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THE FUTURE OF THE SPACE PROGRAM: WHY AND HOW?

Jeremy Stone: This is the first session of the Federation of American Scientists hearings on science and public policy—a series of hearings featuring scientists not only as witnesses but also as interrogators. We hope and expect to continue this series on diverse topics, subject to the vagaries of funding.

Our moderator, Dr. Alton Frye, is famous in Washington and several important world capitals for these four things: First, the high quality of analysis he has provided in many papers and in many conferences; second, the very broad spectrum of issues that he has been able to address; third, his very professional abilities at moderating conferences; and above all, Alton is known for the civility of the dialogue he maintains with all concerned, no matter how hot the issue.

Alton Frye: We do not presume that scientists hold the final truth on issues of high policy. The ambition here is a more modest one. We believe that scientists interrogating scientists can add precision and clarity to the evidence and arguments which all citizens must weigh in setting the course for a democratic nation.

I also want to express the appreciation of all participants for the assistance of Senator Albert Gore in making this hearing room available. As chairman of the subcommittee on Science, Technology and Space, Senator Gore is a valued bridge between the worlds of science and policy.

Issues to Address

The tendency to think twice about next steps in space has been compounded by recent accidents and errors: the Shuttle tragedy, the repeated delays in Shuttle missions, the foul-up that hobbled the Hubble Telescope, the serious underestimation of costs and maintenance requirements for the proposed space station.

SCIENTISTS' HEARINGS ON SCIENCE AND PUBLIC POLICY

FAS is inaugurating a series of Scientists' Hearings on Science and Public Policy. These hearings are much like Congressional hearings with the main difference being that the expert witnesses are grilled by other experts rather than by Congressmen.

It is anticipated that, as a result, the transcripts will, on the whole, penetrate more deeply into the scientific issues. FAS circulates the transcripts to interested parties, including especially the relevant Congressional Committees. And other means of distribution, including their publication in the FAS Public Interest Report, are being explored. ■

Yet there remains wide agreement that a commitment to both national and international ventures beyond the Earth is worthwhile, and indeed, vital. There are second thoughts about what the United States is doing in outer space, but they assume an important activity to be refined, not a dubious one to be killed.

Panelists

The members of today's panel are Dr. Richard Garwin of the IBM Thomas J. Watson Research Center, a physicist who is one of the most prolific commentators on science and technology policy.

Dr. Burt Edelson, former associate administrator of NASA and currently at the Foreign Policy Institute of the Johns Hopkins University.

And Dr. Stanley Rosen, a widely experienced aerospace professional who is Vice President for Public Policy of the American Institute of Aeronautics and Astronautics.

The Interrogators for this session are Professor Robert Park of the University of Maryland who serves as Executive Director for public affairs of the American Physical Society, and Mr. John Pike, the Space Policy Director of the Federation of American Scientists.

Good Ideas and Bad Ideas in Space

Richard Garwin: What can and what should we do in space?

You can categorize space activities as space oriented, Earth oriented, or other oriented. And we have to ask what is better done from space, not only what can be done. Better done include those things that can *only* be done in space and those things that can be done cheaper and/or faster. In some cases, this changes with time.

For instance, a communication satellite can handle a few local telephone calls together with its intercontinental or transcontinental load, but if the local demand grew, it would be served better by a local system.

The larger the program cost, the more important it is to scrutinize *both* sides of the ledger—costs as well as benefits. A program like the National Aerospace Plane, NASP, is consuming the relatively modest sum of \$100 million per year. But that would fund several hundred small groups' grants in science.

A \$40 billion space station amounts to 400 years even of the current NASP program expenditure, and if the Moon Mars initiative would cost \$500 billion over a period of 30 years, it would be an expenditure rate ten times that of the entire National Science Foundation over the same period, or for that matter, ten times the annual NASA expenditure on manned space activities.



Dr. Richard L. Garwin

Manned versus Unmanned

Manned versus unmanned. Should the patient prefer the daring surgeon to provide an exploratory view of the brain or liver or should he prefer "unmanned" magnetic resonance imaging? At one time every elevator had a human operator. Now that is a rarity and the job is done better and more cheaply by automation.

It is easy enough to point to cases in which human presence would be valuable in space or indeed, has been. But one can also point to cases in which the mission has been aborted because of people. People have also been killed.

The decision between manned and unmanned flight should be made on the basis of expected value, timeliness and the like.

Some ask: What about when something unexpected happens that can be interpreted only by the eye and brain of a skilled experimenter? If there is no redundancy and no control from the remote operator, the experiment will fail, as many do. But if it is important, the experiment will be done again.

Indeed, I have missed results right in front of me because my apparatus was made of brass instead of glass so I could not see inside, even though I was right there. When one truly wants to see, one need not be there; one uses a television sensor and a dozen people can watch simultaneously and individually from their offices, labs or libraries.

The cost of having people involved is the requirement to lift their weight and that of the support equipment. It is also much greater than that.

The space shuttle must be put into orbit—a dead mass of orbiter and support equipment some seven times the maximum payload east out of Cape Canaveral, and 15 times the maximum payload it could insert into polar orbit.

For these reasons, I am firmly persuaded that people in space have a much smaller future role than they have played in the past—at least if we are going to benefit from the exploration and exploitation of space.

It is not true that payloads can be retrieved from orbit only if accompanied by people. In fact, from the very beginnings of the space program, containers of animals, film and the like have been retrieved effectively at an increase in mass of something like ten percent for the addition of a thermal reentry shield. Nowadays one could guide the payload to an

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accuracy of a few meters onto an air bag or into a pond.

There is one essential need for people in space and that is to study human beings in space. We should get on with that job, which we have not done well for many, many years.

NASP, Shuttle, and Future Launch Systems

But we should only do in space activities that are worthwhile doing. Now, for projects and programs. The National Aerospace Plane, a small program now, was originally defined as a vehicle that would take off from an ordinary air field and, without rocket propulsion, enter and return from low Earth orbit. It can't, it won't and it doesn't make any sense to demand that it should.

In fact, the efficiency of utilization of rocket fuel to put a payload into low Earth orbit is about 50 percent. Fifty percent of the thermal energy of the rocket ends up in the kinetic energy of the payload, even if the payload is only a few percent of the initial launch mass. No way can you do better with a jet engine or any other kind of motor.

NASP should be cancelled immediately, but it might be redirected, keeping the name, to something that could indeed be called a NASP.

There are competing ideas for substantial reductions in the cost of launch. One of them is to go to expendable rockets which might take off from airfields in order to minimize the standing army which runs up the cost of space launch.

Another approach would be to attempt a reusable unmanned launch system. Rather than a single stage to orbit, which can be viewed alternatively as either extremely stressing of technology or as a high risk approach, one would choose a two stage system. Both stages would have to return to their airfield or launch site.

As for the space shuttle, the continuing expenditure to maintain this system in being is too great a tax on our ability to exploit space. The space shuttle system ought to be retired just as soon as the Titan IV launch vehicle is mature.

Space Station and Mars

Space station Freedom is an easier call. The only clear mission for a manned space station is a sound program to understand how and why humans respond to zero-G, also animals and plants. But if that is the mission, we are going at it in a very inefficient and ineffective way.

In preparation for a manned component to the Moon Mars initiative, we will have to understand long-term response to lunar and to martian gravity. We need a space station which will house humans in small capsules which will rotate at the end of a boom or tether to provide planetary gravity. At the center it should have a de-spun zero-G capsule.

We should start with putting U.S. astronauts on the Soviet space station Mir—which would benefit both of us.

Space Science and Exploration—SEI

So finally, in connection with space science to be done with the space exploration initiative, I would object to burdening science with responsibility for any appreciable fraction of those funds. If science can clearly be done at lower cost in conjunction with the SEI than independently in space or on Earth, then yes, it should be done that way. But if even a

mere ten percent of that \$500 billion for SEI, or \$50 billion, is money Congress and the people think they have spent for science, they will be deluded.

I would rather have science make its own proposals, and get its own money, than to live off a "tax" of the large manned space program.

What's Wrong with NASA?

Burt Edelson: I was called the other day by a reporter with the question: Burt, what's wrong with NASA?

My reply is that there are indeed things wrong with NASA. But NASA is the best technology management agency we have. NASA is more competent, and has a better record than, in my opinion, the Army, Navy, Air Force, Strategic Defense Initiative Organization, Department of Energy and the nuclear development program, the Department of Transportation and so on.

It has been my privilege to be associated with all of those organizations and to see their management, and I maintain that NASA is the best of all of those.

So let me rephrase the question: What's wrong with the way the Federal Government manages projects and promotes science and technology. That's the question we are really addressing today.

Shuttle Problems

In 1980, NASA was planning to launch 50 shuttles a year, one a week. The cost of each shuttle was approximately \$15 or \$20 million.

At that time they were planning a large number of space labs. Astro, which is on the pad now as we speak, was one of those. There was a series of Astro payloads, a set of ultraviolet



Former NASA Associate Administrator Burt Edelson

let telescopes, and we were to launch five or six of those.

The cost of Astro was something over \$100 million. I see it is now estimated at \$150 million to build those telescopes. That appeared reasonable because it was worth \$150 million to fly that set of instruments five or six times, each flight costing \$20 million.

Today, 1990, a shuttle launch costs \$400 million or thereabouts. Only the first Astro remains. The Astro 2, 3, 4, and 5 flights have been cancelled because they can't be fitted into the manifest.

Astro 1's original mission was to be the U.S. contribution to the worldwide cooperative observation of Comet Halley in March 1986. So here we are more than four years later launching a \$150 million payload on a \$400 million shuttle launch. Aside from the difficulty of getting it off the ground, our experience with these space labs is that out of five or six days in orbit, it takes three or four days to check them out, line them up, and go through a difficult acquisition process. So you get one, two days performance.

What Is the Space Program For?

What is the purpose of our space program? I recall that we went to a blackboard under the chairmanship of the late George Lowe, and we listed the purposes of the civil space program.

Up at the top of the board we put national image and we talked about that in terms of prestige among other nations, pride of Americans in accomplishments of their country, and a race with the Russians. I think it can be said clearly that the original purpose of the space program—which sustained it for at least two decades—was a race with the Soviet Union. This was a symbol of the comparison of the Soviet way of doing business and supporting technology and capability, with the American way of doing those things.

Then we listed seven other purposes. We took No. 1, which was national image, and we put a line under it and said that was obviously the top priority. It was the main purpose of the space program.

