A Discussion of NASA's Interplanetary Network with Adrian Hooke

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Adrian Hooke has been a veteran of the space program since 1966. He is a Principal Member of the Senior Staff at the NASA/Caltech Jet Propulsion Laboratory in Pasadena, California. His early work included launch pad operations at the Kennedy Space Center for the Apollo 9, 10, 11 and 12 Lunar Modules, flight control of the Mariner 9 and 10 missions, specification of the Voyager and SEASAT flight data systems, definition of operations concepts for the European Space Agency's SpaceLab, and design of international space-ground data communications standards for the Space Station program.

Since the late 1970's Hooke has been pioneering the development of new space data communications protocols. He is a founder of the International Consultative Committee for Space Data Systems (CCSDS) and has led the development of international standards for IP-like packet-based telemetry and telecommand communications protocols that are now used by over 150 missions across the world space community. More recently he has joined with one of the "fathers" of the terrestrial Internet, Vint Cerf, to lead a new 'Interplanetary Internet' initiative – The Interplanetary Network - aimed at extending the Earth's communications infrastructure throughout the Solar System. He currently manages NASA's Space Mission Operations Standardization program and is chief US delegate to the subcommittee of the International Organization for Standardization (ISO) that develops space data and information transfer standards. Within CCSDS he is chairman of the sub-panel on Advanced Orbiting Systems and manager of the Space Communications Protocol Standards (SCPS) project that is extending the current Internet protocol suite for use in short-delay space mission environments.

Hooke holds a BS in Electronic and Electrical Engineering from the University of Birmingham, England and is registered as a Chartered Engineer with the IEE in London and as a European Engineer with FEANI in Paris. He has been awarded two NASA Exceptional Service Medals.

PS: **Please tell us something about your background. How did you come to work for NASA's Jet Propulsion Laboratory (JPL)?**

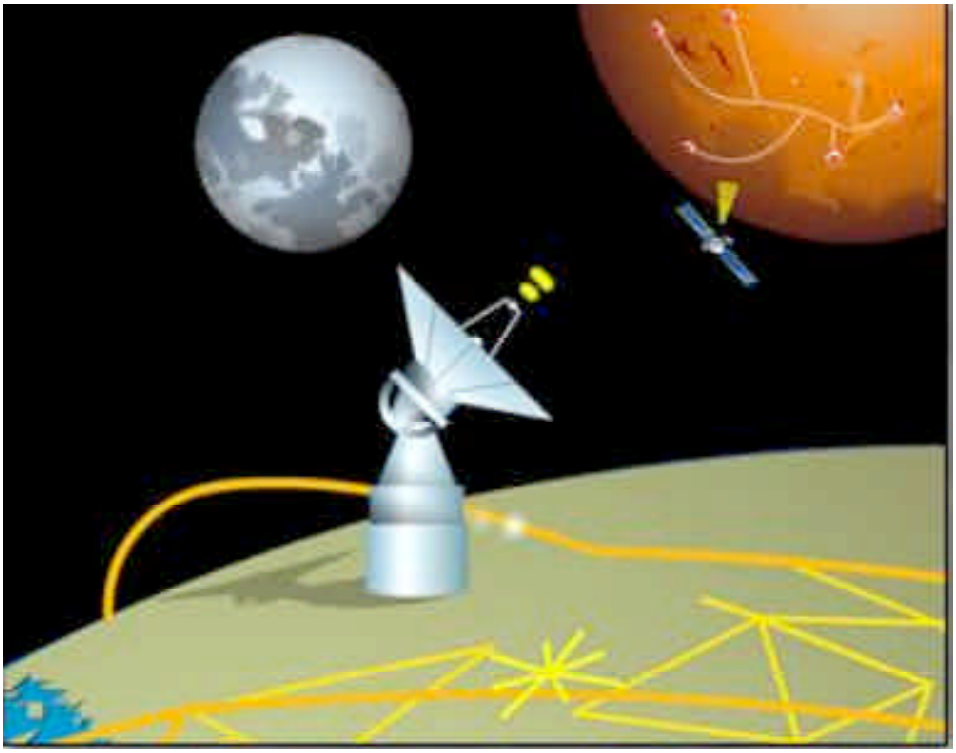
Hooke: I came to the USA from England in 1966 to work on the Apollo Program, and I was very fortunate to land up at the Kennedy Space Center - working on launch pad operations for the Lunar Module during the Apollo 9, 10, 11 and 12 missions. It was a wonderful and exciting time. However, after the successful Apollo 11 moon landing, it was clear to many of us that the program was unlikely to go much further. Luckily, someone who I knew had moved to JPL and invited me to apply. I did, and a few days after the end of the Apollo 12 mission I moved from Florida to California and started work at the lab on December 15, 1969. I've been here ever since, except for 18-months in the mid-1970s when I took a time out to join the European Space Agency in the Netherlands to work on their SpaceLab project, which was part of NASA's Shuttle program.

