Preparing for New Challenges—William Shepherd

William M. Shepherd, commander of the Expedition 1 crew to the International Space Station, secures his helmet to his Russian Sokol spacesuit during a training exercise on 20 October 2000. NASA Image JSC2000-E-27088.

This conference brings back fond memories for me. I recall Alan Shepard being at the Naval Academy in spring 1971 after he walked on the Moon. That was a special moment for me because I have always been interested in aviation. My dad was a Navy flier in World War II. My grandfather flew biplanes in France in World War I. It had long been one of my ambitions to be a naval aviator, but I found out shortly before that day in 1971 that I didn't have the eyesight to be a pilot. So I ended up being a Navy diver, a SEAL. I was sitting there listening to Al Shepard talk about his adventures on the Moon, and I was thinking I probably would never have to worry about doing anything like that. How strange events have turned.

I bring that up because I enjoy talking to kids and making education a very relevant part of space exploration. I think we often forget what impact exploration, technology, and human spaceflight have on the young kids of this country.

A little more personal history: I served in the Navy for thirteen years, was selected in 1984 to go to Houston and to start training as an astronaut. I flew three times on the Shuttle. They were very interesting flights. The longest flight I had was ten days. Right after that, I was asked to go to Washington for two weeks and help as the Administration had changed in 1992. In early 1993, there was a complete review of the Space Station program. We were in the middle of trying to decide whether Space Station Freedom would continue as a program or be canceled or be transformed into something else. So I had a lot of time in Washington working on how we would convert Freedom into something that was more feasible. At the end of that period, we got the Russians involved, which seemed politically to be a really good idea. One thing led to another, and, in 1995, I was asked to go to Russia and start training with another Russian cosmonaut, Sergei Krikalev, to be on the first human crew to the ISS.

So in early 1996, I started training in Russia and basically spent almost five years with Sergei and another Russian cosmonaut, Yuri Gidzenko, who is a colonel and a fighter pilot in the Russian Air Force. We trained, and, finally after four or five major delays, lots of slips and slides, we launched last October [2000] and flew what was called the first expedition to the ISS.

We launched from Baikonur on very much the same rocket that put Yuri Gagarin into space, pretty much an R-7 Russian booster. I was very impressed with the ride. It was very much like the Space Shuttle, very smooth. We lived on the International Space Station for 141 days. At the end of that period in March, the second expedition crew took over. A Russian and two American astronauts are up there now, Yuri Usachev, Susan Voss, and Jim Helms, and flying on the Space Station as we speak. So it was a real privilege to lead the charge, making the ISS a reality.

What I really want to talk about is not so much what we did, but what it all means. As the station is taking shape in orbit now, I think it might be easier to see not only what the issues were on its past development, but some of its future purpose.

To start off, it might be interesting to consider what differences and even similarities there would be between ISS as it is flying right now and a human expedition to Mars. So I'd like to touch on some of the ISS program lessons that are applicable. I think that a human expedition to Mars is going to be characterized by several broad themes.

First, it is going to be international. I do not believe that any single country has the financial resources, the technical know-how, or even the political will to carry out a large and costly exploration program to Mars or even back to the Moon. I think anything that we do in the future will be broad in scope and will be international in character, much as the partnership that's been formed to build and fly the station right now. The station partnership is certainly not perfect. It's got a lot of bumps on it, and we have had many tough times with our partners. Even today we're doing a lot of arguing, but the job is getting done, and I think it's a model for how we might do things in the future. It's not a perfect one, but it is functional.

Secondly, an expedition to Mars will be characterized by things that are big and heavy. I think that the vehicle that flies to Mars will be at least the size of the ISS and probably several times bigger. We need this because we have to have something that's very robust and self-sufficient. I think the crafts that we will see going to Mars are going to be too big to be put up by the current stock of expendable boosters or by the Space Shuttle. This is because we cannot afford to have a vehicle or a fleet of vehicles that are assembled in orbit that take thirty or forty launches. We have got to do this in a way that involves less risk and allows us to have better test and checkout on the ground as these large pieces are sent up into space so that the verification and integration job in orbit is not as large.

So risk, time, expense, and these checkout requirements are all going to favor putting large spacecraft on very large boosters and trying to get them into low-Earth orbit with a minimum number of launches. It is clear that we do not have that capability today. The expedition to Mars, regardless of how cleverly we design things, will be made up of a vehicle or a fleet of vehicles that will be assembled in orbit. Regardless of the technologies that we use, the vehicle that we would send to Mars would be very complex and will require the spacewalking and the robotics techniques that we're developing and proving right now on the ISS. There just is not any way to get some of the larger systems, particularly things like thermal systems or solar panel systems, completely checked out on the ground. We have to be able to assemble and perform such checkout procedures in orbit.