Then we listed underneath that, and we really couldn't agree, but we listed the following words: Exploration, science, applications—which means communication satellites, weather satellites and so on—technology, spin-offs, and societal benefits—education, medicine, foreign relations, commerce, employment and so on.

Today, clearly, the race with the Russians is a thing of the past. We can no longer sustain a space program as a race, but it is still a question of pride and prestige.

So I will end with the idea of pointing out that we must now decide why we are going into space today, what our goals are, which projects to pursue, how to organize them.

Realities Faced by NASA

Stanley Rosen: The recent discussions about the difficulties of NASA do not reflect an understanding of the engineering realities of how major programs are conducted, especially those promoted by the Federal Government.

I am reminded of a neighbor who has a very precocious teenager. When the teenager is doing well the parent is extremely happy, extremely proud and boastful. But when



Dr. Stanley Rosen

that teenager slips, the parents go catatonic. What in the world is wrong with Johnnie?

Well, there is nothing much wrong with Johnnie. The relationship says something about the parents as much as it says about Johnnie.

As we watch the relationship between the American public and the civil space program, I come to some of the same conclusions.

Overview of United States Space Program

The civil space program in this country is aimed at maintaining the United States as the world's premier space seeking nation, but as noted in the National Aeronautics and Space Act, we do this for the benefit of all mankind.

A program to meet those needs includes the systematic exploration of the Earth, the Moon and the solar system and the rest of the universe, and the use of space-based services for the betterment of life on Earth.

These, in general terms, are the goals of our space program. When we talk about the civilian space program, however, we have to remember that is more than just NASA. Civilian activities in space include those of NASA, those of other federal agencies now involved in space such as the Department of Commerce, the National Science Foundation, etc.—even the Department of Transportation—and the other component of civilian space activities in the United States, the private sector space program, which sells goods and services both to the Government and to private customers.

To achieve the goals that I have talked about, the space program has included scientific programs to study the space environment, the planets, the Moon, and to study the effects of space on materials and processes including, as Dr. Garwin mentioned, human and other biology.

We have also developed as part of that civil space program, extensive capability to travel and operate in space with both remote and on-site crews.

In the process, our space program has stimulated the development of United States scientific and engineering capabilities. I think we often forget that we hope our youngsters learn not only the beauties and the joys of science, but also the importance of engineering—which is a quite different set of skills.

The exploration part of our objectives comprises a set of long-term goals which, in my view, should be conducted on a consistent steady level as resources permit. The President has set forward a long-term vision for this country to explore the solar system and beyond.

The past decade has seen the emergence of many practical applications of space systems to improve national and global security and well-being. Today it is the usefulness of the space program in addressing national needs which, I believe, keeps space operations high on the list of national priorities.

In fact, space operations have the potential to significantly bolster our national economy, to monitor and improve control over the environment, to strengthen law enforcement, to improve the use of our natural resources, and to make other major contributions, possibly including new options in energy generation, access to critical minerals and disposal of especially hazardous waste.

In short, although space activities today make a very significant contribution to our nation, their potential is only now beginning to be realized.

Future Role of NASA: Applications Over Exploration

When we look at these objectives we realize that many of the initiatives after Apollo could have been conducted by other governmental agencies.

We didn't need NASA, especially if the ability of the Defense Department to conduct space exploration and development had not been as politically constrained as it has been.

President Bush has recognized this and has directed that the military, as well as the Department of Energy, be involved in the space exploration initiative.

But the Department of Defense already has a mission of providing for the security of the country. To foster the capabilities I've talked about which address urgent national needs to which space can now be applied, we do need a dedicated organization and NASA appears to be that organization. For that reason, I believe that the primary task of NASA should be the development of new products and services, using space to promote national well-being and economic competitiveness.

This role is entirely consistent with previous federal initiatives which opened other frontier areas to the American mainstream, such as the opening of the American West and the support of the fledgling aviation industry.

Clearly, if the United States Government chooses not to take this role, other governments will. They have shown their willingness and understanding of the potential of space to contribute towards their national well-being and to global well-being.

So for this reason I believe that fostering these emerging space capabilities and applications, satellite communications, remote sensing, positioning, locating, or more speculative concepts such as materials processing and development, should be given a higher priority within our civil space program than space science and exploration.

I want to point out that I am not talking about necessarily an industrial policy in which the Government has to pick the competitive winners in an otherwise open marketplace. Rather, the Government takes those steps which make it easier for the private sector or for government agencies which have operational missions, such as the Department of Commerce, the Department of Defense, to find and to develop the best uses of space.

We talked about the shuttle having had the objective of reducing the cost of access to space. It has not accomplished that mission. There are many ideas on the drawing boards which can, and we probably ought to get back to that.

The role of the space station too, and manned operators in space, can be reassessed in light of these priorities, and in my paper I talk a little bit more about the role of men and women and crews in conducting these types of operations.

So, to summarize, I think that the structure of NASA should be one which permits the development of these capabilities which I've talked about, and which continues long-term space science and exploration at a steady level.

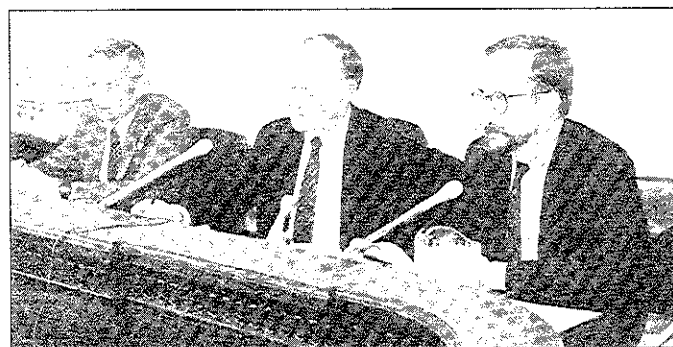
State of U.S. Launch Capabilities

Robert Park: In July of this year, President Bush reversed a long-standing order by allowing U.S. commercial satellites to be launched by the Soviets.

Even China is now launching U.S. satellites. In view of your statement that the primary purpose should be the development of new products and services for the benefit of the people and for competitive purposes, why do we need to have the Soviets launch our satellites? The United States is pretty much out of the launch business. What went wrong?

Rosen: Dr. Park, I think you understand, the United States is not out of the launch business. We have a very vigorous launch capability, not only the space shuttle but the Atlas family, the Delta family and the Titan family which is promoting government operations but which is also available commercially.

Other existing small launch vehicles, and a large number of vehicles on the horizon which are being offered commercially for small satellite launches, such as Pegasus, are available.



Robert Park, Alton Frye, and John Pike question the panelists.

So no, we are not out of the launch business. In fact, we have a very aggressive program not only to lower the cost of what we're already doing, but to offer improved launch capabilities.

You have rightly pointed out, though, that there are emerging opportunities to get access to space through other means and through other countries, just as we have international competition in air transport, in shipping, and in many other transportation systems.

It is going to be important for the United States to carefully consider what it should do to be competitive in this area and to maintain the position where not only we can support our own launch needs, but we can compete as appropriate on the world market.

Economics of Space Activities Questioned

John Pike: You suggested or ran through a fairly long list of ways in which you say space is helping the economy, but it seems to me that communication satellites are really about the only place where one can show a net economic benefit. And the communication satellite industry has been in serious trouble recently because of competition with fiber optics.

The Landsat commercialization experience has been an increasingly bothersome example of the difference between profit-seeking and profit-making activity, and I think the prospects for commercial material processing are probably more remote today than they have been at any time in the last generation or so.

What basis is there for claiming that the space undertaking is, in fact, benefiting the American economy? It seems to me that quite to the contrary, the communications satellite industry is the exception that proves that rule that it is not.

Rosen: Let's be clear about the distinction I tried to make earlier between a commercial activity's ability to make a profit and its having beneficial applications to the U.S. private sector, or to the U.S. economy, or to U.S. well-being overall.

For example, the civil weather satellite program, along with the military weather satellite programs, contribute to U.S. well-being. But they are not in private hands, so the fact that they haven't been commercialized or privatized doesn't mean they are not successful and doesn't mean that they are



Dr. Burt Edelson presents his case.

not making contributions.

In the communications area, it is easy to lump everything together and just say communication satellites are contributing to the United States. But in the area of communication satellites, we have a tremendous number of different applications we're talking about: telephony, data transfer, transmission of data from remotely placed sensors, geo-location and radio navigation, communications with remote terminals, and potentially with hand-held cellular telephones in systems such as are proposed recently.

So in that one burgeoning area, we see many potential ways that space and space operations can contribute to the United States and global well-being.

I have no doubt that the others that I mentioned are also equally likely to make such contributions, and many others on the horizon. If the cost, for example, of space launch were lowered significantly, I think you would see a number of applications of space systems that you hadn't heretofore imagined.

Now, whether they would be commercially viable or not, the marketplace will have to decide. For example, you heard about the idea to launch cremated remains in space. I don't know whether that's a good idea or not, but there are many innovative ideas waiting to be developed, if given the proper support.

Benefits of "Cheap" Launch Systems Questioned

Pike: We've heard an awful lot about "if we could just get down the cost of access to space," that somehow or another this would open up broad new vistas.

In reality, what we have seen over the last 30 years is that—apart from the fact that big rockets are cheaper than small rockets—there has been essentially no improvement in the cost of access to space. And when you look at most space operations, launch costs constitute only a very small portion of the overall project.

This suggests that halving the launch cost of a space operation, from 20 percent of the cost of the project to 10 percent, would be a major achievement in terms of lowering launch costs but would have essentially no impact on the cost of the project as a whole.

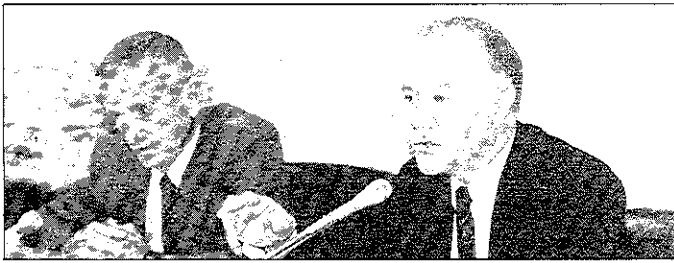
Rosen: Yes, I think your analysis is right but I don't agree with your conclusions.

The reason that most of the space programs today are such that launch costs are a relatively small portion of the total programmatic costs is because those are the programs that have been able to afford the kinds of launches we have today.

