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OUTER SPACE PROPULSION BY NUCLEAR ENERGY,

HEARINGS

BEFORE

SUBCOMMITTEES OF THE JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

EIGHTY-FIFTH CONGRESS

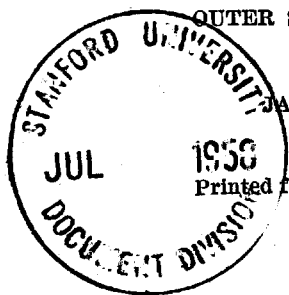
SECOND SESSION

ON

OUTER SPACE PROPULSION BY NUCLEAR ENERGY

JANUARY 22, 23, AND FEBRUARY 6, 1958

Printed for the use of the Joint Committee on Atomic Energy



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INTRODUCTION

The Joint Committee on Atomic Energy has for a number of years concerned itself with the development of nuclear propulsion for a variety of peacetime and military uses. Perhaps the most outstanding example of nuclear propulsion in action is the *Nautilus* and its counterparts in the underseas fleet of the United States Navy. The Joint Committee is proud of the part which it has played in helping promote development of the *Nautilus* and is currently lending its full support to the development of Naval and commercial vessels designed to utilize nuclear energy in their propulsion systems.

In its support of nuclear propulsion activities, the committee has not been unmindful of the potentialities of such propulsion for aircraft, both manned and unmanned, and for space exploration. In this latter category the committee has for several years lent its full support and encouragement to the establishment of a vigorous program aimed at developing at the earliest moment an effective means of nuclear propulsion for space vehicles.

This developmental work, which has been carried out under the name of Project Rover, was begun in the Atomic Energy Commission's laboratories well before the advent of the Soviet sputniks. Despite formidable technical obstacles, the research and development work in these laboratories has been proceeding well and the first experimental reactor is expected to begin operation some time this fall. Results of this research to date have served to point up the optimistic prospects for utilizing nuclear energy in the field of space travel, probably within the next decade.

With these considerations in mind, the Joint Committee, through its several subcommittees, held detailed hearings earlier this year, both in executive and in public session, to provide information for the Congress and the public on what measures are being taken and are contemplated in the field of space propulsion and exploration.

Expert witnesses from a number of Government agencies and laboratories appeared before the committee, including scientists from the Atomic Energy Commission laboratories at Los Alamos, Livermore, and Bettis Laboratory and representatives of the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics. Testimony was also received from Defense Department representatives and scientists of the North American Aviation Co. engaged in space propulsion research. In addition, the committee heard testimony from a private group of individuals, including Dr. Wernher von Braun of the Army Ballistic Missile Agency, who offered suggestions as to the organization of space research activities, and Dr. I. Fred Singer, of the University of Maryland.

It was the consensus among witnesses who appeared before the committee that of all propulsion systems currently under consideration, nuclear propulsion appears to offer the greatest advantage for carrying large payloads great distances, such as interplanetary travel. It

was recognized that chemical systems have achieved a more advanced stage of development at the present time and are more suitable for lighter payloads traveling relatively shorter distances. But the inherent limitations of chemical systems underline the desirability of proceeding with a vigorous program of research and development on nuclear propulsion for future space travel.

It will be noted that in the first 2 days of testimony, which were held in executive session, some portions of the transcript have been deleted. These deletions were made at the request of the Atomic Energy Commission and Department of Defense following a review of the testimony by these agencies for the purposes of removing classified information affecting the national security.

CARL T. DURHAM,
Chairman, Joint Committee on Atomic Energy.

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OUTER SPACE PROPULSION BY NUCLEAR ENERGY

WEDNESDAY, JANUARY 22, 1958

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT,
AND THE SUBCOMMITTEE ON MILITARY APPLICATIONS,
Washington, D. C.

The Subcommittee on Research and Development, and the Subcommittee on Military Applications met jointly, pursuant to call, at 10 a. m., in the committee room, the Capitol, Hon. Clinton P. Anderson (acting chairman), presiding.

Present were: Representatives James E. Van Zandt, Thomas A. Jenkins, and Craig Hosmer; Senators Clinton P. Anderson, John O. Pastore, Albert Gore, John W. Bricker, and Henry Dworshak.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; and George E. Brown, Jr., staff member for research and development, Joint Committee on Atomic Energy.

Committee consultant present: Capt. N. R. Nelson.

Representatives of the Atomic Energy Commission present: Dr. W. Kenneth Davis, director, and Louis W. Roddis, assistant director, Reactor Development Division; Gen. Donald J. Keirn, chief, and Col. Jack Armstrong, deputy chief, Aircraft Reactors Branch, Reactor Development Division; Gen. Alfred D. Starbird, director, Division of Military Application; A. Tammaro, assistant general manager for Research and Industrial Production; Bryan LaPlante, special assistant to the general manager (congressional); and Commander Moore, assistant to Colonel Armstrong.

Representatives of the Department of Defense: Hon. Herbert Loper, Assistant to the Secretary of Defense (Atomic Energy).

Representatives of the Los Alamos Laboratory: Dr. Norris Bradbury, director; Dr. Raemer Schreiber, chief of section, Rover Project; and Dr. Stanislaus Ulam.

Representative of the Livermore Laboratory: Dr. Theodore Merkle.

Senator ANDERSON. This is a joint meeting of the Research and Development Subcommittee and the Military Applications Subcommittee to discuss the present status and future prospects of Project Rover, the nuclear rocket, and Project Pluto, the nuclear ramjet. After this morning's meeting the committee will reconvene at 2 p. m. today for a briefing on outer-space propulsion by representatives of the Atomic Energy Commission, the National Advisory Committee for Aeronautics, and the Defense Department.

I understand the first presentation this morning will be made by Col. Jack Armstrong, deputy chief of the Commission's Aircraft

Reactors Branch. We will then hear from Dr. Bradbury, director of Los Alamos Laboratory, where the work on Project Rover is being carried out, and from Dr. Merkle, of Livermore Laboratory, where the work on Project Pluto is being conducted.

I understand General Loper is also here today from the Defense Department to answer questions which may arise during the course of the discussion.

We are glad to have you with us this morning, gentlemen. Colonel Armstrong, will you please proceed?

STATEMENT OF COL. JACK L. ARMSTRONG, DEPUTY CHIEF, AIRCRAFT REACTORS BRANCH, DIVISION OF REACTOR DEVELOPMENT, ATOMIC ENERGY COMMISSION

Colonel ARMSTRONG. I would like to have General Keirn here for a moment.

Senator ANDERSON. Surely.

General KEIRN. I really want to carry right on with Colonel Armstrong—

Senator ANDERSON. I apologize to you, General Keirn. I didn't know you were going to testify on this. I know you are associated with the nuclear aircraft—

General KEIRN. I will turn the program over to the man who has been following the details of it most closely. I think we might proceed immediately with Colonel Armstrong's presentation.

Colonel ARMSTRONG. We have a great deal to cover here this morning on the Rover program, the Pluto program, and the Snap program. I, being so close to this thing, may get a little involved in my own conversation and if I get into too much detail, please tell me.

Senator ANDERSON. Is Snap by any chance kin to the Pied Piper?

Colonel ARMSTRONG. It is Pied Piper renamed, sir. Snap stands for secondary nuclear auxiliary power.

Senator ANDERSON. Is that classified, by the way?

Colonel ARMSTRONG. The word Snap in itself is not, sir. The fact that it is a program to apply nuclear power on a satellite is classified.*

Mr. RAMEY. Is Pluto classified?

Colonel ARMSTRONG. The word Pluto in itself is not.

Senator ANDERSON. I know.

Colonel ARMSTRONG. The fact that it is a nuclear ramjet program was classified, but it has lost its classification in usage.

Mr. RAMEY. It is still classified when the Senator uses it, but not when a newspaper reporter or anyone else uses it.

Senator ANDERSON. What I mean is if somebody asked me to state on the floor what Pluto was, I would have to stay away from it entirely because I couldn't answer it. However, the newspapers refer to it as a nuclear ramjet. They print that quoting the Air Force and various other people.

Colonel ARMSTRONG. It would be my position and I would recommend to the classification people and I am sure it could be put through very quickly that because of the usage of the term—that Pluto is a

*The association between the Snap program and the satellite program has been declassified since this hearing.

nickname, if you will, instead of a code name for the nuclear ramjet program and it is therefore unclassified.

Senator ANDERSON. Thank you.

Colonel ARMSTRONG. Rover, I think, could be treated exactly the same way and I don't think there would be any argument on anybody's part. This is one of those administrative details which we just haven't gotten to.

Senator ANDERSON. Thank you.

Colonel ARMSTRONG. I would propose to take the Rover program first. I would like to go through Rover, give you the programmatic features, then call on Dr. Bradbury and Dr. Schreiber to tell you what their technical program is, to answer your questions as best as we can on Rover and then to go into Pluto as a separate entity rather than get these programs mixed together.

If you will pardon me I would like to define for you so that we see this in its proper perspective what a nuclear rocket is versus a chemical rocket and how these things work.

A chemical rocket in that it operates outside the earth's atmosphere must carry with it everything that it is going to burn, this creates heat and therefore energy. In other words the rockets, as we know them today, are made up of tanks of liquid oxygen, tanks of kerosene or JP4 and these two fluids are pumped into a combustion chamber and ignited. When they are ignited energy results and the resultant push that comes out of the nozzle is what causes the rocket to go forward.

In the case of the nuclear rocket, there is this difference. We carry only the propellant. We put the heat into the propellant by use of a nuclear reactor. Therefore we don't have to carry any oxygen along with us. All we have substituted is a reactor for the combustion chamber and thereby gotten rid of the need of having oxygen along with us for purposes of combustion.

I would like to just briefly go through the history of the nuclear program to put that in phase. In 1955 there was a program going on at Los Alamos and at Livermore out of funds available to those laboratories, but not as recognized nuclear propulsion projects. Along about September 1955, the kinds of moneys that were being spent obviously indicated that these programs should be recognized as such and we should query the Department of Defense as to their interest in the program. This was done and the Department of Defense indicated an intense interest in this program and a desire that we go ahead with it, but on a base so as not to interfere with the weapons programs going on at Los Alamos and Livermore.

We then went ahead and started to budget for this program and the budget was set up on the basis of the requirement which we then had from the Department of Defense which stated, in essence, that they wanted us to go ahead on a feasibility program to determine the feasibility by ground operation of a nuclear rocket engine by about 1959, looking forward to a possible flight in [deleted] if this appeared desirable. On that basis we took as our objective the demonstration by a ground operation of a nuclear reactor—

Representative VAN ZANDT. When you speak of "we", whom do you mean?

Colonel ARMSTRONG. This is the Atomic Energy Commission, sir. In everything I say today, I will speak as from the Atomic Energy Commission.

In the summer of 1956 a committee was set up by Dr. Eger Murphree to investigate the application of nuclear propulsion to an ICBM. As a result of this committee's deliberations, the Atomic Energy Commission received a letter from the Department of Defense which modified the original requirement and took the sense of urgency off of it and asked that we demonstrate the feasibility of a nuclear reactor for many applications—satellites, space, etc., but—

Senator ANDERSON. You mentioned a committee. We might just as well get the names. That is the Loper committee, is it not?

Colonel ARMSTRONG. That is the committee which was chairmanned by General Loper. It was appointed by Dr. Murphree.

Representative VAN ZANDT. Who was on the committee?

Colonel ARMSTRONG. General Loper was the chairman. There was General Keirn, Admiral Sides, who was Murphree's deputy, Dr. Donovan from Ramo Wooldridge.

Senator ANDERSON. There was J. B. MacCauley, special assistant to the Assistant Secretary of Defense, Dr. Clark Goodman, assistant director for technical operations, General Luedecke, chief of the Armed Forces special weapons project, General Stranathan, director of development planning, Dr. York of Livermore, and Dr. Stewart of California Institute of Technology.

Colonel ARMSTRONG. In view of this new requirement, which was established, we have taken as our objectives the development of a reactor for demonstration of technical feasibility by ground operation of an experimental nuclear rocket engine by 1962. The date of 1962 is one which we have targeted for ourselves in the AEC.

The longer range objective is the concurrent continuous conduct of research and development aimed at more effective means beyond the first stages of how we might do this thing of applying a nuclear engine to rocket vehicle propulsion. In other words, we don't feel that the first reactor or the first nuclear rocket engine which we might be successful with is necessarily the last one. There are lots more exotic ideas that we could go to and make this better and better as we did in the bomb business to make it better and better.

Representative VAN ZANDT. At this point I would like to go back to the statement you made where you said that urgency had been removed. Did you mean urgency had been removed as far as the nuclear ramjet—

Senator ANDERSON. Oh, no.

Colonel ARMSTRONG. The rocket only.

Representative VAN ZANDT. As a result of the removal of urgency from this particular or specific project, you became involved in a much broader field. Is that right?

Colonel ARMSTRONG. No, sir. I would say that when I say the urgency had been removed I would say that our original requirement asked that we establish the feasibility of this by 1959, looking toward a flight in [deleted]. The second letter of requirement did not ask that we look toward a flight at any date nor did the requirement state they wanted feasibility proven by any particular date. They asked us to continue at a moderate—modest level, I believe, is the wording to prove the feasibility of this.

Senator ANDERSON. All right, Colonel. I hadn't expected to get into that quite as quickly, but did the Loper report say, "a program be

instituted promptly within the AEC to determine the following * * *, and was that not changed by the secretariat to say, "a modest effort be instituted."?

Colonel ARMSTRONG. The wording of the Loper report does say, "promptly," as I recall.

Senator ANDERSON. And it also says, "by 1960 to demonstrate." I had better read that paragraph rather than to pick out a line from it.

"The nuclear rocket engine is probably feasible, but since it is the stated objective of the AEC Rover program to demonstrate the technical feasibility of a practical nuclear rocket by 1960 no positive statement of nuclear rocket engine feasibility can be made for several years. Assuming success in proving feasibility, flyable engines could be developed by about 1965." This is 1965, but there was a date of 1960 mentioned in the Loper report.

Colonel ARMSTRONG. General, you don't mind us calling it the Loper report. I know of no other way to designate it.

General LOPER. No.

Colonel ARMSTRONG. I think in all honesty I ought to define the difference between 1959 and 1962. I think that the slowdown that we did meet as a result of the change in requirement probably cost us a year in feasibility and we did say to the Department of Defense from the Atomic Energy Commission that we had now slipped a year in this feasibility. Even though—if we were told to go ahead we had slipped a year at this time.

Representative VAN ZANDT. At this point, can you tell us why the urgency was removed?

Colonel ARMSTRONG. I will answer the question, but then I think you ought to call on somebody else who operated at these levels above me.

Representative VAN ZANDT. How about General Loper?

Colonel ARMSTRONG. If I may answer part of the question, then I would be happy to turn it to General Loper.

I think we had a study to determine the usefulness of nuclear energy for a rocket before anything was really known about a nuclear rocket. I think when you took all of the uncertainties—the engineering uncertainties in any large rocket and you involve all of these engineering uncertainties with nuclear uncertainties, I think it gets very difficult to make a decision.

Representative VAN ZANDT. Are you saying you lacked information in the preliminary effort?

Colonel ARMSTRONG. I think we knew very little about it at that time.

Representative VAN ZANDT. And you had to make first the basic study before you could move out into a broader field?

Colonel ARMSTRONG. I think to determine the application of nuclear propulsion to the ICBM at that time was a very difficult thing to do with the knowledge that we had. I think that is a fair statement.

Senator ANDERSON. Would it not be fair to say the Loper report in paragraph 18, reads:

The potential military value of a nuclear reactor with the characteristics of high power density and high specific impulse to an advanced ICBM are such as to warrant a prompt effort to demonstrate the technical feasibility of such a reactor.

When Secretary Wilson sent that on to Mr. Strauss he said:

Careful study of the report and its conclusions and recommendations leads me to the conclusion that the dates suggested for the demonstration of reactor feasibility and flight tests are not realistic.

Then he went on to say:

At my specific request can the AEC continue on a moderate scale to develop a reactor suitable for nuclear propulsion of missiles, satellites, and the like.

In effect the Secretary of Defense sort of overruled the recommendations of the Loper Committee.

I am not asking you to express your judgment on that. I had better advance that as my own opinion. It did change at least from a prompt decision to a modest scale.

Colonel ARMSTRONG. As I read it, yes.

Senator ANDERSON. And that is what you have been working on in the AEC since. I am merely trying to establish that the AEC has done exactly what it was requested to do.

Representative VAN ZANDT. Mr. Chairman, this slowdown you mentioned did not apply to necessary basic research, or did it?

Colonel ARMSTRONG. Yes, sir, it did. Let me finish about these differences in the 3 years between 1959 and 1962 I think the slowdown cost us a year. I think the availability of construction funds and the reduction of effort to one laboratory probably cost us a year. I think there was year there that never existed. I think that we were a little over-optimistic that we could do this by 1959, so I think one of these 3 years never really existed.

Representative VAN ZANDT. In other words the year we lost would not have produced any valuable information. Is that right?

Colonel ARMSTRONG. No, sir.

Representative VAN ZANDT. You said, "never existed." Aren't you wiping that out?

Colonel ARMSTRONG. What I meant when I said we thought we could demonstrate feasibility by 1959 is that we should have said early 1960. I think we underestimated how big a job we had on our hands.

Senator ANDERSON. You lost a year and you lost a laboratory.

Colonel ARMSTRONG. Yes. If I may go back now and take a look at our funding situation, you will remember I mentioned in 1956 we essentially had the effort going on at both laboratories out of research funds and that there was no recognized project as such. I then mentioned that we got a requirement from the Department of Defense and we funded accordingly. We requested \$17.3 million in operating funds for 1957. The Presidential budget contained that same amount and the Congress appropriated that amount. We also asked for \$25 million of construction funds. The Presidential budget and the appropriation was \$25 million.

Senator ANDERSON. I am sorry. Was it Presidential budget?

Colonel ARMSTRONG. The Presidential budget, as I recall, was amended to add \$9.2 million to it and I believe you gentlemen in May got us those additional funds into the 1957 budget.

Senator ANDERSON. Your figure would indicate the Presidential budget was \$16 million and that is my recollection of what the budget was. The AEC felt it couldn't live with that and asked if they could have a special meeting with the joint committee. A special meeting

with the joint committee was granted and the joint committee promptly said it would get them the \$9 million if it could and it got them the \$9 million. I believe that is correct.

Representative VAN ZANDT. In the closing minutes of the Congress, I remember.

Senator ANDERSON. And we had a very united committee.

Colonel ARMSTRONG. I believe you are correct. My use of the words was probably unfortunate. At that same time we were going through a review and the 1958 budget was coming to the force and the AEC requested \$30 million in operating funds for 1958, and \$20 million construction funds. At this time in view of the reduced requirement we had, the funds were reduced and a decision was made to go to a single laboratory approach.

Going to a single laboratory approach, obviously we did not need \$17.3 million of operating money and we actually spent in the fiscal year of 1957 \$8.4 million. At the same time the construction funds were reduced to \$15 million and the 1958 proposed budget came forward to Congress then from the President at \$9.8 million and at zero for 1958.

Representative VAN ZANDT. What is that top figure?

Colonel ARMSTRONG. This figure up here—this is \$30.2.

Representative VAN ZANDT. It looks like \$302. I am looking at it from an angle.

Colonel ARMSTRONG. It is \$30.2 million.

Senator ANDERSON. Would it not be fair to say right there for the sake of the record that this reduction was made before the Loper report came in. I don't want to take any advantage of you, colonel. General Loper was testifying before this committee and I pointed out that the original budget was \$17 million for operations and \$15 million for construction. There was a blackboard up on the wall there and on that was listed \$17 million for operation and \$15 million for construction. I asked General Loper if that was the difference between a modest scale and a prompt effort—or words to that effect—and he said, "I may say these reduced figures were presumably reached before the committee submitted its report." So it was not based on the Loper report. It was based on a decision taken before the Loper report was made public. The decisions might have been reached by the Loper committee but do not follow the publication of the Loper report or the circulation of it.

Colonel ARMSTRONG. Here I get lost in a complete morass—

Representative VAN ZANDT. We do it many times.

Senator ANDERSON. I only wanted to put in the record this point because I think it is important. My next question to General Loper was, "Then you mean to tell me this was decided upon before the study was completed?" General Loper replied, "I believe that was correct."

I won't ask you to comment. I will just let that stand in the record. This reduction was reached before the Loper committee had a chance to give its advice to the Secretary of Defense.

Go ahead.

Colonel ARMSTRONG. In fiscal 1959 we asked for \$9.8 million. The Presidential budget contains that amount and we have asked for \$5½ million of this original construction money—which was \$25 million—

leaving a net balance due us of this original \$25 million of \$4½ million.

Representative VAN ZANDT. Mr. Chairman, at this point may I ask you about the money you spent in fiscal 1957 and the money you are spending in fiscal 1958. Are you in any way, shape or form restricting your effort through the lack of money?

Colonel ARMSTRONG. Yes, sir, I think we are.

Representative VAN ZANDT. How much more money would you need?

Colonel ARMSTRONG. I think, to be very honest with you, I would be very remiss in my job if we didn't always look at how much better we could do this job, but when you are planning in somewhat of a vacuum, you don't get quite as definitive about these things as you might if you knew additional funds were forthcoming and you could specifically say what you could use those funds for. I think—and I am going to give just a roundhouse figure—please don't pin me to this figure because I would like to look at this a great deal closer—

Senator ANDERSON. We are merely asking for your recommendation.

Representative VAN ZANDT. That is right. You are the expert.

Colonel ARMSTRONG. At this time I would say a roundhouse figure of an increase in 1958—

Senator ANDERSON. In fiscal year?

Colonel ARMSTRONG. Fiscal 1958 of approximately \$6 million in operating money.

Representative VAN ZANDT. That is fiscal 1958.

Colonel ARMSTRONG. This would be tied to some construction funds and now I am again talking off the top of my head—of around \$4 million.

Senator ANDERSON. \$4 million.

Colonel ARMSTRONG. I am sorry, this is fiscal 1958. I am sorry but I get my fiscal years and calendar years all mixed up.

Senator ANDERSON. Would it be easier if you put it this way? Regardless of whether it falls in fiscal 1958 or 1958 you think for the calendar year of 1958 maybe about \$6 million might be spent in operating or are you trying to put it in fiscal years?

Colonel ARMSTRONG. I would rather put it in fiscal years.

Senator ANDERSON. Then you don't think you could use any more money between now and next year?

Colonel ARMSTRONG. I would have to know that indeed those funds were going to be available in fiscal 1959 in order to plan the orderly buildup to that figure that would be necessary in fiscal year of 1958.

Senator ANDERSON. I am not trying to put words into your mouth—

Colonel ARMSTRONG. Obviously if you are going to increase your effort in fiscal year 1959, you should have an orderly buildup to that point.

Senator ANDERSON. Suppose—and I will just take figures out of the air—this committee was going to recommend to somebody that there be an increase of \$6 million in fiscal 1959, would it be proper if we also said, "And in order to see that you can spend this money sensibly, there should be a couple of million dollars in operating funds for fiscal 1958—the few months that are left."

Colonel ARMSTRONG. I think this follows. You just don't go along at this level and jump—

Senator ANDERSON. Do you think it should be \$2 million, \$3 million, or \$4 million?

Colonel ARMSTRONG. May I do one thing in this respect, sir? May I lean a little bit on Los Alamos? They are the people who have to do this job.

Senator ANDERSON. We can always lean on Los Alamos.

Colonel ARMSTRONG. When Dr. Schreiber or Dr. Bradbury talk about their technical program and point out to you the things we feel we ought to be doing, I don't want to be in the position of saying that this is the speed they should run at—if they do not have the capability of running at that speed. May we defer that just a little bit?

Senator ANDERSON. Surely.

Colonel ARMSTRONG. I would say one other thing, and now I am getting a little bit out of my strict path. We don't buy much in time by any increased effort, but we do buy a great deal of insurance of meeting a feasibility date.

Senator ANDERSON. Would you explain? Does that mean you should test more things and make more sure?

Colonel ARMSTRONG. We would go down a great deal more paths. One other thing you should also realize is that we are talking about developing a reactor and rocket engine. Do we just do this? Do we end up in 1962, shall we say, with a feasible reactor and then make up our mind what we are going to do with it? Should we not know or should we not be planning what we are doing to do with this reactor when it proves feasible? If this is so, and if we assume for the moment that the reactor is successful, and if we assume for the moment that there is an application for it as soon as reasonably correct, then should we not also be thinking about the terms of the Air Force money down here which is being spent on the other components of the engine outside of the reactor because, after all, a reactor is no good in a rocket unless we have a pump that will pump the propellant into the reactor, unless it has a tank which will contain this propellant. I think if you are trying to buy time, this is where you buy your time—up here you buy your insurance, but down here is where you buy your time. So one can't talk solely about an increased AEC effort to try and buy time—

Representative VAN ZANDT. At this point, this \$3 million that the Air Force spent or will spend in 1958, has it retarded the development of the auxiliaries you mentioned?

Colonel ARMSTRONG. These moneys are being spent in exactly the time scale that these other things are going on in AEC.

Representative VAN ZANDT. Will the \$4 million permit activity on the part of the Air Force in developing these auxiliaries schedule?

Colonel ARMSTRONG. At this speed, yes, sir.

Representative VAN ZANDT. If we appropriated \$10 million for fiscal 1959, what would this \$4 million figure look like?

Colonel ARMSTRONG. I wish I could jerk a number out of the air. I can't sir, because you have to go back down and take a look at the kind of things that you want to do; the kinds of systems you want to develop and what your final goal is. Where are you trying to go

with this rocket? I would guess just offhand that you just about double that figure. This is not an easy question to answer because a rocket is a very complex thing.

Representative VAN ZANDT. Would you need any additional money in fiscal 1958 there to assist you in a reasonable buildup?

Colonel ARMSTRONG. Yes, sir.

Representative VAN ZANDT. You would?

Colonel ARMSTRONG. Yes, sir. I am getting into somebody else's business entirely here. I just—

Senator ANDERSON. If there is anything wrong about it, it is our fault.

Colonel ARMSTRONG. There is no sense in one partner running if the other partner is not keeping step.

(Off the record discussion.)

Colonel ARMSTRONG. I would like to point out under our present program what our development schedule is. I am not going to go too deeply into this because I know Dr. Schreiber will cover this far more competently than I will, but it points out that our first reactor Kiwi A will go to test late in this calendar year.

Senator ANDERSON. Colonel Armstrong, will you have the charts you just used and this chart duplicated so we can insert them in the record at this point. We want to make sure to insert these charts in the appropriate places in the testimony because it is sort of meaningless without them.

Colonel ARMSTRONG. Yes, sir. We have a second reactor coming up for test late in 1960.

Now down here you will see other reactors and what is known as a breadboard device. By a breadboard device we mean an engine which is not a flyable engine by any manner of means, but a reactor with its associated pumps and controls—that spread out as a laboratory device to run as a whole system in one crack. But these plans, believe me, are ethereal. Only up to this point do we have any real fix on this and again I would like to bow to Dr. Schreiber when he describes these devices to you as to what we are trying to achieve.

Senator ANDERSON. Again the record won't show what you mean by "up to this point." What I am trying to say is can you now tell us up to point (a) or point (b), whatever it may be, so the record will be meaningful to us.

Colonel ARMSTRONG. Our plans are rather firm.

Representative VAN ZANDT. Colonel, another question. Going back to the money again, if these additional amounts of money in round figures we mentioned a moment ago were made available by the Congress, what would it mean in time toward the ultimate accomplishment of having a reactor, we will say, in 1962?

Colonel ARMSTRONG. As far as having the reactor in 1962 is concerned, I don't think you can buy a day with all the millions in the world but you can insure that you will be there at that day.

Representative VAN ZANDT. Then, as I understand it, if we want to guarantee a reactor for 1962 we should appropriate this additional money?

Colonel ARMSTRONG. Those are my feelings; yes, sir.

Representative VAN ZANDT. If we do not appropriate it, then there are possibilities that we will not have a reactor?

Colonel ARMSTRONG. There are always risks when you put all your chips on one horse as we are right now in the [deleted] reactors with a secondary efforts on the [deleted] reactor. If the [deleted] reactor fails, we have just go to start all over again.

Mr. RAMEY. You can't guarantee it necessarily even if you put in a good deal of money. Isn't that true?

Dr. BRADBURY. Anything in the world—all the millions in the world will not guarantee it.

Representative VAN ZANDT. But we have a greater assurance?

Dr. BRADBURY. A greater assurance.

Senator PASTORE. I came in a little late, Colonel. These reactors have to do with the rocket?

Colonel ARMSTRONG. This is the rocket.

Senator PASTORE. Can this be used for a plane also?

Colonel ARMSTRONG. No, sir.

Senator PASTORE. If it works out?

Colonel ARMSTRONG. No, sir; this is tied pretty much to a rocket.

Senator ANDERSON. Won't the experiments be of some value to you in discussing possible subsequent types of transportation?

Colonel ARMSTRONG. I would lean over the other way possibly and I may get violent disagreement—but I would say everything you learn in building this rocket engine high temperature gas cooled reactor would certainly have application to a high temperature gas cooled civilian powerplant. I hope I am not going way off the limb.

Senator ANDERSON. We will ask the others later on, but we want to have your opinion too.

Colonel ARMSTRONG. I believe this to be so. As a matter of fact, I believe all high temperature reactor work being done in the country today is being done in the aircraft reactors branch and I think it contributes to the entire effort. If we never get a flying machine off the ground, I think we have helped the rest of the reactor program tremendously.

General KEIRN. May I make one statement here?

In answering Senator Pastore's comment as to whether this kind of a device might be used with an airplane [deleted]. This kind of a propulsion system might be applicable in this kind of a device.

Senator ANDERSON. It has very definite applications when people talk about travel between the planets and things of that nature. It appears to be sort of fanciful today, but it might not be so fanciful 10 years from now.

(General Keirn nodded affirmatively.)

Colonel ARMSTRONG. We spoke of the \$15 million worth of facility money. This is what we have done with this money. Out in Nevada we have the support facilities, the railroads, the roads and the utility about 72 percent complete. Our control point facilities are at this stage—69 percent complete. Our assembly and disassembly building—that is the big hot cell type of a building—is about 4 percent complete. The cell to test Kiwi A in and the tank farm that goes with it to furnish the propellant is about 3 percent complete.

Senator ANDERSON. Do I understand from that chart that all of those objectives which you have pointed to and designated will be finished during 1958. Is that calendar year?

Colonel ARMSTRONG. That is calendar year 1958.

Senator ANDERSON. So the chart would indicate the first group of facilities might be finished by about July or August of 1958.

Colonel ARMSTRONG. It runs out a little later than that, sir.

Senator ANDERSON. That is the last. I am talking about the first at the top.

Colonel ARMSTRONG. These first two? Yes, sir. This is the assembly, disassembly building which will probably be what? (Question addressed to Dr. Schreiber.)

Dr. SCHREIBER. It will be later than that. The hot portion of this will be appreciably later than this because of the installation of equipment, but the assembly portion which is essential to our testing operation will be done, I think, in August.

Representative VAN ZANDT. Are you on schedule?

Colonel ARMSTRONG. Yes, sir. It is tight. I think Dr. Schreiber will agree with me it is awfully tight.

In addition to this we built some facilities up at Los Alamos out of this \$15 million and I believe these facilities are essentially complete, are they not?

Dr. SCHREIBER. No. They will be finishing up this spring, however. They should be complete by midcalendar 1958.

Colonel ARMSTRONG. The additional facilities money that we have for fiscal year 1959 will go to modify this test cell that we built out of this money. It will go to building a new test cell.

Senator ANDERSON. You say we built out of this money, but it does not show on the record. It shows on the chart but the record won't show anything.

Colonel ARMSTRONG. I am sorry. The money in 1959 for construction will go to modify the test cell that we built of the 1957 construction money. In addition thereto we will build a new facility. We will do modification work on the assembly, disassembly building. We will build a new support building and we will modify our tank farm and our railroad system out there.

Senator ANDERSON. You have money in this upcoming budget for that purpose?

Colonel ARMSTRONG. Yes, sir. We do—\$5½ million.

Senator ANDERSON. Do you need any more construction money?

Colonel ARMSTRONG. If we are going to accelerate, yes, sir, we will need more.

Senator ANDERSON. Would you indicate at a later date what that might cover?

Colonel ARMSTRONG. Yes, sir.

Senator ANDERSON. A supplementary statement that will be added.

Colonel ARMSTRONG. Yes, sir.

Senator ANDERSON. Thank you.