PS: **What is your typical day like?**

Hooke: When I'm not traveling, I spend a very large amount of time communicating via e-mail. It's a form of delay-tolerant networking – I network with people from all over the world, operating on different time zones, and so e-mail is a great way to keep dozens of different conversations going in parallel. I usually get in to work by 7a.m., and so I am able to converse with people in Europe before they go home, and on the East Coast before their lunch. I'd say that over 80% of my work is done with people outside of JPL. And I'm back on e-mail in the evenings as most of my friends and family are spread across the world.

PS: **Recently, NASA has been working on a project called Prometheus to generate nuclear energy in space. Don't you think this is going too far? Could it have serious implications?**

Hooke: Well, everything has a price. Obviously, any sane person has concerns about the safety of nuclear devices and the possibility for their use to militarize space. But we have one huge problem



that inhibits peaceful space exploration, and that is the generation of power. There is only so much solar power that you can afford to generate as you get further from Earth, and when you get to the outer planets (or places like the surface of Mars where there is also an atmosphere and dust to filter sunlight) almost everything that you want to do becomes constrained by power availability.

In particular, it takes quite a bit of energy to transmit data across the Solar System, and so nuclear power sources open up whole new horizons for being able to communicate information at very high rates. Nuclear power will mean that for the first time it may soon be possible to transport enough information from remote places in space to be able to actually recreate a very close emulation of what it's like to be out there – so we could literally be "tele-present" on other planets.

PS: **Please tell us about your recent initiative - The Interplanetary Network. How did it all begin?**

Hooke: We started the IPN work a few years ago by imagining what it could be like in 50 or 100 years when human intelligence has spread across the whole Solar System and beyond. "Intelligence", by the way, does not necessarily have to equate to "human beings" – much of it could be embedded in incredibly smart robots that are better equipped to live and work in hostile places than human beings. Intelligent systems (be they humans or robots) still need to communicate with each other, and so we said "well, why not an Interplanetary Internet to interconnect all those smart systems that may be scattered across hundreds of millions of miles of space?"

In fact, it wasn't at all far-fetched for us, since we have already been developing and using highly standardized Internet-like techniques to communicate with our present fleets of spacecraft. So we knew that we already had the basics of the "backbone" network in place – the long-haul links that connect spacecraft with our Deep Space Network – and that quite soon it would be probable that spacecraft themselves would have little "Internets" embedded within them.

We therefore looked at this as a manageable engineering problem, rather than something futuristic, where with a few key technology developments we could recursively extend the Earth's current Internet (which is basically a "network of connected networks") into an Interplanetary Internet that is a "network of disconnected internets". And so we started developing the protocols that can become the "TCP/IP" of the Interplanetary Internet. We call this suite of protocols "Bundling", because that's what it does. It bundles chunks of dialog from internets all over the Solar System (even though those internets may each use dissimilar communications technologies and may never all be simultaneously connected) and reliably transports and routes those autonomous Bundles in a way that's roughly analogous to what TCP and IP do on Earth.

PS: **What is your vision for the IPN - will it just be a support network for NASA, or is it going to be similar to the Internet that we have here on Earth? What are we going to use it for?**

Hooke: Thirty years ago, a few people – Vint Cerf, who is working closely with us, was one of them – were doing much the same thing with the terrestrial Internet. They were imagining a time when millions of intelligent systems on Earth would want to intercommunicate, and they were building the communications protocols that could support large-scale global dialog. Once you've got the basic underpinnings right, and if they are scaleable, it's just a matter of time and technology and economic demand until you have accreted a really useful capability. We look at it the same way – we will start deploying these new capabilities quite soon on our upcoming space missions and as the number of missions and places that we explore grows, then we will accrete more and more re-usable communications infrastructure. The more infrastructures that you have in place, the cheaper and easier it is for everyone to use it, so the network grows like a rolling snowball. And just like the Earth's Internet, who can possibly know what new applications and industries those capabilities will enable? Sure, the initial users will be the international space-faring agencies, like NASA. But there's nothing to prevent the same techniques being used commercially; for instance, by enterprises doing industrial things like mining asteroids.