If launch costs were reduced, programs which could be done less expensively, and for which there are financial resources available out there, could then go forward.

Pike: Are you aware of a study identifying markets that would benefit from a reduction in launch costs?

Rosen: Well, for example, the Iridium program [satellite-based cellular telephone] that we've talked about will be made, or will fail, depending on whether or not they can show the right cash flow at the right time. Launch costs will be significant portion of the cost of initially establishing a 77



Alton Frye clarifies a point as Robert Park looks on.

satellite constellation and maintaining that constellation.

Pike: It seems to be an implicit article of faith across the spectrum that somehow or another the big bottleneck on space is a reduction of launch costs. Given the amount of policy that is being made on that assumption, I think that we should want to see 150 pages with footnotes and tables showing demand versus launch costs before we went much further in investing in things like aerospace plane or Pegasus or whatever.

Rosen: Two points. First of all, you asked earlier about why we hadn't been able to reduce the cost of space launch after so much work. We are still fairly young in this industry.

Pike: Right.

Rosen: And we have learned a lot. The space shuttle was a good testing ground for how to make a low-cost space transportation system and we learned a great deal, just as we learned from the DC-1. You've heard that analogy too.

So we have a long way to go. We can reduce the cost of space transportation if we want to, and your question is should we? It is a good question. I don't know whether it is possible to prove analytically that there are many applications out there which will be developed if the cost of launch is reduced.

What we can fairly well show though is that there are potentials out there to do things which we cannot now do, and cannot now afford to do, which may be useful.

Space Development Policy as Industrial Policy

Pike: At the end of the day, doesn't all of this, despite your earlier assertion, constitute the dreaded word industrial policy, in the sense that we are picking winners and losers: that we are subsidizing the development of space-based communications through satellites in a way that we are not subsidizing the development of terrestrial communications through fiber optics; that we are subsidizing the development of resource monitoring and remote sensing using satellites in a way that we are not encouraging the development of a similar industry, which already exists and is already profitable, using airplanes.

Aren't we, in a sense, in the worst of both possible worlds from the standpoint of industrial policy? Aren't we pursuing an industrial policy, with all of the risks of politicizing the process that the Bush administration refers to? And yet doing this without any of the benefits which the advocates of industrial policy point to—that is, being able to make an analytical case for why we should back one of these industries rather than the other.

Rosen: Your point is again well-taken and I think if we were to try to pick winners and losers among industries or among applications, to pick specific ideas from somebody who came in and talked to the Government as one would talk a venture capitalist, it would be a mistake in my view.

But consistent with the Space Act of '58, what we are doing is not trying to promote one industry, but promote the development of an entire new region of human activity, and to enable the technology base to allow those industries to come out. Space transportation won't only help the communication satellite industry, it will help an entire new process of development, as we have talked about many times, that has many applications, most of which we can't even imagine today.

Pike: But in fact, haven't we done that by our decision to promote the development of small expendable launch vehicles? Isn't the White House currently faced with a decision on whether to continue to subsidize the development of that industry by precluding the use of surplus military boosters for small satellite launches?

I think Orbital Sciences is a great company and Pegasus is a neat rocket and everything, but we are clearly in the industrial policy business of deciding that we are going to promote a small satellite launch industry. The amount of money that we have spent in pursuing that policy totally dwarfs the amount of money that we have spent trying to figure out whether that is a good policy in the first place.

I am prepared to be convinced that it is a good policy, but in the case of these small satellite launch vehicles, we are very explicitly functioning in the capacity of a venture capitalist deciding that we are going to start up this industry where none previously existed without the benefit of a Government business plan to decide that we ought to do that.

Rosen: Maybe we ought to have such a plan. What we have done in this case, as in other cases, is use defense needs—in this case, the Pegasus was underwritten partially, although not totally, by DARPA, to develop technologies for defense needs, which then have civilian applications.

I think with regard to the small satellites that you are talking about, and the launch capabilities, policy will be made with defense needs in mind as well.

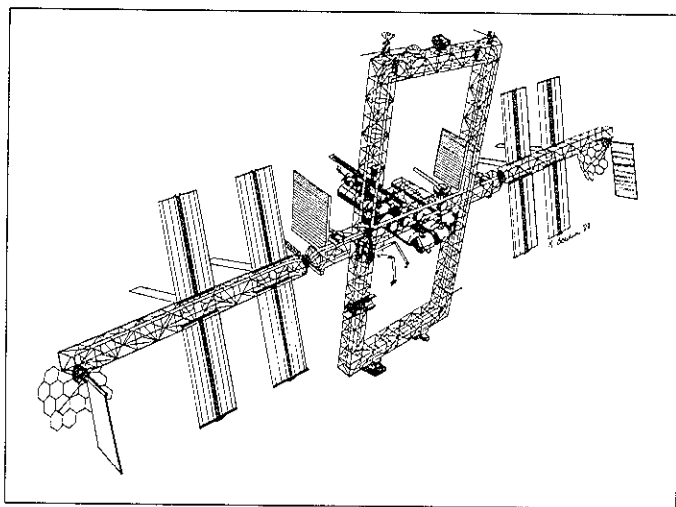
U.S. Use of Foreign Launch Services

Frye: Are the constraints on American applications for using alternative launch services about the right balance today, or are they too severe? Should more American applications have access to other countries' launch services? Were they to be liberated to use those alternate launch services, would they do so more extensively than they do today?

There are some relaxations of those rules taking place. But if the relaxation were general—if it was strictly a cost calculation for the user to decide which launch service to use—what would be the implication for developing the American launch capability?

Would it be death to the American industry?

Rosen: I don't know. I do know that we do have a significant number of examples of American satellites flying on foreign launchers. We fly on Ariane, we fly on the Long March. We



Space Station Freedom

have not yet flown American satellites on Soviet launchers, but we have flown American experiments on them.

So the policy environment is such that there aren't a lot of constraints today, with the exception of the Soviets, on what launch vehicles American payloads can use.

And that policy, as you know, is evolving in respect to the Chinese and it seems to be fairly liberal in terms of looking at both the balance of interest between those who want to maintain the launch capability, and the satellite manufacturers and developers who want to have the choice of launchers.

So I think our policy seems to be fairly well-balanced and going in the right direction.

Now, to the second part of your question—What would happen if we removed all constraints and whether or not the United States would still be competitive? I really can't say.

I have a hunch we would be competitive, but I will tell you frankly, there are those who believe that there is not enough business in that whole market to justify trying to get in and fight it out. There are those who believe that if the Chinese want to play in that market, let them have it. It is not worth competing from a business standpoint.

So that is something that the market would decide.

Frye: The high tech equivalent of the textile industry. I wonder.

Uses for the Space Station

Park: In the early justification of the space station, this was portrayed as sort of a micro-gravity research and development operation. Is that gone completely?

Garwin: I hope so. We had all those years of the perfectly spherical ball bearings promised from space. Of course, there never was one and there never will be because you have very large forces from surface tension, crystalline surfaces, inhomogeneity and all that.

In fact, as we learn more and more, we find less and less that seems valuable to do in a space station. Now, if we go to some other planet—and there aren't very many that are reasonable candidates, but maybe planetary moons—maybe we will find something, but that is not the purpose of the space station.

So a lot of these proclaimed benefits do not exist and never

would have existed under analysis. They were looked at only too briefly and the investigations stopped when it looked positive.

Arguments for improving electrophoretic separation, for instance, never looked into what one could do on Earth with an appropriately designed system, and of course that approach to protein production is now overtaken by genetic engineering.

The arguments for the space station really have changed enormously. The space station program must change enormously. NASA has analyzed the maintenance requirements and found that it will be too costly to maintain by extra-vehicular activity as was planned, and so something must be done about it.

Well, what should be done—if I could pick up one of the other points—starts with more international collaboration. Mir is there and we ought to put people on Mir with our equipment, and get information right away which will help us to build a bio-medically oriented space station soonest.

This will also help the Russians and all the rest of space-faring mankind and I think that's only to the good. I am not in favor of having the United States the foremost space-faring nation in the world, if by emphasizing foremost we do not advance as rapidly as we would have if we had emphasized cooperation.

Why Study Space Effects on Man?

Park: In referring to the decline of the manned future in space, why do you want to study the effects on human beings in space if, as your earlier remarks seem to imply, there is no real purpose for man in space.

Garwin: If the American people want to spend a lot of their money for the entertainment of sending people off to explore Mars, that's their right. In order to do it at reasonable cost and safety, we ought to know more about people in space.

In fact, the NASA analysis has always had as the baseline for sending people to Mars, a zero-G voyage, with absolutely no guarantee that people would be functional when they got there.

I think that if one wanted to have a commitment to putting people on Mars, before we have the available information or the requisite bio-medical miracle—which is what we're counting on right now to negate the effect of zero-G—then we ought to plan to have one of these two-compartment space ships with slow rotation to provide one-G.

But if we are seriously interested in exploration, we will get the results sooner if we do it without people.

Soviet Experience in Zero Gravity

Park: In the zero-G category, the Soviets do have a lot of information. They have had people in zero-G for record periods of time. They do find serious declines in the ability of people to function after long periods in a weightless environment.

Garwin: Well, they have a lot of experience. They don't have a lot of good information by our standards, but we don't have that information either.

The NASA bio-medical effort has been very poor in quali-

ty, in my opinion, compared with the physical and astronomical space sciences.

Zero-G Study as Rationale for U.S. Space Station

Park: Would that then be your idea of the principal focus for a space station, were we to build one?

Garwin: Yes. I think that should be the principal focus for a small special purpose space station, which would not preclude having another one later.

Pike: It seems to me that the space station has been a capability in search of mission ever since the 1950s. Original thinking during that period for how to get to the Moon assumed that a lunar expedition was going to require a medium-sized mountain of fuel. Von Braun's early ideas envisioned several dozen people in a lunar spacecraft because you were going to need several people to navigate the spacecraft, and a couple of people to change the vacuum tubes from the radio and so forth.

By the time people actually went to the Moon, it turned out that, through lunar orbit rendezvous, you only needed a single rocket, and as a result, a space station was bypassed completely.

My impression is that the mass penalty for simply spinning up the Mars vehicle is something like ten percent of the dry mass of the spacecraft—which is basically going to be structural kevlar or structural aluminum—so we are going to need a little more propellant to support that additional mass.