Third, expeditions to Mars also are going to need more power. We probably will not put humans on Mars transfer-trajectory using the energy for propulsion that would come from chemical sources. I am not sure that we will even be able to satisfy the ship's own energy needs with solar power or chemical reactions. Once we get to a place where we want to go, whether it is the Moon or Mars, we won't be able to do mining, in situ exploration of resources, efficient recovery, or manufacturing without large amounts of energy. We will need [not] only energy, but high power levels. To me, all these things say that the enabling technology to make this happen is going to involve some form of nuclear power.

Missions to Mars are going to need more speed. We need to cut down the transfer times to get humans and cargo to Mars and back. In order to do this, we have got to find propulsion schemes that are more efficient than the chemical rockets that we have now.

We are going to look for these types of engines that have to have both high thrust and high efficiency or high specific impulse.

Fourth, vehicles that go to Mars will be different from the vehicles that we fly today in space, because they will need to be highly autonomous. A Mars mission is going to have significant communications delays. Additionally, the trajectories to send vehicles to Mars do not lend themselves readily to good abort trajectories where we can get humans home quickly.

What this means is the crew onboard is going to have to manage and control what they are doing with not a lot of real-time help from the folks on the ground. It also means that the vehicles that we build are going to have to be survivable. We cannot put Soyuz capsules on this kind of vehicle and expect them to be able to get people home. We have to build spacecraft more like we build ships, where they can sustain some kind of damage from combat or some other catastrophe and still carry on. We cannot depend on mission control in either Houston or Moscow to keep turning things on and off all day on the station, because the awareness of what's happening on the ground is going to be 20, 30, 40 minutes behind what's really happening in space. All these factors indicate that the manner in which we are not only going to design but operate these vehicles is going to be quite different than what we are doing right now.

The last thing that I think is going to characterize a mission is that the environmental systems are going to look a lot like what you have on Space Station now. The Russians have done a pretty good job of closing off some of the environmental loops on their Zvezda module. Their equipment works very well and is very robust. It is a pretty well thought-out system. I think for missions up to six months, certainly a year, the kind of environment that we have right now on the ISS is a livable and workable place for humans.

If you include the other factors that I mentioned in trying to go to Mars and do exploration there, I think it starts to be within the grasp of what we could reasonably expect humans to be able to do. There are probably a lot of other questions to consider in relation to a human Mars exploration program, but I'll give you just some of the ones that I think about at night.

The big one would be: What should the structure of a large international partnership for exploration be? How will it be controlled? How will it be managed? I think the issues that we have had recently with the Russians as partners in the ISS of flying Mr. Tito show that we have not worked out all the bugs in the present International Space Station partnership about what partners are entitled to and how decisions are to be arrived at by consensus. We will have to get better at doing this.

Another question is how will high-energy density power plants and propulsors with high efficiency be developed? How will they be tested? Can we do this on orbit? How will a robust, reliable, maintainable, yet survivable spacecraft be designed, knowing that it diverges significantly from how we design here right now for work in space? How will the necessary political will be mobilized to carry out such a program?

One of my favorite questions relates not to technology per se, but to culture. Are we open to the necessary changes in our technical culture here in the United States, here at NASA, here in the ISS program, that will enable these other questions to be answered and these changes to be made? It is not just a question of adaptation at NASA or in the U.S. partnership for ISS, it's all the partners. It's the Russians, the Canadians, the Japanese, all the members of European Union, the Brazilians, and so forth. We have to do a much better job of trying to duplicate some of the efforts of the North Atlantic Treaty Organization to standardize military systems. We need standardized interfaces, components, and designs for space systems. We don't even have a coordinate system that everybody agrees upon as to how to lay a vehicle out and design it for space. We have a Russian system and a U.S. one, but we don't have a standard system.

We do not even have a standard vocabulary, let alone a standard understanding of even how we do the mathematics, the computer algorithms, the intricate computations that are necessary to guide vehicles through space. We think we understand each other's approach, speaking about the U.S. vis-à-vis Russia, but we have not converged on what we consider to be the optimal procedures. So I think something along the lines of the NATO experience is essential as a precursor to getting this exploration program done.

There are also some important issues regarding political will. I think the day is coming soon when people will be very interested to understand why the Space Station costs what it does. I don't think the question about Space Station or space exploration is really one of cost, but rather of value. People need to see a good return on what we've invested in space. They need to see that there is value present in what we are doing.

The ISS is hopefully going to do that in spades when we get more capability in orbit with our laboratories. But already you can see that commercialization of space is going to be a fundamental imperative. I think NASA is going to have to work hard soon at showing that the ISS has very strong commercial value.

I believe also that the role for astronauts, government astronauts, folks at NASA, my colleagues, is not really to do routine operations in low-Earth orbit anyway. We are the folks who need to go build the infrastructure. NASA should make plans to get out of the routine operation business in low-Earth orbit. We should let the marketplace drive that. As was the case in our own country with opening the West and laying rails coast to coast, the government helped facilitate putting down the infrastructure, and we let commerce proceed. I think space exploration will take place the same way. NASA needs to be the risk takers or the underwriters, and, once that era is over, we need to let commercialization proceed. Our business at NASA should be exploration.

