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HEARINGS
BEFORE THE
SUBCOMMITTEE ON
SCIENCE, TECHNOLOGY, AND SPACE
OF THE
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE
NINETY-FIFTH CONGRESS

SECOND SESSION

ON

S. 2527

TO AUTHORIZE APPROPRIATIONS TO THE NATIONAL AERO-
NAUTICS AND SPACE ADMINISTRATION FOR RESEARCH AND
DEVELOPMENT, CONSTRUCTION OF FACILITIES, AND RE-
SEARCH AND PROGRAM MANAGEMENT, AND FOR OTHER
PURPOSES

MARCH 8 AND 16, 1978

PART 3

Serial No. 95-86

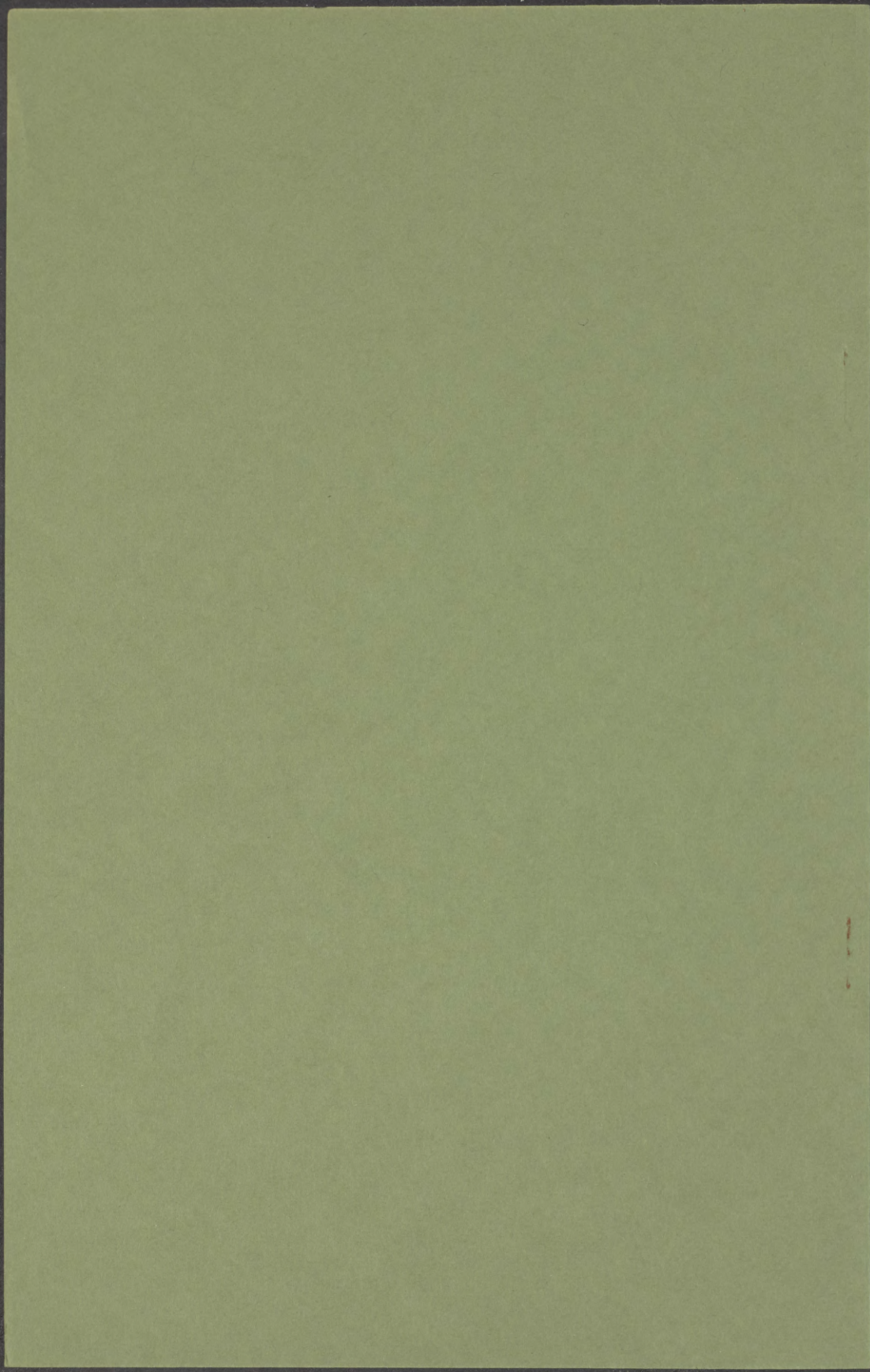
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U.S. GOVERNMENT PRINTING OFFICE

WASHINGTON : 1978

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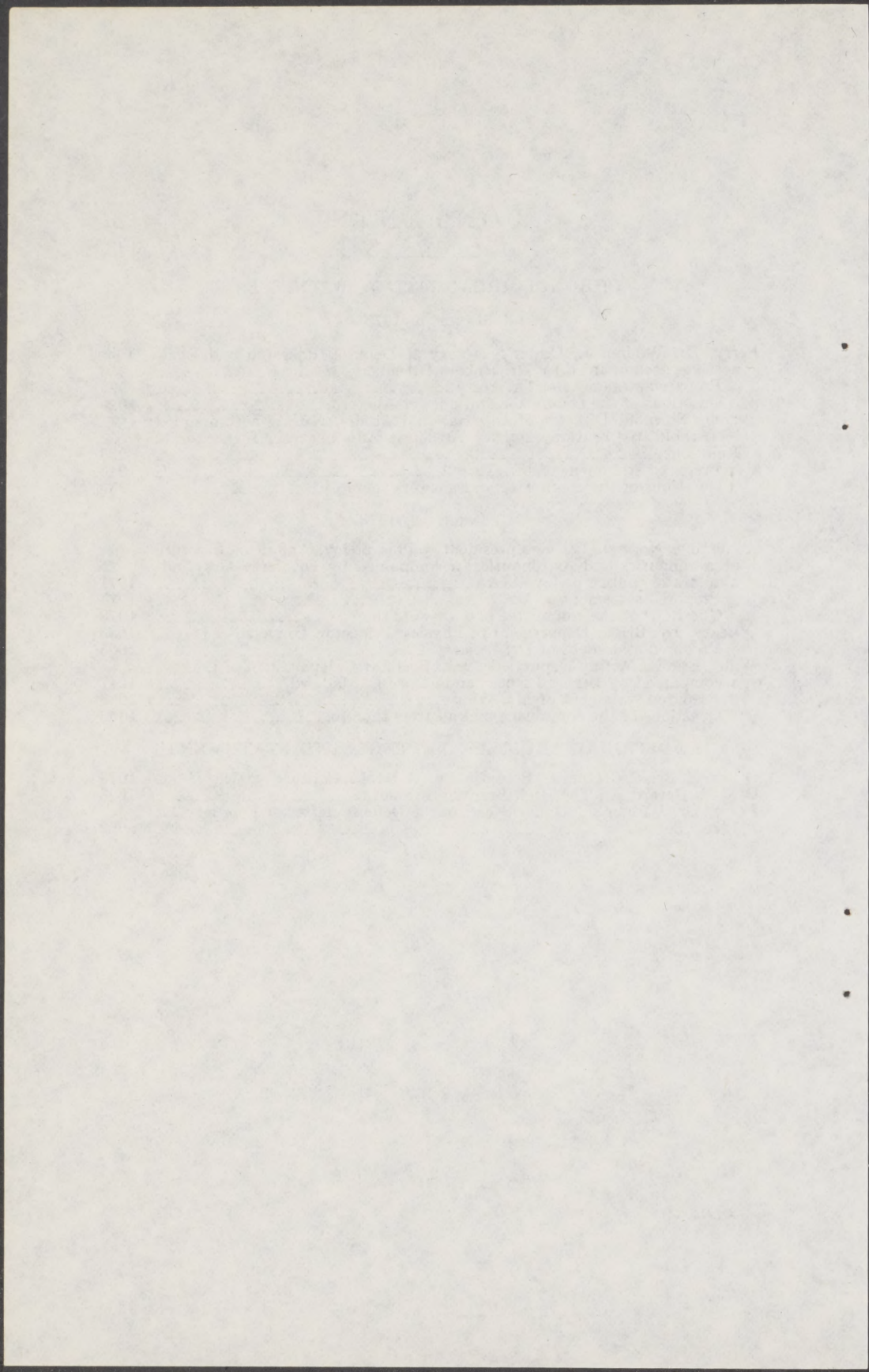
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NASA AUTHORIZATION FOR FISCAL YEAR 1979

WEDNESDAY, MARCH 8, 1978

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

The subcommittee met at 9:08 a.m., in room 235, Russell Senate Office Building; Hon. Adlai E. Stevenson (chairman of the subcommittee) presiding.

Senator STEVENSON. The subcommittee will come to order.

We continue this morning our hearings on the NASA 1979 budget.

Our first witnesses this morning are Norman Terrell, Director of International Affairs of NASA, and Arnold Frutkin, now the Deputy Associate Administrator for External Affairs.

Gentlemen, if you would like to summarize your statements, I would be happy to place them in the record. Please proceed.

STATEMENTS OF NORMAN TERRELL, DIRECTOR OF INTERNATIONAL AFFAIRS, NASA; ACCOMPANIED BY ARNOLD W. FRUTKIN, DEPUTY ASSOCIATE ADMINISTRATOR FOR EXTERNAL RELATIONS

Mr. FRUTKIN. Mr. Chairman, if I may, since I was in charge of NASA's international affairs for a number of years, I have taken the liberty of coming up here to accompany Mr. Terrell who in the last week has become the new Director of International Affairs.

Senator STEVENSON. We are glad to have you both.

Mr. TERRELL. Thank you very much. I will be using some vignettes but, before I begin, I would like to say just a word about the policy basis of our international cooperation. As you know, international space cooperation is mandated in the National Aeronautics and Space Act. Under that mandate, NASA makes available the vehicles to launch the satellites of other nations, and we provide our spacecraft for satellite experiments of other countries. This is done on a reimbursable basis or on a cooperative basis depending on the interest of NASA.

We evaluate cooperative projects on their merits. They must contribute materially and directly to NASA's science and applications objectives. The foreign nation must be able to bear the full cost of its participation and have the technical capability to carry out its participation. NASA does not export dollars or transfer sensitive technology abroad. Finally, these agreements are project oriented. They are based on clearly defined understandings and delineations of the

responsibilities of both sides, and with a clear beginning and end to each project. On the basis of these guidelines we have carried out hundreds of successful projects over the course of the last 18 years.

Now, if I can have the first slide.

CURRENT INTERNATIONAL PROGRAM HIGHLIGHTS

Spacelab and RMS—critical design review.

ISEE-A/B and IUE launched.

IRAS, Galileo, space telescope agreements (\$180 million inputs)

I will now discuss some of the current international program highlights. I have divided my first slide into three to make them easier to see. The Spacelab and the remote manipulator system (RMS) are two important foreign contributions to the Shuttle-based space transportation system. The Spacelab represents an investment of close to \$600 million by the European Space Agency and the remote manipulator system represents a \$75 million investment by Canada. The critical design review of the Spacelab has just been completed a few days ago. No major problems were identified and that project is on track. The critical design review of the remote manipulator system is coming up next month and we anticipate no problems. Both the Spacelab and the RMS are expected to be ready to fly aboard the Shuttle in 1980.

In the past 12 months we launched two important cooperative satellite projects: the International Sun Earth Explorer (ISEE), and the International Ultraviolet Explorer (IUE). ISEE is a joint NASA-European Space Agency mission. NASA provides the ISEE-A spacecraft. The Europeans have provided ISEE-B. The two spacecraft fly in tandem to assess questions concerning the interplanetary medium in the region of the Earth. The International Ultraviolet Explorer is a project in which NASA provided the spacecraft and scientific instruments, the United Kingdom provided the camera system to operate with the NASA telescope, and ESA provided the spacecraft solar arrays and is operating a European ground station.

ISEE-A and B were launched by a single expendable launch vehicle last October 1977 and the IUE was launched January 1978.

Typical of the kind of cooperative agreements we enter into were three agreements signed this last October by Dr. Frosch. The infrared astronomical satellite project is an agreement between NASA, the Dutch, and the United Kingdom. NASA will provide an IR telescope. The Dutch will build the spacecraft and integrate the IR telescope into it. The United Kingdom will provide the ground facility, and all of the cooperating partners will supply focal plane instruments for the satellite.

The Galileo (formerly called the Jupiter orbiter probe) is a joint project with Germany, which will provide the retropropulsion module for the spacecraft. It will be used for the spacecraft maneuvers and to place the spacecraft in orbit around Jupiter. In addition, Germany will fund the participation of 14 scientists who are providing three scientific instruments for the mission. The retropropulsion module, which is the major German contribution, is based on the design module that was successfully used aboard the Franco-German Symphonie communication satellites.

The Space Telescope is a major project in which the European Space Agency is providing the spacecraft solar arrays, the faint object camera and extended operational support.

The total contribution of these three agreements to NASA's scientific program is approximately \$180 million.

Foreign experiments for three spacelabs and LDEF.

Landsat—seven foreign stations operating or committed.

Indian evaluation of village TV experiment.

During 1977 we have made progress in identifying foreign experiments to fly aboard the early Spacelab and Shuttle missions. The first three Spacelabs all have important foreign contributions. Spacelab 1 is a joint NASA/ESA mission and Spacelabs 2 and 3 are NASA missions, but all three missions will have significant foreign experiments aboard.

On Spacelab 1, the Japanese are providing a \$10 million electron accelerator facility on the NASA half of the payload. NASA is also sponsoring life scientists who will conduct biomedical experiments using the European vestibular sled aboard the ESA half of the payload.

On Spacelab 2, the United Kingdom will be contributing a solar telescope and a stellar X-ray telescope.

On Spacelab 3, Australia will be contributing a zero-gravity red blood cell experiment. The long duration exposure facility (LDEF) is another important Shuttle payload. We have selected for LDEF seven major foreign experiments from six foreign countries and the European Space Agency.

In all of these cooperative projects—the Spacelab and LDEF, the new agreements, the cooperative satellites that were launched, the Spacelab and RMS development—the foreign contributions are being fully funded by the cooperating foreign agencies.

We are making progress in significant foreign contributions to the Landsat system. There are now seven foreign stations operating or committed in six countries. Four are in operation—one in Brazil, one in Italy under ESA sponsorship, and two in Canada. In addition, firmly committed to the program are Argentina, Iran, and most recently India. The operators of those foreign stations are obligated to provide Landsat imagery not only within their own country but also to any foreign requests for any area within the coverage of their ground station.

In addition, the ground stations represent an important backup to our own satellite tape recorder readout capability in case, say, something should go wrong with the tape recorders aboard the spacecraft. Each of these Landsat ground stations cost about \$5 million to build, and about \$1- to \$2 million a year to operate. Most of that money comes into the United States in the form of procurement by the foreign station operators for goods and services. In addition, we currently charge a token access fee of \$200,000 a year for access to the Landsat satellite. We anticipate that within the next 3 years we will have about a dozen foreign countries committed to operate Landsat ground stations, and by 1984 that system should bring about \$135 million into the United States in the form of business and foreign exchange.

The Indian Space Research Organization completed an evaluation of the village television experiment this year. This was an experiment that was conducted in 1976 and 1977, using the US/ATS-6 satellite and low-cost Indian ground receivers in rural areas. From a technical viewpoint, the project was a success and the Indian report shows that from the viewpoint of social and educational benefits there were important values in the experiment.

As a result of that experiment, the Indians have decided to establish its own domestic communications satellite system. They have contracted to launch it aboard the Shuttle in 1981 and the satellite will most likely be procured from a U.S. contractor.

Soviet cooperation continuing.

International reimbursable launches.

Soviet cooperation is continuing on the basis of the government-to-government agreement which was renewed by Secretary Vance and Foreign Minister Gromyko in May of 1977. Pursuant to that agreement, NASA and the counterpart agency in the Soviet Union, the Soviet Academy of Sciences, concluded an agreement to study the possibility of future manned space cooperation.

The studies will be to determine whether there are scientific experiments that could profit from using the flexibility and large lift capability of the Shuttle and the long staytime of the Soviet Salyut spacecraft, the spacecraft that is up there right now. These studies are underway. We had a meeting with the Soviets this last November in Moscow, and we anticipate having further meetings this year to see if we can jointly find candidate scientific experiments to utilize these capabilities.

In the unmanned areas, we are continuing with activities such as the search and rescue agreement which was signed with the Soviets in May of 1977. Under that agreement, the Soviets expressed the intent to contribute their spacecraft and their capabilities to the international search and rescue project which we are undertaking with Canada and France.

The Soviets provided us lunar samples in 1977 from their most recent lunar flight. Those samples will be analyzed by the U.S. scientists and will provide them an opportunity to analyze samples from an area that U.S. spacecraft did not reach.

In August 1977, we flew biological experiments aboard the Soviet biological satellite, and we received an offer to identify further experiments to fly aboard the Soviet biological satellite in 1980. Those opportunities give our scientists a chance to fly biological experiments at a time when the United States has no biological program.

We are also testing meteorological rockets, and finally hope to have a meeting with the Soviets this year to discuss the possibilities of exchanging planning data on planetary missions.

The activities I have spoken of so far are in the area of cooperative programs. I want now to address briefly our international reimbursable launches.

We carry out the launches of foreign satellites for peaceful purposes on the basis of full cost reimbursement, and of course on the basis that they will be consonant with international undertakings. From 1965 to 1977 we launched 54 foreign reimbursable launches for 10

foreign countries and international organizations. In 1977, 10 out of the 16 NASA launches were for foreign reimbursable accounts and in 1978 we anticipate that 9 out of 25 of our launches will be for foreign reimbursable accounts.

This is an important source of foreign exchange to the United States. It lowers the unit cost to American customers of launch services. Finally, many of the payloads launched aboard these reimbursable launches are built in the United States, or important procurements are made from U.S. business.

We have made the transition in the reimbursable launch program into the Shuttle era. We have signed up three foreign reimbursable launches of domestic communications satellites for Canada, Iran, and India. The Germans are planning to launch two Spacelabs on a reimbursable basis and the ESA is expected to launch two Spacelabs on such a basis.

Contributions of space activities to U.S. balance of payments

	<i>Millions</i>
Total estimate 1965-77-----	\$2,170
Based on:	
Japanese purchases (launches and satellites)-----	350
ESA reimbursable launches-----	120
Intelsat (launches and satellites)-----	1,160
Other reimbursable launches and satellites-----	360
Cooperative project dollar inflow-----	130
Earth resources-----	50
Current Annual Rate-----	175-200

On this slide I want to show you what the contributions of all of these space activities have been to the U.S. balance of payments. The total estimate from 1965 to 1977 is a positive inflow into the United States of \$2.1 billion. The components of that include Japanese purchases of launch services, satellites, and launcher development services—that is a third of a billion dollars—\$120 million has come from ESA for reimbursable launches. Intelsat—for launches and satellites—has paid the United States over \$1 billion. Other reimbursable launches and satellites have brought in over a third of a billion dollars to the United States. The dollar inflow from cooperative projects is around \$130 million, attributable to the fact that significant amounts of the procurement for the foreign cooperative projects comes to the U.S. suppliers.

Finally, the Earth resources program, Landsat, has brought \$50 million in thus far. These dollar inflows are now coming into NASA and U.S. contractors at an annual rate of around \$200 million.

FUTURE PROJECTS UNDER DISCUSSION

Spacelab future requirements—joint study with ESA.
 Spacelab use sharing—(ESA, Germany).
 Spacelab barter arrangement.
 Search and rescue (Canada, France, U.S.S.R.).
 SEASAT HCMH NIMBUS-G ground stations (ESA, Canada).
 Solar polar mission (ESA).
 Active magnetospheric particle tracer experiment (Germany).

I want to briefly run through some of the future projects now under discussion. We are discussing a joint study with ESA to determine

what future user requirements for Spacelab might look like. On the basis of that study, we will be able to determine what further capabilities and developments of Spacelab might be wanted. We are discussing with the ESA and Germany the greater utilization of their Spacelab missions. This could be in the scientific area or could be in a new area that the Spacelab provides us the capability for, space processing. Both sides have procured significant capital facilities for space processing, such as furnaces, and it's to the mutual benefit of the two sides to get the maximum utilization out of those, of course, with the appropriate protection of proprietary rights on both sides.

We have begun discussions with the European Space Agency on a very interesting barter arrangement. Under this arrangement they would obtain STS launch services in the United States in exchange for Spacelab hardware we would obtain in Europe. This would be done on a barter basis with no exchange of funds. Therefore, it would practically eliminate the foreign exchange implications. Such an arrangement might facilitate future cooperation between the two sides.

I did mention the U.S.S.R. interest on the search and rescue demonstration project. The overall project is based on an agreement we have with the Canadians whereby they will provide transponders aboard U.S. spacecraft which will pick up signals from aircraft and surface ships in distress. These will be relayed back to ground stations where search and rescue forces on a national basis will be able to go to the distress signal. France will contribute and the U.S.S.R. as I said is also contributing. We expect to have a joint meeting of the four parties soon.

The European Space Agency and Canada have agreed to procure ground stations to receive data from three important Earth-looking satellites that are going to be launched this year, Seasat, the heat-capacity mapping mission, and Nimbus-G. There will be important scientific benefits from foreign participation in those programs. In addition, some of the sensors aboard these spacecraft are not suitable for use with tape recorders, so foreign ground stations are the only way to get maximum U.S. utilization out of the data.

Assuming Congress approves the solar polar missions as a new start for fiscal year 1979, ESA and the participating European members of ESA are prepared to contribute \$100 million to that project—\$70 million for the ESA-built spacecraft, and \$30 million for European-supplied experiments. This will be a two-spacecraft mission. One will be provided by NASA, and one by ESA. The two will fly in tandem over the two poles of the Sun and give scientists a look at the Sun they have never had before.

Finally, we are discussing with Germany the possibility of a joint active magnetospheric particle tracer experiment. This will be a two-spacecraft mission. The United States would fly one satellite, and Germany the other. Both would be launched aboard a single Shuttle with an inertial upper stage. Those two spacecraft would conduct large-scale active injection experiments into the magnetosphere that have never been conducted before.

I hope this brief review has given you some impression of the importance of international cooperation to the U.S. space objectives. We

gain important foreign contributions to our national science and applications programs. We gain large foreign exchange inputs into the American economy. In Spacelab and RMS, the foreign cooperating partners are contributing materially to the capabilities of the Space Transportation System. Finally the relationships and mechanisms that have been set up in the last 18 years to conduct programs like this will permit us into the 1980's and beyond, to relate the U.S. space program to foreign opportunities for contributions.

Thank you very much. We would be pleased now to take any questions.

Senator STEVENSON. Thank you.

I will address these questions to both of you, and let you decide how best to answer them.

Mr. TERRELL. Thank you.

Senator STEVENSON. On that last note, as you well know, Dr. Frosch has expressed interest, as have members of the committee, in a global information system. I am sure you are familiar with the outlines of such a comprehensive system as he suggests.

Obviously, it would require international cooperation, and would have to operate within some international framework. Have you given any thought to that possibility? I understand this whole notion is being evaluated by NASA. Are you helping to evaluate the international implications? If so, what are your conclusions?

Mr. FRUTKIN. There are a number of modalities that one could imagine following in supporting such a system. For example, we have attempted purely internally thus far to consider what sort of information services might be made available to the U.N. on a multipurpose basis.

For example, the World Health Organization has communications problems with teams in remote areas. The Food and Agricultural Organization, another specialized agency of the U.N., has similar problems with teams in remote areas. And there are U.N. peacekeeping teams. And one could imagine, for example, a global information system available to the United Nations that could gather national resources data to assist it in its many aid operations.

So, I guess what I am saying is that any global information system does present a good many opportunities and problems at the same time which we are trying to understand and wrestle with.

Senator STEVENSON. Well, it is easy to perceive the services and the information that could be made available to international bodies and to foreign countries. That is not what I am getting at.

I think it is also easy to perceive the interest that foreign countries and international bodies will have in the operation of a global information system. Such a system will require, if not their participation, at least their cooperation.

Now, what I am trying to get at is not the services that could be made available, but how this system might be operated involving foreign countries, with their cooperation, and involving international bodies. I was under the impression that those operational or organizational questions were being addressed by the administration, and that it felt these questions would have to be answered before we could commit ourselves to a global information system.

My own feeling is that we ought to make that commitment and then put the organization together to support it.

I think, as a tactic, it would probably be easier for the United States to command the participation and support of such international bodies and foreign governments, as is necessary, once it is made clear that we are going ahead. But my question is, does the administration want to go ahead on the organizational side first?

If so, what is it doing on that side?

Mr. FRUTKIN. I don't believe that I can give you a complete answer to that question, Mr. Chairman. If we are talking about an informational system which pulls together material of the sort acquired by Landsat, Seasat, and so on, makes that kind of information available—

Senator STEVENSON. That would only be a part of it.

Mr. FRUTKIN. The administration is looking at the operational organization of that kind of system, and that is being done on an inter-agency basis, and I could not tell you how far that has progressed.

Senator STEVENSON. Is this part of the OSTP exercise?

Mr. FRUTKIN. Yes, sir. I had assumed you were speaking of a communications-information system.

Senator STEVENSON. Well, an information system comprehends the remote sensing potentials, communications possibilities, navigation, and climate. I am using it comprehensively.

Mr. FRUTKIN. Right. The current basis for our international information acquisition and dissemination activities is one which the United Nations has endorsed by resolution. And that is the encouragement of regional Landsat data acquisition systems which are available to nations within the ambit of the receiving station.

What follows this interim mode has not been defined, and is the subject of current studies within the administration.

Senator STEVENSON. Do you know if NASA or any other agency of the executive branch has given any thought to the possibilities of international systems for the monitoring of arms control agreements, military activities, disarmament, and the like? Giscard made a suggestion of some sort not long ago. I haven't read it.

Have we given any thought to such possibilities, which I assume would not replace, but would complement, national technical means of verification?

Mr. TERRELL. That is a matter that the French have raised in the U.N. and elsewhere. Since it is a matter that falls primarily within the arms control subject rather than within civil uses of space, it isn't a primary NASA responsibility. But I can say that it is, of course, a matter that is under consideration within the Government. I am not familiar with where that stands.

Senator STEVENSON. Are you familiar with where it is under consideration? Is it active?

Mr. TERRELL. Yes; I would think it is under active consideration.

Senator STEVENSON. Senator Zorinsky?

Senator ZORINSKY. I don't have any questions.

Senator STEVENSON. I think you referred to the United States-Soviet space cooperation agreement signed by Secretary Vance and the Soviet Foreign Minister last May.

Could we have a copy of that for our record?

Mr. TERRELL. Yes; we would be pleased to provide that.

[The following information was subsequently received for the record:]

AGREEMENT BETWEEN THE UNITED STATES OF AMERICA AND THE UNION OF SOVIET SOCIALIST REPUBLICS CONCERNING COOPERATION IN THE EXPLORATION AND USE OF OUTER SPACE FOR PEACEFUL PURPOSES

The United States of America and the Union of Soviet Socialist Republics;

Considering the role which the U.S.A. and the U.S.S.R. play in the exploration and use of outer space for peaceful purposes;

Striving for a further expansion of cooperation between the U.S.A. and the U.S.S.R. in the exploration and use of outer space for peaceful purposes;

Noting the positive cooperation which the parties have already experienced in this area;

Desiring to make the results of scientific research gained from the exploration and use of outer space for peaceful purposes available for the benefit of the peoples of the two countries and of all peoples of the world;

Taking into consideration the provisions of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, as well as the Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space;

Encouraged by the progress made in the course of mutually agreed activities pursued under the Agreement Between the United States of America and the Union of Soviet Socialist Republics Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes, signed May 24, 1972;

In accordance with the General Agreement between the United States of America and the Union of Soviet Socialist Republics on Contacts, Exchanges and Cooperation in Scientific, Technical, Educational, Cultural, and Other Fields, signed June 19, 1973, and in order to develop further the principles of mutually beneficial cooperation between the two countries;

Have agreed as follows:

ARTICLE 1

The Parties will continue to develop cooperation in such fields of space science and applications as space meteorology; study of the natural environment; exploration of near earth space, the moon and the planets; space biology and medicine; satellite search and rescue systems; and, in particular, will cooperate to take all appropriate measures to encourage and achieve the fulfillment of the Summary of Results of Discussion on Space Cooperation Between the U.S. National Aeronautics and Space Administration and the Academy of Sciences of the U.S.S.R. dated January 21, 1971, periodically renewed.

ARTICLE 2

The Parties will carry out such cooperation through their appropriate national agencies by means of mutual exchanges of scientific information and delegations, and meetings of scientists and specialists of both countries, and also in such other ways as may be mutually agreed. Joint Working Groups may be created for the development and implementation of appropriate programs of cooperation.

ARTICLE 3

The Parties will take all necessary measures for the further development of cooperation in the area of manned space flight for scientific and practical objectives, including the use in joint flights of compatible docking and rendezvous systems derived from those developed during the experimental flight of Apollo and Soyuz spacecraft in July 1975. Joint work in this direction will be carried out in accordance with the Agreement Between the U.S. National Aeronautics and Space Administration and the Academy of Sciences of the U.S.S.R. on Cooperation in the Area of Manned Space Flight dated May 11, 1977.

ARTICLE 4

The Parties will encourage international efforts to resolve problems of international law in the exploration and use of outer space for peaceful purposes with the aim of strengthening the legal order in space and further developing international space law and will cooperate in this field.

ARTICLE 5

The Parties may by mutual agreement determine other areas of cooperation in the exploration and use of outer space for peaceful purposes.

ARTICLE 6

This Agreement shall enter into force May 24, 1977 and shall remain in force for five years. It may be modified or extended by mutual agreement of the Parties.

Done at Geneva this 18th day of May 1977 in duplicate in the English and Russian languages, both equally authentic.

For the United States of America For the Union of Soviet Socialist Republics
CYRUS R. VANCE. A. GROMYKO.

Senator STEVENSON. And also the agency level agreement on manned space flight that NASA signed in May? Could we have that for the record?

Mr. TERRELL. We would be pleased to provide that.

[The following information was subsequently received for the record:]

AGREEMENT BETWEEN THE USSR ACADEMY OF SCIENCES AND THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION OF THE USA ON COOPERATION IN THE AREA OF MANNED SPACE FLIGHT

In accordance with the Agreement on Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes between the USSR and the USA, dated May 24, 1972, and taking into account the results of discussions held in Washington, October 19-22, 1976, between the delegation of the USSR Academy of Sciences, headed by the Chairman of the Interkosmos Council of the USSR Academy of Sciences, Academician B. N. Petrov, and the delegation of the National Aeronautics and Space Administration of the USA, headed by the NASA Deputy Administrator, Dr. A. M. Lovelace, the Academy of Sciences and NASA agree to undertake the following steps for further development of cooperation between the USSR and USA in the exploration and use of outer space for peaceful purposes.

I. STUDY OF THE OBJECTIVES, FEASIBILITY AND MEANS OF ACCOMPLISHING JOINT EXPERIMENTAL FLIGHTS OF A LONG-DURATION STATION OF THE SALYUT-TYPE AND A REUSABLE "SHUTTLE" SPACECRAFT (SALYUT-SHUTTLE PROGRAM)

In view of the fact that the long orbital stay-time of the Salyut-type station and the capabilities of the Shuttle spacecraft commend their use for joint scientific and applied experiments and for further development of means for rendezvous and docking of spacecraft and stations of both nations, the two sides agree to establish two joint working groups (JWG) of specialists, charging them with studying the objectives, feasibility and means of carrying out a joint experimental program using the Soyuz/Salyut and Shuttle spacecraft:

A JWG for basic and applied scientific experiments.

A JWG for Operations.

Within 30 days after the Agreement becomes effective, the sides will inform each other of the initial leaders and composition of these JWG. The work of both Joint Working Groups should begin simultaneously. The composition of the JWG can be changed or enlarged at any time as necessary. Appropriate subgroups can be formed.

In their studies, the JWG should proceed on the assumption that the first flight would occur in 1981. The final date would be set in the course of the joint work.

First Phase of the Joint Working Groups' Activity

The following preliminary project documents should be prepared within 6-12 months after the agreement comes into effect:

- Preliminary proposals for scientific experiments;
- Preliminary technical proposals for carrying out the program;
- Preliminary schedules for implementing the program.

Second Phase of the Joint Working Groups' Activity

The JWGS should prepare the following definitive documents within one year of joint work in the second phase:

- A technical description of the joint program and its realization;
- A scientific program for the joint flight;
- A schedule for conducting the joint work;
- An organizational basis for implementing the program;
- A list of additional joint technical documentation which may be required.

The sides will make the final decision on implementing the program at the end of the second phase of the JWGs' activity.

The working period of the JWGs in the first and second phases of their activities can be shortened.

Each side will consider the accommodation on its spacecraft of payloads proposed by the other side for flight in the Shuttle-Salyut program. Such accommodations will be undertaken where both sides agree that the payloads concerned are of mutual value and interest.

II. CONSIDERATION OF THE FEASIBILITY OF DEVELOPING AN INTERNATIONAL SPACE PLATFORM IN THE FUTURE (INTERNATIONAL SPACE PLATFORM PROGRAM)

Both sides recognize that no commitments are made at this stage concerning the realization of any project for creating an international space platform.

The sides agree to establish a Joint Working Group of specialists for preliminary consideration of the feasibility of developing an International Space Platform on a bilateral or multilateral basis in the future.

The JWG will carry out its work on the basis of studies conducted by each side independently and also by the two sides jointly, proceeding from each of the following stages to the next as may be mutually agreed:

Define at the first stage the scientific and technical objectives which would warrant the use of such a space platform.

Consider possible configurations appropriate to the objectives identified.

Formulate proposals on the feasibility and character of further joint work which may be desirable in this field.

At the first stage of its activity, the group will work in close coordination and contact with the JWGs set up to consider ways to realize the Salyut-Shuttle program.

The sides will appoint the initial leaders and members of the JWG for this program within two months after the agreement goes into effect. This JWG should formulate preliminary proposals on possible scientific-technical objectives which could be achieved by an international station one year after beginning its work.

This agreement comes into force at the moment it is signed by both sides.

For the U.S.S.R. Academy of Sciences	For the National Aeronautics and Space Administration of the U.S.A.
A. P. ALEKSANDROV.	A. M. LOVELACE.

Senator STEVENSON. Could you tell us a little more about the status of the Shuttle-Salyut possibilities: where does that stand?

Mr. TERRELL. Yes; we have been doing our internal homework. After the meeting in Moscow, both sides went off to do further preparations. We have set up working groups consisting of scientists, within NASA, from the centers and the universities that have been looking at a number of areas.

The principal areas under consideration at the moment are high energy astrophysics, atmospheric research, active injection experiments, medical and biological experiments, and radioastronomy.

Based on this study, we will get together some experimental concepts that we will be prepared then to discuss with the Soviets at the next meeting, which at this point is scheduled for the spring, perhaps May. The interchange on these experimental concepts by the two sides is intended to lead to the definition of an experimental package that is of sufficient interest to proceed to a next phase of studying a concrete scientific project and determining the cost implications, schedule implications, and operational implications.

All of this is based right now on simply an agreement to study. There has been no agreement to proceed with a joint mission. That is somewhat down the road.

Senator STEVENSON. Will you keep us informed of the progress of these negotiations?

Mr. TERRELL. We certainly will.

Senator STEVENSON. Thank you. You said a meeting with the Soviets is planned this year on each country's planetary exploration programs. How about elaborating on that. Are we planning our planetary explorations in conjunction with the Soviet Union?

Mr. TERRELL. No. We feel a complete and earlier exchange of information about the two sides' planetary programs would give each side an opportunity to plan its program in light of what the other side intended to do to achieve some degree of complementarity, if you will, between the two programs. Now we don't believe that we have had that kind of exchange. That was the point of the report I gave to you, that we want to get together with the Soviets and see what possibilities there are for getting a little bit earlier information, a little bit more complete information.

We will do no joint planning at this stage. I think we are some distance from joint planning. Now we are interested in doing our individual national planning on the basis of a fuller understanding of what the other side may be intending to do. This could, of course, lead in the future to possibilities for joint planning, but that is not what is intended at this time.

Senator STEVENSON. The Soviet press has described the Salyut VI Soviet space station as permanent, not separate or unique experiments, but the establishment of a permanently functioning scientific station.

How much do we know about the concept and results of experiments the Soviets are carrying out in the Salyut VI?

Mr. TERRELL. We know quite a bit from their published reports. I don't have that information right now.

Senator STEVENSON. Is that our source, published reports? Do we get information as a result of continuing cooperation?

Mr. FRUTKIN. Mr. Chairman, the Soviets do publish the results of such scientific work as they do in the course of their program. The results of work done in Salyut VI have not yet reached that state. Then, too under our cooperative agreement, we do regularly and effectively exchange life sciences on physiological data of each unmanned flight.

It is a fairly considerable timelag. But in more precise answer to your question, this is not the only source of information regarding their activities.

Senator STEVENSON. What do we know about this from whatever sources?

Mr. FRUTKIN. I am afraid that the sources would have to be consulted directly rather than NASA.

Senator STEVENSON. Yes. I hope you are not referring to the Soviet sources.

Mr. FRUTKIN. No, sir.

Mr. TERRELL. I thought your question was directed toward what kind of experiments they are doing. They have published the nature of such experiments as they have let the world know about. But as Mr. Frutkin says, the results of those have not been published.

Senator STEVENSON. When the TDRSS becomes operational, why should the United States continue to develop and build Landsat-type satellites that can be intercepted by foreign ground stations?

Mr. FRUTKIN. I assume the question really is directed at whether we should encourage the establishment of foreign ground stations to receive data from our satellites, which we would require in any case in order to function as a source of data for the TDRSS. I assume that is the question.

Senator STEVENSON. Yes.

Mr. FRUTKIN. Yes.

Senator STEVENSON. Wait a minute. Let me ask the staff to elaborate. Why don't you ask the question, Jim?

JAMES GEHRIG. Why, when the TDRSS becomes operational, should we continue to let foreign ground stations have access to the Landsat-type satellites directly?

Senator STEVENSON. Do you understand that? I am still not sure I do.

Mr. FRUTKIN. Yes; I do. The question has been raised to us frequently. And it is a very proper question. One of the reasons that we have accepted and assisted at the establishment of foreign ground stations for the direct reception of data from Landsat is that the Landsat program is represented to the world as an open program. And it is consistent with that openness that there be direct access to it.

As you may know, for a decade, there have been serious questions raised as to the propriety of one nation's conducting such a program which involves overflight by its satellites of other nations' territories and the acquisition of data relating to that other country's natural resources. The basis on which we have avoided negative action in the United Nations toward such a program, and in fact, gained from the United Nations its endorsement of the program, is the availability of that data to the world.

If the data were entirely filtered through U.S. sources, credibility of the program would be at issue. So, there is, in essence, a political reason for Congress to encourage the open availability of the data.

Now, given the establishment and operation of foreign ground stations, the question then arises as to what is the best mode in which countries abroad may acquire data from Landsat. Is it best for them to use Landsat directly, or is it best for them to get the data indirectly through TDRSS?

If they are to get the data through TDRSS, this means that that system acquires the data from the Landsat satellites, relays it to U.S. ground stations, and the data must then be packaged up and for-

warded by aircraft, or retransmitted through commercial communications satellites to foreign recipients. And we have looked at this question very carefully.

It turns out to be more effective from a real time data availability basis, and cheaper, to receive the data directly abroad rather than through TDRSS.

We believe that other countries will continue to prefer to establish ground stations rather than to pay the freight for receiving the data later through TDRSS.

Senator STEVENSON. Couldn't we take the data in at White Sands, process it, package it and sell it for a price that would help to maintain the system? I am not quarreling now with whether it should be open or closed, the proposition, as I understand it, was whether we should make this an indiscriminate form of foreign aid, or sell it to all comers with the expectation that then we would have more revenues with which to maintain a sound operational system.

Mr. FRUTKIN. Well, there is certainly no objection to studies to determine which way we come out best. The objective, at least our thinking, has not been to provide data indiscriminately or as a giveaway. And we are rather proud of the initiation of a fee system for the first time which is imposed on foreign countries which want to use Landsat.

They now pay, as Mr. Terrell said, a token fee of \$200,000 per year for direct access to the satellite.

That fee has been reported to them as simply an initial stab at cost sharing. And it has been made clear to all participants that as the system matures and reaches operational status, we will want to escalate the charge to them so that we make a more realistic recovery of the cost to us.

So, I think that either way we go, we are seeking in the end a realistic recovery or sharing of costs.

Now, the TDRSS route would, we believe at this time, not only burden the TDRSS system with an enormous amount of data, but would, in addition, raise the costs to the foreign countries to a level which would discourage their participation and impair the eventual market.

Senator STEVENSON. Are we negotiating now with additional countries for Landsat ground stations?

Mr. FRUTKIN. Yes, sir, we are. Countries like Japan and Australia are actively considering texts of agreements which we hope will be reached before very long. We expect that we will, within a couple of years, have somewhere between 1 and 1½ dozen foreign stations receiving data and paying an access fee.

Senator STEVENSON. Of \$200,000?

Mr. FRUTKIN. Whether that fee is to be increased is an open question.

Senator STEVENSON. Actually, that fee has been declining with the dollar.

Mr. FRUTKIN. Yes; that's correct.

Senator STEVENSON. Is NASA giving any consideration now to the possibility of raising that fee?

Mr. FRUTKIN. Yes, sir, we have funded a study which was done for us on the various alternative bases which we can use for fees in the

future to explore the way this should be done, because we have a problem with dealing with wealthy countries and poor countries, large countries and small countries, and so on. We have been searching for a proper and equitable basis for the fee, as well as for the proper size of the fee.

We have to assume that a certain portion of the satellite is used by ourselves and a certain portion used by our friends abroad, and then we have to, in effect, divide into their total benefit the number of stations we have got and come up with a realistic fee basis.

At the time that the \$200,000 figure was first arrived at, a calculation of that sort would have given us a fee of about \$800,000 per station. So what we were doing was charging about a quarter of the full amount of cost sharing.

Now, the considerations which went into fixing the sum at a lower level were such as these. We did not at that time have any assurance of continuity in the program, and we did not want to induce countries to spend a great deal of money without understanding where they would end up. We had been quite frank with people about the uncertainties of the program at that time.

We think the program has a much better future today than it did then. Neither Landstat C nor D had been approved, I believe, at that time.

The cost of starting up these programs is considerable for most countries abroad. We were very much interested in encouraging the African countries to establish direct access to Landsat. AID is interested in this. And we want to be helpful in that sort of context. So we have been reluctant to move too fast, too precipitously, in establishing a high cost basis for the operation of those stations.

Senator STEVENSON. Well, I can certainly see how any formula would be complicated, and I share your feelings about being helpful to those countries which need the assistance.

But others are in a position to make larger contributions than the formula now contemplates, so I hope you will keep pushing on that subject.

Without objection, I will place in the record copies of a European Space Agency, June 17, 1977, proposal for exchanging NASA Shuttle launch services in return for ESA Spacelab hardware and services, and NASA's August 26, 1977 response.

[The material referred to follows:]

[Translated from French]

DRAFT

Clearing mechanism between the provision by ESA of Spacelab production equipment and associated support services and the provision by NASA of STS launch services

This paper constitutes a reply to Action No. 1 requested by the Spacelab meeting between NASA and ESA representatives, held in Paris on 3 June 1977. The purpose of setting up a clearing mechanism between the provision of Spacelab production equipment and associated support services and the provision of STS launch services is essentially to avoid as far as possible transfer of funds between ESA and NASA in the context of their further cooperation initiated by the Spacelab Agreements. Secondly, the setting up of such a mechanism makes it easier to solve the problems raised by the contract rules and procedures applicable to each Agency, as well as those resulting from their own imperatives in the area of industrial policy, and simplifies the management interfaces.

The setting up of a clearing mechanism between the two agencies goes beyond the existing institutional framework (Spacelab MOU; MOU on the provision of launch services) and should be expressed in the form of a new bilateral agreement between the two agencies, concluded for example for the period 1978-1990. Under such an Agreement, the parties would mutually undertake to open a line of credit for each other (with a ceiling, if need be). ESA would open a line of credit for NASA for the provision of Spacelab production equipment and associated support services, and NASA would open a line of credit for ESA for the provision of STS services. Each party would need to undertake to keep separate accounts of the costs of services and supplies provided for the other party and there would be automatic clearing. The total amount of credit opened by each Agency for the other would thus at any time equal the total cumulative cost of the supplies and services provided, minus the total cumulative cost of supplies and services received.

As regards the procedure to be followed, the "customer" party would, in respect of each service or item of supply, ask the other party for a technical and financial proposal, following which it would place a corresponding order for provision of the equipment or the service. There would thus be formal agreement on both sides as regards the nature and price of the equipment or services to be supplied. The financial part of each proposal would consist of the cost of the equipment or services themselves (amount of industrial contract), the Agency's support costs and the cost of funding, which will be kept to a minimum. The consequences of the types of price used in such proposals need to be studied in greater detail, as well as the guarantees that could be given to the credit institutions. The time interval after which each party uses the credit granted to it by the other party—which may amount to several years in the agreement considered here (commitment of the FOP in 1978 for NASA and use of the STS by ESA in the 1980s)—requires that account be taken not only of the rates of exchange but also of the trend of economic conditions.

As regards the rates of exchange, all operations between the parties would be carried out in US dollars, the conversion between the currencies used by ESA and the dollar being done at the current rate for the day when the operations are carried out. As regards the trend of economic conditions, the question is far more complex. Each financial operation (payment, receipt, charging of interest) carried out by one party will have to be notified to the other party, so that the reciprocal accounts kept by the two Agencies tally. Those accounts would be kept in accordance with standard bank accounting practice. In order to comply with the objective and spirit of the clearing mechanism, the credit balance of ESA's accounts with NASA would have to be indexed in the light of the trend of costs in the United States and in particular of the trend of STS costs. Likewise, NASA's credit with ESA at a given time would have to be indexed in accordance with the trend of costs in the European aerospace industry and more particularly in the Spacelab consortium.

This paper only reflects very tentative and incomplete thinking, the details of which call for a study in depth. Nevertheless, the mechanism described here meets the objectives laid down and should be financially equitable for both parties.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
Washington, D.C., August 26, 1977.

Mr. ROY GIBSON,
Director General, European Space Agency, 8-10 Rue Mario Nikis, 75738 Paris
Cedex 15, France

DEAR ROY: Thank you for ESA's June 17 proposal for establishment of a clearing mechanism for exchange of NASA STS launch services in return for ESA Spacelab hardware and services. While we see some problems with the mechanism as proposed, we do consider the potential benefits of such an exchange arrangement attractive and we are prepared to enter into more specific discussions with ESA on alternative possibilities.

A major consideration on our side is that any agreement establishing such an exchange arrangement will need to be made subject to the availability of appropriated funds. This requirement stems from our statutory provisions which limit any agency to incurring obligations within the amounts of appropriated funds each fiscal year. Thus an agreement would need to provide that the obligations of each side are subject to their respective funding procedures, as is presently the case in the Spacelab Memorandum of Understanding (Art. VII. 2).

A number of the implementation procedures you suggest, on first review, we agree with. First, dealing exclusively in dollars would simplify bookkeeping and avoid some of the complexities of exchange rates and escalation. It does not appear to simplify the audit procedures which would probably require traceability to other currencies. Second, obtaining technical and financial proposals prior to the signing of an agreement would limit uncertainty and problems of interpretations at a later date.

The mechanism for and time at which the final value of goods and services are determined appears to be a complex issue, having to account for exchange rates, economic conditions and changes. A study of this trade should be broad in scope and open to alternative methods of negotiating the transaction. The alternative which now seems to us preferable is a direct barter agreement. This would take the form of an exchange of a specific list of ESA hardware and services for a specific quantity of launch services expressed in terms of number of equivalent flights and value of optional services per flight. Evaluation of the items to be traded would take place once, at the time of the signing of the agreement. Thus, each side would accept the risks of inflation or growth for the items which they must supply. This barter agreement would appear to have significant advantages in the simplification of bookkeeping and audit procedures.

Opening the trade to encompass the potential use of ESA services for Spacelab operations in such areas as logistics and maintenance, we feel, adds to the usefulness of this exercise. Details for the implementation of this phase might have to be worked separately, but the concept should not be excluded from our planning.

It is our present opinion that a clearing mechanism for the exchange of goods and services between NASA and ESA is advantageous and should be pursued. We suggest Doug Lord and Michel Bignier, with support by the respective headquarters staffs, meet at the earliest opportunity to look at the concept for a trade and the various alternative methods for carrying it out.

Sincerely,

ARNOLD W. FRUTKIN,

Assistant Administrator for International Affairs.

Senator STEVENSON. What is the status of that proposal?

Mr. FRUTKIN. The barter proposal is under discussion between ESA and NASA staff at this point. I think both sides are positively disposed toward it, but the details have not yet been worked out.

Senator STEVENSON. From your vantage point, what kind of payload traffic is the Spacelab going to generate from foreign sources, including international organizations, in the 1980's?

Mr. TERRELL. As I mentioned, we already have three contracts to launch foreign domestic communication satellites, so I believe that we will continue to be launching the same type of satellite reimbursable payloads that we launched before.

In addition, the Germans have signed up for a significant number, a couple of dozen, smaller self-contained payloads.

So we are going to have the opportunity with Shuttles to be launching smaller payloads. Mr. Frutkin pointed out your question is with respect to Spacelab, not the Shuttle. The question was what will Spacelab be generating in the nature of payloads?

Senator STEVENSON. Excuse me. I would be glad to hear about both. But try to zero in on the Spacelab.

Mr. TERRELL. I may not understand the question. Is it directed toward the opportunities for us to be launching Spacelab?

Senator STEVENSON. Well, what kind of traffic is Spacelab going to generate in the future?

Mr. FRUTKIN. There has been a very gratifying early expression of interest from Europe. The European Space Agency has approached us on the launching of two Spacelabs in the early 1980's, and the Ger-

man Federal Republic has approached us on the launching of two Spacelabs. It is the combination of those four which are, I think, virtually assured, that permits us to contemplate a barter, the barter system that you referred to earlier under which our procurement of Spacelab hardware in the follow-on phase would be offset against the launch fees that they would have to pay for launch of those four Spacelabs.

We are in a very early stage, and I don't think I could give a meaningful projection of foreign Spacelab use interests beyond that. But I think the fact that we have four Spacelabs spoken for at this early stage suggests that there will be a continuing utilization of Spacelab, normally on a fee basis, but sometimes perhaps on a cooperative basis.

There has been some indication, much more informal and less firm from Japan, in Spacelab launchings. Beyond that, I couldn't give a substantive answer.

Senator STEVENSON. Well, I cannot expect you to be very precise. But it is an optimistic prognosis. Doesn't it assume five orbiters?

Mr. FRUTKIN. If we are optimistic about the prospects of foreign use —

Senator STEVENSON. As optimistic as you have just sounded.

Mr. FRUTKIN. No; it does not have to assume five orbiters.

Senator STEVENSON. Senator Schmitt.

Senator SCHMITT. Thank you, Mr. Chairman. I am sorry I missed the earlier part of the testimony and the questions. If I repeat the earlier questions, just nudge me or something.

I am curious about the discussions with the Soviets. There has been some suggestion, I guess reading between the lines in the press, that the United States has become less enthusiastic about cooperation with the Soviets than we used to be. Sort of the worm has turned. They seem to be more enthusiastic than we do. Is that true? And, if so, do you have an explanation for that turnaround?

Mr. TERRELL. I wouldn't say that, from NASA's perspective, there has been —

Senator SCHMITT. I said the United States.

Mr. TERRELL. From my part of the U.S. perspective, I don't think there's been any significant change of interest. We are interested in exploring scientific possibilities for cooperation that will be mutually beneficial, that will be cost effective in terms of NASA's expenditures to gain science and applications objectives.

The approach we took to this in our May understanding with Salyut, for example, is a slow, very deliberate approach of joint working-group studies, phased to develop experimental possibilities, to look at those terms of scientific merit and cost, and not to reach a decision about the mission until somewhere down the road, probably for another 2 years or so.

Senator SCHMITT. Have you been given any guidelines by the administration on what your approach should be?

Mr. TERRELL. Yes; our guidelines are to look for projects that have scientific interest, that will be cost effective in terms of our science and applications budget, to look for mutual benefit, and to avoid technology transfer.

Senator SCHMITT. What does that mean?

Mr. TERRELL. What does what mean?

Senator SCHMITT. To avoid technology transfer. It is going to be awfully hard not to have some transfer; isn't it?

Mr. TERRELL. Well, we are talking about significant technology transfers that would not be contemplated under normal conditions. You know, you have controls over technology. Now, not all technology is denied the Soviet Union.

Senator SCHMITT. That's right. Very little, as a matter of fact.

Mr. FRUTKIN. In other programs. There is no provision for technology transfer in any NASA program with the Soviet Union.

Mr. TERRELL. Right.

Mr. FRUTKIN. Projects past and future, that is, Apollo-Soyuz, as well as Shuttle-Salyut, have been designed essentially to exclude the possibility of any significant technology transfer.

Senator SCHMITT. Do you have guidelines, Mr. Frutkin, on what limits there are on technology transfer? The mere fact that we have engineers in contact with each other results in technology exposure and, to some degree, technology transfer.

Mr. FRUTKIN. It is a function of the character of the project. If we were engaged in integrated development of hardware, then there would be inevitably a technology transfer. But we are not so engaged. We are not developing hardware together. The one seeming case was the development of a compatible docking ring—

Senator SCHMITT. Right.

Mr. FRUTKIN. If you remember, and I know you were familiar with that, the Soviet docking ring then in use was the design basis for the compatible docking ring. It was modified purely in terms of the design blueprint. Then each side retired to its own shores and implemented that design in its own and very different way. So that the industrial processes, the implementation of the design was done at arm's length, independently, and there was no technology transfer.

Senator SCHMITT. Let me just make sure that the record is clear. I favor the cooperative efforts, but I think that the boundary is that we will try to avoid joint technology development. We can still try to encourage joint technology exposure, in that you can't fly with them in space without exposing them to your technology. They may not pick it up. They may not be able to pick it up and use it. But the exposure is going to exist.

Mr. FRUTKIN. I think there is a semantic problem, perhaps. We think of Apollo-Soyuz and Shuttle-Salyut very much as though we each were driving our own trucks to a rendezvous point and engaging in joint activities involving the crews of the trucks themselves, but without ever exposing what is under the hoods.

Senator SCHMITT. Well, I understand that, except that when several hundred scientists and engineers work with each other for 3 years and our civilian space program is basically completely open, I am sure that the documents are all available within the Kremlin or some other appropriate place in the Soviet Union, that the exposure to the technology is almost complete.

Now, whether or not there is the capability to use it or not is the issue. But the exposure is very broad.

Mr. FRUTKIN. The exposure is to the products of our technology. In other words, there was exposure of the Apollo spacecraft to the Soviet side. There was exposure of the Soyuz and, in fact, the Salyut to our

side. But what was exposed was a finished product and not the technology or industrial know-how which goes into constructing it.

Senator SCHMITT. You are right. We are arguing semantics then. I don't think you can separate the two.

Mr. FRUTKIN. Yes.

Senator SCHMITT. However, I do believe that exposure doesn't necessarily mean transfer.

Mr. FRUTKIN. Right.

Mr. TERRELL. Right.

Senator SCHMITT. It can and it cannot, depending on how clever and also how sophisticated the exposee is.

Mr. TERRELL. And we would also say on how structured the joint program is.

Senator SCHMITT. I want to encourage you to continue to explore those possibilities. I have detected, though, a reluctance or a hesitation on the part of the administration, not NASA, maybe because they don't yet fully understand these semantic differences that we have talked about today, maybe we don't fully understand them either.

But I think we have to be bold in some of these areas and, as I have said before, partly because the space cooperation offers us a window into the Soviet Union that is basically not open to us in any other way. That window is open to them all the time, through the exposure of American technology.

It is not something that is easily come by with respect to the Soviet Union, and I think as long as they are willing to proceed in that vein, that we should take advantage of it.

Mr. FRUTKIN. I agree, Senator Schmitt. I think that in the Apollo-Soyuz program, we obtained more new insights clearly, because of the previously closed character of their activities, than they did, because of the continuing open character of our activities.

Senator SCHMITT. Would you gentlemen see any possibility of cooperation in the development of large-scale power facilities in space?

Mr. TERRELL. With the Soviet Union?

Senator SCHMITT. Yes.

Mr. TERRELL. I don't think we are at this point yet in our cooperation. There is a provision in the May 1977, Academy-NASA agreement for the possibility of looking together at joint space station efforts.

There has been no direction toward implementing it by either side. Our own internal thinking on that subject is not at a point that we could fruitfully get into anything with the Soviets. Apparently, they are in the same position.

Senator SCHMITT. What about other nations?

Mr. TERRELL. I know of no plans to look at that cooperatively.

Mr. FRUTKIN. There are no plans. We do have regular exchanges with the European Space Agency of our respective forward thinking. So they are quite familiar with the very preliminary thinking in NASA, looking toward power stations in space, and we know what they are thinking about.

What we have here is somewhat of a mismatch in scale. The scale of the European effort and their sense of short range and long range objectives is somewhat at a lower level than our own. At this point it

would be difficult to imagine their entering into an equal partnership with us in the development of power stations in the future. And then I must say, speaking for myself, I do not feel that I fully understand the commercial implications of that kind of activity, and I don't know whether it should be done on a national basis or an international basis.

Senator SCHMITT. What about capital resources? You spoke of the countries that would provide a technological partner. What about those nations that might be interested as a capital resource partner?

Mr. FRUTKIN. You meant investment in our own effort? That, in my judgment, is even less likely. The Europeans have made very clear that their philosophy is that if they are going to put money into space activities, they want the hardware development to be in their own countries, and this is why the \$600 million effort directed to the Space Transportation System is in the form of a development of Spacelab in Europe, and not in the form of an investment of capital in this country.

This is a criterion. In other words, they have the same interest in strengthening their own industry through space investments as we do.

Senator SCHMITT. What about the countries with large capital resources, but no technology?

Mr. FRUTKIN. That is a very interesting question. You are speaking of a very popular target. I do not know that that interest has been explored.

Senator SCHMITT. Has NASA made an assessment of the time function of the competition that is growing from foreign launch capabilities for various types of services that we now provide?

Mr. FRUTKIN. We are watching this very closely. This means Japanese development of the N-1 vehicle, the European development of the Ariane, and a development by some private German citizens, the OTRAG effort.

The technology which is being provided Japan for the development of the N-1 vehicle and to upgrade it is being provided commercially, not by NASA. It is in part restricted, or covered by a condition that it not be used to launch the satellites of third countries without the prior permission of the United States.

This means that Japan would be somewhat inhibited in using that capability to compete internationally with a launch service.

Now, Ariane is not so restricted. It is developed, essentially, commercially through European efforts. There we feel that in the long run Ariane will not compete with the Shuttle and certainly will not provide comparable service.

For example, there will be no retrieval possibility, no testing in orbit before final commitment with the possibility of return, and so on. The services are not comparable, and we can only say that countries like India and Iran, who are looking to the future launching of their—of national communication satellites, are contracting with us for Shuttle launchings, rather than with Europe for Ariane launchings.

So I think we are still in the lead, but I think the question is a very good one and requires careful watching.

I do not think we can rest on our laurels in this field or in any other technical field.

Senator SCHMITT. Well, there is no question that a competitive international community is developing. That pressure should spur us to better technological and economical efforts.

Mr. FRUTKIN. I agree.

Senator SCHMITT. Rather than something that we should fear for the sake of fear itself.

Mr. FRUTKIN. I agree.

Senator SCHMITT. Finally, is NASA looking at the possible application of the Intelsat management model to other types of space activities, that is, international management by user community and nations?

Mr. FRUTKIN. We have done some thinking within NASA, particularly in the area of Landsat, Seasat, and other information services, just how that might be organized in the future, not that we will have a responsibility for so organizing it, but that our activities at the present time and in the near future should be sensible with respect to the future evolution of these arrangements. The Intelsat arrangement is an obvious one. It is enormously successful in its own field. But it is very difficult to transfer the fee basis which is used in Intelsat, the price per channel for communications services, to the Landsat data question.

It is just a very difficult transition, and the application is just a newer one, in the sense that you had preexisting communications agencies in all the countries of the world—

Senator SCHMITT. You had an obvious user community for communications.

Mr. FRUTKIN. Correct.

Senator SCHMITT. You were in the process of seeing if there is one or one developing in the case of the Earth resources.

Mr. FRUTKIN. It had established revenue and charge systems. And you don't have that in the data area. It is a much more difficult thing to approach. But in the end there may be some way to apply the Intelsat model.

I am not sure.

Senator SCHMITT. I wonder if you could provide the committee with a bit of an expansion of that for the record, and particularly those areas in addition to the Earth resources area. Could you do that?

Mr. FRUTKIN. Yes.

Mr. TERRELL. Yes.

[The information follows:]

NOTES ON INTERNATIONAL ORGANIZATION OF REMOTE SENSING

While Landsat and related remote sensing activities are still in the experimental stage, some preliminary thinking has been done over the past decade regarding possible modalities for international aspects of a future global operational system.

Among the options that would presumably be available are these:

(1) A national system operated by the US for US purposes, with foreign access to data on some fee basis.

(2) An international system on the Intelsat model, that is, a consortium of nations organized for commercial operation of a global system, subscribing capital, establishing tariffs, contracting with a competent technical entity for operations, and disposing of revenues.

(3) An international system on the WMO model, that is, a loose association of nations coordinating available national systems for non-commercial exchanges of information.

Taking these options in turn, it would seem that remote sensing has so great a present and future value that the US would wish to be assured of continuity in the acquisition of global data for its own use in any system. A national system is therefore required in any event, at least until an international one comes into being and demonstrates its reliability, technically and politically, to our complete satisfaction.

We assume that the basic data output of such a national system (as distinguished from its technology) would be available to other nations, in view of the repeated commitment of this nation in international forums to sharing earth resources data, the US interest in "open skies" objectives and the nature of UN resolutions on remote sensing. The economic values of Landsat-type data suggests further that the US recover or share costs, i.e., that we charge for data and for direct access to our satellites. This we are already doing, although on a token basis, which establishes cost-sharing in principle but does not discourage early participation and use by others.

The relationship already developed by NASA with the operators of foreign Landsat ground stations represents one variant of the national approach to a global service. It makes the US national (experimental) system available to other states on the basis of mutual interest. Thus, under appropriate memoranda of understanding, NASA programs the Landsats to read out for foreign agencies; these agencies in turn commit to funding and building the necessary receiving and processing facilities (\$4-\$7 million), and operate these facilities at their own cost (\$1-\$2 million per year). They must make data for the entire regions covered by their stations available to NASA and any other requestor. Finally, these agencies pay NASA an annual, token \$200,000 cost-sharing charge for access to the satellites.

As cost-sharing continues and, hopefully, grows to economic proportions, we can expect developments along these lines: (1) The foreign contributors will want a greater voice in the planning and management of global coverage, and (2) Some countries will prefer to spend their funds on national or regional systems of their own.

Anticipating the natural interest of foreign participants in having some opportunity to be heard, NASA arranged to meet regularly with the operators of the foreign ground stations to exchange information and to coordinate mutually-agreed cooperative activities. The interest of other countries in developing their own systems is already in evidence as the French plan their "SPOT" program, closely resembling Landsat, as India readies a more elementary remote sensing satellite for launching by the USSR, and as the Japanese follow a long-range plan for their own Landsat.

Thus, it does seem likely that the maintenance of systems on a national basis, even with generous access for foreign users, will itself tend to generate broader international arrangements and/or competition.

Turning to the major options for international organization of remote sensing systems, it should be noted first that the United Nations itself, after a decade of discussion and observation of remote sensing activities in its Outer Space Committee structure, in 1975 unanimously endorsed a resolution stating that the UN should not now or in the future undertake an operational role in remote sensing. A more specialized international mechanism, akin to Intelsat, would therefore seem an early option to explore.

While Intelsat is remarkably successful in its own area, a number of factors peculiar to the communications industry may have contributed to its success. The Intelsat user agencies, typically the Post Telegraph and Telephone services, the "PTT's" or their equivalent, were long-established in most of the member countries. The tariff and revenue structures for PTT services were also well established and understood. These factors are not present in the remote sensing market. The users are not homogeneous and their use of remote sensing data is not an established practice. No charge or tariff system is obvious. The use of a telephone circuit is a discrete, individual matter whereas the provision of a data frame or tape may more nearly resemble a general publication or even a public service. Indeed, for much of the world, government agencies will be the prime users of remote sensing data. It could, therefore, be that an international remote

sensing organization might more appropriately operate on a capital plus annual subscription basis rather than on a system of tariffs. Subscriptions for the member states might be related to their GNP or to another variable basis that might bring into reasonable relationship the differing ability-to-pay of rich and poor nations, as well as their differing capacity to exploit the information gained. In any case, it would at least seem feasible for interested nations to pool their resources on some formula basis to underwrite an international remote sensing system which could be managed and operated directly or by contract.

At the same time, experience suggests there are major issues to be met in organizing any international agency for an operational function, e.g., whether voting is on the one-nation, one-vote basis or is weighted in proportion to investment or use; whether contracts for operations and equipment are placed on their merits or must be distributed arbitrarily; and so forth. In short the feasibility of such an organization may or may not be matched by its desirability.

As noted earlier, an alternative international modality is that of the World Meteorological Organization, a specialized agency of the UN. The WMO is not in the usual sense of the term an operating organization. It essentially coordinates national weather service activities by arranging and facilitating exchanges of information between them. It serves also as a forum in which nations may plan collaborative programs based on their individual contributions. Thus, it commends itself especially to international situations in which a number of nations operate their own programs but wish to provide for exchanges among them, establish standards and compatibility for data, etc., or profit from particular opportunities to join in projects. If a number of independent Landsat-type programs were to be mounted by different nations, a WMO-type forum might be worth considering as a means of assuring compatibility, complementarity, etc.

We have here noted in a very preliminary way three principal modes which might be considered in organizing remote sensing programs on an international scale:

- (1) A national system, open to foreign participation and cost-sharing.
- (2) An instrumentality of the dedicated commercial type (like Intelsat), managed internationally and operated by a technical contractor.
- (3) An international coordinating and exchange mechanism of the WMO type, bringing together independent national systems on a limited basis.

Under NASA's present charter, these possibilities are studied to the extent necessary to assure that the nation's future options are not foreclosed by arrangements made in the experimental period. As an operational phase is approached, the Administration will have to consider its future organizational mode in a more detailed and immediate sense.

Meanwhile, the pattern of regional service by foreign ground stations participating in the NASA experimental program has grown to the point that large portions of the globe are or will soon be covered. The UN has taken note of this pattern and on several occasions has endorsed it, commending it to member states and urging them to establish regional stations or associate with states which have done so. This pattern can either be further consolidated in line with the first modality discussed above or be modified to evolve along the lines of the others described.

Senator SCHMITT. Thank you, Mr. Chairman.

Senator STEVENSON. Thank you, gentlemen.

