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INTERNATIONAL SPACE EXPLORATION PROGRAMS

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BEFORE THE

SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED EIGHTH CONGRESS

SECOND SESSION

APRIL 27, 2004

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INTERNATIONAL SPACE EXPLORATION PROGRAMS

TUESDAY, APRIL 27, 2004

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, TECHNOLOGY, AND SPACE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 3:35 p.m. in room SR–253, Russell Senate Office Building, Hon. Sam Brownback, Chairman of the Subcommittee, presiding.

OPENING STATEMENT OF HON. SAM BROWNBACK, U.S. SENATOR FROM KANSAS

Senator BROWNBACK. Thank you for joining me here today. I look out and we're a little thin in attendance, but as I say that, I think this will be one of those hearings that we'll look back or we'll backdrop for hearings in future years that will be packed with interest here in this country and around the world. This is where we build the foundational stock of information, and I'm looking forward to the input and the thoughts that the panel will give us today.

One of the most significant products from our space program has been images of our beautiful floating in space, this view of spaceship Earth shows best that all mankind shares a common home. A closer look, though, shows a diversity of aspirations as significant as those we have in common. As we consider the President's new vision for American future in space, we must think about what others around the world are planning and doing.

Nations and people pursue space programs for many reasons. In the 1960s, we had a race to the moon with the Soviet Union. Our space program was more about national security than space exploration. In the 1990s, our International Space Station appeared to focus on the virtues of international cooperation more than science. Other nations, particularly those in Europe, who sought space capabilities independent of the superpowers.

We have a new American vision for space. January 14 this year, President Bush announced a space vision which dramatically refocused our space program. Our space objectives will now be to expand human and robotic presence in the solar system beginning with the moon and Mars and beyond.

As I talk with my colleagues in Congress and at home in Congress, they ask why are we committing significant resources to space now with other pressing needs here at home. I believe the answer really is quite straightforward and quite important. America has always led on new frontiers, frontiers of science, frontiers of freedom and opportunity, and frontiers in space. Other nations are mounting impressive new ventures in space, some of them very low cost, but significant nonetheless. I for one don't think we should need to explain to our children years from now why others are walking on other worlds and reaping the benefits of space exploration when we are not.

For this reason, I've asked experts from the United States and outside to tell us about other nations' space exploration efforts. We are in a global competition for the future. Space is a key element in this competition, but competition does not exclude cooperation. As I know well from our Nation's private sector that a free range of opportunities to compete and cooperate at individual discretion benefits all. We need this same spirit globally to reap the benefits of an unlimited space future.

I've heard from entrepreneurs throughout America that they want a new approach to space. They want the U.S. Government to use the private sector to full advantage as we explore and occupy the moon and Mars and beyond. I intend to work with my colleagues in the Senate to ensure that that happens, and I want to make sure that our private sector can fully utilize the efforts of those outside the United States to their and our benefit. In other words, I'm looking for new architecture of how we explore space.

Today we will hear the significant initiatives of nations throughout the world to expand beyond Earth orbit. Space is no longer the province of one or two powerful nations, but there is a race on for space. This is not necessarily a military race, but a race for the future, and the national security implications of space exploration are always there. Leadership has always been America's strong point and I believe it to be our destiny. I hope we will meet this challenge as we always have. We will lead and we will cooperate with others to everyone's mutual benefit.

We have an outstanding panel of witnesses to present and discuss this topic about what other countries are doing in the space race: Mr. Sven Grahn, Vice President of Engineering and Corporate Communications, the Swedish Space Corporation out of Sweden; Dr. John Logsdon, Director of Space Policy Institute, Washington, D.C.; Ms. Marcy Smith, Specialist in Aerospace and Telecommunications Policy, Congressional Research Service; and Mr. James Oberg, Aerospace Operations Consultant out of Texas. I look forward to your testimony.

What we will do is we'll put all of your testimonies completely in the record, the written testimonies. You are free to summarize or you can present it as well. What I like to do in this Committee is to have as much free and candid dialogue and discussion on your points of view after they're presented.

Mr. Grahn, delighted to have you here. Welcome, and I look forward to your testimony.

STATEMENT OF SVEN GRAHN, VICE PRESIDENT OF ENGINEERING, SWEDISH SPACE CORPORATION

Mr. GRAHN. Thank you, Senator. Yes, I'm here to talk about SMART–1, Europe's first moon probe. This spacecraft was developed on behalf of the European Space Agency by my company, the

Swedish Space Corporation, which is a small company in a small country, and that's actually my message, how is that possible.

The spacecraft was launched piggyback on Ariane–5 rocket in September last year, and it's expected to reach an orbit around the moon in November of this year, so it's on its way and it works very well. The objective of SMART–1 is to test solar electric propulsion for a future deep space mission. The moon is a convenient target for this technical test, but it's not the main objective. By the way, SMART means—it's not a pun—it means small missions for advanced research and technology. But investigations of the lunar surface and other objects in space are sort of a bonus.

The reason why it takes 16 months to reach the moon is that the electric rocket motor has very low thrust. It's very efficient in terms of mass, but very low thrust, so it takes a while to spiral out to the moon and get there. That is the purpose of the flight to test this engine and the moon is nice conveniently nearby.

SMART–1 was not developed within the skunk-works or faster by a cheaper paradigm, but rather used a light version of the traditional system's management and methodology pioneered by the United States in development of ICBMs in the 1950s. The time between our first contact with ESA and the launch was 6½ years, which is a rather short time in the space field, and the design, manufacture, and test phase of the spacecraft, what we call the CD phase in the space world, lasted 39 months, which is really short for a brand new design from the bottom up, it was brand new. So that could be said to be part of a truly industrial approach to spacecraft development, how to be used to permit a small company that cannot reinvent everything to develop such a capable spacecraft in a short time, and I'd like to list those the main part of my testimony.

We used commercial off-the-shelf hardware and software items from non-aerospace industry. These were modified by space use or used as is. An example is the data bussing board, which comes from the automotive industry. The most efficient commercial software development methods available were used, and these come from industries where the time to market for new products is extremely short due to cutthroat competition. I don't have to mention what it is, but the mobile phone industry, of course, where software development has to be made very rapidly.

Though ESA itself provided some very good things, standard software building blocks for spacecraft basic functions, and standardized logic circuit designs for implementing international standards of geometry and telecom, they were using the spacecraft, and these have been developed under ESA's leadership. And that's very similar to what happened in the United States within national advisory committee on aeronautics, which developed, for example, Air Force, to use in the airplane industry.

I think my last thought in terms of method is that modern industry has created a large group of freelance software engineers that are used to working in a new environment where the time to market and industrial working style are primary values, and we need to tap this talent pool. Without them, we couldn't have made it, and they come from the mobile phone industry, for example.

All of this is nothing revolutionary, but it boils down to that for a small company we can't reinvent everything, so this off-the-shelf approach is the only way forward. And my final punch line is one might say that space technology needs to spin on terrestrial and non-aerospace technology in order to be able to provide more spin-off technology that is honed to perfection by the forbidding environment of the space mission. Thank you, Senator.

[The prepared statement of Mr. Grahn follows:]

PREPARED STATEMENT OF SVEN GRAHN, VICE PRESIDENT OF ENGINEERING, SWEDISH SPACE CORPORATION

SMART–1, Europe's First Moon Probe

Facts about the project and how the probe was developed by a small company in a small country

Distinguished members of the Subcommittee,

It is a great honour to describe SMART–1, Europe's first space probe to the Moon which has been developed by the Swedish Space Corporation on behalf of the European Space Agency (ESA). The spacecraft weighed 367 kg (810 lbs) when it was launched by an Ariane-5 rocket on 27 September 2003. It is expected to reach an orbit around the Moon perhaps as early as in November of this year. In my statement I intend to concentrate on those aspects of the project where my own organization has contributed. The account is made from the perspective of the supplier, a quite small company in a small member country of ESA's.

What methods were used to permit us, a company of about 300 employees, to develop a sophisticated lunar probe of brand-new design in 39 months? That is the main question that I will address.

The Mission and Its Background

SMART–1 is the first of ESA's Small Missions for Advanced Research and Technology (SMART). Their purpose is to test new technologies that will eventually be used on bigger projects. The main mission objective of SMART–1 is the flight demonstration of electric propulsion for deep space missions.

In early studies of SMART–1 a mission to an asteroid was considered. However, the piggyback launch opportunity selected put a strict upper limit on total mass and propellant mass. Also, a mission to an asteroid would require the use of busy and expensive ground tracking facilities because of the long distances involved. Therefore a flight to the Moon provided a solution to both these concerns. When the decision to fly to the Moon had been taken it was natural to include as much scientific instruments as possible. The tight mass limit provided an incentive for miniaturized instrument design—a bonus for later missions into the solar system.

Thus the spacecraft uses a 68 mN stationary plasma thruster (PPS–1350 developed by the French company SNECMA and provided as a Customer-Furnished-Item by ESA) which consumes 82 kg of Xenon propellant to provide about 3.5 km/s of increased velocity that will bring SMART–1 from a geostationary transfer orbit to lunar orbit. The travel time will be in the order of 16 months. The final lunar orbit after capture is intended to be polar, between 300 km and 10000 km in altitude with the lowest point close to the lunar south pole.

The Lunar observation phase will last for at least six months. In lunar orbit, the spacecraft will be pointed with one axis at the lunar surface for carrying out a complete programme of scientific observations from lunar orbit.

The spacecraft carries a scientific payload weighing 19 kg which contains miniaturized instruments such as an imager for visible light and near-infrared light, an infrared spectrometer, an X-ray spectrometer and instruments to measure the effect of the electric thruster on the space plasma environment. Important science objectives of SMART–1 are to conduct lunar crust studies in order to test the current theories of the formation of the Moon, and to establish whether the large hydrogen deposits detected near the South Lunar Pole by the U.S. Probes Clementine and Lunar Prospector, is indeed water. During the cruise phase to the Moon, experiments related to autonomous spacecraft navigation will be carried out using images from the star trackers and the miniature imager.

ESA's official cost figure for the SMART–1 project is 100 million euros at 2001 economic conditions (including spacecraft, launch, operations and part of the payload).

The Spacecraft

The spacecraft is designed with regard to the power needed for the electric propulsion, the severe radiation environment that is a consequence of the slow earth escape trajectory and the need for on-board autonomy. The design life of the spacecraft is two years. The spacecraft looks like a one cubic meter (35 cu ft) cube equipped with solar panels with a 14-meter (45 ft) span.

Power is provided by a large solar array with almost 2 kW of initial power using highly efficient triple-junction cells and a 220 Ah Li-ion battery. The spacecraft's attitude control uses reaction wheels and hydrazine thrusters for steering based on inputs from very compact star trackers and gyros. The spacecraft platform contains several new technology elements in addition to the electric propulsion. These elements are both part of the mission objectives and part of the answer to the question how a small company in a small country can build such a capable spacecraft.

Autonomy was a major design driver for the spacecraft so that the long cruise to the Moon would not tie up expensive ground station time and operations staff. Therefore the avionics was entirely new and its architecture was designed so that on-board software could autonomously manage fault detection isolation and recovery.

The Development Task

The project to develop the spacecraft lasted 6½ years from the first contact in March 1997 between ESA and the Swedish Space Corporation until launch. After initial assessment, feasibility and definition studies the development contract was signed in December 1999 and the spacecraft was formally delivered to the customer after 39 months. The spacecraft was stored for a few months awaiting the Ariane-5 piggyback launch opportunity.

The prime contractor team that managed and carried out the development of the spacecraft and several of its subsystems expended 280000 working hours to complete the spacecraft. In addition the team procured other subsystems and equipment under fixed price contracts with vendors. The prime contractor staff reached a maximum size of about 75 persons, including on-site outside consultants for specific development tasks

Previous Experience of SSC as A Prime Contractor

The Swedish Space Corporation designs, launches and operates space systems. We design and build small satellites, sounding rockets and subsystems for space vehicles. At our launch site in the far north of Sweden we launch sounding rockets and balloons and provide communications services to satellites with our extensive antenna facilities. The latest such support task was to NASA's Gravity Probe B launched last week. The company was formed in 1972, has 300 employees, is owned by the government, and operates as a commercial corporation.

The Swedish Space Corporation, at the time of its selection to develop SMART–1, had built and launched three successful spin-stabilized space physics satellites and was finishing the development of a small radio astronomy/aeronomy satellite with extremely accurate pointing capability (5 arc-seconds stability). This satellite, Odin, was launched in February 2001 and has performed brilliantly since then. The level of complexity of Odin is comparable to SMART–1. This made it possible for our company to at all contemplate taking on the development of SMART–1 when this task was offered to Sweden by ESA as part of a package for compensating our country for insufficient "industrial return" on its investment in Europe's future in space.

All our previous projects have been essentially multilateral projects under Swedish leadership. To develop these spacecraft SSC used a "skunk-works" approach in which a highly skilled small group of people is put to work with little outside daily monitoring and using only the documentation needed to build the product. "Peer" reviews of the technical work were used instead of formal reviews.

Such an approach is often confused with the Faster, Better, Cheaper (FBC) paradigm. "Skunk-works" methods can be part of the FBC paradigm, but there is nothing in the "skunk-works" methodology that inherently assumes that higher risks will be accepted. For example; although we used military or commercial parts, tests and other measures were taken to convince us these parts would work, even if the analysis and test methods were unconventional. Sometimes rigorous computer analysis was replaced by simpler "back-of-the envelope" analysis, but extensive testing on all levels was never cut back—rather the opposite. The first small satellite we developed actually was tested, almost fully integrated, daily for almost a year.

In these projects low cost was emphasized as the driving parameter. In the FBC paradigm, as I understand it, higher risk is *explicitly* accepted. This was not so in our earlier projects. Instead schedule or performance could be used as "free" parameters. For example, the Freja magnetospheric research satellite launched in 1992 from China had a very flexible requirements specification which permitted costs and schedule goals to be met. For Odin, the sophisticated radio telescope-carrying satellite, schedule was not critical, but performance and cost was. By using a relatively small team (12 persons), the long development time did not cause excessive cost increases.

Thus, our experience tends to confirm that you cannot get all the letters of FBC if you want to limit risk and have *the assurance* of low risk—you only get two out of the three—unless you add a new ingredient! The new ingredient to possibly resolve the FBC dilemma is smart technology and smart industrial methods. This is what we proposed to ESA for the SMART–1 project and which was in line with the Agency's ambitions for the project. Thus, when ESA presented the spacecraft to the press in April 2003, Dr David Southwood, ESA's director of science described the development paradigm for SMART–1 as "faster, better, smarter".

The Outline of A Truly Industrial Approach to Spacecraft Development

Thus, SMART–1 was not developed within the "skunk works" paradigm but rather a "light" version of traditional system management methodology pioneered in the development of ICBM's in the United States. Tight customer oversight of the supplier was used to provide a measure of assurance of low risk. However, ESA kept a comparatively (to other space science projects within ESA) lean staff of approximately 8 persons for day-to-day monitoring of us as the supplier. The monitoring staff consisted mainly of highly skilled technical specialists but also experts on management, project control and contractual aspects. For major project reviews the Customer used its normal level of resources with about 40 specialists spending 4–6 weeks examining every technical aspect of the project.

The contract type, cost-plus-incentive-fee (even with a negative fee!), was a way of keeping cost low (the risk to the supplier of developing a brand-new spacecraft with much new technology was not slapped on the price), but it also required much more detailed reporting of man-hours and other expenditures than for a fixed price contract.

The organization within the Swedish Space Corporation that developed SMART–1 was the Space Systems Division based at the company's engineering center in Solna, a suburb of the capitol Stockholm. This division has a total staff of 75 persons so the development of SMART–1 was a major task and indeed a difficult one especially in the early parts of the project when our previous working style had to be changed.

However, some choices of technology and methods were worked out with the Customer early in the project that helped considerably in meeting the schedule without losing the assurance of limited risk.

1. Without trying to flatter ESA, *a superbly competent customer* helps any supplier, and it certainly helped a small company like the Swedish Space Corporation.
2. *Commercial-off-the-shelf items from non-aerospace industry* were modified for space use or used as-is, *i.e.,* the CAN data bus developed in the automotive industry and a commercial real-time operating system. These items have been developed for commercial use by injecting massive amounts of human resources that is hard to match in the space industry.
3. Since a very large fraction of the spacecraft cost, perhaps 25 percent, can be related to software development, the most efficient developments methods available had to be used. These can be found in such fields as the mobile telecom industry where the requirements for short "time-to-market" for new products are extreme due to the cut-throat competition. Although so-called *automatic code generation* is not entirely new to the space business, it had not been used systematically in ESA programs. In SMART–1 we used this in the development of the attitude control software, the fault detection isolation and recovery software, and high-fidelity simulators of the spacecraft.
4. *Standard software building blocks for spacecraft basic functions* that were developed previously under ESA leadership were used and removed the need not re-invent them. In this way and by using commercial software building blocks (such as operating system) software development could be concentrated on the tasks specific to the SMART–1 mission.
5. *Standardized logic circuit designs for implementing the international telemetry and telecommand standard* is available through the efforts of ESA, both as ready-made circuits and as code for programming so-called gate arrays—chips that can be programmed to a certain task, for example to be a microprocessor.

6. The modern IT and telecom industry has created an extremely *competent cadre of free-lance software engineers* used to working in an environment where "time-to-market" and an industrial working style are primary values. This talent pool was tapped for SMART–1.

In five of the examples above one can see *the outline of a truly industrial approach to spacecraft development, i.e.,* the widespread use of standard, well-tested building blocks permitting the developer to concentrate on product-specific work. ESA's role in providing standard building blocks is reminiscent of the role of NACA in early U.S. aeronautics when this organization provided basic design standards such as airfoil profiles to the budding aeronautical industry.

This is no revolutionary thought, but it needs to be applied systematically. In SMART–1 we tried to do this and we intend to continue along this approach. For a small company that cannot re-invent everything, this is the only way forward.

One might say that space technology needs to "spin on" terrestrial and non-aerospace technology in order to be able to provide more "spin off", *i.e.,* technology that is spurred to perfection by the forbidding design environment that a space mission provides.