Colonel ARMSTRONG. If you will allow me to perhaps be guilty of underrating your knowledge of these things, I would like to just for a moment go back and restate what I said about what makes a nuclear rocket go versus a chemical rocket and I would like to define for you some terms that you will hear used quite a bit here this morning and you will probably hear them this afternoon and tomorrow. So it might be wise to define these terms for you and to give you a feeling for what they mean.

I would like to define first of all "thrust." Thrust is the push that you get on the back of this rocket which causes it to fly. It is obviously

considerably more than the overall weight of the vehicle or it wouldn't go and it is usually measured in pounds. Thrust is a measure of a term known as "specific impulse." Specific impulse is a measure of thrust that is received when you burn a pound of propellant for one second.

Let me go a step further with that. [Deleted.] If you put together the ultimate chemical system that can be imagined and at the moment that is fluorine and hydrazine, you can probably get a specific impulse of about [deleted] or an increase of about 20 percent. I think you will find that practically all authorities agree that this is the ultimate you will ever receive out of a chemical system.

Representative VAN ZANDT. Are we close to it now?

Colonel ARMSTRONG. We have run some small thrust engines using fluorine and hydrazine, but they are quite small. Fluorine is a pretty nasty acting individual.

Representative VAN ZANDT. How close are we to getting the ultimate benefit out of it? The reason I ask the question is the Air Force told me recently that they could throw a satellite to one of the planets using the rocket engine of the Thor, Jupiter, plus flourine.

Colonel ARMSTRONG. I think I can define for you in just a minute how this comes about. In the nuclear system, if we achieve the temperatures we are looking for which is around—degrees the specific impulse is almost $2\frac{1}{2}$ times better than you can expect from the most exotic chemical system you can imagine.

As Dr. SCHREIBER will point out to you, another scheme they have in mind looks like we may get this temperature up even higher. If we do, some rather exotic things happen and the specific impulse climbs again.

Senator ANDERSON. Right there. Supplementing the question asked by Congressman Van Zandt, do you happen to know or would we have to ask somebody else what the specific impulse is on the present Atlas engine or the present Thor engine? Do you happen to know whether it is in the range of [deleted].

Colonel ARMSTRONG. Around [deleted] yes sir, because to all intents and purposes they are identical engines [deleted].

Senator ANDERSON. So we are dealing with a present chemical ability of about [deleted] specific impulse and we are talking about the possibility of [deleted] maximum on chemical and a possibility of (about $2\frac{1}{2}$ times this) if we get into nuclear?

Colonel ARMSTRONG. Yes sir and if some of these new schemes come out, that will go up again.

Senator PASTORE. May I ask a question at this point? This may be an unfair question, but if you know the answer I would appreciate it. Do you think the Russians have excelled us in this sphere?

Colonel ARMSTRONG. Here we get into the realm of "never-never" land. I could only say this. Some of the information that I have seen leads me to believe they are definitely working on this. I would hesitate to say they were ahead of us and I would also hesitate to say they were behind us.

Senator PASTORE. How do you think they got their satellite up—this way?

Colonel ARMSTRONG. No, sir. I don't think so. I think that is a chemical job.

Representative VAN ZANDT. Didn't they recently say that they had used chemicals?

Colonel ARMSTRONG. They did say they had a break-through on some super-chemicals—higher energy fuels. Whether they are talking about fluorine hydrazine or fluorine ammonia or what they are talking about, I don't know.

There is one other term. That is "staging." Under a chemical system if you want to go a long way and carry a heavy load, the only way that you can do it is to burn the first engine and all its propellents and then drop those off and start up your second stage and let that go on because you just can't afford to carry the deadweight of the thing that has gone before. You keep on putting on stages theoretically to the point—you can get up to 5 or 6 stages, if you wish. One of the things that is nice about the nuclear system is that you are dealing with a single stage device. This means one set of engines, tanks, etc., and starting an engine up in the air is not a simple process. So when you get into the second stage and the third stage type device, you are getting into very complicated machinery. So I think this is a factor which is in our favor.

I am going to say something now—and believe me, there are not a great number of people who think the way I do on this particular item and I could be real wrong—but I would like to point out to you some things which might be feasible in a nuclear rocket. Let me go back this way. Everything that has ever flown has been power limited. You start out with an engine. You have to build the airframe around it. You want to carry a payload and you want to carry it a certain distance. Inevitably you end up with a compromise of all these things. You must sometimes trade off payload for fuel or for airframe weight or you must trade off the range for payload. But everything is inevitably a compromise.

Let's take the Atlas system for a moment and, believe me, nothing I say should ever be construed that I am being critical. I don't mean to be that way at all. I am just trying to point out the things we might be able to do. Atlas was not possible or wasn't even desirable until you were able to get a [deleted] warhead in a reasonable small weight. You have an engine which is capable of [deleted] pounds of thrust. Somewhere in between the weight of the payload that you must carry to make this a desirable system and the capability of the engine, there is thrust left over. This thrust is going to be used to carry the weight of the machinery which connects the nose cone to the engine.

Obviously when you are power limited you must be very, very ingenious as to how you connect these things together and save weight. So I have gone out to the airframe people and said to them—and here they get a real look of bewilderment on their faces, "Gentlemen, if you could achieve a certain accuracy, and this accuracy is a tight accuracy, and you had a nose cone that you knew was going to weigh this much and this is exactly what you wanted to do, how would you design a rocket if you knew in advance that you had an engine that would carry it? Would the rocket look the same as it looks when you know starting out that your power is limited?" The answer is, "Oh yes, it would look the same, but we would just put on more payload." So I say, "Look fellows, back up and take my premise as I

put it to you." Then they begin to start thinking and they begin to come out with some rather interesting ideas.

Now, some of these ideas are these: For instance, you have always had a problem in an ICBM with building a heat sink which would keep this nose cone and bomb from burning up when you come back into the atmosphere. If weight was of no consequence to you, perhaps the heat sink problem would become a great deal smaller. If you want to get the target real close, so you don't miss it by 2 to 5 miles and you want to hit the target maybe with a half a mile error—maybe you won't have a ballistic missile any longer. Maybe what you would do would be to put a small trim engine up here in this nose cone and you would correct the errors that have been introduced into the trajectory so you would now have a guided ballistic missile all the way to the target. But this costs weight and it is the kind of weight a chemical system cannot afford.

Tanks today on a ballistic missile are necessarily very thin and they must be pressurized in order that it has the rigidity to hold the whole vehicle together in flight. This is an expensive process. Supposing you could go out to a boiler manufacturer and, say, "Roll me out a quarter of an inch stainless steel sheet and this is what I will use for my tank." Now it isn't quite so expensive and it isn't quite so tricky. There is redundancy in components in the bomb business. You have redundancy in every bomb because you want to have very great reliability. You want something above [deleted] percent reliability. Should not the carrier be as reliable as the bomb? Perhaps if you could afford the weight of redundancy in components so that if one of them failed, it wouldn't really matter because another would pick up the job, maybe this is a way to bring reliability. So I have asked people to take a look at building a rocket under these kinds of rules.

Immediately the rocket gets too big to be moved by chemical means, but if we are successful in building a nuclear system it is not too big. So maybe you can buy a better rocket, a cheaper rocket and a more reliable rocket if you have an engine to which weight doesn't particularly matter.

In this respect we are fortunate in that we get a much higher specific impulse but if the thing weighed twice as much to begin with, we wouldn't have gained anything but the fortunate thing about this nuclear rocket is that it only weighs less than a chemical rocket to start with. So you have gained two ways. You have more thrust and less intrinsic weight so you can afford to be weight wasteful.

Senator PASTORE. Why is that so? Why is it lighter?

Colonel ARMSTRONG. You have 1 stage, 1 tank, 1 pump and in a 2-stage chemical device you have 4 tanks, 4 pumps, 2 combustion chambers, 2 nozzles and you have all the intricate machinery which is required to couple all of these stages together. It is just intrinsically wasteful.

Senator PASTORE. One stage gives you a better opportunity of redundancy too?

Colonel ARMSTRONG. Yes, sir.

Representative VAN ZANDT. [Deleted] It is the Atlas missile that you are referring to when you make the comparison?

Colonel ARMSTRONG. The Atlas is a stage and one-half.

Representative VAN ZANDT. The missile you are referring to when you make the comparison as to the size? Is it the Atlas?

Colonel ARMSTRONG. No, sir. Let me correct that impression. I don't think we would ever use a nuclear device for an Atlas type mission. I think the Atlas missile fills the bill very well [deleted].

* * * * *

Colonel ARMSTRONG. [Deleted.] I don't think you would ever use a nuclear system. This is too small a job for a nuclear system. It would be better off as a chemical system. But if you want 20,000 pounds out on the end of this nose, then it begins to look like nuclear is the way to do it and for anything above that, there is no question about it.

These are some of the dreams that I have for this type of a system and these are some of the reasons why I still feel that the nuclear system has an application to a super ICBM and is not solely a vehicle for space.

Senator PASTORE. What about optimism? Do you think you will accomplish it?

Colonel ARMSTRONG. Nobody has told me anything yet that leads me to believe I am not right on this. Maybe I am stubborn. I don't know, but nobody has convinced me I am wrong.

Senator PASTORE. Then that answers my question about optimism.

Senator ANDERSON. You will have a little better idea about this next August when they make that first test.

Colonel ARMSTRONG. It is later than August, sir. It is probably November.

Dr. SCHREIBER. The end of the year.

Colonel ARMSTRONG. I have put on here 3 kinds of ways that you could take and put a 100,000-pound nose cone on an ICBM and fling it 8,500 miles away or conversely this identical vehicle will put a 100,000-pound satellite 200 miles away in orbit. I have picked this figure of 100,000 pounds because this is a great big man-sized satellite—really up there doing something. Maybe it has got a man in it. You can extrapolate downward if you wish.

Representative VAN ZANDT. You are going to give them living quarters too?

Colonel ARMSTRONG. Yes, sir. In other words I am thinking in terms here of a satellite that can do something for you.

Senator ANDERSON. Is that 100,000 pounds of payload comparable to the discussions we had about the Russian satellite which weighed 1,180 pounds, but only had 200 pounds of scientific payload in it or is it comparable to 1,180 pounds total?

Colonel ARMSTRONG. This is total weight. The amount of things which would be inside of this satellite which would, say, take pictures or take intelligence and transmit that back and support a living being or more are part of this overall weight. This is a 100,000-pound object in the sky—200 nautical miles out in orbit.

We had lots of arguments over the last year of the relative merits of the nuclear system versus the chemical system for the ICBM.

Senator ANDERSON. You are talking about a mission to the moon. Somebody was talking the other day about a rocket that would go to the moon and the next observation was a rocket that would go in the area of the moon, circle it and come back. Is there any difference

between rockets that would just go and hit the moon and a rocket that would go out and circle the moon and come back?

Colonel ARMSTRONG. For this kind of thinking in getting comparisons of systems, it makes no difference really.

Senator ANDERSON. It is just as hard to put a rocket up to the moon as it is to put one that will go up and come back?

Colonel ARMSTRONG. No, it is harder to put one up that can go and come back, but it depends on what you want to use this 100,000 pounds for. If you want to put it on going and coming back—

Senator ANDERSON. I don't mean the 100,000 pounds of payload. There was a statement about putting a rocket on the moon and one of the services, it seems to me, said it could fire a rocket that would hit the moon—

Representative VAN ZANDT. The Air Force using three rocket engines.

Senator ANDERSON. Are they talking about a heavy payload or a light payload?

Colonel ARMSTRONG. They are talking about a small payload, a very small payload.

Senator ANDERSON. A minute ago you said that for a warhead that had a capability of [deleted] which weighs about [deleted] pounds as far as the device is concerned, and I think had this [deleted] pounds in the nose cone, and so forth, that you can do that with a chemical engine. Can you shoot a rocket to the moon with a chemical engine on your theories?

Colonel ARMSTRONG. It depends on what you want to do when you get there. If you want to make a big splash of something on the moon, let's say [deleted] so that you could see it, I guess maybe you could do this.

Senator ANDERSON. But if you want to have a person go—a manned vehicle, you are going to have to look for some other type of propellant than a chemical device?

Colonel ARMSTRONG. That is when you are getting into this kind of a payload system.

Mr. RAMEY. How long does your rocket run in terms of minutes?

Colonel ARMSTRONG. If you were going to put 100,000 pounds into a 200 nautical mile orbit, it would run 300 seconds—400 seconds.

Mr. RAMEY. 15 minutes.

Colonel ARMSTRONG. Yes. Lots of people argued with us last year and honestly, I think, as to whether you should do an ICBM mission chemically or nuclearly. Most of those same people today give me no argument whatsoever when I am talking about big payloads in orbit or big payloads to the moon. They say nuclear is the only way you can do it—the only way you can reasonably do it.

So with a lot of these questions, as you get bigger payloads and go further distances, nuclear is the answer. There is no question about it.

Representative VAN ZANDT. You said "reasonably," but you still can get a rocket to the moon using chemical?

Colonel ARMSTRONG. Yes, sir. There is no question about it. You can. You might end up with Queen Mary sitting on its stern, but—

Representative VAN ZANDT. I have been told that they could use the three-rocket engines we are using today on the Thor and Jupiter plus fluorine and they can get a satellite to the moon or have it circle Mars and come back to earth.

Colonel ARMSTRONG. But what has it done in the process?

Representative VAN ZANDT. That is right.

Colonel ARMSTRONG. Is this a baseball that went up there or is it something meaningful.

Representative VAN ZANDT. I think it was designed to meet the competition of Sputnik I and II, nothing more.

Colonel ARMSTRONG. And that weighed quite a bit.

That is what I have to say about these comparative studies. For the technical program that is going on and the questions about what Los Alamos is capable of doing for additional moneys, I would like to turn that over now to Dr. Bradbury and Dr. Schreiber.

Senator ANDERSON. Thank you very much.

Dr. Bradbury.

Dr. BRADBURY. I think in view of the passage of time I will defer any remarks I might have and ask Dr. Schreiber to describe the technical program.

Senator ANDERSON. I should warn the members of this committee that this is not going to be a short morning session. We are going to get this information and it does take time.

STATEMENT OF DR. RAEMER SCHREIBER, CHIEF OF SECTION, ROVER PROJECT, LOS ALAMOS LABORATORY

Dr. SCHREIBER. Senator Anderson and gentlemen: I think it was just about a year ago that I reported here on some of this so this is a bit in the nature of a progress report. I also want to add some discussion of the work on the [deleted] reactors which at that time was only a dream in our eye.

My discussion is not going to have to do with missions as Colonel Armstrong has been through that fairly thoroughly. Furthermore our efforts have not been on mission studies, I would say, for two reasons. One is we feel it is rather self-evident that nuclear energy is required for work on rockets of high payloads and long range missions. The other is that the system study field is pretty crowded and highly competitive and we find ourselves less crowded if we go at the hard work of actually finding out whether these things will work or not. So this is what I am going to talk about mostly.

I want to talk about three phases of our program. The first is the work on the [deleted] reactor which has been advanced the most of the three. The second is on the [deleted] reactor system. Then I would like to say few words about our advanced concepts, which I understand is the same topic as this afternoon's session, but I would like to approach it somewhat from the standpoint of the basic work which we are actually incorporating in our Rover program at Los Alamos.

The device which has already been defined as Kiwi A is shown here. It is a test reactor which we are expecting to put on a test stand this fall [deleted] out in Nevada. It is our first step at the high temperature moderately high power density rocket propulsion device, although I must make sure that you understand this is not expected to fly. This is a test device for our own education, if you like, in order to get us the first information on an integral system which has some of the characteristics which we are looking for in actual propulsion engines.

(Classified discussion.)

Senator PASTORE. How much will the whole machine weigh?

Dr. SCHREIBER. This whole thing weighs about 10,000 or 12,000 pounds. We have made no attempt to minimize the weight of this system, but I might interpolate that in this same volume—I don't think I have indicated the scale here—the diameter of this is about [deleted] feet. It is almost a circular arrangement here. By the time one puts all of this on down here, it is quite a sizable beast.

In this same volume one can package about [deleted] times this power. For our purpose we can't stand that because in order to get the temperatures we want, we must have enough—control the propellant flow so that we get the temperature we want here in this and the power related—operating time related to the amount of propellant which is needed to conduct the test.

We are planning this for use with a gaseous propellant and we will start out with helium and will convert this over to hydrogen later in the operation. But it will be gas stored in high pressure bottles and these limitations of the size of tank farm that we feel we can afford and that we can get in time dictates that we must not go above [deleted] for the first test.

This is quite adequate for our test purposes. As I said the relationship between this and a flyable device is pretty tenuous.

(Classified discussion.)

Dr. SCHREIBER. I think I will simply say that the plans for this were started about a year ago and at the present time all portions of it are in various stages of fabrication. We plan to have out initial assemblies starting about in April and will be ready to move this out to Nevada—having gone through the mechanical assembly, a final check for reactivity and other preliminary steps by midsummer. We will start tests then in this stand running it cold first to determine critically—effect of control rods which are in the center here and so on. Our schedule gets slightly fuzzy from there on because we are learning on this and we are prepared to stay up for as much as 6 months if necessary to carry this through up to a hot gas operation.

Senator PASTORE. What do you expect to prove at Nevada?

Dr. SCHREIBER. In the first place we will learn about the controllability of this device—what we call the start-up problem—how does one get this from a cold gas flowing condition up to a white hot heat—a hot gas being emitted from here without losing control of it, and then going into the details and learning how the effects of changing temperature operates on this reactor.

[Deleted.]

Senator PASTORE. How about the problem of contamination?

Dr. SCHREIBER. In the first place this thing is going to be fired actually inverted from the position shown here. There will be fission fragments coming out of the fuel elements. Local experiments have demonstrated indeed that the fission products, particularly gaseous ones, will migrate out of the fuel elements and will go into the air. For local contamination we are having to work under meteorological control in the same fashion that bomb tests are conducted and we have picked out a site to put a lot of wasteland between us and anyone that can be bothered by this.

Total yield from our operation here is of the order of a small fraction of a kiloton and so since we are used to talking in terms—talking in terms of contamination—contamination created by bomb bursts, we have used that as a reference point and we feel we are not particularly concerned about fall-out contamination bothering us locally and we don't feel there is any problem at all about long range fall-out of strontium 90 and that sort of thing because the total yield is trivial compared with even our very small bomb tests, but there is of course a chance. These are the things we will learn.

We can have this thing fail on our test stand. In that case—

Dr. BRADBURY. Fall apart, not explode.

Dr. SCHREIBER. That's right. Fall apart. The nuclear fuel would come spewing out of the nozzle here—that sort of thing. This could happen to us and we have looked at this problem and feel that the worst that could happen to us is to lose the test stand itself. We can have that sort of trouble. As far as public hazard is concerned, I think this is a very trivial problem.

Senator PASTORE. I was thinking in terms of contamination when this becomes a practical instrument whereby you can shoot it out. How about the local problem then?

Dr. SCHREIBER. I think it is perfectly true that one will have to put this on a launching pad which you do not expect to use again for several months. I think, however, these can be located on centers that are not perhaps more than half a mile apart, but you do have a problem of remote firing and of having a local contamination at the time of launching. When we get through perhaps we aren't spewing out fission products, perhaps we are containing same. At the same time just neutron dosage will activate steel, ground, concrete and so there is a decaying time involved.

Representative VAN ZANDT. When the engine reaches the stratosphere of course it burns up and the warhead keeps on its way, then what about contamination?

Dr. SCHREIBER. When the propellant quits in the flying device this thing will burn itself up from self-heat. If it isn't completely consumed by that, when it hits the atmosphere, it will act like a meteorite and disperse itself there. This is true unless this device gets into space which is an easy way of solving your problem. If you are talking about a satellite or about an earth mission, then it is true you will have this contamination added to the atmosphere, but again even for one of these larger devices such as Colonel Armstrong talks about, you are talking about never more than 5 kilotons of equivalent fission yield which again is a trivial amount compared with everything that goes on in weapons testing.

(Deleted.)

Senator GORE. Will this be large enough to create a critical mass?

Dr. SCHREIBER. We use [deleted] in the smallest geometry that we think will be critical [deleted].

Senator GORE. How will you control the rate of fission?

Dr. SCHREIBER. We will use control rods [deleted].

Senator GORE. They, of necessity, would be automatic in operation, would they not?

Dr. SCHREIBER. This, we will have to find out. Ideally of course what you would like to have is a negative temperature coefficient on

these so they would heat up to a certain temperature and level off. This is awfully hard to predict, however, and we will no doubt have to manipulate these control rods in order to bring this up to power.

(Classified discussion.)

Senator ANDERSON. May I stop you there for just a moment? Colonel Armstrong said—and I am not trying to quote him verbatim—but as best as I can remember that if the [deleted] reactor should fail in some way and all of it go out of the exhaust, you had to go very quickly to a second bet. Would this be it?

Dr. SCHREIBER. This is the second bet.

Senator ANDERSON. He also suggested a moment ago that we might be pushing 2 bets instead of 1. Is this a place where you could use some additional money?

Dr. SCHREIBER. We actually have made the determination—as far as we can make determinations—that our technical program should push these two in parallel.

Senator ANDERSON. Do you have money to push them both?

Dr. SCHREIBER. We could use some money.

Representative VAN ZANDT. You could use some more money.

Senator ANDERSON. That is what we are trying to get.

Senator PASTORE. How about facilities? Do you have the facilities out there to do this?

Dr. SCHREIBER. I think we have generally speaking. The development of these [deleted] fuel elements requires quite extensive work in high temperature chemistry. We generally have the space to do this and we have some of the equipment we would need and are starting to buy the additional equipment [deleted].

It is equipment of this sort that we need and which is included in any thinking we have about getting this work onto a basis so we can put a reactor of this sort out in Nevada, say, in late 1960 or early 1961.

Senator PASTORE. Do you entertain the same optimism as Jack Armstrong with respect to the feasibility of this operation?

Dr. SCHREIBER. This [deleted] system?

Senator PASTORE. I mean this whole contraption.

Dr. SCHREIBER. I think so.

Senator PASTORE. The trouble here is that sometimes a suggestion is made. It gets on the record and then it just dies a natural death. Is Los Alamos going to ask for money to do that work you have just been talking about? You said, "We could use more money," but that is a rather nebulous expression. Is an attempt going to be made to get more money to pursue this?

Colonel ARMSTRONG. We have got to get together with Los Alamos. We are in a whole new atmosphere now than we were 6 months ago and in this new atmosphere and in the feeling of urgency we have, we have to get together with Los Alamos and sit down and figure out where we can use money and how much. We are going to do that. When we do that we are going forward to the Commission and tell them these are the things we need to get on with this job.

My meetings with certain of the Commissioners have indicated to me they are extremely sympathetic to this approach.

Senator DWORSHAK. What is responsible for this new atmosphere?

Colonel ARMSTRONG. Six months ago, sir, when I talked about satellites people looked for a man with a white coat to come and get me. Today if you don't know about satellites, you are stupid.

Senator DWORSHAK. Then if sputnik hadn't come along, would you people have continued to go along for years and years on your previous program?

Colonel ARMSTRONG. We might have, but I would not have been happy with it.

Senator ANDERSON. Mr. Davis, how long does it take to get money on this sort of a basis? Here are people who are going to need money in fiscal 1959, and could use some in the rest of fiscal 1958. Colonel Armstrong is going to talk to somebody. Whom does he talk to?

Dr. DAVIS. He would talk to me first and already has.

Senator ANDERSON. He has. Have you passed his recommendation on to anybody?

Dr. DAVIS. Our problem here is first of all to find out what we are going to have in 1959. I think we are all agreed that unless the budget is going to increase in 1959 that you don't need any more money in 1958. If it is decided that the budget level would be higher in 1959, then I think we probably can find funds to provide the additional requirements in 1958.

Senator ANDERSON. There was 1 time when you needed \$9 million more and, as Congressman Van Zandt remarked, you got it almost instantly by coming to this committee and saying, "We have to have more money for construction in this phase of our program." You didn't get a chance to spend it because the Bureau of the Budget froze it, but you didn't have any trouble with the committee and the Congress.

If you are going to need more money—and I think Mr. Van Zandt, as we all are, is somewhat impressed with the desirability of having a few more million dollars in this—when do you plan to ask for it? How do you plan to ask for it? Have you had any trouble thus far in getting in shape where you could ask for it?

Mr. DAVIS. As Colonel Armstrong has pointed out, he does not yet have himself the detailed figures. I was out to Los Alamos last week and Mr. Roddis had also been out to Los Alamos, so we are both up to date on this. When we get the figures from the Aircraft Reactors Branch, we will then be in a position to proceed.

Representative VAN ZANDT. Mr. Chairman, I think we will have the supplemental appropriation on the floor of the House today and one of the arguments that will be advanced in support of this supplemental appropriation for the Defense Establishment is that we are going to save from 9 to 12 months. If we permit this request of Colonel Armstrong's to infiltrate from one agency to another, it is going to be next year. I think the quicker we get accurate figures the better.

Senator ANDERSON. I would want to supplement that by saying that I know if Mr. Van Zandt, who is the ranking Republican member of the committee in the House, and Mr. Durham and Mr. Price, who are the ranking Democrat members, would join in an effort to try to get some money, I believe the House of Representatives would just follow them without a question. I think it is extremely important this thing be done. It is going to be a long, long time going through channels to get this up here. That is going to have to go to the Bureau of the Budget and so on. I would certainly like to see this

progress. If it means that you are going to have a significant demonstration toward nuclear power, we ought to be moving in that direction.

Mr. TAMMARO. I would like to add that we have some figures right now which we are reviewing. They may be horseback estimates maybe, but we do have these figures.

Senator ANDERSON. What figures are you reviewing?

Mr. TAMMARO. The additional figure—

Representative VAN ZANDT. Could you give those figures to me? I would like to offer an amendment to the supplemental appropriation this afternoon.

Mr. TAMMARO. I haven't had a chance to show them to General Fields. We are putting them together right now. They came in by telegram recently.

Senator GORE. I concur with Congressman Van Zandt's statement and that of Senator Anderson. If you cannot get them in time for House action, then try to get them in time for Senate action on this supplemental appropriation.

Mr. TAMMARO. When is that, sir?

Senator ANDERSON. I think if Congressman Van Zandt stood up in the House this afternoon and tried to add \$6 million for 1959 or some commitment of that general nature or anticipated that and stated he—in addition—he wanted to give a supplemental for 1958 of \$1 million and freed the construction funds that have already been voted but held down, I don't see that it would hurt anything in your planning.

I think if he said frankly on the floor of the House that he hoped there would be an increase in fiscal 1959 budget of \$6 to \$10 million that he would be expressing the wishes of the majority of the members, at least of the committee.

We had some testimony here in January of last year—that is a year ago now. We had General Loper here and he is here this morning. I said that I had understood General Loper wasn't called in when the Secretary of Defense discussed this reduction of expenditures and he was chairman of the committee. He said, "Yes, sir." I said, "They didn't even ask the chairman to come in?" He replied, "No." I think that is too bad. These are the people whom we depend upon to move this thing along—Los Alamos, Livermore with their Pluto project, Colonel Armstrong in the Commission.

I tried to say a minute ago that I thought the AEC had carried out exactly what its instructions were from the Secretary of Defense. I regret those instructions. I think they should have gone ahead at a prompt pace instead of a modest effort.

Now here is Mr. Van Zandt suggesting that maybe we ought to give a little stimulus and he couldn't have pleased me more than to say that because I think it ought to have it, both for the needs of Pluto and Rover.

(Classified discussion.)

Senator ANDERSON. One of the reasons the Joint Committee on Atomic Energy was set up was so that confidential and secret restricted data didn't have to be carried to the Appropriations Committee and the floor of the House, but that this committee could stand as guarantors that certain things were needed and certain moves ought to be made. This is a perfect example of, I think, where the joint committee can take restricted and confidential and secret information and

translate it into action merely on the strength of assurance they would give the House.

Senator PASTORE. Would the Senator yield on that point?

Are there any funds that are frozen at the present moment that could be employed for this purpose?

Senator ANDERSON. Construction, yes.

Senator PASTORE. Within the authorization?

Colonel ARMSTRONG. Not on my project.

Senator ANDERSON. Can we divide that into operating and construction? You were given \$25 million for construction. You have never been allowed to use more than \$15 million, but the authorization is in for \$25 million. Is that correct?

So you would only have to have a little money there if you wanted it for construction?

Dr. SCHREIBER. I don't know if I am speaking out of turn here but we have not asked for that additional money to be released because we are trying to balance the operating and the construction. As far as I know we are not in trouble on construction money or, at least, it would be unfair to say that we are because we haven't asked for it.

Senator ANDERSON. I was only trying to answer Senator Pastore's question as to whether some funds are frozen; \$10 million are frozen. You are going to ask for \$4½ or \$5 million this year. I am not trying to suggest any extraordinary procedures. I am merely saying if Congressman Van Zandt got up and made a proposal to add a little operating money, it would not disappoint me. At least I believe they ought to have a little more operational money in fiscal 1958. After all an appropriation bill went through the other day for \$500 million or so in a very few minutes. But when the Atomic Energy Commission comes along and wants a tiny sum of money—relatively—then we take an awfully hard look at that. I don't think it makes too much sense because this to me is the promising end of a space ship.

Senator PASTORE. I understand from Dr. Schreiber that our problem here is not construction money but the problem here is for money for research and operations. That would have to be new money.

Colonel ARMSTRONG. I think he is a little conservative on construction. When I see these kinds of things coming down the pike, I know there is going to be more construction involved here and I am going to stick my neck out now. I am going to give my horseback estimate of what we need in 1959 to get on with this job. We need \$5 million operating money in addition to what we have asked for and we need the balance of \$4½ million which is still on the books of the \$25 million.

Senator ANDERSON. For construction which has already been authorized once.

Colonel ARMSTRONG. Yes, sir.

Senator ANDERSON. And would you stick your neck out a little bit farther and give Congressman Van Zandt some guidance as to what might still be needed for 1958?

Colonel ARMSTRONG. In 1958 I think the sums of money that we would need would not exceed—and no construction is involved here—but I don't think the laboratories have the capability of building up to this increased effort at more than a million dollars in 1958.

Representative VAN ZANDT. That is operational.

Colonel ARMSTRONG. Operating money because it takes time when you have to hire people and get off on a new project. It takes time to educate people and to get your plans and get rolling. I will say that I honestly think we are going to be delayed for the next 3 or 4 months if we go on the basis of just plain hiring and educating people.

Senator ANDERSON. That verifies what I said a minute ago.

Colonel ARMSTRONG. Again I think the \$1 million we need for 1958 can probably be found in the Commission.

Mr. TAMMARO. I think that is something we can do within the program. I think we should talk 1959—

Senator GORE. Wait a minute. Are you telling this committee that you can, within the funds available to the Commission now—

Mr. TAMMARO. What I am saying to the committee is that within the funds presently available to the Commission, I am going to try to get the additional funds needed in fiscal 1958. I think we might do it through reprogramming. The controller is not here and I can't speak for him but I think the kinds of money of which we are talking for 1958 are not large.

Senator ANDERSON. Would it harm you if Mr. Van Zandt got you an additional million? You wouldn't jump out the window of that new building.

Mr. TAMMARO. The kinds of money you are talking about for 1958 are how much?

Colonel ARMSTRONG. \$1 million—

Mr. TAMMARO. This kind of money does not disturb me. We will reprogram.

Senator PASTORE. Are you telling us, Mr. Tammaro, that it is the desire and purpose and the program of the Atomic Energy Commission to accelerate this particular program under available funds?

Mr. TAMMARO. Yes.

Representative VAN ZANDT. For fiscal 1958?

Mr. TAMMARO. Yes; for fiscal 1958.

Senator ANDERSON. Mr. Van Zandt is trying to give a little congressional direction to this.

Mr. TAMMARO. As far as 1958 is concerned, this is the kind of money I think we can program now. Remember I am not speaking for the Commission. The Commission is not here and they haven't seen these figures yet. I only received these figures the other day and I am looking them over. However, I am not concerned about 1958. I think we can find the funds.

Colonel ARMSTRONG. Dr. Bradbury just said my figure of \$5 million in operation should be \$6 million.

Senator ANDERSON. You used that \$6 million figure yourself a minute ago.

Representative VAN ZANDT. Six and four and one-half.

Colonel ARMSTRONG. Four and one-half.

Dr. DAVIS. May I just make my point again about acceleration now of 1958 money because it is true that we can probably reprogram to get the additional funds needed to speed up the program during the balance of 1958. I don't believe that the people in the program would even want to do this unless we were assured that the program level in

1959 will be higher and so until we have assurance that it is going to be higher in 1959, there is no sense in reprogramming money in 1958.