So it seems that the additional cost, both in terms of risk and schedule, of finding out whether we can leave these guys bouncing around inside the spacecraft for six months or nine months, is so high that maybe it makes more sense to simply decide this morning that we are going to spin up the Mars vehicle.

In that case, as with the lunar expeditions in the 1950s and 1960s, maybe we can simply bypass the space station altogether.

Garwin: Well, I certainly agree with that. I think that the conservative and the quickest way to get to Mars with people, if that's what you want to do, would be a one-G trip with a spinning pair of spacecraft.

If you are preparing for a permanent colony on Mars or the Moon, then you really have to look into the fractional G activity and therefore—



The panelists respond to questions.

Pike: But of course, that's something we have done. We have examined the micro-gravity environment in low Earth orbit by actually being there. So couldn't we examine what the long-term effects of the one-sixth gravity on the Moon are by sending some people there and experimenting as the Soviets have on Mir?

Garwin: Especially on the Moon, where you can bring people back quickly if you want to.

Garwin Responds on Launch Costs

I would like to argue with you about reducing the cost of launch, but I can't because you're right. I think your skepticism is entirely justified. There have been many times in the past when we have had big programs to produce new boosters which have actually been produced, which in fact, when they came into being, did not have an adequate market to justify the expenditures in producing them.

So from the very beginning, we have not had major reduction in launch costs when one includes the development cost of those new programs.

So when I talk about reducing launch costs, I mean programs that are economically justifiable in reducing launch costs. That does not mean that one commits a big program without—and makes the expenditure without—some guarantee that the market will be there, a big enough market so that you'll make money on the reduced launch costs compared with what you had.

So I want a lot of thinking about these airfield based expendable rockets. I want a lot of thinking about airfield based reusable rockets. I want a lot of open discussion, and I think this is a very useful discussion that we're having here.

Now, the problem with doing this in NASA is the same as the problem of bringing up small strategic submarines in the U.S. Navy—which has told its contractors you can either build us submarines or think about submarines, but not both. [Laughter.]

Shuttle Failure to Provide Low-Cost Launch

That's the trouble with NASA too. NASA itself knew pretty well in the 1970s—or if they didn't, there was something more seriously wrong with NASA then—what the prospects for the shuttle would be.

But their response was to kill the Defense Department market for expendable boosters by a Presidential fiat. And now the problem of creating additional competitive lower-cost launch capabilities, in an organization that is trying desperately to keep going with an operating system which is of high cost, is insuperable.

Pike: Wasn't that completely explicit in the original thinking behind the shuttle, that lowering launch cost depends on having a fairly large traffic model, and the only way to have so much traffic for the shuttle was by capturing all of the market that was available, certainly including the defense market?

Garwin: Well, initially it was to be captured by market mechanisms—that is, by providing a launch vehicle which was so cheap that there would be no question that anybody would use anything else.

But two things happened. First, it was not so cheap, especially in small numbers, and second, the military missions did not materialize.

The replacement of vacuum tube by transistors and integrated circuits and the extension of life of spacecraft from weeks to years really did cut into the market. Also, some early studies were oriented towards showing that if launch costs were reduced, then people could build satellites more heavily, and they would be a lot cheaper. That didn't materialize either.

Lower Cost of Unmanned Missions Questioned

Pike: I would like to take issue with your comments on the relative cost of manned versus unmanned missions. When one looks at the hundred ton dry weight of an orbiter, and the amount of that dry weight that is attributable to the fact that one has people on board, versus the amount that is attributable to all of the other performance characteristics of the shuttle, one sees that the burden of having the people in the front of the shuttle is relatively small compared to the burden of being able to return very large payloads.

In fact, the one place where I have been able to find a direct apples-to-apples comparison between the cost of manned versus unmanned flight—the comparison between the Apollo program bringing back lunar samples, and the Soviet unmanned lunar program bringing back lunar samples—it turns out that Apollo was just as cost-effective as the unmanned sample return program, and certainly in terms of the scientific payback, was much more productive.

Just as I am concerned about the lack of documented, systematic analysis of whether there is a demand elasticity for lowering launch costs, I also feel it is generally taken as an article of faith that manned missions are much more expensive than unmanned missions. But, again, it seems to me that this is largely based on anecdotal evidence that doesn't necessarily hold together too well.

Garwin: If we had wanted to do sample return from the Moon without people, we would have done it that way, and much more cheaply than the way we did it.

Pike: Program costs but not cost per gram.

Garwin: Well, if we had insisted on bringing back as much we brought back, which we haven't analyzed anyhow, we could have done it much more cheaply than with a manned program.

That's an assertion. I believe it will be borne out.

You don't save much by operating the shuttle without people. But where you make the major saving is by not having to bring back an orbiter. You wouldn't need the orbiter to do the things that you're doing if you didn't have to bring the people back. You would bring back the payload only when it needed to be brought back, and you would bring it back by a re-entry vehicle of its own that was sent up with it, if it was planned for return, rather than sending an orbiter.

An orbiter, if it is one of these reusable next generation unmanned systems, would look nothing like the orbiter looks now. It would not have a payload bay. It would be the short, stubby propulsion unit, which would have now very cheap guidance systems.



Dr. Alton Frye of the Council on Foreign Relations

That's one thing which has changed. In the past, the cost of large rockets per pound of payload was indeed considerably less than the cost of the small rockets. There was a lot of inflexibility and one of the things we need to preserve in the future is a whole range of payload masses in our rocket fleet, rather than sending up a shuttle no matter how small the satellite is that you want to put into LEO.

I do believe that we should make available the surplus rockets for civil and scientific use. That's part of the market system, to recycle, and the costs of this recycling will be reasonable.

Space Activities Should Compete with Earthbound Equivalents

Pike: The implication of your opening statement was that we should regard space as being a place rather than a mission, and that the scientific activity that we conduct in space should be peer reviewed in competition with the scientific activity that we conduct here on the ground.

The NSF budget for astronomy these days is about \$100 million a year and declining. That's for ground-based astronomy, depending on how you want to aggregate it. The NASA budget for space-based astronomy, you could probably round off in the vicinity of about a billion dollars a year.

Under your proposed system, do you think that peer reviewing space-based astronomy against ground-based astronomy would result in a significantly different allocation of funding?

Garwin: I absolutely favor that. I think that space should be used when it is desirable. 20 years ago I told people that satellites for the most part were a passing thing for civil communications, except for mobile communications, simply because fiber optics would take over.

But absolutely, we should do that science which is justifiable and competitive. I hope that if the NASA budget per se is much reduced, that the science budget of the National Science Foundation, or whatever is funding science, will be increased because there are things that you can do from orbit that you can't do from the ground, and that we should do anyhow, even if they are fairly expensive.

NASA is the wrong organization to do many of these

things that we are calling on it to do. It is organizationally wrong, its motivation is wrong, and it has some of the wrong people. We need more competition. Hughes as a satellite manufacturer has done a lot toward the improvement of satellite technology. Intelsat as a satellite operator has done a lot toward sponsoring of new technology.

How Can NASP Be Such a Bad Idea?

Frye: You were particularly emphatic in describing the credibility of the National Aerospace plane venture as very low indeed by saying that its mission [lower cost than rockets] could not be done.

The question I have for you is this: If it is such a clear-cut call, why in the world has the case prevailed to date for cranking some hundreds of millions of dollars into the National Aerospace plane. Is there not more to that program than your rationale suggested?

Garwin: I don't think so. It was put into the NASA budget by the White House, so far as I can see. Somebody likes it.

Now, we've had many cases in the past where such things have happened, and NASA, I believe, are being good soldiers. They are managing it. They hope that some technology, maybe structural technology, will come out of it, because if a National Aerospace plane would have half a chance of fulfilling its mission, it would have marvelous structural technology which could be used to advantage elsewhere.

But if that's what we want, that's what we ought to concentrate on developing, rather than this fiction.

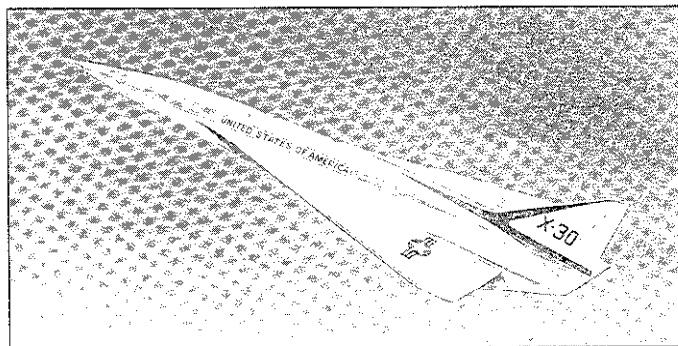
The NASP mission or flight profile could be redesigned so that it is feasible. In fact, I think one of the future promising options is a rocket which will take up from an airfield, fly by rocket propulsion into orbit and maybe even return. You may ask how that is different from NASP.

Well, it sure is different from what was promised initially, and if we would have a free-ranging view of that program, we would probably decide that we could reduce the budget considerably for the next couple of years while we got reoriented. We could still call it a NASP and it would have a fighting chance of doing something useful.

Cost-Effectiveness of Space Program as U.S. "Image Enhancer"

Park: Dr. Edelson, in your comments, you stressed the importance of national image as one of the objectives of the space program, and I happen to agree.

I don't know how to put a dollar sign on that. It is useful, I



National Aerospace Plane

think, to look at some comparisons. For example, the increase requested for the FY 1991 budget for the space station alone is equal to the entire budget of the National Science Foundation for one year. That is just the increases in the space station budget requested and that's before we even have a plan for the space station that's agreed on.

But it seems to me also that the national image is a two-edged sword, as the publicity that is going on right now in the press would certainly seem to indicate. Don't we run a terrible risk when we base our national image on projects that in all honesty have not, in recent months at least, done a great deal for the national image?

Edelson: Yes.

Park: I just wonder if we've considered the risks and how do we measure the cost-effectiveness when we get into that?

Edelson: Let me avoid the question of cost-effectiveness, but point out how significant the national image was in the Apollo program. If there is any single accomplishment that America made in this century that is going to last in future decades and centuries, it is that.

That's why national image goes at the top. Likewise, let me point out what the Soviet launch of Sputnik and their follow-on successes with the Gagarin manned space flight and their first trip to the Moon—they actually got there before we did, unmanned—did for the Soviet image.

Remember the shock that went through our country, through our educational system and our industrial community and so on.