[The statement and questions and answers follow:]

STATEMENT OF NORMAN TERRELL, DIRECTOR OF INTERNATIONAL AFFAIRS, NASA

Mr. Chairman and Members of the Subcommittee, thank you for the opportunity to bring you up to date on NASA's international programs. Let me first briefly summarize the policy framework within which these activities are conducted.

NASA conducts its international programs under an explicit Congressional mandate in the National Aeronautics and Space Act. Under that mandate, NASA makes vehicles available to launch the satellites of other nations, and NASA spacecraft are available for foreign experiments. We do this on a cooperative or a reimbursable basis, depending on our interests. These arrangements are based on well defined procedures. We also support a wide variety of other flight and ground-based modes of participation in our space programs by other nations. As a result more than 100 countries have become constructively involved with NASA in cooperative space activity over the past 18 years.

Foreign proposals for space cooperation are judged on their merits. They must contribute directly to our own national program objectives. In addition, the foreign collaborators must have the technical capability to carry out the work and must meet their own costs. We do not export dollars or transfer sensitive technology. Each cooperative arrangement is undertaken as a specific project, carefully defined and limited with specified responsibilities on each side. Using these guidelines, NASA has engaged in hundreds of successful international projects involving almost all aspects of our programs.

1977 ACTIVITIES

Let me now discuss briefly our major international activities during the past year.

Spacelab and Remote Manipulator System

Spacelab and the Remote Manipulator System (RMS) are the two major foreign contributions to the Shuttle-based Space Transportation System. The Europeans are now investing close to \$600 million in Spacelab and Canada is investing about \$75 million in the Remote Manipulator System. Both systems have reached the Critical Design Review stage and are proceeding toward agreed delivery dates for use with Shuttle beginning in 1980.

Scientific Satellites Launched

Two major cooperative satellite launchings took place in the last twelve months.

The International Sun Earth Explorer (ISEE) mission was launched in October. The European Space Agency contributed the ISEE-B "daughter" spacecraft and the U.S. provided the ISEE-A "mother" spacecraft. The objective of this multi-satellite project is to study the interaction of the interplanetary medium with the Earth's immediate environment.

In January of this year the International Ultraviolet Explorer (IUE) was launched. It is the first international space astronomical observatory. Its purpose is to obtain high resolution ultra-violet spectra of stars, planets and other astronomical sources (such as gas clouds). In this joint project, the UK provided the camera system to operate with the NASA telescope. ESA contributed the spacecraft solar array and is operating a European ground station.

Both the ISEE and IUE spacecraft are functioning well and sending back useful data.

Infrared Astronomy Satellite, Galileo and Space Telescope

Agreements for three new and important joint space science projects were signed by Dr. Frosch last October:

- the Infra-Red Astronomy Satellite (IRAS)
- the Galileo Jupiter Orbiter Probe and
- the Space Telescope.

In the IRAS project the Dutch will build the spacecraft and integrate a NASA-supplied IR telescope into it. The UK will provide a ground facility for tracking, control, and operation. NASA and the UK facility will share responsibility for scientific data receipt and processing. All three countries—Netherlands, the UK and the US—will supply focal plane instruments for the satellite.

Cooperative arrangements were concluded with the Federal Republic of Germany for project Galileo (formerly called the Jupiter Orbiter Probe) and with ESA for the Space Telescope. These are both missions in which NASA has principal responsibility for spacecraft and mission operations, while our cooperating partners contribute major spacecraft subsystems and scientific instrumentation. Both partners will participate significantly in the scientific side of the missions.

The Germans are supplying the retropropulsion module for Galileo. This cluster of bi-propellant engines is based on the design successfully employed in the Franco-German *Symphonie* communication satellites. On Galileo the module will handle all mission maneuvers and place the spacecraft in orbit around Jupiter. Germany will also fund the participation of 14 German scientists (including two principal investigators) who will be supplying three scientific instruments for the mission. These investigators were selected along with a number of U.S., French, ESA and Canadian scientists by the usual Announcement of Opportunity competitive process.

For the Space Telescope project, ESA will provide the spacecraft solar arrays, the Faint Object Camera and extended operational support. In return, ESA-sponsored European astronomers will be allocated ST observing time on the basis of proposals evaluated by the same standards of scientific quality as our own.

Taken together, the foreign inputs to IRAS, Galileo and Space Telescope represent a \$180 million contribution to NASA's Space Science programs.

Spacelab and Shuttle Use

During 1977 significant progress was made in promoting the international use of Spacelab and the shuttle. Initial selections were made by NASA for the first three Spacelab missions. Spacelab 1 is a joint NASA/ESA mission and Spacelabs 2 and 3 are all NASA missions. All will have foreign-funded investigations on board.

For the Spacelab 1 mission, NASA selected a \$10-million Japanese electron accelerator facility, as well as investigations involving Indian, Canadian and French hardware and scientists. These will be part of the NASA half of the payload. In addition, NASA-sponsored life scientists will conduct medical research using the European vestibular sled on the ESA half of the payload.

The Spacelab 2 mission includes a solar telescope and a stellar x-ray telescope, both contributed by the UK. These two telescopes were selected competitively from among the many responses to the NASA Announcement of Opportunity.

On Spacelab 3, an Australian zero-gravity red blood cell experiment will be conducted.

The Long Duration Exposure Facility (LDEF) is another Shuttle payload with significant foreign participation. Seven experiments from six countries and ESA have been selected for flight. As with the Spacelab instruments, these experiments will be funded by the foreign sponsoring agencies.

Foreign Landsat Stations

A significant international dimension to the NASA Applications Program is the growing level of foreign commitment to build and operate ground stations to receive Landsat data directly from the satellites. Currently seven foreign stations in six countries are operating, under construction or firmly committed. The participating countries are Brazil, Canada (two stations), Italy (under-ESA sponsorship), Iran, Argentina and, most recently, India. Chile and Zaire also plan stations but have not yet funded their construction. Ground stations for several other countries are in the active negotiation phase, and still other countries have expressed interest. Over the next two to three years, we expect to see up to a dozen countries committed to operating Landsat stations.

Foreign station operators are committed to provide data not only to their national users but to other users in the region covered by the stations. In addition, these foreign stations serve as a back-up for our satellite tape recorders, and we have access to any of their data which we require. Each station operator pays NASA an access fee to help offset our costs of operating the Landsat system. This fee is currently set at \$200,000 annually.

The US derives other financial benefits from foreign participation in Landsat. The establishment of foreign ground stations, each of which costs at least \$5 million or more to build and \$1-2 million per year to operate, generates substantial purchases of hardware and services from the US. We anticipate that access fee payments and purchases from US industry in connection with Landsat stations will total \$135 million by 1984.

ATS-6 Experiment in India

In 1977 the Indian Space Research Organization completed an extensive technical and social evaluation of the Satellite Instructional Television Experiment (SITE). In this cooperative project, NASA made the ATS-6 satellite available for one year (mid-1975 to mid-1976) for India to broadcast instructional programs directly to low cost Indian-built receivers in more than 2000 rural villages.

The results of the evaluation are now in the process of being published by the Indians. Based on their preliminary reports to us, we can conclude that SITE has proven beyond doubt the practicability of satellite based community

TV broadcasting to rural areas in a developing country. It has also shown that the ability to develop, produce, and operate both the ground segment and the TV programming for such a system is not limited to the highly industrialized nations. Finally, SITE has clearly demonstrated the effectiveness of TV as an instructional medium in a developing country.

Experience with SITE led to India's decision to establish its own domestic communication satellite system. The India spacecraft is scheduled to be launched by Shuttle in 1981.

US-USSR Cooperation

The second five-year intergovernmental agreement on US-Soviet space cooperation was signed by Secretary Vance and Foreign Minister Gromyko last May. It calls for cooperation with the Soviets in space research at about the same level as in past years.

Also in May 1977 we concluded an agency-level agreement on manned space flight. US and Soviet scientists began discussions last November in Moscow on candidate experiments for a possible Shuttle-Salyut mission. A joint mission would be designed to benefit from the flexibility of the Shuttle and the longer staytime of Salyut. NASA officials will meet with the Soviets three times this year (April, July and October) to evaluate and further define candidate experiments and develop a recommended program. The principal research areas under consideration at the moment are high energy astrophysics, atmospheric research, active experiments in the magnetosphere and ionosphere, medical and biological experiments and radio astronomy.

In unmanned space flight, the 1971 agency-level agreement is being extended for a further period. In the meantime, the various working group activities in cooperative science and applications under our space agreement are continuing:

In the Search and Rescue area (under a separate agreement concluded last May), we expect soon to have an initial working group meeting with the Soviets, probably with the participation of the Canadians and the French.

The Soviets provided lunar samples recovered by their Luna-24 mission for analysis in the US. This will supplement our own lunar samples with data from areas not visited by US spacecraft.

Last August, the Soviets flew a second biological satellite mission with US experiments on board. We are now planning to ride a third Soviet mission in 1980. These experiments have enabled US investigators to have flight opportunities in a period when the US is not flying biological satellites.

Also in August, US and Soviet specialists conducted cross-calibration tests on meteorological rocket systems at Wallops Island, Virginia.

We are continuing our exchange of natural environment data with the Soviets in preparation for a possible joint meeting later this year.

Finally, we anticipate meeting with the Soviets this year to continue discussions on the planning of each country's planetary exploration program.

International Reimbursable Launches

Apart from cooperative projects the United States also provides launch assistance to other countries and international organizations on a reimbursable basis. Such assistance is furnished for satellite projects which are for peaceful purposes and are consistent with relevant international obligations. Since 1965, NASA has conducted 54 reimbursable launches for 10 foreign countries or international organizations such as Intelsat. More than 60% of NASA's launches in 1977 were for international customers (10 out of 16). For 1978 we have scheduled 9 out of a total of 25.

Looking forward to the Space Shuttle era, telecommunications agencies in Canada, Iran and India have already deposited earnest money for Space Shuttle launches of domestic communications satellites in the early 80's. The German Research Ministry has made down payment for two Spacelab flights on the Shuttle and for some 25 small, self-contained research payloads. ESA is also planning two reimbursable Spacelab missions in the 1982-83 time period.

Reimbursable launches make a healthy contribution to the United States balance of payments. They also support the production of launchers at levels which reduces unit and overhead costs to NASA's own missions. In addition, many of the foreign satellites launched by NASA are built by US aerospace contractors, adding to the dollar inflow and creating jobs in the domestic economy.

BALANCE OF PAYMENTS

Nearly 200 million dollars per year flows into the United States as a direct result of international space activities. Over the past decade, an estimated 2.1 billion dollars has been spent in this country by foreign organizations for space related projects. This includes purchases of launch vehicle hardware and satellites, earth resources related activities and spending on reimbursable launches and cooperative projects. It does not include program funding benefits or scientific and technical knowledge which we receive from cooperative projects.

FUTURE PROJECTS UNDER DISCUSSION

Looking to the future, I would like to mention some cooperative projects which are under discussion but which have not yet reached the formal agreement stage.

Spacelab Development

NASA and ESA are exploring future user requirements which might suggest the need to expand Spacelab's capabilities beyond the first two flight units. Joint study groups are being established and will begin meeting soon.

Spacelab Use Sharing

With respect to Spacelab use, we are exploring with ESA and Germany possible NASA participation in the four missions they are planning for 1982 and 1983.

One particular field of research in which the sharing of flight opportunities on future Spacelab missions appears to be mutually advantageous is processing of materials in space. A number of foreign agencies, as well as NASA will have already invested in the basic research facilities necessary for these investigations such as furnaces. Thus it is mutually desirable to obtain as many flight opportunities as possible. It is of course important to assure that such flight sharing does not compromise the proprietary rights of any of the participants.

Spacelab Barter Arrangement

We are discussing with ECA a cooperative exchange arrangement in which NASA's Spacelab hardware requirements would be "bartered" for European STS launching requirements. This would permit both parties to meet their needs without transfer of foreign exchange. We believe this arrangement could facilitate future European use of the STS/Spacelab system.

Search and Rescue

Arrangements are moving forward in parallel with Canada, France and the Soviet Union for their contributions to the space and ground segments of a satellite-aided search and rescue demonstration project. A number of other countries are also considering possible ground based participation in the demonstration.

Seasat/HCMM/Nimbus-G Ground Stations

Negotiations are underway with ESA to establish European ground stations to receive data directly from the Seasat-A Nimbus-G and Heat-Capacity Mapping Mission. The stations will be built at their cost. The data will be used by NASA-approved investigators of study test sites within the area of station coverage.

Solar Polar Mission

Assuming that the Solar Polar Mission is approved by Congress as a new start in fiscal year 1979, Europe is prepared to contribute over \$100 million to the mission. Seventy million dollars would be allocated for an ESA-built spacecraft and \$30 million for European-supplied experiments for both the NASA and the ESA spacecraft. These two spacecraft are planned for launch in 1983 by a single Shuttle and Inertial Upper Stage. They will be placed in trajectories that will take them over the poles of the sun, the first spacecraft ever to do so.

Active Magnetospheric Particle Tracer Experiment

Finally, a cooperative study is underway with Germany to define the Active Magnetospheric Particle Tracer Experiment (AMPTE). This would be a two-spacecraft mission to be launched in 1981-82 as part of the Explorer program. It would be the first large-scale active magnetospheric experiment. Under the

plan now being studied, the Germans would provide the Ion Release Module spacecraft and NASA would provide the Charge Composition Explorer to carry out necessary supporting measurements. The study phase will be completed in mid-1979. A decision to go ahead with the project will depend on the outcome of the study and the availability of resources on both sides.

Mr. Chairman, I hope that this brief review of NASA's international activities has demonstrated that space cooperation is an important and constructive dimension of the U.S. space program. These joint efforts contribute directly to our own space science and applications programs. The European Spacelab and Canadian Remote Manipulator System will provide important new capabilities to the Space Transportation System. The national balance of payments account is strengthened. Finally, the worldwide network of relationships established to carry out these activities will contribute to active and relevant international cooperation by NASA in the 80's and beyond.

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

U.S./SOVIET COOPERATION

Question. If we enter into an agreement with the Soviets for a Shuttle/Salyut mission, do you think we would be helping them in establishing a stronger technology base? Do you think it would improve their testing capability or their management capability or any other aspect of their science and technology?

Answer. There is no reason to believe that if the current studies of a possible Shuttle/Salyut mission conclude that such a mission is scientifically and technically justified, and if the decision were made to go ahead with it, that a Shuttle/Salyut mission would help the Soviets to establish a stronger technology base. There would be no joint hardware development. A Shuttle/Salyut mission would provide for coordinated operations in space, and joint or coordinated research. In terms of equipment for science or operations, each side would carry out its development or technical responsibilities on its own. The Soviets would not have access to U.S. industrial processes or related technological know-how.

Likewise there is no reason to believe that Soviet tests carried out in connection with a Shuttle/Salyut mission would improve Soviet testing capability more than tests the Soviets might conduct on their own.

As to Soviet management capability, it is conceivable that a Shuttle/Salyut mission would draw to Soviet attention certain aspects of the U.S. approach to organization and management. This however is a reciprocal matter. Since the U.S. approach is an open book in any case, we would be likely to learn more in this area than the Soviets.

Question. Would you please summarize the U.S./Soviet agreement concluded last May related to the search and rescue area?

Answer. In a protocol confirmed May 18, 1977, NASA and the Soviet Ministry of Merchant Marine agreed on Soviet participation in a planned U.S.-Canadian satellite-aided search and rescue demonstration project. The Soviet side would provide and launch one or more search and rescue-equipped satellites and would establish ground stations in the Soviet Union. The Soviet activity would be compatible technically and in schedule with the U.S.-Canadian program. Each side would be responsible for its own ground stations and would conduct its own search and rescue operations. The parties would establish a Joint Working Group to plan the project in detail. (The Joint Working Group has not met yet.) A copy of the Protocol of May 18, 1977 is attached.

Question. Last August, the United States and the Soviets conducted what are called "cross-calibration tests" on meteorological rocket systems at Wallops Island, Virginia. What was the purpose of these tests?

Answer. The purpose of the intercomparison tests was to improve the comparability of thermodynamic and wind measurements taken by the U.S. Sner Loki Datasonde and the USSR M-100B meteorological rocketsonde system. The Joint U.S./USSR Working Group on Space Meteorology agreed to these tests in 1975 to obtain a better understanding of discrepancies in U.S. and Soviet meteorological rocket data of the Eastern and Western Hemispheres. These measurements were being exchanged under an earlier agreement, to investigate the processes which characterize the stratosphere and mesosphere.

Question. You say you are exchanging data on the natural environment with the Soviets in preparation for a possible joint meeting later this year. What kind of data is this? In what ways is it useful to the United States?

Answer. Under the joint US/USSR Natural Environment Working Group, NASA and the Soviet Academy of Sciences are exchanging ground, airborne and satellite data collected by each country over agricultural, geological and oceanographic test sites. The data the Soviets collect and provide to us is useful in corroborating our own measurements, such as those made with Landsat and meteorological satellites, over Soviet wheat growing regions for the Large Area Crop Inventory Experiment.

REIMBURSABLE LAUNCHER—INTERNATIONAL

Question. You say that launch assistance is furnished for foreign satellite projects which are for peaceful purposes and are consistent with relevant international obligations. Whose "international obligations" are you speaking of and would you please give the Committee some examples of such "relevant international obligations?"

Answer. The relevant international obligations which were referred to are those of both the customer nation or international organization and the United States, which have been established by international treaties or agreements. These include:

1. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies. This treaty, which entered into force in 1967, requires States Parties to use space only for peaceful purposes, bars the testing of weapons in space and establishes international liability for damages caused by space objects.
2. The Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched Into Outer Space. The Agreement, which entered into force in 1968, requires States Parties to assist in the return of any space object or astronaut which might land in their territory.
3. Convention on International Liability for Damage Caused by Space Objects. This convention, which entered into force in 1973, is an extension of the Outer Space Treaty and requires States Parties which launch or procure a launching of space objects to be absolutely liable for any damages which are incurred by such objects.
4. Convention on Registration of Objects Launched Into Outer Space. This Convention, which entered into force in 1975, requires States Parties launching objects into outer space to register such objects with the United Nations.
5. The International Telecommunications Union (ITU) Regulations. Pursuant to the ITU Radio Regulations activities using radio systems in space must be conducted in an orderly manner using, as appropriate, allocated frequency bands, and avoiding harmful interference with other radio systems.
6. International Telecommunications Satellite Organization (Intelsat) Agreement. This Agreement, which entered into force in 1973, requires technical coordination with the Intelsat body of all planned communications satellites projects of member States. In connection with international public telecommunications services, which might compete with Intelsat, member States are required to permit the Assembly of Parties to comment on potential adverse economic impact of such systems on Intelsat.
7. Other bilateral, multilateral or regional agreements may also apply in particular cases, such as the 1976 agreement establishing the Arab Corporation for Space Communications.

BALANCE OF PAYMENTS

Question. You say that nearly \$200 million per year flows into the United States as a direct result of international space activities. How much flows out of the United States from NASA?

Answer. About \$27.5 million is spent by NASA overseas. \$27.2 million is spent on maintaining our tracking and data acquisition stations and the communications facilities needed to support them. The other \$300,000 is spent with seven foreign universities supporting projects of NASA interest.

PROTOCOL ON COOPERATION IN AN EXPERIMENTAL SATELLITE SYSTEM FOR SEARCH
AND RESCUE OF VESSELS AND AIRCRAFT IN DISTRESS

On March 16-17, 1977, a Soviet delegation was briefed at the NASA Goddard Space Flight Center on a proposed test and demonstration of an experimental satellite-based Search and Rescue system, with a view to possible Soviet participation.

The planned experiment would involve the use of two or more low-altitude satellites with transponders on board for the purpose of relaying emergency signals from distressed aircraft and ships to ground stations serving existing search and rescue agencies.

Under this plan, NASA is to provide the satellite onboard processor, and otherwise equip and launch two satellites. Canadian agencies expect to design and manufacture the transponders for the system. The Canadian side would also develop a design for the ground terminals required. Each participant in the experiment is to provide its own compatible Emergency Locator Transmitters for its air and surface craft.

To participate in this planned experimental program, the Soviet side would equip one or more of its own satellites with transponders and would establish ground stations in the Soviet Union for Soviet search and rescue operations. The Soviet activity would be compatible technically and in schedule with the United States-Canadian program.

Each party participating in the experimental test and demonstration could receive distress signals relayed by any of the satellites launched by NASA and Soviet agencies for this specific program. Each party would be responsible for its own ground stations and would conduct its own search and rescue operations according to existing procedures and practices.

It is intended that the test and demonstration would be well underway in early 1981. The parties would meet as required for coordination purposes but in any case would meet approximately one year after sufficient satellites are in orbit for purposes of the demonstration in order to evaluate their experience and to consider any next steps which may be desired.

To plan this project in detail, the parties would establish a Joint Working Group which would have the responsibility for establishing detailed schedules and milestones and for coordination as necessary. The parties would be in direct contact to provide for the earliest designation and meeting of this Joint Working Group.

It is understood that, while informal discussions have taken place at the technical level between the United States and Canadian agencies, final approval by their governments for carrying forward the proposed Search and Rescue experiment is pending. With this understanding and subject to confirmation of the present Protocol by NASA, USA, and the USSR Ministry of the Merchant Marine within 60 days, it is agreed that the parties would participate according to the general plan described above.

It is further understood that this plan, when finally approved, could be related in an appropriate way to the May 24, 1972 Agreement Between the United States of America and the Union of Soviet Socialist Republics Concerning Cooperation in the Exploration and Use of Outer Space for Peaceful Purposes and any extension thereof.

Lists of delegations are attached.

For NASA, U.S.A. :

ARNOLD W. FRUTKIN,
*Assistant Administrator
for International Affairs.*

March 18, 1977.

For U.S.S.R. Ministry of Merchant Marine :

YURY S. ATSEROV,
*President of V/O Morsviazsputnik,
Ministry of Merchant Marine.*

March 18, 1977.

[EXECUTIVE SESSION]

Senator STEVENSON. Our next witness is Dr. William Perry, Under Secretary of Defense, Research and Engineering.

This part of the hearing will have to be in executive session.

I move that the subcommittee go into an executive session in order to consider matters affecting the national security.

Without objection, that motion is agreed to.

Those who are not authorized will please leave the room.

[Pause.]

Senator STEVENSON. Are we secured?

**STATEMENT OF DR. WILLIAM J. PERRY, UNDER SECRETARY OF
DEFENSE, RESEARCH AND ENGINEERING; ACCOMPANIED BY
DR. ROBERT GREENBERG**

Dr. PERRY. Good morning.

Senator STEVENSON. Dr. Perry, let me just say at the outset that Senator Schmitt and I have a disagreeable responsibility of enforcing the Code of Conduct of the Senate. He is the vice chairman of the Senate Ethics Committee, of which I am the chairman. Among other disagreeable responsibilities, we have the responsibility for investigating and disciplining leaks and breaches of national security up here. It is a responsibility that we take very seriously.

I thought I would just mention at the outset that, of course, in the discharge of our responsibilities, we find frequently that the trail leads straight into DOD. I mention this because last time we had this particular hearing, somebody in DOD forgot to censor it, and within a couple of days we read about it in the Aerospace Daily.

I trust that that will not happen again.

If you care to summarize your testimony, I would be happy to enter it in the record.

Dr. PERRY. Thank you, Senator Stevenson.

Relative to your first point, if it happens, it will not happen from this source.

Senator STEVENSON. Without objection, the full statement will be placed in the record.

Dr. PERRY. In summarizing the statement, I want to make a few points that I think are of particular importance.

First of all, I would like to offer you my personal opinion that there is, indeed, very effective coordination and cooperation between DOD and NASA.

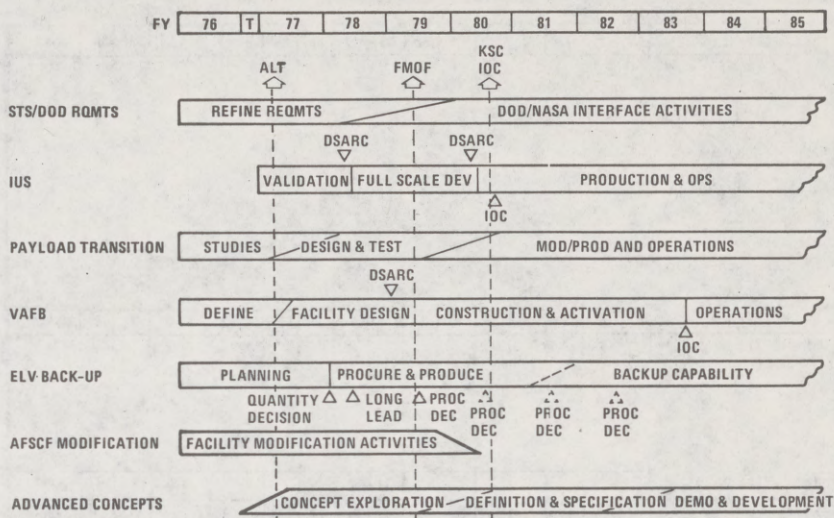
This is reflected in several rather major programs we have under way—the national aeronautics facilities program, which I will be discussing some today; and, perhaps the most visible and dramatic, the Shuttle program.

Let me go directly to a brief discussion of the Shuttle program.

The principal responsibilities of the Department of Defense, as you know, are for the development of the interim upper stage, now known as the inertial upper stage, which will be used both by defense and nondefense satellites; and, for the development of the Vandenburg Shuttle launch facility.

Let me show you on this chart the schedule against which DOD programs are working.

PROGRAM SCHEDULE



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I don't plan to discuss that with you in detail, unless you are interested. What I am pointing out primarily here is that second line which represents the Inertial Upper Stage (IUS) which we are building. It is scheduled for its initial operational capacity (IOC) in 1980.

That program is on schedule. We expect to make that schedule.

Down two lines beneath that, Vandenberg Air Force Base (VAFB). That construction is scheduled to start within a year, and the initial operation capability (IOC) of that facility will be in 1983.

Those are perhaps the two most significant lines in that schedule, since they, first of all, pace when we will be able to put our space systems in orbit, and when we will be able to operate our polar launches out of Vandenberg using the Shuttle.

The polar launch capability, as you know, is required for some of the most important defense satellites. We have, as you see, a period from 1980 when the Shuttle will begin operating from Kennedy Space Center, and, 1983 when we have the Vandenberg Shuttle facility ready for operation for the polar launches. In that period, we plan to use mostly expendable launch vehicles, to boost our satellites into orbit. So there is a period of transition. It is rather complicated to understand how that transition is going to work.

DOD SPACE MISSION MODEL (FY 1977 - 1991) (U)
LAUNCH TRAFFIC

PROGRAM	FY 77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	TOTAL
<i>[delete]</i>																
TL SHUTTLE KSC				■		2	7	8	9	7	4	8	7	7	6	65*
USE SHUTTLE AF VAFB**																
<i>[delete]</i>																
TL SHUTTLE VAFB							③	4	5	4	6	6	6	4	6	44*
TOTAL	14	17	15	10	15	12	14	13	14	11	10	14	13	11	12	195*

* ALL STP SHUTTLE LAUNCHES WILL BE CONDUCTED IN CONJUNCTION WITH OTHER PAYLOAD MISSIONS.

** PRIOR TO TRANSITION TO SHUTTLE SOME PROGRAMS ARE NOT LAUNCHED AT THIS SITE.

1st SHUTTLE LAUNCH FROM KSC

1st SHUTTLE LAUNCH FROM VAFB

349 8

The next chart gives you a feeling for that. On the left-hand column of the chart we have depicted each of the various satellite programs which the Defense Department is planning to launch between now and 1991.

The upper half of the chart represents the launches from Kennedy, the bottom half, the launches from Vandenburg.

Going across the chart, we see the number of launches that are envisioned. I think of importance for this presentation is noting the year at which that number has a square or circle around it. That is the year in which we will make a transition from expendable launch vehicles to Shuttle launch vehicles. So you see it is a somewhat dynamic picture where we have our first experimental launch on the Shuttle occurring as early as 1980. We have our first operational launch, occurring in 1982 from Kennedy. The first from Vandenburg occurring in 1983.

We see a complete transition to the Shuttle occurring by 1985.

You may be interested in having a copy of this chart for the complete files. I will be happy to provide that.

Senator STEVENSON. Thank you, Dr. Perry.

This assumes an operational first orbiter as of June in 1980?

Dr. PERRY. Yes, sir.

Senator STEVENSON. And it also assumes there will be four orbiters?

Dr. PERRY. Yes, it does. The four-orbiter assumption is implicit, not explicit, in this chart. This is our mission model which was pre-

pared independent of the number of orbiters that would be available. It was an input to NASA in the planning of their overall Shuttle program.

Senator STEVENSON. I see.

Senator SCHMITT. Excuse me, Mr. Chairman, if I may follow up on that.

Does this chart change for four versus five orbiters?

Dr. PERRY. It does not, Senator Schmitt. This is a chart we prepared prior to the discussion of whether there would be four or five or three, or whatever.

Senator SCHMITT. So this is just what your requirements are?

Dr. PERRY. These are our requirements, but these requirements are also folded into the NASA planning and the planning is compatible with the launch of these vehicles on this schedule.

Senator SCHMITT. Is there any impact of suddenly finding yourself with three orbiters?

Dr. PERRY. There are several impacts that we would have to consider. The first is that if we suddenly found ourselves with three orbiters, it would probably be the result of an accident, which accident in itself would be cause for delay and investigation of the program.

So that is a problem which would be of considerable concern to us, if the Shuttle program were shut down for a period of months, while that accident was being investigated.

That could have a profound impact on this model.

Senator SCHMITT. Yes, but for your purposes, some of them being extremely critical to our national security, it is conceivable that even in that situation, one would take greater risk, is it not?

Dr. PERRY. It is conceivable. It is also conceivable that if the launches were to proceed, but to proceed with fewer Shuttle vehicles available, there then would be a competition between the various programs as to which ones would go on schedule and which ones would be disturbed.

Some of the DOD programs, I believe, will have the highest national priority.

I believe they would go in any event. And so the adverse impact then would be on the lower priority DOD programs and the civil programs.

Senator SCHMITT. Well, Mr. Chairman, I think we will pursue this a little bit more later. The analogy is, of course, that in the time of armed conflict, you may find a generic problem in H-4's or H-15's, of 4's and of 15's, but you keep flying them, because you have to. That is one difference between the DOD operational program and the NASA program.

NASA would almost certainly close down for any failure until that failure was understood.

I am not sure we would do that for national security purposes. But, again, you have to evaluate the real situation with the real facts, but I think this is a basic philosophical difference of the two programs.

Dr. PERRY. That is a good observation, Senator Schmitt.

While I would not make that statement about all of our department programs, some of them will have a high enough priority and enough time urgency that there will be, indeed, significant pressure to launch them.

We are maintaining a number of expendable launch vehicles as backup.

We could accommodate a certain amount of delay relatively early in the program. But there will come a time in this program when we will not be maintaining those expendable launch vehicles.

Senator SCHMITT. Where is that time?

Dr. PERRY. In the latter part of the 1980's.

Senator SCHMITT. Could you, when you provide us that chart, indicate by, say, a circle around the number or some other indication where your expendable launch capability, backup capability, disappears?

Dr. PERRY. I could do that, Senator Schmitt, with the understanding that there is a basic uncertainty.

Senator SCHMITT. I understand.

Dr. PERRY. We will be going into the program with a defined number of backup vehicles. They are on a contingency basis, and the contingency that would require the use of them is very difficult to predict.

Senator SCHMITT. In a nominal situation, I hate that word, you presumably do have plans for how long you would maintain the vehicle, so it is a backup vehicle?

Dr. PERRY. Yes. Our minimum plan is that we would have the expendable launch vehicles at least until 1985.

Senator SCHMITT. That is for all types of launches?

Dr. PERRY. This would be the Titan III backup booster; and the inertial upper stage, which has been developed so that it could be used either with the Shuttle or with the expendable launch vehicles.

In the earlier chart which I now have off the board, there was a line that was called payload transition so that they can be launched with this inertial upper stage on the Shuttle.

Senator SCHMITT. Thank you.

[The information follows:]

Present plans are to continue the backup TITAN III launch capability only through fiscal year 1985.

Dr. PERRY. Those expendable launch vehicles could be maintained beyond 1985, if it were considered desirable to do this.

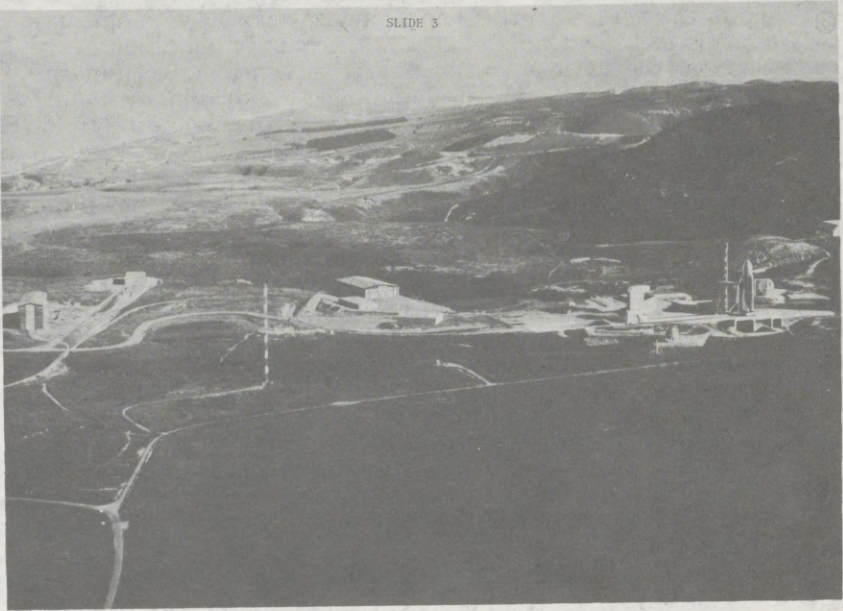
There is an expense, of course, to maintaining them. Our present plan is to maintain them the minimum amount of time we think they would be necessary.

I was planning to go from this to a brief discussion of the activities at Vandenberg. I would be happy to either continue the discussion on the Shuttle—

Senator STEVENSON. Why don't you keep going, and we will come back to it.

Dr. PERRY. All right.

SLIDE 3

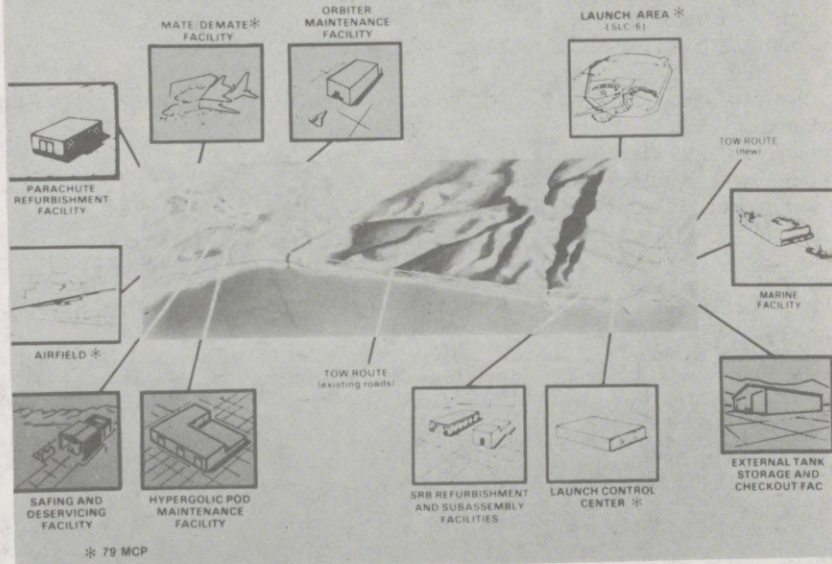


This represents a view of what Vandenberg will look like when the Shuttle launch facility is completed.

The next chart gives an indication of the specific facilities which we have to build at Vandenberg.

SLIDE 4

Vandenberg STS Facilities



It shows the very extensive and somewhat expensive modification to Vandenberg. I don't plan to cover this chart in detail, but, as you can see from the various pictures there, a considerable number of buildings are involved. And it is going to cost a good many hundreds of millions of dollars to build all of these. We are planning to have construction completed, as I indicated, in 1983. Vandenberg at that time will be operational.

I might mention parenthetically that Vandenberg will then provide the Shuttle launch capability for all satellites that require polar launches. It would not only be DOD satellites, but a good many civilian satellites that would be launched from Vandenberg, as well.

Senator SCHMITT. Just very briefly, do you feel that the understanding now exists within the Administration of the national security necessity for the launch facility at Vandenberg?

That was an issue. It was even rumored in the press to have been a bargain that was struck between Vandenberg and a fifth orbiter. To me that makes very little sense, based on my understanding of the DOD requirement for the polar orbit capability and inappropriateness of the KSC plan for that capability.

Do you believe the understanding is real, or is it just another bargaining?

Dr. PERRY. Senator Schmitt, the position of the Department I will give you first, since I am equipped along that line. We require a launch facility at Vandenberg in order to participate in the Shuttle program.

Second, my belief is that the administration is unanimous on the point that the Vandenberg facility is needed. I am not aware of any further debating going on in the administration on this issue today.

Senator SCHMITT. Will you inform the committee at any time that you detect such debate reoccurring?

Dr. PERRY. I will take the most vigorous action available to me.

Senator SCHMITT. Thank you.

Senator STEVENSON. You are familiar with the GAO report?

Dr. PERRY. Yes, I am. I have written a reply to the GAO, as a matter of fact.

Senator STEVENSON. Off the record.

[Discussion off the record.]

Senator STEVENSON. Could we have a copy of your reply for the record?

Dr. PERRY. Yes.

Senator STEVENSON. Thank you.

[Dr. Perry's reply to the GAO follows:]

THE UNDER SECRETARY OF DEFENSE,
Washington, D.C., February 17, 1978.

Mr. R. W. GUTMANN,
Director, Procurement and Systems Acquisition Division, U.S. General Accounting Office, Washington, D.C.

DEAR MR. GUTMANN: This is in reply to your letter to the Secretary of Defense regarding your draft report dated January 1978, on the "Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements," OSD Case No. 4788, Code 952181.

The Department of Defense strongly disagrees with your recommendation that the Congress should not fund Vandenberg Air Force Base (VAFB) modifications to accommodate the Shuttle.

The report does not fully recognize that, to the extent the Shuttle is used to launch military payloads, it is a part of our military capability. The DoD has extensive plans to use the Space Transportation System with its new capabilities when it becomes operational. In the early 1980s we plan to start to transition all of our spacecraft from launch on current boosters to the Shuttle and to begin the phaseout of our current expendable boosters. Shuttle launches will be required from Kennedy Space Center (KSC) for spacecraft which must be placed in low and medium inclination, high altitude orbits. VAFB is essential for Shuttle launch of DoD spacecraft which must be placed in very high inclination (polar, near polar) low altitude orbits.

The spacecraft which we will launch on the Shuttle from VAFB include our heaviest spacecraft which support missions of highest national priority. These spacecraft flown on the Shuttle will be improved growth versions of operational spacecraft now being launched from VAFB. We now are using the full 24,300 lb TITAN IIID payload delivery capability from VAFB, and are fully depending on the 32,000 lb Shuttle delivery capability from VAFB by the mid-1980s. Your report suggests that if range safety constraints are waived at KSC, the Shuttle flying north over the continental U.S. could deliver 25,000 lbs to low polar orbit. Your report also states that this capability is adequate for DoD. In fact, the standard Shuttle payload capability is only 22,000 lbs under these conditions (98° inclination and 150 nmi). We are aware that it may be possible to increase Shuttle performance by several hundred pounds on certain flights without significant risk by off-loading some items from the Shuttle flight manifest. If the Shuttle is configured to deliver a payload but not retrieve an old satellite on the same flight, performance might be increased to perhaps 25,000 lbs. However, from these Shuttle performance figures, we must deduct the weight of a cradle to properly support our payload in the Shuttle—about 2500 lbs. The resulting performance is less than that of current boosters and is totally unacceptable for the mid-1980 period.

Further, we cannot ignore the fact that northerly high inclination Shuttle launches ascending over the Soviet Union, even with prior notification, will be disconcerting and perhaps objectionable to the Soviets. No matter how sophisticated the Soviet radars, the similarity of such northerly Shuttle launches to potential U.S. ICBM launches can lead to adverse Soviet reactions, if done routinely. Under worst case conditions, such as Shuttle breakup during ascent, a severe Soviet response cannot be discounted. Finally, the northerly launch from KSC to polar orbits entails possible casualty expectations (significant risk to life and property) over the U.S. and Canada greater than now considered acceptable.

DoD interest in the Shuttle centers around the new capabilities offered which can lead to more effective military space operations. We believe that our VAFB launched payloads are of highest national priority and are most likely to benefit from these new capabilities. DoD utilization of the Shuttle's most attractive capabilities will be denied if the VAFB Shuttle launch capability is not provided.

Attached are more detailed comments. Data presented in these comments are consistent with that provided previously to your examiners.

Sincerely,

WILLIAM J. PERRY.

Attachment.

Page i, line 5. In April 1972, NASA selected KSC and VAFB as Space Shuttle launch and landing sites. DoD concurred in this site selection and agreed to provide the general purpose Space Shuttle facilities for all users at VAFB. No reference was made to the total number of orbiters, nor to any specific number of orbiters at KSC or VAFB.

Page i, line 19. The President has very recently determined that the production of four orbiters and two launch sites should be authorized now. Additional orbiters will be considered only as needed.

Page ii, line 3, and elsewhere in the report. VAFB is scheduled to be operational in June 1983 consistent with a 6 month delay in delivery of orbiter 103 for VAFB activation.

Page ii, line 4. Approximately \$60M has been incurred.

Page ii, line 19. Launch azimuths of 13° can overcome the first two constraints (sonic boom, and solid rocket splashdown); but overflight of heavily populated

U.S. areas during Shuttle ascent to orbit poses severe problems. Casualty expectations would be greater than is acceptable today over the continental United States. However, the principal arguments against use of KSC for high inclination launches are Shuttle performance degradation to an unacceptable level, and launch over the Soviet Union. Nevertheless, land overflight risks cannot be ignored.

Page iii, line 17. Responsible DoD range safety officials have not indicated that high inclination launches from KSC would be acceptable for routine operations. The individual charged with this determination has specifically refuted the acceptability of this approach.

Page iii, line 21. As stated in the basic letter, DoD requires the full capability attainable by using the Shuttle from VAFB for polar launches. The payloads involved exist and are of high priority. They are not prospective in nature. Additionally, while DoD is a strong proponent of having a Shuttle launch and landing facility at VAFB, the civil community should also benefit greatly.

Page vi, line 23. DoD disagrees with the conclusion that one launch site can meet all foreseeable needs.

Page 1. As noted earlier, the 1972 DoD/NASA agreement is stated inaccurately.

Page 14. The need for a Shuttle launch facility at VAFB is a national need. While DoD will certainly benefit from a Shuttle capability at VAFB which will permit full exploitation of the Shuttle's new capabilities, DoD is not the only beneficiary. DoD has no desire to have its own "ballpark," and this GAO statement indicates a lack of understanding of the importance of polar orbits to civil users.

Page 14, line 4. DoD operation of an STS site is not incongruous with the nation's emphasis on international cooperation and open, peaceful uses of space. The military use of space is provided for in the Space Act of 1958, and is consistent with existing treaties and agreements. DoD space systems support our military forces worldwide. Our space systems are basically information systems and we have no plans to put weapons in orbit. Providing total DoD support with the Shuttle from KSC is no less incongruous than providing the same support from VAFB.

Page 14, line 27. Degradation of Shuttle payload delivery capability is a primary DoD concern regarding KSC launches to polar orbit as noted in the basic letter. These degradations in Shuttle performance result from the need to minimize sonic boom on launch to an acceptable level over populated areas, and the desire to drop the solid motors in relatively deep water so that they can be reused. Even neglecting the sonic boom and motor recovery considerations, the range safety problems associated with polar launches from KSC are formidable. Shuttle trajectories north over the U.S. would result in casualty expectations above those currently considered acceptable for space launches. The concern cannot be dismissed lightly. DoD believes that such risks to the U.S. civil population are probably unacceptable.

Figure 2, Note C. DoD does not concur that, based on objective considerations, the present constraints on KSC northerly launches appear unwarranted.

Figure 2, Note D. The dogleg maneuver does significantly affect performance.

Page 16, line 10. DoD does not support the casualty expectation figures provided in the GAO report. The apparent source of these values was an analysis performed in 1969. The data has not been updated since.

Page 18, line 1. The views of range safety officials are taken out of context. The case postulated is hypothetical. The best judgment of range safety officials today is that northerly Shuttle launches over the continental U.S. pose high risks and should not be accepted as a basis for routine launch operations which support our military and civil space activities for the foreseeable future.

Figure 3, after Page 19. This figure does not accurately reflect the current baseline VAFB facilities.

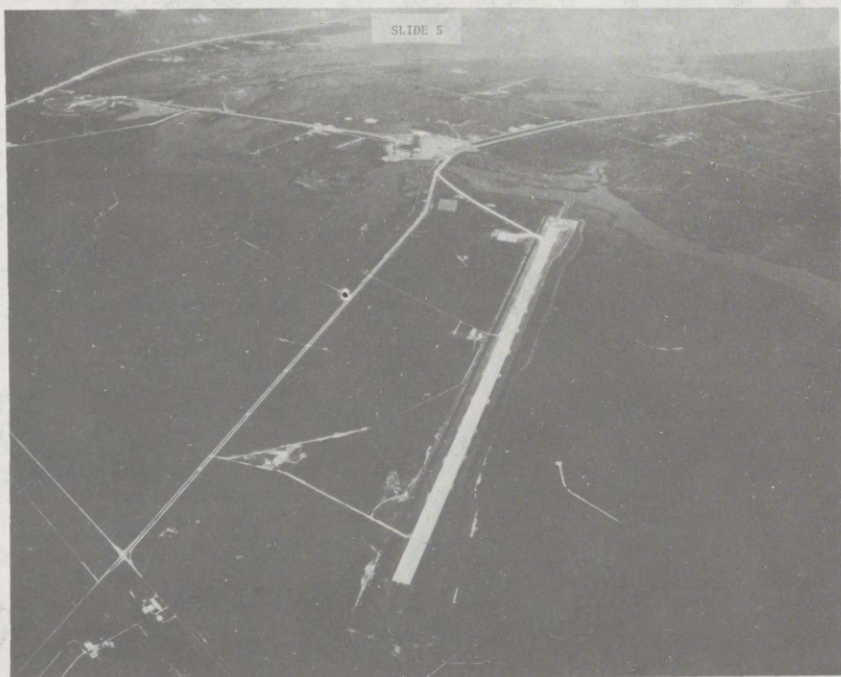
Page 20, line 2. As noted in the basic letter, the Shuttle launched from KSC can deliver only about 22,000 lbs to a 98° inclination, 150 nmi orbit. We are aware that it may be possible to increase Shuttle performance above this standard figure by several hundred pounds on certain flights without significant risk by off-loading some items from the Shuttle flight manifest. Also by configuring the Shuttle to deliver but not retrieve a given payload, performance might be

increased to perhaps 25,000 lbs. However, from these Shuttle performance figures we must deduct the weight of a cradle to properly support our payload in the Shuttle—about 2500 lbs. Further, some orbiters may be overweight and deliver 1500 to 2500 lbs less payload than the standard configuration. The resulting performance is less than TITAN IIID can deliver today and is an unacceptable payload delivery capability for the mid-1980s.

Page 20, line 14. While a number of DoD spacecraft launched now on Scout and Atlas F boosters from VAFB are in the 2,000 lbs or lighter weight category, our major, highest priority spacecraft fully use the 24,300 lb delivery capability of TITAN IIID. A Shuttle launched northerly at KSC would not be able to deliver these heavy payloads to the desired orbit. Planned growth in payload capability over the next decade will require the full Shuttle capability from VAFB (32,000 lbs).

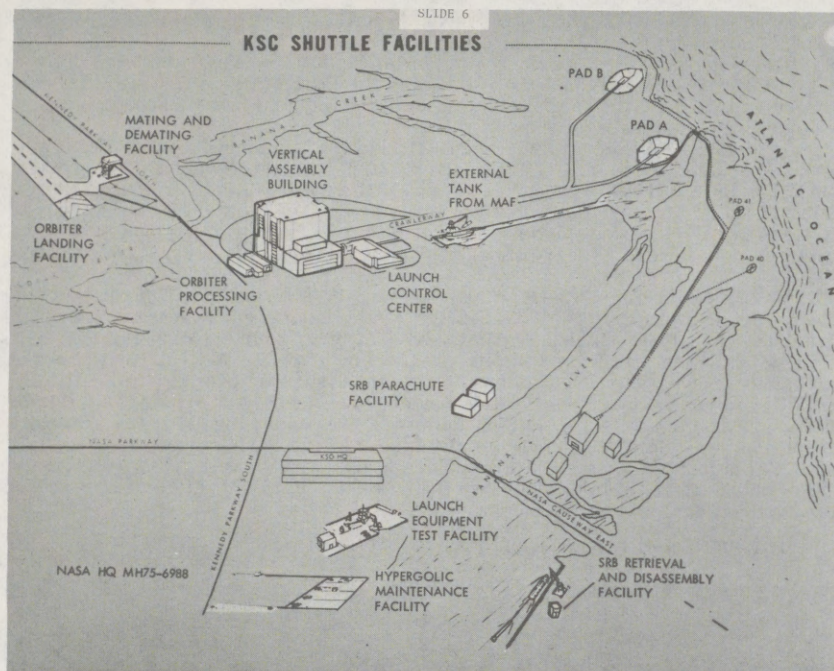
Page 22, "Other Considerations." By denying the military image of the Shuttle, the report inappropriately dismisses the State Department concerns over polar launches from KSC which have extensive overflight over not only the U.S. and Canada, but the USSR and China on the initial orbit. We believe there are plausible reasons why such extensive routine first orbit overflights of the central USSR could trigger undesirable Soviet reactions. Soviet reactions would not necessarily be mitigated by notification procedures under the "Measures Treaty." Such northerly Shuttle launches might appear to the Soviets deceptively similar to ICBM launching. Also, there are accidents that, while very unlikely (e.g., break-up of the External Tank), could confuse Soviet radars and in a worst case, increase the risk of a severe Soviet response.

Dr. PERRY. Let me have the next chart.



This is the Kennedy facility. A good many of our payloads will be launched from Kennedy, as well.

SLIDE 6



And this represents the major Shuttle facilities at Kennedy. NASA, as you know, is providing for the facilities at Kennedy.

DOD is supplying facilities at Vandenberg. But each of us is going to use the other's facility. As you saw from our previous mission model, we will be making extensive use of Kennedy, as well as Vandenberg. We have looked at the possibility of launching our polar orbit satellites from Kennedy, and that is an unacceptable alternative, as far as we are concerned.

It poses unacceptable range safety considerations, safety to the population of the people over whom the Shuttle would have to fly. It requires a loss in performance which is unacceptable for some of the very crucial defense satellites.

Finally, we are concerned about the appearance of a polar launch from Kennedy, as it would be seen from the Soviet Union.

This, seems to me to be a provocation which we would not idly enter into.

Senator STEVENSON. Would you explain—

Senator SCHMITT. You might explain that in more detail. I am not sure the chairman is familiar with the contrast between launching of—

Dr. PERRY. The Soviet Union has a BMEWS, just as we have a BMEWS system that is looking for missile launches coming from the United States to the Soviet Union.

Polar launch from Kennedy would have approximately that appearance.

Now, a refined BMEWS system with a first-class computer could distinguish between them.

[Deleted.] In any event, we think it is a provocation which we would not enter into lightly.

Senator STEVENSON. Doesn't it exist at Vandenberg?

Dr. PERRY. No, it does not.

Senator SCHMITT. With Vandenberg you have achieved orbit before you actually cross the Soviet territory?

Dr. PERRY. That's right.

Senator SCHMITT. So they know it's been launched, and that it's in orbit. We check it out, then it becomes a satellite for whatever purposes it's been launched?

Dr. PERRY. I don't want to make too much of that point.

The other points, namely, loss of performance and danger to the people of the United States and Canada are significant enough considerations.

Senator STEVENSON. How do you lose performance?

Dr. PERRY. In order to fly the 98 degree inclination which we need, we would have to fly a dogleg from Kennedy. We would fly northeasterly from the Cape, until we had dropped off the solid rocket boosters. Then, we would have to make a left turn, so to speak. That is a very inefficient orbit.

The consequences are translated into a reduction of weight which we can deliver to orbit. It is a very significant reduction.

For some of our satellites, it simply means you would carry fewer satellites. That is, you would put fewer satellites into orbit in a multi-satellite mission.

But for some of the large Defense Department satellites, our satellite is too big to even be launched that way, and we would have to enter into a program of modifying our payloads, in order to get the weight down.

Senator STEVENSON. Is it true it cuts the payload by more than half?

Dr. PERRY. In terms of our payloads, let me answer that question two different ways. There is a reduction in gross weight that you can put into orbit. The figure which we are working from is the amount of the weight that will go into a low orbit, which is a consideration on these polar satellites.

The reduction there is from 32,000 to 26,000 pounds or lower.

There is a different figure for a different orbit. So I can't answer your question, precisely.

For the cases of interest to us, it is about a 10,000-pound reduction in payload.

Senator STEVENSON. Was GAO aware of those considerations?

Dr. PERRY. We have reported that to them in our response to their report. I might say, on that point, Senator Stevenson, that there are obviously two different actions you could take to accommodate that. You could take actions within the Shuttle program itself to try to improve its weight-carrying capability by reducing some of the features of the Shuttle system.

The other thing you could do is modify our payloads so that they are not so heavy. So both of those things could be done.

It is not an impossible situation. It is just a situation which we think is undesirable.

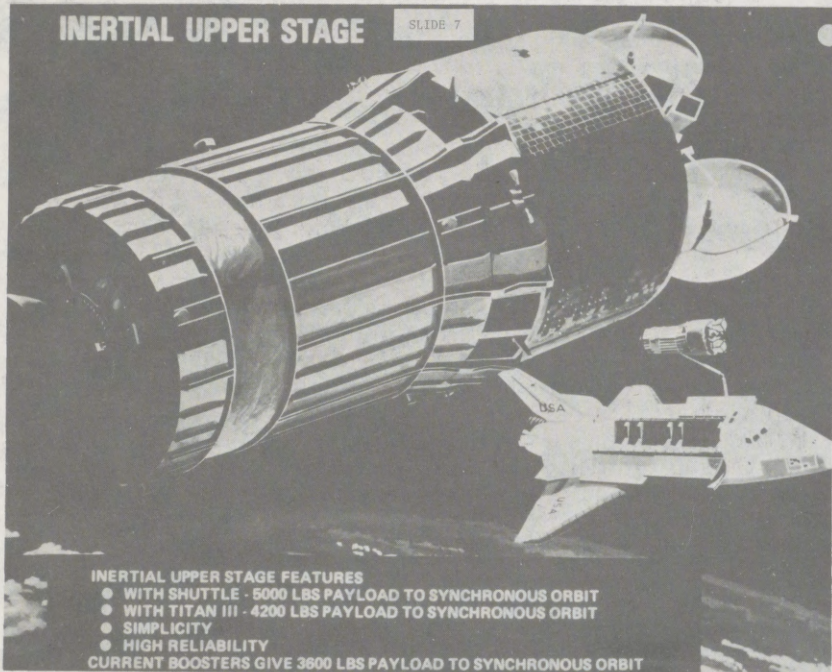
Senator SCHMITT. In an extreme national emergency, would the Defense Department be in a position to use KSC for these kind of launches? And I am thinking of essentially the ultimate extremity—

Dr. PERRY. I believe so.

Senator SCHMITT. So it would still be an option, but only where it was an absolute necessity—

Dr. PERRY. That's correct.

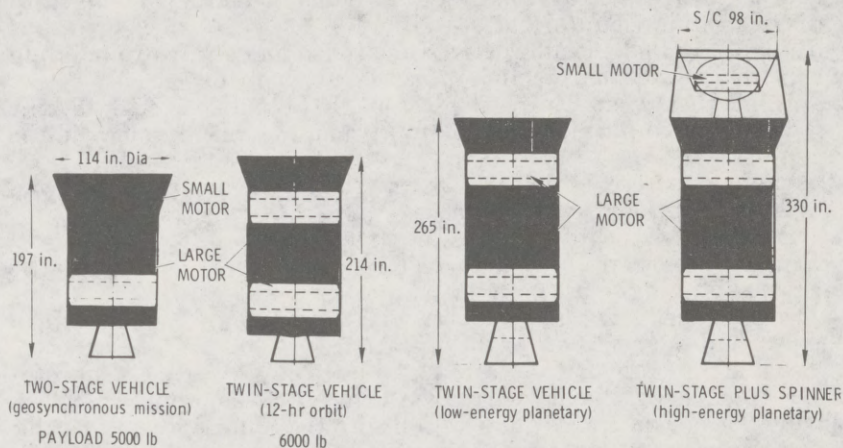
Would you put the next chart on?



This is a picture of the inertial upper stage which we are building. In our request for funding in the DOD budget, which is about \$400 million for 1979, \$124 million is for the fiscal year 1979 development of the inertial upper stage.

As I mentioned to you, this is going to be used both for Defense Department and for nondefense satellites.

Current IUS Vehicle Family



Also it can be used both on Shuttle and on Titan III. This represents a family of configurations which can be made with the inertial upper stage, depending on the orbit to which the satellite is being injected.

Basically, the interim upper stage is —

Senator SCHMITT. Dr. Perry, I think you intended to use the new terminology, "inertial upper stage."

Dr. PERRY. Yes, I did. Unreconstructed, Senator Schmitt. I have a hard time getting rid of the old term.

Senator SCHMITT. We certainly wouldn't want anybody to think we might build a follow-on.

Dr. PERRY. That's right. This is the inertial upper stage. The inertial upper stage is carried in the payload bay of the Shuttle, and is released when it gets up to orbit. Then depending on where the satellite is going, you use one of these four different configurations, depending on whether you are going on a geosynchronous mission, 12-hour orbit, low energy, or high energy planetary mission.

This system then provides the energy and control system for carrying the satellite to its final destination.

We have had some discussions with NASA in the past year about the appropriate use of the Johnson Mission Control Center. The problem there being that Johnson is used for unclassified missions, and some of our missions are going to be classified.

We have worked out a combination with NASA on what we call controlled mode of operation, which will permit us to conduct our classified operation with minimum interference with the unclassified work going on there.

It is going to require some modification of the facility. We have an amount, I believe about \$10 million in the fiscal year 1979 budget, to get that modification started.

I might say that the alternatives we are looking at involve building an entirely new control facility which is extremely expensive.

I think that what has resulted from the discussions with NASA is a creative effort which is going to save quite a bit of money in the program.

Senator SCHMITT. Is that in any way tied to the use of the two control floors that they have at Johnson?

Dr. PERRY. Let me refer that to Dr. Greenberg.

Senator SCHMITT. I frankly don't remember whether the Shuttle operation is going to use both floors, both centers.

Dr. GREENBERG. It really involves all the buildings. It is more than just one building, one part of the operation.

Senator SCHMITT. Right.

Dr. GREENBERG. We have arranged with NASA an approach where during the various stages of operation with the Shuttle we will be able to do our work in a secure environment, then move out—

Senator SCHMITT. But you wouldn't have one of the Mission Control Facilities designed specifically for secure operations? Maybe Bill Schneider knows.

Mr. SCHNEIDER. During the OFT, we will use the single Mission Control Facility, as we have at Apollo. Later on, when we get operational, we are planning on reducing our basic control center down to a smaller unit.

We will have multiple smaller units, because our basic requirement is to have more than one orbiter in flight at a time.

We will use all of building 30. In the operational facility it will look differently.

At present we are not planning on having a special mode.

Senator SCHMITT. You would not segregate then?

Mr. SCHNEIDER. That's correct.

Senator SCHMITT. It would be a mixed operation.

Thank you.

Dr. PERRY. Let me conclude my discussion on the Shuttle system by just summarizing the funding with the Shuttle program.

DOD SPACE SHUTTLE UTILIZATION

APPROVED PROGRAM (THEN YEAR \$ MILLIONS)

	<u>PRIOR YEARS</u>	<u>FY 78</u>	<u>FY 79</u>	<u>TOTAL THRU FY 83</u>
INERTIAL UPPER STAGE				
3600	30.6	67.5	87.6	260
3020	0	1.0	28.9	41
3300	0	0	8.3	8
SUBTOTAL	30.6	68.5	124.8	309
VANDENBERG				
3600	31.2	24.3	39.9	338
3020	0	17.2	60.4	269
3080	0	8.2	15.2	44
3300	0	0	136.8	226
SUBTOTAL	31.2	49.7	252.3	877
OPERATIONS CAPABILITY DEVELOPMENT				
3600	45.0	32.5	42.0	318
3020	0	0	2.4	36
3080	0	0	1.9	2
3300	0	0	0.5	1
SUBTOTAL	45.0	32.5	46.8	357
TOTAL PROGRAM				
3600	106.8	124.3	169.5	916
3020	0	18.2	91.7	346
3080	0	8.2	17.1	46
3300	0	0	145.6	235
TOTAL	106.8	150.7	423.9	1,543

If you go to the lower right corner, you get the bottom line which is the DOD investment in the Shuttle program which will be \$1.5 billion by the time we have completed all of our efforts. And the breakout of that is about \$309 million on the inertial upper stage, \$877 million for the Vandenberg facility, \$357 million for the development of operations leading to the total amount, which you see here.

Of that \$1.5 billion, we are requesting \$424 million in fiscal year 1979.

Senator STEVENSON. Dr. Perry, could we also have that chart for our records?

Dr. PERRY. Yes, you could.

Senator STEVENSON. Thank you.

Senator SCHMITT. Doctor, you mentioned a number of launches through 1991.

Dr. PERRY. That's correct. Our mission model goes through 1991. I would characterize the model, Senator, as conservative, because we only put on the model programs which we could foresee between now and 1991. But there is no doubt we will think up other programs.

Senator SCHMITT. That model now contains 109 missions utilizing the Shuttle; is that correct?

Dr. PERRY. Correct.

Senator SCHMITT. This total does not include the operational cost of those launches and operation of those 109 vehicles in space; is that correct?

Dr. PERRY. It does not.

Senator SCHMITT. This is sort of an R. & D.—

Dr. PERRY. This is startup cost and investment.

Senator SCHMITT. Startup. Thank you.

Dr. PERRY. As a part of our cooperation with NASA we are working out how the costs of these programs would be shared between DOD and NASA.

I think we have worked out a creative approach to that problem. As far as investment is concerned, this chart shows the Department's contribution in terms of investment in the Shuttle program. Most investment you see here will be an investment that will be used and shared by the civil as well as the military users of the Shuttle.

In the ongoing costs, the operation, service and maintenance cost, associated with the launches, we will pay NASA on a cost-incurred basis for those activities.

We will use the Kennedy Center without any charge, and civil users will use Vandenberg without any transfer of funds.

Now, I was preparing to go from the Shuttle to discuss some of our other space systems.

Senator SCHMITT. Excuse me, Doctor, is that an indefinite arrangement? Are there any constraints on the total number of launches at one or the other, where you would start to go into some kind of a fee arrangement?

Dr. PERRY. There is no constraint that I am aware of.

Senator SCHMITT. And there was no discussion or debate over that point?

Dr. PERRY. Well, there was debate, yes. We had quite a long discussion, working out this arrangement. We arrived at an agreement which I think both DOD and NASA are happy with; and which will involve a minimum amount of bookkeeping and transferring of funds.

Senator SCHMITT. I am anticipating what some Appropriations Committee members may ask in the future.

Are you going to be able to document fairly well for the Appropriations Committee at least the approximate cost to each agency of doing the other agency's business?

Dr. PERRY. Yes, we can. And I think if one scrutinizes our figures from a point of view of percentage of cost versus percentage of use of the Shuttle, that they will stand up well.

Senator SCHMITT. I just would encourage you to be ready to answer that kind of question. I know one or two of my colleagues that will almost certainly ask it, so I would just alert you to be able to answer it, because I would like to know the answer also.

Dr. PERRY. All right. Would you like us to send you some figures for that for the record?

Senator SCHMITT. Well, if you have that information now.

Dr. PERRY. Yes, we do.

Senator SCHMITT. A projection, obviously.

Dr. PERRY. Yes, we have that information, both in terms of history of cost to date and projection of what they are going to be.

Senator SCHMITT. Presumably, that would include the breakdown of the NASA-DOD launches to two facilities; is that correct?

Dr. PERRY. That's correct.

[The information follows:]

The costs which will be incurred by the DOD for Shuttle operations at Vandenberg Air Force Base (VAFB) are estimated at \$1,046 million (FY 1975 dollars) through early 1992. The national Shuttle traffic model (487 flights) forecasts 129 launches at VAFB during this same period. Of this amount, 84 flights are non-DOD launches for which the DOD will incur the launch operations costs as part of our cost per flight agreement with NASA. The cost to DOD for these 84 flights is estimated at approximately \$680 million in FY 1975 dollars.

The costs which will be incurred by NASA for Shuttle operations at the Kennedy Space Center (KSC) and Johnson Space Center (JSC) are estimated at \$3,649 million (FY 1975 dollars) through early 1992. The national Shuttle traffic model forecasts 358 launches at KSC and all 487 flights controlled from JSC during the same period. NASA will incur the operations costs for the 69 DOD launches at KSC and 114 DOD flights controlled at JSC. These costs are estimated at approximately \$763 million.

According to the above estimates, NASA will incur \$763 million due to DOD Shuttle launches, and DOD will incur \$680 million due to operations support provided to NASA civil and foreign Shuttle launches. We have, therefore, agreed with NASA that the estimates for operations costs for each agency are essentially equivalent and, therefore, no funds transfer for this purpose is considered necessary.

Are there any other questions on the Shuttle, before we proceed into our other space programs?

Senator STEVENSON. There are many more questions on the Shuttle. I think in fairness to you, we better let you finish. We will keep interrupting, but then we will come back to questions on everything that you have said.

Dr. PERRY. I have left out the major part of this because of your interest in the Shuttle program.

Let me quickly describe some of the other programs. NAVSTAR, so-called Global System, is an extremely significant Defense program. It is the follow-on to the TRANSIT program. It is going to provide a unique position-locating ability, which will enable military and ultimately nonmilitary users to be able to locate themselves on the

Earth with remarkably fine accuracy, on the order of about [delete] or so.

This program will complete its validation phase in 1978, and in 1979 we expect to be able to make a decision to deploy the NAVSTAR system.

A second program of interest is the FLTSATCOM, Fleet Satellite Communications System. This is a communications satellite directed primarily at Navy communications, as its name implies.

We had, just a few weeks ago, a successful launch of the FLTSATCOM. I am happy to report that the launch was successful and the system is operating according to all specifications at this time.

A third program is the DSCS, Defense Satellite Communications System, and the demonstration satellite on DSCS III will be launched in the latter half of 1979.

I want to take a minute to give you a comparison between DSCS III and FLTSATCOM.