Concluding Remarks

We are indeed proud of our product, excited about working with ESA in advancing the state-of-the-art of astronautics and very flattered by the opportunity to share our experience with this distinguished deliberating body.

Senator BROWNBACK. Thank you. I look forward to talking with you more, because what you are describing is something that a number of you have talked about of a different architecture for our space program and I want to pursue that with you.

Dr. Logsdon, thank you very much for joining us today. I want to advise you too, we've got a vote that was just recently called, and in a little under 5 minutes, I will put the Committee in recess and so the next two, I'll come back as quick as I can and we'll continue with the testimony at that time, but I think we can get your testimony in.

STATEMENT OF JOHN M. LOGSDON, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, THE GEORGE WASHINGTON UNIVERSITY

Dr. LOGSDON. Thank you, Mr. Chairman, for providing the opportunity to reflect on the character of space exploration programs around the world. I will focus in my testimony on the explorations plans of Japan and India. However, I was in Europe less than 2 weeks ago, and if time permits, I have some remarks to make about what I found in talking to space leaders there.

As you said in your opening statement, our initial forays in human exploration beyond Earth orbit were a product of the cold war. Forty years later, the Cold War is thankfully behind us. We have no need as a nation to demonstrate our technological and organizational might through dramatic space achievements carried out unilaterally. In the three decades since Apollo, the solar system has become open for exploration to other countries around the world. Among these countries are Japan and India.

Almost a decade ago, Japan set out a long range vision for space development. That vision anticipated that some time after 2010 there would be an international lunar base with Japan as a key participant. In pursuit of this vision, Japan has launched several exploratory spacecraft to Mars and to a comet, and is preparing several more for launch. Awaiting launch is a Lunar-A mission, which will send two small penetrators into the lunar surface for seismological research, and SELENE, which will be the heaviest spacecraft to orbit the moon since the days of Apollo. The SELENE mission will focus on the origins and evolution of the Earth's nearest neighbor. Projected launch date for Lunar A is later this year or early in 2005, SELENE, the following 12 months. But in reality, both missions have been delayed several times in the past and additional delays are probable.

Japan has on the planning boards a mission to Venus and is a major partner with the European Space Agency in a mission to Mercury called Beppi-Colombo. So indeed, Japan has ambitious plans for solar system exploration. But the reality is that Japan's space program right now is pretty much on hold following several major spacecraft failures and then a major launch failure last November. This came just as Japan was reorganizing its space efforts into a new Japanese aerospace exploration agency called JAXA.

Until the short-term problems of assuring mission success are addressed and again the confidence of the Japanese Government, I think Japan will not be able to move forward with its exploration plans.

Last year on Indian independence day, which is August 15, Indian Prime Minister Vajpayeeon announced that India in 2007 would send its first mission to the moon, to be named Chandrayaan–1. This spacecraft is going to spend 2 years orbiting the moon 60 miles above its surface. India has had an active space program for over 30 years, developed its own launch vehicles to access both low-Earth orbit and geosynchronous orbit. Its space program to date has been focused on contributions to Indian development and economic growth.

But now India appears poised to go beyond an Earth-oriented space program to join other nations in exploring the solar system. Visiting the Indian launch site last October, Indian President Abdul Kalam, himself a former space engineer, told the assembled workers, "the exploration of the moon through Chandrayaan will electrify the whole country, particularly young scientists and children. I am sure the moon mission is just a start toward further planetary explorations."

It's worth noting that India has invited the international scientific community to participate in the mission. India has received some 25 proposals from such participation from scientists in the United States, Canada, Israel, and Europe. Clearly investigators from other countries want to ride aboard India's first exploration mission.

With your permission, I will take a couple of minutes to talk about Europe. Europe, first of all, is a very active player already in solar system explorations. SMART–1 is just one of several European missions going to the planets and a very ambitious mission called Rosetta is going on a 10-year journey to a comet. Europe for the past couple of years has been studying through a program called Aurora a human mission to Mars in the 2030 timeframe; this however is only a study program. The plan was to begin to prepare in 2005 and make major investments after 2010.

These exploratory missions have been taking second priority within Europe and within the European Space Agency to an emerging focus on how space capabilities can contribute to the development of Europe as an economic, political, and cultural entity with a focus on Earth-oriented space missions like Earth observation, and navigation and timing.

President Bush's proposed U.S. Vision for Space Exploration poses a Direct Challenge to stated European space ambitions. Europe is going to be faced with a choice with limited resources of whether to proceed on its current path or become a major partner in U.S.-led exploration of the moon. The director general of ESA was quoted after President Bush's speech as saying, I dreamed of the day when the President of Europe would come to ESA headquarters and make a similar policy declaration. In response, a new team at ESA is developing over the coming months, a new approach to space exploration, so there is an action/reaction phenomenon here.

Space exploration is no longer an arena for unilateral display of national power. Exploring the solar system has really become a truly global enterprise. I hope today's testimony has underlined the reality that if the United States public through its elected representatives chooses not to accept some version of the President's vision and make it a national vision for space exploration—which I believe would be a poor choice, by the way—other countries in coming decades will assume exploratory leadership. Writing to the White House in late 1971 to make the case that the U.S. then should not choose to end its program of human space flight, NASA Administrator James Fletcher argued, "man has learned to fly in space and man will continue to fly in space. The United States cannot forego its responsibility to have a part in manned space flight. For the United States not to be in space while others do have men in space is unthinkable and a position which America cannot accept."

I would change one word in Dr. Fletcher's argument. Rather than "cannot," I would say, "should not." We can indeed make as a society the decision that the benefits of human space flight are outweighed by its costs and risks and choose not to explore. To me, that would be a sad choice. Thank you.

[The prepared statement of Dr. Logsdon follows:]

PREPARED STATEMENT OF JOHN M. LOGSDON, DIRECTOR, SPACE POLICY INSTITUTE, ELLIOTT SCHOOL OF INTERNATIONAL AFFAIRS, THE GEORGE WASHINGTON UNIVERSITY

Thank you, Mr. Chairman, for providing an opportunity to reflect on the character of space exploration programs around the world. I will focus in my testimony on the exploration plans of Japan and India. However, less than two weeks ago I was in Europe discussing European exploration plans with space leaders there, and so I will also add a few words on my perceptions of what I heard there.

Between July 1969 and December 1972, twelve American astronauts walked on the surface of the moon. The Apollo program will in historical terms be remembered as the beginning of human exploration of the solar system, and the plaque attached to the Apollo 11 lunar module Eagle says "we came in peace for all mankind." The reality was rather different, as you well know. Sending Americans to the moon was "part of the battle along the fluid front of the Cold War," to quote the recommendation that President John F. Kennedy approved in May 1961 to initiate the lunar landing program.

More than forty years later, the Cold War is thankfully well behind us. We have no need as a nation to demonstrate our technological and organizational might through dramatic space achievements carried out unilaterally. In the three decades since Apollo, the solar system has become open for exploration not only to the United States and its superpower rival the Soviet Union, but to other countries around the globe. Either in cooperation with one of those space superpowers or on missions of their own, many countries around the world have made robotic exploration of the solar system a high priority in their space efforts.

Among those nations are Japan and India. Almost a decade ago, in its "Long Term Vision for Space Development," the Japanese government set out as a basic goal a philosophy that might well be adopted by all space faring countries: to "enable access to the vastness of space and use the infinite potential of space as the common property of mankind, thereby making a full and effective contribution to the enduring prosperity of all inhabitants on earth." That Vision anticipated sometime after 2010 there would be an international lunar base, with Japan as a key participant.

In pursuit of its Vision, Japan has launched several exploratory spacecraft and is preparing several more for launch to the moon. Japan's Nozomi spacecraft was launched toward Mars in July 1998, and arrived there at the end of 2003, after a journey fraught with technical difficulties. A final spacecraft malfunction kept Nozomi from entering Mars orbit. In May of last year Japan launched the Hayabusha (MUSES–C) mission, which will rendezvous with an earth-crossing asteroid in 2005 and return a sample of that body to Earth in 2007.

Awaiting launch are the Lunar-A mission, which will send two small penetrators into the lunar surface for seismological research, and SELENE, which will be the heaviest spacecraft to orbit the moon since the days of Apollo. The SELENE mission will focus on the origins and evolution of the Earth's nearest neighbor. Projected launch date for Lunar A is this year or early in 2005; SELENE, the following twelve months. Both missions have been delayed several times in the past, and additional delays are probable.

In addition, Japan is planning for a mission to Venus in the future and is a major partner in the European Space Agency Beppi-Colombo mission to Mercury.

So Japan indeed has ambitious plans for solar system exploration. But this discussion would not be complete without noting that Japan's space program is currently pretty much on hold, following several major spacecraft failures in 2002 and 2003 and then the launch failure of the sixth mission of Japan's H–IIA rocket in November 2003. These failures came at the time that Japan was reorganizing its space efforts into the new Japanese Aerospace Exploration Agency (JAXA). The combination of investigating the causes of these recent failures and putting into place measures to assure future mission success, together with the bureaucratic and cultural challenges of merging various previously separate Japanese space agencies into an integrated structure, are consuming the energies of Japanese space leaders. It is no exaggeration to say that Japan is undergoing a crisis of confidence in its space efforts. Until short-term problems are addressed, Japan will not be able to move forward with its exploration plans.

However, even given this rather gloomy situation, a standing-room only crowd attended a January 23 symposium on lunar exploration. And, as one of the leaders of Japanese space exploration, Yasunori Matogawa, recently wrote: "I feel my mind is getting stronger and stronger day by day that what could finally relieve ourselves would not come from anywhere but from our own vigorous willpower to carry on 'Exploration.' Its keyword is moon. I cannot help but believe these days that moon is the best-chosen target containing every possibility as to science, global ecology, resources development, safety and security." [1]

Last year, on Indian Independence Day, August 15, Indian Prime Minister Atal Bihari Vajpayeeon announced that India in 2007 would send its first mission to the moon, to be named Chandrayaan-1. The spacecraft will spend two years in orbit 60 miles above the lunar surface. India has had an active space program for over thirty years, and has developed its own launch vehicles to access both low Earth orbit and geosynchronous orbit. Its space program to date has been focused on contributions to Indian development and economic growth. For example, India operates a multi-satellite constellation of remote sensing satellites that provide world-class imagery of the subcontinent.

Now India appears poised to go beyond an Earth-oriented space program to join other nations in exploring the solar system. Visiting the Indian SHAR launch site on the eastern coast of the country last October, Indian President Dr. A. P. J. Abdul Kalam, himself a former space engineer, told the assembled workers that "The exploration of the moon through Chandrayaan will electrify the entire country, particularly young scientists and children. I am sure the moon mission is just a start towards further planetary explorations." He added that he could "visualise a scene, in the year 2021, when I will be 90 years old and visiting SHAR Space Port for boarding the space plane, so that I can reach another planet and return safely as

[1] The Planetary Society of Japan, April 14, 2004.

one of the passengers. I foresee the Satish Dhawan Space Centre, SHAR, to grow into an international spaceport with a capability of enabling launches and landings of the reusable launch vehicles."

India has invited international scientific participation in the Chandrayaan-1 mission. It has received some twenty-five proposals for such participation from scientists in the United States, Canada, Israel, and Europe. Clearly, investigators from many other countries want a ride aboard India's first exploration mission.

Let me add a few works on my views on Europe's plans for solar system exploration, based on conversations during a recent trip to Paris. First of all, Europe is already an active player in robotic exploration in the solar system, with its Mars Express mission in orbit around Mars, the Huygens spacecraft carried to Saturn along with the U.S. Cassini craft scheduled to land on Saturn's moon Titan early next year, Smart-1 on the way to the moon, and the Rosetta spacecraft started on its ten-year journey to rendezvous with a comet. More robotic missions are planned.

For the past several year, the European Space Agency (ESA) has been studying, through a program called Aurora, a human mission to Mars in the 2030 time frame. This was only a study program; the plan was to begin a preparatory phase only in 2005, with any major investments in human exploration well after 2010. Within ESA, a second study group last year proposed setting as a European goal establishing a base on the moon. That was a slightly faster paced program, with a goal of a permanent European presence on the moon by 2025. This second plan did not receive the support of the ESA leadership.

However, these exploratory missions and studies in recent years have been taking second priority to an emerging focus on how space capabilities can contribute to the development of Europe as an economic, political, and cultural entity, with a focus on Earth-oriented space missions in Earth observation, navigation and timing, and perhaps broadband communications and military uses.

President Bush's proposed U.S. Vision for Space Exploration, with its stated intention of inviting other countries to join "a journey, not a race," poses a direct challenge to stated European space ambitions. If the Congress gives the go ahead to the initial steps in achieving this vision—and I believe that it should—Europe will be faced with the choice, with limited resources available for space programs, of whether to proceed on its current path or become a major partner in U.S.-led exploration of the solar system. I understand that the Director General of ESA, Jean-Jacques Dordain, was invited to be here today but rather is in Russia awaiting the return of ESA astronaut Andre Kuipers from his brief stay on the International Space Station. Referring to President Bush's January 14 speech on space exploration, Dr. Dordain has been quoted recently as saying that "dreamed of the day when the President of Europe would come to ESA headquarters and make a similar policy declaration." A new ESA team is just beginning to plan how best to respond to the anticipated NASA invitation to participate.

Space exploration is no longer—indeed has not been for more than thirty years—an arena for unilateral display of national power. As my testimony and that of the others appearing before you today has shown, exploring the solar system has become a truly global enterprise.

Last year I had the privilege of serving as a member of the Columbia Accident Investigation Board. The Board's August 2003 report was explicit in laying out the negative consequences of the lack of a compelling vision for human spaceflight, and characterized that lack as "a failure of national leadership." To its credit, the Bush administration has responded to that criticism with what must be characterized in its essence as a "compelling vision" of a human-robotic partnership for the exploration of our solar system. There is an understandable focus in the Congress on the short-term implications of the proposed vision. I hope that the basic principle put forth by the President—that it is in the Nation's interest, now and for future generations, to take the leading role in extending human activity and presence into the solar system, is not lost in this shorter term focus.

I also hope that today's testimony has helped underline the reality that if the United States public through its elected representatives chooses not to accept the President's vision and make it a "National Vision for Space Exploration," other countries in coming decades will assume that exploratory leadership. Writing to the White House in late 1971 to make the case that the United States should not choose to end its program of human space flight, NASA Administrator James Fletcher argued "Man has learned to fly in space, and man will continue to fly in space. . . . The United States cannot forgo its responsibility—to itself and to the free world—to have a part in manned space flight. . .. For the U.S. not to be in space, while others do have men in space, is unthinkable, and a position which America cannot accept."

I would change one word in Dr. Fletcher's argument. Rather than "cannot" I would say "should not." We can indeed make as a society the decision that the benefits of human spaceflight are outweighed by its costs and risks. To me, that would be a sad choice.

John M. Logsdon is Director of the Space Policy Institute at George Washington University's Elliott School of International Affairs, where he is also Professor of Political Science and International Affairs. He holds a B.S. in Physics from Xavier University (1960) and a Ph.D. in Political Science from New York University (1970). Dr. Logsdon's research interests focus on the policy and historical aspects of U.S. and international space activities.

Dr. Logsdon is the author of *The Decision to Go to the Moon: Project Apollo and the National Interest* and is general editor of the eight-volume series *Exploring the Unknown: Selected Documents in the History of the U.S. Civil Space Program.* He has written numerous articles and reports on space policy and history. He is frequently consulted by the electronic and print media for his views on space issues.

Dr. Logsdon recently served as a member of the Columbia Accident Investigation Board. He is a former member of the NASA Advisory Council and a current member of the Commercial Space Transportation Advisory Committee of the Department of Transportation. He is a recipient of the NASA Distinguished Public Service and Public Service Medals and a Fellow of the American Institute of Aeronautics and Astronautics and of the American Association for the Advancement of Science.

Senator BROWNBACK. I'm going to put us in recess. It's probably going to be about 10–15 minutes and I'll be right back and we'll finish the panel. Thank you.

[Recess.]

Senator BROWNBACK. We're going to be reconvened. Thank you very much for getting back together and staying here with us.

Ms. Smith is a resident scholar, historian on space programs. It's always good to see you here in front of the Committee.

Ms. SMITH. Thank you very much, Senator.

Senator BROWNBACK. We look forward to your presentation.

STATEMENT OF MARCIA S. SMITH, SPECIALIST IN AEROSPACE AND TELECOMMUNICATIONS POLICY, CONGRESSIONAL RESEARCH SERVICE

Ms. SMITH. Thank you very much for inviting me to be here today. You asked that I set the broad international stage to talk about who is working in space these days, to talk about Europe, Russia, and India and how they could participate in the exploration initiative, and to identify issues in which the Committee might be interested.

The new initiative involves both human and robotic space flights to the moon, Mars, and other solar system destinations, as well as space-based observatories and other spacecraft to answer the question of whether there is life elsewhere in the universe. This broadly scoped program opens a wide range of opportunities for international participation. The number of countries involved in space is probably larger than most people realize. The list of launching countries includes the United States, Russia, Europe, China, Japan, India, and Israel. Like the United States, Russia, Europe, and Japan have sent spacecraft to the moon and beyond. Although the United States, Russia, and China are the only countries capable of launching people into space, astronauts and cosmonauts from 29 other countries have journeyed into space on American or Russian spacecraft. Many countries have their own communications or remote-sensing satellites, and virtually every country in the world uses satellites.

Dr. Logsdon has already discussed India and Europe, so I would like to take my time to talk about the Russian space program and then to talk about some of the issues that I've identified in my written statement. The Soviet Union, of course, has a very long and well-established space program dating back to the very earliest days. The Soviet Union accomplished many space firsts, including launching the first satellite, Sputnik, in 1957, launching the first man into space, Yuri Gagarin, in 1961, launching the world's first space station, Salyut 1 in 1971, and many other space firsts.

But during the 1960s, the era of the moon race, they were not about to develop a Saturn V-class launch vehicle and were not able to send cosmonauts to the moon. Instead, they focused their attention on Earth orbit, and over the next several decades, launched seven successful space stations, the best known of which is Mir. Mir has now been deorbited, but it did host cosmonaut crews for many years, including 10 years in which the Space Station was permanently occupied.