International Cooperation is the Future of Space Exploration

Now, the national image was associated with a race for 20 or so years. That clearly is not sustainable today. I believe that international cooperation is the sustaining element of future space exploration.

Why did we go to the Moon? Why might we wish to go to Mars? Not for science. There is no way that science could have justified the Apollo program, and no way science can begin to justify a manned space flight program to the Moon, or even an unmanned exploratory Mars program.

What is sustainable is an international venture of exploration, and if you desire, manned exploration. That is a noble goal and the U.S. image will be increased immeasurably if we can lead such an international cooperative venture; but it has to be international and it has to be truly cooperative.

Park: But if it is truly cooperative, it is not clear to me that we are necessarily recognized as the leaders.

Edelson: That's a very good point and I agree with that. Our image will be sustained and improved if we can provide an impetus to get it going—some degree of leadership in organizing and supporting such a program—and if the United States acts as a true international partner, willing to share its capabilities with other nations, and equally willing to take advantage of the often superior capabilities of other countries.

Europe, Japan, and indeed the Soviet Union have in many areas superior technology, and I personally think we are

losing ground and tarnishing our image by pursuing programs in which we haven't the technology or the financial capability to set clear goals, provide the necessary resources and accomplish them.

Frye: Which programs do you have in mind when you say we should not be pursuing programs for which we have inadequate technology or not the prospect of satisfactory resources?

Edelson: I would say that the space station program and the space exploration initiative should be pursued in a truly international cooperative fashion, or not at all.

Is the Space Age Over?

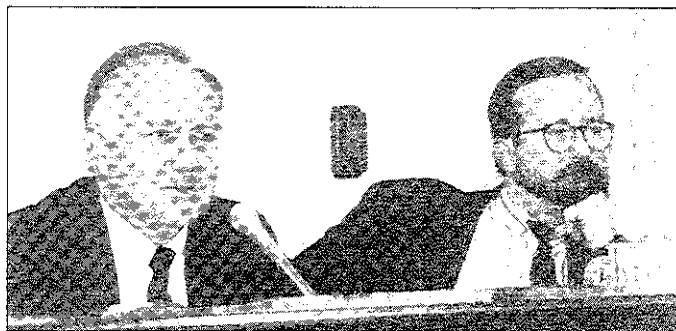
Pike: If we go back and look at your observation on why it is that we have done space—that we are doing it for national prestige and doing it in competition with the Soviet Union—both of those are basically predicated on the United States having a successful program.

Edelson: Yes.

Pike: And even if we eliminate the Soviet competition—and I think it is increasingly clear that that's not going to be an issue anytime soon—unavoidably, whether we like it or not, whether we intend for it to or not, the American space program does reflect on our prestige around the world.

Unfortunately, over the last three or four years, rather than reflecting positively on American prestige, it has, on the whole, reflected negatively on American prestige. I am getting a little bored with reading all these articles about how the Japanese point to America's space program as being an indication of the fact that America is in decline, that American technology doesn't work, and that if the 20th century was the American decade, the 21st century is going to be the Japanese century.

We've run out of easy things to do in space where the chance of succeeding is high, and we have entered an arena where we are either going to be repeating past triumphs—which isn't going to get any applause—or we are going to embark on projects that are so challenging that the risk of failure and loss of prestige is high. Maybe the space age has, as a whole, been an historical aberration. Perhaps it was simply a unique confluence of events—the Cold War, Von Braun, etc., etc.—that for a brief shining moment allowed the space program to be the incarnation of American aspirations. Perhaps that moment is past and we're trying to figure some way of gracefully concluding the space age.



Alton Frye and John Pike

Edelson: I don't disagree that our image has been tarnished, and perhaps the space program has not helped the U.S. image over the last few years.

When it comes to projects and programs that I am familiar with, in the science and applications program, I think that the U.S. program is admired, respected and well-developed.

To start with, astronomy and astro-physics, the Hubble space telescope is the first great observatory, to be followed by the Gamma Ray Observatory and the X-ray facility and the IR facility.

Pike: But the only thing that people are going to remember about Hubble is that the mirror was perfectly wrong.

Edelson: We are admired and respected for undertaking projects of that type.

The planetary exploration program has been a huge success with image. The Voyager program with its Jupiter, Saturn, Uranus and Neptune flybys and all those pictures sent back. You could question the value of the science per dollar spent, but you can't question the enormous prestige value, and enhancement of the U.S. image as undertaking a mission for the benefit of all mankind.

Now, this afternoon you are going to hear about Mission to Planet Earth, an absolutely outstanding program where we are indeed engaged in an truly international cooperative endeavor to gain an understanding of our Earth—as a system of the oceans and atmosphere and solid earth and vegetative cover and the interaction between them and the nutrient cycles and so on, which is going to lead to the continued biological productivity of the planet on which we live.

Pike: But in terms of those first achievements that are relatively understandable to the public, first pictures of Jupiter, first pictures of Neptune, first man on the Moon, etc., it seems that we are starting to get very close to the bottom of the list of achievements whose novelty or visual impact or conceptual clarity—

Edelson: Yes.

Pike: —are going to make them readily communicable to the public. In the process, we are embarking on missions of increasing complexity, increasing technical risk where we have unavoidably, I think, a growing risk that we are going to get into a situation that we've gotten into—that we are in right now on the shuttle—where we can't stop the hydrogen from leaking.

You've got Hubble trouble, you've got GOES woes. I haven't yet figured out a rhyme for Magellan, fortunately.

It seems that the space program is starting to run out of pretty pictures on one hand, and on the other hand we are starting to get into terrain where the answer seems to be that these projects have a negative impact on American prestige. And it seems to me that the American public will support a successful space program but not an unsuccessful program, particularly if it can't figure out what the space program is doing.

Edelson: I think you have a basically good underlying point, but you are getting carried away with your alliteration and references. [Laughter.] In fact, I think you are guilty of the

typical type of NASA bashing where you are lumping a lot of things together.

Let me make just two quick points. I mentioned the great observatories, but I would assert that although it is much more difficult to understand what the product of AXAF [Advanced X-ray Astrophysics Facility] or GRO [Gamma-Ray Observatory] will be, they will be accepted and admired in the world's scientific community and the U.S. prestige will be increased thereby.

In fact, on the Hubble telescope, it is unfortunate that the cameras that make pictures are going to be out of focus. The spectrometers are not badly damaged. The photometer is not badly hurt, and the astrometric instruments, the fine guidance sensors are working fine. It is unfortunate that the public will not be interested in the scientific data that they produce.

Pike: You are saying good science but bad entertainment.

Edelson: That's right, I mean, the public wants pictures, and yet I know NASA is striving now to release data from these other instruments to show that the Hubble telescope is not a total failure.

Prosaic Operations, Utilitarian Benefits

Frye: John has levied a comprehensive challenge and I think both Dr. Rosen and Dr. Garwin could comment usefully on it.

Have we reached a stage where the triumphs may continue but yield less psychological support for the program? More importantly, have we reached a stage where the potential triumphs of the space endeavor are not commensurate with the costs and risks that are involved in the present shape of our space program?

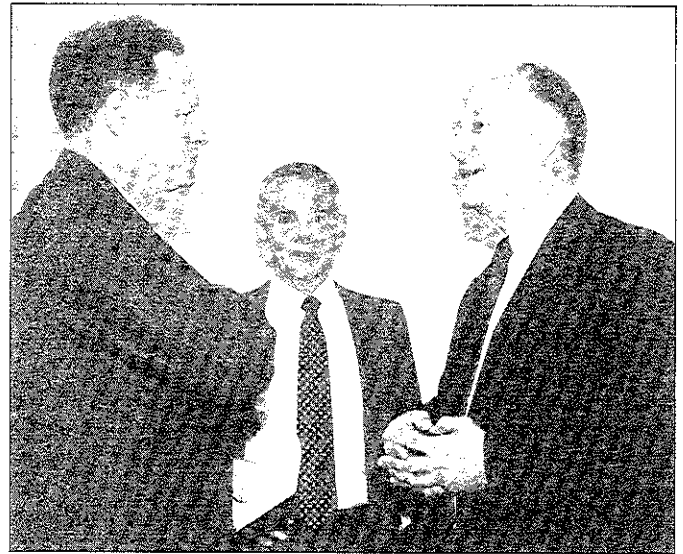
Rosen: To the point that the space spectaculars are going to be harder to accomplish, I absolutely agree, but we don't need spectaculars at this point to demonstrate the real utility and the real benefit of being a space-faring nation. We are beyond that point.

The applications of space operations are not well-known by the public, but they are very well known by those who conduct them and extremely useful in pursuit of American policies and goals. That's where we see most of our space program, I believe, going in the future, for practical applications, useful payback, responsible day-to-day operations.

The spectaculars are going to be hard to deliver, I believe, in a low-cost way. But the utility of space has never been greater. There is no question in my mind that we are at the beginning of the space age, certainly not at the decline and not at the middle, and the American public are just now beginning to understand that.

Garwin: I think the benefits will continue to increase. The benefits of aircraft accrue really to the users, not so much to the operators, as you can see from the problems the airlines are having, and even less to the manufacturers. So it will be with space. It will be a lot less romantic and a lot more beneficial.

I fully support Dr. Rosen's position that now we are seeing the emergence of many practical systems high on the list of national priorities, and these will make, and are making,



Stan Rosen, Robert Park, and Alton Frye

major contributions to safety, competitiveness, wealth and all that.

Communications satellites are an early and quite profitable system that is beneficial to the user. Now, that doesn't mean that the people who make them or run them are going to get rich. They will make, if everything goes right, normal profit. That's what the competitive system does.

Now, in that direction, we are now just at the beginning of a universal navigation system, the Global Positioning System, that will fully replace Transit, with much better performance, and will be ubiquitous in automobiles, in camping equipment, in aircraft.

We have not yet defined the system that will use satellites properly for control of the tens of thousands of aircraft in the U.S. national airspace, let alone the rest of the world, and yet such a system can be built. I chaired a panel in 1971, for the President's science advisory committee, to provide communication, surveillance and navigation to these aircraft. It can be done. It should be done. It is not a NASA job. The Government, the users, the Congress ought to be aware that we should be starting on such a system now.

So I think the challenges are there. They are just of a different type. I think NASA is too big to do the job that is left for it to do. And it is unsuited to develop competition internally to the things that it is already doing or is committed to do. That's just not possible in any single organization. That's no criticism of NASA.