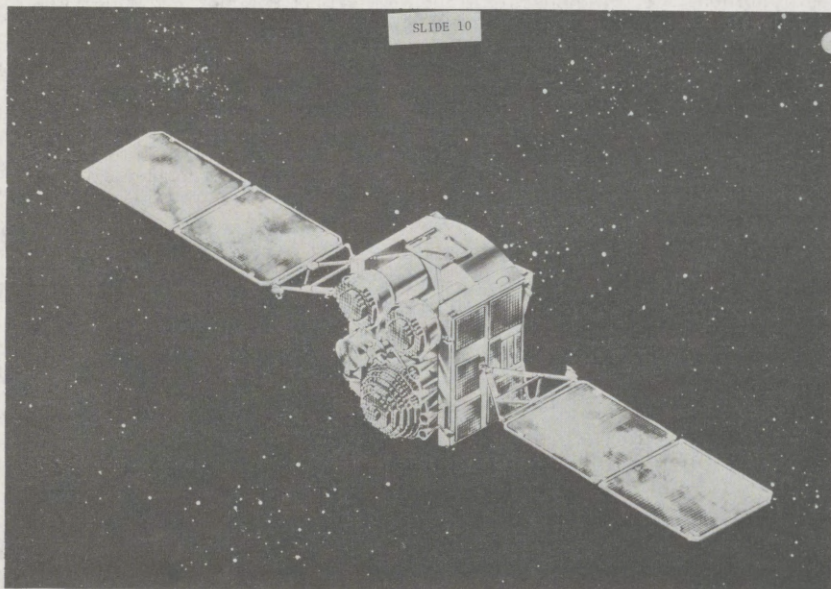
Both are military communications satellite systems, but they have quite different applications.

The DSCS III is intended to be used mostly with fixed terminals. It is a high-capacity, wideband system, and it requires large ground terminals and requires antennas that point to the satellite in space.

So the ground terminals are large, complex, and relatively expensive, but it carries very wideband widths. [Deleted] times the band width of the FLTSATCOM.

FLTSATCOM, by giving up band width, is able to come down to a much simpler system on the ground. Here we envision it being used with terminals on ships, on airplanes, and vehicles with antennas that do not require precise pointing at the satellite in space.

Do you have any satellite pictures that we can cover here, as we describe these programs?



This is an artist's concept of the DSCS III satellite.

FIGURE/CHART DELETED DUE TO SECURITY

This is a picture of the [deleted]. It is a satellite that is used to [deleted]. The program is presently operational, [deleted].

Now, I would like to pivot from these space programs to talk very briefly about our antisatellite effort.

As you are undoubtedly aware, the Soviet Union has an antisatellite program which has been underway for about 10 years now. It resulted in, if my memory's right, [deleted] launches in the past year. I should not use [deleted], since that could be misunderstood. [Deleted] is a better way of describing them.

We have under development an antisatellite system [deleted].

That is an issue which will be determined at a later date.

I think it might be interesting [deleted].

They have a capability which is, I would say, [deleted] today.

They have a system [deleted]. It does [deleted].

It raises a question of [deleted].

There are [deleted].

We have really two generically different options which we might pursue to respond to the program the Soviets have embarked on.

The first option [deleted] is developing an ASAT of our own so we would be capable of responding in kind, if the Soviets were to initiate an ASAT action. The second alternative is developing improved survivability of our own satellites so that we could take countermeasures to protect our own satellites if they were attacked by an ASAT.

We have R. & D. going on in both of those areas. The R. & D. for the protection of our own satellites is [deleted].

In other words, [deleted]. We have [deleted].

What we plan to do is [deleted].

That was all I planned to say on the ASAT, by the way, unless you had questions on it.

Senator STEVENSON. How far along are [deleted], and when might they be operational?

Dr. PERRY. [Deleted.]

So it is a mixed bag, Senator Stevenson. [Deleted.]

Senator STEVENSON. While we are on the subject, could you comment about the charged particle beam possibilities [deleted]? Charged particle beam being the laser——

Dr. PERRY. [Deleted.]

Senator STEVENSON. Yes.

Dr. PERRY. Yes, I could. You are referring to the statements made by General Keagan?

Senator STEVENSON. Well, yes, and others [deleted].

Dr. PERRY. [Deleted.]

Bob, would you like to comment further on that?

Dr. GREENBERG. The only thing I want to make sure of is that people don't get high energy lasers confused with charged particle beams. Those are quite different systems. Laser technology is much more feasible, currently, than is the charged particle beam technology.

Senator STEVENSON. The ground-based laser technology?

Dr. PERRY. Yes, sir. [Deleted.]

Senator STEVENSON. Do the Soviets, are they developing [deleted]?

Dr. PERRY. They are—

Senator STEVENSON. I don't mean [deleted] I guess.

Dr. PERRY. They have [deleted].

Senator STEVENSON. I meant to say [deleted].

Dr. PERRY. We would credit them with having [deleted].

Senator STEVENSON. [Deleted.]

Dr. PERRY. [Deleted.]

Senator STEVENSON. Are countermeasures possible against [deleted]?

Dr. PERRY. Yes, there are. A part of our [deleted].

Senator STEVENSON. Well, then, the last part, what can you tell us about their ability to [delete]?

Dr. PERRY. I consider that to be part [deleted].

In the early years, [deleted].

Again, part of our [deleted].

There are two ways of attacking that.

We can [deleted].

Senator STEVENSON. [Deleted.]

Dr. PERRY. [Deleted.]

Senator STEVENSON. But are we researching and developing?

Dr. PERRY. Yes, sir. We have research in this field.

Senator STEVENSON. [Deleted.]

Dr. PERRY. [Deleted.]

Senator STEVENSON. How long would it take?

Dr. PERRY. I don't know. There, again, the answer would be that it would depend on a system-by-system basis, depending on which system we wanted to go after. Some would be easier than others.

Senator SCHMITT. [Deleted.]

Dr. PERRY. That's correct.

Senator SCHMITT. That is, provided you can [deleted] against the satellite.

Dr. PERRY. [Deleted.]

Senator SCHMITT. [Deleted.] We know that there have been some tests [deleted].

Dr. PERRY. [Deleted.]

Senator SCHMITT. Dr. Perry, a variety of [deleted] information indicates that there has been, over the last few years, a rapid increase in at least the [deleted] devoted to what we think [deleted] R. & D. in the Soviet Union being conducted [deleted]. And I guess, also, we know for the most part that that is actually what is going on.

Does your confidence in [deleted] account the statistical probability of what is going on [deleted]?

Dr. PERRY. I have to say, Senator Schmitt, that I have developed a view of the Soviet R. & D. capability through the years, and there is a high degree of subjectivity in that view. I certainly cannot prove all of the opinions I have about it.

So, when I try to assess what they can do in a case like this, I not only try to take account of the [deleted] on this particular program, but also what I think their overall capabilities are.

A net assessment that I will give you, then, is [deleted].

The negative side is that whenever they have settled on a particular area and are willing to push all of their energies behind it, they can make very impressive progress. And, so, if they have selected this as a high-priority field and are pushing a lot of resources behind it, they may, indeed, have a program [deleted].

I don't think that is a high risk myself. Part of the reason I don't think it is a high risk, is that [deleted].

Unless they have an extremely unbalanced program, then I am not too much concerned, [deleted].

This is only because we have [deleted].

Senator SCHMITT. Dr. Perry, I guess I sort of have the same basic subjectivity, with one modification. I have great respect for the ability of the Soviet mind to work in theoretical areas and to solve theoretical problems.

I think you and I share the feeling that their ability to turn a solution of a theoretical problem into practical hardware, practical capability, is limited, where we sort of have that capability, should we choose to exercise it.

Too often, we don't choose to exercise it.

I guess what is concerning me, is that our so-called strategic triad, as well as, to an increasing degree, our tactical capability, is getting more and more dependent on our space capability in a wide variety of ways.

Even though we may [deleted].

That is what I think is of greatest concern to me.

Now, do you share that concern, and do you feel that the administration shares that concern?

Dr. PERRY. I share that concern.

Senator SCHMITT. Excuse me. Let me just add, we are coming into a very, very critical time, I believe, in terms of our national security. A time when, because of past neglect, or past decisions, at any rate, or nondecisions, we have a period of time where there is an uncertainty, a great uncertainty in our own minds, as well as the rest of the world's, in the relative strategic strength and tactical strength of the Soviet Union and the United States.

And in that period of time, and with the deterioration of events, I think, elsewhere in the world, and the increased perception that maybe the United States is impotent in foreign policy, such as in Africa, the probability of being tested, is increasing, and the pressures that we may be subjected to, even though it is short of outright hostilities, are going to be increasing.

Now, I will go back and let you answer the question I asked you.

Do you share the concern, and do you feel that the Administration shares it sufficiently [deleted].

Dr. PERRY. Yes, I do share that concern. It is a concern which I have discussed with the Secretary of Defense, and I know he shares that, as well.

So the question is what are we doing to manifest our concern? What is our programmatic response to this concern?

I would summarize that as follows:

[Deleted.]

We are also moving in our R. & D. program [deleted].

It doesn't take us anywhere, except to do that one thing.

Senator SCHMITT. Well, Dr. Perry, it is, of course, a matter of judgment. But my concern is that we are [deleted].

If we [deleted].

That is what concerns me. Sometimes your investment, I think, has to be based on that kind of analysis. But it is encouraging that you feel that, should we have to move rapidly, we could. [Deleted.]

I am not sure we will be given [deleted]. That is what concerns me.

Dr. PERRY. I would call your attention to the period in our history when the Sputnik was first launched, and it was decided, as a matter of high national priority, to launch the Explorer Satellite.

My recollection is that that went up in about 4 months from the date of the go-ahead. That illustrates two factors. First of all, there had been an amazing amount of anticipatory work on that in the R. & D. phase and, second, that given direction and high national priority, we are capable of very impressive technological achievements.

I think that is our situation now, [deleted].

But I will give you some assurance that if the situation arose where we would need it, we could get to it very, very quickly.

Senator SCHMITT. Don't get me wrong. I am thinking mainly of [deleted] because our dependency is on our satellites, not on theirs or the existence of theirs as near as I can analyze the situation. That is why I think your [deleted] emphasis is entirely appropriate, and that is the one I would certainly like to see moved very, very rapidly.

Dr. PERRY. I would say that I believe that our emphasis [deleted].

Senator SCHMITT. Just as a small technical issue, will you be testing [deleted] in the Tressel Facility in New Mexico? I know that it is designed for the [deleted] testing. For example, the B-1 aircraft No. 4 will be tested there.

Dr. PERRY. I don't know the answer to that, but I will look it up and get you an answer.

Senator SCHMITT. Would you? If it has not been considered, it may be just a short circuit within the DOD.

Dr. PERRY. I suspect that it's not been considered.

[The information follows:]

At the present time, there is no equivalent facility [deleted]. Tests are conducted in various subscale facilities on component parts and scaled models. Conceptual designs of a large scale facility, capable of testing completely assembled satellites, are in progress.

Senator SCHMITT. It is a tremendous new facility, primarily designed for B-1. The construction is continuing, as far as I know, and it sounds like the opportunity may be knocking also, [deleted].

Dr. PERRY. Just offhand, it sounds like a good idea, but I would guess it's not been pursued, and I will look into it.

Senator SCHMITT. Mr. Chairman, that is an amazing facility. If you ever pass through Albuquerque, I will have to show it to you. It is a six-story structure built entirely of wood and set out in an open basin, so that they can direct high-intensity electromagnetic energy at the target.

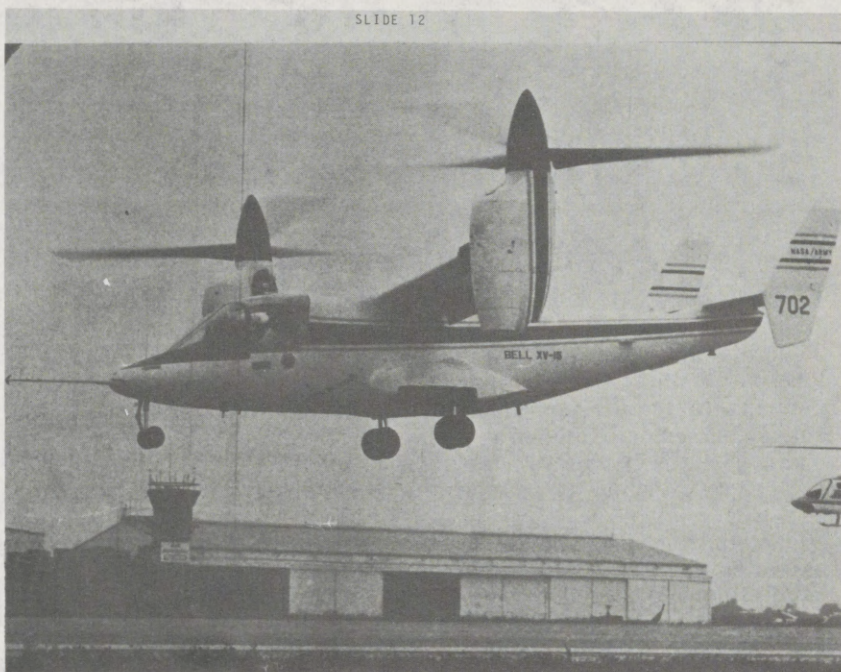
Dr. PERRY. It may be the last big wooden structure ever built in the world.

Senator SCHMITT. It could be. I am sorry, we sort of digressed here into this area. I think maybe we should proceed.

Senator STEVENSON. Have you finished your statement yet?

Dr. PERRY. I had a few more comments on the aeronautical field.

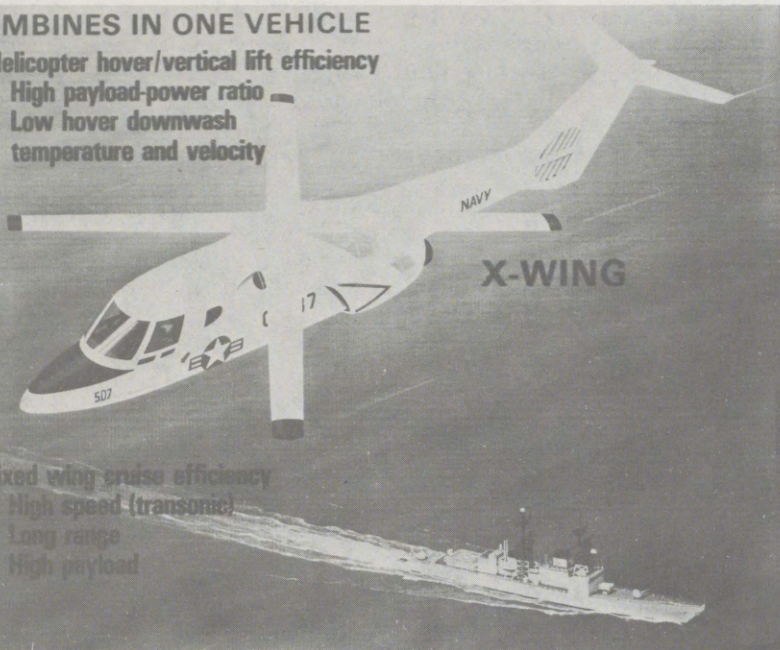
Senator STEVENSON. Please proceed.



Dr. PERRY. This is the XV-15, a joint Army-NASA program, called a Tilt Rotor Research Aircraft. If you look at the picture you can see how it got its name. At the moment it is operating as a helicopter, as you are looking at it, but the engines can be tilted so it can proceed forward to operate with somewhat the efficiency of a standard turboprop airplane. That is one of the research activities going on in the aeronautics field.

COMBINES IN ONE VEHICLE

- Helicopter hover/vertical lift efficiency
- High payload-power ratio
- Low hover downwash temperature and velocity



- Fixed wing cruise efficiency
- High speed (transonic)
- Long range
- Highwayload

There is an alternative approach to achieving somewhat the same objective; namely, an airplane which has the advantages and the performance features of an airplane in forward flight, but which can take off vertically, much as a helicopter can.

This is the X-Wing aircraft and the concept of the X-Wing is to have the rotor, which you see on top, rotate and lift the airplane from the deck.

Then, once it has achieved its altitude, the rotor becomes fixed, and the airplane proceeds forward in flight.

We think that with this vehicle, we will be able to achieve relatively high performance in an airplane that will be operating at the high subsonic speed regions, in the area of mach 0.8.

This project is closely related to another project, also going on at ARPA, which is called the forward swept wing project. Basically, for this to work as an airplane, you have to have a wing, the two front wings, as you see, swept forward. There is a great advantage to forward swept wing in terms of efficiency of flight. The reason you don't see airplanes built that way, is that there is one very important disadvantage that is known technically as [deleted] which I think means that the wings tend to fall off when you fly forward. That is considered to be a disadvantage for operational aircraft.

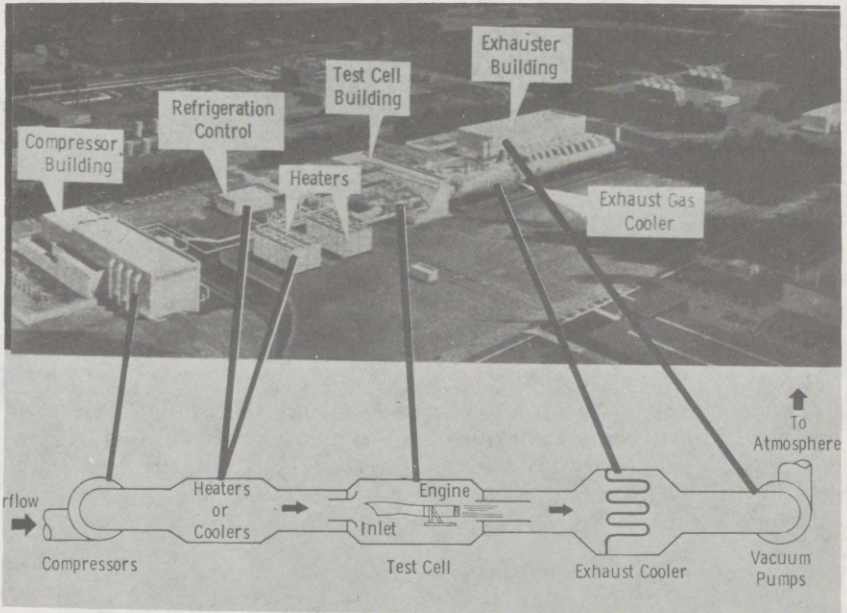
The solution to that problem is to introduce lightweight super-strong material into the wings, and the potential of doing that became clear a few years ago with the introduction of composite materials.

So one of the applications of our composite plastic structures is the forward swept wing. Once we had introduced it in the forward swept wing, it became clear that this X-Wing concept was a possibility.

So that does represent one of the more interesting and novel approaches going on in our aeronautics work today.

I wanted to conclude by very briefly mentioning the National Aeronautic Facilities Program.

This is a joint DOD-NASA facility.



Let's look at the various programs involved.

This is the Aero Propulsion Systems Test Facility, which is being built by the Air Force in Tennessee. That's already been funded. It has a total cost of \$437 million and will be operational in 1981.

It's being built by the Air Force under the Department of Defense budget, but it will be used jointly by DOD and NASA.

PERSPECTIVE - LANGLEY TRANSONIC RESEARCH TUNNEL

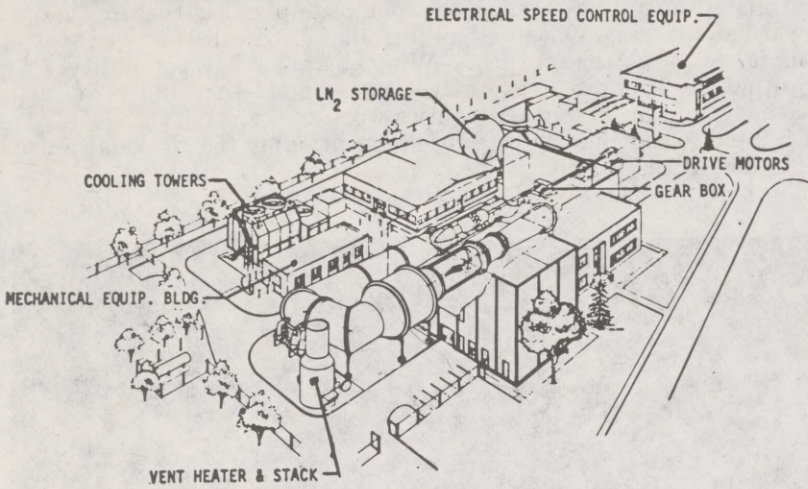


Figure 6.- Perspective drawing of the TRT showing major auxillary components and equipment.

The next chart is a picture of the National Transonic Facility at Langley. This is being built by NASA at a cost of \$85 million. Again, it will be used jointly by NASA and DOD for doing transonic research.

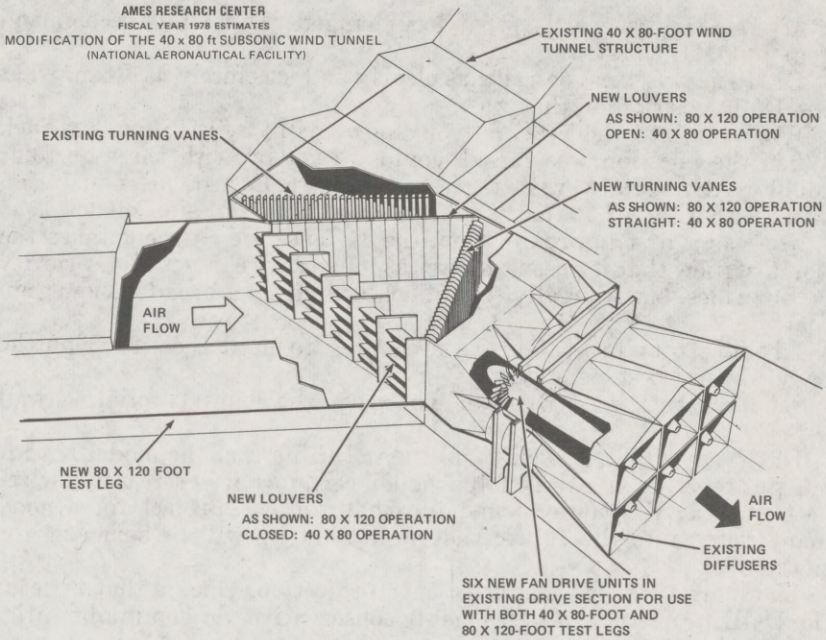


FIGURE 6 — PERSPECTIVE VIEW OF VANES, LOUVERS, AND FAN DRIVE SYSTEM

The last chart represents a modification to the subsonic large wind tunnel at NASA-Ames out at Moffett Field. This is the so-called 40 by 80 Tunnel at NASA-Ames, doing subsonic work. This will be used on research on helicopters, particularly research on the two vehicles you saw in the previous charts, the tilt rotor aircraft and the X-wing.

The NASA-Ames modification is going to cost \$85 million. That is also being funded by NASA.

I think with that, Senator Stevenson, I will conclude my prepared remarks and open the floor for whatever questions you would care to ask

Senator STEVENSON. Thank you, Dr. Perry.

The subject that concerns me most at this point, leaving aside the ASAT issue, is the orbiter.

Last year DOD and NASA made a strong case for five orbiters. And we, and our counterparts on the other side, did a very thorough, serious job of researching the question and concluded that the economies inherent in five, as opposed to four, were very substantial. Close to \$4 billion, as I recall, as a result of the saving in expendable launch vehicles. And I am told now that if we go with four, but subsequently decide on five, that the increase cost will exceed \$200 million.

In other words, we would save over \$200 million by continuing with our earlier decision for five orbiters, instead of accepting the administration's recommendation.

My question to you is, what has changed? Did DOD recommend four to OMB this year?

Dr. PERRY. Let me describe as clearly and succinctly as I can, what the DOD position on that was.

We went into the year, as you know, with a five Shuttle model. When the question was raised, could we get by with three or four, could NASA get by with three or four, we looked, in cooperation with NASA, at what that would do to our own mission model.

Now, as a first approximation, the Defense Department takes the point of view that it doesn't matter as long as we can get high priority on our rides, but we really try to look at it from a broader view than that.

I believe that ultimately we are going to need the fifth Shuttle, based on my best perspective.

Senator STEVENSON. By "we," you mean the country—civil, as well as—

Dr. PERRY. Civil, as well as military. I think that the model NASA has put together is a reasonable model, certainly it is a reasonable reflection of DOD requirements, and that you can project for a good many years into the future that four Shuttles will be sufficient for that model.

There are two problems with that projection. One, is that at least the DOD projection was reasonably conservative. So you might anticipate requirements for more flights developing.

Second, there is always the possibility of losing one of the orbiters. Those are the two issues that we have to be concerned with.

Again, from a DOD point of view, as long as we can have priority on our key missions, it would not affect our model in too fundamental a way.

My best judgment on looking at this, my recommendation on examining this question with NASA, was an approach which I call the four-plus approach. Namely, a commitment at this time to build four orbiters, with a live, viable option to build a fifth one. That means keeping the production line open.

And, finally, the understanding that when the fifth one is built, it may turn out looking different from the first four.

In other words, if we don't make the commitment, the decision to produce the fifth one, for 2 or 3 years from now, there is at least an advantage which we can gain from that. That is the advantage of gaining some experience between now and then that may, indeed, cause the design of the fifth one to come out looking somewhat different from the first four.

From my point of view, then, the crucial question is maintaining the production, keeping the production line open, not whether we start the fifth one now, or start it a year from now, or start it 2 years from now.

In any event, the funds which were projected for fiscal year 1979 were quite modest for the fifth one.

The big issue is not whether we at this time order a fifth one, as it is, whether at this time we take the necessary programmatic actions, so that the production line is kept open for a long enough period of time that the option for a fifth one is a real option.

Senator STEVENSON. Would the budget recommendation from the administration keep the production line open?

Dr. PERRY. That would depend on decisions made primarily in fiscal year 1980 and fiscal year 1981, rather than fiscal year 1979.

Actions taken by NASA, as I understand them, for fiscal year 1979 will keep that option alive. They have to be a better witness to you on that question than I am.

Senator STEVENSON. Could they keep the production line open?

Dr. PERRY. The production line will be open, in any event, in fiscal year 1979. That won't be a problem, that doesn't get to be a problem until the out years.

Senator STEVENSON. If I understand you correctly, you are saying it is not a major concern to DOD, because you assume, with some confidence, that DOD's requirements are going to have priority. If there has to be a cutback in order of operations, it is going to come out of the civil side?

Dr. PERRY. I hadn't meant to give that impression, Senator Stevenson. It is a concern to DOD. If we were to go down to a three-orbiter option, if we would lose one, I think that would put us in a position where everybody's programs would suffer.

Senator STEVENSON. If we were to go down to a three-orbiter position everybody would suffer.

Dr. PERRY. If we were to lose one of the four, which would take us down to three, I think everybody's programs would suffer.

So that is a matter of concern to us. And my question is, how should we address that concern?

I submit that there are two aspects to it.

The first one is, if we are only going to build four, initially, then I think we must keep a production line alive, so that we could go to a fifth one at the time that it is needed.

Then there is the second issue. That is—how long it would take us to get to that fifth Shuttle.

There, it is a matter of program planning and it is a matter of investing some money for long lead items, investing some money for keeping production activities alive that might not otherwise be kept alive.

Senator STEVENSON. Couldn't the design modifications you referred to be accommodated by the original five-orbiter schedule?

Dr. PERRY. I think not. I think they could be accommodated more gracefully by a somewhat stretched schedule for the fifth one, but still a schedule in which there was a definite plan for building a fifth one, and a date by which that action was going to be taken.

What I am trying to describe, Senator Stevenson, is that I think that even if five orbiters were built, the program might benefit if there were some delay between the fourth and fifth. It will cost a little more to do that, but if it is planned from the beginning, I don't think it will cost a delta of \$200 million that you were quoting, or anything like that.

Senator STEVENSON. Aren't you uncomfortable with the prospect of ultimately being dependent on four orbiters and no expendable launch vehicles?

Dr. PERRY. I am satisfied with that conclusion, at such time as the orbiter has proved itself.

Whether that's 1985 or 1986, I am not sure at this stage. But we have a good many years of experience ahead of us yet. The alternative, namely, of maintaining a Shuttle program and expendable launch vehicles, would be enormously more expensive.

And so I think one has to make a decision between those two cases.

Senator STEVENSON. What would be the consequences for DOD and your planning of the 1-year slip from June 1980 to June 1981, in the operation of the first orbiter?

Dr. PERRY. We don't have any operational satellites scheduled for the Shuttle until 1982, I believe.

Dr. GREENBERG. That's right.

Dr. PERRY. The only one we have in 1980 is an experimental program. So that would not have any significant effect on our operations.

Senator STEVENSON. Senator Schmitt.

Senator SCHMITT. Thank you, Mr. Chairman. Last year the Chairman and I put considerable pressure on DOD in these hearings to verify that there was a real requirement for the fifth orbiter.

As I recall, one of the main arguments was the need for reliability and redundancy.

That is still reflected in your comments today relative to what would happen if you suddenly found yourself down to three orbiters.

Dr. PERRY. That's correct.

Senator SCHMITT. And where the priorities would have to lie to meet the mission that you foresee for DOD.

I presume that has not changed, and that those arguments are still valid arguments.

Dr. PERRY. That's correct. I think they are still valid arguments.

Senator SCHMITT. Now, the thing that concerns me even about your statements, Dr. Perry, of the delay giving us the options to create a Mark II or an H model, or whatever we are going to call it of the Shuttle, is that in a delay as long as has been proposed, we actually accumulate costs that would fund a modified sixth orbiter. That is what I think the committee's having trouble with—the economic rationale of holding open the option not to buy the fifth one at a cost, when you decide to buy it, that is greater than having six of them.

So I don't know whether you want to comment on that or not.

Let me just add, there is also the fact that according to the plan, as I understand it, of when the option would be exercised for the fifth orbiter, we really won't have a great deal of operational experience on the Shuttle, by which we might make the decisions to build a Mark II Shuttlecraft.

Maybe you would like to comment on that also.

Dr. PERRY. I guess all I can say about that, Senator Schmitt, is that the longer we delay the decision on the fifth one, the more desirable it is, from a point of view of incorporating changes, based on our experience on flights.

It is quite true, the longer we delay, the more costly it is going to be.

That is just a tradeoff. I couldn't really make a more precise comment on it than that.

Senator SCHMITT. Well, my experience was that when we had the fire at the Cape in the Block I Apollo Spacecraft, we suddenly were ready to build a Block II, for good reason.

Because of the urgency of the program, the feeling of national commitment, we had put off making changes that we had learned we wanted to make, just in the process of building Block I. And we were already in the process of designing a Block II Apollo. So we just implemented that, plus learned our management lessons that we should never had to learn.

Now, I would think that a much more rational policy, if we were going to follow your philosophy, would be to decide today, we are pressing on with orbiter 5, except it is going to be a Block II orbiter 5.

Dr. PERRY. I think that is a very good point.

Senator SCHMITT. Because I think we already know a great deal about what we would do, if we were not committed to stamping out orbiters in roughly carbon copies of themselves.

That might be a very good policy. It is not one that's been proposed to us, that we say, yes, we are going ahead with the fifth orbiter, except right now we are going to begin to implement the improvements we already know we would like to make to Block II.

But that, of course, is not what is being proposed. What is being proposed is that we delay the decision, at considerable cost, if we decide to implement manufacture of the fifth orbiter, as a carbon copy some time in the future.

Dr. PERRY. I think that is a very good point, Senator Schmitt. That the logical conclusion of the recommendation I made would, in fact, be a planning of Block II and getting planning for that under way now.

Indeed, that is not what has been proposed to you. So I don't think it is too late to direct the program into that——

Senator SCHMITT. Well, the chairman and myself are considering a number of options on this. It has obviously been something of great concern to us.

Dr. PERRY. I would only suggest that if, indeed, there is an interest, if there is a desire in the committee to direct a fifth orbiter, that you would at least consider the possibility of its being a Block II orbiter, rather than the fifth one in the present design.

Senator SCHMITT. I certainly won't speak for the chairman on this, but I personally am considering that, and think it is something that the subcommittee should also consider, as we consider the authorization.

Would you talk to us just a little about the status of [delete]? Its schedule, and in particular how you feel about it, and also, how it is being interfaced with the design of a civilian space policy?

Dr. PERRY. [Deleted] is being considered by the National Security Council and the President at this time. I can't really—am not really in a position to predict what might come out of that.

Senator SCHMITT. Are you involved in that?

Dr. PERRY. Yes, we are.

Senator SCHMITT. You, personally?

Dr. PERRY. I, personally, and Dr. Greenberg, personally.

Dr. Greenberg was actually chairman of one of the working groups. I can describe to you what the objectives of [deleted] were and what we are trying to accomplish with it.

Senator SCHMITT. I think the committee is already fairly familiar with that. What you are saying is that you don't know what the status is or can't give us the status?

Dr. PERRY. I know what the status is, but I don't know what the conclusions will be from the deliberations now going on.

Senator SCHMITT. When would you expect that those deliberations would be at a point where recommendations would be made to the President?

Dr. PERRY. I am expecting it soon, in a matter of weeks, rather than a matter of months. The one conclusion which has come out of it already, as you probably are aware, is [deleted].

That is the only concrete decision which has come out of the [deleted] to this date, that I am aware of.

Senator SCHMITT. Is there a corollary to that decision, that we would [deleted]?

Dr. PERRY. No; we are, in fact, proceeding with the development of an ASAT capability.

The problem, of course, is that we are in a symmetrical position right now, where the Soviets already have such a capability, and we don't. [Deleted.]

Senator SCHMITT. I understand that. But there has been a disturbing tendency on the part of this administration, once they decide the way they would like the world to be, that we then resist the temptation, if you will, to continue along a research path, hoping that that is the way the world is going to turn out.

My concern is that we might start to do the same thing here in anticipation of some kind of [deleted].

Dr. PERRY. [Deleted.]

Senator SCHMITT. Do you have the impression in the [deleted] discussions that there are any options for the civilian space program being foreclosed or potentially foreclosed by a decision there?

Dr. PERRY. That was a matter of common discussion in the various working groups. I don't have that impression, but I would like to pass that question to Dr. Greenberg and see—let him give you his personal view of that, since he spent many an hour discussing and debating this with the representatives from the civil, as well as the military.

Dr. GREENBERG. What Dr. Perry said is accurate. We did a great deal of work [deleted] trying to assess these various problems.

I think that the [deleted] groups reached, at least at the working level, amicable understandings of restrictions which might be placed on various systems and capabilities which various systems should have.

We addressed questions like [deleted].

Those were two of the primary things that we were involved in that directly related to the civil program.

Another was the use [deleted] of the Space Shuttle. I think that was highly endorsed by all parties involved in the working level in [deleted].

Finally there was a discussion of an update of the policy and mechanism for resolving issues between the [deleted] agencies involved, and we have sent forward a recommendation on that too for establishing a structure to allow prompt resolution of issues, as they arise.

Senator SCHMITT. Can you give us some details of what that structure would be?

Dr. GREENBERG. That is a decision that is still before the NSC. We made some proposals but I don't know which one the NSC is going to choose.

So I really can't tell you details.

Dr. PERRY. I don't know the status either.

As you know, we have the AACB, which is presently functioning very effectively for the coordination between NASA and DOD. But there were envisioned modifications that would take into account the dental directive [deleted].

I don't know how that is going to come out.

Senator SCHMITT. Well, this committee, again, would be very interested to have at the earliest possible time a delineation of the decisions that you have described that have been made, even though they are decisions at the working level.

I understand that the final policy decision whether to implement those, has not been made.

Dr. PERRY. Why don't we undertake to get you a short, but, hopefully, definitive description for the record of where that stands today?

The following information is provided concerning the draft Presidential directive [delete].

Senator SCHMITT. That would be super. I would really personally like to hear it. I will tell you why I am so concerned here, and it makes me a reactionary I guess to some degree, or something like that. Because in the whole time I was in the space program at least by the time I was very active in a flight program there was nothing that I needed to know or even had any inclination to know, that was classified, except for one briefing having to do with contingency, [deleted].

That happened a day or two before we launched. There was nothing in going to the Moon and returning that I needed to know, that was classified. That is just a symptom of why I think our civilian space program has been, and is, such a critically important part of our national economy. There is a very rapid and direct availability of everything in that program to the rest of the society for use, internally or externally, in terms of imports.

It is also immediately available, of course, to our defense establishment for other purposes.

Now, we have already made decisions such as integrating a launch control center. That is going to inhibit to some degree that kind of freedom of access of information and freedom of activity by people now in my kind of position, as I was in those days, or by many others.

I am concerned about whether or not we are moving slowly, but surely, into a much more highly classified space program, where the civilian side of it will begin not to feed as directly and as easily into the rest of our society.

Now, I am torn, because I think it is extremely important that the defense capability in space be utilized as much as necessary. I think they are right now underutilized.

But I hope that we don't in that process sacrifice what has been such an important part of the civilian space program.

And that is this freedom and accessibility to information in our society.

As I said the other day in the NASA hearings, development of the so-called [deleted] effort, seemingly independent—at least not in parallel track with the development of the civilian space policy, I think is a major deficiency, because you are coming along much faster than apparently is the development of a civilian space policy.

I am afraid we are going to see some options foreclosed, at least priorities may not be the priorities that we would have available to us, if they were going in a parallel path.

Would you like to try to reassure me on that?

Dr. PERRY. I would make several comments on that.

First of all, the [deleted] planning exercise did involve civilian, as well as military, participants. The purpose of it was, indeed, to evolve a civilian space policy, as well as military, to have an integrated policy.

The execution of the policy would not be necessarily integrated.

Senator SCHMITT. Yes, but this committee was told the other day that the actual civilian space policy is not going to be available for many, many months. Am I correct in what we were told, OSTP?

Frank Press told us that that was coming along much later. I don't—I detect an incompatibility between the two.

Dr. PERRY. Well, there are specific points in which there are overlap and potential conflicts between the two. [Deleted.]

That was precisely the objective, to maintain in the civil program the same sort of freedom to data that you had.

We simply believe that with prior planning of these programs and with coordination between the military and civilian sides ahead of time that freedom of control of the program and freedom of data dissemination can be maintained. It is only necessary to get the preliminary coordination on it. Those were the kinds of issues that were being addressed in [deleted]. There is no desire on the part of the military to inhibit the execution of civil programs or to interfere with the data dissemination on those programs.

Senator SCHMITT. Mr. Chairman.

Senator STEVENSON. Do you have a few more minutes, Dr. Perry?

Dr. PERRY. I am at your pleasure.

Senator STEVENSON. Has the [deleted] exercise produced a recommended [deleted] for the NSC?

Dr. PERRY. Yes.

Senator STEVENSON. Can you tell us what it is?

Dr. GREENBERG. [Deleted.]

Senator STEVENSON. Do you have any idea when this exercise would be completed, and we will be able to find out what the resolution of all these issues are, including any restrictions on the civil applications?

Dr. PERRY. I believe that will be in the near future, Senator Stevenson. It may depend on totally irrelevant issues, like the coal strike.

Senator STEVENSON. Yes. It doesn't do me much good. It doesn't accomplish much to express, not just as the chairman of the subcommittee, [deleted] some frustration, I think [deleted].

I have sought some participation in this process, and, so far as I know, [deleted] despite several requests, has received any information,

cooperation or an opportunity for some input in this process. And it is stupid, because in the last analysis, we can, if we want it, have the final say.

I don't know whether I am going to get my say [deleted] here, but I am going to have it. So are others. Well, for that reason, it just isn't smart. And if it is not too late, maybe you could carry back the word again that there ought to be a little cooperation and consultation.

I see the [deleted] on the whole, operating pretty effectively, on cooperation, in the most sensitive subject, until you come to the NSC. Then the process breaks down completely. It is zero.

I have experienced it recently on the [deleted].

Some of us have been more concerned about that particular problem for longer than Mr. Brzezinski even heard of it. Maybe you ought to relay some of my frustration and suggestions with whatever strength of feelings you would like to attribute to me, to somebody up there, and suggest [deleted] that we get consulted in that process before there is a final decision.

Dr. PERRY. I think you have both communicated your feelings very clearly on this subject. I will, indeed, pass these on.

More to the point, I will see if I can schedule some followup action on [deleted] discussion with you.

I will be back in touch with you on that.¹

Senator STEVENSON. Now, you mentioned [deleted]. I am getting an active briefing this afternoon, which I assume would go into that argument.

Dr. PERRY. [Deleted.]

I think that is what I would be most concerned about.

Senator STEVENSON. When we talk about systems in this context, are these [deleted]?

Dr. PERRY. [Deleted.]

Senator STEVENSON. Apply to what in [deleted]?

Dr. PERRY. It would also apply to [deleted].

Senator STEVENSON. You said [deleted].

Dr. PERRY. [Deleted.]

Senator STEVENSON. [Deleted.]

Dr. PERRY. [Deleted.]

Let me just comment, Senator Stevenson, that for this [deleted].

Senator STEVENSON. There is always asymmetry. It just depends which side you are on.

Getting back to the Shuttle again, you sound concerned about it. We are all familiar, to varying degrees, with some of the technical problems that have developed, especially with the main engine. But your suggestion that the production should be stretched out, in order to permit design changes is, well, I guess it is the first time I have heard that suggestion.

I had assumed all along, as I indicated earlier, that the original schedule would permit and, in fact, was accommodating significant design changes.

Am I assuming too much, or are you sounding as concerned as I think you are, about the design of the Shuttle? Are you aware of

¹ After this hearing, Dr. Perry arranged for the National Security Council staff to provide Senator Stevenson a full briefing and discussion on [deleted] activity. The briefing was provided on March 21, 1978.

problems with the Shuttle that are going to, or might require major design changes that can't be accommodated by the original fire-orbiter schedule?

Dr. PERRY. No, I am not expressing concern about the design of the Shuttle. I am only expressing the general feeling that for any program which is going to be in use for a long-time period, 20 years or so, we may have a different idea of how we are going to use it during the second decade than we have during the first decade.

And that, therefore, it would be well to have flexibility in the program which would allow us to incorporate the benefits of more experience, not just experience from the first few tests. As Senator Schmitt pointed out, we already have different ideas about how improvements would be incorporated into a Block II, if there were to be a Block II.

So I have not intended to express a concern over the design of the system, but rather to generally express the fact that we may want to incorporate in the future the benefits of our experience.

Senator STEVENSON. I am missing something, because I thought experience was going to produce design changes, and, in fact, already has. The last orbiters were going to be lighter than the first orbiters under the existing schedule. You seem to anticipate design changes of a magnitude that can't be accommodated by that schedule.

Dr. PERRY. What I am anticipating, Senator Stevenson, is that we will learn of applications that we can make with the Shuttle. We will learn new things to do with it, which we don't now anticipate clearly enough.

I am not looking at discovering there is something wrong with the Shuttle. What I am anticipating is that we will discover that the Shuttle has greater potential than we now anticipate, and that to fully realize that potential, we may want to have some different design characteristics, than we have now built into it.

So I am really taking a very positive view of the Shuttle and, just pointing out that our imagination is somewhat limited, I think, today, in all of the things that we are going to be able to find the Shuttle doing for us.

Senator STEVENSON. Then you go a step further, though, to say that the newly discovered applications for the Shuttle might require more time than the original schedule, perhaps more money to incorporate into the design of the last orbiter.

Dr. PERRY. No; I would just suggest that there might be some break in the building of the Shuttles, and that break might be after the fourth one, rather than after the fifth one. And that, as we build the next batch of them, that Senator Schmitt was referring to as the "Block II," that we try to take advantage of the experience we have gained from the test flights and the new concepts we have about how we want to use it.

Senator STEVENSON. Well, I don't see how anybody can quarrel with that notion, but I still don't quite understand what the implications are for the schedule and our action in this Congress, which only had \$4 million for the fifth orbiter.

Dr. PERRY. It would have very little impact on the fiscal year 1979 budget, one way or the other. The impact would be in the out years, 1980 and 1981.

Senator SCHMITT. Mr. Chairman, if I may interrupt, I think the implication would be if the Congress decided they wanted to authorize limited expenditure of dollars, in order to prepare for the development of a Block II, based on current experience in the timeframe in which the fifth or potentially the sixth orbiter would be constructed. And I am thinking of items such as what we have learned, possibly, and I don't know anything on this, as we become more and more familiar with the hypersonic flight regime, in which the Shuttle is going to operate, frankly, for the first regime, when it is launched on its first orbital test flight.

And we are learning, though, in the wind tunnel tests and other modeling, I believe, a great deal about hypersonic flight, a tremendously important part of the technology of the Shuttle, and we could optimize the Shuttle capability in that flight regime by some Block II type aerodynamics modifications.

It would be that kind of a structural modification that would probably be beyond the capability on the present assembly line.

It would require tooling changes, major tooling changes, for example.

I think you and I are on the same wavelength.

We may not be on the same wavelength of what is the best tactical approach to doing that, whether we should build that into the present schedule and try to have the fifth orbiter or sixth orbiter coming along as a Block II, or whether we should take the President's recommendation that we just hold off and then make that decision sometime later and proceed with a Block II.

I tend to favor the former, if we were going to do anything like that at all, rather than the latter, as being the more economical and also the more rational.

Dr. PERRY. Yes; in my view the action that would be pertinent to fiscal year 1979, relative to that point, is a planning, rather than a building action, but it would achieve the same objective, as you are describing.

Senator STEVENSON. Do you have some more?

Senator SCHMITT. Only if you would give us a quick statement to complete our record, Dr. Perry, on the concern that the DOD has expressed relative to the use of the graphite-impregnated composite materials for air frame construction.

Dr. PERRY. Could you clarify the question, please.

Senator SCHMITT. Well, we understand there is concern about the possibility that graphite filaments may be introduced into the upper atmosphere by the deterioration of a composite material that NASA has had under development for some time, and that, as a consequence there has been a slow down in the development program for that particular composite material.

Are you familiar with that? It has to do with graphite filaments that may stay suspended for a long period of time and, I presume, would create an electromagnetic interference.

Dr. PERRY. Yes; I am generally familiar with that problem, Senator, but I would prefer not to give you an off-hand answer for the question and provide one for you for the record, if I may.

Senator SCHMITT. I think just to complete our record about it, NASA testified on the general issue, and it might help to have your statement.

Dr. PERRY. Yes.

Senator SCHMITT. Recognizing, of course, it would be part of the classified record.

Dr. PERRY. We recognize composite materials have tremendous potential, not only for civil uses, but military uses, as well. We are aware of the potential hazards.

I will prepare a statement for you to try to describe the analysis between those.

[The following information was subsequently received for the record.]

With regard to the potential electrical short circuit problems that may be associated with the release of carbon/graphite fibers from epoxy matrix composites when subjected to fire and explosion situations, the DoD is very well coordinated with NASA. The risk assessment analysis which was discussed by Dr. Kramer before the Subcommittee on Science, Technology and Space, Committee on Commerce, Science and Transportation, United States Senate, is a good case in point. NASA and DoD collaborated on funding two contractors to develop methodologies for conducting such risk assessments. From this jointly funded program, DoD and NASA are in the process of evolving a standardized methodology which will be used by NASA to conduct their risk assessment for civilian aircraft situations and the DoD will use the same methodology for military scenarios. It is much too early to draw any conclusions from these analyses as they are just getting underway. In addition, the DoD is conducting experimental and analytical studies of the vulnerability of certain military equipments to intrusions of these fibers. Accompanying this work is the development of protective measures to eliminate the chances of electrical malfunctions should a carbon/graphite fiber release situation be encountered.

With regard to the development of materials modifications to alleviate the fiber release problem which was also discussed by Dr. Kramer before the aforementioned Subcommittee, the DoD is well coordinated with NASA in this area also. Whereas NASA has chosen the somewhat near term route of modification of existing epoxies and fiber coatings, the DoD is addressing a somewhat longer range solution to the problem that may be achievable with fiber reinforced metals—called metal-matrix composites (MMCs). Preliminary tests that we have conducted with carbon/graphite fibers reinforced aluminum indicate that fiber release is minimal or nonexistent under simulated fire-explosion situations.

Senator SCHMITT. If you could include in that anything that DOD feels alternative to this particular kind of material that you think are well worth NASA continuing to emphasize or to further emphasis in the development of composites, they have tended to have been focused on the graphite filament composite, as their prime thrust for research and development.

It may not be the only one, as far as DOD is concerned, that is worth their attention, assuming that there is, in fact, a real problem in the graphite filament composite.

Is the DOD involved at all in the TDRS activity, the new satellite system, communications satellite?

Dr. PERRY. Let me refer that to Dr. Greenberg.

Dr. GREENBERG. We have had no specific involvement in the system itself. We are going to provide the inertial upper stage for putting the TDRS in orbit.

Senator SCHMITT. What is the status of your research activities related to nuclear reactors in orbit?

Dr. GREENBERG. We don't specifically do the research on the nuclear reactors, those are done by the Department of Energy.

We do use, not nuclear reactors, but radioisotope sources on some of our satellites.

Now there are seven DOD satellites now in orbit that use those radioisotope generators.

We have no plans to use nuclear reactors in space at this time, although we think that there is a possibility of using them sometime in the future, as we need more power and perhaps want to increase the survivability of our satellites.

Senator SCHMITT. Have you done a study at what power levels and other variables it becomes reasonable to consider nuclear reactors?

Dr. GREENBERG. Yes.

Senator SCHMITT. Other than the thermal electric radioisotopic generator?

Dr. GREENBERG. Yes. Roughly, at the level of 50 kilowatts electric output it becomes attractive to use nuclear reactors as the power sources for space applications.

We don't have specific applications that require that much power now, but we can foresee that coming sometime before the end of the century.

Senator SCHMITT. Does the COSMOS 954 experience affect that thinking at all at this time?

Dr. GREENBERG. We have considered it pretty carefully in some discussions that we have had, and analyses we have done with the problem.

We would not propose to put a nuclear reactor in low Earth orbit, where it would be dangerous, unless we were sure there were a multitude of adequate safeguards to insure that its reentry would be safe.

Senator SCHMITT. The traditional approach in our use of nuclear power sources in space has been to insure that there is always a fail-safe position, particularly when you are dealing with low Earth orbit.

I presume that our policy would never have introduced a satellite, such as COSMOS 954 into that particular orbit.

Dr. PERRY. That's correct.

Senator SCHMITT. And have it actually be an operational reactor.

Dr. PERRY. That is completely contrary to the policy under which we would use a nuclear reactor. From our standpoint, that was a very careless way of using a nuclear reactor in space. They had it operating as a nuclear reactor, while it was in a low Earth orbit, with the idea they were going to boost it to a high Earth orbit afterward.

That, in itself, is certainly not a fail-safe way of proceeding, as was demonstrated.

Senator SCHMITT. Dr. Perry, we have a few additional questions which, in view of the time, I would like to submit to you in writing for your reply for the record.

Dr. PERRY. Sure.

Senator STEVENSON. You have been generous with your time.

I apologize for keeping you longer than we had expected. You have also been most forthcoming and cooperative, and I am grateful for that.

If everyone in this administration was as helpful to us as you have been this morning—especially Mr. Brzezinski—perhaps our Government would be functioning a good deal more smoothly than it is today.

I may take a segment from our record today and send it to Mr. Brzezinski, in case he doesn't read about it in the *Aerospace Daily* in a few days.

I would urge you, again, to convey the sentiments expressed in that particular segment to the appropriate people at the other end of Pennsylvania Avenue or over the bridge, or wherever it is.

Thank you, sir.

Dr. PERRY. Thank you, Mr. Chairman.

Senator SCHMITT. Thank you, Dr. Perry, Dr. Greenberg.

Dr. PERRY. Thank you, Senator.

Senator STEVENSON. Thank you, Dr. Greenberg.

[The statement and questions and answers follow:]

THE DEPARTMENT OF DEFENSE

STATEMENT OF DR. WILLIAM J. PERRY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING, DOD

I. INTRODUCTION

This statement provides information on the planned FY 1979 space activities and aeronautical research and development programs of the Department of Defense. The statement has been prepared in five sections. This section provides an overview of some of the key points. Section II highlights the Soviet space and aeronautical efforts and provides pertinent comparisons to U.S. activities. Section III shows DoD space funding for all activities, and discusses our space systems and supporting science and technology efforts. Section IV shows the DoD aeronautical funding, and discusses operational systems and technology. Section V covers coordination and cooperation with NASA.

The Soviet space program is predominantly military in character. An unequivocal priority is given to the use of space for the purpose of strengthening the Soviet armed forces. While we see evidence of success, we also see evidence that they have problems. For example, the Soviets stated they could not meet their commitment to launch a geostationary meteorological satellite by January 1, 1979 in support of the Global Atmospheric Research Programs. The U.S. has a spare synchronous meteorological satellite in orbit which will take its place. Despite the size of the Soviet space effort, we believe that the U.S. now enjoys a position of technological superiority in space in almost all areas where comparisons can be made.

In the aeronautical area, the Soviets revealed in 1977 a short takeoff and landing (STOL) transport prototype, the AN72. The AN72 is similar in design to our YC14 STOL. Soviet production of aircraft continued at the high pace they have been sustaining over the past five years. A number of fighter aircraft were produced last year, some of which were swing-wing aircraft. A new helicopter for anti-submarine warfare, the HAZE, was recently introduced.

The Department of Defense space activities are receiving increasing emphasis in FY 1979, as evidenced by our request for \$3,364.9 million. We are making major commitments to the use of the Space Shuttle which offers new capabilities and can lead to more effective space operations. In FY 1979 we will start the construction of the Shuttle launch and landing facilities at Vandenberg AFB, and development of the Inertial Upper Stage (IUS) will be at a peak. The IUS will be used for our Shuttle launches from Kennedy Space Center (KSC). Payloads are being modified for the early Shuttle/IUS launches from KSC. By early 1979 we expect to make a decision to deploy the NAVSTAR Global Positioning System operationally. NAVSTAR will significantly enhance such missions as troop movements, enroute navigation, artillery siting, blind bombing, missile delivery, satellite location, and rendezvous. By late 1979 we plan to launch the improved Defense Communications Satellite (DSCS III). The operational prototype Simplified Processing Station (SPS) will be delivered which

can back up our early warning satellite ground stations. We now have three operational satellites on orbit. An improved sensor currently in development will allow evolutionary improvement to these early warning satellites. We are strengthening our science and technology programs in a number of areas relating to space and missile surveillance, satellite survivability and anti-satellite technology development.

The Department of Defense is requesting \$2,118.0 million in FY 1979 for aeronautical research and development programs. These programs provide technology for tactical and strategic aircraft, cruise missiles, early warning aircraft, ground and ocean surveillance, and air mobile command, control and communications. Our major thrust is to reduce acquisition and support costs, to achieve new operational capabilities, and to replace and modernize the operational aircraft inventory. The modernization program advanced with the A10 Close Air Support Aircraft achieving initial operational capability and F16 Air Combat Fighter production accelerating. Development of new operational concepts continued with the first tethered liftoff of the XFY-12A thrust augmented wing vertical takeoff and landing aircraft scheduled for 1978. In FY 1979 our requests for exploratory and advanced development funding reflect a real growth above inflation. Key technologies which we expect to lead to lower acquisition and support costs are composite materials for aircraft structures and charge coupled devices which will permit development of miniaturized solid state television cameras and advanced electronic flight control systems. Significant civilian applications continue to spin off from our military aeronautics programs.

Close coordination and cooperation between NASA and the DoD is essential to assure that maximum benefits are derived from NASA programs for Defense use; and, in turn assuring that the technology developed in military programs is available for civil applications. The Aeronautics and Astronautics Coordinating Board (AACB) has proven to be an effective catalyst for achieving such coordination and cooperation. The National Aeronautical Facilities Program developed by the AACB is now under construction. A policy on reimbursement for Shuttle services to DoD has been agreed upon. Comprehensive studies on Shuttle orbiter procurement have led to an administration decision to procure a total of four orbiters for the national fleet. A low cost approach to using Johnson Space Center capabilities in support of classified DoD Shuttle missions has been developed. Cooperative programs with NASA include Spacecraft Charging investigations, SEASAT-A data processing, the Rotor Systems Research Aircraft, the Tilt Rotor Research Aircraft, Super-Critical Wing Technology, and the Fuel Availability program.

II. SOVIET SPACE AND AERONAUTICAL ACTIVITIES IN 1977

A. Space Activity Comparisons

Mankind's efforts to harness the unique attributes of space for civil and military purposes are dominated by the activities of the United States and the Soviet Union. Both nations have made substantial investments in space systems and significant advances in space technology, and we expect the trend of increasing reliance on space for scientific, commercial, and defense benefits to continue for the foreseeable future. Beyond this point, however, the differences in the U.S. and Soviet space activities far outweigh any other similarities.

The basis for these differences is perhaps to be found in the two nation's institutions for advancements and exploitation of space which have evolved over the past two decades. The Soviet space program is under military control and is dominantly military in character. An unequivocal priority is given to the use of space for the purpose of strengthening the Soviet armed forces. The Soviets are attempting to compete—in a military sense—in space. The USSR has invested significant resources in development and deployment of systems for force support.

The U.S. space program entails strong civil as well as defense efforts. Our broader institutional basis provides mutual support for achieving scientific advances, commercial benefits, and important contributions to security. Our space program is also more international in character than that of the Soviet Union. For example, in 1977, seven of our successful launches were of communications, meteorological, scientific, and earth-observation payloads for international organizations and other nations. One of the Soviet launches in 1977 was of a scientific payload for France.

Notwithstanding an initial Soviet lead in space technology and substantial efforts by the Soviet Union to expand that lead, the U.S. now enjoys a position of technological superiority in space in almost all areas where comparisons can be made. This technological advantage has paid off for us in both civil and military applications, through greater capability at lower cost.

It is already evident that the size of the Soviet space program is substantially greater than our own. The U.S. had a total of 26 launch attempts, with three launch failures in 1977. The Soviet Union had several times this number of launches. The Soviet military space effort in 1977 was greater than that of the U.S., in terms of both numbers of successful launches and the range of military space functions.

Along with the evidence of Soviet success in space, there is evidence of some problems. For example, the Soviet Union announced that they could not meet their commitment to launch a synchronous orbit (geostationary) meteorological satellite by January 1, 1979, in support of the Global Atmospheric Research Program (GARP). The United States will provide a spare synchronous orbit meteorological satellite which is now in orbit, to take the place of the unavailable Soviet satellite. In 1977, the U.S. launched the GMS meteorological satellite for Japan and the European Space Agency METEOSAT in support of the GARP.

B. Selected Aeronautical Activities

The USSR inaugurated regular passenger service for the TU-144 supersonic transport in 1976. First flight of the TU-144 occurred in December, 1968, and a production model of the aircraft crashed at the Paris air show in June 1973. The Soviets have apparently had considerable difficulty in achieving sufficient range of the TU-144 to warrant its use in commercial passenger service.

Development of the Soviet AN-72 light STOL (short takeoff and landing) transport prototype was revealed in 1977. The AN-72 is a high-wing, high T-tail design similar to that of the Boeing YC-14 medium STOL transport. We estimate that the AN-72 is capable of carrying a 5-ton payload.

Soviet production of military aircraft continued at the high pace they have been sustaining over the past five years. A new helicopter for antisubmarine warfare, the HAZE, was also recently introduced.

III. U.S. DEPARTMENT OF DEFENSE SPACE ACTIVITIES

A. Introduction

Department of Defense dependence on space systems to support our military forces worldwide continues to grow. The military space systems which have evolved over the last two decades provide support for navigation, communications, ballistic missile early warning, surveillance, and weather forecasting. Space systems offer unique capabilities such as, for example, denied area surveillance, or provide a capability that is highly cost effective, such as high data rate communications links for data collection from facilities worldwide. We are continuing to improve our current space systems, and to introduce new systems where they offer new capabilities or improve the effectiveness of our forces.

The Space Shuttle is one such new system which offers both unique new capabilities and more effective space operations. With the operational Shuttle launch and landing facilities on both coasts, and the adequate fleet of Shuttle orbiters being requested of Congress, the Shuttle can meet all DoD space system needs for the foreseeable future. In FY 1979 we will initiate construction of the Vandenberg AFB Shuttle launch and landing facility. FY 1979 will be a peak year in development of the Inertial Upper Stage (IUS) which is needed for our military launches on the Shuttle from Kennedy Space Center. The IUS and its subsystems will be used also on the Titan III to improve reliability and reduce costs. Payloads are now being redesigned to assure compatibility with the Shuttle environment. Once the Shuttle is operational, transition of all of our payloads to the Shuttle and eventual phase out of current boosters is planned.

In 1978, the NAVSTAR Global Positioning System Joint Program Office will essentially complete validation of the system concept. A four-satellite constellation will support an extensive joint-Service user equipment test program. By early 1979, we expect that the system concept will have been proved with sufficient confidence so that the Department of Defense can make a decision to deploy NAVSTAR operationally. When deployed, the system is expected to significantly enhance such missions as troop movements, enroute navigation, artillery siting,

blind, bombing, missile delivery, satellite location, and rendezvous. In the space communications area, the Navy launched the first Fleet Satellite Communications System (FLTSATCOM) satellite into synchronous orbit in February 1978. This satellite with the three satellite MARISAT System (leased UHF Service) will greatly improve Naval communication capability and provide an anti-jam capability for fleet broadcast. In addition, the satellite provides a transponder in synchronous orbit for the Air Force Satellite Communications System (AFSATCOM). AFSATCOM is expected to achieve an IOC in early 1979 with transponders on the FLTSATCOM, Satellite Data System and other host satellites. The Defense Satellite Communication System (DSCS) presently has a worldwide space segment utilizing three DSCS II satellites and one NATO III satellite. In early 1978, two additional DSCS II satellites will be launched allowing the United States to return the borrowed NATO satellite and place a satellite in orbit as a spare. Full scale development of the DSCS III satellites which began in early 1977 will continue through 1978 with a planned launch of the first DSCS III prototype in the last part of 1979. A fully operational early warning system with satellites over the Western Hemisphere and over the Eastern Hemisphere provides near real time warning of ICBM, and SLBM launches. In late CY 1978 the operational prototype Simplified Processing Station (SPS) will be delivered and the initial development of an austere command and status capability for the SPS will commence. Development of modifications to the satellite to ensure payload compatibility with the TITAN III D/IUS and Space Shuttle/IUS will continue; including the development of improvements to the satellite communications elements.

The Defense Meteorological Satellite, which is the DoD weather satellite system, continues to provide visual and infrared cloud cover data over the entire surface of the Earth in support of strategic and tactical missions. The first improved Block 5D satellite was launched in September 1976; however, an anomaly precluded collection of weather data until March 1977. The second Block 5D satellite was launched in 1977, both of these two satellites are now operational, satisfying both strategic and tactical missions.

We intend to strengthen our science and technology programs in a number of areas. Technologies are being pursued leading to the use of space borne sensors to achieve a long-term solution to the space surveillance problem. A range of concepts, technologies and sensors are being explored to enhance satellite survivability. We are also exploring space-related laser technology, and have made great strides in infrared sensor technology which will ultimately expand our capabilities for space-based sensors capable of attack warning. We are also improving spacecraft subsystem performance, survivability, and reliability and are planning significant demonstrations in space flight of the more promising sensors and subsystems.

B. Space Program Budget

The Department of Defense is requesting \$3,364.9 million in FY 1979 for space related programs. Table III-1 provides a breakdown of our FY 1979 request and funding appropriated in prior years.

TABLE III-1.—DOD SPACE RELATED PROGRAMS

[In millions of dollars]

Program	Fiscal year 1977	Fiscal year 1978	Fiscal year 1979
Mission oriented:			
Navigation.....	104.9	97.4	138.2
Communications.....	720.9	580.4	536.5
Warning.....	87.9	157.7	230.8
Geodesy.....	7.7	7.7	8.3
Weather.....	67.9	75.2	71.3
Vehicle development.....	108.3	287.4	548.8
Space ground support ¹	123.6	140.4	146.6
Supporting R. & D. ²	209.5	291.9	451.0
General support ³	981.2	1,075.7	1,233.4
Total.....	2,411.9	2,713.8	3,364.9

¹ Includes range support, instrumentation, ground-based satellite detection, tracking, and control.

² Includes research, exploratory, and advanced developments.

³ Includes support organizations as well as general operational support.

C. Funding Changes, FY 1978-1979

The \$3,364.9 million being requested in FY 1979 is a \$651.1 million increase over that which was appropriated in FY 1978. The major funding changes—both increases and decreases—are summarized below:

INCREASES

Space Shuttle.—Our funding in support of the Shuttle is increasing sharply in FY 1979 with the start of construction of the Shuttle launch and landing facility at Vandenberg AFB and the procurement of equipment for this facility. The Inertial Upper Stage development peaks during FY 1979, and we will procure ground and logistic support equipment.

Navstar GSP (Navigation).—In FY 1979 two significant factors contribute to the program R&D cost increase. In the first half of the year the concept validation will be completed. Then full scale development will commence for user equipment, system control segment, and the space segment that is planned to be deployed for the operational system.

Afsatcom (Communications).—This program shows increases in the RDT&E, procurement and operations and maintenance areas. The R&D increase is for development of the single channel transponder (SCT) and for the integration of this transponder with the host satellites on which it will be carried. Also the development of the Strategic Satellite System will commence in FY 1979. The procurement and operation and maintenance increases are for the procurement of command terminals for major base locations and the operation of these type terminals that were procured in prior years.

Army Ground Terminal Equipment (Communications).—The major increase in this program results from the initiation of the tactical terminal buy in support of the Army's Ground Mobile Forces (GMF). In FY 1979 the Army will procure 30 Super High Frequency (SHF) terminals and three control terminals that will maintain GMF discipline on a worldwide basis. In addition to 12 UHF terminals, 100 manpack terminals to support Special Forces and Long Range Patrols will be procured.

Early Warning Satellites.—The increases in this program are attributed to RDT&E, Procurement and Operations and Maintenance (O&M). The RDT&E increase will provide for improvements in the critical onboard communications elements and provide an austere command and status, and command uplink for satellite control by the Simplified Processing Station. The procurement increases are for hardware changes to enable the ground data system to process data from and to control the improved satellites, and for the satellite retrofit program. The O&M increase is for software modification to ensure compatibility of the ground data processing facility with the improved satellites.

Supporting Science and Technology.—Significant increases are occurring in the Space Defense area which includes space surveillance, satellite survivability and antisatellite activity. There are also increases in advance space communications, sensor technology and preparations for flights of significant experiments.

DECREASES

Fltsatcom (Communications).—The decrease in this program results from the fact that no satellites are being procured in FY 1979. However, the FY 1978 figure for this program includes the supplemental request forwarded by the President to Congress with the FY 1979 Budget. The FLTSATCOM supplemental is awaiting Congressional action.

Defense Satellite Communication System (DSCS) (Communication).—The major portion of the DSCS III development was accomplished in FY 1978 and prior. The first prototype satellite will be launched in late 1979 with continued R&D tapering off. The procurement reduction results from the fact that no additional satellites are being procured for the program until the DSCS III production satellites are available commencing in FY 1980.

Space Boosters.—Procurement of additional Titan III backup boosters for Shuttle is not needed in FY 1979. This reduction in procurement over FY 1978 more than offsets Titan IIID/Inertial Upper Stage peak year development costs.