In the 1980s, the Soviets finally did build that Saturn V-class launch vehicle that they had wanted, and it's called Energia, and they also developed their own version of a reusable space shuttle, which they called Buran. However, after the collapse of the Soviet Union, the Russian Government decided to discontinue both of those programs and the budget for space activities was sharply curtailed. Yuri Koptev, who headed the Russian Space Agency from 1992 when it was created until last month, often said that the Russian space budget was about one-tenth of what it had been under the Soviet Government.

The Russian space program today is sharply constrained by its funding, but it is still very interested in the types of objectives laid out in President Bush's exploration initiative. They often speak about their own plans to send people to the moon.

In terms of their potential participation in a U.S.-led exploration initiative, they have much to offer. They have extensive experience in human space flight. They had one cosmonaut who stayed in space continuously for 14½ months. They have extensive launch vehicle capabilities. They are the only country that has operated nuclear reactors in space. The United States has launched only one nuclear reactor in 1965, it was a test reactor, but the Soviets used them in a program called Radar Ocean Reconnaissance Satellites.

They do have operational experience, both the pros and the cons. They ended up discontinuing that program because of three instances in which radioactive material either returned to Earth or almost returned to Earth. They also launched a series of biosatellite missions called Bion, in which NASA might be interested, although NASA's participation in Bion missions was controversial after one of the monkey subjects on the flight died after a post-flight examination.

But Russia is, of course, a very strong partner with the United States today and the International Space Station program, and I'll be talking about that a little bit later during the issues, but they clearly have a very mature space program, and except for their funding constraints, could play a very prominent role in such an exploration initiative.

The exploration initiative is still in its earliest definition stages and is likely to take decades to complete. It is difficult to predict at this early stage what issues will arise as it is carried out. Three broad issues, however, may be of interest to the Committee at this early date. What countries do we want to include and will they want to join? Where to draw the line between cooperation and dependence? And whether it is timely to review relevant U.N. space treaties and principles.

Several factors weigh in decisions about whom to invite to join international projects. These will include not only who can offer needed capabilities and funding, but political relationships. In a program such as this likely to span several decades, the latter can be particularly complicated. One question that many people are asking is whether China should be invited, and I know that Mr. Oberg is going to speak about that in a moment. This Committee may wish to consider the advantages and disadvantages of having China as a partner or as a competitor.

Many factors will also play in who will accept the invitation. For all of the successes of U.S.-led international space cooperation over the past 46 years, there have been strains as well. In any international space endeavor, compromises and adjustments must be made. The United States has demonstrated flexibility when partners have not been able to fulfill their promises and others have had to adjust to changes in U.S. plans.

The International Space Station is a prime example of both. Only our partners themselves can say whether they view ISS as a positive or a negative experience, but it necessarily will factor into their judgments about the current offer.

Another factor is what role they would play in setting the goals and objectives of the exploration initiative. So far, the message is that they are being invited only to help, quote, achieve this set of American U.S. objectives, unquote, as NASA Administrator O'Keefe has said. Whether they will want to participate under that condition or choose other international arrangements instead is not clear. With a wider variety of international cooperative opportunities available today, potential partners might want a stronger voice in deciding what is to be done and how to have a shared vision, not just a U.S. vision.

A second issue is the extent to which U.S. space activities are becoming dependent on other countries, notably Russia. Historically, NASA established cooperative programs in a manner such that other countries were not in the critical path, that is, the program could be accomplished even if the foreign partner did not fulfill its obligations.

The new plan laid out by the President and NASA takes the opposite approach, intentionally deciding to make U.S. human access to space dependent on Russia during a 4-year period between the anticipated retirement of the Shuttle in 2010 and the availability of the crew exploration vehicle in 2014.

There is a difference between the emergency situation today, where Russia is providing access to the Space Station because of the Columbia tragedy, and an intentional decision to suspend NASA's ability to launch astronauts into space with the hope that the political relationship with Russia remains stable and an agreement can be negotiated to enable U.S. astronauts to continue working aboard ISS.

In this sense, the President's decision could be interpreted as forgoing assured human access to space. To the extent that decision could create a condition where U.S. astronauts might not be able to work aboard ISS, Congress may choose to explore its implications.

Finally, the United States is a party to four U.N. treaties that regulate space activities. It is not a party to a fifth, the Moon Agreement, which focuses on exploitation of the moon. Issues raised by these treaties may become more prominent as prospects for activities such as mining on the moon come closer to reality. A review of the space treaties and associated U.N. principles that could affect the exploration initiative may be in order.

The exploration initiative offers the United States an opportunity to affirm its historical and fostering international cooperation in space. The key will be whether we can adapt to the changed landscape of cooperative possibilities and continue to lead the world in the peaceful exploration of space.

Thank you, and I'd be happy to answer any questions.

[The prepared statement of Ms. Smith follows:]

PREPARED STATEMENT OF MARCIA S. SMITH, SPECIALIST IN AEROSPACE AND TELECOMMUNICATIONS POLICY, CONGRESSIONAL RESEARCH SERVICE

"Potential International Cooperation in NASA's New Exploration Initiative"

Mr. Chairman, members of the Committee, thank you for inviting me here today to testify about potential international cooperation in President Bush's exploration initiative. You asked that I provide an overview of the international space setting, to provide information about the roles that Europe, Russia, and India might play, and to raise related issues that might be of interest to the Committee.

The New Exploration Initiative

On January 14, 2004, President George W. Bush made a major space policy address in which he directed NASA to focus its activities on returning humans to the Moon by 2020 and someday sending them to Mars and "worlds beyond." The President invited other countries to participate, saying—

> We'll invite other nations to share the challenges and opportunities of this new era of discovery. The vision I outline here is a journey, not a race. And I call on other nations to join us on this journey, in the spirit of cooperation and friendship.

The International Space Setting

The President's exploration initiative involves both human and robotic space flights to the Moon, Mars, and "worlds beyond," as well as space-based observatories and other spacecraft to answer the question of whether there is life elsewhere in the universe. This broadly scoped exploration program opens a wide range of opportunities for international participation.

The number of countries involved in space activities is probably larger than most people realize. The list of "launching countries"—those that have their own launch vehicles and launch sites—includes the United States, Russia, Europe, China, Japan, India, and Israel. Like the United States, Russia, Europe, and Japan have sent spacecraft to the Moon and beyond (see Appendix 1).

Although the United States, Russia, and China are the only countries capable of launching people into space, astronauts and cosmonauts from 29 other countries have journeyed into space on American or Russian spacecraft.[1] Many countries have

[1] Afghanistan, Austria, Belgium, Bulgaria, Canada, Cuba, Czechoslovakia, France, Germany, Hungary, India, Israel, Italy, Japan, Kazakhstan, Mexico, Mongolia, the Netherlands, Poland,
Continued

their own communications or remote sensing satellites.[2] Virtually every country in the world *uses* satellites, primarily for communications, weather, navigation, and remote sensing.

NASA's authority to conduct international space activities is codified in Section 205 of the 1958 National Aeronautics and Space Act, which created NASA. Since that time, the agency has engaged in thousands of cooperative arrangements ranging from the exchange of data, to training scientists how to interpret remote sensing imagery, to foreign experiments on U.S. satellites and U.S. experiments on foreign satellites, to joint development of spacecraft, to construction of the International Space Station (ISS). Cooperation has been undertaken not only with U.S. allies, but with our rivals as well. Even at the height of U.S.-Soviet space competition in the early days of the Space Age, the two countries also worked together—at the United Nations through the Committee on Peaceful Uses of Outer Space, and through bilateral cooperative agreements as early as 1962.

While the number of potential partners for the new exploration initiative is large, it is likely that attention will focus first on countries with whom the United States has traditionally cooperated in large space endeavors such as ISS (which involves Canada, Europe, Russia, and Japan), and those with the ability to launch spacecraft. You asked that I focus my remarks on the potential roles that Europe, Russia, and India could play.

Europe

Brief Overview. European countries conduct space activities in a number of ways. Some countries, such as France, Germany, and Italy have substantial national space programs, and may invite international cooperation in those activities on a bi-or multi-lateral basis. Other European space activities are conducted under the aegis of the European Space Agency (ESA). ESA currently has 15 members: Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom. Some of ESA's programs are mandatory (all members must contribute to them) and others are optional (countries can choose whether or not to participate). Europe's participation in the ISS program is primarily through ESA, where it is an optional program. Eleven ESA members participate.[3] (The United States and Italy also have a separate bilateral agreement covering certain hardware provided by Italy.) ESA and the European Union (EU)[4] are working closely together today, and in January 2004, the European Parliament adopted a "Resolution on the Action Plan for Implementing the European Space Policy." ESA and the EU are jointly sponsoring the development of the Galileo navigation satellite system, and are encouraging other countries to join them in that program.

ESA developed the Ariane launch vehicle; its first launch was in 1979. Ariane launches are conducted by the French company, Arianespace, from Kourou, French Guiana, on the northern coast of South America. ESA also is developing a smaller launch vehicle, Vega, and has a cooperative agreement with Russia to launch Russia's Soyuz launch vehicle from Kourou. Arianespace is often cited as being the dominant provider of commercial space launch services in the world, but the downturn in the commercial space market has affected Arianespace along with other commercial launch services companies. Consequently, ESA adopted a European Guaranteed Access to Space (EGAS) program that will provide 960 million euros to Arianespace through 2009.

Astronauts from several European countries have flown into space as representatives of ESA or their own countries on Russian or American spacecraft. In the late 1980s, ESA announced a plan to develop its own human space flight vehicle, Hermes, but the program was terminated because of cost considerations.

Romania, Saudi Arabia, Slovakia, South Africa, Spain, Switzerland, Syria, Ukraine, United Kingdom, and Vietnam.

[2] A comprehensive list is outside the scope of this testimony, but, in addition to the launching countries, includes Algeria, Argentina, Australia, Brazil, Canada, Egypt, Indonesia, Nigeria, Malaysia, Morocco, Pakistan, Philippines, Saudi Arabia, South Africa, South Korea, Taiwan, Turkey, and the United Arab Emirates.

[3] Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland and the United Kingdom are signatories to the ISS Intergovernmental Agreement. The United Kingdom does not provide funding for the ISS program, however, so in some case the number of participants is cited as 10.

[4] The EU members are Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Ten more countries will join the EU in May 2004: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, and Slovenia. Additional countries have applications pending.

ESA and individual European countries have built and launched a large number of spacecraft including space-based observatories and other scientific satellites (including some to destinations beyond the Moon, see Appendix 1), as well as satellites for communications, weather, and remote sensing. They are primarily for civilian purposes, but some of the non-ESA satellites are military.

ESA's 2003 budget was 2.7 billion euros ($3.1 billion using today's exchange rate).

Current Interest in Space Exploration. ESA initiated the Aurora program in 2001 to formulate and implement "a European long-term plan for the robotic and human exploration of solar system bodies holding promise for traces of life."[5] The Aurora program envisions an international human mission to Mars by 2025. ESA's Mars Express spacecraft is now in orbit around Mars, and SMART–1 is currently en route to the Moon.

The European reaction to President Bush's speech was generally supportive, though cautionary about obtaining the required resources to conduct such a program. In a joint ESA–EU statement, ESA's Director General, Jean-Jacques Dordain, stated that "The important point in looking at the American vision is that space is an international field. A coherent European Space Policy does not make any sense if not grounded in the larger global context." He added that "Unlike in the days of the Cold War, getting to the moon and Mars is not about proving one's superiority over a political enemy. It is about all of us, around the world, working together for the common benefit."[6]

Potential Role in the Exploration Initiative. European countries individually and through ESA could participate in the exploration initiative at many levels, including providing launch capacity, building and operating robotic and human spacecraft, providing scientific instruments, and providing astronauts. The United States has a long history of cooperation with ESA and individual European countries on scientific and human space flight programs, including the space shuttle and the International Space Station.

Russia

Brief Overview. The Soviet Union launched the first satellite into space (Sputnik, 1957), the first person into space (Yuri Gagarin, 1961), the first space station (Salyut 1, in 1971) and achieved many other space "firsts." The Soviets conducted a broad space program similar to that of the United States, with spacecraft orbiting the Earth for scientific or applications purposes (military and civilian), probes sent to the Moon and Mars, and a robust human space flight program. Since 1967, Soyuz spacecraft have been used to take cosmonauts into space. The Soyuz has been upgraded several times, and is currently designated Soyuz TMA. The Soviets were not able to develop a Saturn V-class launch vehicle capable of sending cosmonauts to the Moon during the 1960s, and concentrated instead on activities in Earth orbit, operating seven space stations from 1971–2001. The best known of these is the Mir space station complex (1986–2001). It was permanently occupied by cosmonauts from 1989–1999, and intermittently occupied in other years. Mir was deorbited in 2001. Crews sometimes included individuals from other countries, including the United States.

Russia developed a space shuttle similar (but not identical) to the U.S. shuttle. Called Buran, it was launched only once, in 1988, without a crew. By this time, the Soviets had succeeded in developing a Saturn V-class launch vehicle, called Energia. Energia was launched only twice, however (including the Buran flight).

Following the collapse of the Soviet Union in 1991, Russia sharply reduced funding for space activities. The Energia and Buran programs were discontinued. Yuri Koptev, who headed the Russian space agency from its founding in 1992 until March 2004, often said that the Russian space budget was approximately one-tenth of its level under the Soviet government. According to Mr. Koptev, the 2004 budget for Russian civilian space activities is $526 million.[7]

Russia restructured its space program in March 2004. The Russian Aviation and Space Agency, which Mr. Koptev headed, was split into two, with aviation programs transferred to one agency, and space programs placed in a new Federal Space Agency subordinate to the Ministry of Industry and Energy. Mr. Koptev was replaced by Col. Gen. Anatoly Perminov, who previously headed Russia's military space pro-

[5] See ESA's Aurora website: *www.esa.int/SPECIALS/Aurora/ESA9LZPV16D__0.html*.

[6] Europe's United Response to U.S. Space Plans. European Commission press release, February 18, 2004.

[7] Russian Aerospace Agency to Have $632 Million for 2004 Air, Space Craft Programs. Moscow Agentstvo Voyennykh Novostey WWW-Text in English, 1252 GMT, 29 Jan 04 (via Foreign Broadcast Information Service, hereafter FBIS).

gram. What impact, if any, these changes will have on U.S.-Russian space cooperation is not known at this time.

The United States and the Soviet Union/Russia have cooperated in space activities since the early 1960s in space science and human space flight activities. The two countries conducted the Apollo-Soyuz Test Project in 1975 where a U.S. Apollo spacecraft docked with a Russia Soyuz spacecraft for two days of joint experiments. From 1995–1998, seven U.S. astronauts remained on Russia's space station *Mir* for long duration (several month) missions, Russian cosmonauts flew on the U.S. space shuttle seven times, and nine space shuttle missions docked with *Mir* to exchange crews and deliver supplies. Russia joined the U.S.-led International Space Station program in 1993 and Russians and Americans now routinely fly on each other's space vehicles and share duties on space station crews. Russia is currently providing the only access to the space station for crews and cargo while the U.S. space shuttle is grounded.

Current Interest in Space Exploration. Although the Soviets were never able to send cosmonauts to the Moon, and funding for space activities declined dramatically after the collapse of the Soviet Union, Russian government and industry space officials continue to express strong interest in human exploration missions. At an international space conference in the fall of 2003, then-director of the Russian space agency, Yuri Koptev, outlined long-term Russian plans, including permanent human bases on the Moon and Mars. He added that "we believe that an organization similar to the one for the ISS should be the basis for implementation of such ambitious projects."[8]

Following President Bush's speech, however, Mr. Koptev expressed skepticism, saying that he thought it was "a tool in the current election campaign"[9] and said "It is necessary to drop emotions in order to see what real benefit people can derive from visiting these planets."[10] Mr. Koptev's successor, Gen. Perminov, expressed a more favorable view, saying that he supports President Bush's initiative, and wants more international cooperation in Russian space activities overall.[11] On April 12, 2004, in celebration of Cosmonautics Day, Russian President Putin stopped short of embracing such plans, but said that space "was and remains an object of our national pride" and only by developing its space industry can "Russia claim leadership in the world." He added that the economic situation in Russia constrains the amount of funding available for space activities, but "I want you to know that everyone in the leadership of the country understands that space activities fall into the category of the most important things."[12]

Potential Role in the Exploration Initiative. The Russians could cooperate in the exploration initiative at many levels. They have a range of launch vehicles that are launched from three sites (Plesetsk, near the Arctic Circle; Svobodny, in eastern Siberia; and the Baikonur Cosmodrome, near the Aral Sea in Kazakhstan, which Russia leases from Kazakhstan). As noted, the heavy-lift Energia launch vehicle was discontinued, but possibly could be resurrected if sufficient funding were provided. If development of a new launch vehicle is required, Russian rocket engines could be used. Russia already builds the engines (RD–180s) for one of the U.S. launch vehicle families (Atlas).

Russia has extensive experience in long-duration human space flight. Three Russian cosmonauts have stayed in space continuously for one year or more; the longest mission was 14½ months. (The longest any American has remained in orbit continuously is 6½ months.) The Russians also launched a series of Bion biosatellite missions that carried animals for life sciences experiments. NASA cooperated with Russia on some of these missions,[13] and may be interested in using such free-flying spacecraft to augment research on the International Space Station.

Russia also has considerable experience with the use of nuclear reactors in space, an area in which NASA is interested. Russia is the only country to have used nuclear reactors operationally in space (the United States has launched only one test reactor into space, in 1965). They were developed to power Radar Ocean Reconnais-

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[8] Morring, Frank. Big Plans. Aviation Week & Space Technology, Oct. 13, 2003, p. 29.

[9] Russian Space Chief Calls U.S. Space Plans an [sic] Campaign 'Tool' for Bush. Moscow Agentstvo Voyennykh Novostey WWW-Test in English, 1052 GMT, 29 Jan 04 (via FBIS).

[10] Moscow ITAR–TASS in English, 1028 GMT, 17 Feb 04 (via FBIS).

[11] Pieson, Dmitry. Perminov Supports Moon/Mars Plans, International Cooperation. Aerospace Daily, 5 April 2004, p. 5.