Senator PASTORE. Where do you get that assurance? Who is going to give you that assurance?

Dr. DAVIS. This would have to come from some supplementary appropriation over and above what is in our budget at the present time for 1959.

Senator PASTORE. Couldn't you ask for both? Would you have to wait for the assurance on your supplemental appropriation before you can accelerate this program now?

Dr. DAVIS. I believe, for example, that Los Alamos would be reluctant to go out and hire people unless they knew they were going to be able to keep them on the payroll in fiscal 1959.

Senator PASTORE. Yes, but if you put it in the budget now you would have the money.

Dr. DAVIS. I am not arguing where it comes from.

Senator PASTORE. That is precisely what we are trying to do. We are trying to cut out the redtape.

Senator ANDERSON. The 1958 budget is not yet passed upon by the Congress of the United States. You don't know what you are going to get. That is why we were trying to make sure your 1959 budget carried some additional funds and if Congress voted some little additional funds now in anticipation of what they were going to do in 1959, it might tie the Congress a little more tightly to it.

Senator PASTORE. I think the record ought to be straight on this. I think the problem is this. The budget already before the Congress does not include the accelerated program.

Dr. DAVIS. That is correct.

Senator PASTORE. Therefore in order to get that assurance there will have to be a supplemental to the pending budget bill. That is what you are talking about.

Dr. DAVIS. That is correct. That is right.

Senator ANDERSON. When will that get up here? Have you any idea?

Dr. DAVIS. I am sorry. I can't say, sir.

Representative VAN ZANDT. Based on our experience, I think we could anticipate it would take many months for the additional money needed to go through the routine reviews that are necessary.

As I said a moment ago, there is a supplemental appropriation on the floor this afternoon which is designed to save 9 to 12 months. [Classified deletion.]

For that reason I don't think we should wait for review. I think if we have an opportunity, as representatives of the people, to get this program on its way, let's take advantage of it.

Senator PASTORE. To me this whole problem is very simple. After all you have got to work it out according to the rules and policies of the Congress. They are subject to that. They can't afford to come here and have their ears boxed later on when they are asking for a supplemental. If they can get assurance from this committee to the effect that we will support in the supplemental appropriation bill the additional funds necessary to carry on this acceleration which you cannot regulate under existing funds, I think that is all the assurance they need.

So if, today, you made that speech on the floor that later on there is to be a supplemental bill in order to fortify this accelerated program which will now be dealt with under available funds, but which will have to be increased over the pending budget amount, I think that is the assurance they want so that they can go ahead and hire these people who wouldn't come in if they didn't know how long they are going to be kept. Isn't that your problem, Doctor?

Dr. BRADBURY. Dr. Davis has stated the problem correctly and so have you. One is unwilling to undertake an expansion program unless you see how you can carry it on. I think we need the sort of assurance we are hearing today—this sort of additional appropriation appears to be part of the budget being proposed and then we, I think, are willing to take a chance.

Senator PASTORE. That is right. And it is a clear thing that under the budget that is now before the Congress that this acceleration is not included and it will have to have the money by way of a supplemental.

Mr. TAMMARO. I would like to correct one statement. I think Mr. Van Zandt said it would take us 8 to 9 months—something like that. As I mentioned before, we can find some way of reprogramming. 1959 is another matter which has been clearly stated here. 1958 then we can do. It wouldn't be 9 months.

Senator ANDERSON. He said something quite different. He said we were trying to save 8 or 9 months in time with what is on the floor today.

Mr. TAMMARO. Okay.

Dr. BRADBURY. May I express one mild worry? I think this has been correctly stated by Colonel Armstrong earlier. If you use the word "acceleration" in this context it may be correct in the long range. It is not correct in short range. What this additional \$6 million in 1959 would do is to provide an adequate buttress and very much more insurance that the program as scheduled will come along, but it will not bring it about faster. I think it will make it much more certain.

Senator ANDERSON. If the first one fails and it would have been delayed—

Dr. BRADBURY. If the first one falls on its face, this program would have been delayed. Maybe we can accelerate in the long run, but specific dates in our target will not be earlier because of it.

Senator ANDERSON. I think that is a good warning.

Senator GORE. May I ask a question about this? Would you indicate the dimensions?

Dr. SCHREIBER. I will not pay too much attention to the outside here because we have not tried to shrink it down * * *

Senator GORE. And theoretically you calculate such a reactor could give a thrust in what amount?

Dr. SCHREIBER. This particular reactor has a power of about [deleted] with hydrogen—this is a quite modest thrust—[deleted]—pounds or so. But the expansion of this and the increase in power density will give this probably a somewhat higher—it is a higher thrust to volume ratio. I am not sure it is a higher thrust to mass ratio in a [deleted] system. But one could talk, for example, in terms of a system which is say—[deleted] in diameter producing thrusts in the neighborhood of [deleted].

Senator GORE. I wasn't here when you discussed the advantages of a nuclear system over chemical fuel, but would not one of the advantages be that a nuclear source of energy could be of far greater duration than a chemical fuel that would oxidize rather quickly.

Dr. SCHREIBER. I think the situation is that your duration of operation is limited by your supply of propellant in both cases, but if you can get the lower molecular weight or if you can get a higher temperature or higher energy content, then you get more net thrust and you get a bigger velocity out of the nuclear system and this is more or less measured by this quotation of a specific impulse. The real rigid definition of specific impulse is pounds thrust per pounds of propellant burned or exhausted. So that is a good index of performance and that is what we are talking about if one uses hydrogen in such a system one gets values like 800, possibly up to 1,000 or 1,200 compared with values like 250 up to 300 with the chemical systems.

Senator GORE. I would like to ask one question which is beyond the particular model and project in mind. Once a vehicle is beyond atmospheric pressure, and density, and friction, a rather small source of energy by the process of action and reaction could supplement either propulsion or directional control. Is that correct?

Dr. SCHREIBER. That is true.

Senator GORE. In other words your momentum is not difficult to check nor is acceleration difficult to obtain when you are without friction. Is that right?

Dr. MERKLE. No, no.

Dr. SCHREIBER. I think the situation is this. When you are in a gravitation field—

Senator GORE. I am just advised that you are going to get into that this afternoon and tomorrow and I am entirely premature.

Senator ANDERSON. I was only trying to say that we have these two projects to handle this morning and this is to come up this afternoon. If you could wait—

Dr. SCHREIBER. I will try to finish rather quickly then, Senator.

I would like to say just one more word about the [deleted] and [deleted] system. The question may come up that if the former is so good, why don't you drop the latter and if the latter is going to succeed, why worry about the former, which is sort of like it. I think the answer to this is that in the first place we would like to have two systems—1 as a back-up to the other and 2 systems with rather different problems. This is true of the [deleted] and [deleted] systems.

(Classified discussion.)

Dr. SCHREIBER. We are quite sure we can hold it in at modest temperatures, but whether one can go up to the ultimate in this, we don't know. There are flow distribution problems. In this [deleted] arrangement, the gas which comes out at the bottom of this, for example, one doesn't care what happened to the gas that came out of the top—if it turned out to be cold because too much gas is going through, you cut down on performance. If not enough goes through there you will burn out the fuel elements and you will have a failure.

These problems must be worked out quite carefully. We are not necessarily saying we know today how the details of these will be worked out so they are compatible with each other and we feel that these are the things that we should look into and evaluate rather than

to take one of these and gamble completely that everything will work out just fine.

I think finally in terms of the technical program I should say a few words about the so-called advance system and I am not going to try to tell you why these are important because I believe that is part of this afternoon's discussion.

(Deleted.)

Dr. SCHREIBER. Our work in this—I can't show you a reactor because we aren't trying to design one but we are trying to do basic laboratory calculations and other experiments which will give us a sound basis for evaluating whether one of these things are really good enough to push. We think these are really areas where in the future you would have a chance of getting extremely high performance in propulsion.

If you would like to take the time, I could quickly run through these pictures of the Nevada facilities.

Senator ANDERSON. I think not. We have a quorum call and we have to get on to the Pluto project. What do you want to do? Do you want to answer the quorum and come back?

Senator GORE. Why not come back a little earlier this afternoon. It is lunch time right now.

Representative VAN ZANDT. I would say 2 o'clock. We may have a supplemental appropriation out of the way by that time.

Senator ANDERSON. We will resume with Pluto at 2 p. m.

(Whereupon the committee recessed until 2 p. m.)

AFTERNOON SESSION (2 P. M.)

The Subcommittee on Research and Development and the Subcommittee on Military Applications resumed their joint meeting at 2 p. m. in the committee room, the Capitol, Hon. Carl T. Durham (chairman of the full committee) presiding.

Present were: Representatives Carl T. Durham (presiding), Chet Holifield, Melvin Price, James E. Van Zandt, James T. Patterson, and Craig Hosmer; Senators Clinton P. Anderson, Albert Gore, Bourke B. Hickenlooper, John W. Bricker, and Henry Dworshak.

Committee staff present: James T. Ramey, executive director, Messrs. John T. Conway, David R. Toll, and George E. Brown, Jr.

Committee consultant present: Capt. N. R. Nelson.

Representatives of the Atomic Energy Commission: Dr. W. Kenneth Davis, Director and Louis W. Roddis, Deputy Director, Reactor Development Division; Colonel Jack Armstrong, Deputy Chief, Aircraft Reactors Branch, Reactor Development Division; A. Tammaro, Assistant General Manager for Research and Industrial Production, Bryan LaPlante, Special Assistant to the General Manager (congressional) and Commander Morre, Assistant to Colonel Armstrong.

Representatives of the Department of Defense: General Austin W. Betts, Deputy Director for Guided Missiles, General H. A. Boushey, Deputy Director, Research and Development, Lt. Colonel Marvin N. Stanford and Major Richard C. Orphan, Office of the Assistant Secretary of Defense for Atomic Energy; Messrs. Paul Smith and Carl Sorgen, Office of Assistant Secretary of Defense for Research and Engineering.

Representatives of the Los Alamos Laboratory: Dr. Norris Bradbury, Director and Dr. Raemer Schreiber and Dr. Stanislaus Ulam.

Representative of the Livermore Laboratory: Dr. Theodore Merkle.

Chairman DURHAM. The committee will come to order.

This is a continuation of the briefing we were receiving on advanced atomic engines, satellites, space platforms and space ships. I believe Colonel Armstrong has started this morning but had not completed his statement. I am sorry that I was not here this morning.

STATEMENT OF COLONEL JACK L. ARMSTRONG—Resumed

Colonel Armstrong, will you continue?

Colonel ARMSTRONG. Thank you, I would like to start out the same as I did with the nuclear rocket by defining what a nuclear ramjet is and how it differs from a chemical ramjet and how a ramjet system differs again from a rocket. As you know, we are operating in the earth's atmosphere and in a ramjet it is not necessary to carry an oxidant of some kind along in order to burn the fuel that you carry along. Here you are using the earth's atmosphere as your oxidant and you are carrying only the propellant along. The air coming through the front end of this device mixes with the fuel and is ignited. The energy then which is given by the heat into the airstream is expelled through the nozzle and you get your push.

In a nuclear ramjet we substitute for the fire that is going on in the combustion chamber—a reactor. So we heat the air as it comes in the front end and passes through the reactor. We heat the air up there by imparting energy to it and thereby getting our thrust so we do not have to carry any propellant with us. This gives us the one thing, I think, which is outstanding and that is completely unlimited range.

Dr. Merkle from Livermore Laboratory will go into the technical aspects of this following me so I think you will get a better picture of how this looks.

Our objectives are to demonstrate the feasibility of the nuclear reactor as a heat source in a ramjet propulsion system and to operate an experimental nuclear ramjet engine in our Nevada test site in the same area that we are doing our work on the nuclear rocket. In this way we can combine our facilities and keep our facility cost down. We plan to do this early in [deleted.]

In order to do this, these are the funds that we have programed. As you will notice in 1956 very little money was spent on this project.

In 1957 we asked for and the Congress approved \$4 6/10 million. We actually spent a little less than the \$4 6/10. In 1958 the AEC requested \$10 million of operating money and the budget contained only \$5 million. In 1959 we asked for the same level of effort that we had put on this project in 1958. In addition in 1958 we asked for our first construction—some \$2½ million and in 1959—\$6½ million for total facility cost of \$9 million.

Now, I am going to jump the gun and answer your question before you ask it. Do we have enough money? The answer is, no sir. We do not. We feel that to have a very meaningful program and again

to have assurance of success, we need an additional \$3 million in 1959 for operating.

Chairman DURHAM. That is over and above the budget?

Colonel ARMSTRONG. That is over and above the budget.

Chairman DURHAM. Submitted to us?

Colonel ARMSTRONG. Yes, sir.

Representative VAN ZANDT. Mr. Chairman, let us go back to 1958. When did you cut back on this program?

Colonel ARMSTRONG. We cut back on this program—let me give it to you exactly. We first cut back in this program in October through December of 1956, in that we didn't get the funds that we felt we needed and then in May of 1957 the Littlewood committee reviewed this program and recommended that it be carried forth by one contractor only.

Representative VAN ZANDT. It meant you dropped the second contractor?

Colonel ARMSTRONG. Yes, sir.

Representative VAN ZANDT. In time, what does it represent?

Colonel ARMSTRONG. I am not going to try to give you a period of time because I don't think I can. I don't think I am capable of that, but I do think any time you have 2 horses in a race you stand a better chance than if you have 1 horse in the race.

Representative VAN ZANDT. Would your position here coincide with the position you took on Rover?

Colonel ARMSTRONG. You mean should Rover have money?

Representative VAN ZANDT. From the time standpoint. You said this morning that we had lost a year.

Colonel ARMSTRONG. I have no feeling really for what we may have lost or gained in time. I can only say this to you. I am sure that with more effort on the materials that we stand a greater degree of assurance in meeting this [deleted] to [deleted] date on feasibility.

Representative VAN ZANDT. Then we can simply delete the time factor and say that we have erased or eliminated from the program the assurance—or insurance factors—is that right?

Colonel ARMSTRONG. That is right.

Representative VAN ZANDT. Thank you.

Colonel ARMSTRONG. I would rather have enough funds to run a healthy program at 1 laboratory than to split those funds and run 2 efforts at 2 laboratories.

Representative VAN ZANDT. How much money would you need in 1958 and again in 1959 to reinstate the second operator or contractor, and to give us this assurance that you have talked about?

Colonel ARMSTRONG. I will answer that question in two ways. I will say that I think we need \$3 million more in 1959 in operating money.

Representative VAN ZANDT. \$3 million?

Colonel ARMSTRONG. I think we need a million more in construction.

Chairman DURHAM. In 1958?

Colonel ARMSTRONG. Backing up into 1958, then I would feel that we would have to take a close look at the speed with which we could really spend dollars in building up to that 1959 level and get something for our money. What that might be I would guess is something less than a million dollars.

Representative VAN ZANDT. Would Dr. Bradbury confirm that figure?

Dr. BRADBURY. I am sorry, but that is in Dr. Merkle's hands at Livermore.

Dr. MERKLE. The \$3 million that Colonel Armstrong has mentioned is very desirable for the Livermore effort for it to be more than bare bones. The \$1 million extra in construction for fiscal 1959 that Colonel Armstrong has mentioned is insurance on a construction program for the Nevada facilities.

Representative VAN ZANDT. What about the Air Force?

Colonel ARMSTRONG. The Air Force is running a parallel program along with the things that go beyond the reactor itself—the diffuser, the other portions of the engine which go to make a complete engine out of the reactor.

Representative VAN ZANDT. How much will they need in 1959?

Colonel ARMSTRONG. I am shirttail guessing now, sir. I would like to take a real hard look at that, but I would guess it is a couple of million dollars. I am not in a position to say this until I talk to the Air Force and we go out and talk to the Air Force contractors and say, "This is what we are going to do with the reactor. What additional should we do to get this answer in shape?"

Chairman DURHAM. Did the Air Force get what they asked for in 1958?

Colonel ARMSTRONG. So far as I know, this is a set sum, and it has been approved and is out on contract. This amount of money, of course, is still in our hands.

Senator ANDERSON. Who is the Air Force contractor on this?

Colonel ARMSTRONG. Curtiss-Wright and Marquadt Aviation—both share in the Air Force contract.

Representative VAN ZANDT. Would you say \$2 is a round figure for figure for the Air Force?

Colonel ARMSTRONG. Yes, but I sure wouldn't like to be pinned to that figure because I would like to give it some real close study, sir.

I don't want one of these programs outpacing the other or falling behind the other.

Chairman DURHAM. You don't ask for that anyhow. The Air Force does.

Colonel ARMSTRONG. The Air Force does; yes, sir.

Representative VAN ZANDT. Would you say \$2 million is the money you needed in 1958 as a supplemental?

Colonel ARMSTRONG. I said I thought that if we get this additional money in 1959 we would probably need about a million more here in 1958 to build up to that effort. I hope I am not out of the ballpark.

Dr. MERKLE. That is not a number we have considered at Livermore. I believe that our \$3 million figure in fiscal 1959 presumes the present amount of money in fiscal 1958; that is, the operating money and the larger sum that was authorized a few weeks ago.

Colonel ARMSTRONG. What Ted is saying is that perhaps they need no more money in 1958.

Dr. MERKLE. As far as Livermore is concerned, I do not believe an increase in fiscal year 1958, which has 5 months yet to run, would materially change the picture. The knowledge that \$3 million was available in fiscal 1959 would materially change the rate of hiring at the

laboratory and the rate of procurement of people able to do this job which would have to be cut back at the present level if we were to operate with the sum currently in the budget.

Chairman DURHAM. What is the construction fund plus the Presidential budget in 1958? That is the \$10 million you requested and of which you got \$5 million, and then you got \$2½ million for construction. Was the construction included in that \$5 million item?

Colonel ARMSTRONG. No, sir; this is separate and distinct.

Chairman DURHAM. Then you get \$7½ million.

Colonel ARMSTRONG. Yes.

Senator ANDERSON. And asked for \$12½ million?

Colonel ARMSTRONG. That is correct, sir.

Senator ANDERSON. If you needed that much and didn't get it, why can't you use some more this year since 5 months remain?

Colonel ARMSTRONG. You will recall—or perhaps you were not here—when I said that when we went down to these kinds of levels, we went down to one contractor. You don't turn contractors on and off like a faucet. We just could not at this time, considering the plans that we have made and everything, bring another prime contractor into the picture, and this is the other half of your question, sir; I think the other half of this question is that we would not go to another prime contractor, but we would certainly use that secondary prime contract as a subcontractor to Livermore to assist Livermore.

In fact, Livermore is already planning on spending money up here—Curtiss-Wright—to get them to help out here on the job.

Chairman DURHAM. You are not asking for as much money in 1959 as you asked for in 1958?

Colonel ARMSTRONG. That is correct.

Chairman DURHAM. Why is that?

Colonel ARMSTRONG. Once you have established a level of effort and once you have gone down to one contractor, the foreseeable spending that you can do is never as great as it was when you were back going at high speed and you had two contractors in the business.

Chairman DURHAM. You said if you had two horses you could run better than you could with one.

Colonel ARMSTRONG. I tried to go back to our original position where we had two contractors, and any time you have two contractors facing the same problem and both cranking down the line, you will always have better assurance.

Representative PRICE. Does that indicate that during fiscal 1958 you didn't run into any discovery that would encourage you to step up the program? Is that right?

Colonel ARMSTRONG. We certainly did, sir.

Representative PRICE. Did you set the \$5 million request for 1959 or did someone else?

Colonel ARMSTRONG. Somebody else set that, sir.

Representative PRICE. Who set it?

Colonel ARMSTRONG. It was not my doing. We were working under the ground rules that our programs in 1958 and 1959 would remain at the relative level they were in 1957.

Representative PRICE. Ground rules coming from where?

Colonel ARMSTRONG. I am going to turn to Dr. Davis and find out where—

Representative PRICE. Could anyone tell us where the ground rules are laid down?

Mr. DAVIS. I think they started with the general assumption that the whole budget for the Commission would be held to a particular level and this resulted in some internal decisions which, as Colonel Armstrong said, were in effect; that for most programs the 1959 budget level would be identical with the 1958 budget level.

Representative PRICE. Regardless of the apparent progress in a program wherein you could give some encouragement for earlier development, the budget requirement would remain the same?

Dr. DAVIS. Unless there was some compelling reason for changing, yes, sir.

Representative PRICE. I don't think I let you completely describe to us just how the ground rules are laid down or by whom they are laid down. Who established the ground rule for what this project would be able to ask for through fiscal 1959?

Senator ANDERSON. Who asked for \$10 million and who said it came down to \$5 million?

Dr. DAVIS. I am not sure I could even tell you all the mechanics that this goes through. Essentially what happens is that our division collecting information from the various branches who, in turn, collect the information from the contractors, arrive at a division budget which is inevitably considerably more than we are likely to get. The various division budgets then are added up to the Commission total budget which is also usually much more than they really would get since everybody, in effect, puts in as much as they think they could use.

Chairman DURHAM. Does this project come under your division?

Dr. DAVIS. This project comes under my division. Under various instructions from the Bureau of the Budget and after reviews by the Commission we were, in effect, told we should keep this program at the same level in fiscal 1959 as it was in fiscal 1958.

Representative PRICE. Told that by whom?

Dr. DAVIS. In effect, by the Commission.

Representative PRICE. In other words your division is allocated so much money for the fiscal year coming up, then you just take that and divide it up—cut up the pie and say this project can have this much and this project can have that much.

Dr. DAVIS. It goes through a series of stages obviously.

Representative PRICE. Does it go to the stage that you would get in touch with the people who are entrusted with the operation of the project to determine from them what advances they have made during the past year, what they think they would be able to accomplish next year and then ask them what they think it would take to step up their program in keeping with their achievements?

Dr. DAVIS. Yes, sir, in our preparation of the budget which starts, incidentally, I should say a very long time before the start of the fiscal year we do review the progress which has been made and we do try and foresee what the budget should be for the coming year.

In this particular instance it is true that the amount of money which we were finally able to put into this was not equal to what the laboratories thought they could do.

Representative PRICE. If you asked these people out in the field what they thought they would need and they said they would need \$5 million—

Senator ANDERSON. \$10 million.

Representative PRICE. What did they say they would need?

Dr. DAVIS. \$10 million Colonel Armstrong says in—

Representative PRICE. In 1959?

Colonel ARMSTRONG. In 1959 the request we got from Livermore was \$7,600,000.

Representative PATTERSON. There is a differential in there of \$3 million.

Colonel ARMSTRONG. \$2,600,000.

Dr. DAVIS. \$7,600,000 for Livermore and \$1 million for Atomic International.

Representative PATTERSON. Overall about \$3 million.

Senator ANDERSON. The reason Livermore came down to the \$7,600,000 was because they asked for \$10 million the year before and got cut down to \$5 million.

Colonel ARMSTRONG. Curtiss-Wright and Livermore asked for \$10 million. We were making up this budget back in here when Curtiss-Wright and Livermore were both running in this program and we asked for \$10 million. We got \$5 million.

Senator ANDERSON. So now who is running with it?

Colonel ARMSTRONG. Livermore.

Senator ANDERSON. Curtiss-Wright is out?

Colonel ARMSTRONG. Livermore came in this year and asked for \$7.6 million. We got \$5 million. Actually we got \$4 million for Livermore because there is another million being spent on materials that North American Atomics International—

Representative PRICE. You did say the success of this project was such during the last fiscal year that in the opinion of those handling it it should be stepped up. Is that right?

Colonel ARMSTRONG. I believe this completely.

Representative PATTERSON. Is money the thing you really need now in order to step up progress? You have the brains and you have the projects on which you can use this money?

Colonel ARMSTRONG. I have complete confidence in the success of this device.

Representative VAN ZANDT. Mr. Chairman, I would like to get my thinking straight on this.

As I understand it, if we were to up your \$5 million to \$8 million and your \$6.5 million to \$7.5 million and possibly \$2 million in addition to the \$4 million in USAF there that it would meet your requirement as far as dollars are concerned which would be converted into effort.

Colonel ARMSTRONG. Yes, sir.

Representative VAN ZANDT. Now comes this question and you confused me a moment ago by your answer. Do I understand you do not need any more money for fiscal 1958?

Dr. MERKLE. That is correct, sir.

Representative VAN ZANDT. To prepare for the spending of the additional amount of money we are thinking of adding to fiscal 1959.

Dr. MERKLE. That is correct because fiscal 1958 is already a larger sum than the value that was assigned to us last June. Last June we were told to operate at the \$2 million level. It prevailed at the \$2 million level until, I believe, the first part of December or possibly the latter part of November at which point we received information that the total allocation for the year would become about \$3.8 million. That left us then with plenty of money to finish the fiscal year.

Senator ANDERSON. Then you started with a \$10 million request. You were trimmed down to \$5 million in the budget and then were cut a further sum down to the \$2 million?

Colonel ARMSTRONG. Let me answer that.

Senator ANDERSON. Until after sputnik got in the air.

Colonel ARMSTRONG. That was a really bitter point with me because this did not happen in my office. It did not happen in the Commission. I don't know how the hell it happened but out in California, somehow or other the people who handle the dollars out there and the people who are doing the job got themselves thoroughly screwed up and when I found out that they had been told by the people that we had given the money to that we were running at a \$2 million level there was a bump in my ceiling. I sent a wire out immediately and said, "This is a bunch of nonsense. You have \$3½ million. Now get going."

Senator ANDERSON. I know who cut you to the \$2 million.

Dr. MERKLE. I think this becomes a little tangled.

Senator ANDERSON. They tell me that since the "Ivory Soap" man went into the Department of Defense, there isn't anything more profitable than washing dirty linen right out in the open.

Dr. MERKLE. Would you care to say when the \$3 million figure was firm in Washington? It certainly threw Wally Reynolds. He was operating the laboratory at the \$2 million figure. He was informed there was no more money to operate at the \$3 million level because the budget apportionment had not been made. I believe this was the Bureau of the Budget. I am not sure.

Colonel ARMSTRONG. After all the operating budget was not approved by Congress until some time the latter part of August. So up until that time at least we had to run it at the same rate we were running before because we didn't know what we were going to get. Now there is another angle in here.

Pluto has not been without its committees, believe me, and Pluto has as many enemies as it has friends, if not more. There was a real question on the \$2½ million worth of construction money here in getting it and I can see that confusion would enter into the minds of people out in California when they asked and asked repeatedly for the \$2½ million and didn't get it. I think rightly out there, they probably said, "Well, it looks like this program is going where Rover went a year ago. Why get steamed up about it?"

Senator ANDERSON. Wait a minute. I don't guarantee that I can see that chart, but I think I see that operating budget for 1957 was \$4 million and not \$2 million.

Colonel ARMSTRONG. That is absolutely correct.

Senator ANDERSON. What difference would it make if they were held at the same level as the previous year which is \$4½ million as against \$5 million?

Colonel ARMSTRONG. Remember we had two contractors during this period.

Senator ANDERSON. I am talking about money. It was at the \$4.6 million level. You weren't on a \$2 million level. You were at this \$4.6 million level.

Colonel ARMSTRONG. At that time, sir, we had Curtiss Wright in business.

Senator ANDERSON. When Curtiss Wright went out of business?

Colonel ARMSTRONG. But we didn't know how much phase-out costs of Curtiss Wright were going to be so we had to hold back some of that money to phase them out. In addition thereto we committed money to Curtiss Wright to continue some of the work they were doing because it was very interesting.

Senator ANDERSON. A minute ago we had it that the California group got all mixed up. Now where is it?

Colonel ARMSTRONG. They were mixed up between \$3½ million and \$2 million. They were not mixed up between \$4.6 and \$2 million. If you take \$3½ million from \$4.6 million, \$1.1 million is what we spent up at Curtiss Wright.

I was not at all happy about this confusion that existed out there between \$3½ and \$2 million and I didn't know it.

Senator ANDERSON. This morning we found out that Rover doesn't need any more money in 1958. They could find some money to patch it out. Now we find Pluto doesn't need money for 1958 because it can be speeded up so the whole thing centers on 1959, as Congressman Van Zandt pointed out. Is that right?

Colonel ARMSTRONG. I think that is correct.

I think to take a look at the military advantages of the nuclear ramjet we can take this first item and just dwell on that and nothing else. No chemical system ever known has an unlimited range. As a matter of fact chemical systems are severely limited in range because of the amount of fuel they can carry. When I say "unlimited range," obviously I am not talking about it going forever or anything of the kind, * * * only that it is relatively weight insensitive. So this means quite considerable payloads can be carried.

We have made some very careful studies as to what this might mean in the way of a military mission.

Representative HOLIFIELD. May I ask a question on the weight insensitive part? Does that mean that you have solved the problem of shielding?

Colonel ARMSTRONG. This is an unmanned vehicle. This is a missile. Our shielding problem is not very severe.

Representative HOLIFIELD. I withdraw my question.

Colonel ARMSTRONG. Not that we haven't thought in terms of manned vehicles, we have—but these start to get pretty big.

[Deleted.]

Representative VAN ZANDT. Did you see this week's issue of Life?

Colonel ARMSTRONG. No, sir, I have not.

Representative VAN ZANDT. They have about 3 pages devoted to nuclear powered aircraft, rockets and ramjets in colors. It is a beautiful job.

Colonel ARMSTRONG. Have I seen this issue? In fact all I have seen are these charts since last Friday.

This gives you a feeling for the kind of a job you have to do if you face this kind of a threat. It is not a small one.

Senator PASTORE. I wasn't here in the beginning, but did anyone ask a question as to the optimism on this kind of a thing?

Colonel ARMSTRONG. If I were to bet on which 1 of these 2 systems will be in the air first, I think the nuclear ramjet will be there first. I am very confident on this. I hope my confidence is not misplaced.

Dr. MERKLE. Certainly there is no doubt in the world that a nuclear ramjet can be built.

Representative VAN ZANDT. The nuclear ramjet will be in the air prior to the rocket?

Colonel ARMSTRONG. I would think this would be true. Yes, sir.

Senator GORE. Have you any idea as to time?

Colonel ARMSTRONG. I think if things keep going as they appear to be going right now that we will prove this is a feasible thing in [deleted]. I think then you marry it to an airframe and I think you are probably flying in [deleted]. Am I too optimistic?

(Deleted.)

Senator BRICKER. What is the nature of control by which you could deliver this at a certain point at any time or bring it back?

Colonel ARMSTRONG. It would have to have three types of control. It would have to have some type of inertial system to get you to a known check point, [deleted]—then a map matching technique would take over where this thing would match its predetermined course to the ground it sees below. This would take you into target.

(Deleted.)

I think when Ted gets up and shows you some of these things that we have and that we can look forward to, it will become more clear.

I think our CEP will be closer than you can get with the ballistic type missile.

Representative VAN ZANDT. Mr. Chairman, may I go back into the money now? Do you intend to ask the AEC for additional money?

Colonel ARMSTRONG. Yes, sir, I do.

Representative VAN ZANDT. How soon?

Colonel ARMSTRONG. As quick as I can get together with Ted and Mr. Tammara and I think we should be able to give this picture in about 10 days.

Representative VAN ZANDT. Would you let us know what the answer is?

Colonel ARMSTRONG. Yes, sir.

Representative PATTERSON. Do you know of any opposition to it at the present time?

Colonel ARMSTRONG. No, sir. I have already discussed this with three of the Commissioners and I have their enthusiastic support.

Representative VAN ZANDT. If you get this additional—

Senator ANDERSON. I didn't get that.

Representative PATTERSON. I asked if there was any opposition to the program.

Senator ANDERSON. I didn't hear the answer to that question.

Colonel ARMSTRONG. I guess maybe I didn't answer the question.

Senator ANDERSON. You said you had talked to the Commissioners. I understand that Dr. Libby doesn't like it at all.

Colonel ARMSTRONG. I think you are right. I was not entirely truthful—not meaning to be.

Representative VAN ZANDT. If you get this additional \$6 million, would you say then that you have all the money that is necessary for you to carry out this program and to bring into being a test vehicle in [deleted].

Colonel ARMSTRONG. For my foreseeable needs through 1959, that is correct. I wouldn't say those are the figures I need in 1960 because these things start to escalate pretty quick.

Representative VAN ZANDT. Is there any way to accelerate this program?

Colonel ARMSTRONG. May I defer that question to Dr. Merkle?

Representative VAN ZANDT. Surely.

Senator BRICKER. May I ask one question? What is the basis of Dr. Libby's opposition?

