INTERVIEW WITH

# Jeffrey Hoffman

BY DON COHEN

Currently a professor in the Department of Aeronautics and Astronautics at MIT, the Massachusetts Institute of Technology, Jeffrey Hoffman flew on five shuttle missions as a NASA astronaut, including the first Hubble repair mission. He also served as NASA's European representative for four years. Don Cohen spoke with him at his office at MIT.

**COHEN: You were a scientist first and then an astronaut. How did that come about?**

**HOFFMAN:** I've been interested in space since I was a little kid. When the first astronauts began to fly, I was excited by the idea of flying in space, but I had no desire to be a military test pilot. I took an astronomy course in college, found that I liked it, and went on for a PhD in astrophysics. I was most interested in high-energy aspects of physics for two reasons. I liked the space connection, the fact that you had to go above the atmosphere. And, because we were looking at these wavelengths for the first time, you were almost guaranteed to make interesting discoveries. I was involved in the discovery and elucidation of the nature of X-ray bursts, work I did with Walter Lewin.

**COHEN: And you need to get above the atmosphere to study those wavelengths?**

**HOFFMAN:** Absolutely. For my PhD thesis, we flew gamma-ray detectors in balloons. That was before we realized that you can't do gamma-ray astronomy from balloons: you need more exposure time. Now we do it from satellites, of course. Here at MIT we had our own SAS-3—small university-class satellite—we operated out of the control room at MIT. The commands went to Goddard to send up to the satellite, but it was our satellite, and we determined what commands should be sent. I was also project scientist for the high-energy X-ray experiment on the first

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high-energy astrophysical laboratory, HEOA-1. I've always followed the space program. When I read that NASA was going to need quite a few new astronauts for the shuttle and that they were looking for scientists, engineers, and doctors, not just for test pilots, I figured, "Why not have a go?" I put in my application and was fortunate enough to be selected in the first round. I was in the first group of shuttle astronauts that showed up for work in 1978.

**COHEN: Did being in space live up to your expectations?**

**HOFFMAN:** Yes, both the physical and psychological experience *and* the interesting work that I got to do up there. I was very fortunate in having a lot of different and interesting missions to work on. My career coincided with the heyday of the Space Shuttle as a multipurpose vehicle. I was on missions that launched satellites, did medical experiments, did tethered satellites, materials sciences, and, of course, the Hubble rescue mission.

**COHEN: What are the benefits of having a scientist in space?**

**HOFFMAN:** I think the most valuable thing was the work I did with scientists on the ground preparing experiments to go into space, being able to use my understanding of the environment of the shuttle in space to help them plan experiments. I worked with scientists in many different fields. Every time I got involved in a new project, it was like being a graduate student all over again, trying to understand what they were doing. I've always felt comfortable having a foot in both the science and engineering worlds, even when I was working with sounding rockets and satellites. Being able to work in both disciplines is important. There are many scientists designing space experiments who really don't appreciate the limitations and also some of the special opportunities they would have. When you're doing laboratory science in space, the deeper your understanding of the experiment, the more likely you are to be able to recognize unusual results and take advantage of the serendipity that is a part of most laboratory science. That was very difficult in a Spacelab-type mission because everything was so tightly programmed. You had to do what you were supposed to do and then shut down that experiment and go on to the next one. We didn't have the luxury of turning people loose in the laboratory. NASA is very good at running missions: organizing an EVA [extravehicular activity] or planning for the visit of one of the supply ships. But a laboratory has to be run with flexibility, with rapid response. You need procedures, but you need the flexibility to know when to change things. That's something I hope some day we'll be able to get to in the space station.

