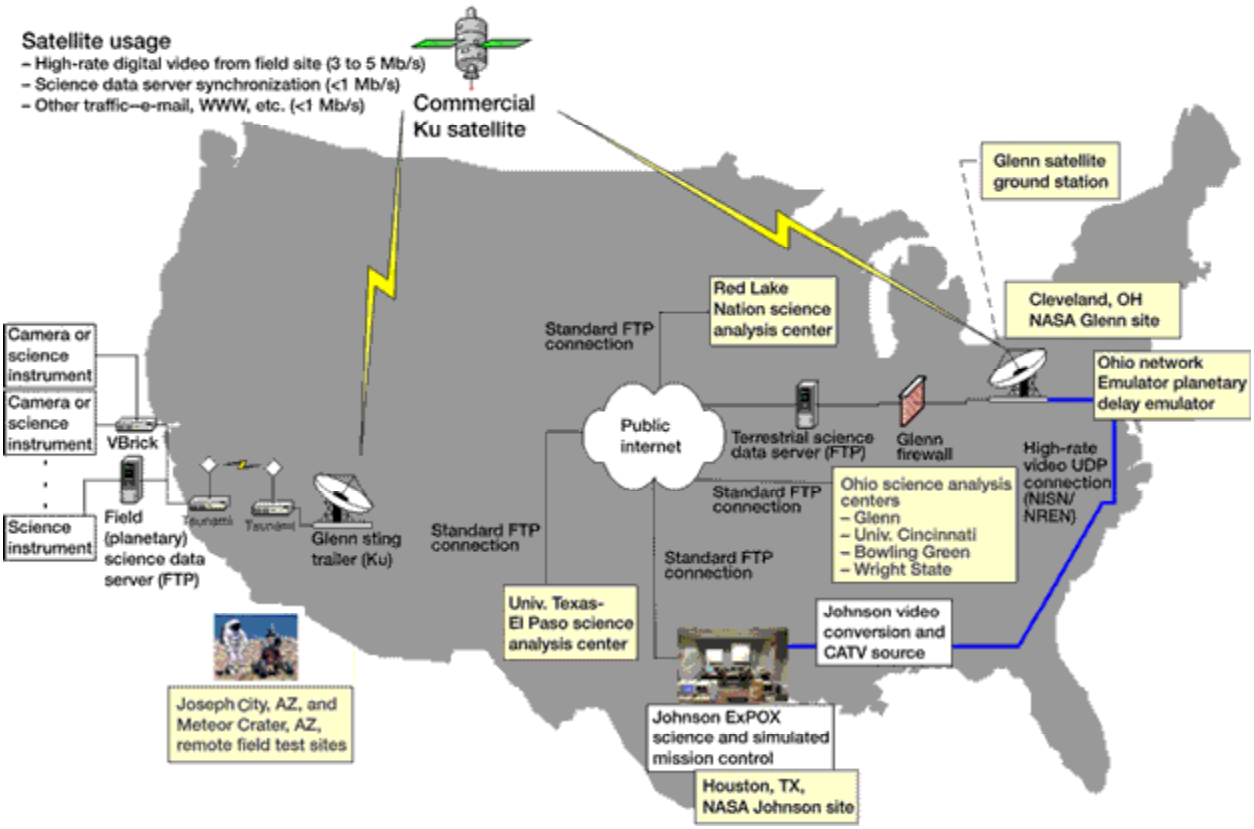
Space Networking Demonstrated for Distributed Human-Robotic Planetary Exploration

Communications and networking experts from the NASA Glenn Research Center designed and implemented an innovative communications infrastructure for a simulated human-robotic planetary mission. The mission, which was executed in the Arizona desert during the first 2 weeks of September 2002, involved a diverse team of researchers from several NASA centers and academic institutions.

NASA researchers are envisioning a human mission to the Moon or to Mars that will include both humans and robots. Humans generally ensure the overall quality of the mission, whereas robots ensure a level of accuracy in measurement that is difficult for suited explorers to attain. The interdisciplinary focus of this work is to study how robots and humans can best interact during exploration using spoken language and to obtain data for comparing human and robotic performance in gathering geological science data. Human subjects wearing an advanced ILC Mark III spacesuit worked alongside an extravehicular-activity robotic assistant rover to perform tasks representative of future exploration. Exploration tasks included geophone instrument deployment and field mapping.

Glenn provided local communications between the "astronaut," the robot, various scientific instruments, and the base camp, and also connected this remote location to mission control and the world outside the field site. The proximity network at the field site was required to handle video, voice, and data transmissions from a variety of sources using Internet protocol. In addition, an innovative suit audio system was developed to facilitate human-robot interaction. This system enabled the extra-vehicular-activity robotic assistant to understand speech commands with very high reliability from a human in a pressurized spacesuit.



Overview of September 2002 space networking architecture test and demonstration. VBrick (VBrick Systems, Inc.), commercial video compression/decompression unit; ExPOC, Johnson's Exploration, Planning and Operations Center; CATV, Johnson's closed-circuit TV network; UDP, User Datagram Protocol, an Internet protocol; NISN, NASA Integrated Services Network; NREN, NASA Research and Education Network.

Long description of figure 1 This is the space networking architecture that was tested and demonstrated by Glenn's research team. The photograph shows the use of satellite connectivity to emulate a backbone, access, and proximity network for simulating human-robotic planetary exploration. The remote field site (video, voice, and science data) were tied to Glenn via a Ku-band satellite, then from Glenn the information was shared through terrestrial networking with other NASA centers and multiple universities.

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The overall communications architecture is shown in the preceding figure. As information was received at the base camp, it was transmitted to "Earth" via a Ku-band satellite link between the Arizona desert and Glenn. For the video and voice data, a temporal delay was applied at Glenn prior to receipt at mission control in order to simulate the Mars communications delay of 5 to 20 min. The delay was emulated using the Planetary-Ohio Network Emulator (p-ONE), developed specifically for this program.

For the science data, a dual server replication architecture was implemented. In this architecture, science data were stored on a "planetary" (field science) server and synchronized with a mirroring server on "Earth." Scientists at Glenn, the NASA Johnson

Space Center, and academic institutions were able to download field science data from the "Earth" server for analysis and provide immediate feedback to the field team. The innovative architecture minimized the use of the satellite link for file transmission and ensured that the science data were returned to "Earth" prior to sharing. In future experiments, synchronization will be delayed to simulate planetary communication delay.

"The field demonstration this year simulated the most realistic interplanetary mission scenario to date, and results of the research will be incorporated into future field demonstrations and, eventually, space exploration missions. Glenn plans to build on this program in future field tests by incorporating more integrated proximity network communications and more realistic long-haul link emulations.

This successful demonstration was the culmination of research performed by several teams. The collaborators include communications experts from Glenn and the NASA Kennedy Space Center; spacesuit and control center experts from Johnson; robotics experts from Johnson and the NASA Ames Research Center; planetary exploration experts from Johnson, the Science Applications International Corporation, the University of Houston, and Bowling Green State University; and geology experts from the University of Texas-El Paso, the University of Cincinnati, Bowling Green, Wright State University, Stanford University, Red Lake Nation tribal college, and the U.S. Geological Survey at Flagstaff. All teams are represented in the following photograph.

2002 Human-Robotic Exploration Field Team.

Find out more about the research of Glenn's Digital Communications Technology Branch http://ctd.grc.nasa.gov/5650/5650.html.

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