But if we're going to have things done differently, we need organizations that will succeed by doing these things differently, and by overwhelming and making useless the systems that are in being. It is too much to expect an organization to do that to itself.

Does NASA Need to Change Direction?

Frye: I hear today a lack of enthusiasm for concentrating major resources on an expanded role for man in space, in the near future at least, not abandoning it, but not emphasizing it.

I hear a general flow of testimony which strikes me as saying there is in the present mix a premature tendency to look toward manned expeditions to Mars, perhaps a prema-

ture emphasis on early deployment of the kind of space station that has been discussed.

So I come to the bottom line that I think would be pressed upon you by an ordinary citizen. We have heard numbers which illustrate that over a decade, launch costs for a shuttle went from \$20 million to \$400 million a shot. That does not breed confidence.

So the natural question becomes: Are the cost we are seeing today, and the program configuration, out of alignment? Is this a program that citizens should be sympathetic to and support, or should there be now a demand that the \$15 to \$16 billion annual program plan for NASA be trimmed significantly and redirected toward the kinds of missions that all of you seem to favor, emphasizing identifiable applications in near Earth orbit, of benefit to Earth-based users.

Rosen: Dr. Frye, I agree with a great deal of what you just said. Let me focus on what I had trouble with.

In terms of exploration, we don't have a price tag for going to Mars because we don't know how we're going to do it, how long it is going to take—we don't know a lot of things.

What we have is a long-range commitment to keep our vision on the horizon and to keep moving, and that is exactly the kind of commitment and long-range vision I think we should have.

Putting a price tag on it is going to be have to be done in a much more rigorous way and I think within budgetary constraints that are politically realistic.

So I am not saying: Don't do the exploration program. Let's do it in a fiscally responsible way.

We don't know a tremendous amount about what we will do on the space station today. The space station is going to be a laboratory in many respects, much as have been Skylab and Spacelab and Mir, and in fact, I think we should be doing everything we can to learn from the experiences the Soviets have gained from Mir, so we don't have to pay to repeat those experiences again.

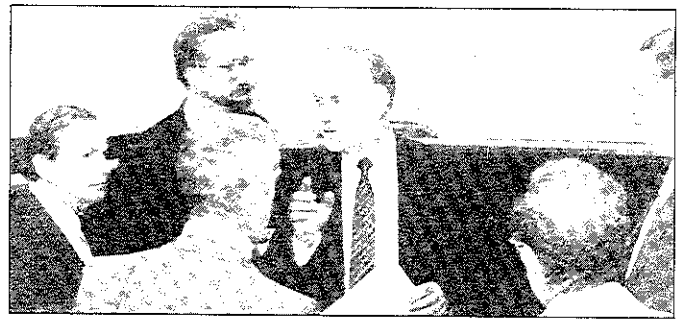
What we really need is more experience as to how man and crews, men and women, behave and operate in space and what they contribute. We're going to learn a tremendous amount from the space station if it is properly structured that way.

Finally, I don't believe that we should reduce our commitment, our fiscal commitment to the civil space program as you suggested.

I think if anything, the civil space program is a bit underfunded for the objective it has been given, and for the potentials which it can realize for the American people. I think that additional resources would be absolutely appropriate to do the kind of things we have talked about today, including new advances in space transportation.

Edelson: I believe that all space exploration, but particularly manned space flight, is done primarily for national prestige. This means the shuttle, the space station and the Space Exploration Initiative. We ought to have an evaluation of each of those programs in light of the fact that its real purpose is national prestige.

It should be supported to the extent it enhances our prestige, our image, our relations with other countries and the



Participants confer before start of hearing.

pride of our citizens—that's what I mean by image—or diminished or even cancelled to the extent that it tarnishes or diminishes our national image.

The other objectives of the space program should be evaluated on their own merits—the science program and the applications program. Whether we provide an array of space telescopes in different parts of the electro-magnetic spectrum, whether we study space physics and the solar terrestrial interface, whether we go ahead with the Mission to Planet Earth, should depend upon whether they are evaluated as good and effective and worthwhile and cost-effective science.

In my own opinion the answer to all of those questions is yes, let's go ahead with the science program.

On applications, I think—and it is not obvious—I think that we have had no policy and very little action over the last few years. There are many commercial potentials in satellite communications—mobile communications, broadcast communications. We are not doing that.

What we've done with the EOSAT program is truly shameful. It was just a terrible decision by the government in which the Congress and the administration and several government agencies, NASA and NOAA all were involved. It couldn't have been worse, and therefore we are losing out on it.

The same goes for the weather satellite program. We have just handled that terribly poorly over the years and those application programs are easily amenable to analysis in terms of dollars and capabilities and so on.

While I am at it, let me mention the search and rescue satellite system which has saved thousands of lives. It is an ineffective system. It has saved over 1,000 lives, but it is an ineffective system. We are spending on the order of \$1 or \$2 million a year on it, and its false alarm rate is still something like 95 percent.

We have just, foolishly, not taken advantage of the technology we have to come up with ways to take advantage of these great dividends of our space program.

Garwin: I see a lot of new applications, some of which will be commercially valuable. Others, like the search and rescue satellite, will have to be provided by public funds because the overall benefit is so diffuse that it could not be captured by the market.

But in my opinion national prestige—the more important part of it—is how you think about yourself. The rest of the world is too sophisticated to buy things from us because of our image. They buy things because the services or goods are reliable and of good value.

I am not happy when I see arguments made to the public that we should support space programs because they forward education, foreign relations, national competitiveness or whatever—not a single one of these claims is supported by any study that I know of, and mostly the opposite could be said just as well, except that nobody in particular benefits by saying it.

I think NASA has done a pretty good job of managing technical programs, an outstanding job on the planetary science programs, on some of the things that were done through JPL and other contractors.

The problem comes more in the formulation and the selling of these programs—where I think the activities of NASA have been negative as often as positive, as in the case with the space shuttle.

NASA is too big a continuing in-house organization by at least a factor two or three. But that doesn't mean that you should save the money that I would take out of the NASA budget. You might even keep the people. A lot of them are very good people who might work effectively on alternative programs.

So this requires a major analysis and restructuring. I think the Norm Augustine panel is up to it, but that is what we critically need now if we are going to think well of ourselves and benefit from our experience and investments in space.

Military vs. Civilian and International Programs

Van Praet: Connie VanPraet, with the Institute for Security and Cooperation in Outer Space. It seems that when we look at the space program, we see distinctive parts that are cooperating but also in competition. You have a military space program about two or three times the size of the civilian.

So I think that the challenge before us, and particularly in the United States, is to view how the military and the civilian space program can work together.

Also, where is the leadership in the United States to really take this question of international cooperation to task? The militaries could compete without weapons, using space to create a new kind of international security system.

Frye: Is there a redefinition of the military/civilian balance in the American space program that is called for at this time? Does any member of the panel wish to address that?

Garwin: The military program is almost exclusively concerned with things other than putting weapons in space. I have had a lot to do with the military program and am totally opposed to putting any weapons in space or to having programs for anti-satellite tests or such. Our military program is observation, navigation, communication and that is the sort of thing it should remain.

The military or national security enterprise has not fully reflected yet the newly cooperative world with the Soviet Union where there will have to be some changes, beneficial changes, in the large systems that we have continued to operate over the years.

President Johnson said that satellite pictures alone are worth the entire cost of the space program. Well, that's a long time ago and we have spent a lot of money since then. We still get valuable information, but we should rethink how

we do this on our own and in cooperation.

Military-Civilian Interactions in the Hubble Program

Frye: An aspect of the relationship between the military and civilian space programs that has recently been identified as causing trouble relates to the Hubble telescope. There are allegations that the Air Force offered assurances that its contractor had the capability to assure the perfection of the mirror and that these assurances, in a sense, encouraged NASA administrators to let their guard down.

At the same time, there are suggestions that some of the testing procedures that might have been conducted under military auspices were not conducted because NASA would not accept the DOD/Air Force demand that there be security clearances for all of the individuals in the NASA program associated with Hubble.

Have we seen impediments to an effective civil space program because of the constraints on some contractors operating under military auspices?

Edelson: I would answer yes to that. NASA procurement at Lockheed and Perkin-Elmer for a spacecraft and an optical telescope assembly, respectively, were going on at the same two contractors that were building highly classified reconnaissance satellites for the Air Force and the intelligence community, and everything had to be protected so there was very little communication back and forth and all kinds of restrictions and limitations on the number of people who could attend and so on.

NASA should have been smart enough so that the mistake didn't happen, but the chances of it happening are much greater with that kind of a barrier existing.

Lack of Civilian-Military Cooperation; Milstar and ACTS

There is precious little cooperation or coordination between the military and civil space systems. Often security is given as an excuse for that, but they are two completely different worlds. And even where they should be in many areas cooperative, like in the development of communication satellites and weather satellites, they are not.

As one example, the ACTS program which I was responsible for at NASA is similar to the Milstar program—two



Questions are posed from the audience.

communications satellites. The total ACTS program, development, launch and everything, is \$500 million and it is roughly on schedule, on price, and quite successful. The Milstar program has been a complete disaster. It is several years late and the satellites are getting up over a billion dollars apiece and I understand even higher than that, and the whole program is in difficulty.

The point I will make is there was no communication between the two organizations which are developing roughly the same kind of satellite, the same size, even similar frequency bands.

Any attempt to have communications between the two organizations is fraught with all kinds of problems. There is no incentive on either side, neither on the NASA side nor on the military side, to cooperate.

I think that a very healthy thing to do would be to have a properly cleared group of the type of Norm Augustine's committee review the military intelligence space program with the same degree of perspicacity and pervasiveness as is being given to the civil space program.

NASA and Military Approach to Contractors Compared

The other thing I would say is that the procurement procedures, ideology and approach are completely different. NASA is a much more demanding, much more knowledgeable, much more hands-on customer than any of the military services.

NASA generally goes into a contractor's plant with people who are as competent as the contractors employees, who look at everything that's going on, participate in inspection and argue with the engineers and technicians in the contractor's plant, and argue with them about costs and everything like that.

Military services, to my knowledge over quite a long period of time, have procurement separated from system program offices and use inspectors who are simply that. They are just people that go in and sign their name to tests which they have witnessed. They are not engineers, they are not scientists.