[12] Russia: Putin Acknowledges Budget Problems in Space Exploration. Moscow, ITAR–TASS in English, 1730 GMT, 12 Apr 04 (via FBIS).

[13] NASA's participation in the last two Bion flights, Bion 11 and 12, in 1996–1997, was controversial, especially after a rhesus money used for the experiments on Bion 11 died during a post-flight examination. After an independent review, NASA suspended its participation in primate research on Bion 12.

sance satellites (RORSATs) beginning in 1967, but the Soviets terminated their use after three incidents (in 1978, 1983, and 1988) in which spacecraft malfunctions caused, or nearly caused, radioactive material to return to Earth. Russia has less experience than NASA with radioisotope thermal generators (RTGs), another type of nuclear power source for spacecraft, but today provides the plutonium used in U.S. RTGs.

Russia has launched many probes to the Moon, Venus, and Mars (see Appendix 1), and two to Halley's Comet. The most recent Russian Mars probes (Phobos 1 and 2, and Mars '96) involved extensive international cooperation

India

Brief Overview. India conducted its first launch in 1979, and typically launches once or twice a year. India has three launch vehicles: the ASLV for low-Earth orbits, the PSLV for polar orbits, and the new GSLV for launches to geostationary orbit. Launches are conducted from Sriharikota, an island off the southeast coast of India. India hopes to enter the commercial launch services market using the GSLV.

Most of India's satellites are test satellites related to the development of new or improved launch vehicles, or are for remote sensing. India also has purchased or built communications/weather satellites that are launched for India by foreign commercial space launch service providers. India's annual space budget is approximately $450 million.[14]

One Indian, Rakesh Sharma, has flown in space, on a Russian spacecraft in 1984.[15]

Current Interest in Exploration. In 2003, India announced plans to launch a robotic spacecraft to the Moon in 2007 and is inviting other countries to participate. India is offering to fly 10 kilogram payloads from interested countries for free. Canada, Germany, Russia, Israel, Europe, and the United States reportedly have expressed interest. The United States and India renewed cooperation in scientific areas, including space exploration, after the United States lifted sanctions imposed in 1998 following India's nuclear weapons tests.

The head of the Indian Space Research Organization (ISRO), G. Madhavan Nair, has stated that the robotic lunar probe, Chandrayaan-1, is only the first step in India's space exploration plans. India's President Kalam and Prime Minister Vajpayee also have made supportive statements not only about robotic missions, but about eventual human space flights to Mars.

Potential Role in the Exploration Initiative. India could offer launch services, and if its lunar probe is successful, that could open possibilities for other robotic missions.

Issues

The exploration initiative is still in its earliest definition stages and is likely to take decades to complete. It is difficult to predict at this early stage what issues will arise as it is carried out. Among those likely to require early attention are specific questions concerning how to prevent unwanted technology transfer while not impeding cooperation, and how to protect the U.S. industrial base while encouraging international participation. Today, however, I would like to focus on three broader issues: who will join us, the line between cooperation and dependence, and whether a review of the U.N. space treaties is needed.

Who Will Join Us? Many countries have aspirations to send human and robotic spacecraft to the Moon, Mars, and beyond. In virtually every discussion, the assumption is that these will be international undertakings because of their cost. While international projects are more difficult to manage, which may increase their total cost, the cost to each participant may be less than if the program were conducted by one nation alone. The President has invited international participation in a U.S.-led exploration initiative. The questions are what countries do we want to include, and will they want to join?

Several factors weigh in decisions about who to invite to join international projects. These include not only who can offer needed capabilities and funding, but political relationships. In a program such as this, likely to span several decades, the latter can be particularly complicated. Few would have expected in the 1980s that Russia would be a partner in ISS a decade later, and the only country capable of sending people and cargo to it today. Not surprisingly, in conjunction with the President's speech, NASA's first outreach was to its partners in the International Space

[14] Rohde, David. India's Lofty Ambitions in Space Meet Earthly Realities. New York Times, January 24, 2004, p. A3.

[15] NASA astronaut Kalpana Chawla, who perished aboard the space shuttle Columbia in 2003, was born and raised in India, but had become a U.S. citizen.

Station program, but the question on many minds is whether China will be included in the new initiative. At a press conference after President Bush's speech, NASA Administrator O'Keefe was asked that question. He responded that there is an opportunity to open that debate, but did not want to speculate on its outcome Congress may wish to consider the advantages and disadvantages of having China as a partner, or as a competitor, in the exploration initiative.

After we identify whom we want to invite, the question will be whether they will agree to join us. The United States has a rich history of international cooperation, and many countries have benefitted from it. We also have, by far, the most financial resources. NASA's budget is five times that of ESA and 30 times that of the Russian space agency. But for all of the successes of U.S.-led international cooperation, there have been strains as well. In any international space endeavor, compromises and adjustments must be made. The United States has demonstrated flexibility when partners have not been able to fulfill their promises, and others have had to adjust to changes in U.S. plans. The International Space Station is a prime example of both. As the leader of that project, though, there is a greater impact when the United States changes its plans, and there have been many throughout the past two decades. Now, the President's exploration initiative involves another major change, with termination of the space shuttle program as soon as space station construction is completed, and ending NASA's use of ISS by FY 2017. The President assured the ISS partners that the United States would fulfill its obligations, but it is not clear how that will be accomplished without the shuttle.

Only the partners themselves can answer the question of whether they view ISS as a positive or negative experience, but it necessarily will factor into their judgments about the current offer. Another factor is what role they would play in setting the goals and objectives of the exploration initiative. So far, the message is that they are being invited only to help "achieve this set of American, U.S. objectives," as NASA Administrator O'Keefe stated after the President's speech.

Whether they will want to participate under that condition, or look for other opportunities where they might be able to develop a shared vision, is not clear. With the end of the Cold War, and the emergence of more countries with launch capabilities, the United States can no longer assume that traditional partners like Europe, Japan, and Canada would necessarily choose to join with the United States, instead of Russia or China, for example.

How Dependent Should the U.S. Be on International Partners? Traditionally, NASA has established cooperative programs in a manner such that other countries were not in the "critical path"—that is the program could be accomplished even if the foreign partner did not fulfill its obligations. This policy began to change when Russia joined the space station program in 1993. Although Congress directed that Russian participation should "enhance and not enable" the space station,[16] the revised design was clearly dependent on Russia for life support, emergency crew return, attitude control, reboost, and other functions, especially in the early phases of space station construction. Today, because of the space shuttle *Columbia* accident, NASA is completely dependent on Russia for taking astronauts to and from the space station, and delivering cargo.

The situation today demonstrates the value of international cooperation, but also raises the question of whether the United States wants to put itself in the position of being dependent on other nations to execute its space activities. As noted, one of the two major U.S. launch vehicle families, Atlas, is dependent on engines designed and built in Russia. Under the President's initiative, U.S. access to the space station between 2010 (when the shuttle is retired) and 2014 (when the new Crew Exploration Vehicle is available) also would be dependent on Russia. While some view that as similar to the situation today, it would, in fact, be quite different. The reasons are too complex to discuss fully in this statement (see CRS Issue Brief IB93017), but briefly, today, there is an agreement in place where Russia is launching U.S. crews and cargo to ISS at no cost to NASA. It expires in 2006, however, and no agreement has been negotiated for 2010–2014. Russia could charge whatever price it wanted for those services, and if the Iran Nonproliferation Act is still in effect, it is not clear if NASA could pay. There also is a difference between the emergency situation today, necessitated by the *Columbia* tragedy, and an intentional decision to terminate NASA's ability to launch astronauts into space and hope that the political relationship with Russia remains stable and an agreement can be negotiated to enable U.S. astronauts to continue working aboard ISS. In this sense, the President's decision may be interpreted as forgoing "assured human access to space." To the extent the decision could create a condition where U.S. astronauts

[16] H. Rept. 103–273, to accompany H.R. 2491, the FY1994 VA–HUD–IA appropriations bill (P.L. 103–124).

might not be able to work aboard ISS, a facility being built largely at U.S. taxpayer expense, Congress may choose to explore its implications. More broadly, where to draw the line between cooperation and dependence might be an issue of congressional interest.

Are New International Treaties or Principles Needed? The United States is a party to four U.N. treaties that regulate space activities: the Outer Space Treaty, the Astronaut Rescue and Return Agreement, the Registration Convention, and the Liability Convention. None of the major space faring countries, including the United States, is a party to a fifth U.N. space treaty, the Moon Agreement, which focuses on exploitation of the Moon.[17] A brief synopsis of the five space treaties is included in Appendix 2. The U.N. also developed several legal principles for space activities, including Principles Relevant to the Use of Nuclear Power Sources in Outer Space, that could impact exploration plans.

Even before President Bush's announcement, some observers were suggesting that it was time to review the space treaties to determine if any changes or new agreements are needed to reflect the growing role of the private sector in space. The treaties were negotiated in an era when space programs were conducted by governments, not private entities. There is growing debate about whether or not the treaties preclude private property rights in space, for example. These issues have not been the subject of intense interest in recent years because the likelihood of any nation or company setting up mining operations, for example, on the Moon or other celestial bodies has seemed remote. With President Bush's announcement, however, that day may be drawing nearer, and a review of the space treaties may be in order.

Conclusion

As is often said, to be a leader, one must have followers. With the wider variety of international cooperative opportunities available today, potential partners might want a stronger voice in deciding what is to be done and how—to have a shared vision, not just a U.S. vision—and choose other international arrangements.

The United States still has by far the largest budget for civilian space activities, however. That fact, coupled with the large number of successful U.S.-led cooperative space endeavors over the past 46 years, may convince other countries to join us rather than establish partnerships of their own without U.S. involvement.

At the same time, questions may arise about whether the United States may be going too far in becoming dependent on other countries for human access to space. Choosing to make the U.S. human space flight program dependent on Russia for at least 4 years is a significant departure from past policy. While it may signal a broader attitude towards cooperation, the advantages and disadvantages of losing "assured human access to space" may be a timely topic for discussion.

The exploration initiative offers the United States an opportunity to affirm its historic role in fostering international cooperation in space. The key will be whether we can adapt to the changed landscape of cooperative possibilities, and continue to lead the world in the peaceful exploration of space.

APPENDIX 1: EUROPEAN, RUSSIAN, AND JAPANESE SPACECRAFT LAUNCHED TO THE MOON AND BEYOND

Spacecraft	Launch Year	Mission
		Europe
Helios 1 and 2	1974, 1976	German spacecraft, launched by NASA, to study the Sun.
Giotto	1985	ESA spacecraft, launched by ESA, that intercepted Halley's Comet in 1986.
Ulysses	1990	ESA spacecraft, launched by NASA, in polar orbit around the Sun.
Solar & Heliospheric Observatory (SOHO)	1995	ESA spacecraft, launched by NASA, at Sun-Earth L–1 Lagrange point for solar-terrestrial studies.

[17] The 10 countries that are parties to the Moon Agreement (meaning they have both signed and ratified it) are Australia, Austria, Chile, Kazakhstan, Mexico, Morocco, The Netherlands, Pakistan, Philippines, and Uruguay. Five others have signed it (France, Guatemala, India, Peru, and Romania), but have not ratified it, so are not bound by its provisions.

Spacecraft	Launch Year	Mission
Huygens	1997	ESA probe that is attached to the U.S. Cassini spacecraft, which will reach Saturn in July 2004. The probe will detach from Cassini and descend through the atmosphere of Titan, one of Saturn's moons.
Mars Express/Beagle 2	2003	ESA spacecraft, launched by Russia, that is in orbit around Mars. Contact with Beagle 2, a lander, was lost after it separated from Mars Express.
SMART–1	2003	ESA spacecraft, launched by ESA, that is enroute to the Moon. Due to reach lunar orbit in early 2005.
Rosetta	2004	ESA spacecraft, launched by ESA, that is scheduled to reach Comet 67P/Churyumov-Gerasimenko in 2014, enter orbit around it, and land a small spacecraft on its icy nucleus.
Soviet Union/Russia		
Luna 1–24	1959–1976	Series of spacecraft to impact, orbit, or land on the Moon, including two rovers (Lunokhod 1 and 2), and three robotic sample return missions (Luna 16, 20, and 24). Luna 2, in 1959 was first "landing" (impact) on Moon. Luna 3, also in 1959, sent back first pictures of the far side of the Moon. Luna 10, in 1966, was first spacecraft to orbit the Moon. Luna 16, in1970, was the first robotic sample return mission. Lunokhod 1 (Luna 17), in 1970, was first robotic lunar rover. This series experienced a mixture of successes and failures.
Zond 1–3	1962	Zond 1 went to Venus, but was not operating when it reached that planet. Zond 2 and 3 made fly-bys of Mars, but were not operating when they reached the planet.
Zond 4–8	1968–1970	Automated precursors for human trips to the Moon.
Mars 1–7	1960–1973	Contact with Mars 1 was lost before it reached the planet.. Mars 2 and 3 were orbiter/lander pairs. The orbiters were successful, the landers were not (both reached the surface, but only Mars 3 transmitted thereafter, and only for 20 seconds). Mars 4 and 5 were orbiters; Mars 6 and 7 were landers. Mars 5 was a success. Mars 4 and 7 missed the planet. Mars 6 transmitted during descent, but contact was lost before landing. Western analysts believe there were other Mars attempts that failed and were given generic Kosmos designations.
Phobos 1 and 2	1988	Intended to study Phobos, one of the moons of Mars, and Mars itself. Contact with Phobos 1 was lost before it reached Mars. Phobos 2 successfully orbited Mars and returned data, but contact was lost when it maneuvered to study Phobos.
Mars 96	1996	Failed attempt to send a spacecraft to Mars that had an orbiter, two small landers, and two surface penetrators. Spacecraft did not reach the correct orbit, and reentered Earth's atmosphere.
Zond 1, Venera 1–16	1961–1983	Series of probes to fly-by, orbit or land on Venus. Mixture of successes and failures. Venera 7, in 1970, made first successful landing on Venus. Venera 9, in 1975, was first spacecraft to transmit pictures from the surface of another planet. Venera 13 and 14, in 1982, used drills to obtain core sample for *in situ* chemical analysis. Venera 15 and 16, in 1983, carried side-looking radars to map Venus' surface from a polar orbit.
Vega 1 and 2	1984	Dropped off landers at Venus, then intercepted Halley's Comet in March 1986.
Japan		
Sakigake and Suisei	1985	Two spacecraft that studied Halley's Comet.
Muses A	1990	Engineering test for future lunar probes.
Nozmoni	1998	Failed attempt to orbit Mars.

APPENDIX 2: SYNOPSIS OF THE U.N. SPACE TREATIES

The United States is a party to the first four of the following treaties, which were developed through the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). It is not a party to the fifth, the Moon Agreement, nor are any other of the major spacefaring countries. The numbers of ratifications and signatures to these treaties shown below are current as of January 2003 (the most recent data available). The texts of the treaties, and the lists of signatories, ("States Parties") are available at *http://www.oosa.unvienna.org/SpaceLaw/spacelaw.htm.*

Treaty on Principles Governing Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies (the "Outer Space Treaty")

Entered into force 10 October 1967. 98 ratifications and 27 signatures.

- Exploration and use of outer space* shall be for the benefit of, and in the interests of, all countries and shall be province of all mankind.
- Outer space is free for exploration and use by all States and there shall be free access to all areas of celestial bodies.
- There shall be freedom of scientific investigation in outer space and States shall facilitate international cooperation in such investigations.
- Outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
- Nuclear weapons or other weapons of mass destruction shall not be placed in orbit or on celestial bodies or stationed in space in any other manner.
- The Moon and other celestial bodies shall be used exclusively for peaceful purposes.
- The establishment of military bases, installations or fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden; the use of military personnel for scientific research or other peaceful purposes is permitted.
- Astronauts shall be regarded as envoys of all mankind.
- States Parties are responsible for national space activities, whether undertaken by governmental or non-governmental (*e.g.,* private sector) entities; the activities of non-governmental entities require authorization and continuing supervision of the appropriate State Party.
- States Parties are internationally liable to other States Parties for damage caused by their space objects.
- Studies and exploration of outer space are to be conducted so as to avoid harmful contamination and adverse changes to the environment of Earth resulting from the introduction of extraterrestrial matter.
- All stations, installations, equipment and space vehicles on the Moon and other celestial bodies shall be open to representatives of other States Parties on a basis of reciprocity.

**Where "outer space" appears in this synopsis, the full phrase is "outer space, including the Moon and other celestial bodies." It was shortened here for brevity's sake.*

Agreement on the Rescue of Astronauts, Return of Astronauts, and Return of Objects Launched into Space (the "Astronaut Rescue and Return Agreement")

Entered into force 3 December 1968. 88 ratifications, 25 signatures, and 1 acceptance of rights and obligations.

- States Parties are to render humanitarian assistance to astronauts in distress or who have made an emergency or unintended landing on their territory, and to return the astronauts to the launching authority.
- States Parties are to return objects launched into outer space or their component parts to the launching authority if they land on their territory.

Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention")

Entered into force 1 September 1972. 82 ratification, 25 signatures, 2 acceptances of rights and obligations.

- Procedures are created for presenting and resolving claims for damages caused by space objects on the Earth, to aircraft, or to other space objects.
- The launching state is absolutely liable for damage caused on Earth's surface or to aircraft in flight; if the damage is caused elsewhere (*e.g.,* in space), the launching state is liable only if the damage is due to its fault or the fault of persons for whom it is responsible.

Convention on Registration of Objects Launched into Outer Space (the "Registration Convention")

Entered into force 15 September 1976. 44 ratifications, 4 signatures, and 2 acceptances of rights and obligations.

- States Parties are to maintain a national register of objects launched into space.
- States Parties must report certain information about the launch and payload to the United Nations as soon as practicable, and notify the U.N. when an object no longer is in orbit.

Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (the "Moon Agreement")

Entered into force 11 July 1984. 10 ratifications and 5 signatures.

