Interview: Building the interplanetary Internet

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by Karen D. Schwartz

(IDG) -- Mars, with its wind-sculpted surface and possibilities of ancient life, has always held deep fascination for humans. Ever since the first Viking spacecraft landed there a quarter century ago and sent back the first pictures of the martian landscape, that fascination has only deepened. In 1997 the Mars Pathfinder became the latest visitor to land there successfully, enchanting the public at home with a series of visually stunning panoramic shots that have whetted the appetite for future and more extensive exploration of the red planet.

What the public didn't know was just how difficult those shots were to engineer and to get back to Earth. The Pathfinder could send data at an average of only 30 megabits a day, meaning one panorama could take many days to relay.

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That just doesn't cut it for the kind of work that scientists at the Mars Network Office -- a federally funded outfit associated with NASA and the Jet Propulsion Laboratory -- want to do next. To achieve their ultimate goal of discovering whether there is, or has ever been, life on other planets, scientists need to significantly improve communications between Mars and Earth.

This year, the Mars Odyssey orbiter will carry, in addition to its suite of science instruments, a telecommunications relay package that will provide support for a 2003 mission that will land two rovers to roam Mars' surface. The rovers will perform sophisticated scientific experiments, such as collecting soil samples and analyzing them at the scene. A second mission planned for 2005 calls for a Mars reconnaissance orbiter that will include a camera capable of capturing images on the planet's surface that are only 20 centimeters wide. Then, in 2007, NASA will collaborate with the Italian space agency to send an orbiter that will be the first to have telecommunications as its primary function.

Ultimately, we could see a spaceborne Internet that could revolutionize how people work in outer space, just as the Internet is changing our more prosaic Earth-bound life. Chad Edwards, manager of the Mars Network Office, talks about taking a major step forward in space exploration that could also have implications for how we use the data gathered from interplanetary visits on Earth.

CIO: What are your long-range plans in terms of telecommunications?

Edwards: We'll get our first experience using relay links with the 2003 rovers, and for 2007, we have proposed a dedicated telecom orbiter that would be a partnership between Italy and NASA. That will be the first time we'll have a dedicated orbiter, so we'll be spending a lot of time during the coming year with our Italian colleagues trying to decide the best way to use that capability. We have studied a number of potential mission concepts for dedicated telecom relay orbiters with capabilities up to 1Mbps continuous data rate from the surface of the planet back to Earth, or about 85 gigabits of data per martian day. That represents a more than three orders of magnitude increase in data return relative to the Mars Pathfinder mission. A gigabit will give you a pretty decent panorama or allow you to send streaming video back to Earth with very good fidelity.

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Other than bandwidth, what else are you working on that will allow better communications with the Mars landers?

Extending the Internet to Mars. By doing so, you can better ensure that all of your data gets to its destination without being compromised. We'd like a rover on the surface of Mars to be able to have its software autonomously decide to deliver a file to wherever it needed to on Earth without worrying about the bits and bytes. In the past, you had to worry about moving bits from one computer to another and how those bits would be formatted, but this way you can send files and the IP stack deals with all of the issues related to getting that file from point A to point B.

How can you accomplish this?

We're working on developing a layered architecture that would allow us to move data from point to point without worrying about the fine details. That way, as new technologies come along, we'll be able to make changes to the underlying physical infrastructures without disturbing the protocols that are already in place. So we'll have a layering of how we flow information across some infrastructure that lets us evolve it in time and accommodate technology infusion without having to scrap our investment. Eventually, we envision a bunch of local Internets that are just like Earth's Internet, scattered around the solar system, and "trunk lines" that would have customized deep-space link protocols to connect them.

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So we're not talking about the Internet as we know it today, right?

Right. The basic IP stack for Earth's Internet was built for Ethernet-connected networks or computers. It is characterized by always being connected and having extremely low bit-error rates, having very reliable Ethernet or fiber-optic connections between computers, having small amounts of latency between nodes and dealing with network traffic congestion as opposed to bit-error rates. For our deep-space links, we're dealing with many issues that can cause the IP stack to break down, like a lot of latency, intermittent links and high bit-error rates because of very low signal strength. We can encounter latency approaching more than 30 minutes on the link from the orbiter back to Earth, for example. We borrow a lot of the concepts of Earth's Internet but come up with protocols that will work in this deep-space application.