Senator ANDERSON. He is a chemist.

Colonel ARMSTRONG. Let me say that one basis that I know of is that Dr. Libby feels very strongly that no reactor should ever be allowed to get off the ground as it is too hazardous. Fission products build up in the reactor and if this crashed in a populated area it could cause a lot of trouble. I think that is one of his feelings about this.

Representative PRICE. They could cause a lot of trouble, too, if they get through from the enemy.

Senator BRICKER. Could it be so built that if it does crash the warhead would not go off?

Colonel ARMSTRONG. It isn't the warhead that gives you the problem.

Senator BRICKER. It is the reactor in flight, of course, but what about the warhead? It will carry an atomic warhead?

Colonel ARMSTRONG. You actually could put a timer into a warhead in such a way that it would not go off until a predetermined time so the warhead gives you no problem here, but the reactor could give you a problem.

Senator BRICKER. What would be the amount of radiation released?

Colonel ARMSTRONG. It would depend entirely on how long the reactor had run as to what inventory of fission products were built up in it. All of these things get involved: whether it crashes upwind or downwind of people; whether the reactor just breaks apart or whether the reactor melts down. These are all things you can imagine, but don't necessarily know will happen. But if you put all of these incalculable things together, you begin to get a problem that looks pretty serious.

Senator GORE. Has this been labeled a "clean" weapon?

Colonel ARMSTRONG. No, sir.

Senator GORE. You will get ruled out.

Senator PASTORE. You can apply this to the Rover project, too?

Colonel ARMSTRONG. Yes, sir. My only answer to this kind of a question is—which is safer? To have an American reactor flying over America or a Russian reactor flying over America?

Senator PASTORE. I think that is the crux of the whole thing. We would feel differently about a lot of these things if we weren't in this competition.

Senator BRICKER. Are they working in this field? Do you know?

Colonel ARMSTRONG. I cannot help but believe they are. When

we speak of nuclear propulsion we talk of it with submarines; we have talked of it with airplanes, obviously. We have talked about it with trains, trucks, and everything else. When you talk about nuclear propulsion you think of any vehicle that could be moved and you wonder if you couldn't put nuclear propulsion on it.

Senator BRICKER. No doubt they are if they read the article Congressman Van Zandt referred to a while ago.

Colonel ARMSTRONG. There was an article in a rockets and missiles magazine which was picked up, including some speeches by a Russian scientist who made a talk on this, in which he had shown what a nuclear rocket engine might look like [deleted]. It showed what a nuclear ramjet might look like and it showed what a nuclear turboprop might look like. People don't talk about these things and draw pictures of them without having done some work on it. The extent they have gone, I don't know.

Senator PASTORE. What is the difference between a ramjet and a turboprop?

Colonel ARMSTRONG. A turboprop depends upon a compressor to compress the air coming in the front engine in such a volume that you have enough air and fuel mixed together to burn it. A ramjet is nothing more or less than a hollow pipe and it depends upon its speed going through the air to ram the air into the end of this thing so you have sufficient air to support combustion. With a nuclear system you just substitute a reactor for kerosene and a flame. You heat the air with a reactor and having heated it you put energy into it and you expand it out through the nozzle. It is a completely nonmoving-part type of device.

Representative VAN ZANDT. Isn't it true the more you ram, the greater the speed?

Colonel ARMSTRONG. Yes, sir. Of course a ramjet does not run until it gets up to the speed that it runs on so what you do is you put a couple of boosters on this thing—maybe solid propellant boosters—something like the Polaris—you put that underneath the thing and fire it. It gets up to speed, the booster drops off and the ramjet engine starts running. But you must get up to speed first.

Senator BRICKER. What is that speed?

Colonel ARMSTRONG. That speed depends entirely on design. If you are designing around Mach [deleted] you probably would start running at about mach [deleted]. If we can invent some tricky things that we have been thinking about like variable nozzles, variable geometry, you might be able to start up at a slower speed, as it builds up speed, change your geometry and build up to your optimum speed. There are lot of tricky things in the wind on this.

Our present program is a room temperature critical experiment which has been performed. It will continue on. It goes out into Nevada early in [deleted] to do something that hasn't been done much in reactors before, if at all, and that is to build an oven out there. As you know you can take a reactor. You can check its criticality under room temperatures, but as this reactor gets hotter the criticality changes. Now we have a very, very short amount of information on the curve to show how that changes so we are going to take this mock-up reactor, take it out and put it in this oven and bring it up to 1300 degrees Fahrenheit to get a fix on how this thing changes

because we are after regimes of temperatures in reactors that we have never approached before. We will then go out in [deleted] with what is known as Tory 2 reactor. This is not the reactor that you would fly with but nuclearly and material-wise it is a scale model. We will run that with an air supply and if it is successful we may then state this is indeed a feasible device.

Now, I would like to turn this over to Dr. Merkle. He can tell you some of the things they are doing out there and I think you will find his discussion far more exciting than anything I have said.

Representative VAN ZANDT. May I ask one question? A moment ago I asked you about acceleration and you pointed to Dr. Merkle. Dr. Merkle did not get the opportunity to answer the question. Will you answer it now?

STATEMENT OF DR. THEODORE MERKLE, OF THE LIVERMORE LABORATORY

Dr. MERKLE. Perhaps using this chart here we can indicate the sort of thing that goes on. The program, as outlined, up to about this time is exceedingly difficult to accelerate for reasons that will become apparent in a moment as I go through the technical problems involved.

Beyond this point when you are trying to work on engine designs and engine test facilities and the like there is a period of time which has been estimated variously by people as [deleted] years, [deleted] years, [deleted] years—you can almost name your poison—but that period of time can be set earlier if you know that you wish to commit yourself to such a program.

Representative VAN ZANDT. That is right.

Dr. MERKLE. And you can thereby shave a considerable chunk of time out of overall development of a complete engine. To accelerate this year and next is most difficult for you are up against specific scientific problems.

I would like to begin this discussion by showing a picture of a conceptual ramjet and this may answer some questions that some of you have in mind. We have a metal duct which is hollow. This green object is called the center body and it is a sort of aerodynamic diffuser for the system and it changes the speed at which air flows and enters the device supersonically and by the time it reaches the reactor it is moving much more slowly. This is accomplished by this section and here is an area in which heat must be added to the gas in the chemical ramjet. This would be done by means of a device looking something like your stove burner. In this nuclear ramjet it is a barrel essentially poked full of holes. The gas goes through these holes and is heated in transit. Then there is this nozzle at the exit end which allows one to recover a bit more thrust.

The device is actually pushed through the air by pressure on the inside surface of this thing here, surprising as it may seem. So these are the components then of a ramjet engine.

(Deleted.)

This [deleted] type of machine is designed around a weight of [deleted] pounds and is supposed to fly at mach [deleted]. There is another consideration that wants to be included and that is what part of this thing is actually powerplant and what part does not require

any development. Here is a cutaway of the interior of the device and the reactor portion is this little section back here in the tail. Forward of the reactor is some coolant to help keep the structure cool at this very high mach number. Forward of that is the bomb compartment. Forward of that is the guidance equipment and the like. The structure—that is the entire airframe can be built using existing technology. No new research is required there.

(Deleted.)

Dr. MERKLE. Then we come to one of the more interesting features of this kind of a scheme. Here is a trailer which is not materially larger than the trailers that carry automobiles around the Nation. This is a scale drawing of a similar device to the one you just saw resting on such a trailer. These devices can be launched from anyone's backyard and can be moved over any highway. The loading on the axle is not very high. It has to be tilted up, sent off on its boosters and it is away. This I believe is very good from an operational standpoint in that it gets around hard or soft target question almost entirely and confounds your enemy completely because he doesn't know where you will be tomorrow morning.

Representative VAN ZANDT. What about contamination at launchings?

Dr. MERKLE. It is very unlikely this reactor will severely contaminate. However, I will not say "Certainly it will not contaminate." One might have to bring it up to temperature on the ground. As you have noticed the boosters carry it up to high altitude before the reactor is brought up to any appreciable power. It is current belief that there would be no local contamination at all. Now there is always a question raised about nuclear ramjets as to whether they can clear objects on the ground. Here is a little study that we made for a gadget designed to fly at mach [deleted] with a wall temperature of [deleted] degrees Fahrenheit. This is rather hotter than we absolutely have to have, as I will show you in a moment.

(Deleted.)

Senator GORE. What advantage does this have other than range over the guided missile which the Navy has operational already?

Dr. MERKLE. What guided missile?

Senator GORE. You know the one I saw.

Representative VAN ZANDT. The Regulus.

Colonel ARMSTRONG. More than [deleted] as much speed.

Dr. MERKLE. What is the payload on the Regulus?

Colonel ARMSTRONG. [Deleted] pounds.

Dr. MERKLE. You can lug a larger payload. Incidentally the range difference is just fantastic.

Colonel ARMSTRONG. It has the capability of going in on the deck which the Regulus does not have.

Senator GORE. I am not sure it doesn't have.

Representative VAN ZANDT. The Regulus flies a level course and is controlled by radar until it reaches the vicinity of the target where it selects a target through—it is somewhat like a proximity nose. Regulus II is not operational yet and it is an improved weapon.

Senator GORE. But both, Jim, are subject to controlled piloted planes that might pick it up in flight.

Representative VAN ZANDT. That is true. It is a drone, but isn't it true this missile has between it and the surface of the ground knowledge as to height.

Dr. MERKLE. Yes.

Representative VAN ZANDT. And terrain.

Dr. MERKLE. It follows it.

Representative VAN ZANDT. The Regulus does not have that type of navigational control.

Colonel ARMSTRONG. It could have.

(Deleted.)

Senator GORE. What you are saying would be more impressive with me if you hadn't said that you had lots of time to do something about the ICBM.

Dr. MERKLE. Lots of time is like 10 minutes.

Senator GORE. In order to intercept it you have to have a thousand and one things occur within split seconds.

Dr. MERKLE. I am not involved in inventing countermeasures for Atlas.

Representative PATTERSON. The employment of this particular weapon, in your opinion, should be as a ground force weapon, Air Force, or Navy?

Dr. MERKLE. This is a question I am not competent to decide.

Colonel ARMSTRONG. I think it is clearly an Air Force weapon as an adjunct to a SAC mission. It is a strategic missile. I don't think there is any argument there.

Representative VAN ZANDT. Isn't it true this practice of penetrating a radar barrier was first made possible by slow flying propelled aircraft and jet aircraft and finally we are moving into the ramjet. So it is nothing new.

Dr. MERKLE. It is not particularly novel. What is novel is that you can do this for extended distances.

(Deleted.)

Senator PASTORE. Could you do it in various stages?

Dr. MERKLE. Such as the first stage is a submarine.

Senator PASTORE. Just like your rockets. Couldn't you, through the use of chemicals, achieve greater distances?

Colonel ARMSTRONG. Yes; that has been thought——

Dr. MERKLE. No, Jack.

Colonel ARMSTRONG. Low speed you mean?

Senator PASTORE. My question is only academic.

Colonel ARMSTRONG. You have gained not much by this, though. This becomes a very complicated big system.

Dr. MERKLE. It is not quite the same as staging a rocket because you are contending with air drag all the way. With the rocket you are striving to build up momentum which then enables you to catapult the small final stage the rest of the distance. Once you have stored energy in the system it kind of remains there. With this machine there is a constant energy drain coming from the push of air against it.

Representative VAN ZANDT. In intercepting a ballistic missile, you can use [deleted] an antimissile [deleted]. You can't intercept this type of missile with another missile because it is flying too low and too fast.

(Deleted.)

Dr. MERKLE. In the first place I believe you could catch this thing with an antimissile missile providing your antimissile missile was close enough to the point that it is flying over. This is a problem in range. If you had detection of the device and you had a launching site for an antimissile missile and the Pluto to fly right over that site practically speaking, then a stern chase could be mounted and you could catch it and you could abort it whereby its bomb would blow up in your face at low altitude. As for throwing things in front of it, I think this would be exceedingly difficult. It is a very rugged machine. It is not flimsy at all. It is a kind of flying crowbar.

(Deleted.)

Dr. MERKLE. Up to now I have spoken about possible operational features. Of course in order that those computations could be made in some reasonable order, we had to assume something about the reactor. The reactor poses problems in three main areas. The first and most important is the area of materials. The second one is the area of nuclear physics which Jack touched upon slightly when he mentioned the problem of critical elevated temperatures and third is the area of ingenuity in mechanical engineering which perhaps is not as trivial as it might sound. Let's take up the materials question.

In order to build a high temperature reactor which can resist oxidation, which is necessary for this job, we have to select essentially from the materials you find on this list.

(Deleted.)

Dr. MERKLE. Then if we impose in addition the question of oxidation resistance we find that we are restricted to only a few of these materials.

(Deleted.)

Dr. MERKLE. The things you must have are both the strength at high temperature and the resistance to oxygen. The other materials, such as were mentioned earlier in connection with the Rover program, for example, will resist reducing atmospheres; that is to say they will resist attack by hydrogen perhaps, but they burn up in the presence of oxygen. It is generally so that the highest temperatures systems can be made out of the carbides. Zirconium carbide, for example, is a nice one. Tantalum carbide is lovely. It goes to nearly 4,000° C., but it burns up in the presence of oxygen so it is not very useful here.

Chairman DURHAM. Has tungsten been tested?

Dr. MERKLE. Tungsten burns up. It oxidizes like mad. Light bulbs, you know. You put nitrogen in to prevent this phenomenon. Oxidization resistance is the primary thing.

(Deleted.)

Representative HOLIFIELD. Would you lose strength in ceramics that will take a higher degree?

Dr. MERKLE. This curve doesn't show you are losing things very badly. Ceramics look real good. At 3,000 there is actually a point here at 31 something with a thousand pounds per square inch yield left in the material.

Chairman DURHAM. With ceramics you get away from the oxide problem.

Dr. MERKLE. You get away from the oxide problem.

(Deleted.)

Dr. MERKLE. The next question that always comes up with a reactor is, "Can you hold uranium in it?"

(Deleted.)

Dr. MERKLE. Some experiments have been made on retention of uranium in both our own laboratory and at Atomics International Laboratory.

(Deleted.)

Dr. MERKLE. There are certain individuals who have made a great thing of [deleted] one of our toughest technical problems. It is not even with present knowledge as serious as it might be made out to be and with further knowledge we might expect to eliminate it altogether.

That I think is a highly significant point and it is the only reason I was able to answer Jack's question of "What do you think about the ultimate success of this thing?" by saying, "There isn't a doubt in the world." I carefully didn't say when it would be done. This is a matter which depends on many things. From the technical point of view you have now seen evidence that leads us to believe as follows: the strength of this material is adequate; its resistance to being oxidized is adequate; its ability to retain fissionable fuel is adequate.

(Deleted.)

There are a lot of other questions that are involved too concerning design details and what not. These have been explored and it looks as though this particular material will be adequate all the way around. It is not the best in the world but it can do the job.

Senator ANDERSON. When you get into these things it is a little bit above my head.

Dr. MERKLE. I wanted to be sure I had available the technical information on which this confidence is based. It is one thing for me to come and say, "Sure, we can do this job." It's another thing to come and say why we can do this job.

This mystic number here [indicating] just says how much is left over to lift the bird, and these are for various temperatures and essentially shows why we are picking Mach [deleted]. The ability of this bird to lift payload increases up to Mach [deleted] and then decreases thereafter.

(Deleted.)

This shows something about trade-off, about wall temperatures and diameters. All I wish to indicate here is the little ones and big ones perform about the same as far as the reactor is concerned.

This one indicates rather crudely the kind of payload, the diameter of the thing, and the open area in it against the uranium investment.

The thing I want to point out is if you pick a [deleted] foot diameter bird the payload would be huge and would take about [deleted] kilograms. That is fairly cheap in terms of uranium.

To explore all of these things more fully, to get the science under control, we need a materials program, which we have at Livermore; and we need a program of high temperature, critical measurement. This is a drawing of the one that is being built in [deleted] in Nevada, and it consists of a lot of heat exchangers to blow hot gas into an oven in which a critical pile is located.

Incidentally, this pile does not become radioactive. It is operated at zero power; so it is very easy to change configurations around it.

Then the material test reactor is located in Nevada. This is sort of an old artist's conception layout, geographically speaking. This is the railroad spur on which it is located, the tie point on which to

connect that system, and pipelines and what not. It is not an enclosure. We are relying on space to shield the personnel 2 miles away at the control room. The railroad enables you to take this hot reactor to the disassembly building 2 miles away for postmortem. It is a very standard procedure. There is no big investment in concrete here.

Representative VAN ZANDT. Is this in addition to the rocket?

Dr. MERKLE. This is separate from the rocket. The question of using it for both programs was investigated very thoroughly, and it looked like it would involve more cost in concrete.

Dr. ARMSTRONG. It is the same area, the same utilities?

Dr. MERKLE. Here is the drawing of the test reactor itself. This is the core of the reactor, a large reflector around the outside of the experimental model.

The reason for putting controls on the outside in the first model was to separate the problems. We did not wish to have to contend with the control rod system operating in hot air at high speed and high pressure in the first model. Furthermore, when we do install such a control system, we would very much like to take over the control with the external one in case the first one gets into difficulty.

So this is the test reactor and it exhausts the hot gases right into the desert air. That is the so-called Tory II device scheduled to be turned on in about [deleted] if all goes well.

Finally, there is a question about radioactive contamination in the atmosphere. We have made some very pessimistic assumptions. We made the assumption that 10 percent of all the fission products generated in the running period would be exhausted in the atmosphere in Nevada and explored very carefully the downwind fission fragment that might damage people, and we find this kind of a result:

"1" on this scale means you can stay there indefinitely and 1 turns out to be 10 miles away downwind, if you insist on running this reactor for $7\frac{1}{2}$ hours at [deleted] assuming 10 percent of all fission fragments made come out. Recent information seems to indicate we can expect something like one-thousandths to come out. This is a pessimistic chart that I brought along to show that even under bad conditions things are never frightening.

That takes care very briefly of the technical material I have to present today, sir.

Chairman DURHAM. Thank you very much.

Senator ANDERSON. I think it is very interesting to hear you express your real confidence in this. I think it is a fine thing.

Dr. MERKLE. It is. It will work. Is is just a matter of do you want it or not.

Chairman DURHAM. Because of this long hearing, we will have to accommodate our out-of-town people, and now we will take up the outer space problem.

AFTERNOON SESSION (3:15 P. M.)

Present: Representatives Durham, Holifield, Price, Van Zandt, Patterson, Hosmer; Senators Anderson, Pastore, Gore, Hickenlooper, Bricker, and Dworshak.

Also present: James T. Ramey, executive director, John T. Conway, assistant staff director, David R. Toll, staff counsel, and George

E. Brown, Jr., staff member for Research and Development, Joint Committee on Atomic Energy.

Representing the Atomic Energy Commission: Dr. Raemur Schreiber, Chief of Section, Rover Project, Los Alamos Laboratory; Dr. Theodore Merkle, Livermore Laboratory; Dr. Stanislaus Ulam, Los Alamos; Col. Jack Armstrong, Deputy Chief, Aircraft Reactors Branch; Dr. Norris Bradbury, Director, Los Alamos Laboratory; W. Kenneth Davis, Director, Reactor Development Division; Louis W. Roddis, Deputy Director; Commander Moore; Byran LaPlante; Mr. Tammaro.

Representing the National Advisory Committee for Aeronautics: Dr. Abe Silberstein, Associate Director, Lewis Flight Propulsion Laboratory; Dr. John C. Evvard, Chief, Supersonic Propulsion Division, Lewis Laboratory; Dr. Addison M. Rothrock, Associate Director for Research (Propulsion).

Representing the Department of Defense: General Austin W. Betts, Deputy Director for Guided Missiles (Holaday office); Paul Smith, Office of Assistant Secretary of Defense for Research and Engineering; Carl Sorgen, Office of Assistant Secretary of Defense for Research and Engineering; Lt. Col. Marvin N. Stanford, Office, Assistant to Secretary of Defense.

Chairman DURHAM. I believe Dr. Ulam is next.

STATEMENT OF DR. STANISLAUS ULAM, OF LOS ALAMOS LABORATORY

Senator ANDERSON. Have you been before the committee before?
Dr. ULAM. No.

Senator ANDERSON. I assume you all know Dr. Ulam was very much interested in the development of the hydrogen bomb. He probably came up with the first suggestion that led to its final development, and while another eminent scientist was always credited with the hydrogen bomb, here is the man who had the idea, and I believe your name is first and maybe the other name is second; is that right?

Dr. ULAM. No matter; alphabetically I suppose.

Senator ANDERSON. Anyhow, I am very proud of the work he did and the very modest way in which he has conditioned his life thereafter.

Dr. ULAM. I am at your disposal.

Senator ANDERSON. Outline some of your ideas first.

Dr. ULAM. I am to cover briefly the whole situation.

I think our eminent speakers before discussed how chemical fuels are limited in energy. The nuclear energy, of course, per unit of weight is by an enormous factor, higher, say a million times higher. The trouble is this energy cannot be used fully or even to a great extent. The reason for it is that the reactors which enable us to put out this energy are of such delicate structure and are to some extent limited in the [deleted] from the running standpoint.

One could get millions of degrees and fantastic velocities from the efflux of the propellant of the rockets; however, the reactor will not stand more than 2,000 or 3,000 degrees centigrade.

The proposal this morning mentioned temperatures of the order in Fahrenheit of four or six thousand degrees higher than any chemical

possibilities, and I want to speak of the advantage which nuclear fuel has. But there is this limit: the limit for a steady operation of reactors.

Of course, long ago, in fact shortly after the war, some of us thought how to circumvent such difficulties, making something much more simple, crude, requiring no watchmaker's precision in parts and pumps, and yet get to extremely high temperatures, extremely high velocities, and some such things that are almost obvious.

You could use the nuclear fuel not in the way you use the chemical fuel, not to heat up something else, even liquid hydrogen, which Dr. Schreiber described, which is a very good thing, but you could be really extravagant and throw out most of the fuel as you burn it.

Clearly the limits at which one can operate in this fashion are higher still. You do not need any delicate construction in the containing of the material.

So one idea was simple to have what I think Dr. Schreiber in the last minutes of this talk alluded to as the Livermore exhaustive scheme for a gaseous reactor.

It would simply consist of shoving into a pipe, a big pipe, if you want to call it that, very mild inefficient bombs releasing each time only about a hundred kilograms equivalent of explosives.

Many times still much higher velocity, still much higher specific impulse and such things were considered, but only, of course, not officially or any big schemes of calculators, but conceptual.

Another scheme of this sort, quite old, was to explode—and I will call it bombs again—bombs outside the vehicle to give it successive pushes. It is almost like Jules Verne's idea of shooting a rocket to the moon. You do it in many stages. I should say it is all for unmanned vehicles for the time being. The accelerations are very great. By exploding such bombs on the outside you can get velocity to the final product.

I thought I was asked to appear before you to discuss these at present more remote sounding possibilities, on which I am expressing my own private opinions, by the way, all the time, not those of the laboratory. Dr. Bradbury might have some entirely different points of view on this thing. I do not think he has, but please remember these things are not tied to any definite program now proceeding with dateline and money.

Nevertheless, it is high time to survey the whole field, which is enormous, if I may digress and give you my own personal impression.

This morning it was tremendously encouraging to hear about these things which are undoubtedly to play an enormous role in the whole field of missiles, and I am just waiting to answer the questions, if I may or can.

Senator ANDERSON. Dr. Ulam, you are regularly working in this sort of field at Los Alamos?

Dr. ULAM. No. I work on many things but happened to be interested in propulsion years ago. We wrote a few reports on such possibilities, which indeed may one day turn out to be very practical.

As Colonel Armstrong said, it is not only the question of insurance, but to do the best one can, especially since nothing is certain in this field. But one thing I am convinced of is that nuclear propulsion will play a decisive role in the next few years.

May I continue talking?

Senator ANDERSON. Yes. I was just going to say that one thing we would like to have you comment on is how do you think the Russians put up sputnik. Did they do it chemically?

Dr. ULAM. The chances are. I do not know. I have no special way of knowing. From all indications it was just a very good three-stage chemical job.

It is my own feeling, as an individual or scientist privately, there is no doubt that they must be working on things like Rover and Pluto. Both schemes described this morning are very ingenious, but by no means do they surpass those of the imagination which you would expect from highly trained physicists or engineers who are there. So my own feeling is a nuclear sputnik might be what we are working on right now. Therefore, all the effort is more than warranted, all the pressure justified. I do not know. I thought there was such a wonderful reception and wonderful feeling in this committee.

Senator ANDERSON. Do you think the possibility of the use of these liquids offers some future possibilities of great interest to us?

Dr. ULAM. Yes, I do.

Senator ANDERSON. This is a little bit like our work in trying to control thermonuclear power so we can make some use of it.

Dr. ULAM. My own feeling is, in principle this thing could be done. Very soon even. They are very expensive, involving material in the amounts, say, of hundreds of kilograms per vehicle. Of course, this would be sort of a propaganda or purely science thing and not a military mission type thing at first.

But all of these things—as you know, the hydrogen bomb at first was an enormity [deleted].

Chairman DURHAM. Dr. Ulam, we have heard a good deal about space platforms, that whoever controlled outer space would control the world. Would you mind commenting on that?

Dr. ULAM. I have no opinions on the military aspects of a platform.

Senator DWORSHAK. Doctor, do you think that the demonstration of sputnik is conclusive evidence that the Soviets are developing destructive satellites, missiles, which indicate that they are far surpassing us in this development?

Dr. ULAM. What the satellites themselves could be used for militarily I do not know.

Senator DWORSHAK. Is that evidence which should be held down to that one performance of sputnik? Or is that evidence they have gone far afield in this overall development and probably have missiles and satellites and rockets which constitute a real threat to the security of our country?

Dr. ULAM. I think it is this last. Sputnik showed they have a very good vehicle in the first stage, and Sputnik No. 2, which weighs half a ton or more, certainly could just as well be a missile. Whether they have enough of these to do anything in this year or next year, of course, I cannot tell. But they have the technology to start developing such things.

Chairman DURHAM. Mr. Ramey.

Mr. RAMEY. Do you think the level of efforts should be moderately increased or greatly increased, as some people have advocated, on going toward space vehicles?

Dr. ULAM. My feeling is that the subject is of enormous importance. How much to increase the real effort right now in the form of setting up organization or making exact blueprints is not clear at all. It would be nice to have a few more brains involved in it in the thinking stages about all the possibilities of nuclear propulsion. That requires really not enormous sums at first, and nobody knows what will happen in 5 years.

I remember when I first came to Los Alamos I was shown the entire existing supply of plutonium—14 years ago—and the amount of fissionable material about which we talked was the head of this match. A lot happened since.

Senator ANDERSON. When did you go to Los Alamos?

Dr. ULAM. At the end of 1943. So things are not predictable.

Senator GORE. Doctor, would it not be necessary first to develop a will and a purpose and a determination to undertake such studies?

Dr. ULAM. Yes.

Senator GORE. Do we have an adequate concentration of effort in this field, in your opinion?

Dr. ULAM. It seems to me the nucleus at least, if I may say so, is right here in the Commission.

Senator GORE. Is it your opinion that a vehicle with some control of mobility in space beyond the earth's atmosphere would be a logical sequence to the successful launching of the Rover?

Dr. ULAM. It is my belief rather than opinion, but very strong belief; yes. The time scale cannot be predicted, but not long.

Senator GORE. If that be the case, what do you think could be done in this second field, some controlled mobile vehicles, pending the successful operation of the Rover rocket?

Dr. ULAM. Do you mean a parallel effort?

Senator GORE. How could the efforts be paralleled?

Dr. ULAM. That could be done by thinking of a few theoretical people—I cannot tell how many—devoted to consideration of such schemes which indeed will come. Sooner or later they will come, and it would be very good to have such. How to organize it or administer it right now is not really my province. But it should be done.

Senator GORE. Is it anyone's problem right now? Just what is being done in this particular field other than what we are doing here today—talking about it?

Dr. ULAM. There is nothing as far as I know. There might be something other in the Department of Defense I know nothing about, and, you might say, private individuals or scientists speculating about it in some organized fashion.

Senator GORE. What is needed in your opinion, if I understand you correctly, is some organization, some responsible group, devoting their energy and talent and effort to this field. Is that right?

Dr. ULAM. Or even showing interest, which apparently exists. It is extremely essential. These things might have sounded visionary or bombastic a few years ago but they do not anymore. Still we need some evidence when the time comes of ability to execute ideas from paper to experiments and from experiments to building things.

Representative VAN ZANDT. Doctor, would you say that a project to explore space is really AEC's territory because of its relationship to the projects Rover and Pluto?

Dr. ULAM. I would say—I do not want to speak presumptuously, coming from Los Alamos. My feeling is definitely it requires people who know about the handling of nuclear material and explosions even. This technology is confined to Los Alamos and Livermore and the people there who know the properties of this whole black magic, if you want to call it that. It seems that way.

Senator ANDERSON. You say explosions?

Dr. ULAM. Explosions, yes.

Senator ANDERSON. I was just going to say the people at Los Alamos and Livermore have had to work with things that are very highly explosive and test them out in small explosions, have they not?

Dr. ULAM. Yes.

Senator ANDERSON. I recall the first time that Dr. Bradbury took me into where they were sawing up dynamite or something far more explosive, and all I was praying was that I would get out of the room alive. I had never seen somebody take a saw and run it into hot explosives. But you have to learn to handle these.

Dr. ULAM. To calculate those things or foresee what will happen if you assemble that much material.

Representative VAN ZANDT. I have another question. From what you say here you at least have given some thought to a project involving space.

Dr. ULAM. Yes.

Representative VAN ZANDT. Do you think the facilities at Los Alamos are adequate to launch such an effort or would it require an expansion of existing facilities?

Dr. ULAM. The facilities so far for the time being in going beyond Rover require paper and pencil and thinking, shall we say. It is for Dr. Bradbury to say whether he wants to. I know he actually wants to hire some more people.

Dr. BRADBURY. Mr. Chairman, Dr. Ulam is putting out some very important aspects of the situation. I would like to add a few remarks to it, just to sort of supplement what he is saying and what Dr. Schreiber was saying this morning.

When we put into the nuclear propulsion program the Rover and the Dumbo concept—we have described the 2 different approaches to the nuclear propulsion program. To get that going within the framework of our budget we had to almost entirely discontinue the work which we were doing on the sort of advanced concept that Dr. Ulam is discussing. There are only so many dollars and so many people, and to protect the short-range propulsion program these longer range things had to be put on a back burner.

I think—in fact, it is quite clear—that with the additional funds that we have been discussing, it is our proposal to go back into these advanced concepts considerably more strongly and explore them, as Dr. Ulam is saying, on pencil-and-paper-basis thinking, and with laboratory-type experiments.

You will recall in Dr. Schreiber's three columns this morning there were various types of laboratory approaches that were necessary for some of these things before one could attack them on a full-scale fashion. This we propose to do.

We have a small group of people that meet informally once a week or oftener that talk among themselves about this sort of thing. The

sky is the limit. No minutes are taken. Let the imagination ramble. I think I would agree entirely with Dr. Ulam that any ideas, at least at Los Alamos at the moment, of a physical expansion necessary for the exploration of these more advanced concepts would be out of place.

There is definite need, definite room, and definite ability, I agree with him also, to do the preliminary paperwork. That paperwork may tell you that the idea is not worth going ahead with. It may tell you it would be good in an experimental effort in a remote field, whatever it may be. It may bring to light some easy technique which no one has thought of yet.

But I think the idea of a large physical expansion at this point is not relevant, but the idea of definitely encouraging people to look at and worry about and think about and do whatever laboratory calculation and laboratory experimentation is concerned is very worthwhile.

Senator GORE. It would require time to think about the work and they would have to have something to live on meanwhile.

Dr. BRADBURY. Of course, those people cannot be worried about the time schedule or we might have another Kiwi.

Senator GORE. Did you say TVA? (Laughter.)

Representative VAN ZANDT. Does it require first additional money?

Dr. BRADBURY. Yes.

Representative VAN ZANDT. How about the authority? Do you have the authority now under your AEC directive to get into this field?

Dr. BRADBURY. The Atomic Energy Commission has always been extremely kind to Los Alamos in letting them do what they want provided they came through good. So I think I have the authority.

Senator PASTORE. How about getting the right people?

Dr. BRADBURY. The right people are always hard to get.

Senator PASTORE. Do you think you can get them?

Dr. BRADBURY. We have many of them. We will want more. But the people with imagination and technical ability, with wide background in physics and mathematics and chemistry and metallurgy, are not for sale on every street corner.