D. Space Shuttle

Present plans are to transition all DoD space system payloads from launch on current expendable space boosters to Shuttle launch after the Shuttle becomes operational in 1980. The Air Force is developing an Inertial (formerly Interim) Upper Stage (IUS) which will be operational by mid-1980 for use on both the Shuttle and the TITAN III booster during the transition period. The Air Force is also developing the Shuttle launch and landing capability at Vandenberg AFB, which will be operational in June 1983. Some TITAN III boosters will be procured as a backup for our critical launches in the event that the Shuttle encounters delays during development or early operational use. When the Shuttle is fully operational, expendable boosters will be phased out of the inventory. Current DoD planning is predicated on the timely availability of an adequate orbiter fleet, based on NASA's national traffic projections for Shuttle use.

The Space Shuttle can support the launch of all projected DoD space systems in the foreseeable future. The Shuttle provides significant new technological opportunities which can lead to more effective and flexible military space operations. Compared to our largest current space booster, the Shuttle can deliver twice the payload weight and three times the payload volume to orbit. We can use this increased capability to incorporate redundancy in critical subsystems, thereby improving the life of our spacecraft in orbit. We can also improve the capability of our spacecraft by prudently adding sensors and communications links. We can improve the survivability of our space systems, in a natural or hostile space environment, by selecting from a number of Shuttle-related options. These survivability options include placing spare spacecraft in orbit, carrying additional on-board propellants for spacecraft maneuvering, or perhaps placing in orbit more spacecraft of a simpler, lower cost design. The Shuttle capabilities offer the opportunity to achieve greater spacecraft modularization and standardization of subsystem while avoiding costly weight reduction programs. The reliability of placing a satellite in its desired orbit projected for the Shuttle/IUS (.97) is higher than the average we are experiencing today on our current expendable boosters (.93). We anticipate that the Shuttle can be used routinely as a development test bed for various sensors and subsystems, thereby reducing the development time for new space systems and enhancing our capability to respond rapidly to changing needs.

Initially, we will use the Shuttle as we would a larger replacement launch vehicle. However, should the Shuttle arrive on-orbit with a payload that did not check out properly, most payloads could be returned to earth for adjustment or modification. In the future, we can design our payloads so that the Shuttle can retrieve them from low orbit when the mission is complete, and return them to earth for refurbishment and reuse, diagnostic purposes, or technological update. Another option which might be equally attractive in the Shuttle era is on-orbit servicing of payloads. Spacecraft designed for automated subsystem replacement could be serviced while in low orbit depending on mission requirements. In the long term, the Shuttle will open the way for many new technical advances in the military use of space.

In FY 1979 we will procure some IUS ground support and logistics support equipment. We will also procure unique ground support equipment for Vandenberg AFB, and continue co-procurements with NASA of common Shuttle ground support and launch processing equipment. The construction of Vandenberg AFB Shuttle facilities is planned to begin in April 1979. Our FY 1979 Vandenberg AFB construction program includes the Shuttle land field, mate/demate facility, launch pad area, and the launch control center. We are also modifying our Solid Motor Assembly Building for IUS processing at Kennedy Space Center.

Since DoD plans to make extensive use of the Shuttle, the timely availability of an adequate national fleet of orbiters to support military as well as civil users of the Shuttle has been a matter of serious concern to us. The fleet size must be based on total traffic—foreign and domestic, civil and military—projected for the Shuttle. Extensive studies conducted by NACA, with Air Force support, plus detailed reviews within the Administration have led to the decision that NASA should proceed with the production of a four orbiter fleet. Additional orbiters can be considered for funding in future years in the event that projected flight rates (or loss of an orbiter) warrant augmentation of the operational fleet.

Present DoD planning for Shuttle launch is predicted on the use of NASA's Johnson Mission Control Center (JMCC) for simulation, training, and Shuttle

flight control for all DoD missions. However, as currently designed, JMCC cannot handle classified payload data. A number of options for accommodating classified DoD launches in the JMCC have been evaluated over the past year by both DoD and NASA. Recently we have tentatively agreed with NASA on a low cost approach to modifying JMCC which should adequately protect classified payload launches on the Shuttle with minimum disruption to civil users. We expect to complete the validation of this approach, which we call the "controlled mode" concept, and assuming that our validation phase is successful, proceed in FY 1979 with necessary modifications to JMCC.

Revision 6 of the Department of Defense Space Mission Model for the period FY 1977-1991 projects 195 launches, 109 of which are Shuttle launches. Initial DoD use of the Shuttle is planned for an experimental payload within the first year of its operation: Launch of DoD operational payloads begins in FY 1982, and by the mid-1980's all DoD payloads will have transitioned from launch on current expendable boosters to Shuttle launch. During FY 1979 Early Warning Satellite, Satellite Data System, Defense Meteorological Satellite Program, and Global Positioning System spacecraft will be in varying stages of design for modification and necessary developmental tests to assure spacecraft compatibility with the Shuttle payload bay environment. The new Defense Satellite Communications System III spacecraft is being designed from the outset for Shuttle launch.

The Intertial (formerly Interim) Upper Stage (IUS), which is being developed so that DoD spacecraft can be delivered to the required orbital attitude and inclination using the Shuttle from Kennedy Space Center, is now in the validation phase and will enter full scale development in March 1978. The IUS will be available in mid-1980 and will be used on both the Shuttle and the TITAN III launch vehicle. Using the IUS on TITAN III will greatly enhance mission success and reduce costs during the early transition period when a number of our spacecraft will still require TITAN III launches.

We are providing a Shuttle launch and landing capability at Vandenberg AFB so that we can continue to support high priority, high inclination DoD launches. Launches into sun synchronous, polar or near polar orbits cannot be conducted from Kennedy Space Center without unacceptable performance loss and overflight of populated land areas during launch. This year we will complete all design criteria, support equipment specifications and initial design work necessary to support start of facility construction in FY 1979. The facility will be ready to support Shuttle flights beginning in June 1983.

For launches from Kennedy Space Center, payload ground processing and flight control procedures have been defined. Work will continue in FY 1979 on payload interface documentation, common support hardware, and security provisions. Modifications to Johnson Mission Control Center to protect classified payload data should begin. In addition, we will provide a minimum number of TITAN III vehicles as a backup for launching priority DoD payloads, should the Shuttle be delayed during the early operational period.

In FY 1979 we are requesting \$423.9 million for our Shuttle effort. Of this total, \$169.5 million is R.D.T. & E., \$108.8 million is Procurement, and \$145.6 million is Military Construction.

E. Mission Oriented Space Programs

1. NAVSTAR Global Positioning System (GPS)

The Navy Navigation Satellite System (TRANSIT) has been in operation since 1964 and is providing excellent radio navigation information for military and civil maritime users. Its availability is insufficient for aviation and other users. A second generation concept for satellite-based radio navigation is being pursued. NAVSTAR GPS is a development program for a system which will employ satellites to broadcast information for precise position-fixing and velocity determination in three dimensions. This system continues to offer the Department of Defense an opportunity to revolutionize its worldwide capability for navigation and position-fixing. Suitably equipped users in virtually every military mission will be able to passively receive information continuously broadcast to any location on the globe. Using the demonstrated technique of placing precise time standards on the satellites, users can lock their less precise clocks into accurate time and pseudo-range from the best four of an average of eight to nine satellites. When deployed, the system is expected to significantly enhance such missions as troop movements, enroute navigation, artillery siting, blind bombing, missile delivery, satellite location and rendezvous.

Historically, radio reference systems have provided position-fixing information over varying distances generally constrained by the techniques used and the precision needed. Generally, transmitters must be located in relatively close proximity to users. The Soviet Union has a distinct advantage in many potential trouble spots because of its command of the broad landmasses to locate installations. NAVSTAR has the potential for restoring the balance in favor of the U.S. First, the high precision information of NAVSTAR is not a function of geography since the system will function equally well anywhere on the globe. Second, it will provide a common grid system that will allow all properly equipped users to work together over vast areas down to very precise, specific locations. Third, it will strongly resist interference and could be denied to unauthorized users.

The program concept was submitted to review and approved for concept validation beginning in December 1973. Having combined the features of several individual concepts, this program has from the onset been perceived as one of the most important and far-reaching programs in the DoD. It is an all-Services, jointly managed program uniquely including not only the development of the satellites, but also the satellite data and control segment, and all of the classes of user equipment. We perceive an expected impact on a growing number of missions throughout the military departments and with the potential for savings in procurement and operation of a broad spectrum of equipment which could be replaced. As we reach significant milestones toward the demonstration of the concept, our confidence increases that the goals and schedules we have predicted will be met.

During this latest year we have made substantial progress in proving that the concept will work as expected. Initially there was a setback due to software and hardware problems in the design and fabrication of user equipment development models. Although solved, they caused a significant cost growth and subsequent delay in the program. Nevertheless, a meeting of the Defense Systems Acquisition Review Council later in the year agreed to continue with the concept validation phase.

The Navy Navigation Technology Satellite II was launched in June and began operating in conjunction with the Inverted Range (satellites on desert floor being used as though they were in orbit) at Yuma, Arizona. Flights of user equipment on a helicopter, a transport, and fighter-bomber have provided real-time data which confirms the predicted accuracy of the system. Additional launches in 1978 will serve to demonstrate the Navigation Development Satellite and other general uses on land and sea.

Following the successful demonstration of the NAVSTAR system concept, we expect to make a decision in early 1979 to deploy an operational system by the mid-1980s. We expect to have deployed twenty-four satellites and a large amount of user equipment in support of almost every mission area of our forces. Our analyses show that we can greatly reduce costs and improve force effectiveness by the earliest employment of the system.

The cost of NAVSTAR GPS through FY 1978 will be \$323 million. Each of the Services applies funds for the joint management with small portions for Service specific needs. The financial leverage of the investment in this program is large since at least one half billion dollars are spent annually in the DoD for research and development and procurement of a broad spectrum of navigation and positioning equipment whose maintenance and operating costs total perhaps another half billion dollars each year. If NAVSTAR provides the expected capability, we can make a major reduction in the use of other, more specialized navigation systems, cut down our supply problem, and achieve the economy of scale inherent in large-lot procurement user equipment. Firm cost goals for user equipment will be determined by the completion of the first phase. Present projections, based on design-to-cost goals, are that the fully implemented program could achieve a net cost saving for military uses of over \$200 million per year. The DoD is, of course, pursuing the system for military purposes and will make a commitment to operationally deploy it based on its performance and cost merits.

We have not seriously studied civil applications, but the potential for a wide number of such uses is evident. We are working with a number of organizations regarding the consideration of civil needs. In addition, the U.S. is encouraging the participants in the NATO Alliance to formulate a plan for cooperative evaluation of the system as it moves into full-scale development. Last year the participants were well along in negotiating a multi-lateral memorandum of understanding (MOU). The MOU would permit the placing of NATO personnel in the Joint Program Office and lead to NATO participation in the development and testing.

In FY 1979 we are requesting \$129 million, will complete concept validation and begin the full Scale Development Phase of the user equipment, control segment and space segment. This continuance, of course, is predicated upon our major review and decision to continue, to be made in early 1979. In the meantime we are procuring additional TRANSIT improved satellites to maintain a mix of the currently operational and new satellites. We are requesting \$9.9 million for continuation of this procurement, the total for navigation satellite expenditures in FY 1979 being \$138.2 million.

2. Satellite Communications

The DoD is acquiring and deploying communications satellite systems which provide communications in three fundamental areas:

(a) Communications, Command and Control (C³) of forces in support of SIOP execution requirement. The existing configuration of this Strategic Satellite System (SSS) is now called the Air Force Satellite Communications System (AFSATCOM).

(b) Wideband, high capacity communications support for the National Command Authorities (NCA), Military Commanders deployed to major headquarters around the world including the Worldwide Military Command and Control System (WWMCCS) and the Intelligence Community. The present system satisfying these requirements is the Defense Satellite Communications Systems (DSCS) which is capable of providing a very modest anti-jam communication capability.

(c) Communications for mobile forces using a global space relay system in lieu of existing, inadequate, High Frequency radio systems to serve as the primary transmission medium for beyond-the-horizon communications with and among airplanes, ships, antisubmarine warfare aircraft and other mobile forces. The current version of this system which does not provide global coverage is the leased MARISAT System. In February 1978, the first FLTSATCOM satellite was launched to augment this systems capability.

Satellite communications systems can be employed to solve high priority communications problems that are unique to the support of worldwide DoD communications requirements. We also plan to use these systems to establish high priority alternate routing for certain terrestrial systems as a means of enhancing survivability, and reducing our dependence on third nations to approve our communications access to other countries. The flexibility offered by this medium to rapidly reconfigure existing communications networks to meet crisis management requirements and provide direct communications to Task Force Commanders is essential as a force multiplier in our present situation of continuing reductions in military manpower.

AFSATCOM. A general war survivable satellite system for communications, command and control of our nuclear capable forces must withstand physical and jamming attacks in the execution of its mission. This is our long range goal for the AFSATCOM program. AFSATCOM I, which will achieve initial operational capability by 1979, will provide us with a global system (including direct connection from CONUS to forces operating worldwide, which will have a modest anti-jam capability. The AFSATCOM I space segment consists of special transponders, installed on selected DoD host satellites, one of which was used in CY 1975 for the test program, and will include the Satellite Data System (SDS), which had two launches and the Air Force capability on the FLTSATCOM satellites, the first of which was launched in February 1978. Extended coverage and back-up to the primary SDS and FLTSATCOM segments are being obtained through special transponders installed on other DoD host satellites. This redundancy will provide the AFSATCOM I space segment with a limited degree of survivability to physical attack.

The AFSATCOM I combined Development and Initial Operational Test and Evaluation program was successfully completed in October 1975. Production of terminals for the bomber fleet and for various airborne command post aircraft was initiated in CY 1976.

The AFSATCOM system will require improvements in resistance to jamming. Both electromagnetic and physical survivability enhancements are planned for the Strategic Satellite System into which AFSATCOM will evolve. In support of this effort, two experimental satellites called LES 8 and 9 were launched in 1976. LES 8/9 has demonstrated the use of high power radioisotope thermoelectric power sources to increase satellite nuclear hardness and to eliminate

the large radar cross section of solar panels, a new gyro which could eliminate dependence on conventional sensors for satellite attitude control which are vulnerable to nuclear effects, new frequency bands for communications, and advanced anti-jam techniques.

AFSATCOM employs short, low-speed (teletype rate) messages for force execution, force report back, and force redirection and CINC internetting. The use of such messages coupled with suitable anti-jam techniques will permit relatively simple UHF low power terminals on bombers, airborne command posts, and intercontinental missile launch control centers to reliably and securely communicate via satellites which are stressed by large land-based jammers.

The FY 1979 procurement request for the AFSATCOM program is for both terminals and a transponder. The missile procurement request of \$4.4 million is for one additional AFSATCOM transponder to be placed on board a host satellite. The terminal procurement of \$26.9 million will procure 10 ground terminals. In addition, the FY 1979 request contains \$27.7 million in aircraft modifications to purchase and install 80 airborne terminals on a variety of B52's, FB 111's, and EC/RC 135's. The RDT&E request for \$33 million is for the development of a single channel transponder (SCT) and for the integration of this transponder with its planned hosts, namely the DSCS III satellite and the NAVSTAR GPS (Phase III) satellite. The SCT will be used to deliver the Emergency Action Message (EAM) to nuclear capable forces and will use both the UHF and SHF bands. In addition, the Strategic Satellite System (SSS) will begin development to achieve the required electromagnetic and physical survivability for SIOP Command and Control.

Defense Satellite Communication System (DSCS). The DSCS is a high capacity, super high frequency (SHF) system to satisfy the unique and vital national security communications requirements for worldwide military command and control, intelligence information transfer and crisis management. The DSCS supports the telecommunications needs of the Worldwide Military Command and Control System (WWMCCS), the National Command Authorities (NCA), the Ground Mobile Forces (GMF), the Diplomatic Telecommunication System (DTS), the Defense Communications System (DCS), and selected allies.

The present space segment which supports the DSCS was approved in July 1968 by the Secretary of Defense. The initial contract for six DSCS II satellites was awarded in March 1969 with follow-on contracts awarded in October 1974 for six satellites and July 1976 for four satellites. The launch vehicle used for the program is the TITAN III C which launches two satellites at a time into synchronous orbit. The planned procurement of 16 DSCS II satellites is expected to maintain a viable space segment until the early 1980s when the DSCS III spacecraft will be operationally available.

The first DSCS II launch, November 1971, revealed a number of technical problems in the satellite design and resulted in premature failure of both satellites. The second launch of December 1973 placed two operational satellites in synchronous orbit, one over the Atlantic Region and the other over the Western Pacific Region. On May 20, 1975, when attempting to place two additional satellites in orbit, the third stage of the TITAN III C failed resulting in the loss of both satellites.

During the early operational period of the DSCS space segment, satellite communication was quickly recognized as the most flexible and reliable means of providing communication support in crisis situations (e.g., evacuation from Viet Nam; MAYAGUEZ situation). However, during September 1976, the Atlantic DSCS II satellite failed leaving the U.S. with a very limited satellite capability.

On January 27, 1977, the NATO III B was successfully launched. As a result of this launch, the U.S. was provided with a limited worldwide communications satellite capability with the DSCS II satellite in the Western Pacific.

On May 12, 1977, the fourth DSCS II launch successfully placed two satellites in synchronous orbit. Acceptance testing of these satellites was accomplished and one satellite was placed in operation in the Atlantic Area. The second satellite was moved to the Western Pacific Area to replace the Western Pacific DSCS II satellite that had operated beyond its 3.2 year life expectancy. This satellite was then moved to the Indian Ocean Area where it now supports all U.S. requirements in the IO area and a number of intra-European requirements. Through this arrangement, some of the loading on the Atlantic satellite is reduced.

The next DSCS II launch is presently scheduled for March 1978. When these satellites became available for operational traffic, one will be placed in the Eastern Pacific. The second satellite will be used primarily as an on-orbit spare.

In December 1976, the Defense System Acquisition Review Council (DSARC) authorized full scale development of the DSCS III spacecraft. In February 1977, a contract was awarded to develop one refurbishable qualification model and two Demonstration Flight Satellites (DFS). The present schedule calls for the first DFS to be launched in mid to late 1979. This DFS will be launched with a DSCS II satellite aboard a TITAN-III vehicle. The second DFS will also be launched with a DSCS II satellite, but the option of using a TITAN III D vehicle with the new inertial upper stage (IUS) will be available. DFS #2 is expected to be launched in mid 1980.

The FY 1979 RDT&E budget request of \$34.2M will provide funds for the completion and ground testing of DFS #1 as well as on orbit RDT&E testing and integration with the launch vehicles. While DFS #2 will just about be completed in FY 1979, additional funds are required in FY 1980 for finalizing the spacecraft for launch and on orbit testing for launch vehicle intergration and related development efforts. (\$36.6M FY 1980). Prior year funds spent on the development of DSCS III are \$96.5M of which \$14.6M for the preliminary design effort of two contractors.

The FY 1979 missile procurement request in the Air Force budget is for \$13.9M. These funds are requested to procure long lead components for DSCS III production models to be purchased in FY 1980, and to support the Titan III consolidated buy plan.

DSCS terminal procurement continues on schedule. The last of the 18 large AN/MSC 78 terminals equipped with 60 foot parabolic antennas will become operational around March 1978. In mid 1978, new contracts are expected to be awarded for the medium terminal (MT) equipped with a 38 foot parabolic antenna and the AN/USC-28 anti-jam communications equipment. These contracts are multi year contracts and the FY 1979 request includes funds to exercise the second option for these equipments. The FY 1979 Army procurement funds request for DSCS related ground terminal equipment is \$118.5M. This includes Army funds and Air Force funds to procure tactical GMF terminals to work with the DSCS satellites.

FLTSATCOM. The Fleet Satellite Communications System (FLTSATCOM), now in production, is a major and vital step in improving Naval communications to meet the needs of the fleet in the late 1970s and early 1980s. High frequency (HF) radio communications have served well for years, but are vulnerable to position location and jamming, subject to communications path outages caused by natural phenomena, and are limited in the degree of connectivity and capacity which can be provided. FLTSATCOM provides protection against jamming for fleet broadcast transmissions (shore commands to ships), is highly available, and provides connectivity to all ships and other naval elements in an ocean area. The FLTSATCOM spacecraft also contains 12-5KHz channels, which have anti-jam, to support the U.S. Air Force AFSATCOM mission. In addition, one 500 KHz channel is aboard the spacecraft for other users.

FLTSATCOM operates in the ultra high frequency (UHF) band and also has an SHF uplink. This use of UHF permits small, simple antennas aboard ships and other mobile users, where size and weight are important considerations. To make effective use of the FLTSATCOM capacity, the Navy is developing a family of information exchange subsystems (IXS) to provide automated traffic and access control over FLTSATCOM channels. Special modulation and control equipment is also being developed to permit assignment of satellite channels in a dynamic way in real time, on demand. The Navy's program includes the procurement of shipboard terminals (e.g., transceivers, broadcast receivers, antennas, etc.) for use with the FLTSATCOM system. FLTSATCOM terminal equipment has been installed aboard ships and the installation program will continue through the 1970s. Non anti-jam broadcast capability has been achieved with these terminals using the MARISAT Leased UHF service. All ships are now equipped to receive the Fleet Broadcast and over 250 have a transmit capability.

In 1976, COMSAT General Corporation MARISAT satellites were launched for coverage over the Atlantic, Pacific and Indian Oceans. These satellites are now being used to provide the Navy with a leased satellite relay capability and will continue to be utilized through 1981. The leased UHF service will be augmented by the first FLTSATCOM satellite launched in February 1978.

A DSARC III held in November 1976 authorized the procurement of 5 FLTSATCOM satellites. With MARISAT these satellites are expected to provide a continuing on orbit capability until follow-on General Purpose Satellite Communication System (GPSCS) satellites are available in the early to mid 1980s.

During 1978 review of the FLTSATCOM program, the Congress did not approve the procurement of two spacecraft and reduced the program level by \$47.4 million. As a result of this action, a comprehensive review of the FLTSATCOM program was undertaken. This review included the MARISAT program, the availability of UHF service from follow-on programs and the Navy's requirement to satisfy UHF service to the operating forces.

The review concluded that regardless of the method used to acquire a follow-on program (lease or buy) the three approved FLTSATCOM satellites along with the leased MARISAT program would result in a gap in UHF service. To eliminate this gap in service, the President included in his FY 1979 budget, an FY 1978 supplemental request for the two FLTSATCOM spacecraft previously deleted. The funds to support the procurement of FM #4 and FM #5 are now \$11.3 million higher than was originally deleted from the FLTSATCOM program. The increased cost for these two spacecraft results from the stretch out of the production by an additional six months and the increased cost to the Navy for maintaining the Atlas-Centaur launch complex. In spite of these additional costs, it has been determined that it is still more cost efficient to continue with the program and procure spacecraft number four and five.

The FY 1979 RDT&E request of \$9.1 million in support of the FLTSATCOM program is primarily for work in improvement in interference reduction and anti-jam capability of terminals. In addition work on improvement in satellite channel utilization is continuing. FY 1979 procurement request of \$21.1 million will procure additional WSC-3 terminals 207 secure voice FLTSATCOM terminals and other related satellite terminal equipment.

General Purpose Satellite Communication System (GPSCS). The objective of the GPSCS program is to provide a worldwide communication capability for the Department of Defense's mobile forces, designated nuclear capable forces and the National Command Authorities.

Exact characteristics of GPSCS remain to be defined by a Tri-Service government team and a System Concept and Design Validation competitive phase with industry. Conceptually, however, the system will consist of four operational spacecraft in synchronous orbit with additional satellites in orbit to provide backup capability to enhance the system availability and survivability. Each spacecraft will deploy in orbit a large UHF antenna. While the GPSCS will have a UHF capability in order to protect the large investment in operational terminals, other frequency bands such as extremely high frequency (EHF) and super high frequency (SHF) with crossbanding will be considered in order to provide greater flexibility and versatility of support to the users in all types of environments. With the primary objective of improved communications capability, the satellite will employ a variety of modulation techniques as well as on board satellite signal processing.

The UHF terminals being acquired today will be used to the extent possible and modified as required. However, any new terminal development will be constrained by the operating characteristics of the intended mobile platforms the system is to support (e.g., submarine tactical aircraft and manpack type terminals).

The FY 1979 request for GPSCS is \$8.1 million to be used primarily for concept study and technical development.

3. Early Warning Satellites

The three geostationary satellites remain the backbone of our ballistic missile early warning system. This system will provide the earliest indication of a hostile SLBM or ICBM launch against the U.S.

In FY 1979 we plan to take delivery of the operational prototype Simplified Processing Station (SPS), initiate development of an austere command and status capability for the SPS; continue development of modifications to ensure payload compatibility with the TITAN/IUS and Space Shuttle/IUS and continue development of improvements to the satellite communications elements. The SPS is a transportable, more austere version of the full-up ground stations, and will have the capability to provide a backup for the existing ground stations,

a terminal for deployment of additional satellites, if required, and a direct readout to additional users. In addition, we gain an increase in data survivability through proliferation.

The development of the improved sensor and on-board processing systems completed in FY 1978 will allow an evolutionary improvement to the satellites. The focus of these efforts will be to improve the system accuracy as well as increase on-orbit operational life. These improvements will then be incorporated into satellite procurements and retrofitted into existing spare satellites. We anticipate that these evolutionary changes will ensure that the system will provide the data needed to support National Command Authorities decisions well into the 1980s.

In FY 1979 our effort for early warning satellite programs is \$230.8 million for all appropriations.

4. *Meteorology*

The Defense Meteorological Satellite Program (DMSP) is operated to satisfy DOD requirements for meteorological satellite data. It is the DOD's single most important source of weather data. The mission of DMSEP is three-fold:

To provide timely, high-quality globally recorded (stored) visual and infrared imagery and other specialized meteorological data to support strategic missions;

To provide direct real-time readout of local area weather data to tactical commanders at key locations throughout the world, including Navy carriers at sea; and

To pursue a technology advancement program to meet new and changing DOD requirements more effectively and efficiently.

Two satellites are in orbit at all times, one providing data at approximately 7 a.m. and 7 p.m. local sun time, and the other providing data near noon and midnight, local sun time. The two-satellite constellation thus provides global data coverage four times a day. The recorded data are stored on board the spacecraft and transmitted to one of two CONUS readout stations at Fairchild AFB, Washington, and Loring AFB, Maine. Another worldwide readout terminal is being installed in Air Force Satellite Control Facility terminal in Hawaii and will become operational this year (1978). From there the data are transmitted via a commercial COMSAT link to the AF Global Weather Central at Offutt AFB, Nebraska and Fleet Numerical Weather Central, Monterey, California, for processing and use. Data from the DMSP satellites are also available to tactical commanders through transportable terminals which are situated at key points around the globe and to the civil meteorological and scientific communities through the National Oceanic and Atmospheric Administration. In September 1976 the first launch of the new Block 5D satellite was performed; however, an anomaly precluded collection of weather data until March 1977. Redesign of subsequent satellites has been accomplished to preclude recurrence of the problem which caused the satellite to become unstable after launch. The second Block 5D satellite was launched into the nominal/dusk orbit (the first is in the noon orbit) and it is operational. The Block 5D provides improved visual and infrared imagery of near constant resolution, extend lifetime through redundancy of critical components such as tape recorders and data transmitters, and space to carry additional special meteorological sensors.

Development was continued for the use of the Block 5D as the basic spacecraft bus for the new civil system satellite, the TIROS-N. Agreement was reached in 1975 between NASA and DOD to use the same basic satellite structure. This has resulted in considerable savings of developmental costs to the government. In addition, there has already been a joint DOD/NASA buy of long-lead items from the spacecraft contractor at a lower per-unit cost than would have been charged for separate purchases. This cooperative effort, which is to continue into the next decade, is being coordinated by the Polar Orbiting Operational Meteorological Satellite Coordinating Board, a joint DOD/DOC/NASA group, which has been in operation for more than two years.

The DMSP program office is continuing the modest sensor development efforts which were underway in 1976 and 1977. These efforts are concentrated primarily in the area of improving the satellite and imaging sensor on-orbit life and to a lesser extent in developing special sensors to collect worldwide data on winds, ionosphere, precipitation, soil moisture, and ocean atmosphere interface.

The Navy participation in DMSP and joint service status commenced in 1969. Since that time the Navy procured the design and development of a shipboard

receiving terminal, conducted technical and operational evaluations of the equipment and received provisional acceptance for service use. The feasibility model installed on USS CONSTELLATION is scheduled to be replaced by a production unit. The first production model has been installed onboard the carrier USS KITTY HAWK. A prototype model is on the carrier USS KENNEDY. Additionally, two land-based versions of the equipment are currently operating at San Diego, and Rota, Spain. The Navy effort is being carried out in two project areas: Shipboard Satellite Readout Equipment (SROE) and Defense Meteorological Satellite Program (DMSP) Navy Support. The shipboard receiving equipment required to receive data from these satellites consists of two 6-foot antennas cantilevered from the sides of the ship port and starboard, which are computer controlled to act as a single unit. Eight racks of below deck electronics receive, process, and display the data.

The Defense Meteorological Satellite Program is a joint service program with the Air Force acting as the executive service. As executive service the Air Force has prime management and funding responsibility for the overall system, particularly the spacecraft, launch vehicles and tracking facilities. The Navy effort is primarily to develop and procure peculiar user equipment and to ensure that the overall system has and maintains the capability to satisfy unique Navy requirements. Required changes to the system to meet these unique requirements are the responsibility of the Navy.

The launch and space segments of the system and CONUS readout sites are employed by the Air Force. The Navy direct readout sites are employed aboard aircraft carriers as specified previously are controlled by the Fleet Commanders. Two land based readout sites are under the control of Director, Naval Oceanography and Meteorology. The two vans can be deployed for contingency purposes for SIXTH and SEVENTH Fleets during crisis.

Follow-on testing of the initial production unit is being conducted to establish full acceptance for service use in FY 1978. Concurrent system hardware development is being conducted to provide a laser/dry film processor to replace the existing Cathode Ray Tube (CRT) wet process currently used on Navy readout sites. A joint Navy-Air Force development of an interim passive microwave imaging system is underway. This development is jointly funded to provide microwave sensors to be installed aboard the satellites in the FY 1981-83 time frame. These sensors will provide the Navy with measurements of oceanographic information in response to CNO Operational Requirements.

Although the DoD does not at this time have any dedicated geosynchronous weather satellites, it takes full advantage of data from the Geostationary Operational Environmental Satellite (GOES) system which is operated by the National Oceanic and Atmospheric Administration. There are three GOES-type satellites (two of which are experimental), one stationed at 75°W longitude, one at 105°W longitude, and one at 135°W longitude, thus providing excellent coverage of the Western Hemisphere (excluding the polar regions, which cannot be seen from a geosynchronous orbit). Future Army applications of synchronous satellite data are centered on ground cover visibility (SATSEE) and severe storm (SATSTM) observations obtained from the U.S. geosynchronous satellite systems. These mesoscale data will be available to provide tactical environmental information for conducting battlefield operations. The Air Force has installed a GOES direct readout site at the Air Force Global Weather Central at Offutt, AFB, NB to support Air Force weather requirements. The Navy has installed a GOES direct readout site at Monterey, CA. for use in research and development, and will be installing a Japanese GOES medium data utilization station (high resolution facsimile) on Guam, M. I., in 1978 to utilize data from the Japanese launched GOES. The Guam medium data utilization station will be used to improve the capability to forecast the movement and intensity of typhoons effecting U.S. military forces.

The DoD and NASA have signed an agreement for the Fleet Numerical Weather Central to conduct a real-time data demonstration experiment with SEASAT-A, scheduled for launch in May 1978. NASA will transmit the SEASAT-A collected at Fairbanks, Alaska to FNMC for conversion to geophysical units (wave heights, sea surface temperatures, surface winds, etc.). These data will be used in global maritime weather analysis and forecasting processes. The experiment is an important step in demonstrating the usefulness of oceanographic satellite data in naval operations.

In FY 1979, our meteorological satellite related effort is \$71.3 million.

F. Ocean Surface Surveillance and Targeting

Ocean surface surveillance information is provided by a combination of sensor systems with worldwide and local-area coverage. The former generally alerts the latter to provide a continuity of focused coverage, allowing enemy shipping to be detected, localized, classified and targeted. Location accuracy and data timeliness requirements have become increasingly stringent with the advent of advancing technology in anti-ship cruise missile weapon systems, with extended engagement ranges beyond the horizon.

The requirements in alternative system concept studies for providing targeting information, initiated in FY 1977, were followed in FY 1977 and FY 1978 by critical low cost field experiments. These experiments have dealt successfully with system concepts and doctrinal issues inherent in the combination and correlation of data. They have utilized data from all available sensors and have transmitted the output within a useful time frame. The results are providing the basis for advanced development.

In the near term, ocean surface surveillance and targeting will utilize the land-based BULLSEYE system, and the ship-based CLASSIC OUTBOARD system. These sensors provide excellent broad area ocean surface surveillance sensor capability. This program will enable limited area surveillance.

Concurrent with the sensor-related efforts, several programs continue in development to provide improved ocean surveillance command, control, and communications to correlate and disseminate significant ocean surveillance data to tactical and national command in a timely manner. These programs include the Fleet Command Center (FCC) and Ocean Surveillance Information System (OSIS) ashore and the Tactical Flag Command Center afloat.

G. Supporting Science and Technology

One of our nation's greatest strengths is its sustained scientific and technological vigor. This national strength is key to our continuing national security as it is to the performance advantage of U.S. military forces and weapons systems, and the technological advantage of U.S. military R&D capabilities over potential adversaries. The Science and Technology Program provides the foundation for such military technological superiority. It is the source of the ideas and inventiveness which lead to new weapons systems, to the improvement of existing systems and to the integration of disparate development and equipment units into the coherent systems which underlie our military strength.

We intend to strengthen our space related Science and Technology effort and have increased our funding to \$451 million in FY 1979. This is an increase of \$159.1 million over FY 1978 funding.

The U.S. enjoys world leadership in space technology, but we must not be complacent about our lead. The Soviets are heavily committed to a steadily expanding space effort supporting their military systems. We believe their space Science and Technology effort has been larger than ours for several years. If they can significantly improve manufacturing and process know-how, they will certainly accelerate their space system capabilities.

First, I would like to discuss our programs in an area which we call Space Defense which includes Space Surveillance, Satellite System Survivability, and our Anti-Satellite Program. The Soviets have reacted to the military importance of space systems by the development and test of an antisatellite (ASAT) interceptor that has capability against some of our satellites. In response we began accelerating our research and development programs to prevent the Soviets from gaining a significant advantage. These programs will permit us to increase our ability to observe and monitor space objects and to improve the survival of our satellites. We feel that it is vital that we continue to increase our efforts in FY 1979 on these important space defense activities.

Space Defense

(a) *Space Surveillance.*—A means for locating, tracking, and identifying objects in space is essential for maintaining a space defense capability. Our current space surveillance network consists primarily of ground-based radar sensors that are deployed for purposes other than space surveillance (e.g., missile warning). This sensor network has a very limited capability to detect objects above 3,000 nm altitude and has gaps in the coverage below this altitude.

To enable us to detect and track satellites at high altitudes, we are procuring a Ground-Based Electro-Optical Deep Space Surveillance (GEODSS) system.

This system, when fully operational in the early 1980's, will permit observation of satellites. Funds are requested this year for procurement of the equipment for one site. As another near-term improvement, we are developing the software to give warning of an impending attack on one of our satellites. This capability will be installed in the NORAD Cheyenne Mountain Complex. We will also incorporate improvements into some of our space surveillance radars to increase their detection range and measurement accuracy.

The long-term solution for providing responsive surveillance up to geosynchronous altitude appears to be the use of space-borne sensors. We are undertaking the research and development of the critical technologies and are planning to launch an experimental satellite to demonstrate the feasibility of this concept. In support of this effort, we are conducting an extensive set of background measurement with a series of seven rocket-launched probes. These probe flights, to be launched during the next several years, will characterize the backgrounds for a wide range of wavelengths.

For this Space Surveillance effort we are requesting \$36.1 million RDT&E and \$17.0 million in procurement funding.

(b) *Satellite System Survivability.*—There are a wide variety of methods available for impairing the operation of satellite systems: interceptors or lasers can impart physical damage; lasers can also be used to deceive or blind some classes of satellites; and terrorism or sabotage can be directed at ground facilities. Currently, due to launch vehicle limitations, satellites cannot be burdened with cumbersome defensive devices since they must be designed within rigid weight and volume constraints. Thus, it is neither a simple nor inexpensive task to achieve a high degree of satellite survivability.

Some techniques available for enhancing survivability include proliferating the number of satellites that perform a given mission, designing satellites so that they are not easily observed, hardening satellites against laser radiation, and employing decoys to deceive or a maneuver capability to evade an attacking interceptor. These are some of the concepts and technologies that are being pursued within our broad-based survivability program. We are also developing sensors such as laser radiation and impact detectors to be mounted on the satellite to provide positive indication in the event of a satellite attack.

We are requesting \$19.2 million in RDT&E funding for survivability.

(c) *Anti-Satellite Program.*—The Soviets currently have an operational capability to attack some U.S. satellites. Since we are becoming increasingly dependent on space assets for command and control, navigation and critical surveillance, we are concerned about a Soviet capability to interfere with these satellites. The United States possesses no such capability; our program is still in the research and development stage. The President has concluded that we cannot accept such an asymmetry and has directed two efforts to alleviate it. First a vigorous U.S. effort is being undertaken to seek means of protecting our satellites and developing the capability to attack enemy satellites. This is not a new effort but it is increased as compared to the level of effort in recent years. Second, the Administration is currently involved in inter-agency reviews which could lead to negotiations with the Soviets on curbing anti-satellite capabilities bilaterally. Such an agreement would be in the overall national security interests of both sides.

Our request for Anti-Satellite programs is \$73.0 million of RDT&E funding for FY 1979.

Infrared Space Surveillance Technology

We are continuing to develop the technology that will support advanced infrared space surveillance concepts for the future. Currently, the primary surveillance mission performed from spaceborne platforms is missile attack warning. Under the Air Force's Missile Surveillance Technology Program, a unique mosaic sensor is being developed which would be sufficiently sensitive for fine grain attack characterization. Further, with this sensor deployed on a space platform, surface-to-surface, surface-to-air, and air-to-surface missiles could be detected and tactical surveillance of theater battlefield events would be possible.

Critical technologies under development by DARPA for future surveillance sensors are: (1) highly sensitive charge couple device (CCD) detector arrays capable of being integrated into mosaic sensors, (2) advanced on-board signal processors based on Very Large Scale Integrated (VLSI) circuit technology, (3) efficient and high capacity cryogenic coolers with long operational life-

times, (4) filters, and (5) lightweight optics for large space-borne telescopes. The key to achieving broader capabilities in future sensors is to be able to detect target signatures immersed in strong space or earth background clutter and, at the same time, to maintain the high search rates required for a surveillance system.

Major strides have been made in FY 1978 toward the required tech-objectives. With the current program, DARPA should establish technical feasibility in each of the critical technology areas by the early 1980's.

DARPA is pursuing a major experimental effort for advanced strategic surveillance from space. The technology and concepts being developed will provide better sensitivity. The first major demonstration of this new generation of space sensors is the TEAL RUBY Experiment, slated for launch on a USAF Space Transportation System Flight. In addition to providing target and background information from space in a number of spectral bands, the TEAL RUBY sensor will include on-board signal processing for real time detection and tracking and a filter for suppression to show the feasibility in an operational system.

Surveillance Experiment

The DARPA technology development program for advanced surveillance is guided by a strategic surveillance concept called HALO (High Altitude, Large Optics). A Mini-HALO space experiment that will validate the maturity of the DARPA space surveillance technology and demonstrate the HALO surveillance concepts was initiated in FY 1978. Mini-HALO is currently identified for joint launch with the USAF Mosaic Sensor Program (MSP). The joint flight will provide simultaneous demonstration of technology options for decisions on the next generation of surveillance systems. In this regard, the MSP technology is relatively low risk, and the DARPA Mini-HALO provides higher risk options with significant potential. The increased sensitivity achieved with the operation employed in the HALO concept, coupled with focal plane technology permits expansion of the current missile attack warning mission of spaceborne sensors.

Space Vehicle Technology

In addition to the extensive sensor developments which are described above, we have an important continuing advanced Space Vehicle Subsystem Technology program to improve spacecraft performance, survivability and reliability.

The Fault Tolerant Spaceborne Computer, which is autonomous, monitors its own condition, corrects its own faults and need not be continuously programmed or updated from the ground will soon be in qualification test. The Fault Tolerant Spaceborne Computer will be a major step toward autonomous satellite operations. The Solid State Mass Memory based on magnetic bubble technology, will be in prototype fabrication in FY 1979. This computer-memory team will have a large computational power, will be radiation hard, and have a high probability of remaining fully operational for a five year space mission—all with a one cubic foot volume weighing about 50 lbs. The Solid State Mass Memory will complete prototype fabrication in FY 1979. The Fault Tolerant Computer and the Mass Memory are both radiation hard. The Fault Tolerant Computer is also projected to achieve a major increase in on-board computational reliability. This computer is redundant on the submodular level and 5 and 7 year life on orbit appears achievable.

To provide increased power, a high density Nickel Hydrogen battery will near completion of life cycle testing in FY 1979. A "Boiler-Plate" experimental Nickel Hydrogen battery is in orbit and successfully demonstrating the basic technology. The producibility of silicon and gallium arsenide cells achieving 16 percent efficiency should be demonstrated for the High Efficiency Solar Panel.

Some spacecraft are presently limited in useful life on orbit by the attitude control thrusters. In FY 1979, the 5 lb. Hydrazine Thruster should complete a one million pulse life cycle test to demonstrate a 7 to 10 year synchronous orbit or 2 year low earth orbit capability. As these advanced technology developments progress, many will be further demonstrated in orbit in future Space Test program flights.

For the Space Vehicle Subsystem program we are requesting \$9.4 million in FY 1979.

The Space Test Program (STP) provides testing in space of experimental payloads, several of which were just discussed, which demonstrate new concepts and technology and provide data on the space environment. This summer we plan to launch the DARPA Gamma-Ray Spectrometer payload to demonstrate improved radiation measurement techniques and to provide information on ionospheric background radiation. A total of six experimental payloads will be integrated with the Spectrometer for launch on an Atlas F booster. Two secondary payloads will be flown on host vehicles. The first will measure extreme ultra-violet background earth emissions to aid in surveillance technology and measure atmospheric density to better predict satellite orbits. The second payload is a geodetic package for the Defense Mapping Agency.

The Spacecraft Charging experiment is scheduled for launch early in 1979. This experiment is to help determine methods for minimizing the buildup of static electrical charges on synchronous satellites, a phenomenon which has caused power and data handling subsystem problems on Defense Satellite Communications System, INTELSAT, and TELESAT satellites. A total of 12 experiments will be integrated to form the complete Spacecraft Charging experiment.

In FY 1979 the DARPA Teal Ruby spacecraft development and acquisition phase will begin. We plan to make available space on this flight for two secondary experiments, one of which is a NASA mercury ion millipound thruster for long term station keeping applications. In FY 1979 we will also initiate activity leading to the launch of the Mosaic Sensor and High Altitude Large Optics experiments.

We are requesting \$44.8 million in FY 1979 for the Space Test Program. This significant increase over the \$25.9 million provided in FY 1978 is due to the fact that we are supporting a number of major experiments.

IV. U.S. DEPARTMENT OF DEFENSE AERONAUTICAL ACTIVITIES

A. Introduction

The DoD Aeronautical Research and Development (R&D) program for FY 1979 supports the national defense through development of technology for tactical and strategic aircraft, cruise missiles, early warning aircraft, ground and ocean surveillance, amphibious and ground air assault mobility, and air mobile command control, and communications. The major interests of our aeronautical R&D efforts are to reduce acquisition and support costs, to achieve new operational concepts and capabilities, and to replace and modernize the operational aircraft inventory.

Key technologies which we expect to lead to lower acquisition and support costs are composite materials for airframe structures, which will reduce weight and the number of parts, large scale integrated circuits which will impact virtually all aspects of avionics reducing size and weight while providing improved performance and increasing reliability, and advanced electronic flight control systems which will reduce vehicle weight and complexity.

New operational concepts and capabilities are exemplified by the joint Navy and DARPA program to develop the "X" wing which combines rotary wing vertical takeoff and landing (VTOL) advantages with high subsonic fixed wing (stopped rotor) performance, and the Air Force Advanced Fighter Technology Integration (AFTI) program which will demonstrate the integration of electronic flight control with fire control and expanded maneuver degrees of freedom.

The modernization program moved ahead this past year with achievement of Initial Operational Capability (IOC) for the A-10 Close Air Support Aircraft and accelerating production of the F-16 Air Combat Fighter. Development of new operational concepts continued with the first tethered lift-off of the Navy XFV-12A, a thrust augmented wing vertical takeoff and/or landing (V/STOL) aircraft. Standardization of systems was aided by the Navy's selection of a derivative of the Army's BLACKHAWK (formerly known as Utility Tactical Transport Aircraft System (UTTAS)) Helicopter for Anti-submarine Warfare (ASW).

We continue our coordinated effort with NASA in support of the Aircraft Energy Efficiency Program. The Air Force has completed wind tunnel tests of an installation of winglets, an aerodynamic drag reduction device developed by NASA, on a KC135. We plan to obtain fullscale flight demonstration of this feature. In future demonstrations in the Advanced Fighter Technology Integration (AFTI) program, the Air Force is working with NASA to obtain flight test data on variable camber concepts that would be applicable to super-critical wing designs for advanced transports.

The role of electronics in aeronautics and space continues to grow as a direct result of rapid evolutionary and revolutionary changes in the field of electronics itself. The principal technologies are electro-optics, microwaves, and signal processing devices. Through these technologies, we are improving technical performance and simultaneously achieving reduced size, weight and life-cycle costs and higher reliability. In electro-optics and experimental inertial navigator employing laser gyros has demonstrated an accuracy of better than one nautical mile per hour of flight. In microwave technology, we are now able to obtain real time processing of data for precision mapping. In signal processing, the availability of low cost, light-weight minicomputers permits us to devise system architectures with greater modularity reducing cost through broader application of standard microprocessors.

Remotely piloted vehicle (RPV) development has continued for high personnel risk missions and for over-the-horizon (OTH) observations.

Significant civilian applications continue to spin off from our military aeronautics programs. NASA has obtained flight data on powered lift and the related acoustic environment from instruments installed on our Advanced Medium STOL Transport (AMST) prototypes, the YC-14 and YC-15. These data will assist in eventual development and certification of civil STOL systems. Transport aircraft are now offered that incorporate gust load alleviation systems that are direct descendants from the DoD effort to develop such a system for the C-5 transport. Advances in radar signal processing which had their origins in DoD needs to reduce radar clutter background have resulted in a Moving Target Detector (MTD) radar processor that should greatly enhance the clarity of civilian air traffic control radar displays. The work load on the controller at the air traffic terminal sites can be greatly eased by eliminating confusing clutter and false alarms, such as from flocks of birds, from the radar display. This is a first step toward the future goal of automating much of aircraft tracking. The DoD is pursuing further advances in signal processors that should have continued impact on this civilian application.

Table IV-1 summarizes the DoD program for aircraft and related equipment requested for FY 1979 and presents updated information for Fiscal Years 1977 and 1978. Tables IV-2, IV-3, and IV-4 are breakdowns for the Military Departments' aeronautical budgets for the same fiscal years. The total Aircraft Research Development Test and Evaluation (RDT&E) budget request for FY 1979 is down 18 percent from the anticipated FY 1978 budget. The principal factor in this decrease is a reduction in engineering development for FY 1979. Although the engineering development requests are lower for all military departments, the single largest factor is the reduced request for the Air Force B-1 development reflecting the President's decision not to proceed to production of this vehicle. We have passed the funding peaks in several major system developments including the Navy Air Combat Fighter, F-18, and the Air Force F-16. In contrast to engineering development, the DoD FY 1979 requests for exploratory and advanced development reflect a real growth above inflation. Major influences in these categories include increases for Navy V/STOL development and for Air Force advanced propulsion development.

In the following sections, process in major technical disciplines and aircraft projects is briefly described.

TABLE IV-1.—DOD AIRCRAFT AND RELATED EQUIPMENT

[Dollar amounts in millions]

Development category	Fiscal year 1977		Fiscal year 1978		Fiscal year 1979	
	Amount	Percent	Amount	Percent	Amount	Percent
Exploratory.....	\$214.1	10	\$221.5	9	\$242.1	12
Advanced.....	253.0	11	271.4	10	360.5	17
Engineering.....	1,647.8	73	1,846.5	72	1,336.0	63
Operational systems.....	141.1	6	233.0	9	179.4	8
Total.....	2,256.0	100	2,572.4	100	2,118.0	100

TABLE IV-2.—ARMY R.D.T. & E. PROGRAM ON AIRCRAFT & RELATED EQUIPMENT

[In millions of dollars]

Projects, by development category	Fiscal year—		
	1977 (actual)	1978 (estimate)	1979 (estimate)
Exploratory development:			
Aircraft weapons technology.....	1.6	1.2	1.9
Aircraft avionics technology.....	4.4	5.8	5.8
Aeronautical technology.....	15.9	15.3	15.7
Air drop technology.....	.8	1.2	1.2
Subtotal.....	22.7	23.5	24.6
Advanced development:			
Aircraft power plants and propulsion.....	3.6	3.1	7.0
Aircraft weapons.....	2.1	1.6	.2
Aircraft avionics equipment.....	1.9	1.7	1.3
Aircraft survivability/EW self-protection equipment.....	4.3	2.4	3.8
Air mobility support.....	1.6	1.3	.7
Advanced V/TOL.....	4.0	1.9	3.4
Tilt-rotor research aircraft.....	2.4	2.3	1.2
Rotor systems research aircraft.....	2.0	.5	0
Joint survivability investigation.....	.5	.6	.7
Synthetic flight simulator.....	.9	1.0	.4
Subtotal.....	23.3	16.4	18.6
Engineering development:			
Aircraft avionics.....	3.8	2.8	6.4
Aircraft weapons.....	3.9	15.7	10.5
Aerial scout.....	0	0	5.5
Air mobility support equipment.....	1.1	0.8	1.1
Blackhawk (UTTAS).....	74.8	38.0	3.0
Advanced attack helicopter.....	130.8	164.9	177.4
Cobra TOW.....	7.2	14.4	10.8
CH-47 modernization.....	25.9	32.0	19.5
Composite rotor blades.....	0	.2	2.5
Synthetic flight training system.....	5.4	5.7	4.6
Aircraft survivability/EW system.....	11.3	10.3	9.1
Remotely piloted vehicle.....	0	0	22.0
Subtotal.....	264.2	284.8	272.4
Operational systems development: subtotal.....	0	0	0
Total, Army.....	310.2	324.7	315.6

TABLE IV-3.—NAVY R.D.T. & E. PROGRAM ON AIRCRAFT AND RELATED EQUIPMENT

[In millions of dollars]

Projects, by development category	Fiscal year 1977 (actual)	Fiscal year 1978 (estimate)	Fiscal year 1979 (estimate)
Exploratory development: Aircraft.....	24.8	29.3	31.0
Advanced development:			
Airborne ASW detection.....	1.0	1.0	5.5
Avionics.....	5.8	7.8	13.8
V/STOL developments.....	3.0	5.2	4.5
Airborne electronic warfare equipment.....	11.5	5.4	6.6
Environmental applications.....	2.4	4.3	2.6
Advanced aircraft propulsion system.....	10.8	6.4	6.1
AVBB.....	0	59.8	50.0
TAC air IR countermeasures.....	0	0	1.1
Helicopter IR C/M.....	0	0	.6
TAC CMD, CONT, COM CM.....	0	.8	3.4
Advance maritime patrol aircraft.....	0	0	4.0
V/STOL support.....	0	4.1	11.7
Airborne life support system.....	1.0	1.0	.7
Target system development.....	0	0	.6
Advance aircraft armament system.....	0	0	4.1
Carrier tactical support center.....	4.2	4.6	4.2
Air ASW advanced.....	4.2	1.4	2.9
V/STOL aircraft development.....	46.0	18.4	40.8
Advanced propulsion for V/STOL (advance).....	4.4	0	0
Acoustic search sensors (advance).....	0	0	.9
ABN mine countermeasures.....	7.3	10.9	15.9
Tactical air reconnaissance.....	5.7	9.1	4.8
Aircraft systems (advance).....	2.3	2.8	9.3
Aircraft survivability and vulnerability.....	2.7	2.9	3.9
NATO cross certification.....	0	0	3.0
Remotely piloted vehicles.....	3.9	.4	0
Subtotal.....	116.2	146.3	201.0
Engineering development:			
Aerial target fund.....	6.5	4.5	7.0
Avionics development/VAST.....	12.9	7.9	.3
Airborne night observation system.....	1.2	0	0
Range instrumentation and system development.....	0	1.7	8.9
AIMS/ATCRBS/mark XII.....	1.3	.4	1.8
Tactical ABN sign expl.....	12.9	0	0
Lamps MK III.....	72.1	107.3	124.5
V/STOL/HELO development (engineering).....	8.7	10.0	5.5
AV-88 (engineering).....	0	0	35.6
Aircraft handling and service equipment.....	1.7	1.5	4.7
Environmental systems.....	0	.3	.4
S-3 weapon system imp.....	0	0	1.0
Airborne ASW developments.....	23.2	12.6	12.3
Aircraft IR sign suppression.....	.8	0	1.0
TAC air adaptive ECM.....	0	2.5	5.8
Advanced radar warning.....	0	2.9	.6
Advanced self-protective system.....	0	2.6	16.1
Airborne tactical signal expl.....	0	0	1.1
Air electronic W/F engineering.....	11.8	5.2	10.1
Aerial target system development (engineering).....	13.0	12.9	27.0
VCX (engineering).....	1.0	1.0	0
CH-53E (engineering).....	12.0	18.5	0
Acoustic search sensors (engineering).....	28.9	22.1	9.7
Navy air combat fighter.....	340.6	625.1	473.6
Life support equipment.....	.8	.5	1.8
CH53F.....	0	1.0	4.6
Advanced signal processing.....	0	0	10.2
Subtotal.....	549.4	840.5	763.6
Operational systems development:			
A6 squadrons.....	1.9	3.0	8.5
A7 squadrons.....	.2	.4	1.1
Early warning aircraft squadrons.....	1.2	0	1.4
Aviation support attack air wings.....	0	1.8	.7
Aircraft propulsion eval gen.....	2.4	2.0	2.4
Aircraft flight test gen.....	4.1	4.8	1.3
F14A.....	15.0	34.8	0
EW counter response.....	3.9	4.7	15.8
Subtotal.....	28.7	51.5	31.2
Total, Navy.....	719.1	1,067.6	1,026.8

TABLE IV-4.—USAF R.D.T. & E. PROGRAM ON AIRCRAFT AND RELATED EQUIPMENT

[In millions]

Projects, by development category	Fiscal year		
	1977 (actual)	1978 (estimate)	1979 (estimate)
Exploratory development:			
Aerospace flight dynamics.....	42.1	44.0	49.0
Aerospace biotechnology.....	23.5	24.8	28.2
Aerospace propulsion.....	36.1	39.5	42.8
Aerospace avionics.....	55.9	50.0	55.9
Train and simulate technology.....	9.0	10.4	9.9
Subtotal.....	166.6	168.7	186.5
Advanced development:			
Aircraft propulsion subsystems integration.....	10.2	10.0	16.0
Advanced avionics for aircraft.....	12.7	9.8	11.9
Flight vehicle technology.....	8.1	5.4	10.0
Reconnaissance sensors/processing technology.....	3.7	3.9	3.9
Aerospace structural materials.....	24.4	21.6	17.0
Aircraft alt propulsion technology.....	0	0	1.0
Advanced turbine-engine gas generator.....	11.5	16.4	20.0
Advanced simulator development.....	2.8	3.9	3.9
Combat aircraft technology.....	1.0	1.0	6.0
Advanced aerial target technology.....	5.9	4.3	3.5
Night attack aircraft.....	0	0	10.0
Electronic agile radar.....	15.9	14.1	14.2
Digital avionics info systems.....	6.0	3.8	8.8
Aircraft nonnuclear survivability.....	1.5	1.5	1.5
Modular auto test equipment.....	0	1.5	3.4
Advanced fighter technology integration.....	8.4	9.0	8.3
Aircraft subsystem technology.....	1.4	2.5	1.5
Subtotal.....	113.5	108.7	140.9
Engineering development:			
Advanced avionics equipment development.....	6.0	14.3	5.2
Aircraft equipment development.....	6.7	9.4	6.8
Advanced aerial target development.....	0	0	8.5
B-1.....	482.7	443.4	105.5
Engine model derivative.....	0	0	2.9
EF-111A.....	44.4	17.1	8.8
Flight simulator development.....	6.0	17.9	12.2
AMST.....	29.3	10.0	0
F-16 development.....	259.1	194.1	107.9
FAC-X.....	0	0	1.0
Cruise missile carrier.....	0	15.0	41.2
Subtotal.....	834.2	721.2	300.0
Operational systems development:			
B-52 squadrons.....	3.5	43.0	64.9
C-5 airlift squadrons.....	18.0	38.1	37.2
KC-135.....	6.2	3.8	1.5
F-4 squadrons.....	4.5	2.0	2.0
F-111 squadrons.....	0	0	2.0
F-15A.....	59.6	62.7	10.0
A-20.....	12.9	17.6	18.0
Tactical drone support.....	0.3	1.0	0
Recon RPV.....	0.1	2.2	3.4
Tactical surveillance system.....	0	0.5	0.2
Other programs.....	7.3	10.6	9.0
Subtotal.....	112.4	181.5	148.2
Total Air Force.....	1,226.7	1,180.1	775.6

B. Aerodynamics and Design

We have made notable progress this year in several areas of investigation.

The Army Airdrop Development Program has solved the long-standing problem of inversion-type malfunctions of main personnel parachutes through development of an anti-inversion net, a basketball-type nylon net added around the circumference of the parachute canopy and extending 18 inches down the suspension lines. The net prevents panels of the parachute from blowing through opposite suspension lines during parachute deployment. It has not only eliminated inversion malfunctions, but has produced a bonus effect of practically no malfunctions of any type. In over 90,000 jumps with net equipped parachutes, only two mal-

functions occurred. This represents a savings in reduced personnel injuries and reduced parachute maintenance previously necessitated by inversion burns. A modification program to add the anti-inversion net to field stocks was completed in 1977; all new main parachutes for the Army are equipped with the net.

The Navy has initiated a contract program to modify an A-6 Intruder wing for flight demonstration of the Circulation Control Wing (CCW) concept. This development promises a significant increase in wing maximum lift capability which could be exploited to either reduce takeoff and landing speeds or to reduce wing area. Successful demonstration could result in improved safety and improved payload capability for future aircraft. Just as the Circulation Control Rotor discussed later in this section, the CCW is a direct result of extensive Navy research in applications of the Coanda effect for lift improvement.

The Air Force is pursuing a program to obtain full-scale flight demonstration of winglets which are wing drag reduction devices developed by NASA. Wind tunnel tests of the proposed KC-135 demonstrator were completed which confirmed analytical predictions of an eight percent increase in range.

The Air Force has completed initial flight test demonstration of an Advanced Environmental Control System. This system is designed to provide improved air quality and control for personnel and to reduce the temperature, dust, and humidity in avionics systems cooling airflow. These factors are major causes of avionics system failures in service. It is expected that application of the technology thus far demonstrated will result in a two to six-fold increase in reliability of avionic systems and a weight reduction in environmental control systems.

A technology program to determine the practical applications of Forward Swept Wing (FSW) aircraft design was initiated by DARPA in mid-1977. Three major airframe manufacturers have presented preliminary findings that demonstrate significant benefits and performance gains that are attainable by properly utilizing FSW. One of the traditional performance aspects measures for air warfare superiority is the ability to perform tight turns without loss of speed. FSW fighter aircraft designs appear to exceed their aft sweep counterparts by from 20 percent to 30 percent in turn capability.

The reason that FSW aircraft are not used today is due to a structural problem which, according to theoretical analysis, can be avoided by the use of advanced composite structural materials. The FY 1978 program calls for wind tunnel testing in concert with the Air Force to further confirm FSW potential and to prove the capabilities of advanced composite structural designs.

Development of helicopter technology continued on a broad front. The Army completed a successful series of flight tests of the Advancing Blade Concept (ABC) demonstrator operating in the pure helicopter mode, attaining speeds up to 170 knots. The Army has joined with the Navy and NASA to pursue further testing of the ABC vehicle in the compound configuration at speeds up to 300 knots.

Navy demonstration of the Circulation Control Rotor (CCR) gathered momentum with delivery of flightworthy blades for build-up of the whirl test article. Whirl tests are anticipated in the Second Quarter of FY 1978. The Navy and DARPA are jointly supporting a program to exploit CCR technology in a stopped rotor "X" wing configuration which combines helicopter takeoff and landing capability with high subsonic speed in conventional fixed-wing flight. Extensive analysis, sub-scale wind tunnel testing, and test bed design have been conducted to demonstrate the concept. A full-scale rotor system of a flight demonstration vehicle is being fabricated for test in the NASA/AMES 40' x 80' wind tunnel in July 1978. Following this test, a small flight demonstration vehicle will be fabricated for a FY 1980 flight test program.

The Army and NASA are studying the effects of helicopter rotor blade tip shapes on noise and vibration. The rotor blade tips on a test UH-1 were modified into an ogee shape; tests have demonstrated a 6dB noise reduction and a 20 percent reduction in power required from this design.

C. Propulsion

Propulsion continues to be the pacing subsystem in development of new aircraft. The major thrust of the DoD aircraft propulsion system program is to insure that advanced turbine engine technology is available when required at a minimum cost and with a minimum amount of risk to meet the requirements of future military aircraft propulsion systems. DoD is continuing to support the three programs which form the base of the large turbine engine technology program. These are:

Advanced Turbine Engine Gas Generator (ATEGG) program takes components resulting from exploratory development and featuring advanced aerodynamics and materials technology, and reduced cost component designs, and assembles them into advanced gas generators. The gas generator is the "heart" or core of a turbine engine and includes the high-pressure compressor, combustor, and high-pressure turbine. The ATEGG program tests these gas generators in an operating engine environment.

Advanced Propulsion Systems Integration (APSI) program includes the development of advanced system responsive components such as inlets, fans, power turbines, augmentors, controls, and exhaust nozzles and the overall integration and substantiation of these components with the ATEGG program.

Joint Technology Demonstrator Engine (JTDE) program integrates advanced components developed in Navy programs with ATEGG hardware for a joint Air Force/Navy demonstrator. The Navy program is oriented towards developing advanced components for possible use in V/STOL propulsion systems. Emphasis is continuing to be placed on small engine technology programs as requirements increase for small gas turbines for use in small remotely piloted vehicles, helicopters, targets, and cruise missiles. A competitive demonstrator engine program in the 800 shaft horsepower class has now been initiated by the Army to demonstrate the latest small engine component technology in a complete engine. The Navy and Air Force are continuing to supplement the small engine program by conducting programs in the areas where they have unique requirements, for example, low-cost expendable missile-type engines and high performance long-range cruise type engines.

The drive train program has focused on the potential for significant weight reduction while increasing reliability. An advanced coupling program was completed this year that promises to provide a 30-pound weight reduction in the UH-60A. There are three active transmission programs to build and evaluate critical transmission components. If these components are successful, transmission weight could be reduced by as much as 20 percent, while cost could be reduced by 20 percent and mean time between transmission removals could be increased by up to 100 percent.

D. Stability and control

The Army has completed flight demonstration of a Container Lift Adapter Helicopter (CLAH) system for "hands-off" pick-up and delivery of external loads. The all-electric CLAH is powered from the aircraft and controlled by the flight crew. A detail design for a militarized version including interfacing components and subsystems has been completed; a follow-on program will fabricate and evaluate this version.

Development tests of a Multicyclic Controllable Twist Rotor (MCTR) continued on the Rotor Test Apparatus in the NASA Ames 40 by 80 foot wind tunnel. The MCTR uses an aerodynamic control surface on the outboard section of a rotor blade to vary the twist of the blade collectively and cyclicly. The concept varies the twist at frequencies above the primary rotor frequency to obtain beneficial loading conditions on the blade. The tests showed that MCTR has the potential to substantially reduce blade stresses and vibratory loads.

The Army has initiated a program leading to the development and demonstration of a digital electronic flight control system for helicopters. This system offers the potential economy of fleet wide use of standardized control components as well as increased reliability and survivability.

The Navy continues its development of an 8000 psi lightweight hydraulic system. During the past year an initial flight test series was completed using a modified T2 aircraft.

The Navy has also completed a laboratory demonstration of a skewed rate sensor package for future aircraft. This system combines a unique arrangement of sensors with the computational power and flexibility of a mini-computer to achieve a significant increase in reliability and reduced weight and number of parts.

The Air Force has completed flight test of a YF-16 modified to demonstrate Control Configured Vehicle (CVV) technology. The configuration included vertical canard control surfaces for generation of direct sideforce and a modified control system for generation of direct lift forces and study of relaxed static stability. Both flight test data and pilot flight reports confirm significant improvements in air-to-ground and air-to-air tracking tasks and in precision flying such as maintaining close formation.

An important milestone was passed in 1977 in the Air Force Advanced Fighter Technology Integration (AFTI) program when competitive preliminary design contracts were awarded to McDonnell-Douglas to study F-15 modification and to General Dynamics to study F-16 modification. This year one of these companies will be selected to perform detail design and to modify either an F-15 or F-16 as a flight test demonstrator for integration of digital electronic flight control, integrated fire and flight control, high acceleration cockpit, and several advanced control mechanizations. The demonstration of digital electronic flight control is a joint program with the Navy which foresees important benefits through application of the technology to future V/STOL aircraft.

E. Materials and structures

For the past few years we have reported on our optimism for the potential of filamentary composite materials. This optimism continues to be reinforced by our production experience with the tail sections of F-14 and F-15 aircraft. These components have so far given completely acceptable performance in all Service tests. Through this experience we have gained greater confidence in these materials for potential use on our newer aircraft such as the F-16, F-18, and possibly on the AV-8B. The Army is also moving ahead boldly in this area by developing composite structures for helicopter components such as the aft fuselage structure and a multitubular rotor spar for the AH-1G. Our research and development program with this new class of materials will be continued to attain a higher level of sophistication with basic materials, design theory and fabrication processes. To overcome the temperature limitations imposed by the plastic matrix, we have also initiated programs in the area of filamentary reinforced metals. These efforts will examine the utility and effectiveness of metal-matrix composite materials for spacecraft and missile applications.

The Army is working to improve toughness of existing high-temperature ceramics relative to their application in gas turbine components. The results obtained to date indicate that energy absorbing layers are a very powerful method of improving the toughness of high-temperature ceramics, although further development is required. Improved toughness increases the chances of successful development of gas turbine hot parts from high-temperature ceramics, which will allow development of higher temperature engines having improved size, weight, and fuel efficiency.