- Exploration and use of the Moon shall be carried out for the benefit and in the interest of all countries, and due regard shall be paid to the interests of present and future generations and to the need to promote higher standards of living and conditions of economic and social progress and development in accordance with the U.N. charter.
- The Moon and its natural resources are the common heritage of mankind; neither the surface nor the subsurface nor any part thereof shall become property of any State, international intergovernmental or non-governmental organization, national organization or nongovernmental entity or of any natural person.
- States Parties shall undertake to establish an international regime to govern the exploitation of the Moon's natural resources as such exploitation is about to become feasible. The regime's purposes include the orderly and safe development of the Moon's natural resources, the rational management of those resources, the expansion of opportunities to use those resources, and an equitable sharing by all States Parties in the benefits derived from those resources, whereby the interests and needs of the developing countries, as well as the efforts of those countries which have contributed either directly or indirectly to the exploration of the Moon, shall be given special consideration.
- States Parties bear international responsibility for national activities on the Moon, whether by governmental or non-governmental entities. Activities of non-governmental entities must take place only under the authority and continuing supervision of the appropriate State Party.
- All space vehicles, equipment, facilities, etc. shall be open to other States Parties so all States Parties may assure themselves that activities of others are in conformance with this agreement. Procedures are established for resolving differences.

Senator BROWNBACK. Thank you. We sure appreciate that.

Mr. Oberg.

STATEMENT OF JAMES OBERG, AEROSPACE OPERATIONS CONSULTANT, SOARING HAWK PRODUCTIONS, INC.

Mr. OBERG. Again, Senator, thank you for the opportunity to come here and share some of our insights and experiences through the years, both individually and with many of the people and others have talked about. As a professional rocket scientist, I've worked 22 years at the Johnson Space Center, I've had the opportunity to learn real space operations and to judge other countries' reports against the hard engineering. That's been a good key to judge Russian reports back in the Soviet days when they had mysteries and they had things they left out, things that were partial truth, even things that were distortions. And it has been very useful in recent years to look at the Chinese program.

We're very close, as we know now, to the Chinese beginning what they call phase 3 of their space program. Phase 1 was the first artificial satellite, phase 2 the flight of Yang Liwei last October, and phase 3 in their explicit terms is the beginning of lunar exploration. They have a probe, they call it the Chang'e, and more specifically and recently, the Chang'e 1, which I think has some significance not being the only probe in the series, but perhaps just the first. That will go into lunar orbit as early as December 2006.

They have also shown with their human space flight last October that they are willing to spend a lot of money. The number given was more than $2 billion between the decision to go ahead with manned space flight and the very first flight. It's not $2 billion per flight, but it's a total $2 billion in investment. That's a lot of money, and even at Chinese wage levels, it shows a major commitment to that type of program.

They've also been very forthright, much more so than the Soviets in the early days of the space race, about the technology of the program and about their intentions and about the people involved in it, and this vast amount of information which they are releasing is of great value to us to analyze what they're doing, because we can see what they're releasing far more than what they can control. We can see things in their pictures that show the identity of certain hardware, we can make deductions from comments they make that other things must be true because of space engineering. This helps us see a whole lot into their program and gives us a great deal of confidence that some of our guesses and some of our predictions are relatively close.

They have said, and it looks like they are serious about being motivated to do space for a series of reasons. They intend to use the space challenge to create a high-tech capability, to create high technology, then to validate those capabilities in the ultimate testing ground of actual space flight, and having validated, to persuade the rest of the world that the technology is valid, that is, to enhance the credibility in the minds of Chinese and foreigners in their high technology across the board. It enhances their high technology commercially, it enhances their high technology weapons systems militarily, it provides multiple benefits, cash value to their country for having done space technology successfully and as successfully as they've carried it out, especially with the Shenzhou manned program.

In looking at some of the strengths of their program, in the interviews they've given and the comments they've made, I think one clear and very impressive achievement they have is their strategy of learning from the whole rest of the world, learning from the world all the activities in space in every other nation of the past history. Now, there are a lot of issues that some of their spacecraft are copies. Some of them are superficially copies. Some systems, such as the space suit they wear inside the Shenzhou capsule are obviously Chinese manufactured versions of the suit the Russians provided them with.

Others look similar, have similar functions, but most have been developed and tested entirely with Chinese engineering. But the strategy to basically learn, to basically not to repeat anybody else's mistakes in space—they made some of their own original mistakes, but only once or twice—but not to repeat things they've seen done wrong in other countries I think is a very powerful tool to let them do things they intend to do in the future. In fact, they are so good at learning from other people's experience, I wish we could learn from that strategy and I wish that in our own country and at NASA and other programs, they would pay more attention to the experience of other people as well as their own experience in the past. I think that's a drawback in our program.

The second major power, the second major strength in the Chinese program is demographic. They have been staffing up their program in the past 10 years, and have, as we now believe, more than 200,000 people in their industry with an average age somewhere in the low 30s. This is a team of people that are going to work together, have already solved problems together, and will keep solving problems together for decades to come.

Those were the major strengths in the Soviet program. They staffed up their program in a big rush at the beginning of the space age, they established communications, they established teams, they worked together, and it was the perfect way to build a space program as long as you assume that the workers live forever. They are now in the Soviet Union facing at least half of the workers that are left in the program will be replaced, they have to be replaced in coming years, because they're now, the average age in many Soviet space engineering areas is beyond the average life expectancy of the Russian male, and this is a serious challenge they have. The Chinese are just the opposite, the U.S. is somewhere in between.

There is a weakness that the Chinese have that may get in the way of some of their ambitions. They brag in their own policy papers of the—they use the most centralized control, top-down direction of all the research, all the solutions to their technology, and a very narrow focused approach toward some of these challenges. Now, in the real world of space engineering, as we know from our own experience, often the problems you run into, which are not forecast by the bosses, are solved by answers and technologies in the next office over or the next division over or some other entire organization, and it is very difficult, if not impossible, for enough problems to accurately be reported up the chain so that they can be solved at the top.

It's possible, and the experience with Shenzhou suggests that the people doing the program were doing a lot of their own problem solving, and that the Chinese official pronouncement that it will be the director from the top that is responsible for their success is for show, is just a way of having the central regime gain the credit from the success of their program. Whatever they have done though, their program has been successful. It's been successful in a lot of very good, prudent, slow, methodical, perhaps cautious or even overcautious small steps, building, taking a launch vehicle family, for example, expanding on those launch vehicles, lengthening the tanks, putting higher pressure engines, putting more strap-on, extra booster stages.

But they've now reached the point where they can no longer expand their launch capabilities by small increments. They have a big step in front of them now, and it's a big step that will determine the future of their program. Can they go to a larger booster system? Tell call it the Long March 5 or the Chang Zheng 5 family, with an entirely new set of fuels, a larger diameter central stage that can't be transported by rail to the launch site they now have, a vehicle that can go from their current maximum about 10 tons in lower-Earth orbit to 25 tons. The new vehicle would give them the opportunity to do heavy commercial communication satellites, which they put as their number one priority, the ability to put large payloads in interplanetary transfer to the moon and elsewhere to launch a near-class space station, which they've said is a goal in the mid term, and the capability to launch a Shenzhou-type vehicle with astronauts on lunar flights.

Now, between now and getting there, they have many steps they have to make, and we're going to watch with great interest. Using the talents and skills they already have shown and perhaps their management problems that could be in the way, we're going to watch them build this booster and we're going to clearly have insight into the program. If in 5 or 6 years they've built a launch pad, test flown this Long March 5, it's called Long March 5–500 series of booster, if it's flying before the end of this decade, it can do many things including opening the path for Chinese astronauts to the moon.

At the point they can make the decision or need to make the decision, they'll look at our own schedule and probably go back to their reasons for doing space flight, which is to enhance the credibility of their own technology. A manned lunar program or manned lunar fly-by ahead of NASA, ahead of anyone else, would be the kind of thing that they clearly already are paying for in other programs and would like to buy again. Well, we may see them do that.

In terms of whether we can take part in cooperation with them, clearly they like cooperation. It's one of the ways they obtain technology and know-how. Our own cooperative programs can teach us a lot, one of which is that, like with the International Space Station, the biggest international space cooperation project ever, we now realize that the promises that were made about bringing the Russians into the program, that it would make it cheaper, faster, safer, better, promises that NASA came here and told Congress about, were none of them fulfilled, and they're not fulfilled for reasons that in some cases had been forewarned.

Parts of ISS that have worked best tend to be not the modules that are all built together with components from each different partner, but components side by side, the Russian module and the U.S. module with supplemental capabilities for atmospheric revitalization, for example, or most critically, for transportation, and the saving grace of the ISS design is that we have two independent access transportation methods to the station. When Soyuz and Progress were not adequate, the Shuttle took up the slack and we kept a record of how much the Russians owed us for that. Now with the Shuttle down, the Russians have taken up the slack and they're doing the bookkeeping to see who owes what.

Perhaps with the Chinese access, a Shenzhou-type vehicle with humans beyond low-Earth orbit, we may see a time 10 years from now when more than one country are in the process of developing independent access to get people into lunar orbit and beyond and we're not considering it a bad thing at all or wasteful, far from it. ISS has shown us that often stand-alone capabilities by two different teams of partners can often work in parallel and create something far more reliable and useful than either alone.

But for the most part, the Chinese have not expressed interest either in ISS or other seriously integrating their programs. They're putting their space station and their spacecraft into an orbit that is incompatible with the International Space Station. They are building ground tracking sites for things like return to Earth that would not be in the right location for spacecraft coming back to Earth, to China, from the International Space Station, so their building these facilities is a clue that they are not looking for any near-term cooperation with ISS.

They have their own reasons. As I said before, and we'll go into at your interest, the reasons are satisfied by them pushing on alone or taking part or being rivals of other groups, other countries, other partners, and it is a cash value to them that they are seen as among the top with space powers on Earth. They clearly show they want to do that and they can spend the money to get there and that they have the talent, they have the people in place now ready for any task the Government decides.

Thank you.

[The prepared statement of Mr. Oberg follows:]

PREPARED STATEMENT OF JAMES OBERG, AEROSPACE OPERATIONS CONSULTANT, SOARING HAWK PRODUCTION, INC.

Thank you for the opportunity to testify before this subcommittee on the question of Chinese intentions regarding lunar exploration. Both in competition and cooperation, China and the United States will be mutually interacting in this arena for decades to come.

This statement will examine the recent Chinese manned space flight, *Shenzhou-5,* to examine what it can reveal about Chinese approaches to selecting space goals and developing space technology, particularly its practices regarding acquisition of foreign space technology and its exploitation of usable lessons from foreign space experience. The Chinese plan for evolution of the Shenzhou program and development of an independent orbital laboratory is becoming clear. Following this, the question of Chinese national goals in space, and expected benefits from space activities, will be addressed.

Then the issue of lunar activities can be considered in the context of known Chinese practices and official policies. A broad and aggressive program for unmanned lunar exploration can be discerned. In the context of high-spirited and enthusiastic press accounts of future Chinese space triumphs, the potential for even more ambitious lunar goals involving Chinese astronauts can also be balanced against predictable Chinese technical capabilities and national policy requirements.

The Flight of Shenzhou-5

On October 15, 2003, at the Jiuquan Space Center near the edge of the Gobi Desert in northern China, the spaceship Shenzhou 5 blasted off at a date and time that had leaked to the world in advance. The spacecraft—its name means "divine vessel" in Chinese—was nearly nine meters long and weighs almost eight metric tons, substantially bigger than the Russian Soyuz space vehicle still in use, and similar in size to NASA's planned Constellation spacecraft whose final design has not yet even been selected.

The first manned flight of the Shenzhou has already had profound political, social, and diplomatic echoes. In addition to garnering international prestige, China hopes that its human spaceflight program will stimulate advances in the country's aerospace, computer and electronics industries. Space successes will raise the attractiveness of exports and enhance the credibility of military power.

China's near-term space plans are quite clear: It will establish its own space station in Earth orbit. Within a decade, China's space activities may well surpass those of Russia and the European Space Agency. And if China becomes the most important space power after the U.S., an entirely new "space race" may begin.

China's Use of Foreign Space Technology

A significant factor in China's success, and a major influence on its future space achievements, is the degree to which its program depends on foreign information. The manned Chinese spaceship used the same general architecture of both the Russian Soyuz and the American Apollo vehicles from the 1960s. The cabin for the astronauts, called a Command Module, lies between the section containing rockets, electrical power, and other supporting equipment (the Service Module) and a second inhabitable module, in front, to support the spacecraft's main function (for the Soviets, the Orbital Module, and for Apollo, the Lunar Module). So despite superficial resemblances and widespread news media allegations, the Shenzhou is in no way merely a copy of the Russian Soyuz—nor is it entirely independent of Russia's experience or American experience.

Its Service Module, for example, has four main engines, whereas Apollo's service module had only one, and Soyuz has one main and one backup engine. Also, Shenzhou's large solar arrays generate several times more electrical power than the Russian system. And unlike Soyuz, the Chinese orbital module carries its own solar panels and independent flight control system, allowing it to continue as a free-flying unmanned mini-laboratory long after the reentry module has brought the crew back to Earth.

On the other hand, one clear example of outright Chinese copying is in the cabin pressure suits, used to protect the astronauts in case of an air leak during flight (A much more sophisticated suit is used for spacewalks.) The Chinese needed a suit with similar functions, so after obtaining samples of Russia's Sokol design they copied it exactly, right down to the stitching and color scheme. Other hardware systems that are derived from foreign designs include the ship-to-ship docking mechanism and the escape system that can pull a spacecraft away from a malfunctioning booster during launching.

Chinese officials have made no secret of such technology transfers. A lengthy article on Chinese space plans appeared in the Xinhua News Agency's magazine *Liaowang* in 2002: "After China and Russia signed a space cooperation agreement in 1996, the two countries carried out very fruitful cooperation in docking system installations, model spaceships, flight control, and means of life support and other areas of manned space flight. Russia's experience in space technology development was and is of momentous significance as enlightenment to China."

The mention of docking systems is especially illuminating. Although Russia and the U.S. have used different types of docking mechanisms over the years to link spacecraft in orbit, photographs of Shenzhou indicate that the Chinese have chosen a Russian variant called the APAS–89. The device consists of a pressurized tunnel 80 centimeters in diameter surrounded by sloping metal petals that allow any two units of the same design to latch together. Originally developed by a U.S.-Soviet team in 1973–1975 for the Apollo-Soyuz Test Project and perfected for use by Buran space shuttles visiting the Russian Mir space station [which never happened, although one visiting Soyuz vehicle was equipped with the system], the APAS–89 is now used to dock NASA's space shuttles to the International Space Station (ISS). Although China is primarily interested in docking its spacecraft with its own small space stations, the decision to employ the APAS–89 mechanism would allow Shenzhou to link with both the space shuttles and the ISS.

Regarding the "escape system" [a "tractor rocket" design developed by NASA and adopted by the Russians], launch vehicle manager Huang Chunping told a newspaper reporter about one particular difficulty in the design, the aerodynamic stabilization flaps. "This is the most difficult part," he explained. "We once wanted to inquire about it from Russian experts, but they set the price at $10 million. Finally we solved the problem on our own." This pattern (of studying previous work but then designing the actual flight hardware independently) was followed on most other Shenzhou systems, and it has already paid off.

What is more, China has launched four ocean-going ships to track its missiles and spacecraft. These Yuan Wang ("Long View") ships have been deployed in the Pacific Ocean to monitor military missile tests and in the Indian Ocean to control the maneuvering of satellites into geosynchronous orbit. The ships are sent into the South Atlantic, Indian and South Pacific Oceans to support the Shenzhou flights. The Russians used to have a similar fleet but scrapped it in the 1990s because of budget constraints. Rather than purchase the Russian ships, China built its own.

Because some of the critical ground-control functions for the Shenzhou's return to Earth must be performed while the craft is over the South Atlantic, China signed an agreement with the African nation of Namibia in 2000 to build a tracking station near the town of Swakopmund. Construction started in early 2001 and was completed by year's end. Five permanent residents occupy the facility, and the staff expands to 20 during missions. The site lies under the reentry path of the Shenzhou, and because the craft's orbit has a different inclination than the International Space Station's, the Namibian base could not be used to track flights returning from there. This suggests that despite the Shenzhou's compatible docking gear, the Chinese seem to have no near-term interest in visiting the ISS.

Long-Range Strategies and Goals

China's long-range strategy was laid out in a White Paper issued in 2000 by the Information Office of the State Council. It stated that the space industry is "an integral part of the state's comprehensive development strategy." And instead of developing a wide variety of aerospace technologies, China will focus on specific areas where it can match and then out-do the accomplishments of other nations.

Further, China would develop all the different classes of applications satellites that have proven so profitable and useful in other countries: weather satellites, communications satellites, navigation satellites, recoverable research satellites, and earth resources observation satellites. It also will launch small scientific research satellites. A unique and highly significant feature of the Chinese space plan is its tight control from the top. As described by space official Xu Fuxiang in February 2001, "China's various types of artificial satellites, in their research and manufacture, are all under unified national leadership . . ." that will "correctly select technological paths, strengthen advanced research, and constantly initiate technical advances. We must constantly select development paths where the technological leaps are the greatest." Strict funding constraints require selecting "limited goals and focus[ing] on developing the . . . satellites urgently required by our country," and on determining which satellites "are most crucial to national development."

The Maoist-style "ideological idiom" for this is: "Concentrating superior forces to fight the tough battle and persisting in accomplishing something while putting some other things aside."

The value of tackling difficult space technology challenges was explicitly described in *Xiandai Bingqi* magazine (June 2000): "From a science & technology perspective, the experience of developing and testing a manned spacecraft will be more important to China's space effort than anything that their astronauts can actually accomplish on the new spacecraft. This is because it will raise levels in areas such as computers, space materials, manufacturing technology, electronic equipment, systems integration, and testing as well as being beneficial in the acquisition of experience in developing navigational, attitude control, propulsion, life support, and other important subsystems, all of which are vitally necessary to dual-use military/civilian projects."

The Next Steps

In 2002, *Liaowang* magazine described the development plan for the manned space program: "After it succeeds in manned space flight, China will very soon launch a cosmic experimental capsule capable of catering to astronauts short stays." This capsule is elsewhere described as "a laboratory with short-term human presence," to be followed later on by a space station designed for long-term stays. In January 2003, unnamed officials provided further background to Xinhua News Agency reporters: "As the next step, China will endeavor to achieve breakthroughs in docking technology for manned spacecraft and space vehicles, and will launch a [space station]. After that it will build a long-term manned space station to resolve problems related to large-scale space science experiments and applied technology and to make contributions to mankind's peaceful development of outer space."