There is an effort called Interplanetary Internet led by Adrian Hooke, manager of NASA's space mission operation and standardization program, and Vint Cerf, one of the fathers of the Internet, that addresses this issue. The goal is to look at how you could seamlessly extend the current Internet to accommodate the deep-space links.

Clearly there is a lot of work to be done. What's really possible?

Developing relay links that increase the amount of data we get back from Mars. Those links will allow us to have small landers on the surface of the planet that can relay their data back through an orbiter and get that information to Earth. We'd also like to extend the Earth's Internet to include other planets. After Mars, the next planet we'll probably attempt to connect to is Jupiter and its moon Europa, which has signs of a liquid ocean underneath the frozen ice cap. One of the things that has driven the search for life on Mars and our understanding about life on Earth is that, where there is water, there is life.

What do you consider a long shot in terms of future capabilities?

Nothing is a long shot. It's just a question of how fast things will happen. One thing that really excites me is the idea of a stationary spacecraft that would hover above a lander just like an Earth geostationary satellite. That opens the door to being continuously connected with the landers on the surface at very high data rates. I don't know whether we'll get there this decade, but it's a capability that would increase by three orders of magnitude our data return relative to Pathfinder, which would change everything about the way we interact with those spacecrafts.

When the Mars network is finished, what will it look like?

I'd compare this to asking, "When the Internet is finished, what will it look like?" Our current strategy is an evolutionary one, where we work to understand the communications needs of our future missions and the technological capabilities that can be brought to bear in meeting them, and then devise a cost-effective strategy for deploying those capabilities.

This is great stuff, but it's complicated. Does the Mars exploration mission need a CIO?

Mars exploration is an international activity. The European and Japanese space agencies will each have an orbiter arriving there in the 2003 time frame, and the French and Italian space agencies are also interested in sending orbiters. We want to use their orbiters for relay communications, and they want to use ours. Dealing with other countries, developing standards and achieving interoperability will require someone to lead the effort, and a CIO makes a lot of sense to coordinate the effort, forge alliances and keep on top of the technology. To some extent, that's my job. I try to lead that type of interaction with our foreign partners to make sure we achieve standardization.

What can we learn from this research to help us deliver satellite-based communications such as the wireless Internet we have on Earth?

There is no way you could justify what we're doing on Mars because it's going to lead the way for solving the problems on Earth. But this is an interesting communication problem that will fuel a lot of creative thought. I see information flowing from both the terrestrial wireless community into our solutions and vice versa.

How about other types of applications? What could your research contribute?

There are a lot of potential applications. One of the simplest is "Mars TV." Imagine that you set down a rover with multispectral imagers and cameras and that bandwidth was no object. You could just start sending back a stream of video from the surface of the planet and provide Mars TV. Businesses could also use the streaming video to develop entertainment applications. They could build a software model of the martian environment and combine it with visual and tactile sensors to allow anyone to be a virtual astronaut. You could basically step into this virtual martian environment and explore it yourself.

Could there come a day when astronauts or colonies of people living on Mars could communicate with Earth in real-time?

Earth-Mars communication is possible, but I don't think we're going to change the speed-of-light constraints. We don't know of a way today to convey information between Earth and Mars at a speed faster than the speed of light. [It takes light six to eight minutes to travel the round-trip distance.] We don't foresee a way to get rid of the latency in the communications. The advanced communications will be there, but the latency will also be there. You can't use a joystick from Earth to command a robot on Mars. That robot has to have a lot of autonomy to take care of itself on time scales of up to an entire day. As we achieve better and better communications, we can shorten that time to ultimately the round-trip light time where we could be interacting with these robots on time scales of tens of minutes. But once we have humans on Mars, they will be able to interact with those robots with effectively no latency. That's a big incentive for getting people to Mars.

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interaction with our foreign partners to make sure we achieve standardization. The primary forum through which we work these issues is the Consultative Committee on Space Data Systems (CCSDS), which is an international organization chartered to establish space telecommunications standards.

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