**COHEN: How did your astronaut experience help scientists who had never flown?**

**HOFFMAN:** I was not the only one who felt it was important to get the astronaut perspective to scientists. There were a number of us—Franklin Chang-Diaz, Bonnie Dunbar, Rhea Seddon—who formed what was called the Science Support Group. We produced a movie where we went through some of the problems that people don't understand—simple things like handling fluids, for example, because people didn't plan on the unusual types of fluid behavior. Experiments can go awry because of that. And thermal control. Particularly in the early days, we lost a lot of locker experiments because of thermal problems. There is no density-driven convective cooling in weightlessness. Also things involving cabling could cause problems. Cables have a life of their own in space. You need to design systems so you can set them up and take them down without spending hours controlling all these things that are floating around. Little parts floating away can ruin your day. There are things you can do to avoid that, but you have to think of them beforehand.

**COHEN: So, for various reasons, good communication between scientists and astronauts is important.**

**HOFFMAN:** Right now, the system places as many barriers as possible between the scientists and the crew. During some of the older Russian missions—I think they still do it this way—it was a requirement that the scientists be there to talk with the crew. At least, that is what some of the Russian scientists told me. We don't allow that. A scientist has to put in a request to get something to the crew, and that has to be sent to the PAYCOM [payload command], and the PAYCOM, who is not a scientist and may not have a deep understanding of the science, has to transmit that up to the crew. It's not the way laboratories should work.

**COHEN: Like a game of telephone, where you lose the message in translation.**

**HOFFMAN:** You got it. People guard the air-to-ground loops very carefully. They don't want people getting on who don't have proper protocols. But frankly it's easier to teach a scientist how to talk over the air-to-ground loops than it is to teach a contractor or someone working at the PAYCOM console to be a scientist. Verbal communication is part of it. The training is much more important. The amount of time the crew can spend getting to know the scientists and understand the science that is supposed to be done is far more critical than the conversation back and forth.

**COHEN: Do you think we're getting better at using the space station for research?**

**HOFFMAN:** A lot of people are working very hard to increase the efficiency of research operations on the station. We're only just starting the operations phase of the space station. It took years before we really learned how to operate the shuttle efficiently. We're pushing in the right direction, but it takes time. There are cultural gaps that have to be bridged. I hope we can do it successfully. At the moment the crews are still overscheduled. I think that maybe the biggest challenge that faces the space station program, at least from the scientific point of view, is transforming the station from a construction project into a flexible, working, scientific laboratory.

**COHEN: The construction is essentially finished …**

**HOFFMAN:** Yes, but the crew is still incredibly busy taking care of the station. People are trying to figure out how to get more crew time available, and not just time on orbit. When crews trained for Spacelab missions, they spent a lot of time with the scientists. In many cases, they were personally invested in the experiments, because they had spent time in the laboratories, they knew what the scientists were trying to achieve. I think that made a big difference in the success of many Spacelab experiments. Crews are so overwhelmed with training responsibilities now—just the basic stuff you've got to do in Russia, plus learning the European module, the Japanese module, robotics training, EVA training. The crew has basically been pulled out of the kind of science training that was a part of Spacelab missions, to the detriment of space station science.

**COHEN: The tradition of astronauts working closely with scientists goes back to geologists training Apollo astronauts.**

**HOFFMAN:** And that made a huge difference. You don't get it by magic. It requires training time.

**COHEN: What are the potential advantages of science in space?**

**HOFFMAN:** In many cases, weightlessness improves the precision with which you're able to make measurements. I remember an experiment where one of the limitations in the lab was the pressure gradient in a fluid caused by gravity. In space, you have no pressure gradient so you can get an order of magnitude improvement in the precision of the measurement. I think there are planned experiments for atomic clocks up in orbit. Because you don't have atoms falling out of the field of view of the exciting lasers because of gravity, you can observe them for a much longer time and that gives you better precision. The hope is that we'll get maybe an order of magnitude improvement in our ability to measure time. Whenever we make an improvement in our ability to measure time, it ends up having technological spinoffs, GPS being the most obvious example. In other cases, you're trying to look at phenomena which flat-out don't exist on the ground. That's probably where serendipity is going to be even more important.