In February 2004, Wang Yongzhi, academician of the Chinese Academy of Engineering, and identified as chief designer of the Chinese manned space program, told the Zhongguo Xinwen She news agency in Beijing that the Shenzhou-6 mission would carry two astronauts for a week-long mission. "Astronauts will have more opportunities for hands-on operation on board the *Shenzhou-6,*" he stated. "The astronauts will directly operate relevant spaceship-borne instruments and equipment to carry out a series of in-space scientific experimental work." No date was given, but most Chinese sources indicate that early 2005 is most likely.

"When conducting space rendezvous and docking experiments in the past," he explained, "both the former USSR and the United States had to successively launch two spaceships in one experiment. At the time of devising a plan for China's space rendezvous and docking experiments in the future, we improved on the past achievements and considered making the Shenzhou spaceship's orbital capsule, left to continue moving in orbit, the target vehicle in space rendezvous and docking. When conducting a space rendezvous and docking experiment in the future, therefore, China will need to launch only one spaceship."

"This plan is feasible, economical, and faster" in its design, and he expects it to take four or five years to be implemented. Foreign experts consider this plan feasible and reasonable and give it excellent chances of success. On Chinese television, Wang added that following flights by *Shenzhou-7* and *Shenzhou-8* (perhaps in 2006–2007), China would launch "a space station of larger scale with greater experimental capacity." A photograph of what appears to be a mockup of this module has been released. It resembles the Soviet *Salyut-6* space station (1977–1980), but with a more modern ship-to-ship docking mechanism modeled on Soviet designs now used by the ISS.

Chinese Interest in Lunar Exploration

In the enthusiasm surrounding the Shenzhou program, many Chinese scientists made bold promises to domestic journalists about ambitious future projects, especially the Moon. Many press comments are difficult to understand, and the problem of translation of unfamiliar technical nomenclature compels outside observers to be very cautious in interpreting them. For example, when Dr. Ouyang Ziyuan, identified as "chief scientist of the moon program", is quoted as saying "China is expected to complete its first exploration of the moon in 2010 and will establish a base on the moon as we did in the South Pole and the North Pole," great care must be taken in determining what—if anything—this really means for future space missions.

Still, even Western observers also expected major new Chinese space missions. "China intends to conduct a mission to circumnavigate the Moon in a similar manner as was carried out by *Apollo-8* in 1968," noted the American engineering and analysis consulting company, the FUTRON Corporation, in its report, *China and the Second Space Age,* released the day of Yang's space launch. "This mission will apparently involve a modified Shenzhou spacecraft and will be launched around 2006," the report continued. And at a trade fair in Germany, spectacular dioramas showed Chinese astronauts driving lunar rovers on the Moon. But those exhibits seem to only be copies of U.S. Apollo hardware with flags added. There is little if any credible evidence that such hardware is even being designed in China for actual human missions to the Moon.

According to Luan Enjie, chief of the China National Space Administration (CNSA), China's first lunar mission will be a small orbiting probe called "Chang'e" (the name of a moon fairy in an ancient Chinese fable). Pictures of the probe suggest it is to be based on the design of the *Dong Feng Hong-3* communications satellite, which has already been launched into a 24-hour orbit facing China (the Cox Commission provided persuasive documentation that the original *DFH–3* was heavily based on European space technology). This lunar probe is expected to reach the moon in 2007, on a recently-accelerated launch schedule.

Chinese press reports also describe widespread university research on lunar roving robots, and especially on the robot manipulators (the arm and hand) to be installed on them. According to an April 7, 2004 report in China's *People's Daily,* Luan said the lunar rover would carry the names of those institutions that take part in the vehicle's development.

The report continued that the lunar rover work was being "carried out under China's High Tech Research and Development Program involving nearly a dozen scientific research institutions." This work was initiated by Tsinghua University in 1999. The rover is to be able to handle a range of driving conditions and use sensors for automated driving around obstacles. Luan is quoted as saying he is "on the lookout for innovation and creativity in building the lunar rover."

Two years earlier, the Xinhua news agency (Jan. 16, 2002) had stated that China's first space robotics institute has been set up in Beijing. Its Deputy Director, Liang Bin, said: "Breakthroughs have been made in many key technologies of space robots. If it is required by China's space plan, the space robot will be sent to space very soon."

That same year, Liu Hong, a professor at Harbin Polytechnical University, showed a four-fingered hand for use in space. Each finger had four joints, 96 pressure sensors, and 12 motors. "The robot may replace an astronaut to conduct some difficult and dangerous operations outside the space capsule."

Dr. Sun Zengqi, identified as Qinghua University's leading expert, is using virtual reality technology to overcome control problems caused by long time delays. Also, he is working on manipulators to handle equipment aboard China's first small space laboratories that will not be continuously manned. "The gap between China and [other] countries in space robot technology has been greatly narrowed," Sun said.

Tsinghua University is designing what they call "LunarNet". It would consists of a polar orbiter equipped with sixteen 28 kg hard-landers, to be released in equally spaced areas on two mutually perpendicular orbital planes. The landing system, probably using airbags, would ensure surviving a landing at speeds between 12 and 22 m/s. Each lander will carry a camera, temperature sensors, cosmic ray detectors, a penetrometer, an instrument for the measurement of soil magnetic properties and other instruments. The stations would use a relay satellite for earth comm.

There is also the "Lunar Rabbit" soft-lander. It would be a 330 kg probe costing as little as $30 million and would be launched on a geostationary transfer orbit from the Xichang space center. Insertion into a lunar transfer orbit will be carried out on the following day using the on board bipropellant engine. At the time of the third apogee the probe will be inserted in a 100 to 200 km high lunar orbit where it will split into two components. The first, apparently based on the Double Star scientific satellites, will carry out an orbital mission, using a CCD camera, an infrared camera, a radar altimeter and a radiometer. The second will head for a lunar landing. This lander, braked by a solid propellant engine, will carry only a camera and will test optimal control algorithms discussed in some length in Chinese literature. Once on the surface the lander will release a 60 sq. meters Chinese flag.

While it is plausible that many of these programs are merely engineering exercises to train students, the doctrine from the 2000 White Paper makes it clear that China cannot and will not waste any efforts in its space program. All activities are to be funded only if they contribute to an existing—if officially undisclosed—unified program. This suggests that these projects are not idle make-work, but are at least candidates for eventual official selection to actually fly.

These probes, and a long-range plan for an automated sample return mission by 2020, will not be direct copies of previous missions by Soviet and American spacecraft. Wu Ji, the Deputy Director of the Chinese Academy of Sciences' Center for Space Science and Applied Research, recently declared that Chinese Moon probes will aim at questions not addressed by previous missions. He stressed the importance of doing "something unique."

The Looming "Great Leap" In Spacelift Capability

The key to more ambitious Chinese moon plans—to the rover mission, for example, or even a fly-by of the moon by a manned spacecraft—is the development of a new and more powerful booster called the CZ–5. Comparable to the European Ariane-5 booster or the Russian Proton-M, it will not be a simple upgrade of previous vehicles in this series, where more power was obtained by adding side-mounted boosters, stretching the fuel tanks, and installing high-energy upper stages. Those incremental advances have reached their limits, and an entirely new design of large rocket sections and bigger engines must be developed over the next five years.

China has stated that it intends to develop this mighty rocket for launching larger applications satellites into 24-hour orbits, and for launching its small space station. The components are too large to move by rail to the existing inland launching sites, so they will be shipped by sea to an entirely new launch facility on Hainan Island, on China's southern flank.

This new launch vehicle is a major quantum-jump in the Long March family and presents very formidable engineering challenges. It will take tremendous efforts, and significant funding, and some luck as well, to make it work on the schedule announced in Beijing. And until the booster is operational, ambitious moon plans cannot be attempted.

Once the CZ–5 is man-rated—and we re talking about at least five years, probably more—a beefed-up Shenzhou vehicle could be launched to the Moon. Two different possible flight plans are available: a simple swing-by (as with Soviet Zond probes in 1967–1970) and a lunar orbital flight (as with *Apollo-8* in 1968). The simpler variant could be carried out with a single CZ–5 launching; the orbital profile could require two launches.

At the present time, however, there is no hard evidence that the Chinese government has officially sanctioned such missions—nor is there any need for them to do so at this point, since much of the technology to realize such options is already under development for more near-term goals. Nevertheless, Chinese capabilities for human lunar missions—at least to orbiting it—can quite reasonably expected to become available in a time-frame similar to NASA's "Return to the Moon" strategy, and the option to fly such missions as an equal participant may prove to be irresistible to the Chinese government.

China vis-à-vis the United States: Strengths and Weaknesses

A comparison between the Shenzhou spacecraft and its direct descendants, versus the still-undefined and undersigned U.S. Constellation project (nee CTV, CERV, etc.) reveals a pattern of relative strengths and weaknesses of the two nations and their approaches to expanded lunar activity.

Both vehicles can carry 3 or more crew, are launched on expendable boosters, have launch-escape-systems, can rendezvous and dock in orbit, and return on dry land. Both promise to outstrip capabilities of the Russian Soyuz vehicle, just as Russia itself wants to replace it with the Kliper design (the Russians see this project funded by Europe and the U.S., in their dreams).

The United States spends $30 billion a year on space, the Chinese perhaps $2 billion. But the Chinese have made it clear they will not duplicate across-the-board all of the activities funded by the United States.

A major problem for China is that their top-down and tightly-focused space management strategy is extremely brittle, and vulnerable to unpleasant surprises and unpredicted constraints. This is because space technology often cross-fertilizes, and difficulties in one area find solutions in seemingly unrelated disciplines, in a manner that top level management is usually incapable of foreseeing. Although methodical and incremental approaches to programs such as Shenzhou have been successful, more advanced projects—particularly the CZ–5 booster—will require longer strides and may reveal the shortcomings of narrowly aimed management. That in turn may encourage more aggressive efforts to find the required technologies overseas.

Beyond mere technology acquisition, China has implemented an extremely effective policy of extracting all usable lessons from other countries space experiences. This is the fundamental issue of engineering judgment, the day-to-day decision-making that propels a program to success—or, if not done properly, to frustration and disaster. The Chinese have studied the Soviet, the American, the Japanese and European and other programs intently, with the explicit goal of learning from them. NASA's culture in recent years, on the other hand, has looked overwhelmingly arrogant towards any outside expertise (even, or especially, from other U.S. agencies, and sometimes actually between different NASA centers). Worse, it has shown itself incapable of even remembering fundamental lessons (such as flight safety) that an earlier generation of NASA workers had paid a high price to learn—only to have it forgotten and eventually (hopefully) re-learned.

The demographics of the space teams in both countries also demonstrates a major difference that goes beyond mere financial resources. While space workers are equally happy to be at their jobs, the workforce in the Chinese program reflects the major build-up of the past decade and is predominantly young, and has been involved in major program development activities. NASA, as a mature civil service branch, has had relatively stable—some might even say moribund—staffing for decades. While there has been a steady flow of new hires, they have in large part been involved in maintaining existing programs, without much opportunity to learn by doing . Outside observers such as Dr. Howard McCurdy have voiced serious doubts that the current NASA culture is capable of sustaining an ambitious and expansive new program (late last year he testified how that could be fixed), but there is little doubt that the Chinese space workforce is, because they've shown it.

The rationale for China investing substantial sums into expanded human space flight—space stations and even lunar sorties—remains unclear, but to a large degree they may be the same motivations that have already funded the Shenzhou program. If Shenzhou continues to be successful, internally popular, and helpful to Chinese economic, diplomatic, and military relations with other nations, then more ambitious projects with similar effects may justify their budgets too.

Weighing these factors, the future of lunar exploration—and China's role in it—is likely to be extremely interesting. While the motivations that fueled the Space Race of the 1960s are largely absent—primarily the naked fear in the U.S. that a world that accepted Soviet dominance in space would have many other consequences undesirable from a U.S. point of view—there remain solid motives for international rivalry, for serious attempts at illicit technology transfer, and for activities that could diminish the world stature of U.S. aerospace technology.

In metaphorical terms, China is now facing a steep road into the sky. It has shown it has the heart and the brains for this chosen path. Now the world must wait to see if it has the muscle and the stamina—and the wisdom. And the same question applies to the United States.

Senator BROWNBACK. Thank you, Mr. Oberg. Let's run the clock at 10 minutes and Will and I will bounce back and forth here. Who, on currently announced schedules or plans that we are ascertaining where people are going if we don't have clearly announced schedules, what country will be the first back to the moon with a human mission and by when, on currently announced or schedules that we are looking at and appraising what they are doing if they haven't publicly made announcements.

Mr. OBERG. I think the competition is not very large because the Chinese have said—the problem with Chinese information is that we're still not certain how to translate a lot of the terms and there's mistranslation and there are comments made from people over there whose authority to make the comments we're not probably sure of, but the comments from Beijing and elsewhere that they have a program to put people on the moon I think are not credible. Nor do they need that program now. What they need now are laying the foundation for later deciding to do it. The only announcement of a schedule I've seen for anyone is NASA's.

Dr. LOGSDON. If the Congress gives the authorization and appropriations to NASA this year to get started on its programs, particularly the Crew Exploration Vehicle, it will be the U.S. first back to the moon. None of the other countries in Europe, Japan, India have human missions on their schedules at this point, and as Jim Oberg has said, the Chinese outlook is I think at best uncertain.

Senator BROWNBACK. China will have the capacity to go with a human mission to the moon by when, given a successful set of developments in rockets that they're into now?

Mr. OBERG. I think we can reasonably expect them to repeat the schedule for the Shenzhou mission: approved in 1992, began construction of the launch facility at Jiuquan in the Gobi Desert in 1993. It took 5 years to build the launch facility and the processing buildings. First unmanned test flight of Shenzhou, 1999, first manned flight, late 2003, so it's about 11 years from approval to first manned flight. They could probably put more money and do that sooner because they've already done it once now, but I don't think a lot sooner. I would say doing it in less than half that time is just not believable. Otherwise, we're just guessing. But 6 to 12 years would be a number I would put as a range from the time they decide, let's send people to the moon.

Senator BROWNBACK. Well, maybe I then didn't hear you quite right on this, Jim. I thought you said that if they successfully test this launch capacity by the end of this decade, they will then be able to make a determination whether or not they want to go to the moon and they will have a number of pieces in place to be able to do that.

Mr. OBERG. They will have those pieces. They would then be able to begin testing spacecraft. Their approach to Shenzhou is much more methodical and slower than most of us outside observers, myself included, thought. It took them longer to get from the first test to the manned flight, but when they got there, they got there perfectly. The mission was, as far as we can tell, perfect. When it comes to lunar flight, if by the end of this decade the Chang Zheng 5–500 rocket is operational and has been launched and they at that point want to use it for a manned lunar flight, it would only be a matter I think of a couple years before they could carry that out. So in that case, we're looking at 8 years, and I think 8 years is something that is plausible, but again, based on decisions I don't think have been made yet.

Senator BROWNBACK. You think from where they are today, they could be on the moon in 8 years if radical decisions are made?

Mr. OBERG. They could be doing flights in lunar orbit. The step to get onto the moon requires that a whole new booster family beyond this new one would come along or they'd begin to go multiple launches—and they do not do multiple launches, have not in the past, although their launch rate is doubling and the budget's doubling. They're launching more vehicles this year than they ever launched.

So getting people in lunar orbit like Apollo 8 is something that is conceivably within their reach in the time scale we're looking at, 8 years I'd say is a good guess. But to put people onto the lunar surface is a whole other project that is again a step beyond that. It's a step for them and for us, because I've seen various estimates of when NASA thinks it could get people back on the lunar surface and we're talking about—well, John, you're more familiar with those than I am.

Dr. LOGSDON. The official date in the President's policy is between 2015 and 2020, so those time scales could converge if China has the appropriate developments with its new class of vehicles, that both the United States and China could be conceiving of human missions landing on the moon the second half of the next decade.

Senator BROWNBACK. And roughly the same time?

Dr. OBERG. Yes.

Senator BROWNBACK. That they would be on track in development to be in a position to put a person back, a person on the moon in roughly the same time the U.S. would be under our current announced schedules?

Dr. LOGSDON. That seems to be the case, yes.

Senator BROWNBACK. OK. Let me talk budget, and nobody else has plans for manned missions to the moon?

Dr. LOGSDON. Well, there was a group within ESA last year that went off by itself and developed a plan for a European lunar base by 2020 or 2025, but it was kind of orthogonal to the main line of ESA thinking and the people responsible for it are not going to be there in the future, so I think that was a dead initiative, although some people in Europe put a lot of work into it.

Senator BROWNBACK. But nobody else has announced lunar—does anybody have announced human missions to other places than the moon? You mentioned Europe has planned missions to—well, Mars, Venus, Mercury, obviously they're not——

Dr. LOGSDON. Europe had a study program built around the notion of human missions to Mars in the 2030 to 2035 time period called Aurora, but it was only a study. It was not, did not have political sanction, and is being revised to reflect the U.S. proposal and be more complementary to what the U.S. has put on the table.

Mr. OBERG. We have some very explicit comments from Chinese officials about their philosophy for their future strategies. They will not be retreading past ground, they've said. They will be doing things with the moon different than have been done in the past, doing things out in space different. If we are fixated on being on the moon to reprise Apollo, we may overlook, what other people have not overlooked. This has been mentioned before, there are other missions beyond low-Earth orbit that don't involve lunar surface access. They are both either lunar orbit or the Lagrange points around the moon, which are of great interest for a number of reasons, for using it for staging eventually to a lunar surface. These missions that don't require a lot more propulsion than getting to the moon, but only more life support to go beyond the moon: either just out into interplanetary space and back, or out at the times when there are asteroids passing within a few million miles of the Earth, to visit then and return.

These near-Earth asteroid missions are attractive. And if I can intuitively say, what would be most attractive to the Chinese based on the strategy they've already developed and the rationales they've already discussed, to make a point to themselves and the rest of the world, I would not put the lunar surface as the target. I would put something that is much more spectacular that would be one heck of a demonstration of their abilities and would steal a march on all of NASA's official plans.