Representative PRICE. Have you had people out in your laboratory who for any number of years have had the imagination to foresee the developments in space?

Dr. BRADBURY. You are talking to one of them—Dr. Ulam. We have others.

Representative PRICE. Among the scientists you know, Doctor, are there any number of them that think it feasible now to start more serious study of the space question?

Dr. ULAM. Yes. Some reports were written on these things years ago. Some of the schemes are old, but you know the amount of material seemed astronomical 10 years ago and they seem paltry now. And who is to say what the next few years will bring.

My own impression is that if half the things expected of Rover are true, it is an enormous thing, completely equivalent to the entire chemical fuel effort.

If you want to speak in poker language, suppose you say modestly there is one-third chance of the Dumbo working. If it works it is

worth many billions of dollars. There is no question about that. So the expenditure of any effort on it is very favorable.

Senator PASTORE. Do you believe in the admonition that the nation that controls outer space will control the world? Do you believe that admonition?

Dr. ULAM. It is a very general dictum and it is to be qualified with time. If some nation controls travel in space and is in possession of the moon, it ipso facto, it seems to me, dominates this planet too.

Senator PASTORE. I would like to not take too much time at it because I know it is quite a panorama. But could you answer the question why that is so?

Dr. ULAM. Well, it is an old statement—high mobility on a really astronomical scale, both from the point of view of surveying and gathering intelligence. And then you can have, if you want to, missiles against which very little defense would exist.

Anyway, the future as a whole of mankind is to some extent involved inexorably now with going outside the globe. Airplanes have done a little bit in this direction. Recently we have been going a hundred miles on exploratory vehicles. There is no question in the next 10 or 20 years the whole aspect of things will again change. It does not take any special prophet to say that.

Representative PATTERSON. Do you think within 10 years, Doctor, there will be actual travel in space?

Dr. ULAM. By travel, you mean vehicles without people in them?

Representative PATTERSON. No; with people in them.

Dr. ULAM. Well, my guess, just guessing, extrapolating from past history and technology, is that within 10 years there might be living beings or perhaps humans going around the earth. Whether somebody will return in 10 years, I would not hazard a guess. But in 20 or 30; sooner or later.

Representative PRICE. You mean going around the earth and safely landing?

Dr. ULAM. Perhaps; yes.

Representative HOLIFIELD. Doctor, in speaking of these things you have testified about today, could you give us a comparison as to what the chance was to accomplish the atomic bomb and the hydrogen bomb? In other words, relate the things we are talking about today in terms of probability to those projects at the time you had to go into them.

Dr. ULAM. It is very hard to estimate what the chances turn out to be, but I remember in Los Alamos during the war years there were many doubts whether the things would fizzle out, doubts based on technical arguments. It was not at all sure there would be an enormous explosion.

Representative HOLIFIELD. You are speaking now of the atomic bomb?

Dr. ULAM. Yes. The hydrogen bomb was still at its inception a more chancy project. In fact, the original schemes which were entertained theoretically did not work out too well. So it is hard to put a numerical value on it, but there was never any certainty at all.

Representative HOLIFIELD. Would it be making a reasonable statement to say that in the stage of technology we are in today some of

these projects we have been talking about have more likelihood of being brought to reality than was the likelihood of bringing the hydrogen bomb into reality at the inception of the project?

Dr. ULAM. I would think, based on present knowledge, it is to my mind a certainty that some method of nuclear propulsion will work and be much more powerful or important in the long range than anything else. About any specific method discussed so far, one cannot have any certainty, but one way or another the problem will be solved is my private conviction.

Representative HOLIFIELD. As I remember the specific theory of the hydrogen bomb was not the one that finally became the reality.

Dr. ULAM. That is true.

Representative HOLIFIELD. It was a breakthrough in joint efforts between you and Dr. Teller that brought a different concept into being the hydrogen bomb; was it not?

Dr. ULAM. That is true.

Representative HOLIFIELD. Could you refresh our minds as to what that breakthrough was? I was out at Los Alamos, Dr. Bradbury, you remember, at the time when the theories were explained to us, and I believe Dr. Teller and Dr. Ulam were there at that time when our subcommittee was out there.

Dr. BRADBURY. This is a subject which, of course, is quite off the path we have been following, and I want you to assure me everyone in the room should hear this.

Representative HOLIFIELD. I withdraw it, although I think everyone is cleared.

Dr. BRADBURY. It is a weapon matter. I am perfectly willing to describe it, but it might offer a problem.

I think the point which you are making, though, is extremely well made, the same as Dr. Ulam is making, in that the obstacles to be overcome in the first atomic bomb and the hydrogen bomb seem now to be very large compared to the obstacle is one has to overcome in going about nuclear propulsion. It looks to be a much better bet. Whether a similar breakthrough that we have not seen yet and do not really seem to need in the nuclear propulsion tests is right around the corner, no one knows, of course.

Representative HOLIFIELD. This is what I wanted to clarify in my mind: that the general feeling among the scientists is that there is greater likelihood or chance of doing these things than there was at that time for those things.

Dr. BRADBURY. Enormously so, compared particularly to the hydrogen bomb. For many years no one saw any way of licking that at all, let's say reasonably. I think one sees the way to like everything foreseen now.

Senator GORE. Let me see if I understand you correctly. If I do, I think you have made a very arresting statement, Dr. Ulam. Did you not say, in answer to Congressman Holifield, that this undertaking of space vehicles appears now more feasible than the hydrogen bomb did when you first began that effort?

Dr. ULAM. You extended my remarks farther than my remarks, I wished them to extend, but that is probably true. I was talking about the means of nuclear propulsion like Pluto and Rover.

Dr. MERKLE. Rover is a good machine, real good. It is no slouch.

Dr. ULAM. There are going to be other tough problems to solve once you solve the immediate Rover sort of application, problems of getting back home, landing, and things of this sort. I think what you said is true, but I was talking about something not as spectacular as you are talking about.

Senator GORE. You still say, though, what I misunderstood you to say is nevertheless true?

Dr. ULAM. I think it is true, yes.

Senator GORE. I think that is something to which this committee must give attention.

Representative PRICE. Do I understand you, Doctor, that now at Los Alamos there are groups doing some talking and maybe some paper work along the idea of space propulsion?

Dr. ULAM. Yes.

Representative PRICE. What size groups are they?

Dr. ULAM. Some are informal of, let's say, 15 people discussing things theoretically. It is not yet at the stage where they propose definite experiment, although it is clear what kind of experiment should be done.

Let me make this remark: In general the Los Alamos and Livermore Laboratories are oriented toward making as big an explosion as possible for military uses. In this field we will have to learn the details and the precision of making small mediocre explosions, more in the nature of burning almost, in order to eject the material, not at the fantastic temperatures of a hundred million degrees but rather some of the order of 8,000 or 10,000. These figures are already very impressive.

Representative PRICE (presiding). Are there any further questions of Dr. Ulam?

Thank you very much, Doctor, for your presentation.

Dr. Merkle, we would like to hear what you have done at Livermore.

Dr. MERKLE. You are interested in hearing what we have done at Livermore about some of these advanced concepts?

Representative PRICE. That is right.

Dr. MERKLE. As Dr. Ulam indicated, not much manpower is being invested in the country in this sort of scheme. We have broken down the problems of other schemes than Rover into several categories, and over the past year and a half we have been attempting to establish, by means of the basic laws of physics and the fundamental cross sections of various kinds of matter, those schemes which appear to have some hope of working and those schemes which appear to be prohibitive in one way or another.

The schemes that we have considered include the gaseous reactors, exploding gaseous reactors or pulsed gaseous reactors, bomb explosions under confinement, combustion of sticks of fissionable material, and the ion rocket. These are the principal ones that we have considered.

In all of the cases except the case of the ion rocket we have been able to show to at least a cursory degree that the schemes are very far away indeed, so far away that we do not see on the face of it an easy way of attacking the experimental problem.

We have also, in the course of doing this, made some modest studies of what you can actually do with Rover-type devices if you are willing to double stage them, and we have used the double-staged Rover as a comparison with these other schemes in attempting to estimate the real relative difficulties of the task and the real relative goals that could be attained.

Let me say the conclusion is very briefly as follows:

If you are interested in navigating in the solar system from the earth to the Moon, to Mars, to Venus, in short, anywhere short of Jupiter, it looks like a two-stage Rover is the most economical, most straightforward, and most do-able way of accomplishing your desires. If you wish to go to the nearest fixed stars, something new will have to be learned. If you wish to go beyond the orbit of Jupiter, it is quite possible that the ion rocket would be the most reasonable vehicle to attempt to develop.

Mr. RAMEY. Would you describe the ion rocket?

Dr. MERKLE. The ion rocket is kind of an interesting thing, which might in some ways come natural to Livermore.

The ion rocket is essentially an accelerator. The power for the accelerator comes from fission reactors, and what you are shooting out of the rear end of this system are charged particles instead of the hot gases normally shot out of the standard nozzle.

The point in doing this is to raise the velocity in which you exhaust the matter that is being thrown away. It is a fundamental principle of rocketry that the faster you throw anything away, the less material you have to have to throw away to attain a given velocity in the payload.

So in principle, if energy is unlimited, you can then throw away a small amount of matter at very high speed and propel a vessel at a very high speed.

This is the sort of goal that the ion rocket keeps dangling in front of you. But with every goal there is always a gimmick. In the case of the ion rocket it has to do with the fact that you must find some means of converting the nuclear energy in the nuclear reactor into electricity, which is lighter than our present lightest electrical generators if the scheme is to be really competitive with the Rover device.

We have made some studies of the performance of this type of device under the assumption that you could get as much as 1 horsepower per pound of machinery, which incidentally is optimistic by a source is substantially trivial, which we believe it would be, with that factor of 4 over present technology. Assuming the weight of the ion type of ion rocket you begin to get a payoff for missions from orbit stations around the earth to such things as Jupiter. With closer missions, it does not compete very well with the Rover scheme.

Senator HICKENLOOPER. What appropriateness this question has I am not sure, but you said a factor of 4 on the pound per horsepower?

Dr. MERKLE. Yes.

Senator HICKENLOOPER. It runs in my mind that our internal combustion engines, the most efficient, may develop a horsepower for less than a pound.

Dr. MERKLE. Indeed they do.

Senator HICKENLOOPER. Is there anything relative in this question as to a factor that could be applied as to how many horsepower from

this electric generation to the accelerators, how many so-called horsepower might be absolutely necessary to project the vehicle as compared to the horsepower in the atmosphere and on the earth on the highway? Is there any comparison?

Dr. MERKLE. There is not any very easy comparison of that. That sort of electrical machinery is notoriously heavy per unit of power transmitted through it compared to internal combustion machinery, turbine machinery, and the like. I am not sure this has to remain eternally so. This would be a nice field for research, but it is a research that would not specifically have to be directed toward space travel.

Senator HICKENLOOPER. I was thinking about under the present concept, the magnitude of operations, size, weight, and that sort of thing.

Dr. MERKLE. These things can be adjusted to suit your fancy. What really counts is not how many thousands of horsepower or millions of horsepower, but horsepower per pound of structure. This is the kind of thing, and I have already given you the kind of an answer—for an ion rocket working in the neighborhood of a horsepower per pound you can extract a reasonable mission. If you want to go as far as Jupiter and if you are willing to take off from an orbiting space station. Incidentally this kind of device cannot take off from earth's surface, and probably never will.

Senator GORE. You mean ion?

Dr. MERKLE. Ion rocket.

Senator HICKENLOOPER. I suppose it is pretty much in theory.

Dr. MERKLE. That is pretty much in theory; yes. These types of considerations have been made with very limited manpower, and so far we have not found anything particularly attractive that would indicate one would want to put a lot of horsepower into it in the near future.

However, I would agree with Dr. Ulam that, in general, it is very nice to have a lot of people—a lot being 5 or 10—at a given laboratory seriously considering possibilities, particularly from the viewpoint of delineating the areas of the possible with the existing science.

You see this is not a matter of inventing devices; it is more like the situation that prevailed in about the year 1700 when the first law of thermodynamics was vaguely understood by some and not at all by others, and all the inventors in the world were trying to invent a perpetual motion machine. A lot of brain power went into that. What you have to go after in that case is the fundamental limiting of matter and energy, which sets the limit of what you may consider.

Senator GORE. You find yourself in agreement then, as I understand, with Dr. Ulam and Dr. Bradbury, that what is needed is the creation of some group that can devote its talent and its energy and its thinking to fundamental research in this field of study?

Dr. MERKLE. I would go one step further than they have already gone, and I think they will agree with me on this step: that if you wish to have such a group function effectively, it functions best if it is an adjunct to and associated closely with an existing nuclear propulsion program that gives it the technological resources to draw on, both from the standpoint of the engineering considerations, scientific matters, and possibly experimental determinations of small points as

they come along. It is very hard to imagine a group of 10 or 15 people isolated in a room some place thinking about this thing creatively over any extended period of time. They kind of run dry. But if they are closely associated with a program which is practical and which is operating, that practical program continues to bring up problems and ideas and whatnot which stimulates further development.

Senator GORE. You have the Rover project in mind?

Dr. MERKLE. That is a beauty.

Senator GORE. Or Ramjet?

Dr. MERKLE. Ramjet does stimulate thinking of this sort. It gets one acquainted with the power densities at which you can run materials, for example. It gets you thoroughly acquainted with the neutronics of reactors. It browbeats you with heat transfer problems so you have a feeling for them in your bones. Many inventions you can cook up on a sort of theoretical basis fail because you overlook some very perfectly obvious thing that is known to the guy across the hall, so to speak. So you need to have the guy across the hall who is working in these various areas all the time so you can ask him questions in his particular sector.

Representative VAN ZANDT. Would you, therefore, suggest that in addition to a group functioning at Los Alamos there should be another group functioning at Livermore?

Dr. MERKLE. Of course, being from Livermore, I would suggest such a thing certainly. Incidentally, I think it is a very good thing, and we are doing a little bit.

Representative HOLIFIELD. Based on the same principle you just stated?

Dr. MERKLE. Based on the same principle, and it has been surprisingly productive for the amount of effort that has gone into it.

Representative HOLIFIELD. This does not really take a great deal of money at this time to do this type of work, does it?

Dr. MERKLE. A man-year at Livermore costs about [deleted]. If you were to devote six men to this thing, that would be a very large effort at this stage of the art.

Representative PRICE. How long do you think it will stay in the imagination period and until it will start in the hardware stage where you do need a lot of men?

Dr. MERKLE. I think the imagination stage is essentially the mapping period. What we are really trying to find out is the nature of the terrain in which such inventions are possible and the nature of the terrain in which such inventions are not possible, the latter being the heavier part of the effort. It is almost as important to know what you cannot do with existing physics as it is to try to invent what you can do with it.

This kind of stage might last a long time or a short time; it is hard to predict when something might turn up. When it turns up, then it is time enough to worry about expanding some kind of a hardware program around it.

As I say, at the present moment we see nothing at Livermore at any rate which would justify a hardware program at all. It is still a study project, maybe a few laboratory type experiments. We are doing one on the centrifugal separator concept, for example.

Representative PRICE. Would the same be true at Los Alamos, Doctor?

Dr. BRADBURY. I would agree very much, yes.

I think one thing is apparent in the time scale. You will have to solve the Rover problems first. That problem, as you heard this morning, is a problem which is pointed toward feasibility in the early sixties. Once you have solved the Rover problem, per se you have automatically at your hands the way to make a massive satellite; once you have a massive satellite you can go to the moon.

Then you can have any solar system type of satellite operation you want to do. I will not be optimistic and say you can get back to the earth. We are pointing at a time scale then for satellite type of operation—I mean massive satellite—some place, it seems to me, in the sixties.

Representative PRICE. You say then the space ship is tied directly to nuclear propulsion?

Dr. BRADBURY. The first space ship.

Representative VAN ZANDT. Primarily Rover?

Dr. BRADBURY. Nuclear propulsion, which is Rover. The kind of thing I am talking about is something which will do more exotic things, go farther or faster, something of that sort. It is a thinking operation, an idea operation.

Representative HOLIFIELD. Then if there was a stronger concurrent effort along this line, that could proceed without any deletion of your people from existing projects, it would more or less give you another phase to think about as you go along in the Rover project?

Dr. BRADBURY. It is the next step.

Representative HOLIFIELD. Can you do something concurrently if you have this project in mind as you go along on this other trail?

Dr. BRADBURY. Right.

Representative HOLIFIELD. So you do not have to wait until the end and then start?

Dr. BRADBURY. That is what we are trying to avoid by adding to the effort now, the massing of effort you describe. We are trying to do that now. The effort at Los Alamos, at least, had to decrease almost to zero—not quite—to put the two parallel concepts for Rover into being, and with the funds we are talking about for 1959 we will again put it back into very active operation by adding people.

Dr. MERKLE. I would like to make a point here. I think there has grown up a small confusion about these matters of space travel. I said a little bit earlier that if you wish to confine your attention within the solar system planets lying near the earth, principally Mars and Venus, and also a satellite on the moon, that the Rover system in a double stage version will do anything you want. That is a fairly firm statement, and it carries the usual provisos. Assuming that the Rover program is reasonably successful—and I have no doubt it will be—the only question is when will it be. And that could be a fairly long question. Therefore, one does not need to reach into the area of exotic propulsion schemes in order to do more space travel than any of us here will ever live to see.

I think this point should be firmly established. The Rover device is a very good device for space travel. At this stage of the game you do not need a better one, and in all probability for many years to come you will not be able to find a better one.

This is part of the mapping operations. We have a few probes out into this vast unmapped terrain, and those probes when they come back always keep saying, "Yes, but Rover will do it too and for not any more money, and a lot more certain technology." It is this kind of thing.

So if you are really talking seriously about landing a man on the moon or landing a man on Venus or landing a man on Mars, which is an enormous mouthful of undertaking, you need not wait until someone invents an ion rocket, or an exotic propulsion scheme. If you want to do it, the concepts are with us now. I think this point kind of gets lost.

Senator GORE. Let's look at it in a little different way. Suppose your aim is not to land a man any place but to give him some controlled mobility in space. Would not what you have just said apply with equal truth?

Dr. MERKLE. It would apply with equal truth; that is, if you wish to have a multistaged rocket system, for example, and let us have Rover as the first stage, a big Rover, which is capable of throwing this thing onto a very high orbit. And this is not much harder to do than the sputnik orbit. Once you make any orbit, you have got practically all of them made.

Senator GORE. Once you develop a nuclear reactor or engine that will put a missile into an orbit, then you have got this question of mathematics and dynamics to develop a different sized one?

Dr. MERKLE. That is right.

Senator GORE. Go ahead.

Dr. MERKLE. That is to say 90 percent of the problem is done when you put a very big satellite on orbit. The remaining part, to be able to steer about in space, taking your time while you are doing it, can be handled by both chemical and nuclear systems.

Senator GORE. By some supplementary source of energy?

Dr. MERKLE. By some supplementary source of energy, Senator, in that day you would also know how to do. It requires no exotic new invention for that either. The lovely thing about having once gotten on orbit is very little energy is required to move you any place else if you are willing to wait a while.

Representative PATTERSON. Is there any theory that states after you get a certain distance from our earth in space then the atmosphere becomes comparable to the one we live in now?

Dr. MERKLE. I am not sure I quite understand your question.

Representative PATTERSON. I do not know just how to put it myself.

Dr. MERKLE. Let me put it this way: The earth's atmosphere which you are currently breathing gets thinner and thinner as you increase the distance from the earth.

Representative PATTERSON. When you arrive at a certain point, then does it reverse itself?

Dr. MERKLE. No, indeed, sir. After you get up a few hundred miles the atmosphere disappears and it never again reappears. Space is truly empty.

Representative PATTERSON. Then is there a possibility of going beyond space when you say a rocket that goes to the moon? What is the atmosphere, if known, within the area of the moon?

Dr. MERKLE. On the moon there is no atmosphere; none.

Representative PATTERSON. That is what we think now?

Dr. MERKLE. As far as astronomical observations can carry it, and they are quite good, there is none. On the other hand, on Mars there is an atmosphere which in composition is a little less desirable than the atmosphere at the top of Mt. Everest. On Venus there is fairly dense atmosphere, but it is masked from view by heavy cloud cover and its composition is not known. We do not know whether there is any oxygen on Venus, for example. There is some on Mars—presumably not enough to support a human being to try to breathe standing on the surface of the planet.

But these atmospheres are like thin skins on the surface of the planets themselves, and between the planets it is just nothing at all for all practical purposes.

Senator GORE. Doctor, how much of this rocket missile research is being done by Aerojet or other private companies? Or is it all being done by the Atomic Energy Commission?

Dr. MERKLE. You mean investigations into possible—

Senator GORE. I mean exploratory research that will eventually give us rockets and missiles and these satellites. Is all of that scientific work being done now by the AEC and its agencies, or are private companies contributing something to that?

Dr. MERKLE. So far as I know—and I may not know about all of the effort—there is the Rover effort at Los Alamos; there is the Pluto effort at Livermore, both devoted to nuclear propulsion. There are pieces of nuclear propulsion efforts at at least two other commercial contractor establishments supported by the Air Force funds, I believe, and there are any number of individuals who have, as a hobby, been considering these matters—some at commercial organizations, some at universities, some at national laboratories, and the like.

Senator GORE. The preponderance of the work is being done by the AEC?

Dr. MERKLE. I would say the preponderance of the work is being done under AEC control, yes.

Colonel ARMSTRONG. I would like to add to that, if I may, we have contracts out of General Keirn's office at AEC with North American, Rocketdyne, and with Aerojet, which contracts are to do work on the components beyond the reactors which are being worked on at Los Alamos and at Livermore. So we have a partnership arrangement here, whereby those who are competent in the nuclear field are working on the nuclear field and those who are competent on the pumps and tanks and things that must go along with them are doing that.

Senator GORE. Thank you.

Representative PRICE. Thank you very much, Dr. Merkle.

Dr. MERKLE. Thank you.

Representative PRICE. Now the committee will hear from the representatives of the NACA. The AEC people who desire to leave may do so, but you are perfectly welcome to stay around if you want to.

We will hear from Dr. Silberstein, Dr. Evvard, and Dr. Rothrock. Which one of you gentlemen will handle the presentation to the committee?

**STATEMENT OF DR. ABE SILBERSTEIN, ASSOCIATE DIRECTOR,
LEWIS FLIGHT PROPULSION LABORATORY, NATIONAL ADVISORY
COMMITTEE FOR AERONAUTICS**

Dr. SILBERSTEIN. I am Abe Silberstein, and I will make the formal presentation.

Dr. Evvard and Dr. Rothrock accompany me.

Representative PRICE. Dr. Silberstein is associate director, Lewis Flight Propulsion Laboratory. Is that right?

Dr. SILBERSTEIN. That is right; NACA.

Representative VAN ZANDT. Is that at Cleveland?

Dr. SILBERSTEIN. That is right; Cleveland.

Representative PRICE. You may proceed, Doctor.

Dr. SILVERSTEIN. Not having been here for some of the other discussions today, I do not know how much of the material I present will overlap what you have already heard and how much will disagree with what you have heard.

Representative PRICE. Some of the material may be overlapping, but we would like to know what your organization is doing in the program. In that sense, then, it will not be overlapping.

Dr. SILBERSTEIN. I thought that I would go through some of the concepts of space flight, bringing out some of the important items that I think need to be clarified. Perhaps these have been brought out already, but let me repeat them.

We have two major phases of propulsion. This is a subject NACA deals with at its laboratories, and Lewis Laboratory, I think, is the foremost laboratory in the country in aeronautical propulsion. We have worked with all the booster engines and rocket engines coming along within the propulsion scheme, with the possible exception of the Rover project. We are working in the nuclear engine field.

In space propulsion, which is the principal thing, there are two main phases. One is the booster phase. We have to have some systems to put objects into the satellite orbit, and these will generally be of impulse character. By impulse character, I mean that the thrust for each stage will be delivered in a major pulse, so that the rocket will reach a speed, for example, of 25,000 feet per second, which will put it into an orbit around the earth.

Once you are in this satellite orbit you can go on to an entirely different type of propulsion system. Then you can go to what we call a low thrust propulsion system because the gravitational force is now balanced by the centrifugal force associated with your path around the earth. A satellite orbit is, therefore, a gravity-free system and no large forces are required to overcome gravity. Therefore, we may accelerate the vehicle with very little force.

TYPICAL SATELLITE TRAJECTORY

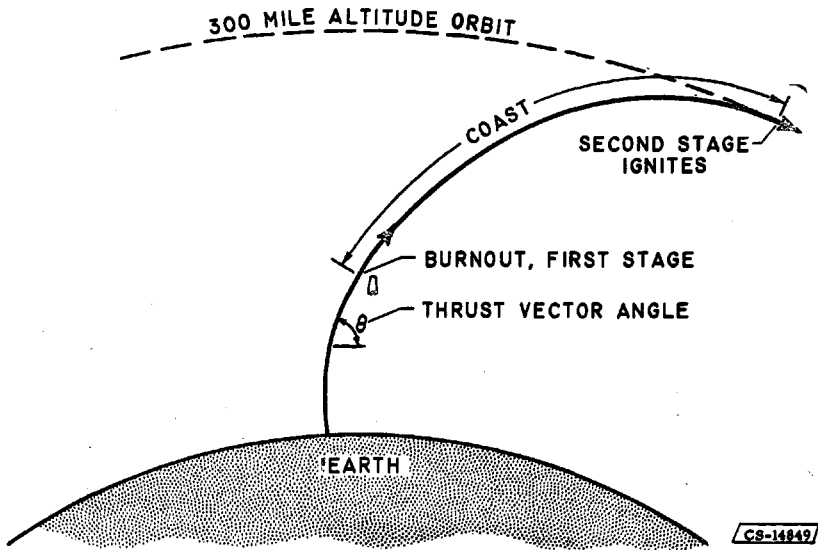


FIGURE 1.

I will now refer to figure 1.

This initial phase, which I will discuss first, I call the booster phase. In this phase you are on the earth and you are going to take a path up into some type of an orbit around which you will act as a satellite. This orbit, of course, can be at any arbitrary altitude. I have shown 300 miles here.

For this phase we are going to use some form of impulse propulsion. It can be chemical propulsion, such as the Russians used to put up their sputnik, or it may be the nuclear propulsion system, such as the Rover system as has been recently described here, I gather.

It is quite clear now that there are chemical systems possible for this job of boosting into the orbit that can provide us very much larger satellites than we are presently thinking about. These are advanced chemical systems. I would like to show you some of these very briefly.

A very important one is a combination of fluorine and hydrogen in a chemical rocket. We burn these materials in the rocket and provide what we call high values of specific impulse. That is, we get a lot of thrust for each pound of fuel we burn.

The range or load carrying capabilities of the rocket go up approximately with the square of the specific impulse. So if you double the value of the impulse it takes four times as much load. This gives us great possibilities for taking quite high loads in high impulse rockets.

The work we have been doing recently is to study fuels that have high impulses.

It seems to be quite clear that in a very short time we will be able to get close to theoretical values. These fluorine-hydrogen rockets have an overall density that is not much different from the present LOX-JP rockets we are using for the missile program.

Representative HOLIFIELD. Are you planning to differentiate between liquids and solids in your presentation?

Dr. SILBERSTEIN. In this presentation I have not, but I can discuss it if you choose.

Representative HOLIFIELD. Just give us a little bit of a comment, if you will. I know your difficulties in your liquids. I understand there is less difficulty in the solids. Could you comment on that?

Dr. SILBERSTEIN. Yes, that is true. This is the present state of the art. There will always be more difficulty in reaching these very high values of specific impulse no matter whether you go to a solid or a liquid. However, in attempting to take large loads into satellite orbit and to really advance this field rapidly, we have to take aboard the difficulties of the fuel when we do it. In other words, the difficulties, for example, of handling hydrogen and fluorine I do not think are of the same order of magnitude, either from a development point of view or from a use point of view, as those taken aboard when you take on the Rover program. They are of different order.

Representative HOLIFIELD. Let's confine it to solids.

Dr. SILBERSTEIN. Current solids have no chance of getting up into these high values of specific impulse.

Representative HOLIFIELD. Do you not think it was a solid the Russians used?

Dr. SILBERSTEIN. I do not know, sir. I do not know.

Representative HOLIFIELD. Would you be inclined to speculate? Most scientists I have talked to speculate that it must have been a solid.

Dr. SILBERSTEIN. I really have no basis for making a judgment.

Representative HOLIFIELD. I was not here this morning. They say that the scientists testified this morning it was more than likely liquid.

Dr. SILBERSTEIN. I would guess the liquid, but I have no basis for it. It would be pure guess.

Representative HOLIFIELD. All right.

Dr. SILBERSTEIN. Let's go on now.

If we are going to take a load into a satellite orbit, the use of the more exotic propellants can greatly reduce the gross weight of the rocket you are sending up, both with respect to the present fuel that we are using for our ICBM's and IRBM's, and with respect to future solids, the best we have been able to conceive so far.

I am not saying the solids are ended here, but I am saying that this is the state of research right now. The hydrogen-fluorine rocket is about one-third the gross weight of conventional liquid propellant rockets and anticipated solid rockets. That is the reason we are very much interested in the hydrogen-fluorine combination and see it as a very potent method for carrying substantial loads into an orbit, and I think preceding the possibilities of doing it with nuclear power.

I think the time scale is all important here, and I think one leg of this overall program needs to be stressed.

Representative VAN ZANDT. Doctor, do you think this combination of fluorine and hydrogen is the final combination of liquid fuels before you move into the nuclear power?

Dr. SILBERSTEIN. Yes, I think it is. One nice thing about chemical propellents is that you can calculate. We know the whole spectrum of chemistry now. We do not think we are going to get new elements in the thing. You can calculate the heats and energies and predict the values very accurately. I say yes.

There is one further opportunity, and that is to use ozone with hydrogen instead of fluorine. This is very questionable. I doubt perhaps whether we will try it. We are doing a little bit of work on it, not throwing it out. But I doubt if it will come through.

Representative VAN ZANDT. What about the recent announcement the Russians made concerning a new type of chemicals for fuel purposes?

Dr. SILBERSTEIN. These were garbled press reports, I think. There was mention of boron. How it got into this thing I do not know, but I think boron does not fit into this picture too well.

Representative VAN ZANDT. They mentioned chlorine and boron, did they not?

Dr. SILBERSTEIN. Newspaper reports I read mentioned boron. I think it was the interpretation by our own press people.

Representative PRICE. Did one large American chemical manufacturer announce some work in the field of boron, and that that was the latest?

Dr. SILBERSTEIN. There is some work going on. This is for gas turbine engines. There is a possibility in solid rockets using some boron hydride, and this increases the impulse of solids up to perhaps a value of 270 as compared with about 370 for high energy liquid propellants.

Representative PRICE. When you get into this rocket stage boron is not in the picture; is that right?

Dr. SILBERSTEIN. It can be in a small way in the solid field, and is in the picture, but not in a big way.

SPACE PROPULSION APPLICATIONS

- 1 INCREASE LIFETIME OF LOW-ALTITUDE SATELLITE
- 2 CONTROL AND ALTER SATELLITE ORBITS
- 3 LUNAR AND INTERPLANETARY EXPLORATION
- 4 AUXILIARY ELECTRIC POWER

C-46483

FIGURE 2.

May I have the next slide? (Fig. 2.)

These are the kinds of things we are going to want to do with space propulsion applications. I think you have discussed some of these and I will not spend much time on them. We are trying to increase the lifetime of low altitude satellites. We want to control and alter satellite orbits, and think a little about auxiliary power.

MOON LANDING

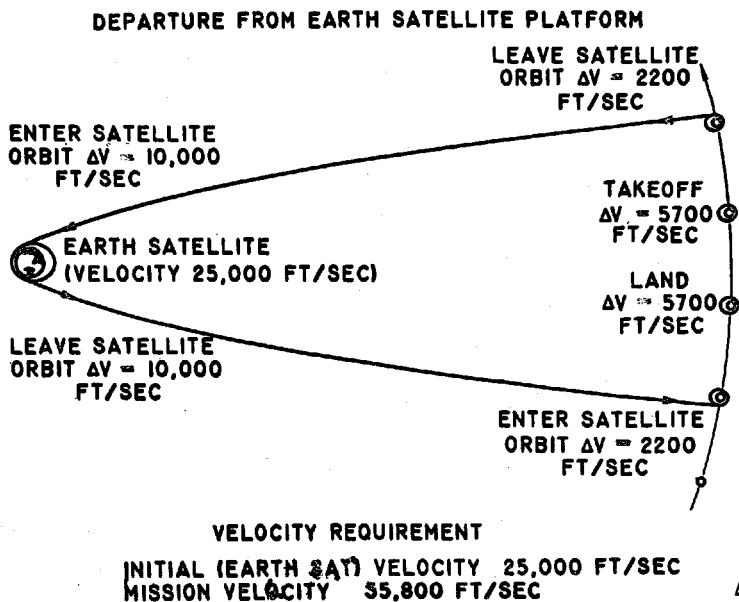


FIGURE 3.