F. Electronics

In past years we have described notable progress in a variety of thrusts including infrared imaging, solid state TV cameras, ring laser gyroscopes, fiber optics, compact displays, phased array radar, solid state microwave devices, microwave tubes, signal processing, computer hardware and software, and mini-RPVs. Roughly half of these efforts are directed to improved reliability and cost effectiveness of electronic systems, with the remainder for improved operational effectiveness.

Some recent advances and additional thrusts are described below: integrated circuits (ICs) particularly the use of large scale ICs and microprocessors. The role will continue to increase in all electronic functions aboard both satellites and aircraft, including flight and engine controls and related areas such as flight planning and training. Work has been initiated on ICs capable of withstanding high temperatures so that they can be used within engine modules.

The major program thrust continues to be in advanced control avionics. This includes digital avionics, which provides both improved operational effectiveness and lowered life cycle costs, including the ease in incorporating updated equipment because of the modular design. Fault tolerant architectures have been demonstrated which will increase reliability. Interface standards have been established to promote interoperability.

Two advanced control programs are noteworthy, both aimed at reducing demands on the pilot. The first is concerned with interactive cockpit displays such as to warn the operator of problems and aid him in his decision process by guiding him through a sequence of corrective actions. Here computed-generation of graphic displays is used to simplify messages and attract his attention. For example, one objective is to carry out the full cycle of landing preparation in proper sequence guided by a computer generated checklist. The second concerns automated management of the power generation and distribution systems. If a

generator fails, for example, a computer automatically redistributes the power control, perhaps by turning off non-essential equipment, and then informing the pilot of what it has done. Related programs are directed towards integration of sensors aboard the aircraft to provide increased redundancy and greater accuracy, such as for the control and navigation functions.

Considerable progress has been made towards improved navigation for helicopters. A system has been demonstrated in which a laser beam is used to detect obstacles such as towers ahead of the helicopter for collision avoidance. Work is continuing on this system to reduce costs and to extend the use of the laser to provide terrain following and terrain avoidance navigation. In an advanced development program, doppler navigators are being developed to provide an increase in accuracy.

The ring laser gyroscope (RLG) program has shown encouraging progress. Performance of 1 nautical mile per hour drift has now been demonstrated in a smaller RLG with which an inertial navigation system has been built fitting Air Force standard navigator sizes. Programs for reducing the RLG cost have proceeded on schedule with production units expected to be available in 1980 with a purchase cost comparable to present gyroscopes (\$50K/unit), but with the life-cycle cost reduced by over \$100K per unit because of the elimination of spinning parts. Efforts have been initiated on extending the RLG navigator to other aircraft functions such as flight control.

Major advances have been made in the mini-RPV program. The difficult problem of landing has been solved with a semi-automated net landing system. Only one failure occurred in the last 100 tests. Additionally, automated flight control has been demonstrated in which the mini-RPV automatically flies a preset navigation path, thus reducing operator demands.

Work has continued on solid-state phased array antennas. For communication satellites phased arrays will provide increased link margins to ground terminals by avoiding interfering sources. For aircraft the conformal nature of the array should reduce drag. Advances in this area are dependent on achieving advances in fabrication of high power solid state microwave sources. Recent progress in demonstrating high power from gallium arsenide field-effect transistors and silicon trapped-plasma-avalanche-triggered-transit oscillators provides encouragement for this goal.

"Zero" visibility landing systems continue to be of interest to DOD, including potential use for VSTOL aircraft. To achieve this goal, aircraft roll and yaw in addition to velocity and height must be accurately and rapidly determined as the landing area is approached. Both ground-based sensors for a near-term solution, and aircraft-based sensors for a longer-term solution are being evaluated.

G. Operational systems and systems development

Our aeronautical development efforts listed along mission area lines, are as follows:

1. *FIRE SUPPORT.* The aeronautical arm of the Land Warfare Fire Support mission area includes the in-development Advanced Attack Helicopter (AAH) and the operational COBRA-TOW helicopters.

- a. *Advanced Attack Helicopter (AAH).* The first phase of the AAH program, a two-contractor competitive airframe development, was completed in December 1976 with Hughes Helicopter selected as the winner to enter full-scale development (Phase 2). During Phase 2, the prime contractor will complete the airframe development and integrate the Target Acquisition and Designation System (TADS), Pilot's Night Vision System (PNVS), and other mission equipment into the airframe.

Design-to-Cost (DTC) principles are being stringently applied to the AAH program and the DTC goal of \$1.7 million (fly away unit cost, in fiscal year 1972 dollars including TADS/PNVs) remains valid.

The AAH will possess features which enable it to withstand enemy 23mm weapon fire and be able to perform at night and in bad weather using the PNVS and TADS packages.

In FY 1979, \$177.4 million is requested to continue the AAH development. During the year, both contractor and government flight tests will be conducted with fully equipped AAHs.

- b. *COBRA-TOW.* The TOW-armed Army's AH-1S helicopter (COBRA-TOW) and the Marines' SEA COBRA attack helicopter modification programs are

proceeding satisfactorily. An updated dynamic system provides the improved performance needed to incorporate the TOW missile system, more capable fire control and stores management systems, an updated gun and turret, and survivability features. Along with modification of existing AH-1Gs to AH-1S, procurement of new AH-1S also continues to achieve a homogeneous fleet of AH-1S attack helicopters to fill the "low" side of the "High/Low" attack helicopter fleet mix.

2. AIR MOBILITY. Air Mobility encompasses development programs designed to provide new transport aircraft capabilities, as well as to modify and modernize existing transport aircraft assets. The historical trend of placing increased emphasis on air mobility continues. Continued emphasis is being placed upon the goal of improving combat survivability, decreasing costs, and achieving greater use of common aircraft throughout the Services and consolidation of present aircraft models to standard configurations. This goal is being accomplished by:

Services utilizing aircraft being developed by other Services; e.g., a derivative of the Army's UTTAS has been selected for the NAVY ASW (LAMPS) requirement;

Modernizing old aircraft models to a standard configuration; e.g., CH-47 Modernization Program and the CH-53 Modernization Program;

Improving survivability. The new generation of helicopters will have enhanced survivability afforded by: (1) ballistically-tolerant dynamic components, (2) redundant load paths and redundant components, (3) crash-worthy, fire resistant fuel tanks, (4) greater acceleration capability, (5) optical countermeasure paint and glass, and (6) IR countermeasure paint and devices.

Decreasing costs. The DoD helicopter commonality policy and supporting committees are designed to ensure that the next generation of DoD helicopters will consist of a small family of baseline helicopters, having incremental ranges of complementary performance capabilities consistent with all the U.S. Services' requirements. This approach is expected to avoid \$1.5 billion in RDT&E costs and produce a significant acquisition and support cost avoidance.

Air Mobility encompasses both strategic and tactical mission objectives. Strategic objectives include the capability to meet worldwide deployment requirements. Tactical mission objectives include the capability to air deliver or resupply combat units within a battle theater, perform search and rescue missions, and provide aeromedical evacuation.

a. Helicopter Developments

(1) **BLACKHAWK/UTTAS.** The BLACKHAWK helicopter (formerly known as Utility Tactical Transport Aircraft System (UTTAS)) is being developed by the Army to replace the aging UH-1 series helicopters in the assault and utility missions. Reliability, maintainability, and survivability are being emphasized during the design and development of BLACKHAWK Helicopter.

Sikorsky Aircraft was selected as prime contractor in December 1976 after a flyoff competition with Boeing Vertol. The FY 1979 BLACKHAWK RDT&E request is \$3.0 million, which will provide for airworthiness, flight characteristics, and cold region testing. Initial production delivery of the planned 1107 BLACKHAWK helicopters will begin in late CY 1978.

(2) **CH-47 Modernization.** This program is aimed at improving reliability, maintainability and safety, while extending the life of the Army's medium-lift helicopters an additional 20 years. The present CH-47 fleet of A, B, and C airframes will be overhauled and seven new systems incorporated: (1) fiberglass rotor blades, (2) transmission and drive system, (3) modularized hydraulic system, (4) auxiliary power unit, (5) electrical system, (6) advanced flight control system, and (7) multi-cargo hook load suspension system. In FY 1979, \$19.5 million is requested for roll-out of two prototypes and first flight.

(3) **CH-53 Modernization.** This program is to modify CH-53A model helicopters to a new F-configuration and will result in improved reliability and maintainability, increased range, and extended service life of the CH-53A fleet. In FY 1979, \$4.6 million is requested to initiate extensive analysis of two fleet aircraft, which will be selected for modification as developmental prototypes for this program. Development of the CH-53E will be completed in FY 1978.

b. Fixed Wing Aircraft Development

(1) *C-5A Wing Modification.* The Air Force has determined that the fatigue life of the C-5A wing is inadequate and will result in a projected aircraft life of about 8,000 flight hours. To achieve the required aircraft life of 30,000 hours, modification and strengthening of the wing are required. Fabrication of fatigue and flight test modification kits will be completed during CY 1978. \$37.2 million is requested in FY 1979, to continue development and begin testing of the modification kits. Full scale production of the kits will begin in FY 1980, with installation beginning in FY 1982 and completion scheduled for CY 1987.

3. *AIR SUPERIORITY AND INTERDICTION.* Soviet and Warsaw Pact tactical aircraft and armor enjoy a quantitative advantage when compared to NATO forces. This formidable threat basically establishes the requirement for our Navy and Air Force developments in Air Superiority and Interdiction mission areas. To counter the Pact numerical advantage, our tactical aircraft strive for significant capability advantage to ensure high loss exchange ratios and to generate high sortie rates. Our high/low aircraft mix concept, coupled with effective weapons and protective devices will allow us to meet these objectives.

a. *F-18 Navy Combat Fighter.* The F-18 continues in engineering development and we have requested \$473.6 for FY 1979. The program is on schedule with the exception of a short delay in the engine schedule which will have no impact on first flight in the latter part of 1978. The shortfall in Navy and USMC fighter aircraft will be alleviated by current procurement of the F-14 and the development and procurement of the F-18. We are developing the "fighter" version of the F-18 since the fighter design must be developed before the "attack" design is completed. To date, there has been no decision regarding a possible reconnaissance version, but we are retaining that option. In the fighter version, the F-18 complements the F-14 in the air defense role and will become the Navy and USMC's primary air combat fighter for airpower projection roles. The F-18 will allow us the option of increasing the tactical aircraft inventory of the Navy and USMC as a low-cost alternative to additional F-14s and, at the same time, will enhance overall capability by reducing the number and types of aircraft and engineers deployed by replacing both the F-4 and A-7 series aircraft.

b. *F-16 Combat Fighter.* The first five full-scale development F-16s, including the first two seater, have been produced and are now flying. The program, including the European consortium aircraft, is on schedule and is progressing toward scheduled IOC. The aircraft was approved for full-rate production in December 1977 after DSARC IIIB. We have requested \$107.9M for RDT&E for the F-16 for FY 1979. We have added a Digital Electronic Engine Control to the program and are continuing work on the engine self-starter, nuclear capability, and the back-up fuel control. We are also continuing development on the Avionics Integrated Support (AIS) system which is compatible with the F-16. These changes provide enhanced capability and should result in real savings over the life of the aircraft. The original concept of the F-16 was to develop a low-cost tactical fighter which would complement the F-15, with costs held down by reduced sophistication. This is still our goal and the FY 1979 program supports our objectives.

c. *F-15A EAGLE.* The F-15 is continuing toward maturity and is meeting all its goals. The PEP 2000 program is under way and will provide increased range through the addition of 2,000 pounds of internal fuel. The F-15 with the AIM-7F will serve as our primary theater air defense interceptor and escort fighter, particularly in Central Europe. We are requesting \$10.0 million in development funds for FY 1979.

d. *F-14A TOMCAT.* We are correcting deficiencies in the F-14A engine and avionics systems and are proceeding with a program to develop improvements in the AIM-54 PHOENIX missile system, for which we are requesting \$24.0 million in FY 1979. We expect current aircraft deliveries to exhibit improved reliability, and especially improved engine serviceability. We are continuing to examine ways to improve this weapon system, as it will be a mainstay of our fleet air defenses for many more years.

e. *A-10 Close Air Support Aircraft.* The A-10 aircraft was authorized to proceed with full-rate production in February 1976. The first operational squadron was activated at Myrtle Beach AFB in June 1977. IOC was achieved in October 1977, three months ahead of schedule. Operational Testing conducted to date has demonstrated that the A-10 can survive in the high threat European

environment and operational experience has consistently shown that A-10 reliability and maintainability exceed our expectations. Phase I of FOT&E was completed in February 1977 and data collection for Phase II of FOT&E began in July 1977. The \$18.0 million requested for FY 1979 will continue the updating of the six RDT&E aircraft to an Air Force logistical supportable status and permit integration of additional avionics (i.e., COMPASS TIE and INS).

f. *AV-8B Program.* The AV-8B Improved HARRIER program is structured to develop a light attack aircraft system in the early 1980s time frame with approximately twice the range-payload of the present operational AV-8A HARRIER aircraft. The basic flight demonstration phase of this program involving the development and testing of two prototype aircraft has been approved. This phase of development will be concluded in FY 1979 and the program will be ready to move into Engineering Development. We have requested \$85.6 million funding for this effort in FY 1979. This aircraft will maintain the USMC light attack force capability to meet the projected threat and transition the light attack force to an all V/STOL force required to achieve responsive, flexible, and dispersed capability for projecting power from air-capable ships and from austere sites ashore in support of Marine Corps missions.

4. *STRATEGIC SYSTEMS.* During the past year the President decided not to proceed with production of the B-1 bomber. This decision did not reflect a judgment that the B-1 was not capable of performing the job for which it was designed. Rather the decision was based on the judgment that our progress in cruise missile development has been such that the use of cruise missiles in lieu of procuring the B-1 will better assure the effectiveness of the bomber component of U.S. strategic forces into the 1980s, and moreover do this job at less overall cost.

We plan to continue development of the B-1 through the fourth aircraft, which is the last R&D aircraft to be purchased. We have requested \$105.5M for this purpose. The first three aircraft will be flown until aircraft number four begins flight testing at which time the testing on aircraft numbers one through three will be terminated. Aircraft number four will then be flown until its flight test objectives have been accomplished. Aircraft number four is the first aircraft with defense avionics and testing of the totally integrated avionics will begin in February 1979. No development related efforts are planned.

5. *DEFENSE SUPPRESSION.* The primary threat to aircraft engaged in tactical air operations is the integrated Warsaw Pact network of sea and land-based, radar-directed air defense artillery, surface-to-air missiles and interceptors. Countermeasures against this threat take two basic forms: (1) lethal (self-homing or guided missiles and bombs) and (2) non-lethal (electronic warfare). Developments discussed below are in the non-lethal category and include:

a. *EF-111A Manned Supported Jammers.* The EF-111A aircraft is designed to jam enemy radars and thus deny radar surveillance and acquisition of our strike aircraft. The EF-111A will replace the EB-57 weapon system, which has an adequate tactical jamming capability. The EF-111A will require \$8.8 million in FY 1979 to complete development and to support subsequent tests and evaluation.

b. *Harassment Vehicle Mini-Drone.* The Harassment Vehicle Mini-Drone is a very low cost, expendable, simple, unmanned weapon system, which can effectively contribute to the suppression of the expanding enemy radar-controlled air defense threat. The Harassment Vehicle is launched by small teams operating in the forward area and is preprogrammed to counter specific types of enemy radars. This minidrone uses a self-contained navigation system to approach and orbit a preassigned area where the radar is known to be operating. Once the radar begins transmitting, the Harassment Vehicle will home on and attack the emitting radar. Should the radar shut down, the drone will return to a orbit pattern until the radar comes back on the air. Tests and analyses have clearly demonstrated a capability for this system to maintain an orbit over the intended target radar and home on its target. Effectiveness of the warhead has been demonstrated. Other tests also show the Harassment Vehicle will be extremely hard to detect and counter with anti-aircraft weapons because of its small size.

6. *SURVEILLANCE AND TARGET ACQUISITION.* To provide the battlefield commander with the best near real-time picture of enemy strength, disposition, and movement, we are pursuing a variety of complementary sensor and target locating and reporting developments which include:

a. *Remotely Piloted Vehicles (RPVs).* The 1973 War in the Sinai Desert demonstrated the severity and effectiveness of enemy air defenses in the forward

area. Because of terrain masking and the need for specific target confirmation and designation, overflight of the enemy forward area is often necessary. Such overflight can be accomplished with relatively simple, small, and inexpensive pilotless aircraft carrying a variety of sensors and laser target designators. In the area beyond the FEBA, the low radar, visual, and aural signatures of such mini-RPVs provide a highly survivable platform which can pinpoint targets for avoidance and destruction day or night. In controlled tests conducted in FY 1976, an RPV with TV and a laser designator successfully designated a tank resulting in a direct hit by a Cannon Launched Guided Projectile (CLGP).

Our FY 1979 program includes \$5.5 million for initiation of Engineering Development of the mini-RPV. This Program is the culmination of an Army/DARPA conceptual development known as the AQUILA program.

7. **MULTI-MISSION NAVAL SYSTEMS.** Developments in this mission area include certain naval aircraft which support the objective to meet new and upgraded threats with affordable costs.

a. *Light Airborne Multipurpose System (LAMPS).* The LAMPS operates from and under the control of surface combatant ships such as cruisers, destroyers, and frigates. This helicopter increases the parent ship's anti-submarine, anti-ship, and missile defense capabilities by extending the ranges of sensor coverage and weapon delivery.

LAMPS MK 1 became operational in 1971 and uses converted H-2 helicopters from Navy inventory. The plan for the improved MK II was abandoned in favor of the MK III which is now under development.

\$124.5 million is requested for the LAMPS MK III in FY 1979. The LAMPS III helicopter will be carried aboard frigates, destroyers, and cruisers commencing in the mid-1980s. It will restore to them an advantage in speed and weapon reach against the nuclear submarine. When employed in conjunction with the Tactical Towed Array Sensor System (TACTAS), we expect that the LAMPS MK III will, for the first time, give our surface ships an effective organic counter to advanced missile-firing submarines. In addition, the LAMPS MK III will provide over-the-horizon targeting for HARPOON anti-ship missiles and will help give warning of enemy missiles.

In FY 1979 we will complete prototype LAMPS MK III helicopters, and continue systems development and integration efforts. Tests to date, including at-sea tests in operational environments, give high confidence in LAMPS MK III's ultimate effectiveness in Anti-Submarine Warfare (ASW).

b. *Advanced Naval V/STOL Aircraft.* Our other major new vehicle efforts are directed toward exploring the sea control potential of V/STOL aircraft technology. The V/STOL Aircraft Development Program (\$40.8 million) supports testing of the XFV-12A thrust augmented wing prototype aircraft as well as development effort for a "Type A" V/STOL aircraft. The Type A would be a generic subsonic aircraft, capable of flying from both aircraft carriers and smaller ships, with various versions performing airborne ASW, airborne early warning and control, carrier-on-board delivery and Marine Corps aerial assault missions. Present aircraft that the V/STOL "A" would replace include the S-3A, E-2C, C-2, and CH-46. The related Advanced Aircraft Subsystem program (\$11.7 million) is developing the technology for a wide variety of aircraft subsystems to meet the 1990 threat. These subsystems will be applicable to V/STOL as well as other types of new aircraft.

The Type A V/STOL will be needed by 1991, if it is to meet fleet replacement requirements. The heavy early funding in this program is in recognition of past problems DoD has experienced with V/STOL technology and is intended to ensure that we will have adequate confidence by the early 1980s in our ability to produce a satisfactory V/STOL aircraft. Should we run into any unforeseen inherent technical problems with V/STOL, we would then have sufficient time to develop one or more new conventional aircraft to fill the gap. A supersonic type V/STOL "B" fighter-attack aircraft is planned for later development as an eventual replacement for the F/A-18 and AV-8B.

c. *Advanced Maritime Patrol Aircraft.* The Advanced Maritime Patrol Aircraft (AMPA) program seeks to define a successor to the P-3C, our most effective ASW platform, and to develop a cost-effective land-based supplement to our naval anti-air and anti-ship forces. In accordance with guidance from the House and Senate Armed Services Committees, we will thoroughly explore the potential of existing types of aircraft, including non-Navy aircraft, before making any commitment to a new development. The FY 1979 request, for initial exploratory work, is \$4.0 million.

V. COORDINATION AND COOPERATION WITH NASA

A. Aeronautics and Astronautics Coordinating Board

The Aeronautics and Astronautics Coordinating Board (AACB) is the principal formal coordination mechanism between DoD and NASA. Major policy issues of mutual interest in aeronautics and space are addressed. The Under Secretary of Defense Research and Engineering and the Deputy Administrator, NASA, Co-Chair the Board. Selected issues treated by the Board are discussed below.

1. National Aeronautical Facilities Program

In its final form as defined by the DoD and NASA, the National Aeronautical Facilities Program (NAFP) contained three large facilities which we are convinced are necessary to continue the efficient development of aeronautical technology and systems through the end of this century. The facilities contained in the NAFP are:

Aeropropulsion Systems Test Facility (ASTF)—sponsored by the Air Force to support the economical development of advanced engines for fighter, large strategic transport, and bomber aircraft.

National Transonic Facility (NTF)—sponsored by NASA to permit research and development testing at High Reynolds number in the transonic Mach number ranger (combines the requirements of this earlier High Reynolds Number Tunnel, sponsored by the Air Force, and the Transonic Research Tunnel sponsored by NASA).

40 x 80 Foot Subsonic Tuned Modification—sponsored by NASA to meet subsonic research needs for the study of rotor craft and large powered lift vehicles.

Significant progress has been made on all three facilities during the past year. In August 1977, the Air Force broke ground for construction of the ASTF at Arnold Engineering Development Center, Tullahoma, Tennessee. ASTF procurement is on schedule with cumulative bids received remaining within the total anticipated cost as appropriated by the 94th Congress. NASA has made significant progress in construction of the NTF and engineering of the 40 x 80 foot Subsonic Tunnel Modification is progressing.

NASA is employing an incremental funding profile to support construction of NTF and the 40 x 80 foot modification. I urge your continued support for the incremental funding as requested in NASA's FY 1979 budget submission.

2. Reimbursement for Shuttle services

In June 1976 NASA offered for comment a preliminary proposed policy on reimbursement for Shuttle services to DoD. This initial policy proposed considering all direct and indirect costs as a basis for establishing a price to DoD for a dedicated Shuttle flight. At the October 13, 1976, AACB meeting, the Co-Chairman agreed to explore simpler approaches to developing a fair, reasonable price for such services to DoD. An approach has now been agreed upon which is simple and encourages efficient operations, early transition from expendable launch vehicles to the Space Shuttle, provides pricing stability, and establishes a mutually acceptable price. The DoD reimbursement to NASA will be based on the costs of materials and services, to be mutually agreed upon. The DoD will provide the Vandenberg Shuttle launch support for all non-DoD users in return for provisions by NASA of all Shuttle launch support from Kennedy Space Center and Shuttle flight operations support for all DoD flights. These services are projected to be of approximately equal value to each agency. DoD will be charged a fixed price for the first six years based on realistic average projected materials and services costs. For launches after the first six years, the price will be adjusted annually, based on forecasts of annual costs for that year for materials and services. Details of the policy based on this approach will be negotiated.

3. FY 1979 DOD/NASA Facilities Coordination

Preliminary coordination was begun between NASA and the Air Force for examination of facility programs most likely to be of mutual interest or with high potential for duplication. The normal budgetary review process within each agency reduced the number of proposals. The early start and detailed nature of the review, as well as the desire to make most effective use of resources, all contribute to assuring elimination of unwarranted duplication early in the proc-

ess. The final DOD and NASA review which is essentially complete involves 58 DOD projects estimated to cost \$270.7 million, and 18 NASA projects totaling \$152.5 million. These facilities were included in the President's budget.

4. Shuttle Orbiter Fleet Size

At the request of OMB, NASA with full Air Force support updated the 1976 "Study on Space Shuttle Orbiter Procurement and Related Issues." The results of this 1977 study were reviewed by the Co-Chairmen of the AACB. This comprehensive effort provided the data essential to detailed reviews within the Administration leading to the conclusion that a total fleet of four orbiters, operating from two launch sites, will meet civilian and military flight requirements. Additional orbiters can be considered in future years should requirements warrant such augmentation.

5. Use of Johnson Mission Control Center

The NASA/DOD Memorandum of Agreement signed in January 1977 states that orbiter flight control will be the responsibility of the NASA Mission Control Center at Johnson Space Center for all Shuttle missions. This responsibility includes flight planning, simulation and training, and post-flight operations and analysis relating to the orbiter itself. The handling of classified data for Shuttle missions supporting certain DOD payloads poses special problems at JSC. At present all facilities at JSC are open to the public and security for classified operations is not provided. Prior studies have resulted in expensive approaches to handling Shuttle operations for classified launches. The security issue was discussed at the AACB meeting on July 13, 1977 with the result that an Ad Hoc Group was formed to reassess the security problem. The Group published their findings on November 17, 1977. A low cost option was proposed by the Group, and accepted by the AACB, to modifying JMCC. This option should adequately protect classified payload launches with minimum disruption to civil users. A detailed engineering and management review is now under way to validate the selected approach.

B. Cooperative Programs

1. Rotor Systems Research Aircraft

We need accurate research data on the aeroelastic behavior of advanced helicopter rotors and control systems in dynamic flight conditions. These data are required to supplement static model and full-scale wind tunnel tests, and to verify analytical methods used in helicopter design and ground based simulation. The Army and NASA jointly supported the construction of such a test vehicle, the Rotor Systems Research Aircraft (RSRA). The RSRA is capable of flight testing new rotor concepts up to 50 feet in diameter as they become available for "proof-of-concept" flight research. It is also capable of flying with or without wings and auxiliary propulsion as a compound helicopter to isolate rotor, wing, and propulsion effects by means of its flight control and instrumentation systems.

During the past year, both RSRA aircraft were flown from the contractor's plant to NASA Wallops Flight Center (WFC), Virginia. Contractor exploratory flight testing is continuing at WFC in preparation for delivery to the Army and NASA later this year.

2. Tilt Rotor Research Aircraft

The Army and NASA are jointly developing a tilt rotor research aircraft to prove the concept and obtain full-scale information on tilt rotor aerodynamics, dynamics, structural and environmental characteristics, military mission capability, aircraft handling qualities, and near-terminal operations. Fabrication of both research aircraft is now complete. The first hover flight of the first aircraft was accomplished on May 3, 1977; ground qualification testing is proceeding to prepare for tests of the complete vehicle in the 40 x 80 foot Low Speed Wind Tunnel at the NASA Ames Research Center. Integrated systems tests have commenced with the second aircraft.

3. Super-Critical Wing Technology

In a joint program to explore application of super-critical wing technology to fighter aircraft, the Transonic Aircraft Technology (TACT) program, the Air Force furnished new outer wing panels for an F-111 and NASA is conducting flight tests of the modified aircraft. 124 flights have been accomplished including the first demonstration of a super-critical airfoil at speeds greater than Mach 2.0.

The test aircraft has demonstrated striking improvements in agility, in buffet onset, and in reduced buffet intensity. Final TACT flight tests were completed during the past year with a series to measure buffet characteristics in support of development of a new wind tunnel test method.

4. Fuel Availability

The alternate fuels program is continuing as part of the long-term coordinated effort with the Military Services, NASA, and the Department of Energy to assure that acceptable aviation jet fuel will be available at minimum cost from domestic sources such as oil shale, tar sands and coal. The DoD program is concentrating on the design, fabrication, integration, and testing of components for a propulsion system fueled by non-petroleum based synthetic aircraft fuel. A comprehensive program of ground testing will document the performance of alternate propulsion concepts. We are presently in the first phase of a program to produce 100,000 barrels of shale crude and to refine the crude in a commercial refinery into military specification fuels. Joint agency testing will investigate medical, chemical and material interactions, storage and handling questions. The Navy is managing this overall program with the support of the Army and Air Force.

5. Spacecraft Charging Technology

The Air Force Geophysics Laboratory (AFGL) is actively involved in the Joint USAF/NASA Spacecraft Charging Technology Program. In addition to developing theoretical and empirical models of the natural environment leading to spacecraft electrical charging at synchronous altitude, AFGL is preparing a handbook that will document the full range of variability of charged particles and fields that can be expected at this altitude. Data from the Air Force Scatha satellite, to be launched in 1979, will be included in a future supplement to the handbook. Scatha satellite instrumentation, supplied by the Air Force, will include electrostatic analyzers, charged particle flux spectrometers, and electron and ion beam systems to assess the feasibility of actively controlling satellite charging and discharging. Close coordination between the interdependent activities of the Air Force and NASA continue through the Joint USAF/NASA Spacecraft Charging Technology Program. Models of the energetic electron flux at satellite altitudes will be instrumented to measure energetic electrons in the range 110 MeV. These measurements are needed to determine the dosage rates that satellite microcomponents will be subjected to under operational scenarios.

6. SEASAT

NASA and the Navy have agreed to a cooperative effort for SEASAT-A data processing. The Navy will do real time processing of the NASA SEASAT-A satellite data at the Fleet Numerical Weather Central, and make the processed data available to NASA for distribution to the user community. In 1977, the agreement was expanded to provide for full global coverage of SEASAT-A data. The Navy will also demonstrate the utility of the SEASAT data as inputs to global atmospheric and oceanographic analyses and forecasts. This analysis capability supports the objectives of the National Climate Program. Data processed by the Navy will make possible several important experiments by the private sector of the civil community which are designed to demonstrate the economic benefits of an ocean satellite system.

Looking beyond SEASAT-A, DoD, NASA and NOAA representatives have met over the past year in an effort to determine what common requirements and concepts might exist for monitoring of the ocean surface. To date we have found our needs remarkably similar and this simplifies the task of development of a concept for a satellite system that would meet the needs of all agencies.

C. Support

1. Astronaut Selection

NASA recently announced the selection of 35 new astronaut candidates for the Space Shuttle program. Twenty-one military officers (10 Air Force, 9 Navy, 1 Army, and 1 Marine Corps) are in this group. Fourteen of these 21 are pilot candidates and 7 are mission specialist candidates.

2. Technical Development

DoD has detailed a number of technically trained persons to NASA to assist in programs of mutual interest. The technological transfer back to DoD in unique functional areas is important. The total number of detailees under the program in FY 1978 is 59 (45 from Air Force, 8 from Navy, and 6 from Army). They are

working in a variety of operational and R&D programs but most are associated with the Space Transportation System. The latter activities include space mission planning, avionics and communications security, crew procedures, payloads software, logistics, and facilities construction.

3. Test Facilities

In addition to the joint DoD/NASA test support activities embodied in the National Aeronautical Facilities Program, the DoD and NASA frequently provide tracking and data acquisition support to each other. For example, the DoD Advanced Range Instrumented Aircraft provide NASA with telemetry reception and data relay support in areas where land station instrumentation is not available. The Air Force Flight Test Center provides tracking and data acquisition support to the NASA Flight Research Center as does the NASA Wallops Island facility to the Naval Air Test Center. This type of interagency support avoids costly duplication of resources and operating locations.

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

SPACE SHUTTLE—FOUR OR FIVE ORBITERS

Senator STEVENSON. With only four orbiters in the inventory, will the Department of Defense phase out all the expendable boosters? Does that mean that even though there will be only four orbiters, DoD will not retain a production capability or backup engineering capability to put the expendable launch vehicles back into production? When will DoD make a final decision on phasing out ELVs?

Dr. PERRY. With only four orbiters in the inventory we believe that we can phase out all of the current expendable boosters once the Shuttle is fully operational, so long as we retain the capability to produce an additional Shuttle orbiter when needed. We now plan to procure a minimum number of backup expendable launch vehicles (ELVs) to give us assurance that we can launch our higher priority payloads if the Shuttle is delayed or encounters difficulties in early operational use. When the Shuttle is fully operational we would not anticipate a need to retain a backup engineering capability to put ELVs back into production, since we will have existing a capability to produce an additional orbiter as needed. Current plans are to begin the phase down of ELV production in 1981; however, no final decision on terminating ELV production needs to be made before 1982. We will retain a launch capability for our backup ELVs previously delivered until about 1985. Our final decisions in the future on terminating ELV production and launch capability will be dependent on Shuttle success in early operational use.

Senator STEVENSON. According to the information provided the Committee, based on the updated traffic model, it would cost the taxpayer \$4.3 billion more to go with the four orbiter fleet and two launch sites in the 1980's rather than with the five orbiter fleet and two launch sites. This reflects the larger number of expendable launch vehicles that must be purchased if there is only a four-orbiter fleet. It is also our understanding that to proceed with the production of a fifth orbiter now, as planned last year, it would cost only an additional \$265 million over and above what it will cost to go with the four-orbiter fleet. What is the rationale for buying only four orbiters?

Dr. PERRY. A determination of how many orbiters will be needed can only be made by considering total projected space launch requirements which involve civil as well as military needs. Based on a detailed review within the administration of all available data, the decision was made that NASA should proceed with the production now of a four-orbiter fleet. Additional orbiters can be considered for funding in future years in the event that projected flight rates (or loss of an orbiter) warrant augmentation of the operational fleet.

Senator STEVENSON. In your statement you say: "Extensive studies conducted by NASA, with Air Force support, plus detailed reviews within the administration, have led to the decision that NASA should proceed with the production of a four-orbiter fleet." Do you know of any studies by NASA or the Air Force which reach the conclusion that a four-orbiter fleet is better than a five-orbiter fleet on the basis of economic, national security, or any other measure of effectiveness?

Dr. PERRY. The studies which have been done by NASA, with full Air Force support, have considered the total projected national Shuttle traffic through 1991. The conclusion on numbers of orbiters required are based on the 12-year period

of Shuttle operations through 1991. For this extended period, I am not aware of studies which show that a four-orbiter fleet may be more effective than a five-orbiter fleet. The point that needs to be made is that the decision to produce four orbiters now does not preclude the procurement of a fifth orbiter when needed. There may be an advantage to delaying the decision to procure a fifth orbiter in that more time will be available to gain flight experience and incorporate design changes found to be desirable.

PAYLOAD RESPONSIBILITY

Senator STEVENSON. When DOD payloads are carried by the Space Shuttle, who is responsible for DOD payload in the Shuttle bay?

Suppose there is an accident with the shuttle with a DOD payload in the Shuttle bay. Who would be responsible for the effects of that payload on the environment?

What are the arrangements for responsibility between NASA and DOD for DOD payloads when on-board the Shuttle?

Dr. PERRY. The "NASA/DOD Memorandum of Understanding on Management and Operation of the Space Transportation System" establishes the broad policies which govern NASA and DOD relationships during the life cycle of the STS. The roles of NASA and DOD have been defined for nominal missions. In these cases, NASA is the responsible agency for Space Shuttle flight planning and integrating all flights and users. NASA provides for management, integration, flight operations, and control for all Shuttle flights regardless of launch or landing site used.

For DOD missions, the DOD Mission Director has the ultimate responsibility for mission success. The DOD will perform payload mission planning and payload operations.

Within this broad context, NASA is responsible for safe operation of the Space Shuttle, for maintaining the specified payload environment, and for inserting the payload into the proper orbit. DOD is responsible for maintaining the health and status of the payload, and for declaring readiness prior to Shuttle deployment of the payload in orbit.

In the case of a Space Shuttle accident while a DOD payload is in the Shuttle bay, a joint DOD/NASA accident investigation would be conducted under the provisions of the existing USAF/NASA Agreement for Joint Space Program Accident Investigations. Such an accident would probably cause environmental damage from the combined effects of the Shuttle and the DOD payload. Since we will probably not have commercial or foreign users sharing the Shuttle with DOD payloads, the responsibility for environmental damage would rest with the U.S. Government. Further assignment of responsibility to either NASA or DOD would only be possible, if at all, following an investigation into the specific circumstances of the accident.

DOD SPACE TRANSPORTATION SYSTEM FUNDING

Senator STEVENSON. Would you please provide for the record a table showing the distribution of space shuttle related funds among the various projects, such as the IUS, the construction of facilities, procurement, etc.?

Dr. PERRY. The table providing the information requested is contained on Slide 9—DOD Space Shuttle Utilization—which appears earlier in this transcript. RDT&E (3600) funding, Procurement (3020 and 3080) funding, and Military Construction (3300) funding are shown for the Inertial Upper Stage (IUS), Vandenberg, and Operations Capability Development. Please note that the heading "Operations Capability Development" includes all of our preparations for Shuttle launch (including Kennedy Space Center) not specifically related to IUS and Vandenberg.

VANDENBERG SHUTTLE FACILITY

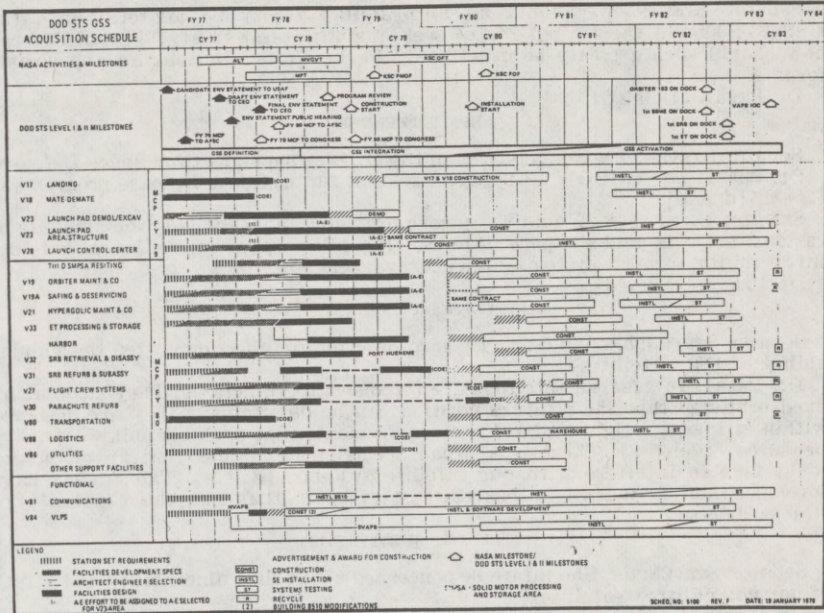
Senator STEVENSON. Would you please provide for the record a schedule for the development of the Space Transportation System launch capability at the Vandenberg Air Force Base?

What is the current estimated total cost for the development of this facility?

Dr. PERRY. The schedule for the development and acquisition of the Space Transportation System Launch capability at Vandenberg Air Force Base (VAFB) follows. It shows facility construction, support equipment (SE) installation, sys-

tems testing and software development for the Vandenberg Launch Processing System (VLPS).

The DOD currently has a total of \$878 million programmed in the five year defense plan (including all prior years) for acquisition of the VAFB Shuttle capability. An upper bound for the total cost has been estimated at \$1.2 billion. This is a rough order of magnitude estimate only, and a detailed breakout is not available.



INERTIAL UPPER STAGE

Senator STEVENSON. Some weeks ago it was reported that the Department of Defense was having a funding problem on the Inertial Upper Stage and that this may cause a slip in the IUS program. What is the status of the Inertial Upper Stage Program?

Dr. PERRY. The Inertial Upper Stage development is going very well and there are no current funding or technical problems. We have just completed the Milestone II review and are proceeding with Full Scale Development.

Senator STEVENSON. What is the total estimated cost to develop the Inertial Upper Stage (IUS)?

Dr. PERRY. The total RDT&E cost for the Inertial Upper Stage (IUS) is estimated at \$260.2 million through FY 1983.

Senator STEVENSON. Last year the Department testified that its best preliminary estimate of the cost per flight of the IUS for government users was \$4.8 million per flight in FY 1975 dollars. This was composed of \$3.8 million for the Upper Stage itself and \$1 million for launch services. What is the estimated cost now?

Dr. PERRY. The Milestone II established an average cost per flight for the first 25 two-stage Inertial Upper Stages at \$6.5 million (in 1975 dollars): \$5.6 million for the Stage and \$0.9 million for logistic support and launch services.

Senator STEVENSON. What is the estimated cost for non-government users?

Dr. PERRY. The DoD is currently formulating a pricing policy for non-government users considering a user charge which would recoup production and operations costs and a share of the DoD's investment in IUS development.

ANTI-SATELLITE TREATY

Senator STEVENSON. If a treaty prohibiting [deleted] anti-satellite systems were agreed to, could we police the treaty; that is, could we detect violations?

Dr. PERRY. [Deleted.]

Senator STEVENSON. Will it be possible to differentiate between a shuttle-type mission intercepting a satellite and the testing of an anti-satellite system?

Dr. PERRY. [Deleted].

Senator STEVENSON. If we can get an agreement that other countries not develop anti-satellite systems, can the United States feel confident [delete].

Dr. PERRY. [Deleted]. If a verifiable agreement of these terms were reached, deployment of an ASAT system would be unnecessary, and of course, would not be permitted by the treaty. [delete].

Senator STEVENSON. Should an anti-satellite treaty be bilateral with the USSR or should the United States seek a multilateral treaty? If multilateral, how should such a treaty be negotiated? Is the United Nations an appropriate forum?

Dr. PERRY. [Deleted].

SPACE DEFENSE

Senator STEVENSON. How much is in the DOD space budget for Space Defense?

Dr. PERRY. The DOD FY 1979 budget request for all Space Defense programs is \$208M. [delete].

Senator STEVENSON. Would you please provide a table showing the amounts of various projects under Space Defense, including space surveillance, satellite survivability, satellite systems, high energy lasers, etc.?

Dr. PERRY. [Deleted].

SATELLITE VULNERABILITY

Senator STEVENSON. Would you please describe for the Committee the vulnerability of U.S. satellites?

Dr. PERRY. In general, satellites are intrinsically vulnerable. They move along fixed orbits so that their future position can be determined; they are designed within stringent weight and volume requirements that prohibit bulky defensive measures; [deleted]. There is a broad spectrum of actions that an adversary could take to interfere with our satellite systems. [delete]. The Soviets have developed and tested an anti-satellite interceptor that has the capability to attack [deleted].

SATELLITE SURVIVABILITY

Senator STEVENSON. Should we be concerned about the vulnerability and safety of our non-military satellites?

Dr. PERRY. Yes, I believe there should definitely be a concern for the vulnerability and safety (survivability) of non-military satellites. Foremost in my mind are the communication satellites [deleted].

SOVIET SPACE PROGRAM

Senator STEVENSON. How do you evaluate the importance of the Salyut 6 space station being visited by Soyuz 26, 27, and 28 and being reprovisioned by Progress I?

Dr. PERRY. By virtue of these activities, the Soviet Union is gaining considerable experience with respect to man-in-space operations and area where the U.S. has held a strong lead for several years. The sophistication of Soviet man-in-space activities has clearly advanced since the Apollo-Soyuz program, but we believe that any near-term gains by the USSR will be quickly offset when the U.S. space shuttle begins routine missions. The scale and intensity of Soviet man-in-space developments is of long-term concern, however, [deleted].

Senator STEVENSON. Is the Salyut 6 mission a significant event in the progress of space activities?

Dr. PERRY. Certainly, in the context of Soviet space programs, but the contributions to international space progress is less evident.

Senator STEVENSON. In terms of space progress, what is your view of the Skylab reboost mission and its future reprovisioning? Would that be a significant advance in the U.S. space program?

Dr. PERRY. It will of course be the first time we have undertaken these technically demanding operations. We are seeing the beginning of a new era in space, and the Shuttle activities will signal important changes in the character and economics of space programs for the U.S. and the world.

Senator STEVENSON. You mention briefly in your statement some of the problems the Soviets are having with their space program: one of which is their failure to meet their commitment to launch a geostationary meteorological satellite by January 1, 1979, in support of the Global Atmospheric Research Program.

Does the Department have any specific idea as to why they are unable to meet that commitment?

Dr. PERRY. The Soviet announcement that they would not meet the GARP schedule may simply be a matter of priorities. The Soviet space program, as you know, is dominantly military in character, and in fact their total program is under military leadership. There are possible technical reasons: most of the booster types employed by the USSR are not suited for placing satellites in geostationary orbits, and they may have experienced difficulty in meeting instrumentation requirements.

Senator STEVENSON. How many geostationary satellites have the Soviets launched to date?

Dr. PERRY. The Soviets have deployed [deleted] payloads to geostationary orbit. [Deleted].

Senator STEVENSON. The Soviets have not made much use of geostationary orbit. Why?

Dr. PERRY. Geostationary satellites are deployed in the equatorial plane, and the coverage available for, say, communications relay purposes diminishes as the geographical latitude of the ground terminal increases. Because much of the Soviet Union lies near or above the Arctic Circle, use of geostationary orbits may simply have been less attractive to the USSR than the orbital configuration they have extensively employed. This configuration—the so-called Molniya orbit—entails deployment into an inclined, highly elliptical orbit which is optimized for coverage of the northern hemisphere. Requirements for injection of a payload into the Molniya orbit are less demanding than for the geostationary orbit, but two satellites are required to provide continuous service.

Senator STEVENSON. You also note that the Soviet systems are generally less reliable than U.S. systems. [Deleted.] Why are U.S. satellites generally more reliable than Soviet systems?

Dr. PERRY. Achievements of long on-orbit operational life requires careful attention to technological detail and quality control during system fabrication. The payoff for such efforts is lower operating cost. The Soviet space program is evidently less constrained by the kinds of cost considerations that govern our program, and the Soviets appear to be investing technological resources in achieving a wide variety of space mission capabilities—several of which have no U.S. counterparts—rather than in achieving very high quality systems.

Senator STEVENSON. How can it make sense for the Soviets to launch [deleted] satellites—their [deleted] spacecraft—which [deleted] have a lifetime of, at most, a few months?

Dr. PERRY. From our standpoint—in terms of how we would use technology to accomplish similar functions—the Soviet program does not make sense. One can only conclude that the Soviet Union has given a very high priority to trying to achieve a [deleted] capability, and that the technology available to them is inadequate to support a less costly approach.

Senator STEVENSON. [Deleted.]

Dr. PERRY. [Deleted.]

Senator STEVENSON. [Deleted.]

Dr. PERRY. [Deleted.]

Senator STEVENSON. The Soviets launched [deleted] space missions in 1977 and had [deleted] failures; the United States had a total of 26 launch attempts and 3 failures. Clearly for 1977 the Soviet launch success rate was substantially above that of the United States. How does their launch success rate over the last ten years compare with that of the United States?

Dr. PERRY. Over the last ten years, the Soviet Union achieved a launch success rate of approximately [deleted] percent. The corresponding U.S. figure is 93 percent.

Senator STEVENSON. How do you evaluate Soviet capability for developing advanced aerospace technology?

Dr. PERRY. The Soviet aerospace development programs are generally shrouded in secrecy, and we can only infer their capability in terms of the systems they have actually deployed. Even in such instances, our understanding of their technology is frequently incomplete. The Soviets appear to subscribe to a policy of exploiting available developments to the greatest possible extent, rather than developing new technology to achieve better performance or lower-cost systems. There is no question, however, that they have been innovative and aggressive in seeking applications for their technology which have no U.S. counterparts.

Senator STEVENSON. What do you see as the basic weaknesses in Soviet technology, particularly in their aeronautical and space technologies?

Dr. PERRY. If there is a basic weakness in Soviet technology, it is in capability to produce equipment and systems embodying advanced technology in significant quantities. There are of course important exceptions to this observation, but the lags we see in technological quality of Soviet aeronautical and space systems generally fall in areas requiring advanced production technology and skills.

Senator STEVENSON. What is your estimate of the Soviet space budget?

Dr. PERRY. There are no reliable data on Soviet outlays for space. Uncertainties in the character an implementation of certain Soviet space programs preclude a precise determination of the U.S. cost to duplicate the Soviet space program, but we estimate that it would have cost us at least [deleted] to duplicate Soviet space activities in 1977.

DOD BASIC RESEARCH

Senator STEVENSON. How does DoD differentiate between basic and applied research? Is support of basic research an appropriate function for the Department of Defense?

Dr. PERRY. DoD does not categorize its research efforts into basic and applied research. The DoD Category "Research", which is often referred to as 6.1, supports fundamental work having a potential relationship to DoD's mission. Many of the efforts are of very basic nature and their resolution are important to the Department's goal of having technical options available for the solution of long-term critical national security problems.

Senator STEVENSON. What is current Department of Defense policy with respect to the support of basic, research, and how has this policy changed in the past few years?

Dr. PERRY. There has been no fundamental change of policy with respect to the support of basic research in the past few years. Research proposals are scrutinized for quality and a potential relationship to long-term national security needs. It is our intention during non-crisis periods to increase our support of Research, including higher risk and longer term research efforts, to improve our long-term defense posture. This is reflected in our FY 1979 request for the Research Category which provides for 7 percent real growth over the FY 1978 program.

DOD RESEARCH PROGRAM

Senator STEVENSON. What trends can you identify in DoD support of basic research? How has the Mansfield Amendment affected DoD's support of basic research and DoD-university relations?

Dr. PERRY. The DoD Research Category, which includes basic research, was essentially level funded during the period FY 1966—FY 1976. However, this trend was reversed in FY 1976 to provide for an increased rate of growth for this part of the DoD Research, Development, Test and Evaluation Program. The provisions of section 204, PL 91-441 which requires a potential relationship to a military function or operation, in DoD's view, has not adversely affected the DoD's Research Program. However, parts of the academic community perceive the Act as an impediment to strengthening the DoD-university relationship.

DEFENSE SCIENCE BOARD TASK FORCE

Senator STEVENSON. In 1976, the Defense Science Board Task Force on Fundamental Research in Universities issued its report on the status of basic research in the Department of Defense. This report contained several recommendations, including: (a) the allocation of up to \$100 million in "new money" for basic research; (b) that some form of peer review mechanism for review and selection of research proposals be developed by DoD; (c) that additional emphasis be placed on institutional grants as opposed to individual investigator grants; and (d) that emphasis be placed on the funding of proposals received from younger faculty members.

What has been the DoD response to these recommendations? What changes in policy have come about as a result of this Task Force report?

Dr. PERRY. The DoD has studied the recommendations and they have been an important stimuli to the following DoD actions: (1) The Department of Defense has requested that the Research Program be increased by 7 percent, in real terms, in FY 1979; and, (2) DoD plans to commence in FY 1979 a new Defense Science and Engineering Program (DSEP) with the objective of improving long-range national defense capabilities by making greater use of high quality scientific creativity and engineering inventiveness resident within the academic community. DSEP, however, is not an institutional aid program to universities

but seeks high quality long-term research in broad yet focused scientific and engineering areas of interest to DoD. Younger faculty academic researchers will be encouraged to send in proposals. The proposals will receive thorough and competent technical reviews developed by the Offices of Scientific Research in the Military Departments. In addition, the Department is working with the President's Science Adviser in attempting to achieve greater use of younger faculty members.

R&D INCREASE BECAUSE OF PRESIDENTIAL DIRECTIVE

Senator STEVENSON. In November last year during the preparation of the FY 1979 budget when presenting the National Science Medal, President Carter noted that Federal agencies had given R&D a low priority in the FY 1979 budget requests. He directed OMB to increase these items.

Was the R&D budget of the Department of Defense increased as a result of this Presidential Directive?

Dr. PERRY. This Directive was a factor in establishing a growth rate of 7% in real terms for the Science and Technology portion of DoD's Research, Development, Test and Evaluation request.

AEROSPACE TECHNOLOGICAL LEAD

Senator STEVENSON. Is U.S. leadership in aerospace technology threatened?

Dr. PERRY. If we continue to maintain a strong science and technology program coupled with a broad industrial base, I do not believe U.S. leadership is threatened.

TOTAL DOD FY 79 RESEARCH AND DEVELOPMENT REQUEST

Senator STEVENSON. What is the total DoD research and development request for FY 1979?

Dr. PERRY. The total DoD Research, Development, Test and Evaluation request for FY 1979 is \$12,468.0 million.

TOTAL DOD FY 78 RESEARCH AND DEVELOPMENT REQUEST

Senator STEVENSON. How does this request compare with your FY 1978 budget.

Dr. PERRY. The FY 1978 total DoD Research, Development, Test and Evaluation budget is \$11,412.6 million.

R&D INFLATION RATE BETWEEN FY 1978 AND FY 1979

Senator STEVENSON. What is your estimated rate of inflation going from FY 1978 to the FY 1979 budget?

Dr. PERRY. The inflation rate between FY 1978 and FY 1979 was approximately 6%.

R&D INFLATION RATE BETWEEN FY 1977 AND FY 1978

Senator STEVENSON. What was the inflation rate between FY 1977 and FY 1978?

Dr. PERRY. The inflation rate between FY 1977 and FY 1978 was approximately 7%.

DOD R&D BUDGET

Senator STEVENSON. What percentage of the Department of Defense R&D budget is devoted to aeronautical and space activities?

Are you satisfied that these requests will permit the department to carry out the aeronautical and space programs needed for the national security?

Dr. PERRY. In the Department of Defense Fiscal Year 1979 budget for research, development, test, and evaluation, 17 percent of the funds are programmed for aeronautical activities and 10 percent for space activities.

The overall decrease in aeronautics funding for FY 1979 is caused by a reduction in the engineering development category. Although the aeronautics engineering development requests are lower for all Military Departments, the single largest factor is the reduced request for the Air Force B-1 development reflecting the President's decision not to proceed to production of this vehicle. We have passed the funding peaks in several major system developments including the Navy F-18 and the Air Force F-16. In contrast to engineering development, the DoD FY 1979 requests for exploratory development and advanced development in aeronautics reflect a real growth above inflation. Major influences in these

categories include increases in Navy V/STOL development and for Air Force advanced propulsion development. I believe that the requested aeronautical funding for FY 1979 is adequate to carry out all the programs needed for our national security.

The overall space activity research, development, test, and evaluation funding requested in FY 1979 is \$1,260.7 million. This is a substantial increase over the FY 1978 funding level of \$844.1 million. The increase is largely attributable to the accelerating pace of our program for Shuttle use, and to increasing development effort on certain space systems, such as the NAVSTAR Global Positioning System and the Air Force Satellite Communications System. Our Space Defense effort has increased sharply and we are placing much more emphasis on our science and technology which provide the foundation for our military technological superiority. I believe that the funding requested in FY 1979, if managed vigorously, will maintain the needed momentum in our space activities.

NAVSTAR/GLOBAL POSITIONING SYSTEM

Senator STEVENSON. Recently the Air Force launched the first NAVSTAR Global Positioning System (GPS) satellite. How is the first GPS satellite behaving?

Dr. PERRY. The first satellite was launched on February 22, 1978 from Vandenberg Air Force Base, California. The final orbit maneuver was performed successfully on March 22, 1978, and all satellite subsystems are operating at or above specifications.

Senator STEVENSON. You state DoD has not seriously studied civil applications for the NAVSTAR Global Positioning System. Is there any real bar to civil applications?

Dr. PERRY. No. We have concluded that the so-called "Coarse/Acquisition" signal of NAVSTAR could be made available for civil use under all conditions, providing navigation accuracies of 100-200 meters to suitably equipped users. The precision signals, however, could provide adversaries with a capability detrimental to national security. For this reason, the Department of Defense expects to maintain control of the system so that we can deny the precision (10 meter) information to unauthorized users under certain conditions.

Senator STEVENSON. What equipment is required on the satellite to permit civil sector use?

Dr. PERRY. The satellites as currently configured, continuously transmit two distinct signals: (1) A "Precise" signal capable of providing the full 10-meter accuracy, and (2) a "Coarse/Acquisition" signal that is capable of providing navigation accuracies of 100-200 meters and is also used as an aid to acquire the more precise signal. Equipment can be produced for civil use of the Coarse/Acquisition signal without any modification to the satellite.

Senator STEVENSON. What type of user equipment is required to take advantage of NAVSTAR capability? How expensive is this equipment?

Dr. PERRY. Military equipment currently in development ranges in cost from \$10,000 to \$30,000, depending on the performance and intended application of the equipment. Except for the lowest-cost receiver, all military equipments employ the precise signals and are capable of providing highly accurate positioning and navigation data. These units are designed for installation in aircraft, ships, land vehicles and in manpack form. It has been estimated that user equipment for civil use could be produced in large quantities at unit costs of \$3,000 or less, depending on whether or not the satellite signal waveform is modified. The Department of Defense is not developing this type of equipment.

Senator STEVENSON. Would NAVSTAR be unavailable to the civil sector in the event of a national emergency?

Dr. PERRY. The Department of Defense expects to maintain control of the system so that the precise (10 meter) positioning capability can be denied to unauthorized users under certain conditions. Our current thinking is that the "Coarse/Acquisition" signal, capable of providing 100-200 meter navigation accuracy would be available for civil use under all conditions.

DOD SPACE PROJECTS COST AND SCHEDULE

Senator STEVENSON. Would you please provide for the record a table showing the estimated total cost (including launch costs) and the launch schedule for each of the DoD major space projects?

Dr. PERRY. The estimated cost for each major space project is contained in the enclosed table as you requested and is similar to that provided for the record last year.

TABLE—SUMMARY FOR MAJOR DOD SPACE PROJECTS

[In millions of dollars]

Program	Funding			Total	Space launches	Remarks
	Fiscal year 1978 and prior	Fiscal year 1979	Estimated funding fiscal year 1980-83			
Navstar GPS.....	325.0	129.0	1,386.0	1,840.0	Fiscal year 1977, year 1; fiscal year 1978, 3; fiscal year 1979, 2. Further schedules not established.	DSARC II planned for early 1979. Total funding represents extensive user equipment (30,000 user) and operational satellite constellations. Funding includes all services.
AFSATCOM (FY DP).....	44.0	13.9	52.2	110.1	Transponder launches—Launches reported by host program	Funding shown is for space segment only. Terminals are not included.
DSCS II.....	523.0	8.1	10.4	541.5	Fiscal year 1977, 2; fiscal year 1978, 4; fiscal year 1979, 1; fiscal year 1980, 1; fiscal year 1981, 2	Funding for terminals for DSCS is not included. Includes launch vehicle procurement dollars.
DSCS III.....	110.2	43.0	383.8	537.0	Prototype satellite launches in fiscal year 1979 (1) and fiscal year 1980 (1). Production launches start in fiscal year 1982 (2).	DSARC III scheduled for current year 1980. Includes IUS procurement and STS launch costs.
Fitsatcom.....	489.5	104.4	431.2	1,025.1	Fiscal year 1978, 1; 2 remaining, schedule not established.	Funding shown is for space segment and terminals.
Leased Fitsatcom.....	66.5	29.7	142.1	138.3	3 leased satellites (Gapfillers) are presently in orbit	Leased Fitsatcom's will augment Fitsatcom until GPS/CS is available.
Defense metrological satellite program (DMSP).....	397.0	63.4	374.4	834.8	Fiscal year 1978, 2; fiscal year 1979, 2; 4 additional through fiscal year 1983.	Air Force funding only. Navy funding fiscal year 1979, \$5,500,000; fiscal year 1980-83, \$31,000,000; total, \$68,500,000.
Space Shuttle.....	257.5	423.9	861.9	1,543.3	No launches planned before fiscal year 1980.	Space Shuttle planned to be operational at KSC in 1980 and at Vandenberg AFB in 1983.

¹ Leased through fiscal year 1981. Lease may be continued if satellites are operating properly.

HYPERSONIC RESEARCH

Senator STEVENSON. NASA recently deemphasized hypersonic research and withdrew from the joint NASA-Air Force National Hypersonic Flight Research Facility which was to be a versatile test bed for flight testing of advanced structures, aerodynamic configuration, propulsion, and other subsystems. Is DOD concerned with NASA's withdrawal from this project?

Is the Department of Defense continuing its hypersonic research?

Dr. PERRY. As Dr. Kramer, Associate Administrator for Aeronautics and Space Technology of NASA, noted to you in his statement of 7 March 1978, the deemphasis in hypersonic research involved deferral of the manned flight research vehicle, the National Hypersonic Flight Research Facility (NHFRF). The NASA hypersonic research program continues. The Department of Defense (DOD) is not concerned by the NASA withdrawal from the NHFRF program. We do not believe that manned hypersonic flight test, as envisioned by NHFRF, is necessarily the best course for hypersonic research at this time.

The Department of Defense is continuing hypersonic research at a low funding level with the emphasis on obtaining information from ground based testing.

AEROPROPULSION SYSTEMS TEST FACILITY

Senator STEVENSON. What is the current cost estimate for the Aeropropulsion Systems Test Facility? Do you anticipate any technical problems or cost escalation of this project?

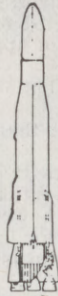
Dr. PERRY. Our current estimate is that the Aeropropulsion Systems Test Facility (ASTF) will cost \$437 million as appropriated by the 94th Congress. We expect no technical problems or cost escalation on this project. The ASTF required no technology advances to achieve the design performance; it is conceptually similar to other engine test facilities at the Arnold Engineering Development Center. Our confidence in meeting the cost is bolstered by the receipt of construction bids. With over eighty-five percent of the construction program bids received (based on anticipated dollar cost), firm bids accepted are underrunning the estimated cost by a small amount.

DOD LAUNCH VEHICLES

Senator STEVENSON. Would you please provide for the record a set of charts showing the DOD space launch vehicles in production and development and the total cost of each vehicle, including launch operations cost, for each configuration.

Dr. PERRY. The requested chart follows.

**DOD EXPENDABLE LAUNCH VEHICLES
TITAN III OPERATIONAL CONFIGURATIONS
FY 79 PROCUREMENT**



ATLAS E/F



T III D/IUS



T III D

PAYLOAD	2300	24,600	24,600
90°/100 NMI (WTR)	-	30,900	30,600
100 N MI (ETR)	-	~ 4000	-
SYNC EQ	-	-	-
ESCAPE ETR	-	-	-

RECURRING
COST
(\$ MILLIONS)

\$ 7.8
@ 4/YR

\$53.8
@ 1/YR

\$44.3
@ 3/YR

LIGHTER THAN AIR TECHNOLOGY/HEAVY LIFT

Senator STEVENSON. What is the DoD doing in the area of lighter-than-air technology for heavy lift applications?

Dr. PERRY. All current Department of Defense efforts in lighter-than-air technology for heavy lift applications are being performed by the Navy. The Navy is focusing its activities on two concepts which employ combinations of lighter-than-air and rotary wing technologies. The first concept, a rotating winged and powered balloon, has recently been flight tested at large model scale and the results are being analyzed. The second concept, a conventionally shaped dirigible, augmented and controlled by four helicopter type rotors, is presently undergoing wind tunnel model tests and preliminary design studies.

Senator STEVENSON. How much are you budgeting for this work in FY 1979?

Dr. PERRY. Approximately \$400,000 is budgeted for this work in FY 1979 with the final amount to be determined at the time of appropriation of Navy Exploratory Development funds by the Congress.

Senator STEVENSON. Are you coordinating this activity with NASA?

Dr. PERRY. Yes.

Senator STEVENSON. Do you believe lighter-than-air has advantages or disadvantages over heavy lift helicopters?

Dr. PERRY. Hybrid lighter-than-air concepts that combine dynamic lift and buoyant lift appear to be more cost effective than helicopters for heavy lift payloads above 40 tons. There is a concern, however, about possible problems associated with operating and basing support for large hybrid, LTA vehicles.

Senator STEVENSON. What is the current status of your work on heavy lift helicopters?

Dr. PERRY. Heavy lift helicopter work is directed at introducing the CH-53E with its 16 ton life capacity into production and into service use. As indicated in our FY 1979 budget request, engineering development work on the CH-53E will be completed in FY 1978.

SPACE DEFENSE

Senator STEVENSON. What are the purposes of the special infrared sensor satellite system known as TEAL RUBY and the [deleted] satellite system, [deleted]?

Dr. PERRY. The purpose of TEAL RUBY is to demonstrate an advanced infrared [deleted] sensor concept for aircraft surveillance from space. [Deleted]. The potential application for which these experiments are being conducted is quite different and as a consequence the technologies are quite dissimilar.

NASA/DOD COORDINATION

Senator STEVENSON. In your view, does NASA consider adequately the DoD needs in structuring its aeronautical and space program?

Dr. PERRY. I believe that NASA does adequately consider DoD needs in structuring its aeronautical and space programs. The major mechanism for advising NASA of DoD needs is the Aeronautics and Astronautics Coordinating Board which is chaired by Dr. Lovelace for NASA and myself for DoD. The Board provides broad policy guidance on major problems of concern to both agencies and its subsidiary panels and subpanels provide annual review of objectives and programs for aeronautics and space.

Many other joint activities exist through which NASA gains insight on DoD perceptions of needs. They include:

- Joint Steering Committees;
- Topical Reviews of Technology;
- Workshops;
- Joint Study Teams;
- Joint Program Management;
- Ad Hoc Review Committees.

Senator STEVENSON. Are you satisfied with the aeronautical research support you are receiving from NASA?

Dr. PERRY. I believe that NASA's aeronautical research support to DoD is good. All of our Military Departments rely in some degree upon NASA research. To the Army, the major contributors are NASA efforts in helicopter rotor airfoils and vehicle dynamics. To the Navy, the major contributions come from NASA

efforts in V/STOL flow fields near the ground and lift augmentation. To the Air Force, the major contributions are in aeroelastically tailored wings and advanced airfoils for all speed regimes.

Senator STEVENSON. Are there any specific areas of research which you believe NASA should emphasize in the national interests—for either military or civil purposes?

Dr. PERRY. I believe that NASA should continue its program in helicopter-related research where there is still great opportunity for improvements in aerodynamics, dynamics, and mechanical systems. This area is important for both military and civil purposes. The development of Vertical or Short Takeoff and Landing (V/STOL) technologies is especially important to the Navy. NASA assistance is inherent in our plans for the development of V/STOL for military needs.

The Aircraft Energy Efficiency (ACEE) program is a must for both civil and military needs in the future. Our conceptual studies of land-based patrol aircraft with long endurance depend heavily on NASA success in this area. The continued balance of payments advantage for our civil aircraft industry is clearly dependent on maintaining an economic performance advantage for our aircraft which is the main focus of the ACEE program.

Senator STEVENSON. Would you please provide for the record a discussion on the mechanisms, including frequency of use, that exist between the Department of Defense and NASA for coordination, technology transfer, and technical assistance on an ad-hoc basis to assure the maximum interchange and application of new technology and the elimination of duplicate technical efforts. Briefly describe some examples that illustrate the use of these mechanisms.

Dr. PERRY. Mr. Chairman, I believe that coordination between NASA and DOD is quite effective and provides project cooperation, coordination, technology transfer, and technical assistance as well as minimizing duplication of effort. I think just how effective will become apparent when I review some of the mechanisms for coordination and what they have accomplished.

A. Aeronautics and Astronautics Coordinating Board

The Aeronautics and Astronautics Coordinating Board (AACB) is the principal formal coordination mechanism between DOD and NASA. Major policy issues of mutual interest in aeronautics and space are addressed. The Under Secretary of Defense Research and Engineering and the Deputy Administrator, NASA, Co-Chair the Board. I will discuss several selected issues treated by the Board.