Dr. LOGSDON. Senator, if I could add just one more thing. I quoted in my oral testimony the President of India, Dr. Abdul Kalam, about the inspirational effect of the first Indian lunar robotic mission. He went on to say, he could "visualize a scene in the year 2021 when I will be 90 years old visiting the Indian space port for boarding a space plane so I can reach another planet and return safely as one of the passengers. I can foresee this center to grow into an international space port with a capability of enabling launches and landings of reusable launch vehicles."

So clearly in the broadest Indian thinking, human missions to other destinations are part of the future. Those aren't approved missions and there's no schedule, but it's part of their thinking.

Senator BROWNBACK. Let's talk budget. Ms. Smith, you may be the best one to help me on this. Give me the respective general budgets for space exploration, announced and then also hidden budget, if other countries, China, for instance, has an announced project but it actually pulls from a number of different sources so that the total amount is more. Do we know the space budget for a number of these other countries, or if somebody could articulate that for me?

Ms. SMITH. It's difficult to get at a true total number from some of those sources that may not be publicized, so what we know is what government officials say about their budgets. So for the Russian Space Agency, for example, Yuri Koptev, who was head of the agency until recently, said that the 2004 budget for the Russian Space Agency is about $500 million when you convert it into dollars, but whether or not they're also getting revenue from other Russian commercial space activities to augment their budget is not something that's made public, so it's very difficult to get an exact number, but it's on that order of say $500 million. I think the Indian space budget is also around $450 million, John, something like that.

I think if you look at the total European spending on space, military and civilian, I've seen numbers around $7 billion, of which about $4–1/2 billion is for civilian space activities. The budget for the European Space Agency last year was about $3 billion U.S. I don't know which other countries you would be interested in. The Chinese budget I think is around $2 billion.

Senator BROWNBACK. Annual?

Ms. SMITH. Annually. But in reference to what you were discussing earlier in terms of who has plans to go to Mars, for example, for example, I'm not sure anyone has, quote/unquote, "a plan to go." Even we don't. The President said that we were going to go the Moon and Mars and worlds beyond, but there was no schedule for that either.

I think a lot of the countries have visions, and they have studies, and they have the desire, and they want to go, and they're all waiting for some catalyzing event to make it happen, and they're all looking for money, which is why, whenever these long-term visions are discussed, they're almost always discussed in an international context, because people assume that you're going to have to get a lot of countries together in order to afford it.

Senator BROWNBACK. Jim, what's happened in the Chinese budget over the last 5 years—space budget?

Mr. OBERG. We've seen the budget—the official budget figures double. We've seen the launch rate——

Senator BROWNBACK. The last 5 years?

Mr. OBERG.—the last 5 years. And we've seen the launch rate double, and may double again in the next year or two.

The Chinese have not made a lot of launches. In their Long March series of rockets over the past 30 years, they total about 70–75 launches, and a few from other programs, as well. That's what the Soviets would launch in a year and a half back in the space race. At the same time, there are more launches now coming down. And what we've seen, already, they're ramping up.

With Shenzhou, at first we thought, that after the first flight, they would begin a Gemini-like program of flying every several months, three, four, or every 6 months. They decided they're not going to fly even this calendar year at all, and fly the next Shenzhou mission next year.

But clearly they fly a mission once, learn from it, and don't keep repeating it. The next mission is two people for a week in space. That's pretty much now the official comment. The mission beyond that would involve a space walk with space suits to go outside, and some testing of rendezvous and docking, the technology they need for a space station. They've said that their approach is different than the West, than the U.S. and the Soviets did; they will launch into orbit, detach the forward nose section of their spacecraft, back away and re-dock with it several times. So they only have to launch one vehicle, instead of two, to practice this rendezvous and docking. That's entirely plausible. It would leave them in a position, after only 4 or 5 flights over the next 3 or 4 years, to begin use of what they say is their next step, which are short-term space laboratories that would be visited by crews. After that comes the time to get their large vehicle up, their Mir-class vehicle. They said that will take awhile before they're ready for it. And, sure enough, it's also going to be awhile before the launch vehicle is ready.

So they've discussed in public what is converging on a description of a plan with Shenzhou that is going to put them into essentially a Russian-level capability within a couple of years, beyond anyone else's. And is Shenzhou really Chinese—not for "Magic Vessel," which is the word for it—it might be the Chinese for "Constellation." There's a spacecraft that NASA would like to build sometime in the next 10 years that will probably look a lot like the spacecraft the Chinese are now flying.

Senator BROWNBACK. Astronaut Bill Nelson?

STATEMENT OF HON. BILL NELSON, U.S. SENATOR FROM FLORIDA

Senator NELSON. Is that spacecraft the crew-exploration vehicle?

Mr. OBERG. I'm referring to the current—that's the current acronym for it. I wouldn't want to guarantee how long that will be the name.

Senator NELSON. And does it look like that?

Mr. OBERG. It looks a lot like—we don't know there are three or four different drawings I've seen. The Shenzhou followed a procedure that the Chinese learned from their own experience and ours, you develop a spacecraft based upon the mission requirement. You don't build a spacecraft to please aesthetics or Hollywood or different contractors, or even—pardon me—you know, different politicians. You build it based on the requirement. And the Shenzhou appears to do that. Whether we're going to be smart enough to copy the Chinese philosophy or not, I'm not yet sure.

Dr. LOGSDON. Well, but this time NASA, at least on paper, claims it's doing it right, setting out the requirements for the spacecraft first and then designing to that requirement. Those requirements are not set, so what the spacecraft is going to look like at this point, in April 2004, is only speculation.

Senator NELSON. Well, you all are the experts. I want to find out from you—Why back to the moon before we go to Mars? Now, Jim, Mr. Oberg, has just laid out a very practical building-block-by-building-block program that the Chinese have a reason—also with their politics, their world prestige, et cetera, et cetera. But for the rest of the world, and maybe for the Chinese also, what happens if the rovers that we send up there to Mars in 2007 and 2009 and 2011, building on the discovery that has just been made by one of the rovers that there was a sea, and that we start to discover—let's say we start to discover fossils. Isn't that going to, first of all, ignite the curiosity and imagination of the American people? And is that not going to refocus as to whether or not we should go to the moon or go straight to Mars? That's question one. And then, could not we have international participation in that?

Ms. SMITH. It's been a long-running debate as to whether to go back to the moon or just go directly to Mars. There are people who have strongly held views on both sides. Those who think that we should go back to the moon first usually cite the fact that it's close to home, so if something goes wrong you can get people back very quickly; whereas, if you sent them to Mars, they're pretty much committed. And they also point to the fact that you can use materials on the moon to launch future missions to Mars, and that's what President Bush raised when he announced this initiative in January.

There are folks—I'm sure that you know them as well as I do—who think that we've been there, done that, don't need to go back to the moon; let's choose a very challenging goal, realizing that there very probably be lives lost along the way, and just go directly to Mars and accept that risk. But, at the moment, the President has decided that we should take the slower approach and go to the moon first.

Senator NELSON. The slower approach was announced before the little rover discovered that there was a sea on Mars, and so I'm just asking "What if?" What if, by 2007 and 2009 and 2011, we suddenly find that there were forms of life on Mars? Doesn't it accelerate the whole quest to go to Mars and have a human dig around and try to find out what was there?

Ms. SMITH. It may depend largely on how much risk everyone is willing to take, because you may not have the knowledge that you need at that point as to what the effects are on people when they journey that long in weightlessness and how they're going to react when they're on the surface of Mars, which is a third G. You may not have the radiation studies completed that you want to have completed. So it'll probably boil down to risk and money.

Mr. OBERG. But this is also what ISS has been teaching us in this past experience, and proving its value in that ISS has taught us that we're not smart enough to build a spacecraft yet that can spend 3 years without resupply and without fresh spare parts showing up. The experience of ISS is that we need to practice better in low-Earth orbit and potentially also in the area around the moon—or maybe not—but at least to practice before we commit to the long flights to Mars. We're going to expect losses—is not something you can do with high-level losses, because the support will be gone. So that when you leave for Mars, you're going to have to be, like what the Chinese launched, Shenzhou 5. They methodically did intermediate steps, checked them out thoroughly, took longer than other people thought, but may have been just cautious enough to make the flight of Shenzhou 5 successful.

On Station, as you've been aware, there have been a number of problems. Equipment's broken down faster than it was expected to. Also, without being repaired with Shuttle missions, there are a number of other systems which are right now teetering on the brink. There are backups, because of the multinational nature of it. Some systems that we have that won't work, the Russians will step in, and vice versa.

There, I think we do see the strength of an international partnership, where there are complementary capabilities that each country contributes, as opposed to one vehicle built of pieces from all the different countries.

So if we go international, I think one thing to enhance the reliability of an interplanetary flight is having at least two different teams—perhaps a U.S., with its partners' teams, the Chinese with their partners' teams—being able to send crewed human vehicles. Perhaps a fleet, perhaps two vehicles going together, standing by to help each other out, might greatly enhance the chance of the crew getting back. And it wouldn't take a whole lot longer or cost a lot more, because with international cooperation, we've found out that it never saves you money.

Dr. LOGSDON. If I could add just a slightly different angle to the discussion. First of all, I don't think we're finished with the moon. There are potentially resources there that could enable, for long periods of time, space exploration beyond the moon. We need to go and see whether they're really there or not. Maybe we can do that robotically and don't have to send crews back, maybe not. This is mainly the water frozen as ice in the deep craters at the poles.

I use the word advisedly, the "genius" of the President's plan, because there are lots of problems with it, is its flexibility. It really doesn't commit to particular destinations; it lays out an initial path that can be changed if discoveries along the way merit it. We're not building, like we've built for Apollo, a system only good for going to the moon.

One of the problems with the Apollo capsule and the lunar modules—they were great for getting people to the moon and back, and not very good for anything else, and so we retired then in 1972. One hopes that we will build a flexible system for interplanetary travel by humans that can be used to get back to the moon, if that's the destination we choose, that can go on to Mars, that can go to Lagrangian points, that can go to near-Earth-orbit objects and give us the capability to really move out into the Solar System to whatever destination we choose along the way.

Mr. GRAHN. May I add just a——

Senator NELSON. Please.

Mr. GRAHN.—reflection? Well, it sounds interesting and good with a vehicle that can do a lot of things, but it reminds me of a Swiss Army knife—each blade can be used, but no blade is any good.

[Laughter.]

Mr. OBERG. But because this vehicle, exploration vehicle, is apparently expendable, or at least fewer re- uses, as—we can do as the Soviets did, develop several different evolutionary paths with the same basic airframe, with major commonality between different vehicles, but more specialized toward the specific mission plan for that particular kind of a vehicle. So we're not going to build a vehicle that can do everything. We're going to have a design that, with modifications and additional equipment, can do one or the other, or a third option.

I would like to have thought—and, Senator Nelson, I was feeling very much like you, a Martian for many years—that we should go to Mars quickly, take the bit in our teeth and go out there. Watch the experience on the Space Station and experience that the Russians have had. As good as they were with Mir, keeping it going, they kept it going only because of resupply from the ground. Parts would break that were not predicted to break. The Shuttle could bring things up that they couldn't fit in their own cargo craft, and they kept Mir going, did a marvelous job.

If Mir had been sent toward Mars, the crew would have died. Not because of a fire or a collision or the other accidents, but because things broke down and they ran out of spare parts. We're running of spare parts on ISS now. What spare parts to pack?

There may be things that we can do and practice around the moon that won't delay getting to Mars at all, that we'd have to practice somewhere. It's like a testing ground, and it's like the testing ground that the Chinese find in space for their high technology.

Space is the ultimate judge. There's no bluffing outer space. You can't fool Mother Nature, as Dr. Feynman said. And testing the techniques, technologies, required for interplanetary flight—far harder than I know I thought 10 years ago, and many others—you need somewhere to try it out. The moon may be one area, other areas around the moon, the Lagrangian points that have been mentioned, and, as I mentioned, near-Earth asteroids, a very tempting target of high scientific value and intermediate challenge. Those are all out there as options, and NASA's strategic planning is looking at these options, I think, in a very mature way.

But the options that we're looking at for our purposes are not the same as the Chinese are looking at, and they would want to—they may just look at what we're doing, and pick and choose what they can do to make the most impressive point. Their intention is not to match us program by program by program. They've said that. Their intention is to find the project that we're doing, find the one, the most spectacular one, that they can do first, perhaps, make the point, and perform that. And that is the kind of strategic thinking that can lead to, I think, very spectacular Chinese successes in the next five, ten, fifteen years.

Senator NELSON. Well, I would just say, in conclusion, Mr. Chairman, that one of the things that we have to worry about is whether or not we can get the money, and how do you translate the will of the people into votes. And right now that's a very difficult thing to do.

It may well be—and I'm sure the thought has occurred to you, Mr. Oberg—that because the Chinese are headed to the moon, there might be some of this old Cold War competition that comes back into the factor of the politics that allows us then to translate the concern of that into dollars that's allocated to the space program, but it's too early to know. But that certainly is a possibility.

And when China orbited their astronaut, that was one of the first things that I thought of, it might be a help to us.

Mr. OBERG. It's not a zero-sum game that—the Chinese can succeed, can compete in a peaceful area. I think, looking historically at the space race, at the Soviet participation—and I'd be happy for other comments here—the Soviets found an area of competition in which they could make a contribution—they could impress the world and their own people in a beneficial kind of activity that judged how good they were, and rewarded them when they succeeded, and didn't involve military or oppressive techniques. And as they earned more respect outside their own country, justified respect for their activities, in many ways this, I think, softened the xenophobia and the garrison mentality that they had from Stalinist days. They were happening anyway.

Perhaps these are coincidental. But success in space strikes me—each country's success is the success of the whole world, and they build on each other.

We can look at a case in the future, when the Chinese are going to be building things in space. We're going to realize we should be matching them because it's a new arena. Leaving it to them and other nations is not going to be good for practical terms or psychological terms for the United States.

We're never going to dominate entirely again, but—and we're never going to have one unified world program, but a mix, a balance of different approaches, based on past experience and a good view of the history, I think, can benefit everyone.

Dr. LOGSDON. Think of yourself as a politician in 2020. If China's on the moon—India is headed in that direction, maybe Japan, maybe Europe as a partner with one or more of them—and the U.S. has chosen not to go, is that a politically acceptable position to leave to your successors?

Senator NELSON. The answer to that is no. And at that point, if the route is through the moon, I hope we're on the moon, getting ready to go to Mars.

Dr. LOGSDON. Indeed.

Senator BROWNBACK. Let me—Mr. Oberg—thanks, Bill, for being here—let me pursue this idea, because I had not thought about that, about China going to a near-Earth object, instead of back to the moon, and that's a great—and they would land a craft on——

Mr. OBERG. A manned craft, and run some robots on it, get some samples. As we all realize, we have profound interest in the structure of Earth-crossing asteroids, because at some point, if not this year or even this century, we're going to have to go and interfere in the course of some of these. And we'd need the preparation of what do they do when you—how do they respond to us pushing them? We can get that from unmanned vehicles, as well as manned vehicles. But often, because of the fast approach and that they're only nearby for a little while, a manned vehicle could well be the most efficient scientific technique.

Senator BROWNBACK. By what time would they have the capacity to be able to do that on the development approach that they're in now?

Mr. OBERG. If we're looking at being able to send a Shenzhou-type spacecraft and a mission module of about the same mass that could keep them alive for several months, we're talking about several launches of this CZ–5–500 new booster, which could be online and ready by the beginning of the next decade. If they wanted to make that dash, try some practices, even send a crew out a million miles and back as a sortie into interplanetary space, with the intention of, not being a stunt, but being pioneers on plans they would like to see done, I think that would be tremendously respected by, and impressive to, the rest of the world.

And then later on, when there is an asteroid they might wan to visit, they would have to send an additional mission module, a housing module with equipment. That could come later.

Dr. LOGSDON. You know, one question to which I do not have the answer is when a suitable body will be in the proximate vicinity of the Earth system that could be a target for landing.

Mr. OBERG. They tend to be—we're finding enough now, at least every year or two, if not more frequently. Some require longer voyages than others. Some are quite convenient; you can make a voyage out and back in a few months. Others require almost 12 months in flight, which is much too long for initial flights. And the initial flight might just be a flight out beyond the Earth-Moon system, test navigation in interplanetary space, and return to Earth, just as a sortie.

The first sortie out beyond the Moon would almost pull the rug out for any value—well, it would make going back to the Moon look almost pedestrian in comparison, but it would be easier than going back to the Moon. And that strikes me as an attractive kind of strategy. Maybe we shouldn't have published it.

[Laughter.]

Senator BROWNBACK. Mr. Grahn——

Mr. GRAHN. Yes?

Senator BROWNBACK.—I want to talk about micro-satellites and those sorts of missions that are going on. Why do you—I'm kind of curious about ourselves, the United States, and you, maybe, as a space observer and person that understands—why haven't countries like ours pursued investing in low-cost micro-satellite-type missions? Do you have any thoughts on why?

Mr. GRAHN. Well, I'll try to reverse the reasoning, because I don't want to answer straight to the point.

Sweden, for example, a very small country, very short of money, is—the only way for us to get into space—that's the only option, to do a low-cost approach. And Europe only spends $3 billion a year on space. It's—we're just not affluent enough. In the United States, your resources are much bigger and——

Senator BROWNBACK. But if these are micro-——

Mr. GRAHN.—the pressure is not on——

Senator BROWNBACK.—if these are micro-satellites, you can get them up, your cost structure is much reduced, you still get valuable information out of them—perhaps disproportionately valuable, relative to the cost of doing it?

Mr. GRAHN. Yes, but the—well, I don't want to say something political, but it's—you know, big organizations want to do big programs; small organizations can get along with smaller programs. So it's a matter of the organizational context. And you don't get to be a big boss in a big organization by running a small program. You run a big program. I mean, it has something to do with the organizational setup and the mindset of the organization running programs—unless you set up a little organization within a larger one.

I remember when we started with space activities in Sweden. We read some paper from the AIAA called "How to Run a Small Project Within a Large Organization." And it takes—you have to set aside a group of people and say, "OK, you guys are allowed to work in a different way, have your own mindset." Because, otherwise, the—this may be construed as dangerous to the organization as a whole if you can do things in a different way.