Let's go ahead to figure 3.

This moon landing I put on here simply to show you some of the velocities we are after. For satellites it is 25,000 feet per second. If we are going to land on the moon and do a reconnaissance flight around the moon, we can start from a satellite orbit and leave with velocity of 10,000 feet a second. We have already got 25 and if we add 10 it gives us 35, which enables us to go to the moon.

Now if we reach the moon, when we come to the moon we have to put in another velocity hereof 2,200 feet a second for orbiting around the moon. We have to carry this capability in the rocket fuel with us to provide this velocity, and if we wish to land we have got to put another velocity, the component of 5,700 feet per second. This is slow-down velocity. We got out of the gravitational field of earth and are now going to drop into the moon unless we slow up. We are being attracted now by the moon and we have to push against its gravitational field.

To get back to earth, we have to again add another 7,900 feet a second in two steps: 5,700 to get into the satellite around the moon and 2,200 to get back to the earth satellite. I simply showed the

numbers in order to give you a feeling for the kinds of velocities we are talking about in these missions.

I mentioned there were two different types of propulsion once you are on orbit. There is the impulse type where you put all the energy in at one time such as we are doing in ICBM and IRBM. These are nuclear rockets or conventional rockets. There is also the very low thrust system in which a constant small amount of energy is put in continuously. Figure 4 shows that with the orbit required for a constant thrust system to get to the moon, it might take 83 days. You would not use this system in going into the moon. You have to circle around very slowly because actually the thrust force you are putting into that vehicle is only one ten-thousandths of its weight. So you can see it is a very small force in terms of its weight and therefore, velocity is increased very slowly.

CONSTANT-THRUST TRAJECTORY FROM SATELLITE ORBIT

THRUST/WEIGHT = 10^{-4}

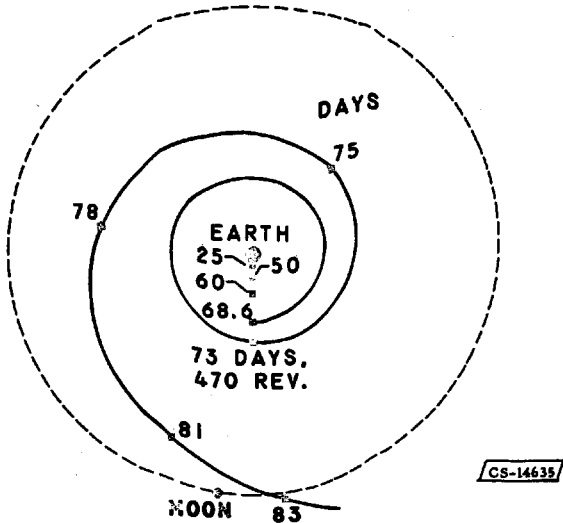


FIGURE 4.

For example, in ICBM's, to take off the ground we put a thrust in that is 1.4 times its weight. In the low thrust system the thrust to weight ratio is 10 to the minus four or one ten-thousandths. So you can get a feeling for this. However, for missions other than perhaps going to the moon these things will become very important.

I think all of you are familiar with the fact that if you are going to fly an airplane or anything else, and depending how far you want to fly it, there are two terms that are important. One is the weight of the vehicle and the other is the weight of the fuel.

If we want to stay in the air a very long time, such as would be required for a mission to Mars, a thousand days or twelve hundred days, we want a low specific fuel consumption, that is, we want to

burn a very small amount of fuel; and we do that by using the low thrust such as the nuclear-electric ion jet. However, it must be remembered that thrust is the product of the jet velocity and the rate of fuel consumption. Therefore, in order to obtain an equivalent thrust per pound of propellant consumed, it becomes necessary to increase the jet velocity in direct proportion to the reduction in fuel consumption. For example, an ion rocket, with 1 percent of the fuel consumption of a chemical rocket, would require a jet velocity 100 times greater in order to give an equivalent amount of thrust per pound of propellant.

To produce this high jet velocity we need very heavy electrical machinery because we must supply a lot of electrical power to accelerate the ions. Consequently, the weight of an ion rocket will be very large and this is why we get thrust to weight ratios so low as one ten-thousandth. The justification in going to these low thrust, low fuel consumption engines is that for long space flights we must figure on staying out for a long time.

Now for short missions—by that I mean missions such as circumnavigating the moon—there is no purpose in using an engine with this type of characteristic (the ion rocket). For missions such as the Mars mission perhaps you can show a good relationship between the low thrust engine which accelerates very slowly and gradually takes you out to the Mars orbit.

The point to make, here, is that we have a whole spectrum of power flights with all of the different characteristics. The ion type propulsion systems have their own characteristics—very low specific fuel consumption, do not carry much fuel along. What they do have in high initial weight is compensated by the high specific impulse.

The impulse rocket, on the other hand, burns many times more fuel than those rockets with the higher initial weight. That is always the comparison to make. Selection of powerplant will be determined largely by the length of flight we want to make. Later I have some mission studies to show how our studies at Lewis Laboratory tend to weigh these things.

The next slide, figure 5, shows a comparison of two different ways of going to Mars. In one case we use the impulse type rocket, and in the other we use the constant thrust.

You will see here for the low thrust system it takes 127 days to escape from the earth satellite orbit out into the Mars orbit. Then we coast down for 268 days with a total time of 1205 days to complete the journey.

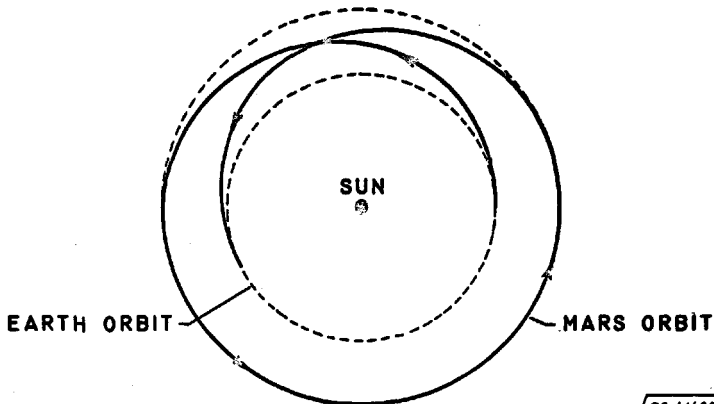
With the impulse rocket it takes 915 days. So you can see there is not a great deal of difference in total time, largely because the waiting time comes in here. You have to wait until Mars and earth are in proper relationship to each other to come back.

Representative VAN ZANDT. Do you think it is worth taking out travel insurance?

Dr. SILBERSTEIN. There are other ways of going in which you can have a shorter time than this, except the loads you can carry will be less per pound of air frame you have. That is the thing you are always trying to weigh.

May I have the next slide here? (Fig. 6.)

FLIGHT PATH TO MARS



TIME IN DAYS FOR MARS JOURNEY

CS-14638

SYSTEM	ESCAPE FROM EARTH ORBIT	COAST	DESCENT TO MARS ORBIT	WAIT	TOTAL
LOW THRUST ($F/W_0 = 10^{-4}$)	127	268	85	245	1205
IMPULSE ROCKET	—	268	—	415	951

FIGURE 5.

EFFECT OF POWERPLANT WEIGHT ON PROPULSION TIME FOR MARS TRIP

(PAYLOAD = $0.5 \times$ TOTAL INITIAL WEIGHT)

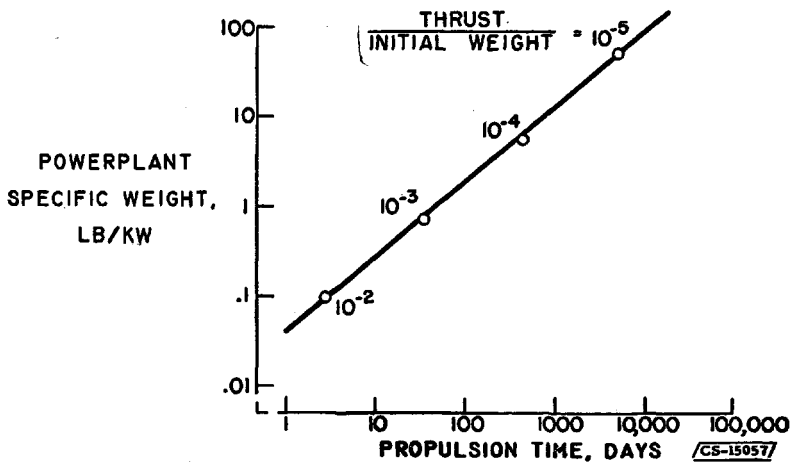


FIGURE 6.

Here you get a feeling for time. The propulsion time I was talking about was about 1,000 days with a thrust to initial weight ratio of 1 to 10,000, one pound of thrust for each 10,000 pounds of space vehicle weight.

You can shorten the time if you slide down this curve and get higher thrust value and get propulsion time down quite a bit. However, you are going to find sooner or later that you are not going to be able to carry the payloads you want to carry.

Representative VAN ZANDT. This schedule is based on chemicals?

Dr. SILBERSTEIN. No; this is based on basically all systems.

Representative VAN ZANDT. All systems?

Dr. SILBERSTEIN. Yes. Let's go ahead now.

Now, since these electrical propulsion systems are the agreed key to all the ion plasma systems, I thought I would list for you the basic energy sources we have to work with, the types of generation we can use, and the actual accelerators or thrust generators. They are shown in figure 7.

ELECTRIC PROPULSION SYSTEMS

BASIC ENERGY SOURCES	ELECTRIC POWER GENERATORS	THRUST GENERATORS
CHEMICAL	CHEMICAL BATTERIES	ELECTRIC ARC
RADIOISOTOPES	RADIOISOTOPE BATTERIES	CHAMBERS
SOLAR	THERMOPILES	ION ACCELERATORS
RADIATION	SOLAR BATTERIES	PLASMA
NUCLEAR	TURBO-ELECTRIC	ACCELERATORS
FISSION	GENERATORS	PHOTON
NUCLEAR	INDUCTION FROM	ACCELERATORS
FUSION	MOVING PLASMA	

C-46482

FIGURE 7.

Basic energy sources—chemical, radioisotopes, solar radiation, nuclear fission, and nuclear fusion. These are the types of methods we generate power by, either by radioisotope batteries, thermopiles, solar batteries, turboelectric generator, induction from moving plasma. Then we accelerate the fluid by these means: electric arc, ionic accelerators, plasma accelerators, or photon.

This covers pretty much the range of possibilities we see ahead. However, there are many things concealed within the separate objects listed.

Senator ANDERSON. Do you not think we ought to have copies of those charts for the record in order to make it possible for us to reconstruct some of the things you have said?

Dr. SILBERSTEIN. You can have copies of the charts along with a description of the whole thing. We will be very happy to let you have them.

Now let's try to get a little closer to descriptions of some of these things to see what you might look like. So far they are pretty much words. Go ahead with the next slide. (Fig. 8.)

We are talking first about the kind of electrical power sources that are fairly common that we know of. What I have plotted here is the weight of these systems in pounds per watts of power, against the number of days that you are going to use them. Because if you are going to be, say, in a satellite flight continuously circling the earth, it may be that you need power for a long time.

For example, we have a feeling that the source of power for Sputnik went out after so many days. We may want to go longer than that. This curve shows, of the various systems we can conceive, which might be the most effective.

We have listed here fuel cells, thermopile, and solar batteries which generate electrical current as a result of exposure to radiation from the sun, shown in two ways: one, in which they are getting sun half the time, and the other full time, which is a function of whether or not they are being shielded by the earth in their passage.

LOW POWER ELECTRICAL SOURCE

CONTINUOUS OPERATION P_0^{210} ENERGY SOURCE

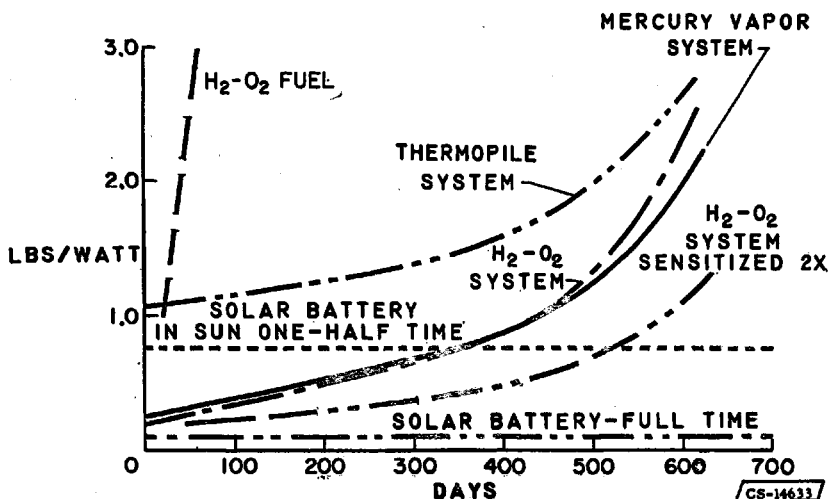


FIGURE 8.

Representative VAN ZANDT. At that point, in regard to Sputnik I and II, have you any information that this type of battery was employed by the Russians in those 2 satellites?

Dr. SILBERSTEIN. The only information I have is based on second-hand information obtained as a result of discussion of our director, I think, with one of the scientists, Russian, who claimed for Sputnik I they were putting in 80 pounds of battery. With 80 pounds of battery, the thing calculates about right from this chart for the length of time it ran.

Representative VAN ZANDT. In other words, the answer is yes?

Dr. SILBERSTEIN. The answer is yes, if my information is correct. It is not factual. So it is my feeling that they used a battery system. These batteries, of course, are very much more advanced.

I want to call attention to one point. You see what we have here. We have values of 2 and 1 pounds per watt. These values are far, far too high. One pound per watt is a thousand pounds per kilowatt for this type of equipment.

In order to make these things fly, these space systems fly, we are going to need to get the whole system to values closer to 10 pounds per kilowatt, or lower than that if we can.

So that these systems for long-term use for primary propulsion for space vehicles are basically out. None of these systems shown here will provide it. However, they will provide and can be used for very small powers you might need for instruments or something like that for reasonable lengths of time.

Representative VAN ZANDT. The question I asked you a moment ago, did I understand your answer to include these batteries are solar?

Dr. SILBERSTEIN. No, no. My answer was they were cells more like the chemical cells we have now. The most advanced type in conventional batteries.

Representative VAN ZANDT. Thank you.

Dr. SILBERSTEIN. Let's get around to some of these arrangements for generating power. I think probably these have been discussed with you.

In figure 9 we have a system in which we have a nuclear reactor here, and the nuclear reactor has a liquid metal passing through it to cool it and take out its heat, passing through the upper loop system. We could consider the upper loop through the reactor and heat exchanger, perhaps, to be lithium, and it might be sodium in the lower system. We take the hot material, which might be hot sodium vapor, and expand it through the turbine and take work out of it. As we take work out of it, of course, it will cool down some but there will be a lot of heat left in, and we will have to take the material over through a radiator to radiate this heat out into space, and then we can return this material back to the cycle? How?

We have a shaft here in this turbine. We pump the material back through the cycle again and also get power left over that we can drive the electric generator again.

This system is able to generate electric power which we are going to need in all forms of ion and plasma accelerators we are talking about. Somewhere or other we have to have an electric machine in here. This is one way to do it.

As you all know I think—and this remark was made a few minutes ago—electrical systems are heavy as now designed. But no effort really has been made to lighten them because there has been no need for it. However, I am sure that their weight can be reduced to a quarter very easily by simple design, and perhaps by breakthroughs as a result of research we can reduce the weights much below this. There are possibilities that have been suggested at our laboratory, and I think other places, for reducing the weight by concepts of superconductivity, reducing the temperatures of these materials down to the point where the resistance of material reduces practically to zero, or to zero. These studies are for research, and I am sure we are doing some work in it now and I think others are. I think we will see some progress ahead as this work is reported.

I think we can count on reducing the weight of these things markedly.

SIMPLIFIED CYCLE ARRANGEMENT TWO LOOP

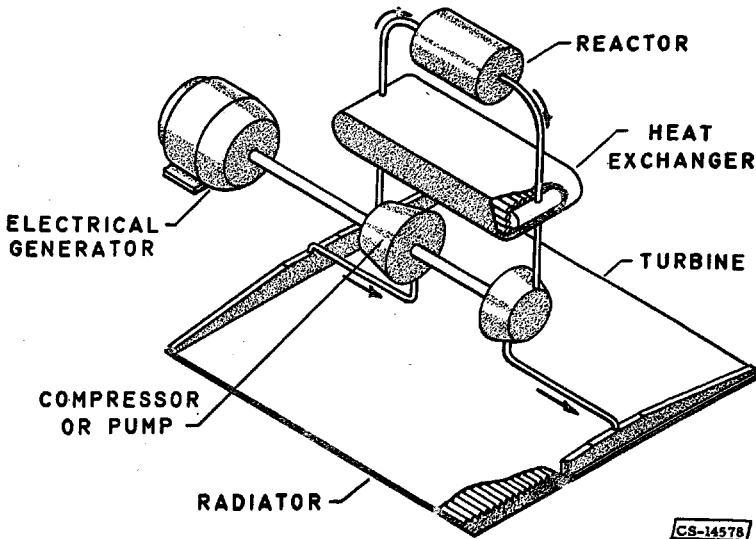


FIGURE 9.

The reactor system here is not a great advance in this case above our present reactor technology. Its weight is not as critical as you might think because the major weight in the system does not lie in this area.

The next slide, figure 10, shows a hypothetical space vehicle using the reactor cycle just discussed. The reactor component we looked at a minute ago might be at one end of a 600-foot long pole, and since it is gravity-free space you do not have to worry about the weight distribution. You might have to worry about the forces along the axis.

HYPOTHETICAL SPACE VEHICLE

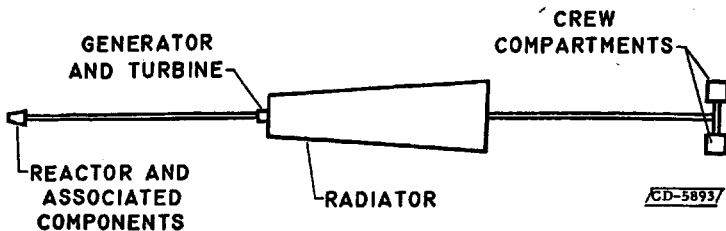


FIGURE 10.

This is the radiator, the heaviest component. We design the shield here for separation of the passengers who are down here in the crew compartments. The passengers might be rotated also to give them some feel of gravitational pull, the component associated with centrifugal force of rotation. That is a detail.

Figure 11 shows another possible method of generating power. We can imagine, of course, that we can get power by taking the sun's radiation, allow it to evaporate a fluid, just as we do in a steam system; take the heat and make steam and drive a turbine with it, and then drive an electric generator. And this is a system for doing it.



SOLAR TURBO-ELECTRIC POWER SUPPLY

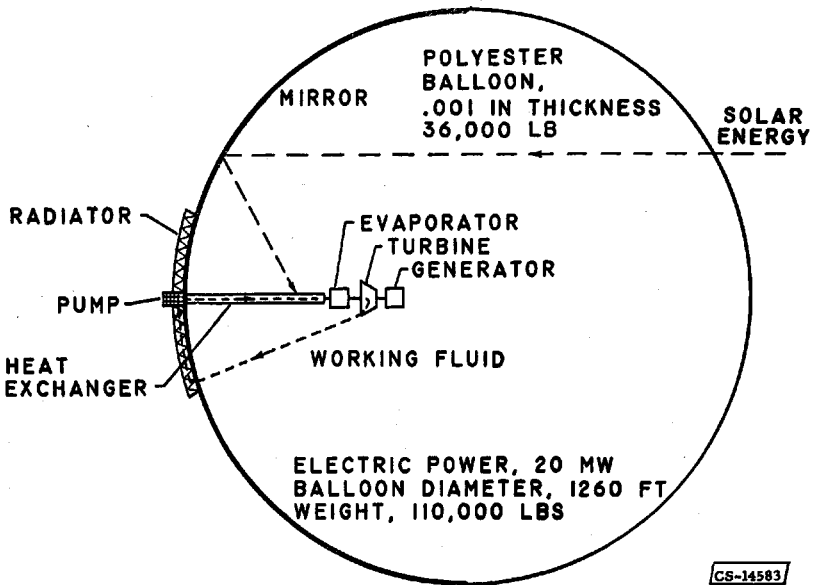


FIGURE 11.

Again, some of these things lead you to wonder whether you are in fact still sane, but we are talking about a balloon here which is one-thousandths inch thick, made out of mylar, and some balloons we are putting up now are not much thicker than that, 1,260 feet in diameter. Total system weighs 110,000 pounds. The balloon itself weighs 36,000 pounds. The sun comes down through the balloon, is reflected off the mirror on to evaporators, and we pick up the sun's energy here and go through our cycle.

Representative VAN ZANDT. At what altitude?

Dr. SILBERSTEIN. This is in space?

Representative VAN ZANDT. In space?

Dr. SILBERSTEIN. Yes. You see, there is quite a bit of power. The sun, if you take the actual watts that are delivered on a square foot of surface, gives off considerable energy. Particularly, in space, you have no absorption by the upper cloud layers. So this system here, if it is a possibility, is a system based on weight.

What we have done is to try to add up, based on our studies—and we carried studies along for sometime—what the competitive position might be. For example, the solar turbo-electric system just discussed appears to be as promising on a weight basis, as the nuclear system.

Representative PRICE. How long have your studies been?

Dr. SILBERSTEIN. We have been working in this area for several years now. The work has been in the study phase, and some of it has gotten into experimental phase. I perhaps will show you some.

Chemistry rocket work, of course, is very old. We have been working in that field for 15 years. The space systems, we have been working for about the last year more intensively, but very casually, just looking around.

Let's go ahead. We have talked so far about generating the electric power through nuclear into the thermodynamic cycle and into electric generators. Now we are going to use the electric power. We have electric power and are going to put it in either a magnetic field or an electrostatic field, and accelerate the particles. Basic components of such a system are shown in figure 12.

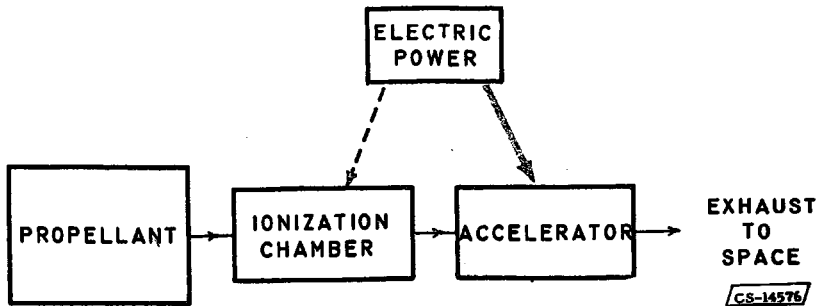


FIGURE 12.

I am going to show some of the things we might use to accelerate particles.

In figure 13 is one system called the ion electron source; due to a man named Stuhlinger it was brought to our attention.

ION AND ELECTRON SOURCE (STUHLINGER)

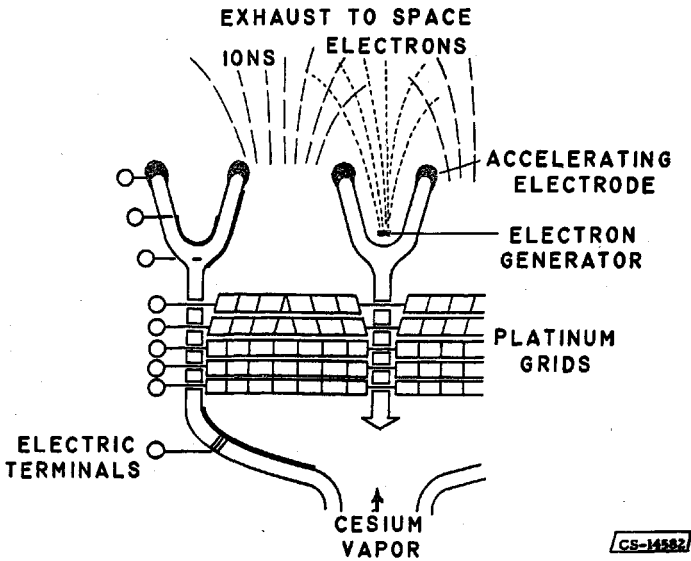


FIGURE 13.

What you do is ionize cesium vapor which passes up through a series of plates, and there is a potential difference between these plates and ions that are formed. The positive particles are accelerated through the plates and out of the jet. Electrons are concurrently discharged from the electron generator.

Characteristic of this system, it is necessary that the space charge due to the positively charged ions issuing from the jet be very rapidly neutralized by electrons. Otherwise we build into space here a charge and cancel the thrust. This system has possibilities. It is in the early stages of its thinking. It requires research and efforts to find out just how effectively you can cancel this space charge by bringing the electrons and ions together—how large a jet you can make and still cancel the charge. There are many scientific problems here. This represents one type of system.

Let me have figure 14. This is another one. This is called Bostick's plasma accelerator. It differs from the ion simply by having both the positive and negative charges together. A plasma is a mixture of ions and electrons. So that here in this generator what we do is to discharge a capacitor across two electrodes to produce an arc. Current flowing through the arc produces a magnetic field. The magnetic field and the current interact to produce a force that accelerates the plasma into space.

There is every reason to believe a system like this will work. We have played with systems like this and feel they do have possibilities—experimental.

BOSTICK'S PLASMA ACCELERATOR

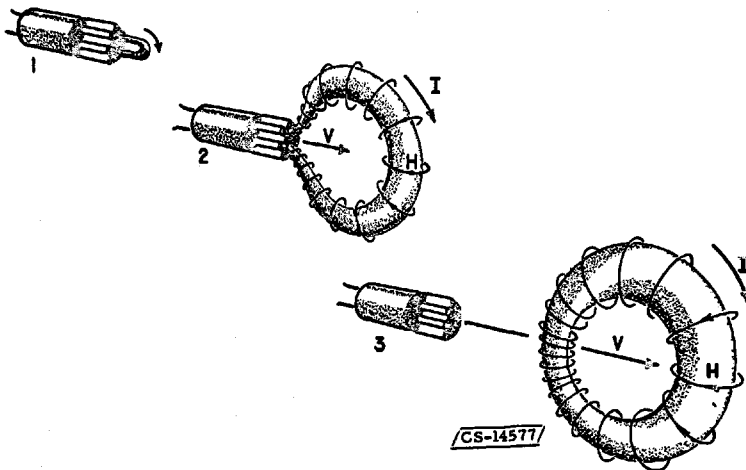


FIGURE 14.

Figure 15 shows another system we are working with now for producing acceleration of plasma and ions. What we do here is take this electric energy we have created and we flash an arc across a section near the right end. This arc travels down two rails and since it is highly ionized it can carry a current, and we use a magnetic field here to accelerate it out the back as a beam. We are experimenting with this system and have investigated it at the laboratory.

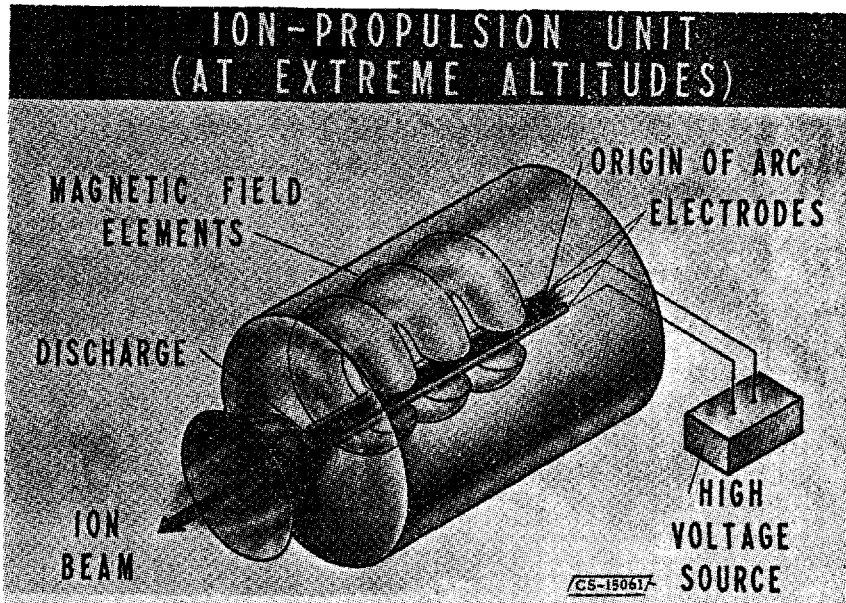


FIGURE 15.

The next slide, figure 16, shows you a small system we built and demonstrates the fact we were getting thrust on it. To do that, we put a pinwheel out to the right. These are the rails, to the left. The ion jet is impinged on the pinwheel and the rotation of the pinwheel indicates that we are getting useful thrust.

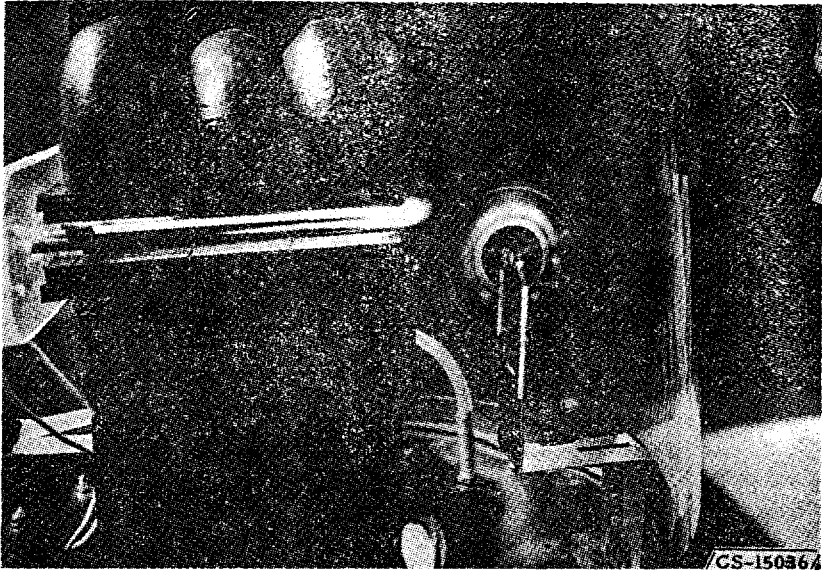


FIGURE 16.

Figure 17 is another system that can be used. We do not look upon it with too much favor. But you can take the current that you generate in this system and cause an arc to form across here between an electrode here and the wall, and then by passing a gas through the system and heating it, we can create a plasma flow.

ARC-JET PROPULSION SYSTEM

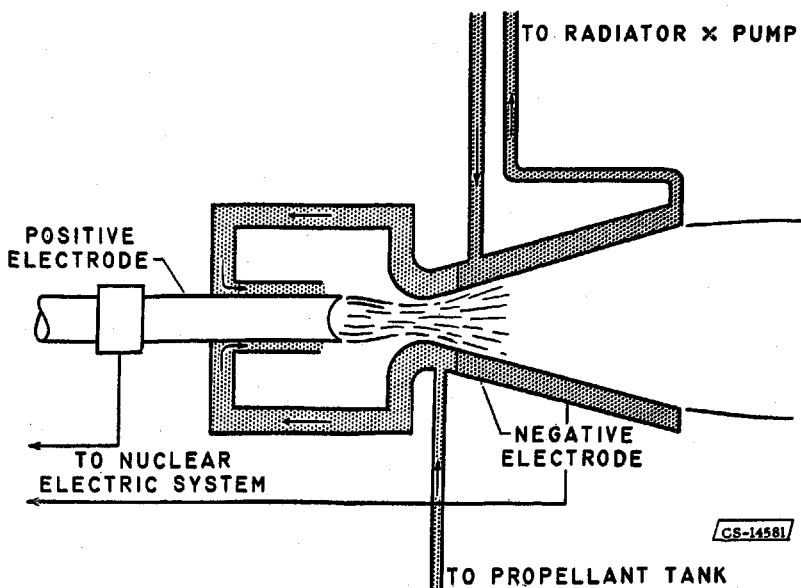


FIGURE 17.