Rosen: We have better cooperation in the Air Force with NASA than we do with the Navy. We really don't cooperate with the other services very well, and so how do you fix that problem? It is not a problem between military and civil. It's a problem of human nature and there are many institutional and personal obstacles that I have seen over the years that get in the way of cooperative programs.

Garwin: I disagree rather gently with Burt Edelson. I have been involved with military programs. I have visited some of these contractors and it is not always the way that he says. But the key, as Dr. Edelson said, or implied, is to provide the incentive for NASA and the military programs to communicate beneficially. It takes effort.

Recent Problems with the Shuttle

Stein: Rob Stein with UPI. Could the panel briefly give me their thoughts on what they think grounding the shuttle says about NASA and the future of the space station?

Rosen: To me one of the issues that we've raised here which I feel very strongly about is that there is a general lack of understanding in the public and in some ways in the government about the difficulty of certain engineering projects.

We are not literate in terms of what it takes to carry off a major engineering activity, and we seem to expect magic.

I think although the Federation of American Scientists doesn't have the word engineering in its title, it can really contribute to the public understanding of what a major engineering activity is all about.

Meaning of "International Cooperation"

Pryke: Ian Pryke with the Washington office of the European Space Agency. A question for Burt Edelson: You made the statement space exploration should be totally international or not at all. Would you enlarge on what you mean by truly international?

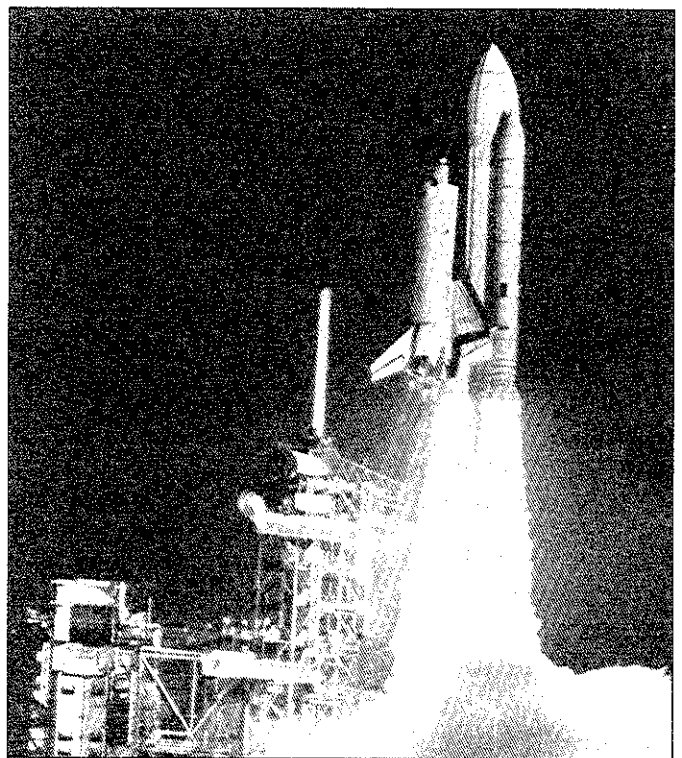
Edelson: The international partners participate in the planning, management including the decisionmaking on funding and operations, and in operations.

We have several examples of that. Well, ESA is itself an example of countries getting together and participating. They have a management structure. We have that kind of participation in the ISTP, the International Solar Terrestrial Physics Program where Japan, the U.S., ESA and the Soviet Union all participated in the planning and have participated in the operations.

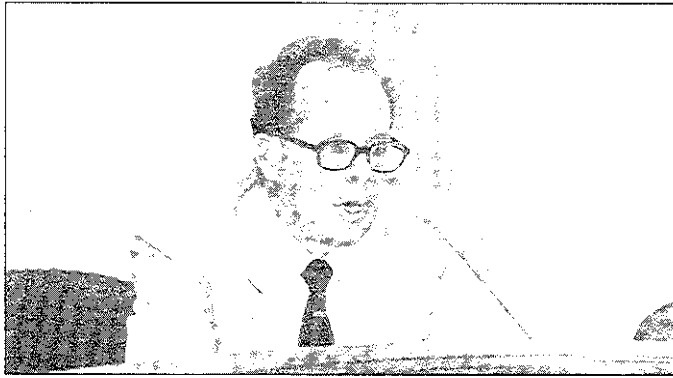
So it can be done. I think that is the way to do space exploration, and particularly the SEI.

Concluding Remarks

Frye: I am going to ask each of our participants now to make a concluding observation.



Space Shuttle



Jeremy J. Stone explains the purpose of the scientists' hearings.

Edelson: My feeling is that the manned space flight program and exploration should be looked at in the terms of national prestige. Each of the programs really needs to be re-oriented.

The space shuttle is obviously not cost-effective and reliable in terms of getting into orbit. We need a reliable, cost-effective launch system in this country. We should continue the space shuttle for the sake of manned space flight for the rest of this decade, but take all other launching away from it.

The space station has been brought out before and has to be organized so that it is producing some useful ends, and my suggestion is that it be internationalized. The same goes for the SEI.

I have nothing bad and many good things to say about NASA's conduct of their science program and their applications program, and the fact that I was in charge of that program for five years really has nothing to do with my opinion. [Laughter.]

Rosen: We are at an exciting point where we have developed a space-faring nation and a space-faring world. We have accomplished a great deal in the last 30 years, but we are just at the take-off point. I think what we've heard today is that there are tremendous opportunities to do more in civil space activities to promote national and international well-being.

We ought to take advantage of those opportunities. Those opportunities include new applications of space systems as well as new opportunities for developing infrastructure, especially new opportunities for space transportation, not only launch but also orbit-to-orbit transportation.

I will tell you there are some astounding possibilities out there.

We have just begun to touch on the opportunities for military space systems to promote international security and stability and that's a subject for another discussion.

With these maturing capabilities, and these growing opportunities, I think the nation will come along with proper understanding of what the opportunities are and what the costs are. If we can help the American public understand and have realistic expectations about what can be done in space, what can be done from space, and what the true cost and difficulties of those things are, they certainly will be willing to bear the burdens of bringing those kinds of opportunities to fruition.

Thanks again for the opportunity to be here.

Garwin: Well, I would emphasize also the costs, the benefits and the risks of any of these programs that are to be done in the future, including pure science or exploration.

That means free presentation of alternatives. The public presentation of the 90-day study on the human exploration initiative was truly defective in not citing costs even as they were, poorly, understood at the time. Of course, everybody wants to do something which is cost-free, and that's how it looks if there are no costs estimated.

I think we are certainly going in the right direction but there is a lot of ways to go in openness and permission to allow U.S. scientists to put their experiments on foreign satellites, and to allow foreign launchers for U.S. satellites and to allow—I am in the allowing mood—the use of surplus rockets for scientific and commercial purposes.

The more allowing we do, the richer we will be, and also the more secure.

That openness should extend, as it has been recently, to the revealing of problems in the program and to openness to potential solutions.

There are all kinds of things that one can do to manage if one doesn't get one's preference. One might take second-best, which altogether might make a better program.

Park: It is time now to completely rethink the basis for the space program. I don't think that the initial efforts to reexamine the space program are going nearly far enough. I am, in fact, disturbed by the composition of the panels that will be examining the role of NASA. I think it needs a much broader discussion than it is going to get.

Pike: I think that the problems that have been demonstrated with the space program over the last six months or so represent the gap of understanding between the producers of the civilian space program, NASA, and the consumers of the civilian space program, the taxpayers and their representatives here in Congress.

I think that the task of the Augustine panel is to somehow or another bridge that gap and to develop a program that is both deliverable by NASA and supportable by the public. I think that this task is going to be increasingly difficult, and I am afraid that in the limited amount of time that the Augustine panel is going to have available to it, that they're probably not going to be able to make nearly as much progress in that direction as is needed.

I am hopeful that in some small way we are contributing to that process here today.

Frye: A very gifted scholar named Karl Deutsch used to say that prestige is to power as credit is to cash, and that was an argument that served the space program very well in its earlier days.

We now recognize that it is no longer a sufficient argument, though in some degree, it carries weight even in the altered circumstances of the 1990s.

I want to thank all of our panelists for helping us begin this process that necessarily will be quite protracted, of re-thinking what should be a sensible, forward looking space venture for Americans that meets the international requirements set forth in that first space act by the American Congress many years ago. □

BUY DOWN RATHER THAN BUILD UP

Moscow has something to sell which Washington badly wants: the destruction of Soviet missiles aimed at the United States, including, for example, its SS-18 heavy missiles.

Washington could purchase such destruction with the money it would otherwise spend—in the absence of dramatic strategic disarmament—to modernize its own strategic forces. Accordingly, why not, at no net cost, “buy” a speed-up in strategic force disarmament?

For its part, the Soviet Union no longer needs a large strategic armory to defend against the United States. As perestroika gives way to free-enterprise in the Soviet Union, there are not even any ideological grounds for the Soviet military to fear an attack from the United States. In any case glasnost has eroded Soviet strategic fears.

In fact, at a recent conference on international affairs, a Soviet analyst “threatened” the West with the possibility that Moscow would reduce unilaterally to a minimum deterrence and leave the United States with no partner for disarmament. Thus the Soviets recognize that they need less in the way of strategic arms than they now have. And the Soviet need for foreign currency is, after all, substantial.

Or Should We Wait for Soviet Unilateral Disarmament at No Cost?

But should the U.S. government wait for the possibility that Soviet economic difficulties, and new-thinking in the military sphere, will produce Soviet unilateral reductions?

There are many reasons not to do so. In the first place, it might not happen. Or, Moscow might get rid of some, but retain other, still usable missiles. Worst of all, the present era of friendly cooperation could change as the Soviet Union goes through a convulsion that could produce a return to authoritarian control, or even military control.

There is, thus, a window of opportunity for Washington to close any putative window of vulnerability now, with a disarmament “sweetener” that costs nothing. After all, Washington would, presumably, prefer to forgo rail-mobile MX and Midgetman if it could have Soviet missile levels reduced below START.

All things considered, Washington would be better off providing funds to the Soviet Union in return for the destruction of its heavy missiles (or other excess weaponry) than spending the same monies on its own weapons. Keeping glasnost and free-enterprise thinking alive in Moscow is devoutly to be wished. If Moscow needs resources to keep renovation alive, Washington is better off providing it than not. And the funds, presumably offered as credit against purchases of U.S. grain, airplanes and the like, would benefit the U.S. economy and offset the economic impact of the strategic force modernization cutbacks.