Senator BROWNBACK. There's much discussion here about going to micro-satellite programs now, and even perhaps going to and having private sector doing micro-satellite-type programs. Do you—are you hearing a great deal of discussion about that, as well, going more along your model of what you're doing?

Mr. GRAHN. Yes, I think that certainly private entities can launch things to other planets if they can get the money to do it. Just because, as I said, there is certainly a standardized approach, standardized industrial methods that can be used. So it's not something that's impossible to do.

If you look at unmanned robotic spacecraft, they are entering into the area where they are, sort of, reaching the industrial stage. By that, I mean that there are interchangeable parts that can be used, and you don't have to reinvent the wheel every time.

There's this old story about the coat factory, which was supposed to be the first company that pioneered replacement parts, but they found a bunch of files in their cellar when it went bankrupt.

This is, I think, the key to spacecraft development, is the use of standard parts, standard methods. And it is—we were on the verge of reaching that situation with the Constellation missions, the telecommunications Constellations.

But I think recent events, as I described in my talk, in non-aerospace technology has helped spacecraft development, because software is such a huge part of a spacecraft. For example, the SMART–1 space probe, I think that 25 to 30 percent of the incurred cost is just coding, software development. Then if I also count designing electronics by programming, so-called "gateways," it's more—making electronic circuits is looking like software programming. So that's a huge chunk. And now that the industrial methods have finally reached the software arena, this can greatly help the development of spacecrafts.

Senator BROWNBACK. Let me ask about Chinese/Russian cooperation in future space exploration programs. One of you presented about the great legacy of the Russian programs—I think, Ms. Smith, that you did—talking about length of time, space stations, the number of firsts that the Soviet program had in the legacy of Russian, and that one of you had mentioned, as well, that the Chinese space suit looks a lot like the Russian space suit adopted here.

What about the likelihood of a Russian/Chinese participation, joint venture, on an international space effort to a near-Earth object, Moon? Are any of these things being—do we know if these sort of things are being discussed?

Mr. OBERG. There has been no explicit reference to a near-Earth object mission that I've seen in the Russian or Chinese literature. The Chinese literature on lunar flight looks to me to be extremely derivative of the Western reports on it, but they have talked very ambitiously about Chinese and Russian extended cooperation on other missions. So they clearly do like to cooperate.

The Russians will sell China what it wants. The Chinese won't always buy it, because they can't afford it. But for future missions it's certainly very plausible.

In terms of—we're speculating on things that the Chinese could find useful and attractive, I have not seen any explicit reference in their literature toward anything but lunar flight, and even lunar landing. But the lunar- landing discussions strike me to be entirely derived from reading Western reports, not any of their own native research.

Senator BROWNBACK. What if there is a Chinese/Russian partnership on going to the Moon? Doesn't that move forward the Chinese ability to do this quite a substantial amount, given the Russian knowledge?

Mr. OBERG. I think the prime Russian motivation for space cooperation has got to be cash-flow. And as Marcia Smith has said, they receive a substantial amount—I believe the figure is almost half of their budget—from Western sales. They probably will keep to the concept, "dance with the guy what brung 'em" when it comes to where their program is centered. The Chinese don't have anywhere near that much money. And while the Russians still need that flow, they'll probably stick with their current partners for that very reason. But there's no—but other partners, other partnerships, can be formed.

The Chinese clearly want to partner with other countries. They partner with Brazil on Earth resources, they partner with ESA on science satellites, including one that was launched a few days ago. They want to partner more with Japan, with South Africa on software. The only country they haven't really discussed wanting to partner with much is the U.S., and they're still feeling, I think, that the termination of their satellite launch services, commercial and satellite—they no longer launch satellites for money, and it's primarily because of ITAR, primarily because of U.S. policy.

Dr. LOGSDON. I would add that Russia's potential primary partner for cooperation is Europe. There are lots of back and forth between Europe and Russia on future plans. After all, Europe is financing the creation of a Russian—of a launch site for the Soyuz vehicle at the European launch site in South America, which will give Europe, using Russian hardware, independent access for people to space sometime in the next four or 5 years. So there's a lot of interaction there; I think much more than a Moscow/Beijing axis emerging.

Mr. OBERG. And Russia has the hardware to do these missions. If they had the financing, they could be a third party to go beyond low-Earth orbit. They always wanted to. They have the—they could turn their hardware toward it, but it would take funding levels far beyond what they have available now.

Ms. SMITH. I think the key is that international cooperation is pervasive, because here in the States we tend to think of it in terms of U.S.-led international cooperation. But all of the major space-faring countries have own cooperative outreaches to various partners. And so there's Europe and Russian, and Europe and China, and China and Russia, and all of these different avenues for international cooperation are available these days.

You know, back in the Cold War era it was American allies cooperating with America, and Russian allies cooperating with Russia. But now the gloves are off, so to speak, and so you can form whatever relationship is most advantageous to you.

So that's part of the whole changing paradigm of international cooperation that's underway right now, which is why potential partners have more options than they had in the past. But, fundamentally, it usually boils down to money, and the United States, by far, has the most money. And I think that's why a lot of countries look to us.

Senator BROWNBACK. Ms. Smith, take me—in your role as a historian, you've been studying—the Congressional Research Service—how many years, U.S. space?

Ms. SMITH. Do I have to say?

[Laughter.]

Ms. SMITH. An eternity.

[Laughter.]

Senator BROWNBACK. Well, you've got—you're a national treasure, but you've been at this a lot of years, and I always appreciate your thoughts.

And I'm not quite sure how to ask this, other than, At what point in decisionmaking are we right now in U.S. space program relative to other times where we've made major decisions on space programs at this country? Are we at a point, do you think, of deciding to discontinue human flight, and this is analogous to a period when we were looking at it with Apollo?

Give me a historical analogy of where we are, policy decisionmaking, right now for the United States, with all the factors that are existing here and around the world. And what's the best outcome in looking at those historical analogies?

Ms. SMITH. Well, of course, I imagine you're talking mostly about human spaceflight choices, and——

Senator BROWNBACK. Yes.

Ms. SMITH.—of course, the Apollo program was decided in the Cold War era, primarily as a competitive venture because we wanted to demonstrate our prowess, technologically, compared to the Soviets.

At the end of the Apollo era, everything had changed. The interest in human spaceflight activity, it pretty much dropped off after we did, in fact, land people on the Moon. And so in the early 1970s, the focus was on developing something in the human spaceflight arena, but something that was very low cost, and that's when the Shuttle decision was made.

And after the Shuttle was approved and it was flying—NASA had always seen the Shuttle as a truck to go somewhere, which was to a space station—and so after a couple of flights, NASA declared the space Shuttle to be operational, and said, "OK, now it's on to the next step." And that was the step that President Reagan took, in terms of building the Space Station, which was basically the destination to which the Shuttle was going to go.

The Station has taken much longer than anyone had anticipated, in terms of getting built. It was announced 20 years ago.

Senator BROWNBACK. Space Station was? Wow.

Ms. SMITH. It was in President Reagan's 1984 State of the Union Address, and he called for NASA to complete it by—within a decade, by 1994. And here we are in 2004, and not only is it not done, but it's really not clear how much more of it we're going to build.

At the moment, it seems as though the United States remains committed to launching the rest of the hardware that's waiting down at Kennedy Space Center to be launched, and to launching the international partner modules. But the President's decision is to terminate the Shuttle at that point, and it's not clear how the Space Station is going to be operated thereafter without the Shuttle, on which everyone was going to rely, for taking these large cargo pieces that Mr. Oberg was speaking about, and for getting not just crews back and forth, but the results of scientific experiments, all of those things that the Shuttle was going to do.

So the President's decision—although everyone is focusing on the Moon and Mars aspects of it, the long-term aspects—is actually much more interesting in its near- term implications. As I mentioned in my statement, the fact that we're making a decision—we're actually deciding to suspend our own ability to put people into space. We did have a period like this in the 1970s. After the end of the Apollo program in 1975, there were 6 years in which we didn't launch anyone into space, waiting for the Shuttle to come along. The Shuttle was a couple of years late, but there was a decision at that point that we were going to have a hiatus in human space flights. And we're making that same decision now. But the difference is that now there's a Space Station up there, a Space Station that, under the President's proposal, would be the site where we're doing the research that needs to be done in order to enable the completion of the rest of his vision.

So it is a very unique time, I think, in the development of U.S. human spaceflight policy where at the—on the one hand, we're saying that America is so interested in human spaceflight that we're going to spend $170 billion over the next 16 years to return people to the Moon, but, at the same time, we're deciding that, for roughly 4 years, we're not going to be able to launch any Americans into space.

Dr. LOGSDON. I can't help but say, if Marcia's been around a long time—her first job was working with me.

[Laughter.]

Dr. LOGSDON. I must have been around even longer, and got my start writing a book called "The Decision to Go to the Moon." So I think I can speak with some authority to make the comment that we're at a singular decision point in U.S. space policy equivalent, if not even more profound, than the time President Kennedy committed us to go to the Moon.

We, as Marcia just said, have proposed a plan that burns some bridges, that says we're going to give up our current means of human access to space, we're going to stop doing things in low-Earth orbit as government programs, or at least civilian government programs, and we're going to head out to the Moon, to Mars, and beyond.

Again, run the null scenario. What happens if the Congress' wisdom, representing the public will, says, "No, we don't want to do that"? We are left with no human spaceflight program in 2010. If we are committed to retiring the Shuttle, what else do we have left if we don't go down this path?

I've got a piece that should be in Space News next Monday, that asks, "What did we know 3 months after President Kennedy said we were going to the moon, in terms of details of the program?" The reality is, we knew very little. The plan that President Kennedy approved was using an immense launch vehicle bigger than the Saturn V, called Nova, and going directly to a landing on the Moon. We didn't do any of that. By the end of 1961, we had invented a whole new program, called Gemini, and put it into the program. This piece is a little critical of the kind of detail that Congress is asking out of NASA for the plan, I must add.

This is a key point in the history of U.S. in space. And there's a proposition on the table that, if accepted, sends us one way that—for centuries; not only years or decades, but centuries. If we don't take this proposal, then I think it is the responsibility of all of us to say, "If not that, then what?"

Ms. SMITH. And it's historic not only in terms of the actual human spaceflight program that's been laid out, but in terms of the attitude toward international cooperation, because historically the U.S. attitude has been that we want to cooperate with other people, but they're not going to be in the critical path. And now we are deliberately choosing to put other countries in the critical path. It's a profound change in how we're——

Senator BROWNBACK. What do you by——

Mr. SMITH.—approaching international cooperation.

Senator BROWNBACK.—"critical path," Marcia?

Ms. SMITH. Well, when you put someone on the critical path, it means that if they don't show up with whatever——

Senator BROWNBACK. Oh, OK.

Ms. SMITH.—they promise to show up with——

Senator BROWNBACK. OK.

Ms. SMITH.—then the program doesn't happen. So if something happens in 2010—you know, we don't have an agreement with Russia at this point for them to provide services to the United States from 2010 to 2014, assuming that those are the years in question. It could take a little bit longer for the Shuttle to complete the Station. Maybe the CEV is going to take a little longer to develop. But for the moment, we'll just talk about this 4-year gap. Even if we have an agreement with them to provide these services, suppose something happens to the Soyuz? Accidents happen. The Soyuz has had a very reliable history. But something could happen with the Soyuz. Suppose our relationship with Russia changes? We've put all of our eggs in the Russian basket, basically, for that four-year period.

Senator BROWNBACK. Now——

Ms. SMITH. It's a very different manner of operating than we're accustomed to. It may be a perfectly fine way of operating, but it is very different from what we're——

Mr. OBERG. We have actually done that before. Even though Congress told NASA not to put Russia in the critical path of the Space Station, NASA disobeyed that willfully and put them in the critical path of the Space Station. And we paid the price for that in delays and extra costs, but we are to the point, and especially now, dependent on Russian goodwill. And it turns out we banked a lot of it by being good to them during Shuttle/Mir. And I think it's more reliable now than—I'll tell you, than I forecast that it would be.

Senator BROWNBACK. Because we've had this dual relationship, these dual——

Mr. OBERG. We've had this dual back and forth.

Senator BROWNBACK.—systems, that we've——

Mr. OBERG. Dual systems.

Senator BROWNBACK.—been able to go up.

Mr. OBERG. Each were there when the other wasn't.

Senator BROWNBACK. You know, I've got to say to all of you, you guys are great observers of this and have a historical perspective that I don't, although I've been fascinated by this for years. But many of my years, I was sitting on a tractor in Kansas being fascinated by it, so I didn't get to have this perspective that you're giving me here today. I just don't pick up the enthusiasm in the Congress for continuing the Shuttle a whole lot longer, other than if you were a contractor state; then there's enthusiasm that's based upon something we all understand—jobs in the particular state. But outside of that, just as far as enthusiasm—this is the right way to go, this is the place for us to spend $5 billion a year—no. And it's kind of—you know, it's kind of, "Why? Why are we doing this?" But you do sense that, "Yes, we want to continue manned spaceflight. We're not pulling out of this. This is something we should do."

It has enormous psychological value, if you can't put a price on it. It has an enormous value to the atmosphere of the country. Either way, if you're there or if you're not there, it has enormous consequences of it. So the people are willing to invest $170 billion over 6 years.

Ms. SMITH. Sixteen.

Senator BROWNBACK. Sixteen years, OK. Yes, I'm sorry. I wrote that—thank you. I want to correct my budget numbers on that, that's for sure.

That there is a willingness to do that, and—but it needs to be something that looks to be a worthy object. And, you know, if we can rely on other countries and we can work with other countries, I think people are going to be looking, you know, for that as being—you know, can we find good, reliable partners that we can work with? The Russian experience has been, overall, I think, a good one, in spite of the early years being some negative side of it. Without them, where would we be with the Space Station—International Space Station now, as you point out?

So there has been—you can look at that as a high value, that that's made the International Space Station continue to be able to operate right now. Without out it, it wouldn't be operating.

Ms. SMITH. That's absolutely true, but there is an agreement already in place that obligates Russia to provide these services to NASA. It's called the balance agreement that Mr. Oberg's been talking about. You know, what do we give, what do they give? And so under this balance agreement, Russia is obligated to provide these services, and that pretty much ends, in terms of the human spaceflight component, in 2006. So there won't be that kind of obligation on the part of Russia.

So Dr. Logsdon has talked about, How is everyone going to feel if, in 2020, you know, China's on the moon, or whatever, and the United States isn't? And Senator Nelson said that was unacceptable. And I think the question that needs to be asked is, What happens if, in 2010, the United States no longer has the ability to get up to the Space Station, and it's Russia and Europe and Japan and Canada that are using it, even though it was built primarily at U.S. taxpayer expense, and the United States is not able to send its own astronauts up there, we've turned the keys over to the other partners, and we've decided not to use it?

It may be that Congress and the White House and the public thinks that that's fine, that they feel that they've done enough Shuttle and they've done enough Space Station. But it is a question that needs to be asked, and people need to understand that this is one of the choices that's being made.

Senator BROWNBACK. Understood.

Dr. LOGSDON. Your colleague and counterpart on the other side of the Hill, Mr. Boehlert, last week, speaking to the AIAA, said something I think was very wise, which is that he's going to work with you, the authorizing committee, to try to separate the details of the specific budget request of FY 2005, and the ability to give a green or—he said, a green or perhaps an amber light, in principle, to the notion of this space exploration as the appropriate goal for human spaceflight. And I do hope that that signal gets sent out of the Congress this year, that we are going to go down that path, with the details to be worked out.

Senator BROWNBACK. No, I think it will. I hope it will come out. I don't sense, really, much—anybody saying we should pull out of human space exploration. It's just a real question about continuing with the Shuttle when you've got a stream of $5 billion annually.

Dr. LOGSDON. Well, as I think you know, Senator, I served on the Columbia Accident Investigation Board last year, and so got more familiar with the Shuttle, I guess, than I wanted to be. And it is a remarkably capable technological vehicle. It is also an extremely risky vehicle. So our recommendation was, the sooner we got off of sending people to orbit on the Shuttle and on to another system, the better it is for the country.

Senator BROWNBACK. That's part of the feeling here, too, and that if you have another Shuttle accident, it's just——

Dr. LOGSDON. We're done.

Senator BROWNBACK. That's——

Ms. SMITH. Well, I think the key is that you can make a decision that you don't want to have a break in the U.S. ability to put people into space, but that does not necessarily mean that you're choosing to extend the life of the Shuttle. You can try and accelerate the crew exploration vehicle.

Senator BROWNBACK. Absolutely.

Ms. SMITH. The key is to not have the gap. Dr. Logsdon has talked about how the CEV right now is envisioned as a vehicle—a Swiss Army knife, so that it can do, you know, Earth orbit, the Moon, the Mars, whatever. And may turn out that that's going to be a very expensive and lengthy process. It may be that in spiral-development philosophy that NASA's using for this program, that they can find something that's simpler and easier to do, that it would at least give you Earth orbit by 2010.

Senator BROWNBACK. Well, and plus——

Ms. SMITH. Something that was being discussed with the orbital space plane last year.

Senator BROWNBACK. We want to bring a whole 'nother set of people into this discussion, other than countries. We want to bring the private sector into the architecture of this set, and leave some legacy through them, so it's not just other countries; it's that. And that's going to be part of what we're going to try to design in the legislative proposals here, is that we're engaging that sector, U.S. and globally, for it. And that's a challenge, too, you know, of how you do that. And maybe it's that you pay the private sector for a certain set of services, and the effect of that payment is that they can develop this service and they can sell it to others, or use it to other individuals, is how you leave that legacy in place, rather than a 5-year plan that's strictly a government-run, government-done, and, when it's over, government-shut-down operation.

Thank you very much. We've had a wide ranging discussion here on important topics, and these are the building blocks of how we try to do these reauthorization bills for NASA, and try to figure out our funding approaches as we build the budgets together on this. It's been quite insightful.

Thank you for joining us and for your expertise. The hearing is adjourned.

[Whereupon, at 5:25 p.m., the hearing was adjourned.]

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