Representative PRICE. Does that have any relation to some the things they are working on in the controlled thermonuclear program, what you have shown us here?

Dr. SILBERSTEIN. In a sense there is a relation. This one has no real relation, but the fundamental principles of the thermonuclear pinch system, I would say, are not too greatly different than the ones showed for the plasma accelerator. In other words, the same principle of carrying a current within a plasma and then allowing it to be pinched down as a result of its magnetic field.

These same things are implicit in the plasma generator I showed you before. There is a relationship. The application is the difference.

Representative PRICE. How do you coordinate the work you are doing with other agencies of the Government that are working in similar fields?

Dr. SILBERSTEIN. We have many means of coordination. The principal one is the subcommittee structure of NACA. The NACA has the main committee and many subcommittees, and on the subcommittees we have representation from all of the military services; we have representatives from industry and the AEC, and these people continually carry on coordination. We have other means of coordination

through our headquarters staff, through visits of our staff to other agencies.

We do, I think, keep in touch. I think other people keep in touch with us.

Our laboratory, I think—for example, last year we had some 4,500 visitors during the year, which gives you an idea there are a lot of people coming in to find out.

Senator ANDERSON. You keep in touch with Los Alamos a little bit, too; do you not?

Dr. SILBERSTEIN. Oh, yes.

Colonel ARMSTRONG. I am a member of one of the subcommittees on rocket propulsion, so I keep them informed what we are doing.

Dr. SILBERSTEIN. Let me have the next slide, figure 18.

There is another interesting thing here. This is called a radioisotope sail. Here we depend upon having a sail which on one side stops the alpha particles given off by a radioisotope, whereas the alpha particles are permitted to travel down in the other direction. Their reaction against the sail, coming out on one side and being restrained on the other, gives you a force which will move the body.

RADIOISOTOPE SAIL

THRUST/SQ FT	1×10^{-6}
WEIGHT/SQ FT ($t = 0.0012"$)	9×10^{-3}
THRUST/WEIGHT (IDEAL)	1×10^{-4}

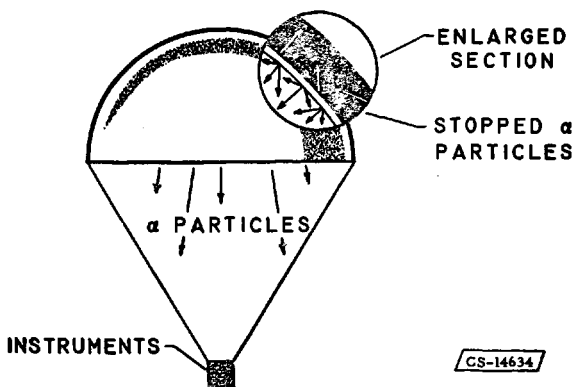


FIGURE 18.

We have calculated the thrust it is possible to reach with this sort of thing. We previously talked about thrust with 10 to the minus 4. This is minus 6. We are talking about thrust of one-millionth of a pound to a square foot of sail. It is very small but you do not have the resistance there.

Colonel ARMSTRONG. Might I interrupt you, sir? We tried this and it worked. We measured the thrust and it worked.

Dr. SILBERSTEIN. Yes; it will work. The question is, is this the best way to make it work?

There are many things that will work. This is the problem we have all the time—you want to get the best one. I am quite sure it will work, but I am not sure it is the best way to do it.

PHOTON SAIL

THRUST/SQ FT	2×10^{-7}
WEIGHT/SQ FT ($t = 0.0005"$)	3×10^{-3}
THRUST/WEIGHT (IDEAL)	7×10^{-5}

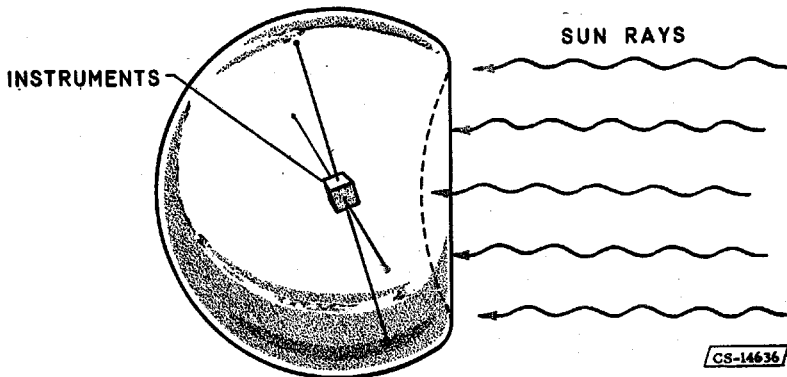


FIGURE 19.

Figure 19 is another one in which you use the sun's rays directly. The sun rays, of course, can be considered as photons that are impinging on this sail and they are driving it. For years this has been a laboratory experiment of having light fall upon a body, and I think you might have observed some of the things that are caused to rotate. If they happened to rotate backwards, that is another thing.

This is another method of propelling yourself in space. Again I do not know how this one—this gets to be a little farfetched, but maybe not. We will have to look and see.

We have tried to put the stuff together that we have been thinking about, to see where all of these different systems fit together, and we took some typical trips we could imagine.

For example, a roundtrip to the moon with an 8-man crew landing and exploring the moon. They had a basic payload of 10,000 pounds and another 15,000 pounds of equipment to help them in their exploration.

We said, what would the overall weight of the system be to do this mission? We looked at the chemical rocket, we looked at the nuclear rocket and we looked at the ion system to do it. In looking at it closely, we found there is not a great deal of difference in weight between the high energy chemical rockets and the best of the systems.

So, for this mission, a mission of this length, which is just to the moon, from an engineering point of view it would appeal to us to try to do the thing by means of chemical rockets because it requires the smallest extension of our present technology.

We could actually do it with chemical rockets, trying to use things that exist, and I think there is a possibility of doing it. Again, it would have to be considered very carefully if going into an engineering project. But certainly we do not need anything very exotic in the way powerplants to conduct this particular trip.

Senator ANDERSON. What sort of lift would you have to have to get that off the ground, this chemical rocket in the very first column? What sort of lift are you going to have to have?

Dr. SILBERSTEIN. For this system you would need about 450,000 pounds of thrust to get it off the ground, that much rocketry.

Senator ANDERSON. About what the Atlas has?

Dr. SILBERSTEIN. Well, the Atlas has about 360,000 pounds at take-off. These are launched from the satellite. These are not from the ground.

Pardon me. I left out a very important statement. It would still be true that it would take that thrust to get them off the ground, but all of these are launched from a satellite.

Senator ANDERSON. In other words, if you can get the platform up, you can then go on?

Dr. SILBERSTEIN. Yes. I am very sorry. I should have made that clearer.

Let's now consider a trip further away—an unmanned Mars trip—satellite to satellite again. Payload, 2,000 pounds. Unmanned, the payload is small.

Here again, comparing the chemical rocket with the nuclear electric ion system, it probably does not pay to go to the more complicated systems. The chemical propellant is about on a par with the ion system for this mission.

Senator ANDERSON. How do you get up to the satellite?

Dr. SILBERSTEIN. From the ground to the satellite you have two choices basically. That is what I discussed in the early part of my talk. Either take them up with chemical high energy rockets or take them up with nuclear rockets.

I think you will find if you take them up with the chemical rockets they will weigh more, the whole system will weigh more, but you will probably be able to do it a little earlier with the chemical rocket, because the chemical rocket is basically an easier job. We have a lot under our belt and the problem is further along.

Senator ANDERSON. It is no problem when something is in orbit up there to take a rocket off and still make connections up there?

Dr. SILBERSTEIN. No; I would say this is a thing that has been demonstrated. I think you need auxiliary power, but this I have not discussed. I only talked on how to get them there. You need the power after you get there to connect them, to rendezvous. You need other power then.

Mr. RAMEY. Could you get from earth to Mars with nuclear power directly?

Dr. SILBERSTEIN. I think so.

Mr. RAMEY. Without an intermediate satellite step?

Dr. SILBERSTEIN. I think you could, but I think it might be—I am not sure of your payload. I do not think we have made that study, have we, John?

Dr. EVVARD. I do not know.

Dr. SILBERSTEIN. I do not recall that study. I think you can do it, would be my guess, but the payload probably would not be high, as high as you would like.

It is on the really long trips where it begins to pay off to go to the advanced systems. Now we are talking about roundtrip Mars expedition with 8-man crew, satellite to satellite, landing and exploration, with total payload of about 110,000 pounds.

For a mission like this, a chemical rocket would weigh millions of pounds, whereas the nuclear rocket and electric-ion rockets would be competitive at weights below one-half million pounds.

You might say this system (nuclear rocket) is further along, and those that argue the other way will say that the nuclear electric system is further along because the nuclear part is greatly easier. I leave that for a matter of discussion. I do not think it can be answered definitively now.

I think that, sir, completes my discussion I have, and I will be glad to answer any questions.

Dr. EVVARD. Could I make one comment?

Representative PRICE. Yes.

Dr. EVVARD. This discussion might suggest that the nuclear rocket is competitive with the nuclear electric system on the estimated initial weight, and hence you would never use the nuclear ion system. I think this was concluded by the previous speaker. However, you must recall that the specific impulse of the nuclear electric ion system is on the order of 10, 12, 14 times as high as it is for the nuclear rocket. So that, if you were going to make more than one trip, you would only have to put one-tenth as much fuel into the sky for the second trip as you do for the first trip.

Senator HICKENLOOPER. Wait a minute. You left me there.

Dr. EVVARD. If you are going to establish, let's say, a street car between the earth and Mars satellite, or satellite to satellite, it takes you roughly 10 times as much fuel by means of nuclear rocket, maybe 12 times as much fuel using the nuclear rocket than it does for the ion propulsion system. Now the total weight is about the same initially due to the fact that there is so much more weight in the generating system. But if you make a second trip, if you go there, come back, and then go again, on the second trip you only need one-tenth as much fuel for the ion propulsion system as you do for the nuclear rockets.

Senator HICKENLOOPER. I will come back some other day.

Dr. EVVARD. You already have the electric generating equipment put up in the sky. So the amount of extra supplies you have to bring from earth up into a satellite for the second trip is roughly one-tenth as much.

Colonel ARMSTRONG. We would like to avoid the filling stations in the sky. We would like to go from earth up there.

Dr. SILBERSTEIN. There are possibilities both ways.

Senator HICKENLOOPER. I still cannot follow what you are saying. If I start my automobile out of the garage this morning it will take so much gasoline to push it, but I come downtown to the office build-

ing and then turn around and go back and start out tomorrow morning my automobile takes a lot less gasoline to get it out of the garage?

Dr. EVVARD. The total weight is, say, 600,000 pounds. I do not remember the figures exactly, that you have to put into the satellite for the first trip. On the nuclear rockets of this 600,000 pounds a substantial portion will be fuel.

Representative HOSMER. Consumable fuel?

Dr. EVVARD. Consumable fuel.

If you made the second trip you would have to replace that much consumable fuel.

Senator HICKENLOOPER. It is the same principle, that the second morning it does not take as much gasoline in the tank to push the car out of the garage.

Representative HOLIFIELD. In the first trip you go up to the top of the hill and on the second you coast back to the garage.

(Discussion off the record.)

Senator HICKENLOOPER. I still want to get this straight. Do I understand the reason it will take a lot less to take this thing off again is that the fuel load is lighter?

Dr. EVVARD. Yes.

Senator HICKENLOOPER. That is the same as the automobile analogy.

Representative HOLIFIELD. When you start from the earth you are starting with gravitation and when you start from the satellite you are not.

Dr. EVVARD. The fuel load for the nuclear rocket is 10 times the load for the ion rocket. Initially this weight is made up in the weight of electrical equipment which, once you got it into the sky, you do not have to put it up the second time.

Representative PRICE. Where do you leave it?

Dr. EVVARD. I think the point is that, perhaps, if you are going to make more than one trip, the ion rocket is still competitive for a Mars journey.

Senator HICKENLOOPER. I think maybe I am cutting through this fog of confusion. I understood the original premise to be if you started out from here and went to the moon and came back here and then took off again and went to the moon it would take a vast amount less to get you up there the second time.

Now, somebody else tells me what you meant first was you take off here and go up to the satellite and take off and come back to the satellite and take off again. I can understand that, but I did not understand that was it.

Dr. EVVARD. From satellite to satellite.

Senator ANDERSON. Before we get confused again, let's start on the next step.

Dr. ROTHROCK. This completes our presentation.

Colonel ARMSTRONG. I think Dr. Silverstein said something that should not be forgotten. He said the machinery that goes into the nuclear ion device is a more complicated situation than that which goes into the nuclear rocket device.

Senator ANDERSON. I want to say this has been a most interesting presentation. I am happy to know there are people who are continu-

ing to think about this even though a great many people thought they did not need to think about it.

Representative PRICE. Do you do development work there on the ions, studies?

Dr. SILBERSTEIN. We—

Representative PRICE. Research?

Dr. SILVERSTEIN. We do basic research at our laboratory, and all we are trying to find out from the studies of this general type is what are the things in which greatest emphasis should be applied, and then we do development work in that area. We are a research organization. There are times we cannot go out on the market and buy generators, ion generators, so we create them for our own use.

Representative PRICE. Do you do theoretical studies on these, Colonel Armstrong?

Colonel ARMSTRONG. The program we put off until tomorrow, secondary nuclear auxiliary power—this is a very small nuclear device producing electrical energy, which is one step along the path he was leading you a little while ago, of then using that for a steering device for steering the satellite in the sky and moving around. This is not a theory, this is something we are cutting metal on now. This we will have tomorrow morning.

Dr. SILBERSTEIN. This whole area is really quite young. I think we all recognize that, and it is going to take a great deal of work all the way through it to pin down these things that we vaguely see, in some cases see better than in others. I think many aspects should be supported. Without it, I think there will be very little progress.

These things seem to be a little bit far off, but actually, they are not too bad. Actually the hardware is not so far away as it looks. You can do these things. There is nothing here I showed you that you cannot do.

Representative PRICE. You say you have had studies for several years. How many years?

Dr. SILBERSTEIN. Actually we started a group studying in this area, I would say, almost 2 years ago. But a year ago we emphasized the work. In fact, I think John was put in charge when we emphasized the work.

Senator ANDERSON. I think it might be well, Chet, if we ask them to put SNAP on early tomorrow afternoon and go through the other things tomorrow morning, if you prefer to have it done that way.

If there is no great objection, we will try to have SNAP at two o'clock tomorrow.

Mr. RAMEY. The Department of Defense will give its presentation in the morning.

Representative PRICE. Are there any questions of the NACA people?

Gentlemen, you have made a fine and very interesting presentation. We appreciate your kindness and courtesy and we have had a very interesting afternoon.

Dr. SILBERSTEIN. We have been happy to do it.

Representative PRICE. We will recess then until 10 o'clock tomorrow morning.

(Whereupon, at 5:40 p. m., the joint subcommittees recessed until 10 a. m., Thursday, January 23, 1958.)

OUTER SPACE PROPULSION BY NUCLEAR ENERGY

THURSDAY, JANUARY 23, 1958

CONGRESS OF THE UNITED STATES,
SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT
AND SUBCOMMITTEE ON MILITARY APPLICATIONS,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D. C.

The subcommittees met, pursuant to notice, at 10 a. m., in the committee room, Hon. Clinton P. Anderson, presiding.

Present: Representatives Van Zandt and Hosmer; Senators Anderson (presiding), Pastore, Hickenlooper, and Bricker.

Also present: James T. Ramey, executive director; John T. Conway, assistant director; David R. Toll, staff counsel; and George E. Brown, Jr., staff member for research and development, Joint Committee on Atomic Energy.

Representatives of Department of Defense: Gen. Austin W. Betts, military executive assistant to the Director of Guided Missiles (Holaday Office); Paul A. Smith, Office of Assistant Secretary of Defense for Research and Engineering (on loan to Holaday); Carl Sorgen, Office of Assistant Secretary of Defense for Research and Engineering (Dr. Foote's staff); Dr. M. M. Slawsky, Office of Scientific Research, United States Air Force; Lt. Col. Paul Atkinson, Office of Scientific Research, United States Air Force.

Representatives of industry and university: Dr. I. Fred Singer, University of Maryland; Dr. Stanley V. Gunn, Rocketdyne division of North American Aviation; Dr. William Parkins, Atomics International, North American Aviation; Mr. John Simpson and Dr. Sidney Krasik, Bettis Laboratory.

Others: Col. Jack Armstrong, Commander Moore, Dr. Theodore Merkle, Livermore; Bryan LaPlante, Dr. Raemer Schreiber, Los Alamos; Kenneth E. Davis, Atomic Energy Commission.

Dr. John C. Evvard, chief, supersonic propulsion division, Lewis Laboratory; Dr. Addison M. Rothrock, assistant director for research, NADA.

Maj. Joseph E. Boyland, Office, Legislative Liaison, United States Air Force; Lt. Col. Marvin N. Stanford, Office of Assistant to Secretary of Defense (Atomic Energy).

Senator ANDERSON. The committee will be in order.

This is a continuation of yesterday's meeting of the Research and Development and Military Application Subcommittees to discuss advanced atomic engines for space propulsion. This morning we will lead off with representatives of the Defense Department who will then be followed by representatives of industry and the academic community.

The committee will reconvene at 2 p. m. to hear a continuation of Colonel Armstrong's briefing on auxiliary propulsion systems for outer space.

General Betts, Military Executive Assistant to the Director of Guided Missiles of the Defense Department, will be our first witness this morning.

Proceed, General, when you are ready.

STATEMENT OF GENERAL AUSTIN W. BETTS, MILITARY EXECUTIVE ASSISTANT TO THE DIRECTOR OF GUIDED MISSILES, DEPARTMENT OF DEFENSE

General BETTS. I would like to introduce Adm. Paul A. Smith, formerly of the Coast and Geodetic Survey, since he is a consultant to Mr. Holaday, primarily on the Vanguard program, and also Mr. Carl Sorgen of the Office of Assistant Secretary of Defense, Research and Engineering, who has a background in propulsion systems.

To set the stage for what we have to say about current capabilities, I would like to state that we have available as technical advisers to Mr. Holaday a group of very competent scientists which we refer to as the special capabilities panel. This panel was set up to advise in the satellite program for the International Geophysical Year, and has been active in that program ever since.

Early in September we were impressed by the fact that we should have a better grasp of the total space program which should be supported by the Department of Defense. At that time we asked the Stewart panel to make a comprehensive review of all of our capabilities in this area, and propose to the special assistant for guided missiles a program which they felt we should follow.

Right after sputnik, of course, the requirement for this kind of information became an overriding one. So we went to the chairman of the special capabilities panel, Dr. Homer J. Stewart, and asked if it would be possible for his group to spend a great deal more of their time on this study than they had previously thought they could and expedite getting the answer to Mr. Holaday. We had originally asked that the study be completed in about March of this year.

At that time they agreed they could give us at least an interim report by sometime in December and in fact they did produce on about that schedule. We now have on hand a report from this group which is to some extent interim in nature since they were pressed for time, but it does give us the basis for two things: One, a rather complete overall assessment of our national capabilities in this field, and in some measure a recommendation of where we should go from here, with, of course, special reference to immediate decisions that are necessary.

Senator ANDERSON. May I stop you right there to ask whether that report is available or is likely to be available to the Joint Committee?

General BETTS. I see no reason why it could not be made available. At the moment I do not have additional copies of it which I could give to you, but I see no reason why the Director of Guided Missiles would be unwilling to make it available. I do not think we should try to go into the details of that report, but I would like to pick out what we consider to be the major recommendations that were made.

The first of these is that we must have a long-range and comprehensive satellite program.

Senator ANDERSON. Would you excuse me right there? I wanted to explain the reason for my asking you about the availability of it. The atomic energy law says in part in section 202:

The Department of Defense shall keep the Joint Committee fully and currently informed with respect to all matters within the Department of Defense relating to the development, utilization, and application of atomic energy.

So if there is anything in the report that relates to the development, utilization, or application of atomic energy, we would expect to have the report filed with us.

General BETTS. I do not think there is anything that specifically refers to the utilization of atomic energy. The report does not try to go into the details of how we should get thrust levels that are necessary to carry out a space program, but rather indicates what these thrust levels will have to be. They have a relationship to you, and I think are of direct interest.

Senator ANDERSON. Is it too hard for you to extrapolate from these levels whether or not they can be put up by chemistry at the present time?

General BETTS. I think not. I think we can point out to you where these steps are and what is the important aspect of the thrust situation.

As part of this recommendation that we have a comprehensive satellite and space program, the committee made a particular recommendation that we devote at least 10 percent of that effort to exploratory research and development. They were very sure that we had not done enough work in this area to be able to point to those subareas of this field within which we might expect to have very significant breakthroughs which could change some of these capabilities which we will discuss.

The second major recommendation is that we should take a very early first step to exploit to the maximum extent possible the potential of the intermediate range ballistic missile thrust units to get rather considerable weights into orbit at 200 or 300 miles. [Deleted.] Their third recommendation is that we step from the IRBM supported program into the heavier program that will demand the thrusts that one gets from boosters now in the intercontinental ballistic missile program. They have laid out a step-by-step approach to these larger thrusts.

Their fourth recommendation is that this should be a national program. That it is very important that it not be purely a military program. There is not only interest in the scientific capability of such explorations, but in the capability of scientists in various laboratories around the country to contribute to what this program might accomplish, it is a contribution which they felt could be made on a more comprehensive basis if the program were in fact a national program, rather than purely a Department of Defense program. In other words, there should be academic industry and Government support for it.

The last recommendation, in summary, is that we should immediately step up our effort in the propulsion area to get to larger thrust units than now appear in the hardware stage of the ballistic-missile program as it is today.

Senator ANDERSON. Did they indicate how that was done?

General BETTS. Yes, sir. We will get into this in pointing out what the steps should be.

Senator ANDERSON. Did you indicate, or could you indicate, the names of the people that were on the Stewart Committee?

General BETTS. Yes, sir. Dr. Homer J. Stewart, of California Institute of Technology, associated with the jet propulsion laboratory; Dr. Robert W. Buckheim, of the Rand Corp.; Mr. George H. Clement, of the Rand Corp.; Dr. Joseph Kaplan, of the University of California; Dr. Charles C. Lauritsen, of the California Institute of Technology; Dr. Robert R. McMath, of the University of Michigan; Dr. Richard W. Porter, of the General Electric Co.; Dr. J. Barkley Rosser, of Cornell University.

Admiral Smith works with the Committee as a consultant for the Department of Defense, and we have a Mr. James O. Spriggs, who is the executive secretary of this group.

It was clearly indicated in the gross aspect of this report that some very early decisions with respect to program are necessary. In other words, there is not time for us to take the time to make an overall national assessment of capabilities and work out a step-by-step, long-term program in this area before we make these decisions.

Senator GORE. I don't quite understand you, General. There is not the time?

General BETTS. We cannot take the time now to study all of these national capabilities and do what I would call staffing. In other words, get all of the people into the act that there should be, and work out a comprehensive program for the next 10 years before we make some immediate decisions. I think this will become apparent. I will point these out. In other words, we must make some immediate decisions in the satellite business before we have in hand what I would call a true national program.

Senator GORE. Could you, briefly, tell us why such time heretofore has not been utilized to do this kind of survey and study?

General BETTS. This group has been working since last September, and they have presented a picture of national capabilities. Obviously, these capabilities will have interferences with some of our current missile programs. Obviously, they will present different capabilities. They represent incremental decisions as to what organization is to work on this program, and that, in turn, will have impact on other things we were doing. It has a relationship to military capabilities.

The net picture here is that you cannot decide in a few weeks' time how much of this should be done, looking to a 10-year program. What I am saying is that we must have such a comprehensive program, but we must make some decisions right now with respect to these events that will happen late in calendar year 1958, and through calendar year 1959.

Representative VAN ZANDT. The use of the term "national capabilities"; I imagine what you have in mind there is the ability of the country as a whole to furnish the necessary scientific knowledge?

General BETTS. This is one of the recommendations.

Representative VAN ZANDT. And engineering and production capabilities.

General BETTS. Yes; that is right. This is one of the recommendations of this program; that the program we devise shall be a national

program, not just a Department of Defense military program. It will be both a scientific and military program.

Representative VAN ZANDT. This organization you are identified with, as you said, was organized last September?

General BETTS. No, sir. This is the special capabilities panel, which has been in an advisory capacity to the Secretary of Defense since 1955, when we started the Vanguard and the IGY satellite program.

Representative VAN ZANDT. I did not want the record to show the Army or Defense Establishment just started to work on missiles last September.

General BETTS. No, sir. We asked them in September to make a study of our national capabilities in this area.

Because of the requirement for some quick decisions, Mr. Holaday has decided to tackle this in two ways. First, he has gone to the Army, Navy, and Air Force to ask for their recommendations as to what steps they would propose be taken immediately to make hardware commitments for a satellite effort that will start almost immediately. He has asked them in that request what funds they have now in the program, what funds they have available to do this acceleration and to point to what additional funding will be necessary. We did not ask the Stewart group to get into funding, since this was a scientific group and we felt it was not really appropriate to ask them to tackle that part of the effort.

The second thing that he has asked the services to do is to study the report of the capabilities panel and make their proposals to the Department of Defense for a national program. I am sure you are aware that we have made the decision to set up an agency within the Department of Defense which we will identify as the Advanced Research Projects Agency. This Agency will have the responsibility for the direction of a national satellite and space program.

Obviously there are capabilities available in each of the three services today to support that effort. The Advanced Research Projects Agency will coordinate and direct the capability that now exists and where they see the necessity to contract for additional effort, or to set up within Government facilities or capabilities for additional effort, this Agency will have the power to do so.

This, then, gives you two things which we can get out of our immediate effort in this area.

Senator ANDERSON. Does this Agency involve our civilian effort, as well?

General BETTS. This will be the Department of Defense Agency. We will, and have started at the talking level, undoubtedly work with the National Science Foundation and the National Academy of Sciences to work with the Advanced Research Projects Agency to set up a national program.

Senator ANDERSON. You think that the advanced projects we were talking about are primarily military in their purpose?

General BETTS. Our present estimate of our capacity to carry out such a program is that it would be, for administrative reasons, managed within the Department of Defense in the Advanced Research Projects Agency.

Senator ANDERSON. I don't believe that quite gets the question. The President has been talking about peaceful control of outside areas. Secretary Dulles spoke about cooperation with these various groups, and leaders in Congress have been talking about that. You visualize it as primarily military?

General BETTS. Our capabilities today are almost completely military in terms of the propulsion effort. The scientific aspect of this thing goes outside the military and the capability for a considerable amount of the scientific help in the IGY program is outside of the military. I think we should separate what we are talking about in terms of the peaceful control of space from that with which we may be faced in terms of the military use of space. If we can, in fact, get international agreement that the use of space will be for peaceful purposes only, then I would presume—and I have no other basis than presumption—that the direction of this program would be taken away from the Department of Defense. [Deleted.] I don't think we can afford to sit back and wait for something else to happen.

Senator ANDERSON. I do not think you have to wait for something else to happen. You confess that the committee was set up as soon as the Russians announced that they had an ICBM.

General BETTS. No, sir; I did not.

Senator ANDERSON. You gave a date that followed the Russian announcement.

General BETTS. I gave a date which asked them to expand their technical interest in our program.

Senator ANDERSON. You say you started it in September. When did the Russians make their announcement?

General BETTS. This was in August.

Senator ANDERSON. So it did follow.

General BETTS. But the setup of the committee was back in 1955.

Senator ANDERSON. Do you conceive that this program has any atomic applications?

General BETTS. We will undoubtedly get to atomic applications as we get to the larger thrust units, I am sure.

Senator ANDERSON. Do you propose to take that away from the Atomic Energy Commission?

General BETTS. No, sir, I do not. We have excellent relations with the Atomic Energy Commission today in getting them to supply us those things which we need in our military systems. I do not think there will be any problem of interrelationships with the Atomic Energy Commission.

Senator ANDERSON. Like Rover?

General BETTS. This is one of the elements. I was thinking primarily of our atomic and thermonuclear warheads which are a fundamental part of our missiles systems, and without which some of our missile systems would not be of much use. Some of the larger missiles at least.

I would like to point to some of the major things that this committee saw as the need to support their basic recommendation that we must have a comprehensive program [deleted].

Representative VAN ZANDT. Will you describe now what you mean by capabilities just so we have it in the record?

General BETTS. I will point to things which we consider to be capabilities in these charts and those things which we have selected as the most interesting of these capabilities.

Further with regard to our ——— requirements, we have indicated that the satellites could be an aid to navigation, both ship and air. We could obtain weather data which would be very useful and extend our ability to predict weather.

We can get communications aids in terms of extending our ability to get more reliable communications. Certainly ultimately we could get a weapon capability from a satellite missile. Of course, there is the ultimate capability of travel to the moon, the possibility of occupying it. We have in hand in the military at the moment a rather comprehensive study of just exactly what it would take to put people on the moon, to keep them there indefinitely as an outpost and what that study concludes would be the usefulness from the military point of view of such an installation.

Senator GORE. How long has that study been under way?

General BETTS. That study must have been under way, I would say, for literally years. The report was probably put together in the last few months. It is a contractor's effort and I don't know just how long ago they started the study.

Senator ANDERSON. What sort of lift do they indicate is necessary to get that sort of ship off the ground?

General BETTS. I would have to furnish that, sir. I don't remember the specific propulsion in that study.

Senator ANDERSON. It runs into millions of pounds.

General BETTS. It does.

Senator ANDERSON. Do we have any chemical process that would now give millions of pounds of lift?

General BETTS. I think our chemical limitations are going to start getting pretty severe when we get much over a million pounds.

Senator ANDERSON. So you have to depend upon nuclear propulsion to get this sort of project under way?

General BETTS. This is now indicated, unless we have breakthroughs in this area as we go forward with further development of chemical propulsion units.

Senator ANDERSON. Would not that tie closer to the Rover project than the military applications?

General BETTS. Yes, sir, I think it would. What I would like to do is to show you from the Stewart capabilities panel report those capabilities which they selected as typical of our national possibilities.

Representative VAN ZANDT. May I ask a question, General, about this study that is being made? What is the magnitude of it?

General BETTS. Which study are we talking about?

Representative VAN ZANDT. The study of space ships and so forth. You mentioned it just a moment ago.

Senator ANDERSON. This was a contract job. Who had it?

General BETTS. This is the Glenn L. Martin Co. for the one I mentioned. It is a thick document. I don't know how many people they have on it.

Representative VAN ZANDT. When did they go to work on it?

General BETTS. I am guessing. They had to do work in this area for years to have the competence to come out with this kind of a document.

That is the kind of corollary thing they do in connection with other programs. I would say that sitting down and doing this specific study may have taken them 3 to 6 months. I don't know when they laid the study on.

Senator GORE. Did the report indicate the feasibility of stationing human beings?

General BETTS. This was just the point of the report, to show that, within our present technological capabilities, this thing could be done. I think you can get an argument as to whether or not everything they point to as possibilities is really within our present technology.

Senator GORE. My question is, Was the conclusion of the report affirmative as to feasibility?

General BETTS. Yes, sir.

Senator ANDERSON. Did they get this contract subsequent to the first showing of sputnik?

General BETTS. This was, to my knowledge, not a specific contract, but a contractor's study made within his own capabilities. I do not believe it was requested by the military.

Senator ANDERSON. When was he asked to do it?

General BETTS. I don't believe he was asked to do it.

Senator ANDERSON. You mean he did it voluntarily?

General BETTS. That is right.

Senator ANDERSON. Did he contribute it freely?

General BETTS. Yes, sir; this happens constantly in terms of this type of study.

Senator PASTORE. Don't you think the seriousness of this—

Senator ANDERSON. I want to check that answer, please. It is not in accordance with my study.

General BETTS. The Glenn L. Martin study?

Senator ANDERSON. Yes, sir.

General BETTS. I qualified my answer by saying I was not sure. We do get this kind of thing.

Representative VAN ZANDT. Does this gentleman have additional information?

Mr. SMITH. No, sir; I do not.

General BETTS. I can get the information for you.

Senator PASTORE. Don't you think the seriousness of this report hinges on whether or not it was commenced with the view that the Russians had shot up sputnik as to the recommendations that might have resulted? It is generally felt, and I think you will subscribe to this, that we did not take this whole study seriously until the Russians did shoot up sputnik. I think the gravity of the situation is accentuated by that.