Bilateral negotiated disarmament, one may say, was supposed to do this for us. But, clearly, the disarmament process has slowed. And neither the U.S. nor the Soviet leadership are as interested in disarmament per se as they are in helping the Soviet Union successfully navigate its economic transformation.

Should Washington wait until it builds rail-mobile MX and/or Midgetman and new strategic bombers to negotiate

A HYPOTHETICAL EXAMPLE

Option: Continue the Arms Race

United States

Build MX-rail—\$10 B
Build Midgetman—\$30 B
\$40 billion cost
—spent in U.S. economy

Soviet Union

Keep SS-18s
Receive little or
no economic aid
from U.S.

Option: Buy-Down

United States

No MX or Midgetman
Give S.U. \$40 billion
in credit for U.S. goods
—spent in U.S. economy

Soviet Union

Get rid of SS-18s
Receive \$40 billion
in economic
assistance

new disarmament treaties?

In the old days, we thought we needed to have “bargaining chips.” But we clearly don’t need them now. And if the West German government can pay \$8 billion to the Soviets to remove their troops, we can pay like amounts to the Soviet Union to remove their missiles.

Amounts Tied to Costs of Specific Strategic Systems

Would we be setting a bad precedent? Might Russian negotiators hold out from further mutual, or unilateral, disarmament until they were paid to disarm? They might try. But Washington should pay for reductions only the funds it would otherwise have spent on its own strategic projects, it cannot be held at ransom and would lose nothing.

Forgoing rail-mobile MX might provide \$10 billion over 15 years. Forgoing Midgetman might provide \$30 billion over the same period. Advocates for the B-2 bomber envision spending \$40 billion for it. Our Trident submarines are being modernized also. (Note that the word “modernize” has always reflected the lack of any necessity to upgrade the weapon systems.)

“Buy-down” need not be acted out in a formal negotiated way. If such a deal would offend sensibilities on either side, an arrangement could be made less directly. Just as Washington saw Moscow’s cooperation in the Iraqi crisis as grounds for stepping up consideration of economic aid, so also could Soviet cooperation in a race to disarm be taken as a cue for economic aid. Money would be saved on U.S. weapons not built, and funds would be allocated for Soviet purchases in the United States.

In sum, this zero-net-cost-buy-down provides the possibility of funding emergency help to the Soviet Union—just when it needs and deserves it—while providing the United States with greater strategic security at a unique moment in Soviet history when Moscow may be willing to offer it.

Perhaps never has the arms race offered both parties a better deal. —Jeremy J. Stone □

SOME RECENT FAS ACTIVITIES

● **On Iraq:** FAS is working to secure a "Leadership Committee for National Emergencies" in each of the two congressional houses. Working with consultant Scott Cohen, former director of the Senate Foreign Relations Committee, FAS co-authored a *New York Times* op-ed on August 19, drafted a relevant bill with the help of a congressional staffer, and stirred things up on the Hill. On October 5, Senator Sam Nunn said he would be offering such a bill and Senator Brock Adams did so earlier.

FAS wrote the director of the Arms Control and Disarmament Agency to observe that President Carter had once solemnly advised the United Nations that:

"The United States will not use nuclear weapons against any non-nuclear-weapons state party to the Non-proliferation Treaty or any comparable internationally binding commitment not to acquire nuclear explosive devices, except in the case of an attack on the United States, its territories or armed forces, or its allies, by such a state allied to a nuclear-weapons state or associated with a nuclear-weapons state in carrying out or sustaining the attack."

Would this apply to Iraq? Director Ronald F. Lehman II responded, on August 28, that this "negative security assurance" was still operative and had been reaffirmed by successive administrations. Apparently, it precludes the use of nuclear weapons in the Iraqi case even in response to chemical attack.

● **Activities of the U.S.-Soviet Disarmament Project:** Frank von Hippel testified in September before the Supreme Soviet on underground testing and, indeed, helped them hold the hearing by bringing with him experts from various U.S. weapon laboratories.

His project's book *Reversing the Arms Race: How to Achieve and Verify Deep Reductions in Nuclear Weapons* is available to members for \$15.00. See box on page 20.

● **Scientists' Hearings on Science and Public Policy:** FAS has held three hearings on Space Policy as examples of a general process of analyzing science and society issues through extended interrogation of experts by experts.

● **Project on Biological and Chemical Warfare:** Gordon Burck and former Ambassador Charles Flowerce have completed their book entitled: *The International Handbook on the Global Chemical Weapons Threat*.

Council Member Robert Weinberg of MIT has convened a "working Group on Biological and Toxin Weapons Verification" which, after meeting several times, has drafted proposals for the Biological Weapons Convention Review Conference next year.

● **Space Policy Project:** In response to the Gulf crisis, Project Director John Pike analyzed SDI technology in regard to the Iraq ballistic missile threat. He described to a congressional audience the relatively small amount of funding in the "star wars" budget aimed at the countering the short range missiles in the Iraqi arsenal.

The project has been particularly effective during the congressional debate on major military space issues such as the Strategic Defense Initiative (SDI or "star wars") and anti-satellite weapons. The project was instrumental in facilitating Congress' oversight and funding of "laser brightness verification technology"—a government research program aimed at providing instruments for verifying a future space arms treaty.

The project has begun a review of major civilian space initiatives such as the international Space Station Freedom and the Mission to Planet Earth—a \$30 billion system of observation satellites for monitoring changes in the environment.

● **Project on Scientific Exchange with, and Peace in, Indochina:** The high point of this project's success was the shift in U.S. policy toward the Cambodian problem. The administration began to tilt toward "stop the Khmer Rouge" and away from "strangle Hun Sen". How far the administration plans to go is unclear. But there was an immediate fallout as the Chinese decided to improve their relations with Vietnam, and to resolve the Cambodian problem if they could, in response. Ironically, they feared a "U.S.-Vietnamese access" that might result from the talks that Secretary Baker announced he would hold between the U.S. and Vietnam. In effect, the U.S. "played the Vietnamese card" in its China relations—probably without knowing it.

● **Project on Protecting the Space Environment:** A new series of SDI tests, known as the Strategic Target System (STARS) envisions the launch of some forty missiles from Kauai, Hawaii, to the Kwajalein Atoll. In response to numerous requests from concerned Hawaii citizens opposed to the program, Steven Aftergood and John Pike provided research assistance on the military and environmental issues involved and helped organize a legislative response. This is part of an ongoing review of the environmental impacts of space activities, and measures to mitigate them.

In response to a request from Hawaii State Senator Andrew Levin, Aftergood helped draft legislation to restrict the launch of nuclear materials from Hawaiian territory. The measure was passed by both houses of the Hawaii Legislature.

Though Aftergood has defended the use of space nuclear power beyond Earth orbit in solar system probes such as Galileo and Ulysses, FAS has also sought to eliminate unnecessary risks. This intermediate position is reflected in a new United Nations policy, adopted by subcommittees of the Committee on Peaceful Uses of Outer Space, that "the use of nuclear power sources in outer space should be restricted to those space missions which cannot be operated by non-nuclear energy sources in a reasonable way." We had lobbied the Committee delegations to take an even stronger position against nuclear power in Earth orbit, but we consider this to be a significant and responsible step forward. □

HEARING ON MISSION TO PLANET EARTH

FAS devoted the second of its scientists' hearings on public policy to an examination of NASA's Mission to Planet Earth. Mission to Planet Earth is the largest, most expensive environmental research program ever proposed. While its objectives enjoy broad political support, there are serious questions about its design.

Will Mission to Planet Earth provide the information required for tough environmental policy decisions, or simply delay those decisions? Should Mission to Planet Earth be restructured to support the most urgent global change research? Should NASA's emphasis on a small number of large, and hence vulnerable, satellites be altered? Indeed, with finite budget resources available for work on global change, what should be the relative priority between data collection and action?

These and related questions were explored at our second scientists' hearing on September 6. Our expert panelists included Dr. Shelby Tilford, NASA director for Earth science and applications; Dr. D. James Baker, who recently chaired an important National Academy of Sciences review of Mission to Planet Earth; and Dr. James Hansen, of the NASA Goddard Institute for Space Studies. They were questioned by John Pike of FAS and by Dr. Dan Lashof of the Natural Resources Defense Council. Dr. Alton Frye once again served with great insight and subtlety as the moderator.

While no final consensus could be reached, given the diverse views of the participants, several important concerns emerged. Most notably, John Pike repeatedly pressed the NASA panelists about the wisdom of basing the Earth Observing System on two series of large orbiting platforms. With so much of the program invested in just a few platforms, the loss of any one of them due to a launch accident would be a massive blow. Breaking up the platforms into smaller satellites, on the other hand, would yield a more resilient program. And to the extent that simultaneous measurements by different instruments were required, it would seem that they could be flown in formation.

The NASA representatives did not yield on this point. But

a few weeks later, a leading Administration space official told us that NASA was now inclined to break up at least the second series of large Earth Observing System platforms into smaller satellites. And he specifically attributed this new decision to our hearing which, he said, conveyed to NASA the cogency of such a move!

A copy of the transcript of this hearing on Mission to Planet Earth may be obtained for \$10 from the FAS office.

Hearing On Mission To Mars

Our third scientists' hearing, also dealing with space policy, scrutinized the rationale for a human voyage to Mars. Outstanding advocates and critics of the President's proposal for a piloted mission to Mars by the year 2019 were questioned about the justification and the urgency of such a mission. We got some straight answers from our expert panelists, including Professor Carl Sagan, sociologist Dr. Amitai Etzioni, and former Shuttle astronaut Charles Walker. They were questioned by John Pike and by Dr. Sidney Winter, Chief Economist of the U.S. General Accounting Office.

The transcript of this hearing will be available shortly. □

FAS-Soviet Book Published; Special Price to Members

Reversing The Arms Race—How To Achieve and Verify Deep Reductions in Nuclear Arsenals, the book that caps three years of work by the FAS-CSS Joint Research Project, is available in the paperback edition at a special members' price. Edited by Roald Sagdeev and Frank von Hippel, the volume examines the technical basis for arms-reduction agreements that could cut the sizes of the US and Soviet nuclear stockpiles by 90% or more. Cost to FAS members is half the cover price, plus shipping charges—\$15.00 total. Please make checks payable to FAS and address your order to FAS-CSS Book, 307 Massachusetts Avenue NE, Washington, DC 20002. ■

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