So what are the problems? We've discussed many ideas. Some are well within reach of solution, while others are not. We've talked about commercialization. No one really knows well yet how to do it with the ISS, although we're heading in that direction.

We have talked about standards and the need for stronger ones, discussing how we merge all these partner nations into a joint international enterprise. I contend that we have done a particularly poor job of capturing the design philosophy. Why is the ISS or the Space Shuttle, or any rocket for that matter, built in its own specific way? Why didn't we put this filter over here? Why didn't we pick another type of fan to put in here? Why are the fuel lines or the fuel tanks for the rocket shaped in a particular way or made out of any kind of material? These aspects of development reside within U.S. contractors, but we are very poor at grasping the essence of why these decisions were made and cataloging them so people who come behind who have to do this job again can learn from these developments.

We talked a lot about having autonomous systems. We need to develop some type of pilot advocate, a high-level computer system that can logically run complex systems. But before that, probably the first step that we need to undertake is to decide on a common language, a common computer application, that will enable us to model complex systems to provide the necessary data for the human interfaces and displays, and to build and drive those displays.

We need to work on higher energy systems and nuclear power. I was over in Russia in 1995 at the Institute of Thermal Processes, where Sergei Korolev worked in the 1930s. We were over there looking at possibly adding a solar dynamic generator to the ISS. It was going to be a carbon block through which a gas flow led to a turban, and the carbon block was heated by a big parabolic reflector. The Russian engineers had a big chart on the wall, showing that this was going to be about a 10-kilowatt system with an exponential development growth. I said, "Can you guys say what the heat source is going to be for this system?" They said, "Well, of course. It's going to be nuclear." So I think the technical ability to do this is certainly right around the corner, and the Russians clearly have been thinking about this as well.

We also need to figure out how to energize a plasma by creating some type of electric-propulsion device that can both push very hard on an object with high thrust and also have very high exhaust velocity so it is very efficient. We are working on these types of technologies right as we speak in Houston at the Johnson Space Center. It is very possible that before too many years are out, this technology will be utilized to alleviate the ISS's drag. The ISS has a drag on it of only a couple of ounces, but this causes it to come down a couple hundred yards every day in its orbital decay. A highly efficient propulsion source could oppose that drag with a small amount of continuous thrust. This would keep the ISS from falling out of the sky and would significantly reduce our need to fly fuel up to re-boost it. This is important because when the ISS is fully assembled and weighs on the order of 500 tons, we're going to fly something on the order of 10 tons of propellant up to it every year to re-boost it. With a system such as this, that goes down by a factor of ten. We could have around a ton of hydrogen gas, but xenon might be a better gas that can be used in this plasma engine to propel the station and solve this re-boost requirement. This is a direct precursor of the kind of technology that will be useful to push crew transport vehicles to Mars.

There are a lot of other questions that have to be answered. We've got to go after closed life support. The Russians are working hard on this. They've got twenty years of experience base on Mir, and what they've put on the ISS right now is doing a good job of partially closing some of the gas and water loops. But we haven't totally solved such problems.

I think the biggest single issue in addressing any of the problems that I have mentioned is we do not have a way to marshal the adequate academic and intellectual resources in this country to solve these problems. So I would suggest that the country take a look at some of the national educational institutes that we have in the military. There are eight or nine of them—The National War College, Industrial College of the Armed Services, and so forth.

We need to have a National Space Institute that has some kind of Federal Charter. Its purpose would be to make available the intellectual resources necessary for the human exploration of space. It would have this as a single purpose. It would be a place where the appropriate knowledge, the experience, and the intellectual energy could be focused on this single goal. It would have the status of other national colleges. It would also be a virtual college or a university, and it would be collaborative with colleges and universities and other learning institutions all across the country and perhaps the world. Experts on space from almost any corridor could participate and contribute to what this institute would do.

It also would have very strong business participation. We would have folks from industry come to this environment, learn, go back and work, and then come back and teach. It would be a means for individuals to become more proficient in the technical engineering operations, as well as the business and political aspects of space exploration. Such a national space institute also would need to establish and maintain close contact with ongoing development and operations in human space programs. Now this needs not to be some intellectual outpost well away from what's happening, but rather needs to be in the center of the mix. I think this would probably be the most direct way to address the many technical, political, and cultural problems that I've mentioned.

In closing, my experience in space has led me to believe most strongly that all these issues can be addressed successfully. Sure, there are problems, but I think we are well on our way to finding the necessary answers, at least to enable human exploration back to the Moon and probably to Mars. It's just a question of marshalling the intellect and the will to go do it.

Should we have a clear policy at a national level to go make this happen? It is certainly something that can be carried out by the people who are in the field right now.

One hundred and forty-one days in space. I came back from my tour on the ISS thinking that spending your day looking at the surface of Earth is very enjoyable, a paradise as Mr. Tito says. Nevertheless, I really think that we should expand our vision by looking at the surface of other planets in this solar system. I am convinced that we have the means to do so.