1. *National Aeronautical Facilities Program.*—In its final form as defined by the DOD and NASA, the National Aeronautical Facilities Program (NAFP) contained three large facilities which we are convinced are necessary to continue the efficient development of aeronautical technology and systems through the end of this century. The facilities contained in the NAFP are:

The Aeropropulsion Systems Test Facility (ASTF) sponsored by the Air Force, the National Transonic Facility (NTF) and the 40 x 80 Ft Subsonic Windtunnel Modification, both sponsored by NASA. Significant progress has been made on all three facilities during the past year.

2. *Reimbursement for Shuttle Services.*—As a result of an AACB initiative in 1976, an agreement on DOD reimbursement to NASA for Space Shuttle Services has been reached. The approach is simple and encourages efficient operations, early transition from expendable launch vehicles to the Shuttle, provides pricing stability and establishes a mutually acceptable price for NASA Shuttle services.

3. *FY 1979 DOD/NASA Facilities Coordination.*—This is essentially a review of facility programs most likely to be of mutual interest or with high potential for duplication. A combination of normal budgetary reviews and final inter-agency reviews led to some 58 DOD projects estimated at \$270.7 million and 18 NASA projects totalling \$152.5 million, all of which are included in the Presidents' budget.

4. *Shuttle Orbiter Fleet Size.*—At the request of OMB, NASA with full Air Force support updated the 1976 "Study on Space Shuttle Orbiter Procurement and Related Issues." The results of this 1977 study were reviewed by the Co-Chairmen of the AACB. This comprehensive effort provided the data essential to detailed reviews within the Administration leading to the conclusion that a total fleet of four orbiters, operating from two launch sites, will meet civilian and military flight requirements. Additional orbiters can be considered in future years should requirements warrant such augmentation.

5. *Use of Johnson Mission Control Center.*—At the July 1977 meeting the AACB addressed the problem of providing security at Johnson Space Center for classified DOD missions aboard the Space Shuttle. An Ad Hoc Group was formed to reassess the problem and this group provided to the AACB a low cost option for modifying JMCC. This option should adequately protect classified payloads with minimum disruption to civil users. A detailed engineering and management review is now under way to validate the selected approach.

B. Cooperative Programs.

1. *Rotor Systems Research Aircraft.*—The Army and NASA jointly supported the construction of a test vehicle, the Rotor Systems Research Aircraft (RSRA) to provide accurate research data on the aeroelastic behavior of advanced helicopter rotors and control systems in dynamic flight conditions. These data are required to supplement static model and full-scale wind tunnel tests, and to verify analytical methods used in helicopter design and ground based simulation.

During the past year, both RSRA aircraft were flown from the contractor's plant to NASA Wallops Flight Center (WFC), Virginia. Contractor exploratory flight testing is continuing at WFC in preparation for delivery to the Army and NASA later this year.

2. *Tilt Rotor Research Aircraft.*—The Army and NASA are jointly developing a tilt rotor research aircraft to prove the concept and obtain full-scale information on tilt rotor aerodynamics, dynamics, structural and environmental characteristics, military mission capability, aircraft handling qualities, and near terminal operations. The first hover flight of the first aircraft was accomplished on May 3, 1977; ground qualification testing is proceeding to prepare for wind tunnel tests of the complete vehicle.

3. *Super-Critical Wing Technology.*—In a joint program to explore application of super-critical wing technology to fighter aircraft, the Transonic Aircraft Technology (TACT) program, NASA has been testing Air Force furnished new outer wing panels on an F-111 aircraft. Final TACT flight tests were completed during the past year with a series to measure buffet characteristics in support of development of a new wind tunnel test method.

4. *Fuel Availability.*—The alternate fuel program is continuing as part of the long-term coordinated effort with the Military Services, NASA, and the Department of Energy to assure that acceptable aviation jet fuel will be available at minimum cost from domestic sources such as oil shale, tar sands, and coal. The DoD program is concentrating on the design, fabrication, integration, and testing of components for a propulsion system fueled by non-petroleum based synthetic aircraft fuel. A comprehensive program of ground testing will document the performance of alterante propulsion concepts. We are presently in the first phase of a program to produce 100,000 barrels of shale crude and to refine the crude in a commercial refinery into military specification fuels. Joint agency testing will investigate medical, chemical and material interactions, storage and handling questions. The Navy is managing this overall program with the support of the Army and Air Force.

5. *Spacecraft Charging Technology.*—Close coordination between the interdependent activities of the Air Force and NASA continue through the Joint USAF/NASA Spacecraft Charging Technology Program. The Air Force Geophysics Laboratory (AFGL) is developing theoretical and empirical models of the natural environment leading to spacecraft electrical charging at synchronous altitude, and is preparing a handbook that will document the full range of variability of charged particles and fields that can be expected at this altitude. The Air Force will launch a Scatha satellite which will yield data for future studies of spacecraft charging problems including an assessment of the feasibility of actively controlling satellite charging and discharging. Measurements of the energetic electron flux at satellite altitudes are needed to determine the dosage rates that satellite microcomponents will be subjected to under operational scenarios.

6. *SEASAT.*—NASA and the Navy have agreed to a cooperative effort for SEASAT-A data processing. The Navy will do real time processing of the NASA SEASAT-A satellite data at the Fleet Numerical Weather Central, and make the processed data available at NASA for distribution to the user community. In 1977, the agreement was expanded to provide for full global coverage of SEASAT-A data. The Navy will also demonstrate the utility of the SEASAT data as inputs to global atmospheric and oceanographic analyses and forecasts.

This analysis capability supports the objectives of the National Climate Program. Data processed by the Navy will make possible several important experiments by the private sector of the civil community which are designed to demonstrate the economic benefits of an ocean satellite system.

Looking beyond SEASAT-A, DoD, NASA and NOAA representatives have met over the past year in an effort to determine what common requirements and concepts might exist for monitoring of the ocean surface. To date we have found our needs remarkably similar and this simplifies the task of development of a concept for a satellite system that would meet the needs of all agencies.

C. Support

1. *Astronaut Selection.*—NASA recently announced the selection of 35 new astronaut candidates for the Space Shuttle program. Twenty-one military officers (10 Air Force, 9 Navy, 1 Army, and 1 Marine Corps) are in the group. Fourteen of these 21 are pilot candidates and 7 are mission specialist candidates.

2. *Technical Development.*—DoD has detailed a number of technically trained persons to NASA to assist in programs of mutual interest. The technological transfer back to DoD in unique functional areas is important. The total number of detailees under the program in FY 1978 is 59 (45 from Air Force, 8 from Navy, and 6 from Army). They are working in a variety of operational and R&D programs but most are associated with the Space Transportation System. The latter activities include space mission planning, avionics and communications security, crew procedures, payloads software, logistics, and facilities construction.

3. *Tracking and Data Acquisition.*—In addition to the joint DoD/NASA test support activities embodied in the National Aeronautical Facilities Program, the DoD and NASA frequently provide tracking and data acquisition support to each other. For example, the DoD Advanced Range Instrumented Aircraft provide NASA with telemetry reception and data relay support in areas where land station instrumentation is not available. The Air Force Flight Test Center provides tracking and data acquisition support to the NASA Flight Research Center as does the NASA Wallops Island facility to the Naval Air Test Center. This type of interagency support avoids costly duplication of resources and operating locations.

Following are current examples of memoranda of understanding or agreement that exist to achieve coordinated programs between Department of Defense Agencies and the National Aeronautics and Space Administration.

A. Army

1. Development of Tilt Rotor Research Aircraft.
2. Development of Rotor Systems Research Aircraft.

B. Navy

1. Development of Advancing Blade Concept (also Army).
2. Upgrade of NASA Ames Simulation Facility (for V/STOL programs).

C. Air Force

1. Development of Transonic Aircraft Technology (TACT).
2. Development of Advanced Fighter Technology Integration (AFTI) Aircraft.
3. Loan of F-15 Aircraft.
4. Loan of YF-12 aircraft.

ADVANCED MEDIUM STOL (AMST)

Mr. STEVENSON. Are there any funds in the 1979 Budget Request for the Advanced Medium STOL Transport (AMST)?

Dr. PERRY. No, all funding for continued development of the AMST has been deleted from the FY 79 President's Budget.

ADVANCED MEDIUM STOL TRANSPORT (AMST)

Mr. STEVENSON. What is the status of the AMST Aircraft?

Dr. PERRY. All current and outyear funding for the AMST has been deleted. The Air Force is presently in the process of suspending Source Selection of a winning contractor, which was in progress at the time of the budget decision. As you know, each of the competing contractors, Boeing and McDonnell Douglas, developed and tested two prototypes each during the Advanced Development

phase. These prototype aircraft were designated the YC-14 and YC-15, respectively. All four prototypes are currently in storage at Edwards Air Force base California and are being maintained in a flyable condition. We are investigating potential projects in which we or other agencies, such as NASA, might make good use of those prototypes.

Mr. STEVENSON. What was the principal purpose of this aircraft?

Dr. PERRY. The AMST was designed for intratheater tactical airlift with emphasis on heavy unit moves of "outsize" equipment including main battle tanks, self-propelled artillery and other large and heavy equipment that exceeds the weight and volume capacity of present C-130's and C-141's. This mission also requires movement of people and logistical support cargo within a combat theater of operations.

Mr. STEVENSON. How much money has been spent by the government on this aircraft? How much by the contractor?

Dr. PERRY. Of the \$246.4 million appropriated for AMST development through FY 1978, \$221.2 million has been expended. \$105.9 million went to Boeing and \$100.3 million to McDonnell Douglas under the terms of the prototype contracts. \$22.9 million was expended on government costs including lab and study efforts. \$2.1 million was reprogrammed into other programs and \$15.2 million remains unobligated. In addition to government funding, Boeing and McDonnell Douglas have spent \$39.5 and \$12.5 million respectively on their prototype development and test programs.

Mr. STEVENSON. Is the Department considering proceeding with the AMST or a similar STOL aircraft in the future?

Dr. PERRY. Based upon current analysis of intratheater Tactical Airlift requirements, that possibility appears unlikely. The unique capabilities of the AMST such as STOL and the capacity for large heavy equipment such as main battle tanks were not demonstrated to be worth the cost, particularly in the European Theater, which is a major concern. There are cheaper alternatives to the proposed \$11 billion AMST program for meeting the essential Tactical Airlift needs that don't include the outsize equipment.

At the same time, we recognize the need to modernize the current tactical airlift force. For this reason, the Secretary of Defense has initiated a comprehensive study effort to redefine tactical airlift objectives and identify the most cost-effective means to meet those objectives. This effort will be completed this summer and will serve as the basis for a Tactical Airlift Modernization Program expected to be presented in the FY 1980 budget.

Mr. STEVENSON. Why is so much money spent on these development programs and then there is no production? Is that a wise way for the Department of Defense to spend the taxpayers' money?

Dr. PERRY. A primary goal of the AMST Advanced Development Program was to competitively develop technology prototypes and demonstrate alternative concepts of STOL technology for relatively large wide-body transport aircraft. To this extent, that goal was met. However, as we approached the decision to enter Engineering Development, leading to production, the AMST simply failed to pass the test of cost effectiveness, which is a major detriment in that decision. A lot has been spent, but much more remains to be spent before we could begin production. Advanced Development is complete, but Engineering Development has not begun and the estimate was \$750M for that phase. Eventual procurement costs were projected at about \$10 billion. At the same time, our analysis indicated only marginally-increased effectiveness, in terms of NATO defense capability compared to the conventional Warsaw Pact threat, over our current intratheater Tactical Airlift capabilities. In view of overall priorities within the Defense budget, continued AMST development would not have been sound investment policy.

NUCLEAR POWER FOR U.S. SATELLITES

Senator STEVENSON. Dr. Perry, it is understood that the Department of Energy budget includes \$2 million for development of an advanced nuclear power reactor to provide satellite electrical power. Has the Department of Defense asked DoE to develop a nuclear reactor power source for space use?

Dr. PERRY. Based upon studies conducted by a joint DoD/DoE Space Nuclear Applications Steering Group, DoD has requested DoE to pursue development efforts to provide options for possible future advanced space nuclear reactors in the 10-100 kilowatt (electric) range. DoE has responded by initiating a technology

program with \$2 million in its FY 79 budget. This program will concentrate on critical component-level experiments intended to verify some of the performance projections of advanced space reactor design studies. We have only requested modest technology development to insure reactor system availability with minimum developmental time should the need arise for high power which could not be satisfied by other means.

Senator STEVENSON. Would this be an operating reactor as opposed to the Radioisotopic Thermoelectric Generators now used on several satellites?

Dr. PERRY. The DoE program to be initiated in FY 1979 would address technology for reactor systems as opposed to Radioisotopic Thermoelectric Generators (RTG). As you know, reactor systems produce electricity by converting the heat generated by controlled fission of Uranium 235 in contrast to RTGs which convert the heat from the radioactive decay of Plutonium 238. The reactor would not begin operating, thus not generating hazardous fission products, until it had been inserted into its appropriate orbit. Such an orbit would most likely be long-lived to prevent reentry while the fission products were still dangerous. We would not operate a reactor in any orbit unless we were sure there were a multitude of adequate safeguards to insure a safe reentry.

Senator STEVENSON. What other sources are you considering for large amounts (30-50 kilowatt range) of satellite power?

Dr. PERRY. DoD is also considering advanced solar array-battery systems for providing large amounts of satellite power. The necessary technology improvements are being pursued by both NASA and the Air Force. Within the 30-50 kilowatt electric (kwe) range, the current performance projections for advanced solar array/battery systems and advanced space reactor systems are generally considered competitive. For power requirements in excess of 50 kwe, reactor systems appear to be the only viable solution. For the 30-50 kwe range, we are exploring the relative merits of both types of systems.

Senator STEVENSON. The subcommittee is adjourned.

[Whereupon, at 12:30 p.m., the hearing was adjourned, to reconvene, 9 a.m. Thursday, March 16, 1978.]

NASA AUTHORIZATION FOR FISCAL YEAR 1979

THURSDAY, MARCH 16, 1978

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

The committee met at 8:30 a.m., in room 235, Russell Senate Office Building; Hon. Harrison H. Schmitt presiding.

Senator SCHMITT [presiding]. The committee will come to order.

Good morning. In continuing our hearings on the budget for NASA for fiscal year 1979, and in particular the authorization request, S. 2527, we will begin with Dr. Eric H. Willis, Acting Deputy Assistant Secretary of Energy Technology, of the Department of Energy.

Dr. Willis and I have had previous associations which I enjoyed. I understand that the last association left him in the cold. It was an exciting beginning to the operational portions of the wind energy program in New Mexico where we saw a large wind turbine begin its operation. I was able to participate in that because it was a program that some years ago we were finally able to get started. NASA and ERDA finally were able to reach an agreement where more agreements were not possible for interagency cooperation and transfer of funds.

I think there will be several things which Dr. Willis will talk to us about this morning where NASA and DOE and their predecessors have found that cooperative management yields great dividends—at least, I hope you will, Dr. Willis.

Would you like to proceed?

STATEMENT OF ERIC H. WILLIS, ACTING DEPUTY ASSISTANT SECRETARY, DEPARTMENT OF ENERGY; ACCOMPANIED BY BERNARD ROCK; AND JAMES F. MADEWELL

Dr. WILLIS. Thank you very much, Mr. Chairman.

I would like to introduce my two colleagues who are here this morning. Bernard Rock, who is responsible for space nuclear power systems; and James Madewell, who is responsible for a portion of the renewable resources work which is being done in cooperation with NASA. That includes wind energy conversion and also currently the satellite power systems, which are very much in the public eye.

We have within DOE and NASA essentially the same arrangements which were in effect between NASA and ERDA—and as you mentioned, Mr. Chairman, worked so well. We do have a very good coordination council, which meets regularly and discusses problems, enunciates policy, and reviews progress.

After what might be called, as you know, some shaky starts, we have got on to a very good relationship. We have common purpose and dedication, and we are bringing the vast expertise which resides in the NASA community to bear upon some of our more critical energy problems.

Now, in the current fiscal year, 1978, a total of \$105 million to \$110 million of DOE funding is programed for passthrough to NASA for implementation. And we are funding an additional \$31 million with the space nuclear effort; Mr. Rock is responsible for that area.

The budget for fiscal year 1979, which is of immediate concern to us, will increase about 10 to 15 percent; that will make it from \$115 million to \$120 million.

The DOE space nuclear technology effort is going from \$31 million in 1978 to \$40 million in 1979.

In addition, NASA supports the DOE in the management of DOE-funded contracts. This is a very important contribution that they make, so their total contribution, it should be stressed, is in addition to that passthrough money. The projected fiscal year 1979 total is about \$23 million.

Now, the work underway by NASA units evolves around six NASA field centers. The principal activities are shown on the chart here.

PRINCIPAL COOPERATIVE EFFORTS

Program areas	DOE program organizations	NASA field centers
Transportation conservation.....	Division of Transportation Energy.....	Jet Propulsion Laboratory, Lewis Research Center.
Solar heating and cooling.....	Office of Solar Heating and Cooling.....	Marshall Space Flight Center.
Photovoltaics.....	Division of Solar Technology.....	Jet Propulsion Laboratory.
Wind energy.....	do.....	Lewis Research Center.
Satellite power systems.....	do.....	Johnson Space Center, Marshall Space Flight Center.

Transportation conservation, solar heating and cooling, photovoltaics, wind energy, and satellite power systems.

The wind energy program is getting to be extremely interesting, and we are rather optimistic about it. The Jet Propulsion Laboratory in Pasadena has taken a very active part in photovoltaics, and we are preparing to give JPL more responsibilities. Once more it has been directed toward the reduction in cost of the silicon array, which, as you know, were handmade. And we are now proceeding to the point where with sufficient volume we can get automated and into production, stimulate an industry and get the price down to where the arrays are competitive.

At that point, of course, the total systems integration becomes extremely important: the storage element and also the power conditioning that will translate the direct current from the photovoltaic arrays into 110-volts, 60-cycle alternating current for normal use in domestic consumption. We are extremely optimistic that in fact we can attain by 1982 something on the order of \$2 a watt for the array. We feel this is getting to the point where an exotic market can start to approach a popular market.

This is an extremely important point. It is where the exotic market, which is just for the curious few, gives way to something which is a

way of life. After that time, photovoltaics can be as common as having a refrigerator in your kitchen.

Senator SCHMITT. Dr. Willis, if I may interrupt, what new markets will exist at \$2 per watt as things exist now? I am aware of the exotic uses of photovoltaic cells. What do we suddenly find opening up?

Dr. WILLIS. We start to penetrate the residential and domestic market. Certain States, particularly California, are encouraging this by tax credits. The State of California has just instituted a 55-percent tax credit, which essentially reduces the effective installation price. At that level you are starting to get, I think, a bit of the domestic market coming in.

Of course, associated with dispersed systems there are institutional and socioeconomic problems which we really have to lick. That is also true of wind energy, as you know.

Senator SCHMITT. Are there major commercial uses developed? This is approximately a factor of 10 drop of the cost when they start to be used for home station?

Dr. WILLIS. That's right. That's correct.

Senator SCHMITT. Are there any new major commercial uses that may come up for home use?

Dr. WILLIS. Rural applications.

Senator SCHMITT. What about defense facilities in remote locations?

Dr. WILLIS. They could. Yes, they do open up possibilities, perhaps where there are propane generators. But we still have to lick the storage problems so that any remote location can in fact have accumulated energy stored to have a continuous supply of electricity. The intermittent nature militates against the reliability needed for widespread use in a defense mode.

Senator SCHMITT. Is your battery technology work aimed at providing this kind of thing?

Dr. WILLIS. Yes; it is. It's in parallel with all the renewable technologies.

In transportation, NASA has participated for some years in advanced engine development, and since last year in electric and hybrid vehicle work. The Lewis Research Center is providing total management supervision for the development of the propulsion subsystems. JPL manages the vehicle systems development.

NASA also provides technical management of DOE's near-term electric vehicle program. And there again, of course, you come back to batteries; if you don't really lick that battery problem you don't really lick the other problems. So there's a symbiosis between all of these technologies; one doesn't work if the others don't.

The proposed funding for fiscal year 1979 in the transportation area is \$43 million, up from an estimated \$26 million in fiscal year 1978. And NASA management of DOE's contracts in this area is \$13 million in 1978 and is planned to remain roughly at that level in 1979.

In solar heating and cooling, the Marshall Space Flight Center manages selected development tasks in support of the program of demonstrations in residential and commercial buildings. And I ought to add, Mr. Chairman, that in this particular area, solar heating, the demonstration phase of the Federal Government is probably reaching

a climax, in the sense that we have effectively discharged our development responsibility, and the program is going into the private sector.

Marshall Space Flight Center is also providing management support to the program for the solar heating and cooling.

The estimated funding for 1978 is \$16 million; that Center has funding for 1979, currently being negotiated, at about \$7 million—for the reasons I have stated.

NASA management of DOE contracts in this area totals \$5 million in 1978 and is projected to remain constant through 1979.

And I have mentioned to you the photovoltaics at JPL, which we are very well pleased; JPL also conducts solar thermal power systems work and is coordinating this work for us, and particularly in the small thermal power systems. Some of the bigger ones are being done directly with the utilities. For example, the 10-megawatt plant is a cooperative effort of a utility, the city of Los Angeles and the State of California.

The proposed passthrough funding for fiscal year 1979 for thermal power systems is \$8 million, up from an estimated \$7 million in fiscal year 1978.

In photovoltaics, as I mentioned earlier, the funding has been \$34 million in 1978 and \$29 million in 1979; the difference being quite a bit of capital investment and buys in 1978.

The Lewis Research Center together with MIT's Lincoln Laboratories—

Senator SCHMITT. Excuse me, Dr. Willis. Does the \$29 million include the increased responsibilities you have suggested?

Dr. WILLIS. That's an extremely pertinent question. I would rather fancy that this might be renegotiated in the light of that possibility; but I would like to reserve judgment on that and perhaps supply it for the record as you deem it appropriate.

[The following information was subsequently received for the record:]

JPL's responsibility is to reduce the cost of silicon solar arrays. The fiscal year 1979 budget for this task is approximately \$29 million. In fiscal year 1979 and in fiscal year 1980 we plan to consider expanding that work in cost reduction to thin film arrays, amorphous materials and other array materials.

Senator SCHMITT. I think it's something the committee should review. You realize in the reimbursable area the funding is not really on a fiscal year basis. We tend to itemize it on the table that way, but the negotiations and concentrations are continuous; that funding may arrive in October or it may arrive in January.

Dr. WILLIS. That's correct.

Senator SCHMITT. Depending on the need and status of the actual fund transfer and project status.

Dr. WILLIS. That is correct; yes. That's something which does not appear on the numbers; sometimes they look rather disparate, when in fact they are not.

You referred to wind energy, the Lewis Research Center continues to be the mainstay of the Federal program for the large wind turbines. We have both seen the precursors to that, and we are continuing with a 2 megawatt machine at Boone, N.C. this coming fall.

The proposed funding for the wind energy at Lewis is \$15 million for 1979, up from an estimated \$12 million in 1978.

DOE-NASA COOPERATIVE PROGRAMS—DOE PASSTHROUGH FUNDING TO NASA, BUDGET AUTHORITY

[In millions of dollars; fiscal years]

	Estimated 1978	Proposed 1979
Conservation and solar applications.....	\$42.0	\$50.0
Solar technology.....	53.0	54.0
Geothermal energy.....	.7	.2
Electric energy systems.....		1.0
Energy storage.....	5.4	6.8
Fossil energy.....	3.6	3.6
Nuclear research and applications.....	.2	.3
Environmental research and development.....	.7	.6
Total.....	105.0-110.0	115.0-120.0
DOE funded and implemented: Space applications program.....	31.0	40.0

Turning for a moment to satellite power systems now under DOE management, the present efforts are directed at conceptual evaluation. And just this week, Mr. Chairman, we sent to the Congress a document describing, in detail, the plan for developing and evaluating the SPS concept in the period from July 1977 to August 1980. This document was sent to the appropriate Senate and House committees. It represents the views of both NASA and DOE. In this effort, NASA will study the technical problems and the hardware systems—the satellite, the transportation system and the ground receiving antenna. At this point there is no known technical barrier to the concept.

However, there are a lot of consequential problems in the health and safety, in comparative assessment, and in the socioeconomic concerns, both domestic and international. These have to be resolved; we really have to know the total picture. We are not dealing with a space project in isolation. This will impact on society in a very big way, perhaps more so than any other project which is being currently undertaken in the space program—with the exception of the Intelsat.

Senator SCHMITT. Dr. Willis, I agree with your comments. However, I do have, and the committee has, some concerns that the money is still largely going for paperwork. We tend to be reshuffling the technology that we already know about. I think the committee is going to consider very strongly to suggest, if not direct, that more work be done on actual technology advancement. The economic analyses will always have to go hand in hand based on new information, rather than just the old information.

Dr. WILLIS. I take your point on that. There is an inseparable linkage between the two and one cannot go in advance of the other. I think we have to know what the potential showstoppers are. They have to be identified.

The showstoppers are not necessarily technically derived showstoppers, but the solution may be a technical one. There may be an institutional showstopper that has a technical solution. We have, for instance, currently the supposition that the ionosphere may be heated by the SPS microwave beams; we have to do experiments to determine whether that hypothesis is valid or not.

So I think you are right in saying that we shouldn't just do studies; nevertheless, there are a variety of studies which are extremely germane to the technical output.

Senator SCHMITT. I am not arguing the point, I am just saying we must prove the technological extrapolation relative to the economic considerations.

Dr. WILLIS. Yes. If that were the case we would be working only on socioeconomic studies on totally outmoded data.

Senator SCHMITT. Two technical questions:

Do you anticipate any further examination of the laser energy transmission option in parallel with NASA?

Dr. WILLIS. I believe NASA is now looking at that option. That could continue. We have not had a full reading from the NASA on the analysis.

Senator SCHMITT. I remember a few years ago we pretty much rejected it; but more recent evaluation, particularly by individuals at the ADM conference, come up with some interesting technical as well as philosophical arguments in support of that option.

Dr. WILLIS. Yes.

Senator SCHMITT. Maybe a reexamination of that earlier decision might be worth doing. I would encourage it at the appropriate time. Probably NASA or some others around could do it, to see if that was a correct decision. One of the factors, of course, has to do with weight in space; another factor has to do with the area utilized on the ground.

Dr. WILLIS. Yes; that's an extremely important, pertinent factor. The area on the ground may have quite a large impact on the technical decision. But since the power density of lasers has gone up very considerably in recent years this may be an option which can be considered now, which had been out of the question earlier.

Senator SCHMITT. Isn't this true of your work in various laboratories, and in some of the DOD laboratories? Things which didn't even enter into our imaginations a few years ago can be considered now as a possible option.

Dr. WILLIS. I am sure that will be taken into account.

Senator SCHMITT. Another area is the increasing power density of the flasher system which has some relevance here. We aren't quite as much worried about weight. A few years ago there was a system of sodium heat developed by Ford Surge. Now I believe that any work being done at all is primarily by Philco. There was a discussion of a grant by UNICEF in this area. I don't know whether that happened or not.

Based on what I remember from several years ago it is encouraging to look at some of these alternative technologies where you might get a significantly higher margin of efficiency with solar thermal cells.

Dr. WILLIS. Well, there is a possibility of getting to about 30 percent efficiency with multijunction cells, which would materially cut down the required collection area in space; and therefore the space construction costs, which appears to be a critical factor. In the current SPS concept, I think that the dimensions of the collector are about 5 by 20 kilometers on a side, which was a formidable undertaking.

Senator SCHMITT. Do you anticipate that the 1980 conclusion will be either to stop, or to do more study, or to press on with the major and well-funded effort to create a prototype?

Dr. WILLIS. I would—

Senator SCHMITT. Are those the options you have?

Dr. WILLIS. I would consider more studies as being almost synonymous with a stop.

Senator SCHMITT. That's why I asked the question.

Dr. WILLIS. I surmised that.

Senator SCHMITT. What I am trying to get at is DOE's attitude. Are you really looking for a go-no-go decision by 1980?

Dr. WILLIS. Essentially we are. We are to commit funds. Once we start getting committed to this kind of funding level, it has to be done in competition with ground-based systems; and therefore a thorough cost analysis has to be done.

In the next stage after this, we'll be doing more experimentation to solve any potential showstoppers which are brought to light by this study. This current study will also point how to resolve those issues.

So I am hopeful that the next stage would include experimentation, to solve some of the basic issues, without necessarily going into a fully fledged space activity. There are a number of problems to solve on the ground before we get that far.

Senator SCHMITT. Do you feel that there is sufficient experimentation going on now and anticipated in that study to back that study up, and to give you the opportunity to make the decision you would like to in 1980?

Dr. WILLIS. I think it is, and our NASA colleagues seem satisfied. But I think it might be pertinent to ask them the same question.

Senator SCHMITT. We have and we will. I am not sure Congress is satisfied, that's why I am asking the question. I get the feeling from many people—those technically trained as well as those not—that there are other areas of experimentation that could be pursued without any loss to the country, and would enhance the results of the study. Those areas, if pursued, would still have a value to the country, even if it were a negative decision.

Dr. WILLIS. Particularly in conjunction with other projects.

Senator SCHMITT. Yes.

Dr. WILLIS. What I might suggest, Mr. Chairman, is that if the committee would wish a briefing on this document, it might be given to the committee at some point and then the committee can make up its own mind as to the efficacy of this program.

Senator SCHMITT. We'll try to arrange that.

Dr. WILLIS. For fiscal year 1979, the proposed DOE passthrough funding for NASA for this effort is, I must say, relatively modest: it's \$1.3 million. In addition, \$3.3 million will support DOE work on environmental factors and the things that I have mentioned.

In fiscal year 1978, the NASA share is \$1.7 million; the DOE share is \$2.8 million.

In geothermal energy, the Jet Propulsion Laboratory is providing technical management support. It's at a relatively low level, about \$200,000, because a lot of that work is now getting into the commercial sector in the California area.

In electrical energy systems, the Jet Propulsion Laboratory will be initiating technical management and analysis of the results for two projects. And the proposed DOE passthrough funding for 1979 is about \$1 million. These are concerned with lightning-induced surges

on electric distribution systems, and on communication links for load management, which is extremely important to the dispersed systems and the windmills. The communication link project deals with getting power on line at the right time, balancing the contributions from various units. Everything is dependent entirely upon a communication link with the central nerve center. You can't have all these units starting up and closing down at will. You have to synchronize this. JPL is looking at that.

In energy storage systems we are funding the NASA Lewis Research Center and JPL, and the proposed funding in these projects is \$6.8 million in 1979, up from \$5.4 million in 1978.

Fossil energy support by NASA at the NASA Lewis Research Center and the Marshall Space Flight Center is continuing. The proposed DOE 1979 passthrough funding to NASA for the program totals \$3.6 million, the same as 1978.

In addition, Lewis Research Center supports DOE in the management part of our fuel cell program. This effort totals about \$5.5 million in 1978, and again is expected to continue at about the same level in 1979.

In nuclear research and applications, DOE utilizes the JPL again, and funding levels here are at \$200,000 in 1978 and \$300,000 in 1979.

In environmental research and development, the NASA work funded or cofunded by DOE is at Ames Research Center, Johnson Space Center, Langley Research Center and Lawrence Berkeley Lab of DOE in California. And that's approximately a \$600,000 effort.

Now, this completes the discussion of DOE's efforts that are performed by NASA with DOE funding. I now come to the DOE space applications program, which is funded and implemented by DOE, but of course in close cooperation with NASA and DOD.

The objective of this activity is to provide low-cost nuclear power systems for space applications. The program for fiscal year 1979 for which we have submitted our budget includes:

First, the continued flight system design, fabrication, assembly and life testing of the selenide isotope generator for use in NASA's Jupiter Orbiter Probe Spacecraft, scheduled for launch, I believe, in early 1982.

Second, continued design of the engineering flight hardware and testing of the dynamic isotope power system being developed for use by DOD.

Third, the initiation of development of an improved selenide isotope generator incorporating the general purpose heat source, a modular plutonium-238 fueled unit, for the NASA solar polar mission.

Fourth, maintenance of plutonium-238 fuel form production and encapsulation capabilities to provide up to 4 multi-hundred-watt radio-isotope heat sources for testing purposes. This is a heat source and not a reactor.

Fifth, the evaluation and assessment of operations necessary to insure safe and environmentally acceptable operation of the dynamic isotope power system unit and Jupiter Orbiter Probe isotope power units.

And, finally, the initiation of a program to evaluate the feasibility of a nuclear reactor power supply for use in space.

Mr. Chairman, the space applications program just described was, of course, formulated and submitted prior to the unfortunate recent incident involving a Soviet satellite. Nevertheless, I think it is worth while to emphasize, as this committee knows full well, that all U.S. isotope power units currently planned for space use have an imposed safety philosophy of intact reentry and containment of the fuel material throughout the abort environments. They are not likely to spill over a long footprint. We have placed only one nuclear reactor in Earth orbit.

Senator SCHMITT. I just might add, Dr. Willis, I can vouch for the efforts made to protect those isotope sources; they were so good we were almost unable to get the isotope source out of it.

Dr. WILLIS. Oh, dear.

We have placed only one nuclear reactor in Earth orbit, and I think it should be a matter of record that it was the Snapshot, launched in 1965; now, that reactor is currently still in orbit with a lifetime of 4,000 years.

And the only portion of the fiscal year 1979 funding concerned with Earth-orbital reactor activity is a \$2 million technology study and experimental verification effort aimed at evaluating the feasibility of a concept—a concept, I might add, that is not presently hardware oriented. The safety concept in this study is based on the launch of a cold, nonoperating reactor system, which would achieve power operations only after a suitably safe long-term orbit had been established. In other words, it would not be in the low orbit that brought the unfortunate occurrence with the Soviet satellite.

We are currently reviewing our program and budget so as to insure conformance with the evolving national policy regarding the use of nuclear materials in space. Now, this review will be conducted in cooperation with DOD and NASA; and we will be advising this committee of the results of that review as soon as it is complete. We are pursuing it as a matter of urgency.

The proposed DOE funding for the space applications program in 1979 is \$40 million, up from an estimated \$31 million in fiscal year 1978.

In summary, the final chart will recapitulate the funding of DOE activities in cooperation with NASA.

SPS FUNDING—BUDGET AUTHORITY

[In millions of dollars]

	DOE	NASA	Totals
Fiscal year 1978 funding to NASA, partly passed through to DOE.....	\$2.8	\$1.7	\$4.5
Fiscal year 1979 funding to DOE, partly passed through to NASA.....	3.3	1.3	4.6

The upper four-fifths of the page shows funding passed through to NASA. At the bottom of the page is the space applications program, both funded and implemented by DOE.

In conclusion, Mr. Chairman, we feel that our cooperative programs and institutional relationships with NASA continue to be very healthy. Further experience demonstrates that the arrangements instituted by NASA and ERDA are effective for maintaining these

good relationships and resolving the issues. And I can attest to that very personally.

That concludes my testimony, Mr. Chairman. I would be happy to respond to any questions you may have of me.

Senator SCHMITT. Thank you very much, Dr. Willis. I will ask questions for a while. I am sure I will have some additional questions for the record.

Dr. WILLIS, do you feel the satellite power systems work should continue indefinitely to be directed to DOE?

Dr. WILLIS. Absolutely.

Senator SCHMITT. Would you state your reasons?

Dr. WILLIS. The reason for that is it should be energy driven; it is not space driven. It's a space solution of an energy problem, not an energy derivative of a space problem.

Senator SCHMITT. Do you see any difficulties arising from that kind of division of responsibility?

Dr. WILLIS. No; because I think it is a logical one. That is not to say that people in the space community should not be advocates for such a solution. I believe it is not only a legitimate but an extremely healthy thing for them to be proponents of an idea which they conceive to be extremely germane to our energy problems in the latter part of this century. And I think that is extremely healthy.

However, the final analysis has to be made of the efficacy of that solution and that technology in competition with the land-based systems. Competition may be on the basis of cost effectiveness, environmental acceptability, or other socioeconomic issues. I think the problem has to be energy driven.

Senator SCHMITT. DOE and its precursors, ERDA and AEC, have not always been accused of absolute objectivity in the development of power systems. Do you think DOE has overcome any biases that may have existed in the past, and will there be an objective evaluation within this program of satellite power systems versus the competitive ground-based, and maybe competitive space-based systems?

Dr. WILLIS. I think our most ardent supporter, if there is one, would not accuse us of absolute objectivity. We can't do that. We have to in some way, by the nature, of the institution, prefer certain views.

However, if that lack of objectivity is taken to the point of foot-dragging when there are viable options being proffered and offered by other communities, then we would indeed be very delinquent. And I am hopeful that the present relationship with the NASA management, particularly its director and senior staff, would militate against any lack of objectivity on our part.

Senator SCHMITT. Now, I am personally impatient for the development of fusion energy, because I think with a combination of solar and fusion and a hydrogen-based transmission system we'd really have 21st century solutions to the problem of providing energy.

My question to you is do you think the balance of the program between our advanced fusion program—I am not talking about increasing the program at all—and our basic central power solar energy program is appropriate?

Dr. WILLIS. And by central power energy program you are including space satellite?

Senator SCHMITT. Yes.

Dr. WILLIS. To take the terrestrial part first, we are demonstrating proof of principles, as you know, with the 10 megawatt power tower; we will see where that goes. We'll see how effective it is, hopefully.

I think the time of the big investment in space power systems, when it comes, is way down the road yet. It will rely very heavily, for instance, on second generation shuttles. So it is not something which we are contemplating tomorrow. It is something for which we are laying the foundation for today, but the harvest would be tomorrow.

And I think in that sense it is balanced; it is not balanced in the sense of having equal dollars in both sides at the moment because fusion energy quite manifestly has been going on now for 20 years, and they are getting very near to the point of energy input-energy output balance. And so it is quite reasonable to expect that that will have the higher budget investment at the moment.

Later on this may well overtake it, but not today.

Senator SCHMITT. The committee, and I think the Congress, will probably urge you one way or the other to increase, as I have indicated before, the technical output of the program, by both you and NASA. There will be further questions on it for the record.

I would like to shift gears and talk to you a little bit about nuclear waste disposal. The committee will have at least one, and I anticipate more, discussions through the hearing process about the status of science and technology for nuclear waste disposal. Do you anticipate DOE examining the possibilities of certain types of waste disposal in space?

Dr. WILLIS. Yes. I think they are open to all options of that fashion certainly being discussed, proposed. There is—today I think—the DOE report of a task force on disposal. I have not read that task force, and I do not know whether in fact they deal with that possibility in it.

Senator SCHMITT. I have not read the task force report in its entirety. The New Mexico delegation has been working closely—although not quite close enough—with DOE in their waste disposal efforts, the impetus for that being the primary experimental facility, a waste isolation plant to be located in Carlsbad, N. Mex.

Dr. WILLIS. Yes.

Senator SCHMITT. At our insistence a section was added to that report which begins a discussion of alternative techniques, one of which may be for certain concentrations of isotopes, particularly gaseous isotopes, for a space option.

Dr. Willis, I will submit questions for the record in the following areas, and I will not pursue the questioning further, but so that you can anticipate what I personally am interested in, I will be asking you about your ideas on how the fuel cell program will be accelerated; on the status of the gas turbine research development—both of those programs having been in cooperation with NASA at various times.

I will also be interested in your judgment on the potential for growth and cooperation between DOE and NASA; how those areas of cooperation could expand if other things were provided for, such as the difficult question of personnel slots for both DOE and NASA. It's a problem which eventually will have to be resolved. I don't

know what NASA's limit will be, but there will be a point where without transfer of slots the job won't get done.

Dr. WILLIS. Yes; it's an increasing problem, sir.

Senator SCHMITT. Yes.

Another question would have to do with whether or not you see an advantage or disadvantage to some competition within NASA. I am thinking primarily of the technical, professional competition, which is very healthy, between JPL and the Lewis Research Center. This question is not designed in any way as criticism of those two centers, or of NASA in technical management.

I think the committee would like to know whether or not you see any problems developing there, or any potential of having two centers with very great expertise, and that expertise really being in similar areas.

I also will ask you a question about how you personally feel about using solar power as a substitute for existing energy sources as a viable concept?

Dr. WILLIS. I may just interject my quick reply on that. I am very enthusiastic about the prospect of repowering, particularly in the Southwest; and we have had a number of discussions with Public Service of New Mexico, who are very avid supporters of this. And I think we have got something.

Senator SCHMITT. Thank you, I am glad to hear that. I am very excited about that. I am happy to hear you say that.

Another area I am very interested in is the possible acceleration of improvement of technology for solar heating and cooling. It has been my impression the demonstration program is one of using more or less existing technology as a base. I would like to know if you feel there is an opportunity for increased funding in this area that would decrease the cost of solar heating systems and increase their maintainability or reliability.

Finally, and I am sure there will be other questions that occur to me, I am interested in something said to me the other day about the possibility that the best place to have fusion reactors is in space. I would like to hear any comments that you or your people may have on that, the idea being, of course, the high vacuum and maybe some environmental advantages in placing fusion reactors in space and transmitting power.

Dr. WILLIS. On an SPS mode?

Senator SCHMITT. Yes.

Dr. WILLIS. Yes.

Senator SCHMITT. Senator Ford has now joined us. Mr. Chairman, I will turn the gavel over to you.

Senator FORD. Doctor, I have no questions, and I appreciate your attendance this morning. There is a possibility we will send you additional questions for the record.

Dr. WILLIS. We would be more than happy to provide that.

[The statement follows:]

STATEMENT OF ERIC H. WILLIS, ACTING DEPUTY ASSISTANT SECRETARY FOR ENERGY TECHNOLOGY, DOE

Mr. Chairman and Members of the Subcommittee, I am delighted to have this opportunity to present an overview of the continuing space activities of the Department of Energy, with particular attention to those activities conducted in

cooperation with or requiring support from the National Aeronautics and Space Administration. These cooperative efforts, which trace back many years, were formally institutionalized in 1975, after the creation of the Energy Research and Development Administration, and are being continued under the Department of Energy.

DOE and NASA have agreed to continue management and coordination of their cooperative and related energy programs under essentially the same arrangements as those that were so fruitful for ERDA and NASA. Inasmuch as Donald A. Beattie, the then ERDA Deputy Assistant Administrator, Solar, Geothermal and Advanced Energy Systems, described the functions of the Program Coordinating Committee in his testimony before this subcommittee a year ago, I shall not go into much detail today. Suffice it to say that the Program Coordinating Committee, which normally meets quarterly, has been quite successful in coordinating policy and budgets, and I trust that it will continue to do so. There have been some changes in membership: Dr. Alan M. Lovelace continues as NASA Co-Chairman, but the Under Secretary, Dale D. Myers, is now the DOE Co-Chairman. A complete membership list is appended as Attachment 1. Responsibility for management of individual DOE-funded programs remains in the hands of Division Directors at DOE Headquarters, unless major cross-cutting policy issues should arise. The corresponding DOE organizations and NASA Field Centers are listed in Attachment 2.

I should add that the long-range institutional planning initiated by ERDA for its laboratories, and recently completed by DOE, was expanded, by mutual agreement, to include the broad energy-related programs of NASA's Jet Propulsion Laboratory and Lewis Research Center. The more narrowly focused programs, such as that of the Marshall Space Flight Center, were not included.

The DOE/NASA cooperative efforts encompass a broad scope of DOE energy programs, as follows:

Conservation and Solar Applications; Transportation (Advanced engines, electric and hybrid vehicles); Solar Applications (Heating and cooling).

Solar Technology; Solar Thermal; Photovoltaics; Wind Energy; Satellite Power Systems.

Geothermal Energy.

Electric Energy Systems.

Energy Storage.

Fossil Energy; Magnetohydrodynamics; Advanced Power Systems; Coal Mining Technology.

Nuclear Research and Applications.

Environmental Research and Development.

Total pass-through funding from DOE to NASA for these programs amounts to an estimated \$105 to \$110 million for FY 1978, and about \$115 to \$120 million is proposed for FY 1979. In view of DOE's basic policy to maximize technology transfer to the non-Federal sector, it is important to note that most of this funding is for industrial contracts managed by NASA, not for in-house NASA projects.

In addition to these programs supported by passthrough funding, DOE supports directly a cooperative Space Applications program, at an estimated level of \$31 million for FY 1978 and a proposed level of \$40 million for FY 1979. In yet another form of cooperation, NASA manages, on behalf of DOE, a number of contracts funded directly by DOE. These total an estimated \$25 million for FY 1978 and a proposed \$23 million for FY 1979. A table summarizing the DOE funding of DOE/NASA cooperative programs is appended as Attachment 3.

CONSERVATION AND SOLAR APPLICATIONS

Transportation

Since 1972, NASA has been supporting the Transportation Energy Conservation's automotive heat engine programs, such as aerodynamic design of gas turbine engines, characterization testing of gas turbine and Stirling engines, and providing technological improvements in combustors, gas bearings, ceramic regenerators, and low-cost fabrication techniques. In these efforts, NASA provided manpower for technical management of DOE contracts funded directly by DOE with industry, management of DOE-funded NASA contracts, and NASA in-house technology support activities.

NASA is providing total project management, facilities for testing vehicles, engines, and components, and legal procurement support.

In FY 1977, NASA completed the in-house testing of the Chrysler baseline gas turbine engine, and initiated testing on the upgraded gas turbine. Major procurement activities included successful negotiations with the Ford Motor Company on the first and second line Stirling engine programs.

NASA has participated in the electric and hybrid vehicle elements of DOE's Transportation Energy Conservation Program since FY 1976. The Lewis Research Center has been assigned project management responsibility for propulsion subsystem development, and the Jet Propulsion Laboratory for vehicle systems development. During the past year (FY 1977), an extensive review of existing vehicle technologies provided the first comprehensive characterization and assessment of the current state of the art. NASA is also providing technical management of DOE's near-term electric vehicle program, which is intended to demonstrate that such vehicles can meet all the requirements for a satisfactory commuter automobile. Complete test vehicles will be evaluated in FY 1979. In addition, increased support will be given to work on hybrid vehicle systems and advanced propulsion subsystems. NASA's role is primarily project management; most of the funding will provide for industrial contracts, including specifically aid for small business. Proposed funding for FY 1979 is \$43 million, up from an estimated \$26 million in FY 1978. NASA-managed DOE contracts amount to a proposed \$13 million in FY 1979, the same as the estimate for FY 1978.

Solar Applications

The Marshall Space Flight Center (MSFC) is managing selected development tasks in support of the demonstration program for solar heating and cooling of residential and commercial buildings. The goal of this program is to stimulate the creation of a manufacturing and marketing infrastructure capable of normal market penetration. Industrial development contracts of three types have been awarded: (1) integration of complete systems from current or emerging marketable subsystems procured by MSFC from both large and small businesses; (2) improvement of the marketability of existing systems; and (3) development of complete factory-packaged systems for low-cost mass production. MSFC is also providing management support to the Commercial Buildings Solar Demonstration Program in the review of competitive proposals and in the award and management of selected contracts. Estimated funding for FY 1978 is \$16 million; proposed funding for FY 1979, about \$7 million. In addition, NASA is managing DOE contracts amounting to an estimated \$5 million in FY 1978 and the same proposed amount for FY 1979.

SOLAR TECHNOLOGY

Solar Thermal Power Systems

The Jet Propulsion Laboratory is the coordinating center for the Advanced Solar Thermal Power Program. This function includes broad-based R&D program planning, project and contract management, and proposal review. JPL works closely with DOE laboratories and with other NASA centers, such as Lewis Research Center (LeRC). Program plans being developed for advanced technologies include intermediate- and high-temperature distributed systems, central receiver systems, hybrid systems, absorber surface materials, and heat engines. Trade-offs among different systems are being examined. JPL is also providing extensive management support to Small Power Systems technologies and applications. The objective is to foster commercialization of systems in the 1 to 10 MWe range for small communities, rural areas, and industrial users. Proposed passthrough funding for FY 1979 is \$8 million, up slightly from an estimated \$7 million in FY 1978.

Photovoltaics

Both the Jet Propulsion Laboratory and the Lewis Research Center are providing field management and technology transfer support for important DOE photovoltaic program elements. JPL has managed very successfully the Low-Cost Silicon Solar Array Project, whose objectives include development of low-cost automated processes for producing encapsulated silicon sheets for cells and arrays. A real cost reduction of about 30 percent has been achieved since last year, exceeding our expectations. Proposed FY 1979 funding is \$29 million; estimated FY 1978, \$34 million. LeRC (together with MIT's Lincoln Laboratories) has been responsible for field application tests in remote localities, such as isolated data collecting sites of the National Oceanic and Atmospheric Administration. This relatively small project is being phased out in FY 1979.

Wind Energy

The Lewis Research Center continues to be the mainstay of the Federal program for large wind turbines, both for technical development of large machines and for the management of systems development contracts. The first large machine, the MOD-O, 100KW unit at LeRC Plum Brook, designed to provide engineering test data, has been operated successfully in phase with a commercial grid. Three MOD-OA systems rated at 200 KW are being constructed and will begin field tests this year. The first, at Clayton, New Mexico, was dedicated on January 28, 1978; the other two will be installed at Culebra Island, Puerto Rico, and at Block Island, Rhode Island. The goal of the MOD-OA program is to incorporate these machines into small utility networks as soon as possible. This will require satisfying institutional as well as technical and operational requirements. LeRC is also managing the development of much larger wind machines: the MOD-1, 2 MW turbine to be built by General Electric and to be installed at Boone, North Carolina, for a two-year test and evaluation program by the local electric cooperative; and the MOD-2, 2 to 3 MW machine to be built by Boeing. The latter, some 300 feet in diameter, will be pushing the limits of present technologies to help evaluate the scaling of power costs with increasing size. Unit costs are expected to decrease significantly in future systems. Proposed funding at LeRC is \$15 million for FY 1979, up from an estimated \$12 million in FY 1978.

Satellite Power Systems

Satellite power systems are proposed systems for collecting solar energy out in space beyond the earth's atmosphere, converting it to microwave energy that can be beamed through the atmosphere to receiving stations on the earth, and finally converted to conventional electric power for any of the many familiar end uses. This long-range proposal is in the concept evaluation stage. In accordance with an Administration-approved decision made last year, DOE is now the lead agency for overall management of this program. This week we have provided copies to you of the Satellite Power System Concept Development and Evaluation Program Plan for 1977 through 1980 which was prepared by NASA and DOE. In this plan, DOE is responsible for studies of crucial environmental, health, and safety questions, of socio-economic, international, and other institutional issues, and of comparative assessments with alternative energy systems. Proposed DOE funding for FY 1979 is \$4.6 million, of which \$1.3 million is passthrough funding for NASA to carry out systems definition. The NASA funding for this effort in FY 1978 is estimated at \$1.7 million. The environmental and institutional problems appear to be the critical questions, which may control an early decision whether to proceed with the costly engineering development that would be required.

GEOTHERMAL ENERGY

NASA's Jet Propulsion Laboratory provided most of the effort required to produce the initial Program Definition Report (ERDA-86, October 1975) mandated by the Geothermal Research, Development, and Demonstration Act of 1974 (P.L. 93-410). Since then, JPL has contributed to regional operations research studies in California, under joint sponsorship of DOE (then ERDA) and the California Energy Resources Conservation and Development Commission. Currently, under DOE sponsorship, JPL is working on high-temperature elastomers and on new concepts in energy conversion cycles. It is also providing technical support to the DOE San Francisco Operations Office. Proposed DOE FY 1979 funding for geothermal projects at JPL is about \$165 thousand, down from an FY 1978 estimated level of \$730 thousand.

ELECTRIC ENERGY SYSTEMS

The Jet Propulsion Laboratory is providing technical management and analysis of the results for two proposed new projects to be started next year: (1) a seven-year project to collect meaningful data on the frequency and severity of lightning-induced surges on electric distribution systems, with the participation of about twenty utilities in different regions of the country; and (2) a modeling project on the use of distribution lines as communication links for load management and distribution automation. JPL will analyze the results to establish procedures for predicting communications capabilities. Proposed DOE passthrough funding for FY 1979 is \$1 million.

ENERGY STORAGE SYSTEMS

The Department of Energy is funding NASA centers for the development or program management for four types of energy storage systems for use with a number of different energy sources, such as solar energy or waste heat. The Lewis Research Center is conducting a program to develop and demonstrate the feasibility of "Redox" battery systems, in which the energy is stored in tanks separate from the power generating portion of the battery. Total system tests in FY 1978 will determine whether to proceed beyond the feasibility studies; if successful, "Redox" systems show promise of being more economical than conventional batteries in some applications. LeRC also has primary responsibility for the high-temperature thermal energy storage program, whose aim is to develop cost-competitive thermal energy storage systems for use at temperatures about 250°C., including both sensible and latent heat storage methods. Currently major systems studies are underway for key applications. Another energy storage system under study at LeRC is the storage of mechanical energy in rotating flywheels with extremely low friction losses. System studies indicate attractive economic potential for use with solar energy systems. Jet Propulsion Laboratory has the lead responsibility for developing economic thermochemical hydrogen production systems, in which heat rather than electric current is used to decompose water to produce hydrogen. The project also includes broad systems studies of the use of hydrogen energy storage systems. Proposed DOE funding for FY 1979 is \$6.8 million, up from an estimated \$5.4 million in FY 1978. In addition, NASA is managing an estimated \$1.2 million in DOE FY 1978 contracts.

FOSSIL ENERGY

Magnetohydrodynamics

The Lewis Research Center, with DOE support and through in-house and contract studies, is assisting the MHD program in three ways: (1) it is developing and utilizing computer models of alternative subsystem designs for use in MHD plant analysis and optimization; (2) it is performing an independent evaluation of three competitive conceptual design and system engineering studies of a proposed engineering test facility, and it is performing preliminary engineering studies for integrating test facility designs; and (3) it is providing technical support for DOE program management, to include studies of proposed long-duration MHD systems. Estimated FY 1978 funding is \$2.5 million; proposed FY 1979 is \$2.6 million.

Advanced Power Systems

LeRC is providing project management support for several advanced power system studies: (1) identification and evaluation of advanced energy conversion systems for industrial cogeneration applications during the period 1985-2000; (2) development and demonstration of turbine combustors that will operate with environmentally acceptable NO_x emissions, on a variety of liquid fuels with high nitrogen content; (3) development of long-life thermal barrier coatings for gas turbine components, which will not only keep engine parts cooler, but also protect them from the corrosive environment of low-grade liquid fuels; (4) advanced R&D on combustors, materials, and corrosion problems for systems using coal-derived fuels; and (5) project management for development of technologies to provide additional supplies for industrial fuel cells in onsite integrated energy systems. Estimated funding in FY 1978 and proposed for FY 1979 are both \$1 million. In FY 1978, NASA is managing an estimated \$5.5 million in DOE contracts on fuel cells and will continue at about the same level in FY 1979.

Coal Mining Technology

The Marshall Space Flight is continuing two relatively small projects previously supported by the Bureau of Mines: (1) development of sensors for detecting the interface between coal and rock, so that a long wall machine can be steered remotely; and (2) development of a guidance and control system for the shearer that can be incorporated into an automated face system.

The proposed DOE FY 1979 funding for the total NASA fossil energy program total \$4 million, about the same as in FY 1978.

NUCLEAR RESEARCH AND APPLICATIONS

DOE utilizes the Jet Propulsion Laboratory for long-term testing of thermoelectric generators in the Space Nuclear Power Systems effort. Estimated funding for FY 1978 is \$200 thousand; proposed for FY 1979 is \$300 thousand.

ENVIRONMENTAL R&D

NASA research on environmental problems that is funded or co-funded by DOE includes three projects concerned with atmospheric pollution and one that is concerned with long-term human exposure to high-energy heavy ions. DOE, through the Ames Research Center, has been providing supplemental funding for the development of selected laser techniques, using resonance absorption or fluorescence, for the measurement of highly reactive radicals in the atmosphere. This measurement is of importance in predicting the effects of atmospheric pollution from fossil fuel combustion and conversion. DOE, through the Johnson Space Center, is sponsoring a high-altitude atmospheric sampling program. Samples of radioactive and stable gases and particulates are collected by means of various instruments aboard a WB-57F aircraft. DOE has also been sponsoring the development at the Langley Research Center of sensitive direct-inlet mass spectrometer methods for the detection, identification, and measurement of trace inorganic and organic pollutant gases in the atmosphere, in industrial plants and in stack gases. Proposed DOE funding for these programs in FY 1979 is approximately \$600 thousand, down slightly from \$700 thousand in FY 1978. In addition, DOE provides support for NASA biomedical research aimed at estimating the effects of long-term human exposure to high energy heavy ions. This research is conducted at the BEVALAC, the high-energy heavy ion accelerator facility at the Lawrence Berkeley Laboratory. DOE absorbs the BEVALAC operating costs for this research, which is of potential importance for manned space flights, and also for the satellite power systems program.

SPACE APPLICATIONS

The overall objective of this activity is to support the Nation's civilian space exploration program and national security interests by providing low-cost nuclear power systems for specific NASA and DOD applications in space. It is funded by DOE directly to its contractors, not by passthrough funding, but clearly it requires close cooperation among the agencies concerned. Highlights of the proposed space nuclear applications programs for FY 1979 are as follows:

Continue flight system design, fabrication and assembly of the Selenide Isotope Generator for use in the NASA Jupiter Orbiter Probe spacecraft scheduled for launch in early 1982; the Selenide Isotope Generator ground demonstration units will be continued on life test using electrical heat sources.

Continue design of the engineering flight hardware and testing of the Dynamic Isotope Power System ground demonstration system being developed for use in the DOE/Air Force Space Test Program launch scheduled for late 1982/early 1983.

Initiate development of an improved Selenide Isotope Generator incorporating the General Purpose Heat Source, a modular plutonium 238 fueled unit, for the NASA Solar Polar Mission scheduled for launch in early 1983.

Maintain plutonium 238 fuel form production and encapsulation capabilities to provide up to 4 multi-hundred watt radioisotope heat sources for testing with the static and dynamic conversion systems under development for the NASA Jupiter Orbiter Probe and DOD Space Test Program applications.

Evaluate and assess operations necessary to ensure safe and environmentally acceptable operations leading to flight approval of the Dynamic Isotope Power System unit and the Jupiter Orbiter Probe isotope power units. All isotope-powered units planned for space use have an imposed safety requirement for intact re-entry and containment of the fuel, whether in normal or aborted operations.

Continue efforts to decontaminate and decommission the Mound Facility since Pu-238 fuel form production and encapsulation operations have been transferred to the new Savannah River Plutonium Fuel Facility.

Initiate a program to evaluate the feasibility of a nuclear reactor power supply. This effort is not at this time a hardware-oriented program. The safety concept in this study is based on the launch of a cold, nonoperating system, which would start power operations only after a safe, long-term orbit has been established.

The proposed DOE funding for this program in fiscal year 1979 is \$40 million, up from an estimated \$31 million in fiscal year 1978.

This space applications program just described was, of course, formulated and submitted prior to the recent unfortunate incident involving a Soviet satellite. We have placed only one nuclear reactor in Earth orbit, the Snapshot

launched in 1965. That reactor is currently in an orbit with a lifetime of 4,000 years. The only portion of the proposed fiscal year 1979 funding concerned with the reactor power supply is \$2 million for a concept feasibility study.

At present the DOE is reviewing the program to insure conformance with evolving national policy regarding the use of nuclear materials in space. This review will be conducted in cooperation with the Department of Defense and the National Aeronautics and Space Administration, whose activities we support with our developmental, production, and safety programs. We will advise the Committee of the results of this review as soon as it is completed.

CONCLUSION

In conclusion, the Department of Energy feels that its cooperative programs and institutional relationships with the National Aeronautics and Space Administration continue to be healthy. Further experience demonstrates that the Program Coordinating Committee instituted under ERDA is an effective mechanism for maintaining these good relationships and resolving issues at the policy level. It has also fostered excellent coordination at the technical working level, even though the interfaces are complicated by the very broad spectrum of markets and technologies involved. We feel not only that the technological program as a whole is making good progress, but also that the increased emphasis in some sectors on environmental, economic, and institutional issues will help to enhance the program's contributions to meeting the energy needs of the Nation.

DOE-NASA PROGRAM COORDINATING COMMITTEE

NASA membership:

Dr. Alan M. Lovelace, Deputy Administrator (Co-Chairman)

Dr. John E. Naugle, Chief Scientist

Dr. James J. Kramer, Associate Administrator for Aeronautics and Space Technology

Mr. Kenneth R. Chapman, Acting Associate Administrator for External Relations

Mr. John M. Coulter, Office of External Relations (Co-Secretary)

DOE membership:

Dale D. Myers, Under Secretary (Co-Chairman)

John M. Deutch, Director of Energy Research

Robert D. Thorne, Acting Assistant Secretary for Energy Technology

Donald A. Beattie, Acting Assistant Secretary for Conservation and Solar Applications

Phillip S. Hughes, Assistant Secretary for Intergovernmental and Institutional Relations

Robert W. Ritzman, Office of Intergovernmental Affairs (Co-Secretary)

COOPERATIVE EFFORTS

DOE ORGANIZATIONS

NASA FIELD CENTERS

TRANSPORTATION

Division of Transportation Energy	Pet Propulsion Laboratory,
Conservation (CS)	Lewis Research Center

SOLAR HEATING AND COOLING

Office of Solar Heating and Cooling	Marshall Space Flight Center
(CS)	

SOLAR THERMAL

Division of Solar Technology (ET)	Pet Propulsion Laboratory,
	Lewis Research Center

PHOTOVOLTAICS

Division of Solar Technology (ET)	Jet Propulsion Laboratory
	(Lewis Research Center)

WIND ENERGY

Division of Solar Technology (ET) Lewis Research Center

SATELLITE POWER SYSTEMS

Division of Solar Technology (ET) Johnson Space Center
 Division of Biomedical and Environ- Marshall Space Flight Center
 mental Research (EV)

GEOTHERMAL ENERGY

Division of Geothermal Energy (ET) Jet Propulsion Laboratory

ELECTRIC ENERGY SYSTEMS

Division of Electric Energy Systems Jet Propulsion Laboratory
 (ET)

ENERGY STORAGE SYSTEMS

Division of Energy Storage Systems Lewis Research Center
 (ET) Jet Propulsion Laboratory

MAGNETOHYDRODYNAMICS

Division of Magneto hydrodynamics Lewis Research Center
 (ET)

ADVANCED POWER SYSTEMS

Division of Power Systems (ET) LEWIS RESEARCH CENTER

COAL MINING TECHNOLOGY

Division of Coal Mining and Marshall Space Flight Center
 Preparation (ET)

NUCLEAR RESEARCH AND APPLICATIONS

Division of Advanced Systems and Jet Propulsion Laboratory
 Material Production (ET)

ENVIRONMENTAL RESEARCH AND DEVELOPMENT

Division of Biomedical and Environ- Ames Research Center
 mental Research (EV) Johnson Space Center
 Langley Research Center

SPACE APPLICATIONS

Division of Advanced Systems and N/A
 Material Production (ET)

DOE/NASA COOPERATIVE PROGRAMS—DOE PASSTHROUGH FUNDING TO NASA, BUDGET AUTHORITY

[In millions of dollars; fiscal years]

	Estimated 1978	Proposed 1979
Conservation and solar applications.....	42.0	50.0
Transportation.....	26.0	43.0
Solar applications (heating and cooling).....	16.0	7.0
Solar technology.....	53.0	54.0
Solar thermal.....	7.0	8.0
Photovoltaics.....	34.0	29.0
Wind energy.....	12.0	15.0
Satellite power systems.....		1.3
Geothermal energy.....	.7	.2
Electric energy systems.....		1.0
Energy storage.....	5.4	6.8
Fossil energy.....	4.0	4.0
Magnetohydrodynamics.....	2.5	2.6
Advanced power systems.....	1.0	1.0
Liquefaction.....	.1	
Nuclear research and applications.....	.2	.3
Environmental research and development.....	.7	.6
Total.....	105.0-110.0	115.0-120.0
DOE funded and managed:		
Space applications program.....	31.0	40.0
Satellite power systems.....	12.8	3.3
DOE funded and NASA managed:		
Solar applications (heating and cooling).....	5.0	5.0
Energy storage.....	1.2	
Advanced power systems (fuel cells).....	5.5	about 5.0
Transportation energy.....	about 13.0	about 13.0

¹ Passed through from NASA to DOE.

[The following information was subsequently received for the record:]

QUESTIONS OF THE COMMITTEE AND THE ANSWERS THERETO

Question. You stated that the Department of Energy's Budget includes \$2 million for evaluation of an advanced nuclear power reactor concept to provide satellite electrical power.

What electrical power levels require a nuclear reactor power source?

Answer. Electrical levels in the 10 KW(e) to 100 KW(e) power range appear to offer several attractive overall spacecraft options to a nuclear reactor power source.

Question. Has the Department of Defense or NASA asked DOE to develop a high power nuclear reactor power source for space use?

Answer. No. But the Department of Defense supports the conduct of studies and experiments aimed at retaining for the DOE the option for a future reactor system development in the 10 KW(e) to 100 KW(e) range. Elements of this activity have potential significance, in the longer term, to the evolution of nuclear electric propulsion which is of interest to NASA. The studies and experimental verification efforts will provide the information for evaluating the feasibility of a space reactor concept—a concept that is not at this time hardware oriented.

Question. During the 1960's, we spent a large amount of money on the development of the SNAP-8 reactor system before it was cancelled. What is a rough estimate of the development cost of the concept you are planning to evaluate?

Answer. The Department of Energy does not plan to undertake the development of a space reactor system without a firm requirement from either DOE and/or NASA. The technology assessment and verification phase is targeted at \$2M per year over a five to seven year period. A hardware oriented space reactor flight development program is estimated to cost between \$200 million to \$300 million.

Question. In view of the recent Soviet reactor incident, what are your views on using nuclear reactor systems for satellite power?

Answer. Nuclear reactor systems could supply the electrical power needs of spacecraft in such future missions involving high altitude, extra-terrestrial bodies, exploration of the solar system using nuclear electric propulsion or semi-permanent lunar bases.

Question. How would you propose to package and operate a nuclear reactor power source for satellites to avoid launch hazards or the hazard of an inadvertent reentry of the reactor?

Answer. The U.S. space reactor safety concept is based on the launch of a cold, nonoperating reactor system which would only achieve power operation after a suitable safe, long-term orbit has been established. Under this safety philosophy, in the event of a launch abort or short orbit reentry situation, the release of radioactive material would be minimal because the reactor will not have operated.

Question. What other source are you considering for large amounts of satellite power (30-50 kilowatt range)?

Answer. NASA and the DOD continue to assess the use of solar cell power systems in this power range.

Question. What are your views on H.R. 10601, the "Solar Power Satellite Research, Development and Demonstration Program Act of 1978" introduced in the House by Mr. Flipbo in January 1978?

Answer. I have studied H.R. 10601 and believe that the development and demonstration efforts proposed therein are premature. I believe that we should proceed according to the jointly approved DOE/NASA plan (DOE/ET-0034) which was recently sent to the Congress. There is much to be learned about the SPS concept within the context of existing knowledge. For instance, we are developing information relating to the potential effects of microwaves on widely used communication, navigation, and radar systems, as well as on the biota and the ecology. As we learn about these effects, we are also becoming aware of the need for pertinent experimentation, some of which will be done within the program described in DOE/ET-0034, and others at a later date. Should the requirement for development and demonstration activity become apparent to answer critical issues, we would not hesitate to request the necessary funds.