PS: **What are the primary challenges you are facing today?**

Hooke: Our biggest challenge right now is getting the new technology injected into near-term space missions – there aren't

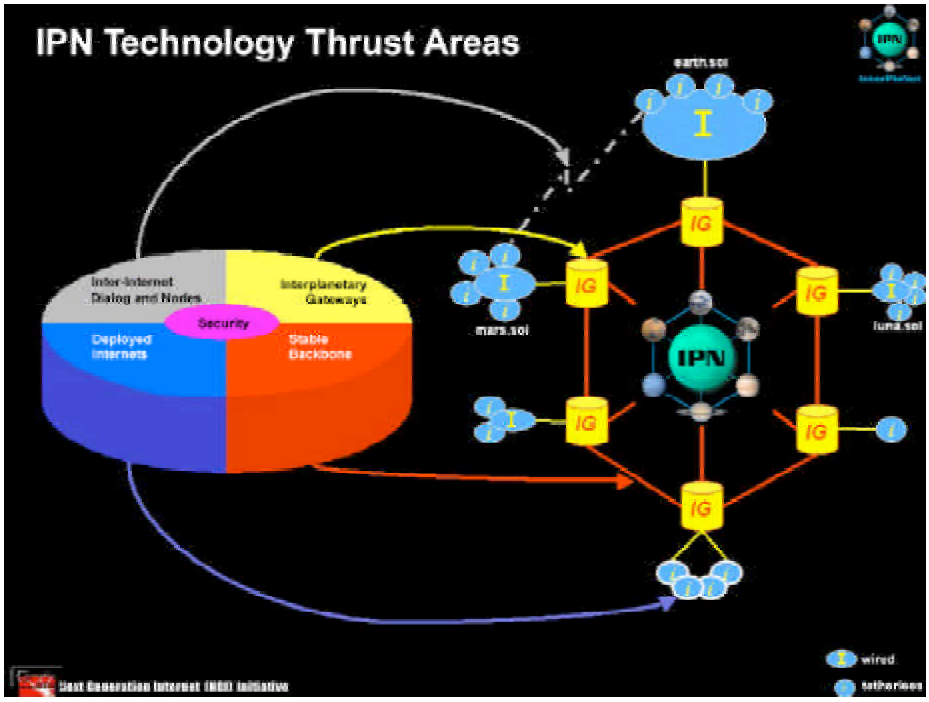
many of them, and their designs tend to be conservative. We are really in a time that's quite analogous to the early 1970s, when only a few mainframe computers were networked together and Cerf and his colleagues were patiently building capabilities for the future Internet. We hope that the next twenty years of space exploration will see a similar kind of rapid growth, where new capabilities create new opportunities, that increase the demand for the new capabilities – and the snowball starts rolling.

***PS:* Is it realistic to think of people living on the Moon and outer planets like Mars, or is that too far fetched? Wouldn't it be dangerous?**

Hooke: It's certainly *realistic* to think about it; the big question is whether we can afford it. Yes, human beings are vulnerable in hostile environments like space, and it costs a very great deal of money to keep them comfortable and safe, so we need to strike the right balance between putting human beings in harms way, and putting smart surrogate human beings (robotic devices) there to act as their remote senses. At some point quite soon, we may find that robotics and telecommunications technologies have advanced so fast that we only rarely need to use human beings to explore new places in person. For the most part, humans may work in safe habitats, supervising robots that allow them to be telepresent anywhere they want to go. But I expect that there will always be those "special missions" where human beings want to go and see things first hand, and are willing to take the risks.

***PS:* How would access to the Interplanetary Internet be regulated?**

Hooke: Well, the desirable "end point" scenario would obviously be that users should simply be able to connect up to the Earth's Internet just as they are now, and be allowed to access a "worlds wide web" of information sources scattered across space. In the short term, with expensive and fragile space mission systems at risk, and governments paying for nearly all of the investment in communications infrastructure, it's more likely that



access will be granted primarily to the scientists who are in charge of space investigations. But we'd actually like to find ways in the short term for some members of the public to be able to communicate across space. It's not technically difficult, but it would take money that we don't have in hand right now.

***PS:* Should we be worried about terrorism in space? What about the risk of hackers breaking into the Interplanetary Internet?**

Hooke: Right from the start we mounted a major data protection effort, hired a security expert and built security measures right into the bundling protocols. We are pretty confident that we can protect our systems.

***PS:* Where do we stand today vis-à-vis the vision of an IPN? What are the current active research areas?**

Hooke: Right now we have a surprising amount of the needed IPN capabilities in place, although on a small scale. We have backbone international data communications protocol standards in use that allow just about anybody's spacecraft to communicate with Earth and with each other. We are just starting to deploy new automated capabilities that allow applications on spacecraft to transfer files back and forth – and one of those new capabilities is in fact an early form of Bundling. For the next few years, in fact, our evolving current capabilities can probably handle our requirements without a need for the true Bundling protocols – it may be the early part of the next decade before we have enough systems in space to warrant an "IPN".

Meanwhile we are focusing on getting the Bundling protocol specifications developed and their implementations rock-solid, and to do that we are experimenting with them in some terrestrial applications. There are several Earth-bound environments (remote outposts, battlefields etc.) where the communications infrastructure can get severely disrupted and techniques like Bundling can probably help a lot. So we are quietly working away at deploying and testing the new capabilities on Earth – just as Cerf and his colleagues did thirty years ago. Meanwhile, we are constantly looking for an opportunity to rendezvous with an upcoming spacecraft and put the new capabilities onboard. Stay tuned – the IPN is just around the corner!