**COHEN: What kinds experiments would you personally like to see happen at the space station?**

**HOFFMAN:** Telling time better is probably at the top of the list for me, if only because there have been so many benefits from telling time better in the past. Demonstrating the efficacy of the station as a useful investment for our country is probably going to come from biotechnology. I was in Houston last weekend at the International Space Medicine Summit. They announced that they are reactivating the bioreactor program, which I think has a tremendous potential for health. If it turns out that this bioreactor research in orbit can lead to better vaccines and medicines and treatments, that's the sort of thing that the public will really respond to. What goes on in laboratories doesn't make the news, except when they make major discoveries. We hope there are going to be some significant discoveries from the space station.

**COHEN: Would you explain how a bioreactor works?**

**HOFFMAN:** Everyone knows about petri dishes for growing tissue cultures. You can put a little bit of substance into a petri dish to see if it has antibiotic effects, but you can't grow three-dimensional tissue, which is the way tissue exists in our body. Think of a bioreactor as a cylinder which rotates. It's filled with a liquid and you can put in nutrients as required. You put tissue in suspension in the liquid and the tissue can then grow three-dimensionally.

**COHEN: And the advantage of having a bioreactor on the space station is what?**

**HOFFMAN:** Suppose you have a bit of liver tissue. It starts to grow. As it gets bigger, it sinks toward the bottom. So you rotate the bioreactor so it's at the top again. It's continually falling through the liquid and it continues to grow. The problem is, as it gets bigger and bigger you have to rotate faster and faster to counteract the settling forces. Eventually you build up shear forces, which will rip the material apart. So there's a limit. In space, where you don't have the settling, these three-dimensional tissue cultures can be grown much bigger. That's been demonstrated. The original work was done up on the Mir station. They've actually seen vascularizaton of tissues; they've grown knee cartilage, liver cells, cancer cells. You can then use these to test drugs. If you can get good three-dimensional human tissue to test on, you could save one or two years in the development of a drug. At $100 million a year—my understanding is drug development can cost that much—that's enough to finance experiments up in space. Assuming that we can do them quickly. That's part of the other challenge I mentioned before: turning the station into a working laboratory. If the pharmaceutical company or a research university comes up with something they'd like to test and they've got to wait three years in the queue, you've lost it.

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**COHEN:** **Do you think the station has a role to play in future space exploration?**

**HOFFMAN:** I very much believe in the space station as preparation for long-duration spaceflight, and I hope we will take up that mantle again.

**COHEN:** **And fly to Mars some day?**

**HOFFMAN:** The more we learn about Mars the more fascinating a place it is in terms of geological history, potential for biology, and resources. For long-term activities on Mars, we need to be able to do ISRU, *in situ* resource utilization. All explorers have lived off the land. The first time we go there, we'll take everything we need, just like the first time we went to the moon, but for longer-term exploration we need to learn how to use the local resources. That's absolutely critical. It makes a huge difference in terms of the ultimate cost as well, if you can make your own oxygen and rocket fuel. We need to do that first on the moon. There are differences between the moon and Mars, but would we really rely on surface operations that we've never tested out on another heavenly body the first time we go to Mars? I don't think there needs to be a permanently manned moon base; I don't want to see us build another space station there. Let's remember that we can operate equipment on the moon telerobotically from the earth. The Mars rovers have to be pretty much autonomous, and when they run into problems, they have to shut down and wait for advice, whereas we can keep things running 24-7 if we want to on the moon, and periodically visit to set them up, make repairs, do whatever you have to do for operations while they're building up supplies. We need to do that before we are ready to go to Mars. We also need to develop and demonstrate the capabilities for deep-space travel. That's where visits to asteroids come in, because you don't have to land on them. We don't now have the technological capability to do entry, descent, and landing on Mars with human-class vehicles. I think we can develop at least the entry capability with experiments in the upper reaches of the earth's atmosphere, which I know NASA is thinking about, but we've never had successful demonstrations. So there's a lot that has to be done before we go to Mars. ●