Question. Do you think this Bill would expedite action on this energy potential?

Answer. I do not think that HR 10601 would resolve key SPS issues at the present time. Thus it would not expedite action on this energy potential.

Question. Why is it that the Executive Branch is willing to spend hundreds of millions of dollars a year on a fusion energy source—Mr. Augustine in his paper says \$647 million is proposed for fiscal year 1979—and only a few million dollars in fiscal year 1979 for work on a solar satellite power system?

Answer. The U.S. Magnetic Fusion Program has been in formal existence since 1951. Since that time, it has undergone numerous research and development phases with major funding commitments having been made only in recent years. The present level of funding has been reached as a result of major technical accomplishments and past achievements.

In contrast to the above, the ERDA/DOE Space Satellite Power System Program (SPS) is only now starting and, as is the case with other new programs, there are some serious questions to be answered before major program dollar commitments are made. For example, there are potential adverse environmental effects and power conversion processes are currently only concepts. The Space Satellite Power System program is engaged in an effort through fiscal year 1980 to answer such questions. To increase funding significantly in the time period before 1980—prior to the evaluations planned—would appear imprudent at this time.

Question. From a technical point of view, isn't the science and technology involved in fusion much more difficult and not so far along as the science and technology needed for a solar satellite power system?

Answer. Both the SPS and the Fusion concepts draw on highly advanced science and technology. Both are potential options for future energy sources. Fusion has been studied long and in greater detail. The major problem in fusion energy is the achievement of the plasma conditions necessary for the fusion process. The demonstration of these conditions is expected to occur in the next five years through the operation of experimental reactors now under construction, such as the Tokamak Fusion Test Reactor. Subsequent development of the fusion process to commercialization is expected to be similar to programs already successfully executed.

On the other hand, while the concept of space power systems has been around for about ten years, the system has been studied in depth only for the past few years, and the technical problems are beginning to identify themselves. Some insight into the nature of our understanding of SPS can be obtained by comparing the two approaches being studied—the Johnson Space Center version and the Marshall Space Flight Center version. These differ substantially in such fundamentals as power output, choice of solar cell material, method of space construction, method of transportation to orbit and in other substantive parameters. The ongoing systems study effort and the environmental studies will narrow the uncertainties in the SPS concept. The current planned joint activity with NASA seems to be appropriate to the level of understanding of SPS.

Question. In the plan that you have presented, you propose a substantial effort on environmental factors and socio-economic issues, some additional work in systems definition and a comparative assessment but almost nothing for technology development or demonstration. The total amounts to 15.6 million dollars over a four year period through August 1980. Fusion will not yield useful amounts of energy on an operational basis until well into the next century, but we have an energy crisis now, and many think the solar satellite power system offers some hope. So, why don't we spend a little more than \$3 to \$4 million dollars a year on it to find out about the technology and perhaps demonstrate it so in a few years we know how to proceed with the SPS?

Answer. Much of the uncertainty about SPS can be resolved through related research and development now under way in DOE and NASA, which is not part of the SPS programs itself, and through information already in the literature. This information will be available when needed for decisions as scheduled in the SPS program plan. The SPS, which cannot become operational in less than 15 to 20 years, offers no hope of providing energy now or in the next decade. Additional effort during the next few years on SPS technology could not contribute significantly to understanding of the key environmental and comparative analysis issues. Therefore large increases in funding for SPS programs are not needed at this time.

Question. ERDA was assigned a responsibility for conducting an evaluation of the solar satellite power system and the committee requested that it be provided with a copy of this plan when it was complete. It is understood that a first plan was completed sometime last summer but was unacceptable to OMB. How did that plan differ from this Plan? Why was it unacceptable to the OMB?

Answer. On being assigned the responsibility for SPS, ERDA formed a task group to evaluate the concept, and recommend a course of action. The results were published in a widely distributed "Final Report of the ERDA Task Group on Satellite Power Stations, ERDA-76/148, November, 1976." The first Program Plan covering the years 1977 through 1980 was jointly prepared by DOE and NASA, and issued in May, 1977. Subsequently, OMB requested that space related technology elements be eliminated from the plan as being premature. This deletion is reflected in the February, 1978 document.

Question. It seems that just about everybody has seen this plan before it was sent to the Committee. Why did it take so long to get a copy of the plan to the Committee?

Answer. The present SPS program plan, dated February, 1978, is essentially a condensation of the May, 1977, document; the only substantive change was the deletion of the space related technology studies. No distribution of the program plan was made prior to the formal transmittal from DOE to the appropriate Congressional Committees. This occurred on March 13, 1978.

Question. What approaches are used to move solar heating and cooling technology developments from NASA and/or DOE to the private sector?

Answer. Virtually all technology developments are being performed by the private sector. The Department of Energy laboratories and NASA do relatively little in-house R&D. The issue is one of transferring the technology from these individual developers to the industry as a whole. The responsibility of the Department of Energy is to guide these individual technology developments into a fully commercialized industry. Implementation of this commercialization process involves planning, program management, removal of barriers, and the establishment of government policies conducive to accelerated commercialization, and finally, the dissemination of the technology to a broader industry base. Industry, on the other hand, provides the necessary resources, the expertise, the facilities, and the capital. Industry also conducts the development of the technology and ultimately turns the technology into a marketable product or system.

To insure the dissemination of the information flowing from this program, the DOE has established an information system which involves the publication of all useful information emanating from this program. This information is made available to the public and the industry through a national information center located in Rockville, Maryland, under the operation of the Franklin Institute. This information takes the following forms:

Information dissemination.—For example:

Articles published in technical journals

Papers presented at solar energy meetings

Contractor reports circulated through the DOE Technical Information Center

Telephone and written answers to questions submitted to the National Solar Heating and Cooling Information Center.

Licensing of DOE-developed technology.—For example:

Compound Parabolic Concentrating Collector developed by Argonne National Laboratory has several industrial licensees

10× Fresnel lens concentrating collector licensed by NASA/JPL to Owen Enterprises in Los Angeles.

Eventually, the responsibility for complete data dissemination might be placed at the Solar Energy Research Institute in Golden, Colorado. To assist the industry in assessing the performance of the various heating and cooling options, a national data program has been established in which a minimum of 200 test sites will be fully instrumented to evaluate the performance at the system, subsystem, and component levels. This information is being collected, analyzed, and reported through the National Technical Information Center. In summary, the technology transfer to the private sector is accomplished through a supporting research and development program, a systems development program, a field test program, and a supporting study program. An information system is in place to hasten the transfer of the information to the interested industry participants.

Question. What progress is being made in advancing the technology of solar cooling systems for residential applications?

Answer. The Solar Applications Research and Development Branch of the Office of Conservation and Solar Applications is preparing a national plan for solar cooling. This plan is presently in draft form, and is expected to be released in several months. This program plan recognizes that the ultimate commercialization of solar cooling will depend on the development of higher performance in cooling concepts which have system reliabilities commensurate with conventional cooling systems. Further, this plan recognizes that a cost goal of three to four times conventional installed system costs is mandatory for large scale consumer acceptance.

As part of the development of this plan the various solar cooling technology options have been evaluated. Those technologies most likely to achieve residential market acceptance have been identified and a vigorous development program to convert those options into integrated heating and cooling systems has been initiated. The options may be divided into passive cooling techniques, which require minimal or no electric power to actuate the cooling system, and active systems which do require the introduction of electric power for the continuous operation of the cooling system on demand.

A variety of passive concepts are under development including the use of architectural techniques to reduce the solar load on the dwelling. Passive techniques are also being developed using specialized hardware to collect the thermal input from the dwelling and reject it to the environment, the sky, or the ground. The Department of Energy recognizes that in certain climates these passive techniques will not be adequate and that active cooling concepts will also have to be developed. The active cooling concepts include absorption air-conditioning, heat engine power vapor compression systems, desiccant systems, and specially designed heat pump systems which enhance the heat pump performance using the solar heating components. A total of 20 such active cooling concepts are presently being developed for residential applications.

The steps in the development process require the development of the cooling subsystem, followed by the integration of the cooling subsystem into a complete heating and cooling system. The cooling system is then tested prior to a field test program during which more extensive engineering data is collected. At the present time 7 of the 20 concepts under development have advanced to the systems development phase. Two of these 7 systems programs have resulted in test

activities in operational environments. As a direct result of this program Arkla Industries of Evansville, Indiana have designed, fabricated and installed a truly integrated three-ton residential absorption cooling system into a new dwelling located in Evansville, Indiana. This installation was completed in November 1977 and is currently undergoing a thorough evaluation by Arkla Industries. The auxiliary power requirements of this new cooling system are approximately 30% lower than present systems, and the overall cost is 15-20% lower. Upon successful completion of these tests, the larger scale field testing of this system will be initiated. Within FY 1979 an additional four completely integrated residential cooling options are planned for operational testing by the manufacturers.

Currently, the installed cost of residential cooling systems is about \$8-\$10,000 per ton of cooling. At the conclusion of the field test program the DOE expects that this installed cost will reach \$5-\$7,000 per ton. While this cost will be about one and a half to two times the cost target required for large scale market penetration, it will be low enough to allow penetration of certain prime solar cooling markets.

Question. What progress is being made to increase the efficiency and reliability and drive down the cost of residential solar heating systems?

Answer. The problems of solar heating system cost, efficiency, and reliability are being addressed in the Solar Demonstration and R&D programs in the Office of Conservation and Solar Applications.

The Demonstration program is helping to reduce system cost by providing the developing solar industry with an incentive to tool-up for mass production. The ongoing HUD and DOE commercial and residential demonstration programs offer a greatly increased market for such cost-levering items as collectors, and thereby push the industry toward large-scale production with resulting decreased costs. Also, results from the instrumented demonstration projects, are fed back into the R&D program to help provide guidance for funding to further reduce system costs.

The R&D program is working at reducing system costs by:

- Improving thermal performance of components, subsystems and systems for both new construction and retrofit applications;
- Reducing manufacturing and installation costs;
- Enhancing reliability and service life, reduced maintenance;
- Lowering operating and auxiliary energy costs.

Some examples of projects which are contributing to these goals are:

Collectors fabricated from low cost non-metallic materials such as plastic and concrete.

Water and rock storage containers manufactured from such inexpensive and improved materials as lightweight concrete and plastic composites.

Development of improved solar heat pump systems for residential applications.

User-oriented computer design methods for solar heating systems and handbooks which are widely used by architects, engineers, and designers.

Passive solar heating development and utilization activities to stimulate cost effective approaches. A DOE/HUD Passive Heating and cooling Design and Construction Competition for Passive Residential Buildings has been initiated. Major emphasis of the competition this year is on residential heating applications.

Activities to promote cost-effective solar retrofit applications are being pursued, and include: the development of improved solar heating systems and components with reduced cost, improved performance, and the availability of design methods and reference material to facilitate practical use of solar retrofit systems.

Question. Please provide the Committee with a copy of each of the 16 references listed in the SPS program plan report number DOE/ET-0034.

Answer. To provide a full set of 16 documents would involve massive copying effort, since only one copy of most documents is available. These are available in the SPS Project Office. Copies of four representative documents are provided to the Committee as follows for its files.

"A Survey of Satellite Power Stations," Planning Research Corp., September 1976.

Memorandum of Understanding Between ERDA and NASA, June 23, 1975.

"Electromagnetic Compatibility Tropospheric & Ionospheric Aspects of SPS MPTS Operations," March 1978.

Draft—"Compilation & Assessment of Microwave Bioeffects," AO-02-01/EA81028 Preliminary Report—Survey of Pertinent Literature, Research Needs & Bibliography, December 1977.

Question. Are there any mechanisms in place or under development to assure that only quality hardware is offered to residential customers?

Answer. There are several mechanisms in place or under development to assure quality hardware is available to solar energy consumers. There are standards now in effect for solar collector testing and solar storage testing. HUD has promulgated Intermediate Minimum Property Standards for solar heating systems on residences. A solar collector certification program is now underway whereby collectors will be tested and rated and a catalog published. Also, the development of a model building code for use with solar energy systems is underway.

Question. Do we have a commercial base established that is capable of providing efficient, reliable, durable and reasonable cost solar heating systems for residential applications?

Answer. We are currently witnessing very rapid growth of a solar industry to produce residential solar heating systems. For the past several years in fact, this new industry has been doubling in size every 8-9 months. This is evidence that a commercial base is being established.

"Reasonable cost" or ability to compete with alternative energy supplies differs from region to region. However, recent studies have shown solar hot water heating to be competitive with electricity and fuel oil in many regions. On a life cycle cost basis, solar space and hot water heating are competitive across the country. The solar tax credit, if enacted by Congress, will have a dramatic positive impact on solar economic feasibility.

Concerning reliability and durability, current standards exist under HUD's minimum property standards. Consensus standards, being developed in cooperation with the industry will be a future means of consumer protection. The Department is also establishing collector testing centers and a collector labeling program to assure buyers of reliable durable systems.

Senator Ford [presiding]. The next witness this morning is Dr. Norman Augustine, vice president, public policy, American Institute of Aeronautics and Astronautics.

I might say to these witnesses and to the next one, my phone has been jumping off the hook to come immediately to the majority leader's office. I told him I was holding a hearing, and I would hope to adjourn prior to 10 o'clock. So I want to be over there as soon as I can.

If you can condense your statement and be brief, we will submit questions to you for the record.

Mr. Augustine, please proceed.

STATEMENT OF NORMAN R. AUGUSTINE, VICE PRESIDENT, PUBLIC POLICY, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS; ACCOMPANIED BY DR. JERRY GREY, ADMINISTRATOR, PUBLIC POLICY, AIAA

Mr. AUGUSTINE. Fine, Mr. Chairman, I will submit a formal statement for the record; and I will give a synopsis this morning.

Senator Ford. The formal statement will be included in the record.

Mr. AUGUSTINE. Mr. Chairman, and members of the committee, we appreciate first of all, those of us with the American Institute of Aeronautics and Astronautics, the opportunity to appear before you this morning, and share with you our views on the aeronautics and space program as reflected in the fiscal year 1979 budget.

With me is Dr. Jerry Grey, who is our administrator for public policy; and he will join me in answering any questions you wish to ask.

I would like to begin by saying that our comments are intended not to be merely critical, but rather to be constructive.

We are gratified in some areas, for example, in the area of aeronautics, with the growth of support that the program is projected to receive.

On the other hand, there are a number of areas, nine specifically, that we would like briefly to call to your attention as deserving of greater support if indeed we are able to realize the promise that the aeronautics and space program holds in the decades ahead.

Beginning with the aeronautical category, by far the most critical of these problem areas, we believe, is the support given to the supersonic cruise aircraft. Failure to proceed with a variable-cycle experimental engine program in fiscal year 1979 could well impose major delays on our building to implement a viable future operational aircraft of the supersonic cruise type; an effort which we believe will be inevitable. The only question is when will it happen?

The second area within the aeronautical category concerns hypersonic aircraft research. This is an area, as you know, that received little attention since the days of the X-15. It is an area that promises one of the major breakthroughs in atmospheric flight; and yet we are in danger of losing that already too small category of people who are skilled in the areas of hypersonic aerodynamics, structures, controls, thermodynamics, and so on.

The third area I would like to mention concerns rotary wing aircraft. The rotary wing field by and large is at the point today that fixed wing aircraft were perhaps three decades ago. We are just beginning to see the helicopter maturing; it's on the verge of being able to perform many new missions with economic efficiency. There's a great deal yet to be done to underpin that next step. And as we move in the next year or two into the immediate applications, it's our hope that we won't neglect the needed work in such areas as materials, controls, engines, dynamic components, and the like.

The balance of my statement this morning is devoted to space. Our perspective of the space program would be that in the 1960's we necessarily devoted great effort to the matter of really getting into space. In the 1970's we began to reap the benefits of our efforts to improve the quality of life here on Earth through space activity.

And now we again are on a step of maturing space program made possible by the Shuttle, which will permit industrialization, if you will, of space. However, before we can fully realize this promise, one of the areas of shortcoming on my list is the lack of a sound rocket propulsion technology program. This is of particular concern for upper stages for the Shuttle. The current Shuttle is rather limited in its capability to inject payloads into geosynchronous orbits and Earth-escape trajectories, especially the large payloads that one would project for important missions. The projected inertial upper stage and spinstabilized upper stage are important efforts, but don't begin to meet the capability that's needed for a standardized orbital transfer vehicle. The key technology in this area, we believe, is advanced liquid rocket propulsion technology.

I'll move ahead quickly, Mr. Chairman, in keeping with your request and turn to the fifth point we would like to touch upon: it concerns the space power technology program for space vehicles themselves.

Even in the short term the Shuttle's fuel cell powerplant, basically an Apollo derivative, will considerably limit important missions that

are projected for the Spacelab and other Shuttle-related programs. We will need photovoltaic supplies up to the 50 kilowatt level, and eventually 100 kilowatt level nuclear power supplies, or even higher.

I say this fully mindful of the experience in recent weeks of the problem of the Soviet nuclear power system that impacted on Canada. It is our view that with adequate design attention one can construct a nuclear power supply that is completely safe and can be relied upon to reenter intact should that be necessary.

Another major concern in the proposed 1979 NASA budget is the lack of program support for large structures in space. So many of the missions that are contemplated for this decade and the decades ahead involve construction in space, either for manufacturing in space or for assembly of materials originally processed here on Earth. The program today to advance this technology is very limited indeed.

The applications that we have in mind go from the near term, which would perhaps involve the use of an antenna farm concept to support multifunction space communications systems, all the way to the employment of space as a source of power, electrical power, to be used here on Earth. I am referring to the space based solar powerplant.

This is the seventh area that I would like to suggest on behalf of the Institute that we consider as deserving of greater funding. It is an area that won't have a payoff in the next few years; on the other hand, it does appear it would be extremely promising in the long term, and it offers a virtually inexhaustible fuel supply that's clean and relatively safe.

If we are to realize the benefits of a space based solar powerplant, we need to pay some attention to ground-based technology verification of that power system. The Institute has recently conducted a study of the requirements to support such an endeavor. It is our belief that a program on the order of \$30 million a year is needed in the next few years, and that that program will permit technology verification efforts on the ground that could eventually lead to 250 to 1,000 kilowatt electric power demonstration satellite placed in low Earth orbit.

But I would emphasize even if it is some time before the space solar power system has a payoff, or before we could even afford to fund it at large levels, the need still is very compelling to support research and technology efforts in the fabrication of large space structures for a variety of missions.

The next area we believe deserving of additional support is the Shuttle program itself, which is the basis for the industrialization of space we see forthcoming in the century ahead. Without such a system, of course, hardly any of the programs that are now projected will be possible. Therefore it seems to us to be perhaps pennywise and pound foolish to withhold the \$4 million needed in fiscal year 1979 to maintain for another year the option to have a fifth shuttle in the program. We say that not only because of the traffic that is very likely to be required of the Shuttle, but perhaps even more importantly, it seems to us it's low-cost insurance: a hedge, if you will, against an accidental loss of one of the currently projected four vehicles.

The final point, the ninth one on the list that I mentioned, relates to what we consider to be NASA's principal purpose, which is to conduct research and development of new aeronautical and space

technology systems and capabilities. As space becomes industrialized and the day to day demands of operations grow in magnitude, it is our concern that this latter category of endeavor might impact on what we consider to be NASA's primary mission.

We believe therefore that it's not inappropriate even at this time for the committee to begin to consider the various management approaches for manning operational aspects of space activities. These approaches are varied. one might be to expand NASA's charter and include in NASA's budget funds to conduct those operations; another possibility is to set up new Federal agencies or rely upon existing agencies, such as has been done with weather satellites; another would utilize private industry, as has been done in the case of communications satellites, or even multinational consortiums.

But it does appear to be true that in many of the programs ahead, the Shuttle being one, once they have reached operational status, that could place such great demands in such areas as selling tickets and maintaining airframes and engines, that they could detract from the important thrust we believe is NASA's: to propose space opportunities for the future and develop the technology that permits us to fly the opportunities that we see.

Mr. Chairman, I will close at that point; and again thank you on behalf of the Institute and its 25,000 members for being able to share our views with you. Dr. Grey and I would be happy to answer any questions you or the members might have.

Senator FORD. Mr. Augustine, I appreciate your testimony this morning, and also your constructive comments.

There will be several questions I will submit to you in writing. One thing I am interested in is nuclear reactor systems. I would like to have your comments, particularly for myself.

I do thank you, and Dr. Grey for your attendance this morning; and I regret we don't have more time. But we don't set our own schedules, and even then somebody else always interrupts them.

Mr. AUGUSTINE. Thank you.

[The statement follows:]

STATEMENT OF NORMAN R. AUGUSTINE, VICE-PRESIDENT, PUBLIC POLICY, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS

The American Institute of Aeronautics and Astronautics is the technical society whose membership of 25,000 engineers, scientists, and students represent all the disciplines of aerospace science, technology, and applications. We have frequently presented testimony on aerospace activities before this Subcommittee and its predecessor Committees, and we appreciate this opportunity to express our views on the nation's aeronautics and space programs as currently defined by the President's proposed FY 1979 NASA budget.

In aeronautics, we are gratified to see the considerable increase in support for aeronautical research in general, continuing the trend established by the FY 1978 budget growth. A number of the research areas we supported in our previous statements have indeed received attention, but there are still a few subjects which we believe represent serious inadequacies in an otherwise healthy and commendable R&D growth pattern.

By far the most critical of these isolated problem areas is the reduced emphasis on what was already (FY 1978) an inadequate program in research and technology efforts applicable to supersonic-cruise aircraft. Although we recognize that there are non-technical concerns which tend to keep this activity at an overly low level, the failure to proceed with a variable-cycle experimental engine program in FY 1979—or even to increase substantially the research/technology ef-

fort on supersonic-cruise propulsion—could generate major delays in the eventual (and, we believe, inevitable) implementation of the supersonic-cruise research activity into a viable future operational aircraft.

Another major shortcoming is the continued lack of emphasis on hypersonic aircraft research. While there is little likelihood for early implementation of this research in the form of an operational aircraft, it does represent one of the few real opportunities for major advances in the science of atmospheric flight. The lack of a hypersonic research aircraft program comparable in scale to the X-15 continues to hamper any real progress in this key research area, and results in a continuing erosion of the nation's already too-small cadre of technical capability in the aerodynamics, structures, controls, heat transfer, and propulsion technologies applicable to hypersonic flight.

A third area of concern relates to rotary wing aircraft technology. In many respects, rotary wing aircraft are just now maturing to the point where fixed wing aircraft were several decades ago. In fact, the use of helicopters today could well be on the very threshold of a whole new vista of capabilities and applications. In order to realize these benefits there is a need for solid underpinning of on-going developmental activity with a strong research and technology effort in such fields as materials, controls, engines, dynamics, etc., all relating to rotary wing applications. The current program sponsored by NASA in these areas is generally excellent in quality but limited in scope. With respect to the management of this program, NASA's support of joint efforts with the Army could well be a model for cooperative research among governmental organizations.

The balance of my statement is devoted to space. In the past two decades, the U.S. space program has come nearly full circle. Our initial efforts were of necessity exploratory, seeking to develop the technology and capability needed for more ambitious future endeavors. In the decade of the 1970's we turned more and more to the utilization of our space capabilities to improve the quality of life here on earth. Applications to communications, meteorology, national defense, resource detection, and the development of new scientific knowledge about the Earth, the Sun, the solar system, and the stars have become the principal focus of space activities.

Now, we are preparing to begin again the process of maturing a whole new gamut of capabilities. The advent of the space shuttle both enlarges our ability to perform applications-oriented missions and opens new vistas of what we can accomplish in space. But, while NASA does an excellent management job in general, and while the FY 1979 budget devotes adequate attention to the applications (including scientific exploration)—which is both excellent and necessary—the agency is not preparing properly for the potential expansion of space activities which is made possible by the introduction of reusable space transportation systems.

Our most serious concern is the lack of adequate technology programs in those areas most needed for fulfillment of the promise of space. These include propulsion and power, under the jurisdiction of the Office of Aeronautics and Space Technology, and Advanced Programs in the Office of Space Transportation Systems.

The lack of a sound NASA rocket propulsion technology program, identified over three years ago by NASA's own Research and Technology Advisory Council, is already beginning to affect plans for proper shuttle utilization. Many of the shuttle's prospective customers require higher energy orbits than the shuttle orbiter can provide, especially geosynchronous orbits and Earth-escape trajectories. The projected inertial upper stage and spin-stabilized upper stage do not begin to meet the capabilities required of a standardized orbital transfer vehicle—and the principal lack is that of a good, advanced liquid-propellant rocket engine, which in the long run could reduce transportation costs and make the shuttle system economically more attractive. As a consequence, the shuttle may suffer a serious loss of potential business; e.g., to the ESA Ariane launch vehicle.

But the lack of an active and viable rocket propulsion technology program has even more serious consequences: a loss of intrinsic capability in this area. Our impressive past successes in space were in no small measure the result of several decades of building propulsion capability: test facilities, production facilities, support facilities, propulsion hardware, and, most important, people.

NASA's cadre of experienced rocket propulsion personnel is dwindling rapidly (as are key NASA cadres in other space technologies). There are no new peo-

of specific NASA-developed technologies, and that such benefits will continue to accrue from future specific activities. A prime example of such a future opportunity is the expansion of satellite communications capability and Earth observation system capabilities into a comprehensive global information system.

My final point is related to our previously-expressed views on revitalizing NASA's space technology capabilities. NASA's principal purpose—research and development of new space technologies, systems, and capabilities—should not be allowed to become secondary to the operation of applications programs, with the consequent deemphasis on advanced programs designed to support future needs. We recognize, of course, the need for someone to operate our space systems—Earth resources, space transportation, astronomical and scientific satellites, and so on—but we should not foreclose on our preparation for the future in order to do so.

We believe this Subcommittee should initiate the exploration of the various approaches to implementing the operational aspects of space activities. Possible options are to expand the original NASA charter defined in Public Law 85-568, as was suggested by former AIAA President Daniel Fink in *Astronautics & Aeronautics* back in 1973; to set up new federal agencies; to transfer operational activities to an existing cognizant federal agency (as was done with weather satellite operations); to encourage private industry to take over operations, as was the case with communications satellites; or, when operations have a multinational application, to organize an international consortium such as Intelsat. Even the shuttle, once it has reached operational status, should perhaps be operated by an entity more like a commercial airline, allowing NASA to perform its proper function of improving the shuttle and developing follow-on capability rather than selling tickets or doing airframe and engine maintenance.

It is already clear that the U.S. is not the only nation interested in the potential of space as a long-term economic opportunity. According to British expert Kenneth Gatland, Soviet space planners already believe that "no industrialized nation is likely to remain competitive without access to space". Further, Soviet spacecraft designer Dr. Konstantin Fokhtistov's views on space industrialization—particularly solar power satellites—have prompted "... many Western observers (to) see the future of space more clearly defined in Moscow than in Washington ... Unless the U.S. is prepared to capitalize on all the progress it has made in space over the last decade—and go on to develop a space station—we could easily see this big initiative slipping in favor of the USSR."

Thank you for this opportunity to present our arguments in support of the view that too shortsighted a program goal in advancing technological capability can seriously prejudice the attainment of useful and viable space objectives.

Dr. Grey and I will be pleased to answer any questions you may have.

[The following information was subsequently received for the record:]

RESPONSES TO QUESTIONS BY SENATOR WENDELL FORD

Question.—Supersonic aircraft research. You comment on the inadequacy of the supersonic cruise aircraft research program. What level do you think it ought to be? What objective, and in what time frame, do you think the NASA supersonic research program ought to have? Why do you think this is important?

Answer. NASA's present supersonic cruise aircraft research (SCAR) program has been funded at a level adequate only to define problems and to identify promising solutions via analysis and a few small-scale experiments. This minimal effort has not been able, however, to demonstrate whether or not the indicated solutions are truly viable.

To demonstrate such viability in the form of technology readiness for a commercial aircraft project by, say, 1983 (which we believe would be the "ideal" objective and time frame for the NASA SCAR program) will require considerable sub-scale and full-scale component and subassembly testing. Prior estimates have placed the total cost of such testing in the range \$400 to \$450 million for airframe elements and \$250 to \$800 million for the variable-cycle engine, or an average cost of \$125 to \$250 million per year for 5 years. This average funding could, of course, be "stretched out" over a longer period than 5 years, but only by increasing the total cost.

Now, we do not advocate that Congress add \$125 million to the FY 1979 budget for supersonic cruise research. However, the key pacing element in establishing the economic and environmental viability of an advanced supersonic transport (AST) concept is the propulsion system and, in particular, the variable-cycle engine. We believe the House of Representatives' recommendation that \$12 million be added to NASA's FY 1979 budget for accelerating research in this area, although still far below the ideal level, is at least a step in the right direction. Although it is perhaps only a third of what would be needed (in the first year of the suggested five-year program) to begin establishing technology readiness for an AST, it does represent an adequate first-year level for establishing such technology readiness by the late 1980's. However, we believe a commensurate increase in effort on long-lead airframe problems, particularly titanium structures and advanced wing configurations, should also be implemented in FY 1979.

We believe that a proper level of supersonic cruise research and technology programs by NASA is important in order that U.S. industry be equipped to compete with the growing foreign capability in air transport. The U.S. Congress decided in 1971 not to pursue a U.S. prototype SST, but time does not stand still. Perhaps by the mid-to-late 1980's, and almost certainly in the 1990's, a considerable commercial market for an economically viable and environmentally sound supersonic transport aircraft will exist. The present highly favorable U.S. balance of trade in commercial aircraft exports, as well as the multitude of spin-offs to U.S. commerce which result from our dominance of the world aircraft market, will not persist unless U.S. industry can compete with the descendants of the Concorde, the A-300, and even the Tu 144—all, incidentally, heavily subsidized by government funding.

We do not imply that the U.S. government should develop an advanced supersonic transport, but we do advocate that NASA not forego its traditional (government) role of conducting and/or supporting the long-lead, high-risk research and technology base necessary before U.S. industry can, in good faith to its stockholders, invest in the design and development of a commercially competitive supersonic aircraft.

Question.—Rotary wing aircraft technology. NASA is in the process of consolidating its rotorcraft research at the AMES Research Center and laying out a program to emphasize this research. Do your comments on the NASA program take into account the current attention NASA is giving to this activity? Do you believe that more effort is required than NASA plans to provide? Are the proper areas of helicopter research being addressed by the NASA program?

Answer. As mentioned in our statement, we are gratified by the increased support reflected in the FY 1979 budget request for the overall aeronautical program, and particularly the rotary wing effort supported therein. Our concern, however, is not with the *rate* of growth but rather with the absolute magnitude of the funding. Only two years ago, the relevant rotary wing line item was funded at merely \$100,000. Hence, significant rate of growth was inevitable if the program was to even approach viability.

I would emphasize that we are indeed pleased by the increased attention being given by NASA to rotary wing technology, and we do believe the consolidation of this effort at a single NASA center will be helpful. Nonetheless, much remains to be done . . . including work in such areas as noise suppression, vibration reduction, advanced dynamic components, fly-by-wire control systems and rotor materials. Although NASA's program does incorporate these areas, we believe they could benefit by increased budgetary attention. Further, additional prototyping is needed in advanced compound helicopters of a type suitable for commercial transportation, as well as heavy lift systems for both military and civilian application.

The rotary wing aircraft is just now emerging from its pioneering stage, and as in other areas of civil aeronautics, U.S. efforts are facing increasingly formidable competition from abroad, particularly in Europe. A significant technology effort will be required if we are to remain competitive and to realize the promise of future rotary wing designs.

Question.—Technology for future space programs. You mention three specific areas of weakness in the NASA space research program:

- (a) Advanced rocket propulsion for geosynchronous operations or for escape trajectories.
- (b) Adequate electrical power systems to support orbital operations.
- (c) Technology to fabricate, deploy and utilize large space structures.

Are there other areas of the NASA budget that should receive a lower priority of funding in order to support these research areas? If so, what are they? Or are you advocating an overall increase in the NASA budget to support this work?

Answer. The levels of funding needed to provide adequate support in the three areas we have suggested are quite small. Proposed NASA funding in all three areas totals less than \$10 million. But because they are the key technologies in virtually any expansion of space activities during the next two decades, we believe their support should be increased, not only in FY 1979, but at an accelerating rate in subsequent years.

The House of Representatives has suggested increasing FY 1979 budgets by about \$13 million for power conversion, advanced systems, and efforts related to large space structures, and has identified comparable reductions in other areas (e.g., expendable launch vehicles and space flight operation). We believe small additional increases in propulsion research/technology are also needed (see our response to Question No. 5 below). Because it is so important that these long-lead fundamental technology-base capabilities be nurtured properly, we believe that if necessary, the total NASA budget be increased by the tiny percentage needed to do so. In subsequent years, a small part of the decreasing need for shuttle RT&D funds could be allotted to increasing support in these advanced-capability areas we have highlighted.

Question.—Estimate of space benefits. The research areas that you identify as vital for future space activities presuppose substantial benefits to be realized. Do you know any new economic studies which would support significant increases in space research investment? Has the AIAA Economics Task Force developed data along this line that would be of interest to the Committee? If so, could you submit it for the record?

Answer. The function of the AIAA's Economic Task Force, as with all AIAA Technical Committees and Task Groups, is not to develop new data, but to collect and interpret existing data and communicate it as effectively as possible to the various audiences having interest therein. The Task Force's most recent effort in that direction was a collection of articles published in the March 1977 issue of "*Astronautics & Aeronautics*" (pages 28 to 54). Although these papers cover a broad scope of subjects, several of them do touch on the question. Past studies cited by the Task Force which have addressed the quantification of benefits attributed to space activities include those by Denver Research Institute (1963, 1971, 1972), R. Konkel and M. Holman (1967), Stanford Research Institute (1968), Midwest Research Institute (1971), Rockwell International (1974), Mathematica (1975), Chase Econometrics (1975), Ginzberg et al (1976). The Mathematica study, in particular, because it concentrated on specific elements of technology, provides perhaps the most realistic indication of the economic impact derived from investments in space activities.

Question.—Rocket propulsion technology. You say that lack of a sound NASA rocket propulsion technology program is already beginning to affect plans for proper shuttle utilization. How did AIAA reach this conclusion? You say that many of the shuttle's prospective customers require higher energy orbits than shuttle orbiter can provide and that the projected inertial upper stage and the spin stabilized upper stages do not begin to meet the capabilities required. Our understanding is that the shuttle with its prospective upper stages can meet all of the orbital requirements of the mission model. Your statement seems to contradict that. Can you explain that to the Subcommittee please? You say that the shuttle may suffer a serious loss of potential business, for example, to the ESA Ariane launch vehicle. Do you know of any mission that the Ariane will be able to perform that the shuttle will not be able to perform? While I tend to agree with your view that NASA should have a strong propulsion program and that the absence of a strong continuing propulsion program implies an approaching obsolescence for future space programs, what should NASA be doing that it is not doing now? Can you give the Committee any specifics? Are you talking only about the conventional type rocket engines or are you talking about new concepts of propulsion such as the "mass driver" which we will hear about in a few minutes?

Answer. The point we raised in our testimony is that generic space propulsion research in NASA has decayed to the point at which it no longer provides the technology base on which to build new developments required to meet future specific mission requirements. For example, this research base is not at a level adequate to support, whenever needed, the development of a reusable orbit

transfer vehicle, a high-performance transfer stage for interplanetary missions, or primary propulsion for advanced shuttles.

We do not mean to imply that these vehicles are needed now; they clearly are not. In fact, all missions in the present NASA mission model can probably be served by the IUS, the SSUS-A, and the SUSS-D, but only because these are the only stages available. There are many potential missions which are compatible with the shuttle orbiter but which do not appear in the mission model solely because they require higher-performance upper-stage transportation. Further, these limited-capability stages impose inefficient shuttle utilization modes. Several planetary missions described by John Niehoff at the March 1978 American Astronautical Society's Goddard Symposium each require four IUS's (two shuttle launches) plus complex and potentially troublesome series/parallel deployment procedures. Service to geosynchronous orbits for both civil and military missions is also limited by these stages.

Again, we do not propose that higher-performance stage projects be initiated now, but only that a propulsion research and technology effort be sustained at a sufficiently high level so that such projects can be pursued efficiently whenever warranted by the demand and the available resources. We believe a significant loss in NASA space propulsion research capability occurred when the Lewis Research Center turned its primary attention to terrestrial energy R&D, and that capability needs to be replaced.

The major area for research growth is liquid-propellant rocket propulsion, with lesser efforts required in electric propulsion and concomitant systems, including the mass driver. Specific liquid-propellant rocket engine research topics should concentrate on (a) technology readiness demonstration of a high-performance reusable cryogenic-propellant engine suitable for orbit transfer vehicles, which must be first selected from among several current cycle options, (b) high-performance space-storable engines (e.g., fluorine/hydrazine), now supported at an inconsequential level, (c) expanded research activities in "classic" subjects such as heat transfer, non-adiabatic boundary layer flows, reacting nonequilibrium flows in nozzles, continued studies of new propellant combinations, etc.; and (d) advanced booster engine technology; e.g., dual-mode, dual-expander, and compound engines as well as derivatives of the SSME and even earlier high-performance engines. A sound NASA research base in this area could be a significant factor in forecasting and avoiding developmental problems such as those which have occurred with the SSME.

With regard to Ariane competition with the shuttle for payloads, we do not mean to imply that Ariane can outperform the shuttle/SSUS-A combination. However, as pointed out by Wilbur Pritchard in his comparison of Ariane and the shuttle in the April 1978 issue of *Astronautics & Aeronautics* (pp. 12-15, 35), "When the payload can be comfortably designed to fit within the limitations of Ariane, when the users are under no political constraint, and if ESA can maintain its competitive price, it will probably be the vehicle of choice". Our point here is that the shuttle, with its far greater reliability, flexibility, size, mass capability, etc. is compromised by the limited-performance upper stage available (a point clearly made by Pritchard in his article), so that Ariane, instead of being totally outclassed as it should be by the shuttle system, remains a potential close competitor for much of the shuttle's prospective business.

Question.—Nuclear reactor systems. AIAA recommends that NASA and/or the Department of Energy undertake the development of new nuclear reactor systems for on-board space electric power. However, President Carter has proposed that the United States and the Soviet Union agree not to put nuclear reactors into orbit around the Earth and that seems to have some popular appeal here in the United States, although the Soviets stated that they will continue to use reactors in space. Nevertheless, the President is against using nuclear reactors in space and it's going to be pretty hard to get that into the budget. Did AIAA take all that into account before making their recommendation? What do you think it would cost to develop a new nuclear reactor space power system? Do you recall the SNAP 8 system which was a zirconium hydride nuclear space reactor? Many hundreds of millions of dollars were invested in that nuclear reactor and its power takeoff system before it was cancelled without any use being made of it. Why do you think we should do that again?

Answer. We are aware of the political circumstances associated with the use of nuclear reactors in space, as noted in our statement. However, even President Carter has left a caveat in his position: he is against using nuclear reactors

in space *unless* they can be shown unequivocally not to pose a potential hazard to any of the Earth's people, a viewpoint with which we are in total agreement. We believe the U.S. design approach does provide that assurance; i.e., a space reactor is not activated until it attains its prescribed orbit, and, unlike the Soviet approach, its core is designed to remain intact (not to breach its containment) upon reentry. Further, reactor-powered spacecraft launched in the shuttle era can, in the event of emergency, be visited (by unmanned teleoperators, if necessary) to correct any potentially hazardous orbit perturbations.

Thus we believe it shortsighted to close out an important future option for high-level space-based power requirements. Again, we do not advocate that NASA (or DOE) develop a nuclear reactor system, but only that a modest but adequate supportive base of research and technology be maintained to meet the need when it arises. The reactor technology would be DOE's responsibility; indeed, DOE's FY 1979 budget request does include a substantial increase for that purpose. However, NASA's OAST budget request does not include commensurate increases in the technology of compatible power conversion systems, heat rejection systems, power conditioning, and system integration.

The SNAP 8 program was an excellent example, along with the NERVA (nuclear rocket) program, of an unwise management decision. Both programs were developments without mission requirements—an approach doomed to failure even if technologically successful. There simply wasn't any demand in the 1960's for 30 kilowatts of electric power in space at the specific mass levels then obtainable. SNAP 8 should have been sustained as a technology effort, with plenty of flexibility to accommodate new technology advances, rather than having been "frozen" prematurely in an early-sixties technology.

The situation today is very different. There are significant prospects for long-term, high power requirements in space in the 1980's, 1990's, and beyond, and advanced technology compact nuclear power systems could be valuable assets at that time, as has already been recognized by DOE in its support of a 500 kWe advanced heat-pipe-cooled reactor technology effort. But without the sustained complementary NASA research and technology program that potentially valuable option will not be available when it is needed.

Question.—Microwave energy transmissions. It has been reported that Dr. Frank Drake has found that as a result of experiments at the Arecibo Observatory microwave transmissions from a solar power satellite might jam most police, taxi and citizen band radio communications. Do you have any information on this matter?

Answer. Dr. Drake has admitted his error in making that statement. I quote from a letter dated 2/27/78 addressed to the Washington Post by Dean W. E. Gordon, of Rice University, who directed the Arecibo experiments Dr. Drake referred to:

"The Washington Post of 21 February 1978 carried an article . . . with the headline, 'Energy Beamed From Solar Satellite Might Jam Police, Taxi and CB Radio,' and with the lead paragraph, 'The solar power satellite suggested as a cure for Earth's energy ills would heat up the ionosphere to the point of jamming most of the world's police and citizens band radio transmissions.'

"In June of 1977, at the Arecibo Observatory in Puerto Rico, I conducted a series of experiments designed to heat the ionosphere and to look for possible communications effects . . . We heated the ionosphere with radio waves at frequencies of 10 MHz, 430 MHz and 2380 MHz attempting to stimulate the heating effects of the solar power satellite. We looked for communication effects with a sensitive radar properly located to observe any effects if they were to occur. No communication effects were observed in any of the tests . . .

"If the ionosphere is heated at a radio frequency that resonates with the local ionization, a strong disturbance, an instability, is produced that is known to provide communication paths not normally present . . . We, in fact, produced this instability over Arecibo in order to check that the radar was located properly to detect any communication efforts. The solar power satellite would operate at microwave frequencies, far too high to excite this instability.

"Your article quotes as your source Frank Drake, Professor of Astronomy at Cornell University and Director of the Arecibo Observatory. I telephoned him and found that he was unaware of the frequencies we used in the tests and mistook the check of the radar location using the known instability as a communication result associated with the solar power satellite, when in fact the heating mode is of a different type and one not applicable to the solar power satellite . . .

"In summary, on the basis of tests performed to date there is no evidence that the solar power satellite will interfere in any way with communication systems. We and others recommend that additional tests be included in the evaluation of the solar power satellite concept and that the tests be performed at higher power levels."

Senator FORD. Our next witness is Dr. Brian O'Leary, Department of Physics, Princeton University. Will you come forward, sir; we would be delighted to hear you.

**STATEMENT OF DR. BRIAN O'LEARY, DEPARTMENT OF PHYSICS,
PRINCETON UNIVERSITY**

Dr. O'LEARY. Good morning.

Senator FORD. I would appreciate it if you would summarize your statement.

Dr. O'LEARY. Yes.

Senator Ford and members of the committee staff, you heard testimony 2 years ago from Gerard O'Neill, my colleague at Princeton University; and much of what I will be saying will be similar to what he had said to you 2 years ago. During the past 2 years there has been a great deal of progress in the concepts that we have been working on relating to the use of lunar or asteroidal materials for constructing satellite power stations and other products in space.

And so I think I can safely keep my comments down to 10 minutes, and be able to answer your questions for the record later.

I appreciate the opportunity to express my views on the Nation's space program. The opinions and recommendations I will present are attributable, in part, to experience derived from diverse roles I have played with respect to space exploration over the past 16 years—as a space scientist, astronaut, critic, experimenter on a planetary mission, congressional energy consultant, and, most recently, as a participant in the development of an exciting new concept.

Finding a unified long term objective for full and efficient use of the Space Shuttle seems to be a difficult or elusive task sometimes. Along with an increasing number of colleagues, I feel that such a goal does in fact exist, but early progress in defining that goal is beleaguered by major political obstacles, bureaucratic inertia, and the fears of a fiscally-conscious Office of Management and Budget.

The concept I will be discussing is well matched to the capabilities of the Space Shuttle during the 1980's, and would require no major new development in Earth-to-space transportation. If tests prove out existing studies, a large share of the Nation's energy problem may be solved by the turn of the century.

The concept, first proposed by my Princeton colleague, Gerard K. O'Neill, suggests that the cost of retrieval of resources from the Moon or asteroids is far less than that from the deep gravity well of the Earth. These nonterrestrial materials would be processed in space by continuous solar energy into satellite solar power stations, which would supply to the Earth base-load central station electricity by microwave link from geosynchronous orbit. Economic analyses suggest a favorable cost-benefit ratio for delivered electricity when compared to coal and nuclear power, and the environmental cost appears to be far less.

The problem is in having the foresight to take the first critical steps in determining whether such a program is entirely feasible or worthwhile. Unfortunately, the current trend is in the other direction.

Satellite solar power and space industrialization are the subjects of recent and ongoing NASA studies, but the few million dollars of funding allocated to these studies does not include what I feel may be the only viable option—the use of nonterrestrial materials.

A Lunar Polar Orbiter resource prospecting mission proposed by NASA has been turned down. Inexpensive, unmanned missions to survey the resources of the Earth-approaching asteroids have been virtually ignored in favor of other planetary and asteroidal missions. The work which has begun to synthesize these three areas—prospecting, industrial operations in space, and satellite solar power—has been funded at only \$50,000 so far this year at Princeton University, which is the center of activity for the research. Major unanswered questions are being postponed indefinitely from year to year.

If this concept appears to be feasible and in the public interest, a decision in favor of its development would have several positive and long-lasting effects:

First, it would solve a large gap in world energy supply during a period of dwindling nonrenewable resources;

Second, the potential for growing large quantities of food in space and the retrieval of metals from the asteroids may provide cost-effective delivery of food and resources to the Earth as soon as the turn of the century;

Third, the achievement of self-sufficiency in space could lead to outlets for human survival and opportunities for exploration;

Fourth, a national commitment to develop the resources in near-Earth space would help redress balance of payments imbalances and free the United States from dependence on Arab oil;

Fifth, it would provide continuity and challenge for the Nation's aerospace talent which has contributed so effectively to the achievement of Apollo; and

Sixth, space would again capture the public imagination, tapping what I feel to be a pervasive, though currently latent, constituency. Over the past year, about 10,000 inquiries have been directed to us in Princeton about our work, which has also been the focus of numerous conferences, books, and television documentaries.

There are several efforts underway in Congress to overcome this slow motion and bureaucratic inertia. Concurrent House Resolution 451 would provide for increased Federal support of critical research and development on these concepts and for an Office of Technology Assessment study so that an informed go-no-go decision could be made in 1980 or 1981. The bill states in part

that the Congress hereby finds and declares . . . that every feasible means now shall be mobilized to explore and assess the resources of the "High Frontier" of Outer Space to better understand and to make practical, beneficial uses of those resources.

Representative Flippo and 11 colleagues in the House last month introduced a bill, H.R. 10621, which would fund satellite power research in fiscal year 1979 with \$25 million. Senator Harrison A. Williams of New Jersey has introduced the high frontier feasibility

amendment to the National Science Foundation Reauthorization Act, which would provide for a 2-year NSF study at an annual funding of \$500,000.

What I am proposing is the open discussion, timely funding, and systematic progression of a concept which would have enormous implications for this Nation and the human race. With this goal in mind, I have a number of recommendations for the subcommittee's consideration in dealing with NASA and the Carter administration during the next few years.

And among those recommendations are:

One, provide active consideration and support for congressional initiatives and create new initiatives.

Two, work with NASA to identify those long-term goals which are consistent with the public interest and are of fundamental importance.

Three, help clarify agency jurisdictional problems.

Four, in order that informed decisions be made, use the committee's power of authorization in restoring vigor to the most promising programs which have long lead times, which require study and development, and which may develop into a major activity. This would include opening a dialog with the Office of Management and Budget and reversing some of their decisions; for example, cuts in the modest funding of satellite power, advanced planning, space industrialization, and Lunar Polar Orbiter.

I hope you agree with me that an exciting new concept has been developed. For the first time in history, the vast quantity of energy and materials available to us in space present an imaginative and practical new outlet for human experience. Dennis Meadows, an author of "The Limits to Growth," said, "What we need is a second Copernican Revolution, and we don't have it." I believe we do.

With your permission, Mr. Chairman, I would like to submit for the record copies of recent papers given at the 1978 annual meeting of the American Association for the Advancement of Science, and a recent article by Dr. O'Neill on Astronautics and Aeronautics on the concept of establishing a space manufacturing facility.

Senator FORD. Those will be entered into the record.

Dr. O'LEARY. Thank you, sir.

[The statement and material referred to follows:]

STATEMENT OF DR. BRIAN O'LEARY, DEPARTMENT OF PHYSICS, PRINCETON UNIVERSITY

Mr. Chairman and members of the committee, I appreciate the opportunity to express my views on the nation's space program. The opinions and recommendations I will present are attributable, in part, to experience derived from diverse roles I have played with respect to space exploration over the past sixteen years—as a space scientist, astronaut, critic, experimenter on a planetary mission, Congressional energy consultant, and, most recently, as a participant in the development of an exciting new concept. In these hearings I will be speaking as an individual, and the opinions I will express are purely my own.

About seven years ago, when NASA started development on the Space Shuttle program, I opposed spending \$5 to \$10 billion on this new space transportation system for a number of reasons. I felt that a commitment to this project would divert NASA's resources from its more fundamental goals of space science and applications and that public apathy would make it difficult for NASA to muster the larger budgets required to simultaneously meet those goals while being able

to make full use of the enormous growth in the capacity of Earth-to-orbit transportation offered by the Space Shuttle.

Finding a unified long term objective for full and efficient use of the Space Shuttle seems to be difficult or elusive. Along with an increasing number of colleagues, I feel that such a goal does in fact exist, but early progress in defining that goal is beleaguered by major political obstacles, bureaucratic inertia, and the fears of a fiscally-conscious Office of Management and Budget.

The concept I will be discussing is well-matched to the capabilities of the Space Shuttle during the 1980's and 1990's and would require no major new development in Earth-to-space transportation. If tests prove out existing studies, a large share of the nation's energy problem may be solved by the turn of the century. The implications are potentially enormous.

The concept, first proposed by my Princeton colleague, Gerard K. O'Neill,¹ suggests that the cost of retrieval of resources from the Moon or asteroids is far less than that from the deep gravity well of the Earth. These non-terrestrial materials would be processed in space by continuous solar energy into satellite power stations,² which would supply to the earth base-load central station electricity by microwave link from geosynchronous (stationary) orbit. Economic analyses,³ suggest a favorable cost-benefit ratio for delivered electricity when compared to coal and nuclear power, and the environmental cost appears to be far less.

It may be surprising, at first glance, to find that such a project could be undertaken over the next 10 to 20 years within the constraints of NASA's current annual budget, and that no major new technology development is required. Yet studies continue to show that these facts are true.⁴ A step-by-step program could be developed which could demonstrate the concept before a final, irrevocable decision involving billions of dollars would be made.⁵

The problem is in having the foresight to take the first critical steps in determining whether such a program is entirely feasible and worthwhile. Unfortunately, the current trend is in the other direction. Satellite solar power and space industrialization are the subjects of recent and on-going NASA studies, but the few million dollars of funding allocated to these studies does not include what I feel may be the only viable option—the use of non-terrestrial materials. A Lunar Polar Orbiter resource prospecting mission proposed by NASA has been turned down. Inexpensive unmanned missions to survey the resources of the Earth-approaching asteroids have been virtually ignored in favor of other planetary and asteroidal missions. The work which has begun to synthesize these three areas—prospecting, industrial operations in space, and satellite solar power—has been funded at only \$50,000 so far this year at Princeton University, the center of activity for the research. Major unanswered questions are being postponed indefinitely from year to year.

I believe it reasonable to conclude that a lack of foresight in allocating a small fraction of the nation's space budget to making a thorough assessment of a potentially vital energy option, which has survived early scrutiny, constitutes a lack of public responsibility.

If this concept appears to be feasible and in the public interest, a decision in favor of its development would have several positive effects: (1) it would solve a large gap in world energy supply during a period of dwindling non-renewable resources, serious threats to the environment, and international stress (2) the potential for growing large quantities of food in space and the retrieval of metals from the asteroids may provide the cost-effective delivery of food and resources to the Earth; (3) the achievement of self-sufficiency in space could lead to outlets for human survival and opportunities for exploration; (4) a national com-

¹ O'Neill, G. K., "The Colonization of Space," *Physics Today*, Vol. 27, No. 9, September 1974, pp. 32-40.

² O'Neill, G. K., "Space Colonies and Energy Supply to the Earth," *Science*, Vol. 190 (Dec. 5, 1975), pp. 943-47.

³ O'Neill, G. K., "Progress toward Space Manufacturing," *Astronautics and Aeronautics* (Oct. 1976).

⁴ The 1976 NASA Ames/OAST Summer Study on Space Manufacturing from Nonterrestrial Materials, *Progress in Astronautics and Aeronautics*, Vol. 57, American Institute of Aeronautics and Astronautics (AIAA, 1977); *Space Manufacturing Facilities 2, Proceedings of the Third Princeton/AIAA Conference on Space Manufacturing Facilities*, AIAA (1977); *The 1977 NASA Ames Summer Study on Space Manufacturing from Nonterrestrial Materials*, NASA SP-volume (in press, 1978); O'Neill, G. K., "The Low (Profile) Road to Space Manufacturing," *Astronautics and Aeronautics*, March 1978.

⁵ Driggers, G. W. and Newman, J., (the 1976 Study); Vajk, J. P., Engel, J. H., Shettler, J. A., (the 1977 Study).

mitment to develop the resources in near-Earth space would help redress balance of payments imbalances and free the United States from dependence on Arab oil; (5) it would provide continuity and challenge for the nation's aerospace talent which contributed so effectively to the achievement of Apollo; and (6) space would again capture the public imagination, tapping what I feel to be a pervasive, though currently latent, constituency. Over the past year, about 10,000 inquiries have been directed to us in Princeton about our work, which has also been the focus of numerous conferences, books, and television documentaries.

To give an example of what could happen as early as the 1980's I would like to describe a scenario which has been mainly the subject of my research. The scenario starts with the launch from Earth of a long, narrow solar-powered electric motor called the mass driver, a device which is currently under development. Fifty weekly shuttle flights would be required. The motor is assembled in a low Earth orbit, then is launched on a trajectory a nearby asteroid. With a rather low expenditure of energy, the motor would rendezvous with the asteroid and would slowly tug it into a very high orbit around the earth. By 1995, this "New Moon," weighing about one million tons, could begin to be processed into enough satellite solar power stations to meet a significant portion of the nation's increased demand for electricity by the turn of the century.⁹ The total cost would be less than the several hundred billion dollars of projected capital expansion of coal and nuclear power plants, even under the most conservation-minded extrapolations in electricity demand.

It is tempting to dismiss these scenarios as speculative fiction. But the studies are indicating the reverse.¹⁰ There are numerous historical analogues to unexpected developments in technology. The Apollo Program, for example, was successfully carried out from its inception in eight years within its planned budget. To have contemplated its completion within twelve years of the launch of Sputnik in 1957 would have appeared heretical.

A recent example of the political dichotomy which appears to be developing between the Administration and the development of the new concepts is the January 25 and 26 hearings before the House Science and Technology Committee. Uncharacteristically, about fifteen members of Congress attended both days to hear the testimonies of Dr. O'Neill, NASA Administrator Robert Frosch, Presidential Science Advisor Frank Press, and others.

In his opening statement, Dr. Frosch said, "I am not supposed to be Columbus, but Queen Isabella's agent for getting things done in space. I do not believe the human race will go to space in submarines to live in synchronous orbit or at L-5 points."

After Drs. Frosch and Press testified, Congressman Larry Winn of Kansas said, "I have been sitting here for one hour and I haven't learned a damn thing that's new. If we are going to count on this type of thinking at NASA and the DOE to solve our energy problems, we had better sell the Saudis the F-15 fighters they want tomorrow, for we will need their help."

In referring to our concepts, Rep. James Scheuer of New York said, "This effort is pusillanimous. What we want is a Manhattan Project here and all we detect is diffident waves from NASA."

There are several efforts underway in Congress to overcome this slow motion. Concurrent House Resolution HR 451 would provide for increased federal support of critical research and development on these concepts, and an Office of Technology Assessment study, so that an informed go-no-go decision could be made in 1980 or 1981. It states, in part, "that the Congress hereby finds and declares . . . that every feasible means now shall be mobilized to explore and assess the resources of the 'High Frontier' of Outer Space to better understand and to make practical, beneficial uses of those resources."

Representative Ronnie G. Flipppo and eleven colleagues in the House last month introduced a bill, HR 10621, which would fund Satellite Power Station research in fiscal year 1979 with \$25 million. At this writing, Senator Harrison A. Williams of New Jersey is preparing to introduce the High Frontier Feasibility Amendment to the National Science Foundation Reauthorization Act, which would provide for a two-year NSF study at an annual funding level of \$500,000.

⁹ O'Leary, B. T., "Mining the Apollo and Amor Asteroids," *Science*, Vol. 197 (July 22, 1977), pp. 363-366; "Mass Driver Retrieval of Earth-Approaching Asteroids," The Third Princeton/AIAA Conference (1977); "Asteroidal Resources for Space Manufacturing," IAF 28th International Congress (1977); O'Leary, B., Gaffey, M. J., Ross, D. J., and Salkeld, R., "The Retrieval of Asteroidal Materials," (the 1977 Study).

I am proposing the open discussion, timely funding and systematic progression of a concept which would have enormous implications for this nation and the human race. With this goal in mind, I have the following recommendations for the Subcommittee's consideration in dealing with NASA and the Carter Administration during the next few years:

1. Provide active consideration and support for Congressional initiatives and create new initiatives.

2. Work with NASA to identify those long term goals which are consistent with the public interest and are of fundamental importance.

3. Help clarify agency jurisdictional problems. For example, the lines of responsibility for satellite solar power between NASA and DOE are not clear and may be retarding a timely study of important concepts. The capabilities of NASA in this area, in my opinion, are extraordinarily strong.

4. In order that informed decisions be made, use the Committee's power of authorization in restoring vigor to the most promising programs which have long lead times, which require study and development, and which may develop into a major activity. This would include opening a dialogue with the Office of Management and reversing some of their decisions—for example, cuts in the modest funding of satellite power, advanced planning, space industrialization, and Lunar Polar Orbiter.

5. Take part in presenting to the American people those options which appear to be most promising once they have been studied and partially developed.

6. Participate in debates and decisions on these issues after the data are made available.

I hope you agree with me that an exciting concept has been developed. For the first time in history, the vast quantity of energy and materials available to us in space present an imaginative and practical new outlet for human experience. Dennis Meadows, an author of *The Limits to Growth* said, "What we need is a second Copernican Revolution and we don't have it." I believe we do.

With your permission, I would like to submit for the record copies of recent papers given at the 1978 annual meeting of the American Association for the Advancement of Science and a recent article by Dr. O'Neill on the concept of establishing a space manufacturing facility. All three are brief, being summaries of the more detailed studies listed in the references.

Senator FORD. Doctor, I appreciate your cooperation this morning, and again, I regret we have to move on. At the first hearing of the Space Committee when Dr. O'Neill brought his ideas to our attention, we found them fantastic and fascinating. New technologies that are available to all of us continue to be fascinating.

I do appreciate your attendance this morning. I thank all of you. This hearing is recessed.

[Whereupon, at 9:45 a.m., the hearing was adjourned.]

RESOURCE POTENTIALS OF ASTEROID CAPTURE

MACRO-ENGINEERING: THE INTRA-STRUCTURE OF TOMORROW

AAAS Annual Meeting, Washington, D.C., February 13, 1978, Brian O'Leary, Department of Physics, Princeton University, Princeton, New Jersey 08540

O'Neill has proposed that lunar and asteroidal materials may be economically mined and processed in space for the construction of high orbital habitats¹ and satellite solar power stations.² The 1976 NASA-Ames Summer Study on Space Settlements³ corroborated early estimates that these concepts could be carried out on a large scale in the 1990's with an initial investment comparable to that of the Apollo program using technologies which are now in grasp. In the scenario which was considered, an electromagnetic mass driver on the Moon would propel lunar material into free space for subsequent transfer to a space manu-

¹ O'Neill, G. K., "The Colonization of Space", *Physics Today*, Vol. 27, No. 9, September, 1974, pp. 32-42.

² O'Neill, G. K., "Space Colonies and Energy Supply to the Earth", *Science*, Vol. 190, December 5, 1975, pp. 943-47.

³ O'Neill, G. K., "Engineering a Space Manufacturing Facility", *Astronautics and Aeronautics*, October, 1976, pp. 20-8, 36 (Summary): the collection of papers published in Volume 57, *Progress in Aeronautics and Astronautics*, AIAA, New York, December, 1977.

facturing facility (SMF) for chemical processing and fabrication into large structures. The mass driver would also serve as an orbital transfer vehicle, possibly reducing the cost of transport from low Earth orbit, where the external tanks for the space shuttle would be pelletized into reaction mass.⁴

In earlier papers^{5,6} I have explored the possibility of using mass driver tugs to move earth-approaching asteroids at opportunities of low velocity increment (Δv) to the vicinity of the Earth. Carbon, hydrogen, nitrogen and free metals—apparently scarce on the Moon—may become available in abundance from some of these objects and it is possible that the retrieval of asteroidal materials will be cost-competitive with that of lunar materials in an early program of space manufacturing. In favorable cases, the total energy required to move material from its present orbit to a high earth-orbital manufacturing site is comparable to that from the lunar surface, but logistical considerations (full time solar energy, no need for soft landings) may make the asteroidal scenario more cost-effective than the lunar scenario.

An asteroid resource study group convened at the NASA-Ames Research Center during the summer of 1977 to test some assumptions made in the earlier work and to refine earlier scenarios.⁷

A major conclusion of the study⁸ was that, through the techniques of multiple gravity assists by the Earth, Moon and Venus, the total one-way Δv from Earth escape (or capture) to rendezvous (depart from) existing asteroids, in favorable cases, is in the range 2 to 6 km/sec. For example, one opportunity was studied in which the retrieval material from the asteroid 1977 HB to high Earth orbit was 3 km/sec. Analysis of the most probable mission opportunities indicates that a single-stage low Earth orbit-to-asteroid mass driver with an exhaust velocity of ~ 8 km./sec may be the most cost-effective alternative, and is less sensitive to Δv than multiple stage devices with lower exhaust velocities. There exist several mission opportunities to existing targets which can be immediately investigated. Further refinements of mission analysis techniques for known objects will permit a more precise determination of opportunities. In addition, opportunities will arise as the number of known objects increases appreciably over the coming years.

The total asteroid-retrieving mass consists of mass driver, mining equipment, and reaction mass for the boost. In the range of likely Δv 's to be encountered, the total mass required for launch to low Earth orbit for the retrieval of ~ 50 percent of a 1 million ton asteroid is close to 10,000 tons, similar to the lunar case. This magnitude of mass could be launched by an upgraded (Class II) shuttle during the mid-to-late 1980's with the external tanks used as reaction mass, at a cost of approximately \$2 billion. Development costs ($\sim$ \$10 billion) would dominate and would be absorbed in subsequent, larger scale asteroidal retrievals.

Perhaps the most unique aspect of the retrieval of asteroidal materials is the availability of large quantities of volatiles (water and carbon compounds) and free metals. These materials may not be available in large quantities from the Moon. The requirements for $\sim 30,000$ tons of consumables for space settlements supporting the construction of satellite power stations suggest that the bulk of these could come from the asteroids rather than from the Earth. Moreover, free metals separated at the asteroid and alloyed at the space manufacturing facility (SMF) into useful structures may eliminate many of the complex steps of chemical processing required in the lunar case. Hydrogen and oxygen from a water-rich asteroid could also provide an alternative rocket fuel for the retrieval of materials in the event that structural dynamics instabilities prove to limit the effectiveness of mass driver reaction engines in space.

In the scenario which was considered, a significant fraction of $\sim 500,000$ tons of asteroidal material which would arrive at the SMF could be water and carbon if a type I or II carbonaceous object at a low to moderate Δv could be discovered. The possibility that the Earth-approaching asteroid Betulia is carbonaceous and

⁴ O'Neill, G. K., "The Low (Profile) Road to Space Manufacturing", *Astronautics and Aeronautics*, March, 1978, in press.

⁵ O'Leary, B., "Mining the Apollo and Amor Asteroids", *Science*, Vol. 197, July 23, 1977, pp. 363-66.

⁶ O'Leary, B., "Mass Driver Retrievals of Earth-Approaching Asteroids", The Third Princeton/AIAA Conference on Space Manufacturing Facilities, May 9-12, 1977, Paper 77-528.

⁷ O'Leary, B., Gaffey, M. J., Ross, D. and Salkeld, R., "The Retrieval of Asteroidal Materials", 1977 NASA Summer Study on Space Settlements, to be published.

⁸ Bender, D., Dunbar, R. S. and Ross, D., "Round-Trip Missions to Low Δv Asteroids and Implications for Material Retrieval", *ibid.*

statistical considerations suggest that such a discovery, in an expanded search and follow-up program, is probable at some time over the next few years.⁹ Such an object would obviously be a prime target for a precursor mission.

The 1977 Ames Summer Study asteroid group and a panel of scientists convened in LaJolla, California later in the summer recommended that the following studies and programs be carried out immediately to better assess details of this option:

1. *An increased near-Earth asteroid search and followup program.*—The current inventory of 39 Earth-approaching asteroids whose orbits are known can be increased appreciably with a modest investment in dedicated Earth-based and perhaps orbital telescopes. The followup work of orbital determination and chemical analysis are also important. A major objective of compiling this inventory is to identify carbonaceous objects with low-to-moderate Δv opportunities.

2. *Precursor missions.*—Because of the potential importance of obtaining volatiles—and possible free metals—from asteroids, it is clear that precursor missions to the prime carbonaceous candidates will be required. Such missions are also important from the point of view of assessing mineralogical structure for designing the mining and processing apparatus. Specifically recommended was a fiscal year 1980 new start in the NASA budget aimed toward a program of asteroid rendezvous and landing missions which would answer these questions between 1982 and 1985.

3. *Continuing studies of the potentials of asteroid retrievals and a list of the most favorable missions.*—These studies would continue to assess the tradeoffs between the retrieval of asteroidal, lunar and to Earth materials for space manufacturing in the light of new information as it comes in, with the plan that the first retrieval mission could be carried out during the 1990's.

4. *Technology support.*—Design concepts of asteroid-retriever mass-drivers and mining and processing equipment will need to be developed further and technology development milestones must be established in parallel with lunar option.

