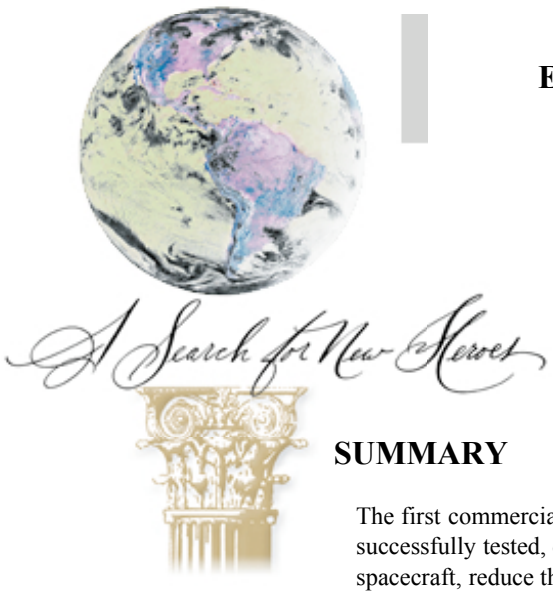

Robert Carrigan,
Chairmen of the Chairmen's Committee

Ron Milton,
Vice-Chairman of the Chairmen's Committee

Dan Morrow,
Chief Historian

EXTENDING THE INTERNET INTO SPACE PROJECT

2005 COMPUTERWORLD HONORS CASE STUDY

SCIENCE

THE FIRST COMMERCIAL-OFF-THE-SHELF INTERNET PROTOCOL-BASED ROUTER ONBOARD AN ORBITING SATELLITE HAS BEEN SUCCESSFULLY TESTED, DEMONSTRATING THE ABILITY TO GREATLY REDUCE TIME AND COST TO DESIGN, BUILD, AND TEST SPACECRAFT, REDUCE THE COST OF GROUND STATION DESIGN AND OPERATIONS, AND PROVIDE GREATER COMMUNICATIONS FLEXIBILITY AND SECURITY. **[20055305]**

SUMMARY

The first commercial-off-the-shelf Internet Protocol-based router onboard an orbiting satellite has been successfully tested, demonstrating the ability to greatly reduce time and cost to design, build, and test spacecraft, reduce the cost of ground station design and operations, and provide greater communications flexibility and security.

APPLICATION

Satellites are typically custom built and require a number of proprietary interfaces and non-commercial standard protocols. Each satellite consists of a primary communications bus surrounded by one or more instruments, all of which are provided by different vendors or subcontractors. Because each satellite and each instrument is unique and because the systems were not designed to be networked using commercial standards, integration, testing, and verification is extremely time consuming, expensive, and often does not occur until the physical integration of the system—when the components are brought together. Therefore, integrated testing usually occurs when it is too late to make wholesale design changes without affecting the schedule. Problems found late in the program can be extremely expensive to correct and usually result in significant launch delays.

Reducing the number of personnel and collective time spent on a project is the only meaningful way to lower mission life cycle costs. Using common Internet Protocol (IP) interfaces has the potential to dramatically reduce the total time required to design, build, test, and validate spacecraft. IP interfaces can also reduce the cost of ground station design and operations and provide greater communications flexibility.

A satellite built and launched by Surrey Satellite Technology Ltd in Guildford, England, containing a miniature IP-based router supplied by Cisco Systems has successfully demonstrated the use of IP in space.

BENEFITS

Satellites and the ground-based systems employed to command and control them use a variety of proprietary interfaces and non-commercial standard protocols. The use of common IP interfaces demonstrated in this project has the potential to dramatically reduce the total time required to design, build, test, and validate spacecraft, conservatively reducing costs by a minimum of 25 percent according to NASA-sponsored studies. The use of commercial, off-the-shelf IP interfaces can also impact the cost of ground station design and operations.

By using commercial standard equipment and commercial standard protocols like IP to communicate with the space and ground systems, command and control personnel have more ground stations to draw upon. The ability to use multiple ground stations results in more available contacts and greater contact time with the satellite, as well as faster response time. For example, a request to take an image over Japan may be received. The spacecraft may have its next available contact time over a ground station owned by company-A in Australia. Personnel could send the commands to take an image of Japan through company-A’s ground station in Australia. The image would be taken and stored. The image could then be transmitted to the ground through company-B’s ground station in Alaska.

Furthermore, the ability to use multiple ground stations enables large file transfers to take place over multiple ground stations' contact times. This architecture allows system implementers tremendous flexibility in the design of the space system. It would be possible to reduce the downlink transmit rate and corresponding transmit power because of the increased contact time. One no longer has to transmit an entire file in a single

contact time. Potentially, this enables systems with longer life expectancies, lower battery power, and less mass.

Looking toward the future, the use of common standards and interfaces may enable new markets for space and ground system providers and encourage competition.

IMPORTANCE

The traditional approach to satellite communications has relied upon proprietary protocols that have created barriers and complicated the development, testing, and operation of satellites and ground stations, adding time and cost to missions. Just as the Internet changed the way businesses, organizations, and individuals communicate, the use of IP onboard spacecraft enables completely new operations models and ways to exchange information.

ORIGINALITY

This program was the first end-to-end demonstration of a network router in space and the first use of mobile-IP based mobile networking in such an environment. It also was unique in the number of different organizations involved. NASA, the US Department of Defense, General Dynamics, Surrey Satellite Technologies Limited in the UK, Universal Space Networks, and Cisco Systems were all involved in the effort. The mobile networking concepts demonstrated here have the potential to significantly impact communication between satellites and ground facilities.

SUCCESS

This experiment was conducted to demonstrate the capability of a commercial, off-the-shelf router aboard an experimental satellite to be remotely controlled using an IP-based command and control application providing secure, virtual mission operations. The IP networking experiment has already met and exceeded its initial goals. However, the primary mission of the satellite, to provide images of the earth for international disaster relief, is expected to last five years. Therefore, the experiment will continue with more yet to be done.

The team has identified a number of concepts that should be pursued. These include routing data between devices onboard the satellite to take better advantage of high-speed downlinks, demonstrating large file transfers using multiple ground stations, and upgrading to IPv6, the next generation of IP protocol.

DIFFICULTY

The project team faced severe time constraints in testing the router and IP networking capabilities. The router consumed 10 Watts, a significant portion of the satellite's available supply, creating a power drain that could not be sustained for long periods of time without affecting other tasks. The satellite is in low Earth Orbit, which results in contact times of 8 to 10 minutes. And the IP networking experiment was just one of many activities of the satellite, including its primary mission to provide highly refined, multi-spectral images of the earth's environment for international disaster relief. The highly successful primary mission, disaster monitoring, reduced the availability of the satellite for experimentation with the router.

For these reasons, the IP in Space project team only had access to the satellite in ten-minute intervals two or three times per week—typically at 5am. All testing and software configuration had to be confined to these short intervals. A nearly identical ground-based model of the on-board system allowed the project team to test new software configurations or instructions before uploading to the satellite.

The success of this experiment depended upon the participation and assistance of many organizations, often going above and beyond their contractual obligations to get things done. Nonetheless, it required the integration of networks and systems and the sharing of information by participating organizations. Government and non-government organizations were involved. A high level of trust had to be established between organizations so that each could get the information they needed on how the others' systems operated, what their comfort level was from a security standpoint in sharing that information, and what they were willing to share or not share.