LIMITS TO GROWTH IMPLICATIONS OF SPACE SETTLEMENT

PROSPECTS FOR LIFE IN THE UNIVERSE: THE ULTIMATE LIMITS TO GROWTH

AAAS Annual Meeting, Washington, D.C., February 15, 1978, Brian O'Leary, Department of Physics, Princeton University, Princeton, New Jersey 08540

The world stage appears to be set up for a pervasive ideological battle—should world systems continue to grow or must they settle into a steady state? I believe that this debate will become irrelevant over the next few years because of the assumption that humanity must depend on the Earth's biosphere for survival. Nevertheless, it is worth examining some of the issues which have driven people to consider seriously the potentials for using the energy and materials available in space.

Growth advocates feel that a rapid transition to a steady state is not possible with the existence of poorer nations seeking to raise their standard of living to that of the western nations.¹ The transition itself, they argue, is contrary to the tenets of existing political systems and would appear to be impossible, on purely practical grounds, for at least decades. They suggest that a steady-state world would impose severe restrictions on individual freedom and opportunity.

The steady state advocates, on the other hand, feel that growth must stop for human survival.² With the limits to growth models taken at face value, even allowing for some room for guessing exactly when they will be reached, the no-growth argument is that political systems and life-styles must adapt to the limits or suffer the consequences which any biological system must when it overbreeds and runs out of prey. There seems to be little dispute that this reasoning is valid when applied on a global scale.

Others have attempted to reconcile these views by acknowledging the seriousness of the problem and proposing long-term Earth-based solutions. There is, for

⁹ Gaffey, J. J., Helin, E. and O'Leary, B., "Near-Earth Asteroidal Resources", *ibid.*

¹ Hellbroner, R., *An Inquiry Into the Human Prospect*, (New York: A. W. Norton, 1974); Rustin, B., "No Growth Has to Mean Less is Less", *New York Times Magazine* (May 2, 1976).

² e.g., Daly, H. E., *Toward a Steady-State Economy*, (H. H. Freeman and Co., San Francisco, 1978); Meadows, D. H. et al, *The Limits to Growth* (Universe Books, New York, 1972).

example, Benoit's dynamical equilibrium economy³ which advocates a shift in growth from the depletion of non-renewable resources to the rapid development of renewable resources, elimination of waste, reduction and eventual stabilization of population growth, and the reliance on science and technology to provide innovation for services and increased quality of life. Forrester⁴ has argued that more attention needs to be paid to social rather than physical limits aimed at solution on a national scale and in a time frame of decades. Schumacher⁵ has proposed that technologies and human activities will need to be developed on a small scale, with individual and small group accountability rather than the amorphous large organizations which currently control our destiny. As to whether these measures are politically possible or would be adequate to turn the tide is open to debate; there appears to be skepticism about whether these proposed solutions could be realistically implemented before widespread disaster strikes.

The space solution to the limits to growth transcends the dilemma—at least on a timescale of decades to centuries. The terrestrial limits to growth of food, energy and material resources, of pollution, and of population, could become relieved in a matter of years after the first retrieval of materials from the shallow gravity wells of the Moon or asteroids. The resources could be directly recovered on Earth or fabricated into satellite power stations for electricity supply to the Earth, human space habitats and food-growing areas in space. Useful materials and solar energy are abundant in space, potentially expanding the physical limits to growth by factors of thousands to millions compared to what is available on Earth. The pioneering work of O'Neill⁶ followed by extensive engineering and economic studies,⁷ have assessed the feasibility and cost of a program of the manufacturing of non-terrestrial materials. The unanimous result of such studies is that this program could be carried out using currently available technology, the space shuttle for Earth-to-orbit transportation,⁸ and with a total investment which would be a tiny fraction of the United States gross national product.

Such an effort could begin to relieve global stresses in fifteen years and grow exponentially thereafter, with the possible cost-effective delivery of energy,⁹ food⁹ and resources¹⁰ from space to Earth. Eventually large scale industry could move into space, relieving the Earth of pollution pressures. Population stresses could be relieved by the option to live in space. The space solution provides new outlets for the further development of human exploration (first the solar system, later the stars), basic science, social experimentation in a variety of settings, and an increased potential for human survival. Some have suggested that we are on the verge of a major new step of evolution, analogous to the first animal movement from water to land.

A growing number of scientists and writers feel that such a project is an obvious and perhaps inevitable solution to the limits to growth on Earth.¹¹ I share that view, with the caution that the implications for uncontrolled exploitation and economic gain could further upset social order and create new difficulties on a massive scale.

³ Benoit, E., "The Coming Age of Shortages", *Bulletin of Atomic Scientists* (January, February and March, 1976).

⁴ Forrester, J. W., Limits to Growth '75 Conference, Houston, Texas, (October 20, 1976).

⁵ Schumacher, E. F., *Small is Beautiful*, (Perennial Library, New York, 1975).

⁶ O'Neill, G. K., "The Colonization of Space", *Physics Today* (September, 1974); "Space Colonies and Energy Supply to Earth", *Science*, Vol. 190 (December 5, 1975), 943-947.

⁷ "Space-Based Manufacturing from Nonterrestrial Materials. The 1976 NASA Ames Study", *Progress in Astronautics and Aeronautics*, Vol. 57 (Edit. O'Neill and O'Leary, AIAA, New York, 1977); *The 1977 Ames Summer Study on Space Settlements*, in prep.; *Space Manufacturing Facilities. The Proceedings of the 1974 and 1975 Princeton Conferences*, (AIAA, 1977); *The Third Princeton Conference on Space Manufacturing Facilities*, (AIAA, 1978).

⁸ O'Neill, G. K., "The (Low) Profile Road to Space Manufacturing, *Astronautics and Aeronautics*, (March, 1978).

⁹ O'Leary, B., "Food and Raw Material Supply from Space to the Earth", Seminar on World Scarcity of Food and Raw Materials, Santiago, Chile, January, 1977.

¹⁰ Gaffey, M. J. and McCord, T. B., "An Extraterrestrial Source of Natural Resources", *Technology Review*, July, 1977.

¹¹ O'Neill, G. K., *The High Frontier: Human Colonies in Space* (New York: Wm. Morrow & Co., 1977; Bantam Books, 1978); T. A. Hennenheimer, *Colonies in Space* (Harrisburg, Pa.: Stackpole Books, 1977); B. M. Hubbard, *The Hunger of Eve* (Harrisburg, Pa.: Stackpole Books, 1977); G. Feinberg, *Consequences of Growth: The Prospects for a Limitless Future* (New York: Seabury Press, 1977); T. Leary, *Neuropolitics* (Los Angeles: Starseed Peace Press, 1977); G. H. Stine, *The Third Industrial Revolution* (New York: G. P. Putnam Sons, 1975); P. J. Valk, "The Impact of Space Colonization on World Dynamics", Lawrence Livermore Laboratory UCRL-77584 (November 14, 1975).

No-growth advocates and ecologists, particularly, have pointed to some of these problems.¹² An exploitation of space which merely provides mankind a relief valve from the biosphere could result in a cancerous one-way growth into the solar system and would merely buy time before coming up against new limits. Visions are conjured of profit-hungry exploitation, creating energy overdemand and the relaxation of dealing with our problems here on Earth now that we have a panacea.

In other words, the solution to a critical human problem, the shifting the consumption of non-renewable resources on Earth to renewable and non-terrestrial resources, and raising the standard of living of the poor countries, may help to create a new problem—exploitation on a larger scale and relaxation of interim standards. The asteroids contain enough material to provide abundantly for populations tens of thousands of times that of the Earth currently, and solar energy in space is abundant. Civilization may opt for the "Dyson Sphere", a shell of mankind concentric to the sun to capture all its energy.

These considerations should provide ample warning that an international political framework for controlling the exploitation of space must be developed. Only 50 million tons of material—an excavation on the Moon one kilometer square and 15 meters deep, or a 300-meter diameter asteroid—are needed to construct enough power satellites to supply the world with all its energy in 2000. Eventually it may be desirable to establish large colonies for developing exploratory opportunities and alternative lifestyles. In any case, I think that the possibility of a desperate situation here on Earth in the relative near term, and the best hopes of mankind, require a vigorous effort in establishing something like Benoit's dynamic equilibrium economy and the space manufacturing of satellite power stations. To hesitate on the basis of vague fears of runaway growth and environmental deterioration, in my opinion, would be unwise and contrary to human nature.

The need to plan for ten, twenty and thirty years from now is essential. The stakes are too high to be tentative in exploring the space manufacturing option. Regardless of the outcome of debates on growth, energy policy and political philosophy, the evidence is clear that research and development of space-based manufacturing from non-terrestrial materials should begin immediately as a viable option. The alternative appears inevitable and undesirable: growing international inequities in energy and food supply, future oil embargoes, expensive energy, the depletion of nonrenewable resources, the proliferation of dangerous nuclear technology, massive hunger and starvation, and tighter controls over human freedom.

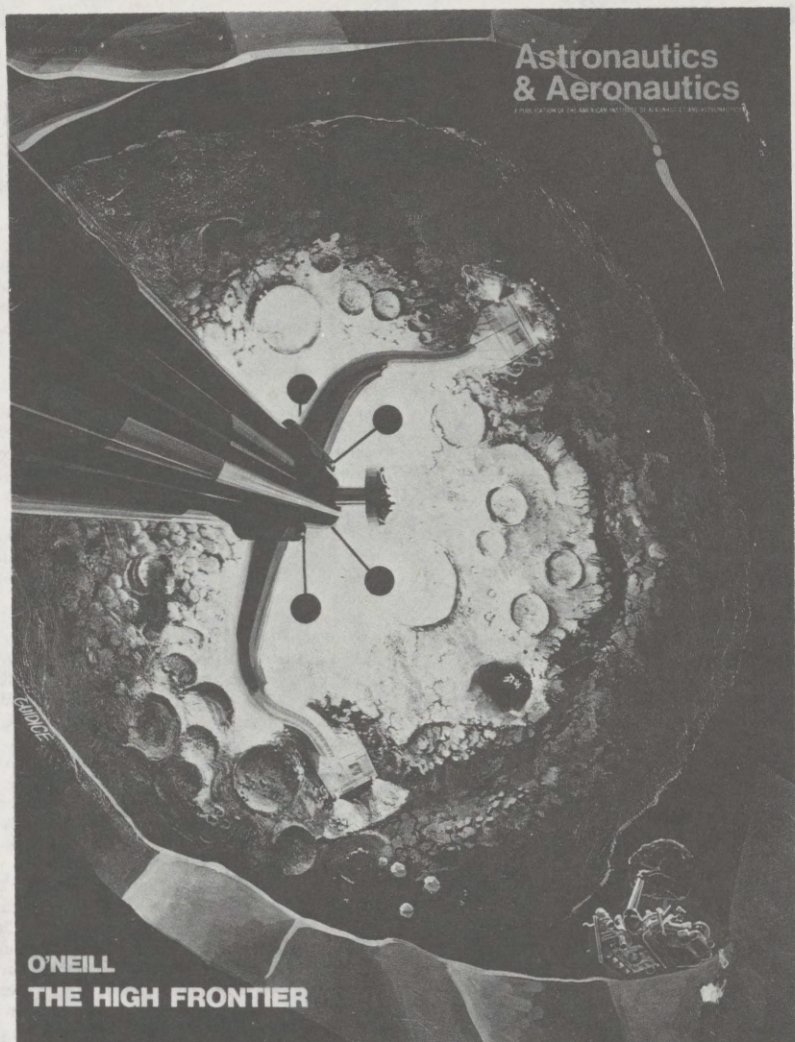
Starting a logical progression of steps required to use the vast resources and energy available to us in space demands a unity, discipline and perspective now lacking because of a collective tentativeness in trying something so totally new. The challenge is more one of communication rather than technical feasibility and economics. History makes it clear that this project will go ahead sooner or later. The arguments seem compelling that this is the time to begin to fulfill some of mankind's highest hopes.

"What we need is a Copernican revolution and we don't have it", said Dennis Meadows.¹³

We do have it.

¹² *Co-Evolution Quarterly*, Spring, 1976.

¹³ Meadows, D. H., Limits to Growth '75 Conference, Houston, Texas, October 20, 1978.

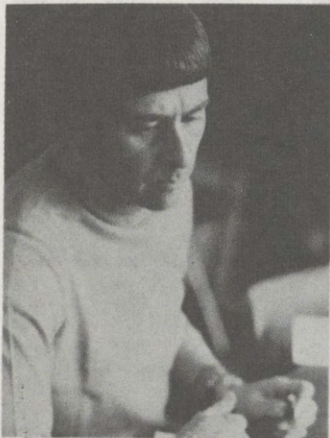


SPECIAL SECTION

High Frontier— Technical Progress, A Resolution, Commitments

By GERARD K. O'NEILL
Princeton University

Unless we remain forever planet-bound, the new millenium will surely see the emigration of humanity not only to the far reaches of our own solar system but beyond



This special section of *Astronautics & Aeronautics* follows by only a few months the second of two summer studies in which well-qualified groups of professionals subjected to detailed review the "High Frontier" concept: the opening of non-terrestrial material and energy resources for human benefit. The special section also comes at a time when a Congressional Resolution on the "High Frontier" has been introduced and is under consideration (see boxed item). And it arrives just after publication of Volume 57 in the AIAA Series, *Progress in Aeronautics and Astronautics*, a book presenting the results of the 1976 NASA-Ames study, "Space-Based Manufacturing from Non-Terrestrial Materials," as peer-reviewed papers on the application of near-term technology to the transport, processing, and use in space of lunar materials. The past few months have also seen publication by AIAA of the proceedings of three conferences held at Princeton on space-based manufacturing—one volume covers the 1974 and 1975 conferences and a second covers 1977's. Moreover, popular books (five, by my last count) on the new possibilities are now available, and recently a Nova television special introduced a still wider public to the possibility of large-scale productive human activity in space.

Some nine years have now passed since I began exploring the possibility that our generation might open a new ecological range for humanity; a range of unlimited volume, three-dimensional rather than Earth's two, and blessed with unlimited clean solar energy and a reservoir of materials vastly greater than our beleaguered Earth could ever provide. In the first several years, I became convinced of the inevitability of a large-scale movement of humanity into space, not for mystical reasons but rather for the same ones that have always pushed us toward new ecological ranges: because whenever a new range opens there is a burst of growth in wealth and opportunity, and the species that makes the transition is—for a time at least—free of the restrictions imposed by Darwinian competition.

The article that follows, on "The Low (Profile) Road to Space Manufacturing," represents the line of thinking I have been pursuing for nearly two years. It is engineering- and economics-oriented, and makes no concession to popular interest—for example, to interest in large Earthlike space colonies. Yet I have gradually come to realize that we in engineering and science, who feel so much more comfortable with this nuts-and-bolts reasoning, are missing entirely a lesson that everyday experience teaches: The public grasps instinctively the significance of a new ecological range, because such a move has so many parallels in Earth's history. Like the 19th Century's westward movement, its

96th CONGRESS
1st Session

H. CON. RES. 451

CONCURRENT RESOLUTION

Directing the Congress and executive agencies to determine how they may aid in achieving national goals in outer space.

By Mr. TEAGUE

DECEMBER 15, 1977

Referred to the Committee on Science and Technology

Whereas historically it is an inherent genius of the American people that we vigorously reach out to explore, to fulfill and enhance the resources of new and challenging frontiers, for the benefit of all humanity; and

Whereas the magnificent achievements of our explorations into space in the past twenty years have proved decisively that this tiny Earth is not humanity's prison, is not a closed and dwindling resource, but is in fact only part of a vast, expanding system rich in extraterrestrial opportunities as yet far beyond our comprehension, a "high frontier" which irresistibly beckons and challenges the American genius; and

Whereas our ventures into space, though daring, have not been rash, but have in fact succeeded only because of rigor, discipline, careful analysis, planning, training and skilled performance, thus establishing standards and precedents which must continue to guide all further national policy decisions and efforts in space; and

Whereas in 1977, as we cross the threshold into our Nation's third century, because many Americans seem for the moment beset and confused by complex problems, discouraged by alleged "limits to growth" and by careless waste of this Earth's resources, there is thus a crucial need to identify and enunciate both immediate and long-term national goals which shall unite and inspire the free, competitive American people, guiding and galvanizing our inherent genius to explore, to innovate, to learn, to achieve; and

Whereas the "High Frontier" of Space does provide valid opportunities whereby

we can help conserve and enhance humanity's existence on Earth, including but not limited to such social and economic benefits as greater employment, a cleaner environment, new energy sources, new knowledge and understanding, improved health, education, living standards, and international cooperation as inspiring goals for our third century. Now, therefore, be it

Resolved by the House of Representatives (the Senate concurring), That the Congress hereby finds and declares the following national policy:

(1) It is vital to the well-being of the American people, and all the people of this Earth, that every feasible means now shall be mobilized to explore and assess the resources of the "high frontier" of outer space, to better understand and to make practical, beneficial uses of these resources.

(2) As immediate priorities, research efforts shall be intensified to reveal and to better understand the solar system and the universe beyond it, to develop a practical, efficient transportation system in space,

and to perfect Earth-orbiting satellite systems to gather and disseminate information and for all forms of communication, thus building systematically on the pioneering results already achieved by our space programs in recent years.

(3) As longer range, high priority national goals, it is anticipated that by the year 2000 these explorations will have opened the resources and environment of extraterrestrial space to an as yet incalculable range of other positive uses, including, but not limited to, international cooperation for the maintenance of peace, the discovery and development of new sources of energy and materials, industrial processing and manufacturing, food and chemical production, health benefits, recreation, and, conceivably, the establishing of self-sustaining communities in space.

(4) The Congress hereby encourages and instructs all pertinent legislative committees and executive agencies to determine how they may most effectively act in cooperation with each other and with the leadership of both Houses and with the President to achieve these urgent national goals.

To assist in these efforts the Office of Technology Assessment specifically is requested to organize and manage a thorough study and analysis to determine the feasibility, potential consequences, advantages and disadvantages of developing as a national goal for the year 2000 the first manned structures in space for the conversion of solar energy and other extraterrestrial resources to the peaceable and practical use of human beings everywhere.

greatest significance is new opportunity for people. Again and again I have done interviews, spending hours to lead writers or hosts through the logic of manufacturing from nonterrestrial sources—only to see editors or producers, with sure instincts for public interest, zero in on the excitement of a new frontier movement for ordinary people.

That lesson was reinforced a few months ago by the extraordinary set of events that led to the introduction by Congressman Olin Teague of House Concurrent Resolution 451:

"That the Congress hereby finds and declares the following national policy: . . . that every feasible means now shall be mobilized to explore and assess the resources of the "high frontier" of outer space, to better understand and to make practical beneficial uses of these resources....

"To determine the feasibility, potential consequences, advantages and disadvantages of developing as a national goal for the year 2000 the first manned structures in space for the conversion of solar energy and other extraterrestrial resources to the peaceable and practical use of human beings everywhere."

That initiative came from a citizen's group in cooperation with members of the House of Representatives. They sought language that would include not only manufacturing in nearby space, but also the longer-term goal of human movement into the new "High Frontier."

The timing of the Resolution may be premature; it may fail; or even if it passes, its effect may be diluted and diverted by the forces of reaction with which every new movement must contend; but as one of my good friends in the government put it, "You can't put the genie back in the bottle."

To many of us who have struggled through the past several months of Washington politics, however, it does seem that we are in the midst of an attempt to "put the genie back into the bottle." Fortunately, that attempt has come too late. If it had come three years earlier, and been supported by independent, non-governmental organizations like the AIAA, the "High Frontier" concept could have been discredited before it had time to develop its conferences, its NASA studies, and the rest of the solid, professional literature that has now given it a hold on reality. In the behind-the-scenes attempts

by highly placed officials to block or deflect the Teague resolution, the AIAA publications were vital as evidence that the new concepts were more than Sunday-supplement entertainment.

Now that its first year is past and it has a chance to find its feet, the new Administration will have an opportunity to do solid homework on the "High Frontier" concept. Good work can be done under Federal sponsorship in the next few years—if the Administration can overcome the no-growth philosophy it entered with. That philosophy was based on the old-fashioned idea that wealth can only flow from resources within the Earth's biosphere—that space beyond spy-satellite altitude will be an arena only for scientific observation.

If these educational attempts fail, what then? In the past months, a number of people, especially students, have asked me fearfully if I would give up and turn to easier, less controversial topics if the Executive Branch made a determined effort to stamp out research into the "High Frontier." I say, no, and so do friends to whom this work owes so much. Those of us intimately involved in the research feel sure that we are on the right track, that we are carrying on an activity that will benefit humanity immensely, either soon or a little later. To walk away from that, whatever the environment, would be an act of cowardice. As long as we can keep the work going, in any way that we can, we will. If funding from the Executive Branch ceases (it was suspended for two months in the autumn of '77), we will keep the work going from other sources, either from Washington, from state capitals, or from private funds.

To that end a small, independent institute has been set up, the Space Studies Institute, Box 82, Princeton, N.J. 08540. A few friends and I operate it without drawing salaries, and it depends for its life on tax-deductible private donations. Already it has served a vital role, permitting us to keep research going while no money was flowing from Washington. It will be the only source of funds for materials to build the second mass-driver model, described briefly in the following article. Friends within the aerospace profession who feel that our work should go on can insure that it will by supporting the Institute.

How should the "High Frontier" concept be linked to the overall body of aerospace research?

First, the time for "summer studies" clearly has passed. The 1977 study, based on the general logic of the "Low (Profile)" article, went about as far as any group can reasonably expect to go within the limits of a short-term, intensive review. The group leaders of that study agreed unanimously that the work should be continued full-time. Essential elements like mass-drivers and chemical processing

plants must be tested in model form; minimum-investment scenarios like that of the following article must be raised from an individual, intuitive level to the objectivity of computer programs flexible enough to accept and measure sensitivities to various guesses on R&D costs and time-scales.

In its "Low (Profile)" version, the "High Frontier" concept should be a salable, common-sense item of national research. The most severe physical problems now facing this country and the world are the limits on available energy and materials. The Shuttle opens up routine access to virtually limitless materials and energy. Never mind, for the moment, the question of what will be the first large-scale use of non-terrestrial materials. Building satellite power stations may be the first use, but the satellite-power concept could die before being realized, whether because of some flaw in the concept itself, or because some alternative energy technology may be developed that appears more economical. Bypassing satellite power stations could slow but need not stop a well-thought-out space-based manufacturing program, if the basic thrust of the program is to open up the nonterrestrial reserves for use in space.

A space-based manufacturing program based on the Shuttle as the carrier of equipment to low orbit makes sense because the Sun shines full time in space, the lunar gravitational potential is only one-twenty-second that of the Earth, and there are materials resources vastly greater than we could use even in hundreds of years reachable in the inner part of the solar system without our having to fight strong gravitational fields. In the long run, those unalterable facts are going to determine the arena of our activity—whatever the particular products first made in large tonnages in space, and whenever large-scale practical returns come, in the 1990s or only in the next century.

We tend to forget that there is more than a hundred-year mark soon to be passed. There is also a millenium. Unless we remain forever planet-bound, the new millenium will surely see the emigration of humanity not only to the far reaches of our solar system but beyond. Now that we realize the possibility of Earthlike habitation in space, all star systems become potential sites for colonies, whether or not those systems have planets.

Governmental myopia may delay for a while the movement into the "High Frontier," but we should not be discouraged. Governments have the habit of being myopic. Perhaps also we should not feel too badly if some other nation than our own seizes the initiative. Several have the technological ability given a decade or so of intensive effort. As scientist and engineers we can take comfort in the fact that the numbers in our favor are constants of nature; time is on their side, and on ours. ■

IMPRESSIONS OF SPACE MANUFACTURING

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As an outgrowth of the 1977 NASA-Ames Summer Study, artist R. Guidice was asked to paint the most recent engineering concepts depicting the building-block phases of a program of space-based manufacturing from non-terrestrial materials. The paintings on this issue of *A/A's* cover, and on the opening pages of the following article, were produced in close consultation with the study group. For example, the paintings of the mass-driver reaction engines and the modular habitats are based on engineering sketches drawn by one of the study participants, J. Shettler of General Motors.

The paintings depict two of the scenarios treated in the summer study: retrieval of lunar materials and retrieval of asteroidal materials. Both scenarios assume mass drivers used for low-to-high orbit transportation along the lines described in G. K. O'Neill's article following here. Mass drivers would also propel lunar materials into free space for processing and pull Earth-approaching asteroids on gravity-assisted retrieval missions into high Earth orbit. In his article, O'Neill describes a "low-road," bootstrap program based on the lunar option.

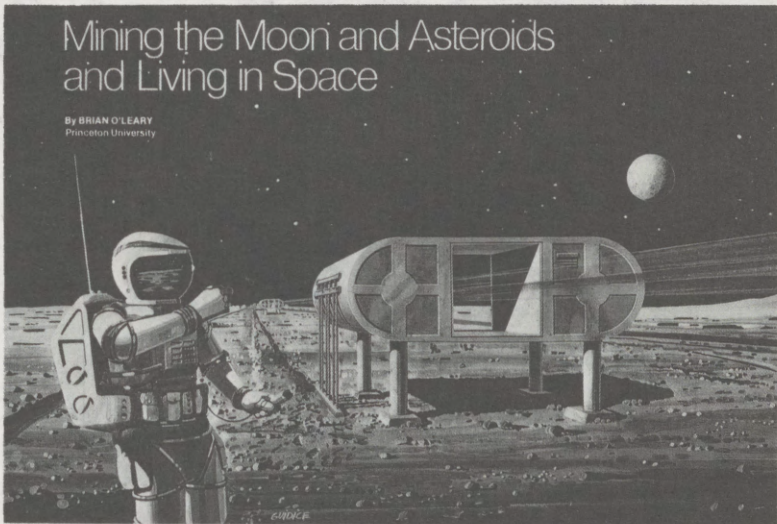
The summer study also made considerable progress in exploring the asteroid alternative. An asteroid study

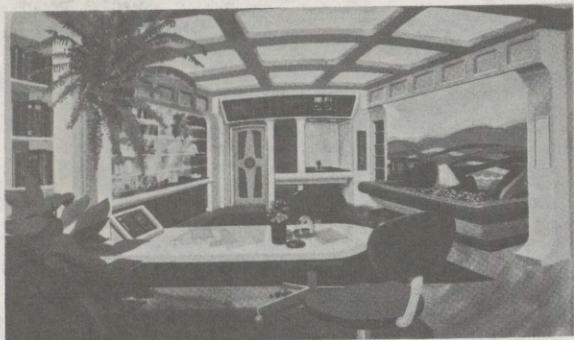
group found that the retrieval of asteroidal material may be cost-competitive with the retrieval of lunar material. Some Earth-approaching asteroids, if gravity-assisted by Venus, Earth and Moon, were calculated to be as accessible (in terms of energy) to space manufacturing sites as the lunar surface.

Scientists and engineers at both the 1977 summer study and at a NASA Office of Space Science-funded workshop on near-Earth resources held later in the summer of 1977 in La Jolla unanimously recommended an increased effort in the telescopic search for Earth-approaching asteroids, follow-up work in determining their orbits and chemical classification, and a Fiscal Year 1980 new start on a program of rendezvous missions for the mid-Eighties to prime asteroid candidates for chemical assay.

Advantages of the asteroid case include the probable availability of water, carbon and free metals, the availability of continuous solar energy and freedom from the need for soft landings. Disadvantages include poorer knowledge of available materials and greater distances and times required for retrieval. At this early stage it seems wise to keep both options alive by vigorous research.

Optical flying-spot scanners measure the position and velocity of sacks of lunar material as they pass through correctors downrange of the mass-driver before launch into space. Sequences of payload-charging/electrostatic deflection/payload discharge downrange are calculated to yield a targeting accuracy of ± 1 meter at the collection point in space. The sacks will be collected near the Lagrange stability point, L_2 , about 63,000 km beyond the Moon, and will be transferred subsequently to the space-manufacturing site in high Earth orbit. The astronaut is shown inside the "safety fence" only for scale.



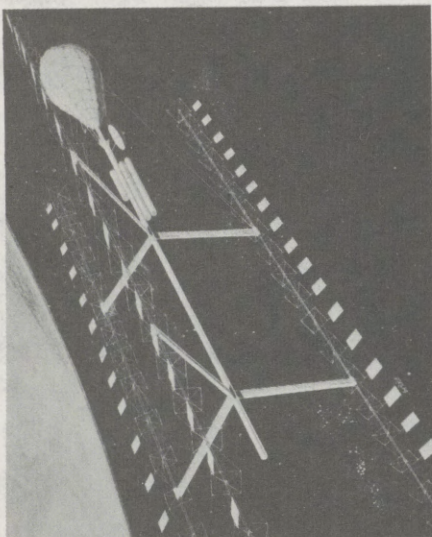


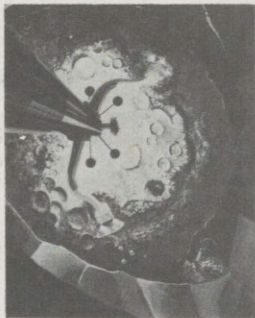
This interior view of a habitat module shows the living accommodations and office of a crew member. A cylindrical liquid-hydrogen container from a Shuttle external tank forms the pressure shell of each module. In this design, generated by a 1977 NASA-Ames Summer Study group, modules are divided into some seven levels, with three pie-shaped living accommodations on each level. These modules would be clustered, shielded, tethered by cables, and rotated to provide Earth-normal gravity during the buildup period of space-based manufacturing from non-terrestrial materials. All illustrations in this section courtesy of NASA.



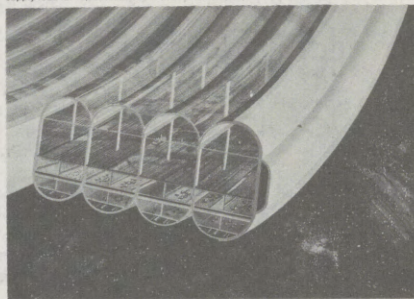
At the lunar base's operations center, controllers monitor the mining of lunar soil and its emplacement into mass-driver buckets. The mass-driver accelerates the lunar material to the Moon's escape velocity of 2.3 km/sec. The throughput of material, estimated to be initially tens of thousands of tons per year, and later hundreds of thousands of tons per year, would permit constructing several satellite power stations and space habitats per year.

In this view, three mass-driver reaction engines have been attached to a 100-m-diam (1-million-ton) asteroid and are taking it on a gravity-assist trajectory past Venus. A bag encloses the asteroid to contain debris as it is mined. Some debris supplies reaction mass to make the necessary velocity changes. A solar furnace and storage tank for extracted water, carbon, and free metals ride the center axis of the assembly.

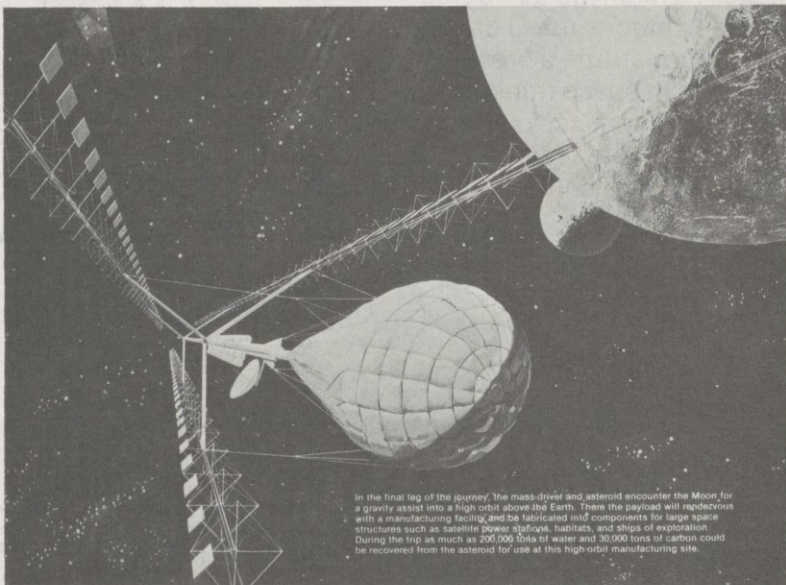




Looking inside the debris container, along the center axis of the assembly shown here, you see the mining operation on the asteroid. Material goes from the surface miner into the center tube for processing, selection of volatiles and metals, and feeding into the mass-driver. The mass-driver launches about 4 kg/sec to propel the asteroid. In three years it reaches Earth with half the asteroid (0.5 million tons) remaining as payload.



Plant and animal agricultural areas, shown in this cross-sectional view, occupy toroidal rings at the ends of an early space settlement fabricated from nonterrestrial materials. The rings supply food for 10,000 residents of the settlement, a sphere about 500 meters in diameter.



In the final leg of the journey, the mass-driver and asteroid encounter the Moon, for a gravity assist into a high orbit above the Earth. There the payload will rendezvous with a manufacturing facility and be fabricated into components for large space structures such as satellite power stations, habitats, and ships of exploration. During the trip as much as 200,000 tons of water and 30,000 tons of carbon could be recovered from the asteroid for use at this high-orbit manufacturing site.

SPECIAL SECTION

The Low (Profile) Road to Space Manufacturing

By GERARD K. O'NEILL
Professor of Physics, Princeton University

Rendering the Shuttle's external tank into powdered propellant for a mass-driver would constitute a breakthrough in space transportation economics, in effect, a quicker route to large-scale space manufacturing



GERARD K. O'NEILL chairs the Task Group on Large Space Structures of the Universities Space Research Association in addition to holding down his Princeton post. At the time this article was written he was on sabbatical leave at MIT as Hunsaker Professor of Aerospace. His book, *The High Frontier*, won the Phi Beta Kappa award as the best science book of 1977. O'Neill received a Ph.D. in physics from Cornell Univ. and specialized in high-energy particle physics.

Early in 1977, an exciting new possibility for speeding space industrialization came up. Several of us at MIT checked out working-model hardware for it in the spring of that year. An independent NASA-supported study that summer wrung out the concept much more thoroughly, with similar results. In this article, I will outline the concept in its original brief form, and note significant changes made as a result of the detailed review.

In the autumn of 1976 the articles from the 1976 NASA-Ames Summer Study on Space Manufacturing from Non-Terrestrial Materials were completed.¹ They gave us for the first time necessary formulae for optimizing the design of magnetic "mass-drivers." In addition, they gave us detailed numbers on space-manufacturing plants: mass, throughput of materials, power requirements, and workforce needs.

The new data suggested to me that, within the lift constraints of the Shuttle era, we might be able to reach the "takeoff point" at which space manufacturing will begin to regenerate and grow exponentially in its culture-medium of full-time solar energy and lunar-derived materials. Although caution is always advisable, it may not be an overstatement to describe the new work as a substantial advance.

It has several components:

- A method by which the Shuttle could be upgraded to geosynchronous capability.

- Planning of a minimal facility on the lunar surface, from which materials could be transferred at low cost into free space.

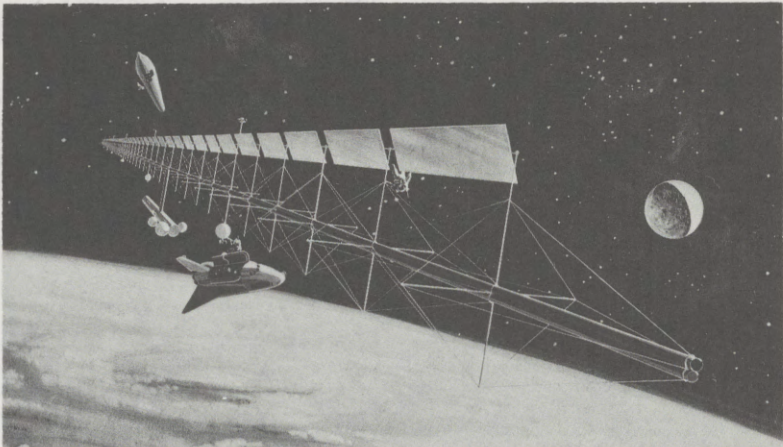
- Evaluation of a processing and fabrication facility in space.

- Calculation of the inputs required in order for an initial facility to grow to the takeoff point.

Combining these building-blocks, I find that the total requirement for lift from the Earth may be equivalent only to a few dozen Shuttle flights per year for several years.

For both technical and political reasons, we must squeeze the most performance, payback, and productive lifetime out of the Shuttle operational era. Our first problem is that the missions with a high potential economically—satellite power system deployment and the utilization of non-terrestrial materials—go to geosynchronous or lunar orbits; but the Shuttle is a low-orbit machine. Is there a way to bypass this problem and give the Shuttle geosynchronous-orbit capability?

The conventional answer has been *no*, other than by accepting a penalty in payload transferred, through the necessity of carrying propellant as payload during the Earth-to-low-orbit lift. That penalty would reduce the Shuttle's modest payload (29 metric tons per flight) by a factor of 2 to 4—to a point too low for the seeding of a space-manufac-



A mass-driver reaction engine several kilometers long being assembled in low Earth orbit from Shuttle-carried sections. The astronaut in the foreground is adjusting the solar collectors that provide power for the mass-driver. Spent oxygen-hydrogen fuel tanks, in powdered form, will be fed into the mass-driver from a container in the background and expelled as reaction mass at 8-10 km per sec. Mass-drivers like the one shown are being studied as orbit-transfer vehicles for large payloads. Painting courtesy of NASA.

turing program even of minimal type.

The problem in fundamental terms: the Shuttle can accumulate payloads in low Earth orbit; to raise them to geosynchronous orbit would take energy, reaction mass, and an engine able to use them.

Solar energy is available, and has long been considered the prime candidate to power ion or plasma engines for deep-space missions. But to raise accumulated Shuttle payloads, several hundred tons at a time, from low to high orbit would take an engine of substantial thrust. In order to escape the loss in payload incurred by transporting propellant to orbit, a geosynchronous system would also need another source of reaction mass.

As designed, the Shuttle Orbiter carries no fuel for its main engines. It must bring its external tank (35 metric tons empty weight) almost to orbital energy. But either by the sacrifice of a few percent in payload to additional OMS (orbital maneuvering system) propellant or by storing hydrogen slush rather than liquid hydrogen, the external tankage could be brought into orbit to serve as reaction mass. To prevent the reaction mass from becoming a hazard to orbiting spacecraft, it should be ground into a fine powder, and after acceleration by and release from the carrier bucket, dispersed by being charged electrostatically. From 60 Shuttle flights per year, the reaction mass powder entering the atmosphere would amount to less than 1% of natural micrometeorites.²

The electromagnetic mass-driver (see the Oct

1976 *A/A*, page 23) seems to be the best, and perhaps the only, reaction engine with adequate specific impulse, thrust, and efficiency to use so unlikely a substance as powdered Shuttle external tankage as reaction mass. Essentially a linear electric motor, the mass-driver uses small buckets, constrained laterally by magnetic forces, to accelerate liquid or solid payloads to high velocity before releasing them and returning for reuse.

Once the processing of lunar materials in space begins, almost surely liquid oxygen will become the optimum material for reaction mass. Oxygen constitutes 40% of lunar surface soil, is likely to be a waste product from its processing, should be easy to handle as a liquid, and after acceleration would disperse by boiling to molecular form.

The third of the three articles contains formulas and numbers on which designs for a mass-driver reaction engine can be based.^{3,4,5} Later articles summarize without derivation formulas for optimizing system mass, based on the most recent theoretical work.^{6,7} We have now established as a baseline a system in which each bucket has just two coils, the drive circuits are of two phases in quadrature, and the current in each drive coil oscillates through one complete sine wave as each bucket coil passes.

The 1977 NASA-Ames Study concluded that total system mass changes little with cross-sectional dimensions. For constant throughput, system mass changes by only 50% as payload varies by a factor

of over 1000. To keep the driver length within practical limits, it must use high acceleration (several hundred Earth-gravities).

The mass-driver employs superconductors only in the buckets; the stationary drive windings are of ordinary aluminum. For commercially available superconductors, field-strength limits are not reached even at accelerations of more than 1000 g. (Mainly for historical reasons, the earlier calculations on mass-drivers were based on rectangular geometries similar to those of an MIT Magneplane transportation concept.⁹ Calculations indicate tight-coupled axial structures, advocated by H. Kolm of MIT, to be lighter by more than a factor of 2 for the same performance.⁴)

At a nominal 60 flights per year, the Shuttle can bring to low orbit approximately 1700 tons of payload and 2100 tons of reaction mass (i.e., external tanks). For spiral orbits, missions to lunar distance require an engine with specific impulse in the general range of 1000 sec, if the engine is to be returned and a substantial payload carried. A mass-driver of that sort would have these characteristics based on the latest 1977 Study results:

Exhaust velocity, m/sec.	10,000
Specific impulse (I_{sp}), sec.	1,020
Bucket acceleration, m/sec ²	10,000
Engine electrical components mass, including power, tons	90
Total engine mass, tons	170

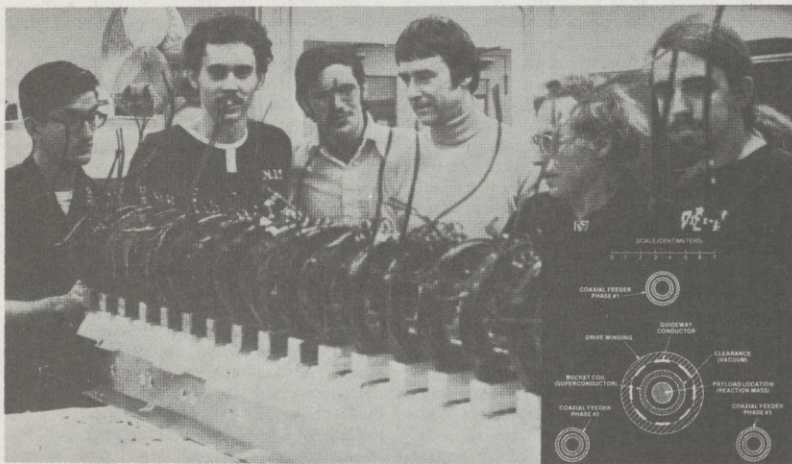
Round trip time to lunar orbit, days	200
Reaction mass use rate, tons/yr.	2,100
Payload from low-Earth orbit to lunar orbit, tons/yr.	1,300

The 1977 Study identified as a major necessary development for reaching this performance reducing the weight of a silicon-controlled rectifier to only a few times the weight of the silicon wafer alone. Present silicon rectifiers, designed for entirely different service with high duty cycles, weigh far more.⁸

Until the 1977 Study, the mechanical stability of the long, thin mass-driver structure as buckets accelerated and decelerated remained unclear. After a great deal of work the Study concluded that the machine would just remain stable. Therefore, the system mass includes a yardarm and guywire structure with slow-acting servomechanisms to maintain straightness. (The Stanford Two-Mile Electron Accelerator, located almost on top of the San Andreas earthquake fault line, is given occasional adjustments based on a laser-beam sight line. Its aperture is about 1 cm.)

The nominal design just outlined would give more than twice the specific impulse of the Space Shuttle Main Engine, which is the state of the art for large chemical rockets.

To the best of my knowledge, no physical upper limit on mass-driver output velocity exists (other than c); but the optimum I_{sp} for missions in the



F-1 Scale model demonstrates mass-driver action. H. Kolm (with glasses) and O'Neill together with student volunteers from MIT built it last year. It can push a 1-lb "bucket" to 85 mph in 0.1 sec for an acceleration of 35 g. Photoflash capacitors discharge into fixed coils to drive a moving coil. Diagram shows cross-section of mass-driver for use as an upper-stage engine for the Space Shuttle.

Earth-Moon system is 800-1000.

So we should be able to lift about 1300 tons/yr of Shuttle payloads from low-Earth to lunar orbit, without having to devote additional Shuttle flights to carrying propellant. What minimal facility would then be necessary on the Moon to convey lunar materials into space?

My original estimates centered on 1050 tons. A more detailed evaluation carried out during the 1977 study concluded with a figure of just under 1000 tons.⁸ The axial mass-driver for the lunar surface contributes less than a quarter of the total, excluding its foundations. That machine would be sized for an eventual throughput of 600,000 tons/yr, but the photovoltaic array first sent to the Moon could handle only a twentieth as much throughput. The machine parameters are:

Acceleration, m/sec ²	1000
Design maximum velocity, m/sec	2400
Total length (accel. + decel.), m.	4320
Efficiency, d.c. to kinetic power, %	96
Photovoltaic power supply (at lunar surface), tons/Mw	15
Waste-heat radiators, tons/Mw	20

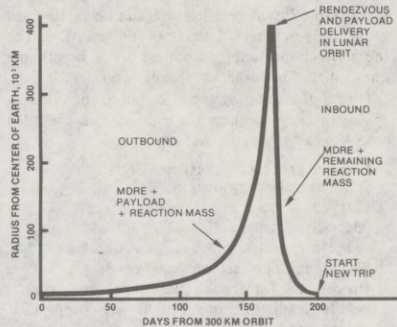
The mass budget figures in tons for initial lunar-surface operations would be as follows:

Axial mass-driver electrical components ..	232
Foundations	100
Maintenance enclosure	100
Photovoltaic power supply (for 30,000 tons/yr)	93
Downrange course-correction stations	50
Habitat (temporary for 50, long-tour for 10) ..	300
Life-support resupply (50 people, 1 year, at 10 kg/d)	180
Silicon and glass-fiber plant for materials encapsulation	30

In addition, resupply for a 10-person crew using 10 kg per person per day would total 37 tons per year.

To soft-land that equipment, an equal quantity of propellant must be brought to lunar orbit. For operations both on the lunar surface and in space, we must ante up about 2800 tons of Shuttle payloads—about 100 Shuttle flights—to commence transporting materials from the lunar surface to a precise point in space. The 2800 tons breaks down as follows:

Total lunar surface equipment and supplies ..	1085
Propellants (LOX-H ₂) to soft-land	1085
Mass receiver (diam of 110 m) at L-2	100
Habitat in space (30 people, at 10T)	300
Mass-driver engine	170
Lunar lander (LOX-H ₂ engines, tanks, controls)	7
Shuttle and interorbital crew module	11



F-2 In mission scenario for mass-driver reaction engine (MDRE) operating as an interorbital transfer tug, total mass in low-Earth orbit (LEO) would be 2075 tons. The engine would expend 1000 tons of powdered Shuttle tankage in the spiral-orbit climb to the Moon. After dropping a 730-ton payload in lunar orbit, the unmanned tug would spend the remaining reaction mass in a relatively quick return to low-Earth orbit for maintenance, refurbishment of solar-cell arrays, and reloading with payload and reaction mass.

Interorbital tug (LOX-H₂ engine, tanks, controls)

Supplies for personnel in space (for 1 yr at 10 kg per person)

The 1977 Summer Study obtained a similar total from a slightly different mix. Lunar landers and personnel transfer tugs had more mass, but converting spent Shuttle external tanks to 21-person habitats for use on the Moon and in space saved substantial mass. Those habitats could be spun on cables to create normal gravity, and would be divided into private apartments, one for each person in the original workforce.

At the first plateau, a number of milestones would be reached: proof of the concept of lunar materials transport, provision of large quantities of reaction mass for all later operations, and opening of a large reserve of mass for shielding manned operations at geosynchronous or higher orbit.

In reaching this plateau it will *not* have been necessary to learn how to chemically process or fabricate from lunar materials, nor to learn how to set up agriculture in space.

Once at the plateau, with the availability of lunar soil as reaction mass, the throughput of equipment from the Earth to geosynchronous and higher orbits will no longer depend on powdered Shuttle tankage. (That might be a good time to deploy a Shuttle-derived lift-vehicle, so that subsequent launch operations can be of lower cost.)

The next step requires chemical processing, making oxygen in lunar materials (40% by weight) available as propellant for lunar landers, as

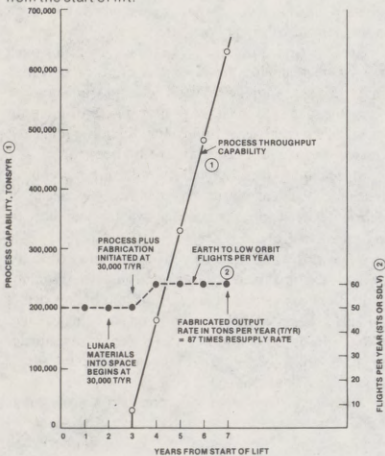
vaporizable liquid reaction mass (able to be used more freely in mass-drivers than can solids), and as the most important component of a breathable atmosphere for workers in space.

During the setup of the pilot-plant operation in space, the key numbers (as estimated in the 1976 NASA-Ames study) would be:¹⁰

Assumed process plant efficiency, %	60
Input average composition, %	
Oxygen	40
Metals	30
Silicon	20
Throughput/power, tons/year per Mw	650
Process and fabrication plant throughput (includes radiators but not power supply), tons/year-ton of plant	200
Photovoltaic power in space, tons/Mw	5.3
Labor utilization (Si plus metals, fabricated), tons/year per person	60
Resupply needs (after oxygen extraction becomes practical), kg/person per day	2
LEO to high orbit mass penalty (personnel transfer)	Factor of 4
Totals for process and fabrication:	
Throughput, ton/yr.	30,000
Output fabricated Si and metals, tons/yr.	9000
Plant mass, tons	150
Power-supply mass (at 5.3 tons/Mw), tons	245
People required	150

F-3 "IGNITION" POINT

Within Shuttle-era launch constraints, growth of space manufacturing to the "ignition point," at the sixth year from the start of lift.



Habitat requirement (at 10 tons per person), tons 1500

The 1977 Study updated these numbers, but the major conceptual breakthrough on chemical processing during 1977 was laying out a new basic process-flow chart depending on a carbo-chlorination reaction rather than on carbothermic reduction of aluminum-bearing minerals. The change reduced the peak temperature in the system by a thousand degrees to bring it in line with normal industrial practice here on Earth.

Once chemical processing is tested and working, the next step is fabricating a limited range of products from chemically separated lunar materials, such as photovoltaic arrays (lunar material, 20% silicon by weight) and thermal radiators to upgrade both the lunar launcher and the processing/fabrication plants in space. Products might later include structural components. We estimate an output of about 9000 tons per year of fabricated components—of these, about 20% would be photovoltaic arrays and 80% would be habitat components.

Together with 1800 tons/year from the Earth (21 flights/year of a Shuttle-derived freight rocket) and 750 people per year (13 Shuttle flights), this system would grow at a rate of 150,000 tons of additional throughput per year. When that growth reaches 630,000 tons throughput per year, or 190,000 tons/year of fabricated output products, the system output would equal in mass two 10,000-Mw satellite power stations per year.¹¹

Minimum transport investment up to that point comes to just under 300 flights from Earth to low orbit, or about 42 flights per year averaged over seven years; of these, over half would be Shuttle flights (STS) and the remainder Shuttle-derived lift vehicles (SDLVs).

F-3 summarizes recommended transport investment. It includes additional safety factors—mainly 96 additional SDLV flights to provide the 3000-person workforce in space with 8400 more tons of supplies. These may be in the form of 1 ton of organics per person to stock later space farming, of 2 kg per person per day of emergency resupplies adequate for two years, and 4300 tons of Earth-built components for habitats or for products exportable to geosynchronous orbit.

If (as assumed) space agriculture has not yet been developed, 25 SDLV flights per year will be required to transport food to the 3000-person workforce, at 2 kg per person per day. At \$20 million per flight that will add about a dollar per pound to the cost of fabricated products. (The rate of developing agriculture in space will likely be affected less by direct lift-cost economics than by the need to

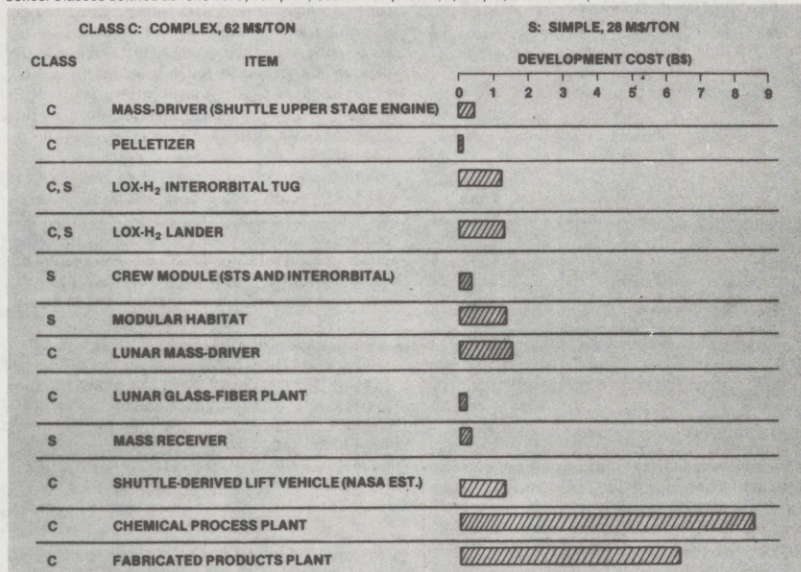
maintain workforce morale by providing enjoyable fresh foods.)

The range of output products and the rate of diversification of products will depend on the economics of construction in space vs. lift from Earth. To sustain rapid exponential growth, an increasing share of the total must be built in space. For example, if 5% of the output products' mass must still be obtained from Earth when 600,000 tons per year is being processed, about 100 flights per year of a Shuttle-derived freight rocket will be

decade, to a point where the entire market for new generator capacity worldwide apparently might be provided by space-built satellite power. That Study found the market 25 years from now \$200-400 billion per year. It found exponential growth essential for beating interest costs, and ran into the biggest uncertainty over what fraction of the products assembled in space must be hauled from Earth. As both studies in the past two years have concluded, effort must go into designing fabricated products optimized for construction from lunar

F-4 R&D COST ESTIMATES

Based on Shuttle experience. Most of the items with estimated total R&D costs below \$1.5 billion appear to be necessary to or strongly beneficial to any program of large-scale high-orbit activity, whether or not based on the use of lunar materials. In some cases, a range of costs is shown, with earlier estimates cross-hatched and current estimates open boxes. Classes defined as follows: C, complex, \$62 million per ton; S, simple, \$28 million per ton.



required to transport that 5% to low orbit. Strong economic incentives will exist at that time both to diversify industry in space and to upgrade Earth-to-low-orbit transport, either by a reusable Shuttle first stage or by a wholly new (possibly single-stage) vehicle. The justification for such developments will be far easier then, after several years of intensive Shuttle use and the continuing pressure of space productivity, than in the early 1980s.

The 1977 Study traced the time-line for another

materials. The exercise resembles substitution studies carried out in wartime or when cartels threaten supplies. Lacking the lunar-materials option, we would still be making studies of that kind in these next years, as materials shortages and cartels increasingly rule our industries.

For the limited span of time covered by F-3, the most uncertain numbers appear human related: habitat mass, productivity, duration of tours of duty, and fraction of the workforce engaged in

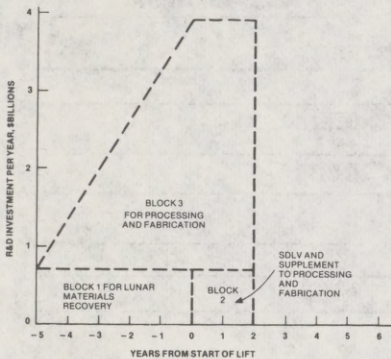
export labor. The latter two have been ignored in this simplified treatment. The time-line appears rather insensitive to those numbers until the first plateau; after that, the actual growth rate depends on them more.

The takeoff point in space manufacturing will reflect our cultural values. It might be defined in one way as the point at which the rate of value-generation exceeds the rate of investment, the latter including development, construction, transport, and interest charges.

R&D cost estimation is a notoriously uncertain business. Given the transport economies just outlined, R&D costs may dominate the total in-

F-5 R&D INVESTMENT SCENARIO

Based on starting processing research at the same time as other items. A phased-decision plan would defer the area of Block 3 until after completion of Blocks 1 and 2.



vestment required to reach the takeoff point. R&D costs have ranged from as little as \$6 million per ton in 1960 dollars for a throwaway rocket whose engines had already been developed, the Saturn V, to over \$200 million per ton for the Apollo Command Module.

To estimate R&D costs for space manufacturing, it seems best to use a modern example: Shuttle R&D totals \$6.3 billion.¹² Of that total, I take two-thirds as devoted to the Orbiter, a complex but reusable 68-ton vehicle. Orbiter R&D costs approximately \$62 million per ton. The relatively simple external tank and one SRB total 76 tons, and cost \$28 million per ton for R&D.

The components of the space-manufacturing program just described have been analyzed for cost on that basis, as summarized in F-4. Mass-driver structures were estimated on the basis of individual non-equivalent sections every 5% in bucket

velocity. The crew-transport module for 60 people was taken as a Shuttle payload of 11 tons dry mass, and the workforce habitat module was assigned a mass of 12 tons. To compare this primitive approach with the more detailed estimates made during the 1977 study, all mass-driver R&D in F-4 costs \$2.4 billion. Several months later different persons obtained a figure of \$3.3 billion, which includes construction of several mass-driver tugs and an extensive program of unmanned observations by lunar polar orbiter and exploration by roving lander. No sensible person would conclude from that a figure of \$2.7 billion $\pm 20\%$. Other estimates, equally defensible, were higher and lower by factors of two.

F-4 shows a range of cost estimates for some items for which there are data from previous studies of orbital transfer vehicles, space stations, a lunar base, and a Shuttle-derived lift vehicle. All estimates are necessarily rough and do not consider overall integration, government infrastructure, and commonality with other applications, but they do serve to show that the investments fall in a reasonable range.

Both studies reveal clearly that reaching the economic takeoff point does not require large monolithic habitats ("space colonies"). Furthermore, colonies could not be developed like aerospace hardware, for R&D cost reasons. When the time comes to build such structures, they will have to be designed and constructed like ships or like buildings rather than like jet aircraft. Space-farms, like monolithic habitats, do not appear to be essential in reaching the takeoff point.

The 1976 Ames Study concluded that over the range of 1 to 30 kg/sec in throughput, chemical extraction and fabrication plant mass and power should be proportional to throughput. For minimizing R&D costs, therefore, it seems best to design such plants for moderate size (1 kg/sec or 30,000 ton/yr) and then to parallel identical units.

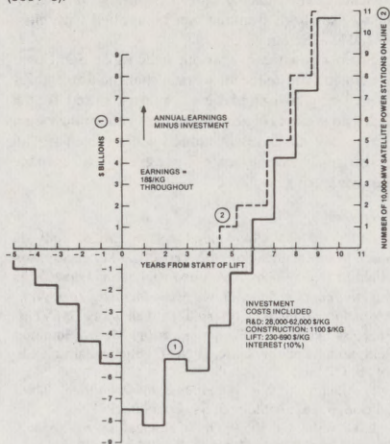
It is reassuring to find that most of the necessary early R&D steps have potential benefit to all large-scale high-orbital activity, whether or not using lunar materials.

To indicate the uncertainty of R&D cost estimation, in a recent NASA Johnson Space Center study a large, fully reusable Class IV launch vehicle was assigned an R&D cost of \$6 million per ton—a factor of ten below the figure used in this article, and one-seventh of the average for the Shuttle.¹¹ Until far more detailed work is done, it seems premature to argue which, if any, of these estimates is near the truth. I use the higher figures mainly to be on the safe side.

The required R&D investment falls naturally into three blocks:

F-6 INVESTMENT AND EARNINGS SCENARIO FOR SPACE MANUFACTURING

Based on Shuttle and SDLV costs of \$20 million per flight, with SDLV payload of 87 metric tons. R&D schedule from F-5. "Ignition point" means the time when dollar income exceeds dollar investment—in this case, the sixth year (see F-3).



1. All items necessary to reach the first plateau, at which point the base would begin putting 30,000 tons per year of lunar materials into space. That first block would cost \$3400 million, or \$700 million per year spread over five years—a sum and rate well within governmental R&D funding patterns, being far less than the annual Department of Energy budget for nuclear-power R&D, and well under peak funding for Shuttle development.

2. SDLV development plus intermediate-level (\$400 million per year) research on processing and fabrication. This would cost \$700 million per year for two years—also within government precedents.

3. A remaining \$14 billion for processing and fabrication development falls intermediate in scale between Shuttle and Apollo R&D. The processing-design group at the 1977 study rather strongly believed that estimate far too high. If that figure is high, it is likely to be compensated for by errors in the other direction made on other items.

In brief, the gradual, step-by-step approach to space manufacturing comes within the general range of NASA funding, at least until processing and fabrication plants must be developed. If a decision on R&D funding of the third block were delayed until then, at that point prospective investors would know that the major questions of lunar-materials transfer, of low-cost interorbital transport, and of the long-term health of workers in

space had been answered. If the requirement then existed for large tonnages of manufactured products in geosynchronous orbit, funding for additional R&D would be easier to justify than it would likely have been earlier.

A total of \$14 billion in R&D funding spread over several years comes within the ability of the private sector. In 1990, for example, the electric utilities will have to be investing in new generator capacity at a rate of more than \$20 billion per year. Even in 1977 the life-insurance companies, major financiers for the utilities, disposed of some \$45 billion in investment cash flow.

In a stepwise approach, the items requiring relatively large R&D expenditures can be deferred to a late stage in the program, when the most unusual and therefore high-technical-risk items have been proven, and when profits from manufacturing are in sight.

On the Advisory Panel of our Task Group on Large Space Structures formed by the Universities Space Research Association, we have several senior executives of major utilities and life-insurance companies. The Advisory Panel has discussed R&D funding of a space-manufacturing program at some length. They feel private sources of capital unlikely to appear on a significant scale, that is, on the scale of tens of billions, until technical risks have fallen to the level of hydroelectric power. They agree that demonstrations of lunar-materials transport, of satellite power transmission, and of the processing of lunar materials to pure elements in space would constitute adequate reduction of risks. After that, our financial friends assure us, there should be no difficulty in obtaining ample private funding for a rapid buildup if the economic estimates show clearly that space-manufactured satellite power will undersell that from coal and the atom.

Given the breakthrough in transport economy described here, the pacing item in the development of space manufacturing appears to be the start of processing R&D.

Many development scenarios are possible, and I provide one (F-5) as illustration. It delays the peak of the third block of R&D funding until the two-year period for replacing the lunar-materials transport system, and is consistent with F-3. A still more cautious scenario would insert an additional decision delay until starting the transport of lunar materials, and would make the third block of R&D funding a more highly peaked three-year effort.

F-3 and F-5, combined with a hardware cost assessment of \$1100/kg, a 10% interest rate in constant dollars (17% discounting), and an assigned value of \$60/kg for fabricated export products made in space, allow calculation of the takeoff point as six years after the start of lift. I

assume that the equipment to be located in space will cost on Earth eighteen times as much per kilogram as the value per kilogram in geosynchronous orbit of the products fabricated in space. The first is based on the cost of military aircraft, while the second is based on satellite power stations of 83,000 tons mass,¹¹ figured as worth \$500/kw at the busbar on Earth. For the time line of F-6, the total program up to takeoff would cost \$24 billion, exclusive of interest. After "takeoff," debt retirement and earnings would accelerate rapidly.

The 1977 Study considered many points not brought up in my simplified argument: workforce selection and training costs, salary costs, crew-exchange times and resulting transport loads, and an overall higher estimate of R&D costs. It reached quite similar conclusions on times and buildup rates, but gave a total investment up to the takeoff point of more like \$50-60 billion—about the cost of an Apollo project in today's dollars. Both efforts constitute simply first cuts toward a generally promising approach. Better answers, or still more efficient scenarios, will have to await longer-term or continuous studies using the well-known but expensive techniques of critical-path analysis and cost/benefit theory embodied in large, thorough, flexible computer programs.

The mass-driver clearly plays a key role in the development of space manufacturing. Without that, or something equivalent to it, the upgrading of the Shuttle, lunar-materials transfer, and low-cost interorbital transport will all be impossible. Recognizing that fact, the propulsion division of NASA's Office of Advanced Science and Technology has recently begun support of mass-driver research at a modest level. As a first step, a group of student volunteers, together with Prof. Kolm and myself, built a 2-m-long mass-driver of larger caliber than the Shuttle upper-stage engine.¹³ The model was built almost entirely of scrap or surplus materials. The group completed the mass-driver in three months, and demonstrated it at the May 9-12 Princeton/AIAA Conference on Space Manufacturing, at the final briefing of the 1977 Ames Study, and at the California Aerospace Day celebration a few hours before the first Shuttle free flight.

Unfortunately, the uncertainties of changing administrations in Washington have delayed funding for a second, much higher-performance model. Funds assured at the time of writing would not even buy materials for that model, the superconducting bucket of which would reach a speed of 700 mph in 5 m to impart an acceleration of 1000 gs in vacuum. Partly to end these delays, a group of us has formed the Space Studies Institute, a non-profit corporation able to receive tax-

deductible subscriptions.¹⁴ Subscriptions from persons of all ages and backgrounds have already begun flowing in, and we will depend on them to construct the second model of the mass-driver. The officers of the Space Studies Institute serve without salary, so funds donated can be applied with close to 100% efficiency.

From a practical viewpoint, the most significant conclusion of the recent work is that the Shuttle, far from being a limited device poorly suited to the tasks now emerging as of greatest economic value, may prove an excellent launch vehicle even for an ambitious, large-scale program of space manufacturing.

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[The following information was subsequently received for the record:]

PRINCETON UNIVERSITY,
DEPARTMENT OF PHYSICS,
Princeton, N.J., March 23, 1978.

MR. JOHN G. STEWART,
U.S. Senate Committee on Commerce, Science and Transportation, Dirksen Office Building, Washington, D.C.

DEAR JOHN: Thank you for sending me questions on asteroid mining. The answers to most of your questions are contained in my summary paper *Resource Potentials of Asteroid Capture*¹ which I recently presented at the annual meeting of the American Association for the Advancement of Science in Washington. This paper is one of three brief papers which I have submitted for the record to accompany my recent testimony to your committee. In the interest of time, I ask that you refer to that paper, and will very briefly address the questions in this letter.

A number of scientist and engineering colleagues and I have addressed the question of what engineering would be required to retrieve a small earth-approaching asteroid as a materials resource for the space manufacturing of satellite power stations and other products. We believe that the most cost-effective way of doing this would be to assemble an electromagnetic mass-driver from Space Shuttle launches during the late 1980's and send the mass-driver rocket, some mining apparatus and a small crew to the asteroid sometime during the early 1990's. The mass-driver would rendezvous with the asteroid, and tow the asteroid on a trajectory which would place it in a high earth orbit for processing. Fuel would be asteroidal debris accelerated in recyclable buckets along the mass-driver and power would come from solar collectors along the mass-driver.

The technology required to undertake this activity is well-understood, but a period of development, testing and demonstration, perhaps during the early 1980's, would need to be carried out first. The 1977 Ames Summer Study group estimated the total research and development costs attributable to asteroid retrieval to be on the order of \$10 billion. The retrieval of a one-million ton asteroid would be about \$2 billion. These estimates are preliminary and subject to further analysis. A parametric study indicated that the cost of retrieving and processing asteroidal materials would be less than that for lunar materials and many times lower than that for terrestrial materials. The main reasons for cost-effectiveness in the case of asteroid retrieval is that the asteroids have zero gravity fields, contain materials useful for space manufacturing, continuous solar energy would be available at the asteroid during its retrieval and the processing of its materials, and there exist many candidates whose orbits are reasonably accessible to near-Earth space.

I hope this material will answer your questions and I look forward to a continuing relationship with your Committee as these concepts become further developed.

Sincerely,

BRIAN O'LEARY.

¹ See p. 1088.

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