General BETTS. On a national basis you are right.

Senator PASTORE. Even on a Glenn L. Martin basis.

General BETTS. This I can't answer.

Senator PASTORE. Therefore, I think it is quite important to determine some time—it ought to be inserted in the record if it is not today—that this is a study that was made as a result of what the Russians had made rather than merely an incidental study that was made along the lines of all their military preparedness.

General BETTS. I think this is certainly proper for the record. I will try to find out exactly when they started, and whether or not it was asked for by the military and paid for by the military.

Senator PASTORE. Yes.

Representative VAN ZANDT. I want to ask the General about this committee, and the study made by Glenn L. Martin. Have you made any attempt to coordinate all of the studies of the various agencies of Government today?

General BETTS. This is the specific purpose of asking the special capabilities panel to review our total capabilities and propose a program.

Representative VAN ZANDT. Have you made any step in that direction as yet?

General BETTS. Yes, sir; we asked them in September to make such a study.

Representative VAN ZANDT. Asked who?

General BETTS. The special capabilities panel. That was then asked to be available about in March. After sputnik we asked if this could be accelerated, and it became available at least as an interim report in December.

Representative VAN ZANDT. Has this committee talked to the Atomic Energy Commission witnesses we had here yesterday, from Livermore and Los Alamos?

General BETTS. This committee used the military staffs to obtain their information. We asked the military staffs to present to the committee the total capabilities they felt they had in the various organizations working for them, and what they as military organizations felt were the ones that were most important, and the needs that were most important. We did not get into the application of atomic-energy capabilities because the group did not try to define how we would get these thrusts, but rather what thrusts were needed to do various things in space and satellite effort.

Representative VAN ZANDT. I think we received information here yesterday from representatives of Livermore and Los Alamos Laboratories that went far beyond the nuclear-powered rocket. We were talking about space and the function of ships in space.

General BETTS. I think this is undoubtedly so. This is one of the reasons why one of the key recommendations of this group is that on a comprehensive basis we must work out a national program; that we should go outside of the military and find out what these capabilities are, and have a national program.

Representative VAN ZANDT. Then we can expect in due time that this special committee will bring together all of the thinking of agencies of Government, including those nonagencies of the Government who have contracts, and wrap up all of their thinking in one program?

General BETTS. We have gone beyond the program of this special capabilities panel at the moment to get the technical staffs of the three military services to review their report, and to bring in these additional capabilities that may be available to them. We have also taken at least preparatory steps to get, in this total assessment, help from the National Science Foundation and the National Academy of Sciences. I think if we get into details such as how we would obtain these various thrusts, undoubtedly we would have to bring in the Atomic Energy Commission from the point of view of the thrust levels. At the moment these are based on thrusts now existing in the program and relatively short range from the point of view of time. I am sure

that we will have to get into much higher thrusts at some later stage. At the moment we have not jumped that far ahead.

Representative VAN ZANDT. Thank you, General.

Senator ANDERSON. How long have you been in Mr. Holaday's office?

General BETTS. I was assigned to Mr. Murphree when he was first made Special Assistant for Guided Missiles.

Senator ANDERSON. Back in 1955?

General BETTS. No, sir. In 1956, Mr. Murphree took office. At that time I was his Army adviser. When Admiral Sides moved to the Weapons Systems Evaluation Group, I then took his job with Mr. Holaday as military executive assistant. This is, roughly, almost 2 years.

Senator ANDERSON. Do you know anything about the fact that some other studies have been made in this field previously? In your work, have you had occasions to go back and review the history at all?

General BETTS. I am familiar, at least to some extent, with the studies that were made with respect to the Rover project, not in detail, but in a general way.

Senator ANDERSON. The Chairman of the Atomic Energy Commission was asked the other day if he knew anything about Project World Series, and he said he never heard about it. Have you heard about it?

General BETTS. No, sir; I have not heard about this.

Senator ANDERSON. Would you be interested in knowing that the headquarters of ARDC requested a study of a satellite to be used in the International Geophysical Year in July 1955, and put a label on it, "World Series"?

General BETTS. No, sir; I was not familiar with that.

Senator ANDERSON. I wonder how this information would get to you in the normal course of events? The Holloman Airbase went to work on it, and proposed a satellite using the ICBM motors as a booster, and an Aerobee missile as the satellite stage to give a 300-mile orbit. Has that been called to anybody's attention in the Department?

General BETTS. I can't answer that. I will furnish it for the record. I would assume it has been. I might qualify our history position with respect to the satellite capabilities. When Mr. Holaday's office was first set up or when Mr. Murphree was first set up as Special Assistant for Guided Missiles, he did not have responsibility for the Vanguard project or for any of the space-exploration effort. He was a guided-missile man and that was specifically delineated as his area of responsibility. This was still true when Mr. Holaday first took over. As a matter of fact, when Mr. Holaday first took over, he had responsibility for less than all of the missiles that were in the program. He was told to concentrate just on the long-range ballistic missiles and the long-range missiles like the Snark and others which were in competition with ballistic. He also had the antimissile missile. Later, he had the Vanguard added to his area of responsibility.

Senator ANDERSON. If he was associated with long-range missiles, these things would be of interest to him. Holloman, at that time, when they made that recommendation, outlined it would have a take-off weight of [deleted] pounds. That the final stage would run about

[deleted] pounds. Has that study ever been called to anybody's attention?

General BETTS. I think Admiral Smith could answer that question, to some extent, better than I.

Admiral SMITH. I believe, Mr. Chairman, that report, which I did not recognize under that name, was made available to the Stewart committee in their first consideration.

Senator ANDERSON. Did it have any other name than World Series?

Admiral SMITH. I don't know. I don't recognize it by that name.

Senator ANDERSON. It is the only name it ever had. It was not Dingdong, that became generally MB-1. This stayed World Series from the time immemorial, as far as they are concerned, as far as I know. Why I am interested, in August 1955, they made a study of the growth potential by a combination of Atlas and Aerobee, decided it could achieve escape velocity in traveling in space, that the payload could be increased [deleted].

In March of 1956, about the time you were in the program, General, they filed the final report. The title of it was "Studies in Ballistic Test Vehicles and Analysis of Problems Associated with [deleted]."

General BETTS. I can say, categorically, it was not made available to our office, and we did not know about it.

Senator ANDERSON. Probably not, because a minute ago you were talking about [deleted]. Here this study is already on file on that matter and has been for 2 years and a couple of months. There is a study by Rand that estimates that the Atlas—this is a separate study, now—coupled with [deleted]. Was that called to Glenn Martin's attention when it made its study?

General BETTS. I do not know, sir.

Senator ANDERSON. Did somebody arrange with Glenn Martin? If you don't know, who would know?

General BETTS. I am sure that if someone arranged with Glenn L. Martin to make that study, it was the Air Force, and I am sure we can get information from the Air Force. I think that was a company proposal.

Senator ANDERSON. But it followed the meeting up in Baltimore. Are you familiar with the fact that there was a meeting in Baltimore to consider what should happen in the ballistics field after the satellite was put in the air by Russia?

General BETTS. No, sir.

Senator ANDERSON. Are you kept currently informed? I know this committee is not. You are in Mr. Holaday's office.

General BETTS. Many things happen within the contractors' organizations and within the military services which never come to us.

Senator ANDERSON. Glenn Martin was asked to throw together, as quickly as it could, the report of how you could put somebody on the moon. Here was a carefully studied report of how a missile could be put on the moon. It was not just tossed out quickly. Do I understand that you don't know whether it was or was not given to the Martin Co. so it could make use of it?

General BETTS. I do not know, sir. But I will try to furnish this for your record.

Senator ANDERSON. Would you try to find out whatever happened to this item that I have referred to? It was in March 1956 when this

study was put together. It represented the views of many of the recognized missile experts who were at Holloman—Von Braun and other Germans were there. They had a fairly good collection there. This was the result of long deliberation and very, very careful study. Could you find out if anybody has seen that study since March 1956, and, if so, who it was charged to when he left the office?

General BETTS. I will obtain that information.

(Information follows:)

COMMENTS WITH RESPECT TO THE "WORLD SERIES" SATELLITE PROPOSAL

Comment: A review of the record discloses that the "World Series" proposals is included in full with the Stewart group's report dated August 1955 (appendix B, pp. B1-B39). This was an engineering study by Dr. Ernst A. Steinhoff, then at the Holloman Air Development Center, advocating a scientific satellite project based on the Atlas booster with a modified Aerobee-Hi upper stage. It was estimated by Steinhoff that this system could put a large scientific payload on a 35° inclination orbit at 300 miles altitude.

In August 1955 and from later testimony before the Stewart group, there was considerable doubt that Atlas could be used—even if it made its then planned schedule—without serious interference with the ICBM program.

The Stewart group recommended the development of a scientific satellite vehicle in two phases: (1) An immediate program for achieving a 5- to 10-pound satellite on orbit during 1958, and (2) a program to launch a satellite vehicle of significantly larger payload and higher orbit at some future date. Noting that on technical grounds the use of the motor of the intercontinental ballistic missile would unquestionably provide the greatest performance margin, the group disqualified themselves on the question of whether this could be accomplished during the period of the International Geophysical Year because of uncertainties with respect to the degree of interference with the ICBM program that might be tolerated and uncertainties regarding the validity of the current ICBM schedules. The majority of the group recommended the use of the 3-stage launching vehicle proposed by the Navy; a minority recommended the use of the Redstone missile as the basis of a 4-stage launching vehicle, as proposed by the Army. The group further recommended that, in any case, studies of the use of an ICBM booster should be pursued as a responsibility of the Air Force.

The recommendations of the majority of the group were approved by the Secretary of Defense.

Senator ANDERSON. Would you find out what the comments of the Secretary of Defense were when it got up to him?

General BETTS. I will make an effort to do so.

Senator ANDERSON. Thank you. I would appreciate that, because this is where we waste our time and money. We go through these studies once, and they are put away and nobody ever sees them again. This was a very serious effort.

General BETTS. I would say to set the tone for whatever discussion we have further here that until the sputnik was flown there was a rather definite overall atmosphere of lack of interest in space travel or satellite programs as such. You will remember in setting up the IGY satellite, the original program estimate for that effort was \$10 million, and there was some considerable controversy about whether it was worth the \$10 million effort that would be involved. The estimate was later raised and we are now in the process of putting up \$110 million to do what was originally proposed. I say categorically if \$110 million had been tied to that effort as the original price tag, I doubt if it would have obtained sufficient overall support from either the Department of Defense or the Congress to do it at all.

Senator ANDERSON. I only want to say to you in reply that the Project World Series was what was set up to propose a satellite to be launched during the IGY. This is the project.

General BETTS. I understand. I will try to relate it to those things which were studied at that time and see if I can identify this name "World Series" which I did not know before.

Senator ANDERSON. I would be happy to have you look at the résumé of the "World Series" studies which I requested General Davis, of the Air Force Missile Development Center, to prepare, and he did prepare in 1957. I had heard that the people who worked on this project were very disappointed that we decided not to put a satellite in the air during the International Geophysical Year. They spent a lot of time on it. They never understood why it could not get anywhere. I went down and asked General Davis if he would give me a memorandum setting up the work that was done at that time, and in his closing paragraph which I had not seen or thought of for a long time, while he pointed out—the last two paragraphs—this March 1956 study says that with a chemical missile of several stages you could put a [deleted]-pound scientific payload in orbit at 3,000 miles altitude. It is strange that Russia when they put theirs up put 1,180 pounds up. This was done in March 1956. What I am worried about is that the information must have gotten to the Russians and they did something with it.

This is the résumé by General Davis. "In independent studies Rand has estimated"—it must have been made before November, because this is done in November—that a combination of certain types of chemical missiles [deleted] could put a gross load of 300 pounds on the moon."

So I assume since this is the commanding general of the Air Force Missile Development Center, that he is quoting from official documents that must be available somewhere. So far as I know, nobody has been able to find this document but it was a very, very interesting document.

General BETTS. There are as many capabilities projected to do things about satellites as there are contractors who are deeply interested in this program. This is what I would like to show you in terms of the more interesting of these capabilities that have been tabulated for us by the special capabilities panel.

Senator GORE. Did I correctly understand you to say, General, that either you or someone in the Army had requested Glenn L. Martin Co. to make this study?

General BETTS. I said I did not know whether they had been requested to make it or not; whether this was an internal company effort or whether it had been paid for by the Air Force. I will try to find that for the record.

Representative VAN ZANDT. General, it is not unusual for a company to make a study?

General BETTS. Not at all.

Senator ANDERSON. I did not question that.

General BETTS. Aerojet General has come up with a specific satellite proposal concluding a study they made, and I am sure they were not asked to make a study. It is a company proposal saying they could do it.

Representative VAN ZANDT. I remember when they canceled out the Atlas the Convair people continued for several years at their own expense to develop a missile along the lines of the Atlas.

General BETTS. This is not unusual.

Representative VAN ZANDT. Thank you.

Senator GORE. It might be observed that it would appear abstruse to me for the Army or the Air Force having continuing contractual relationships with a given company to request that company to make a study without charge. It would seem that would prejudice proper relationships between the two.

General BETTS. I would say this does not necessarily follow. We are in the business of trying to get and keep competition in American industry, even in the missile program. We can't let fixed price contracts for development efforts where we are not really sure what the development effort will turn up or what kind of a goal it will get to. Of course, therefore, we can't put a real price tag on a program early in the game. We do, in order to get as much competition as possible—if we have an idea for a new missile system—go out to these contractors and say this is a requirement, this is what we think we want, a missile that will go so far, so fast, so high, no bigger than thus and such, solid propellant, or what have you. Then many contractors spend their own time and effort making such studies and come in with specific proposals. We don't pay them anything for this. They are competing for business. That is what this amounts to.

Senator GORE. That is not a description of the possibility which you suggested may have prevailed.

General BETTS. I am not sure in this case, Mr. Gore.

Senator GORE. I understand that. The point I was suggesting is that that violates my idea of proper relationship between a Government agency and a Government contractor for the Government to be asking favors of the contractor.

General BETTS. I would not put the kind of study I was talking about in terms of a favor. Whether this moon study was a favor or whether it was a proposal to get business, I don't know.

Senator GORE. You say you don't know?

Senator ANDERSON. I think it would be interesting to have you supply the information.

(The information follows:)

COMMENTS WITH RESPECT TO THE GLENN L. MARTIN STUDY ON REQUIREMENTS FOR A MANNED STATION ON THE MOON

Comment: I have been informed by Mr. George S. Trimble, Jr., vice president for engineering of the Glenn L. Martin Co., that almost 2 years ago personnel of their technical staff began to think seriously about the problems of establishing a manned station on the moon. By July 1957 their studies had progressed to the point that they felt prepared to make a formal presentation of the work to the Air Force. This formal presentation was made to the Air Force Scientific Advisory Board on July 1, 1957, and it was essentially complete in terms of the time frame in which such a program could be carried out and the expected cost of this effort.

In order to consolidate their own thinking in this matter, this presentation was reduced to a written report and that written report was completed in draft form in about 2 months time. It was then furnished to the printer and the date of the finally printed report was October 1957.

After the sputnik flights of the U. S. S. R. a great deal of interest was generated in space programs generally and some of this interest centered on the study which the Martin Co. had previously prepared. In view of this expressed

interest the Martin Co. then made distribution of this report to the agencies such as the Office of the Director of Guided Missiles where it was apparent that the information would be pertinent to established responsibilities. The Glenn L. Martin Co. was not asked to do this report by any agency nor have they been reimbursed in any way for the effort involved. The study and report presentation have been paid for by the Glenn L. Martin Co.

Senator ANDERSON. My very sketchy information is that Glenn L. Martin came in and wanted to do a job and brought you a proposal to give them a contract to put a satellite on the moon, and give them a very, very expensive contract running into millions and millions and millions of dollars, which did not involve any of the work previously done by the Department of Defense, nor any of the work done by the atomic energy agency.

General BETTS. This did appear in that light to us and I would like to get you the answers.

We do not present this as the total national capability, but those things that were recommended by the service technical staffs. The Special Capabilities Panel picked out as some of the outstanding capabilities that we have with hardware that is either currently in the program in more or less final configuration or is well along in the early development stage. I would like to start with the kind of capability we now have in the Vanguard effort to show you what these interrelationships are.

If one makes some straightforward product improvement in the Vanguard program, it is estimated, as we see the technology now, this has the ultimate limit of about 55 pounds in a 200-mile orbit. These are all reduced to a 200-mile orbit so you can see the interrelationship. [Deleted.]

Going to further developments in this area, this means that one could use four of these solid propellant upper stages [deleted] presumably clustered together.

[Deleted.]

This is why the committee says it is important, because the IRBM is well ahead of the ICBM in terms of the reliability of the booster, that our first effort is to push off in the IRBM field to get higher satellite capabilities than we have with our present scientific program.

The time scale would be much earlier than we could get using ICBM.

Senator ANDERSON. Did you tell us where that study came from?

General BETTS. This came from the special capabilities panel report which I mentioned, and which I said we would furnish you a copy of.

This chart identifies the backup satellite program which we have recently released, using the Redstone missile which we have termed "Jupiter-C." [Deleted.]

Senator ANDERSON. How many times has the Sergeant missile been fired?

General BETTS. I could not give you a number on that, sir. [Deleted.]

Senator ANDERSON. I was at White Sands when they sent a Sergeant up, and took it down again because it did not go off.

General BETTS. These are not the full-scale Sergeant missiles as such [deleted]. This is a scale model of the solid propellant part of the Sergeant missile.

Senator ANDERSON. Which is a successor to the Corporal.

General BETTS. That is right, sir.

From these many capabilities and these that are listed in the tabulation are not all, they have picked out some of interest [indicating] when these might be achieved. We have a time scale to relate to the program I have just discussed.

(Classified discussion.)

General BETTS. The other capabilities would follow on at later dates. These are just representative of the things that can be done with an early decision, using hardware that is now in the program.

Senator ANDERSON. Did this special committee in preparing that have a staff?

General BETTS. No, sir.

Senator ANDERSON. Where did it get all these figures?

General BETTS. All of these many capabilities were presented to them by the Army, Navy, and Air Force, using the Army, Navy, and Air Force technical staffs and staffs of their contractors to collect this information to present to the special capabilities panel. This points up the reason why we have divided our present decision-making problem into two areas; one a comprehensive program which will lead on into these [deleted] pound thrusts, these very high lift capabilities, which may be 5 to 10 years away, and the other to decide from this kind of a complex what things we must do so that when we finish up the present satellite program we have additional satellites which will continue to use the tracking capability and continue to use the satellite capability already established. So that we do have a continuing program.

Mr. Chairman, I did not intend to go further into details of this program. I thought we might do it by a question and answer program. I would like to ask Mr. Sorgen of Research and Engineering to discuss the propulsion support which has been in the Department of Defense up to this time, and which is interrelated with these satellite capabilities.

Representative VAN ZANDT. What are his connections with the Government?

General BETTS. He is in the Office of the Assistant Secretary of Defense, Research and Engineering, and propulsion systems are one of his responsibilities.

STATEMENT OF CARL SORGEN, OFFICE OF ASSISTANT SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING, DEPARTMENT OF DEFENSE

Mr. SORGEN. Gentlemen, I have been requested to make a brief statement to you on the overall Department of Defense flight propulsion program. Since the Wright brothers' first successful flight, man's ability to create flight vehicles of ever-increasing performance capabilities and utility has been geared to the development of advanced propulsion systems. Along with these advances, we have increased manifold the variety of systems from which we may make a choice to accomplish a specific job. At the same time the overall program has become increasingly complex and extensive in scope. Therefore, more difficult to evaluate and manage properly.

The basic criterion which distinguishes flight propulsion systems from other power generation systems is the essential emphasis on minimum system weight. That is, the combined weight of the engine, its associated components, and the fuel or propellant consumed during the vehicle's mission. It is this primary and essential emphasis on minimum propulsion system weight which strains our technology, stretches the state of the art, and creates a demand for new concepts and knowledge. It is also why the development of new systems is inherently time consuming and costly.

In the preliminary study of a new flight vehicle, knowing the mission requirements, the first step would be to determine whether there are propulsion systems available or coming along which can do the job within the weight allowance which can be allotted to the propulsion system. If there is none, then the problem is insoluble and must await the creation of new concepts, ideas, and inventions. If it appears that only one kind of propulsion system is uniquely capable of doing the job, then things are somewhat simplified, because that particular approach may be concentrated on without much argument.

As is most often the case, however, it may appear that a number of different systems may be capable of doing the job with varying compromises. Then there arises the difficult task of making a selection where other factors, such as relative cost, reliability, hazards, and status of development and feasibility must be weighed. The entire Department of Defense propulsion research development and engineering program in the field of flight propulsion must maintain a proper balance between support of current weapons systems, next generation systems for which requirements are reasonably firm, and basic and applied research on advanced systems for which requirements have not yet crystalized.

For the fiscal years 1957 through 1959 the Department of Defense is supporting research, development, and engineering of engines at an average annual rate of about \$620 million. This is for engines as such, and does not include the cost of the special test facilities and supporting research and other technical fields, such as high-energy fuels, propellants, materials, and other items which contribute to advances in the propulsion art. A rough distribution of this engine development effort is as follows:

In the field of air-breathing systems, which includes gas turbines, ramjets and further includes the Air Force support of the nuclear turbojet and nuclear ramjet, Pluto, the air-breathing system share is about 62 percent.

Senator ANDERSON. Of the \$620 million?

Mr. SORGEN. Yes, sir.

Senator ANDERSON. \$37 million or \$38 million.

Mr. SORGEN. Sixty-two percent of \$620 million. These are rough figures.

Senator ANDERSON. \$360 million.

Mr. SORGEN. That is correct.

Senator ANDERSON. Of which about 3 or 4 million is for the nuclear ramjet?

Mr. SORGEN. Yes; if you wish. The Department representatives have not indicated specific project support. I possibly can give you a rough idea.

Senator ANDERSON. About one-ninetieth is going into that.

Mr. SORGEN. Project Rover.

Senator ANDERSON. Yes.

Mr. SORGEN. I understand it is running about 7 to 8 million a year.

Senator ANDERSON. I do not think so.

Colonel ARMSTRONG. The Air Force Pluto budget is \$3 million in 1958.

Representative VAN ZANDT. What is Rover?

Colonel ARMSTRONG. The same thing exactly.

Mr. SORGEN. I divide this into three categories. First, the air-breathing systems. The next category would be the non-air-breathing systems, which include liquid and solid propellant rockets of all sizes, shapes, and forms. In the rocket field about 35 percent of the total is being applied. As I understand, you gentlemen are interested in space flight. There is a third category of so-called advanced propulsion systems which amounts to about 3 percent.

Senator ANDERSON. \$18 million in space flight?

Mr. SORGEN. May I explain, sir? I will explain what we put in that category. This includes Air Force support to the nuclear rocket project, Rover, and basic research and exploration on other advanced systems primarily applicable to extended space flight. Included in these categories would be such items as solar heat source rockets, free radical propellant, ionic propulsion, magnetohydrodynamic, and possibly eventually up to the nuclear fusion rockets.

Senator ANDERSON. When you speak of ionic propulsion work, are you doing that directly or through NACA?

Mr. SORGEN. First, let me say the amount of money that I am referring to here is money which is going out under Department of Defense contracts, either Air Force, Navy, or Army. It is direct contractual support. In addition to the effort supported by the military departments, we have the basic research and development effort carried out by the National Advisory Committee on Aeronautics in their laboratories and in the nuclear propulsion field what the AEC is doing in the reactor development side.

Senator ANDERSON. Specifically, I asked you about ionic propulsion. Are you doing something in addition to what NACA is doing, and if so, what?

Mr. SORGEN. Right now I cannot answer.

Senator ANDERSON. You mentioned it.

Mr. SORGEN. Yes, sir. I will explain why. There are general basic research projects; for example, by the Air Force Office of Scientific Research which cover the study of new energy sources, new methods of energy conversion, looking into the future. These are sort of blanket projects that carry on studies both within the Department's laboratories and by direct contract with academic institutions, and with the engine manufacturers. It is in a study stage. For example, the rocket division of North American is studying ionic jet. Aerojet is working on it. I think some of the major system contractors. Convair, and so on, carry on studies of these things. They are in a conceptual stage right now.

Senator ANDERSON. Is Rocketdyne getting money for rocket propulsion?

Mr. SORGEN. I can't answer that directly.

Dr. GUNN. Yes, sir; we are.

Mr. SORGEN. All I wanted to point out is that in this distribution 38 percent of our total propulsion effort is devoted to the kind of propulsion systems which are applicable to space flight or some type or another. Over a third of the total dollars are going into that.

Senator ANDERSON. If you are using 3 percent of your total figure you are using \$18,600,000.

Mr. SORGEN. I am including the big rockets, which as General Betts has pointed out are currently available, and can be adapted.

Senator ANDERSON. I thought you said you had 35 percent for rockets.

Mr. SORGEN. Yes.

Senator ANDERSON. What is this 3-percent figure again?

Mr. SORGEN. The 3-percent figure, 1 specific project is the Air Force support to project Rover, the nuclear rocket.

Senator ANDERSON. That is \$4 million.

Mr. SORGEN. Yes; that is right. The balance is spread over a number of basic research types of projects.

Senator ANDERSON. \$14,600,000.

Mr. SORGEN. I can give you the actual figures.

Senator ANDERSON. I would like to have them.

Mr. SORGEN. Do you want them right now?

Senator ANDERSON. Later is all right. I talked to a scientist who said that if Aerojet and Rocketdyne would meet more than once, they would have better team reaction. I don't know whether that is true or not.

Mr. SORGEN. About the middle of last year the Office of Assistant Secretary of Defense for Research and Engineering initiated a survey of the entire Department of Defense aircraft and missile propulsion research and development program. The assistance of a group of recognized experts was solicited in making the survey which was initiated on the 1st of August, and we hope will be completed about march of this year. Mr. Abe Silverstein, who I understand spoke to you people last night, is serving as chairman of this group. I do not want to get into technicalities or attempt to express any opinion as to the relative merits of the different kinds of propulsion systems which are underway or proposed, since I don't wish to prejudge or prejudice any conclusions or recommendations which Mr. Silverstein and his group may reach.

I understand you have already heard from many technical experts in the field and probably will continue further into that. However, I shall be pleased to attempt to answer any questions or to acquire any specific data which you may desire on the current programs.

Senator ANDERSON. I may come back to you.

General Betts, in 1953, when you were working on satellites, there were four contractors that submitted power designs, and at that time were trying to get contracts. By 1955, the interest was down so low that it was just sort of handed to General Schriever because they did not know where else to put it. Atomics International designed some sort of powerplant at that time. Do you know how much was actually being done on satellite work in 1955?

General BETTS. No, sir. I am not familiar with this in detail. The only general information I have is that which we collected from our

files to furnish to the Congress with respect to the proposals that were specifically made to support the International Geophysical Year satellite program.

Senator ANDERSON. I had a notation that about \$1,100,000 was given to Atomics International, \$1,100,000 to Martin, a few hundred thousand to Thompson Products for work on satellite propulsion last year. Is that correct? Do you know about it?

General BETTS. No, sir, I do not have those figures. [Deleted.] How that is broken down I don't know.

Senator ANDERSON. Where did that go?

General BETTS. I do not know how that is broken down within the Air Force support of that program. I think probably the Air Force officers could answer that.

Senator ANDERSON. Could they answer that?

General BETTS. We don't have the breakdown of that. I will have to furnish it for the record, sir. That is fiscal 1958 money.

(The information furnished was classified.)

Senator ANDERSON. Here is Herb York, who has a fine show at Livermore, who was crying for a little money at one time to keep on work for Project Rover, but it had to be cut out entirely because you could not give him a million dollars. Yet at that time we could hand 2 or 3 companies several million dollars for activities without too much definiteness in the program. Yet York knew what he wanted to do. That is why I would like to know where this \$18 million went. That is the very time they started to cut these laboratories down on their work.

General BETTS. This will be the breakdown of the \$18 million.

Mr. SORGEN. I ran a rough average of the 4 fiscal years, and I can give you some suggested figures for fiscal 1958. One of the major projects, looking far into the future in these new concepts, is the Air Force Office of Scientific Research project, entitled, "Research on Advanced Propulsion." That has an item of \$6.19 million in 1958. The last budget figure I had was \$5.77 million in fiscal 1959.

Senator ANDERSON. What are they doing with that? Are they contracting with somebody for studies in advanced propulsion?

Mr. SORGEN. That is correct. Some of the work is carried out within our own laboratories. I can give you an idea of the type of projects that are included under such a general type of thing.

Senator ANDERSON. You can supply that later.

Mr. RAMEY. Are they doing the more advanced type of research and paper studies on propulsion, including nuclear propulsion?

Mr. SORGEN. The way these things are handled, as I understand it, in nuclear systems, the way the work is running now, the AEC is supporting the nuclear heat source equipment that is necessary for a given propulsion system. The military department, presently the Air Force, in parallel supports the development of what we would call the engine part and all the hardware and components that go on with it, utilizing the particular nuclear heat source. In some of these advanced systems, I don't know whether we would call them engines any more, particularly when we get into the electrical system such as an ion rocket, depending on efficient and lightweight source of electrical power generation which presumably would depend on some nuclear process.

Mr. RAMEY. You have not gotten to the experimental or even hardware stage on this ion rocket, for example?

Mr. SORGEN. I gather that is still very much in the conceptual stage. A lot of people are thinking about these various kinds of systems and conducting what experimentation they can.

General BETTS. The statement was made yesterday that such a rocket would have to be launched from some kind of a satellite space station. I think we have to learn to walk before we can run, and it is going to take a considerable program before we are prepared to put such a satellite station up on orbit to where it could be used in this way.

Mr. RAMEY. Of course, they are doing development and are almost to the hardware stage for a reactor type that might provide the electrical energy for such a system, as I understand. We are going to have some testimony on that this afternoon.

Senator ANDERSON. Was Atomics International designing this powerplant for the satellite or does somebody else have a contract for that?

General BETTS. The satellite program as we now see it for the next few years will use chemical propulsion and will use it from the boosters that are now in our military program. We have indicated that we have thrusts now well up over [deleted] in the total thrust package, but this is with [deleted] approach. We have a development program which should before very long give us [deleted]. We have in the study stage an engine which we expect will get us about a million pounds of thrust. The real problem with respect to the chemical propellents—

Senator ANDERSON. In clusters or all by itself?

General BETTS. One engine at a [deleted] pounds of thrust.

Senator ANDERSON. What is the largest we have now?

General BETTS. We now have [deleted] by straightforward further development and design work in terms of propellants, diffusers, and the kind of things that are part of that engine development program.

Senator ANDERSON. We have been working on these quite a while, and the farthest we have is [deleted].

(Discussion classified.)

Senator ANDERSON. Do you think it might be more practical to try to get a million pounds of thrust out of an atomic engine?

General BETTS. This must be taken into consideration. As you explore these designs thoroughly, you either go ahead with that or abandon it, and go to nuclear propulsion to get these thrust levels. I don't think we know enough about what it takes to give a million pounds of thrust with a chemical engine.

Senator ANDERSON. If a contractor would like to do it, would you let them try it?

General BETTS. We would not let him build the engine until we know more about the design parameters, and this is what we are exploring at the present time.

That is the summary of what we proposed to say, Senator, and if you have further questions, we would be glad to be responsive.

Senator ANDERSON. We are happy to have you here and know what you are doing. I have a lot of questions in my mind as to why we try for a million pounds when we are reasonably sure it is going to

be extremely difficult to get, but yet we will stop the Atomic Energy Commission from spending another million or two on something that looks like a very good possibility.

General BETTS. I think these have to be relative technical judgments, and I am not in a position to be able to say what these are.

Senator ANDERSON. Could it be that the Atomic Energy Commission does not have the salesman at either the Statler Hotel or the Mayflower?

General BETTS. This is always a distinct possibility.

Senator ANDERSON. Thank you, General. You do not have to leave. We have some industry representatives with us. Who is here from North American?

Suppose we start with Dr. Singer.

STATEMENT OF DR. I. FRED SINGER, OF THE UNIVERSITY OF MARYLAND

Dr. SINGER. Thank you, Mr. Chairman.

Senator ANDERSON. We thought maybe you would give us a little idea of the purposes these satellites might serve and why we want to get in outer space in the first place.

Dr. SINGER. I think this is a very good thing to discuss. It seems to me the justification for all this work has to come first before one really gets down to do a certain job. I thought about this subject for a number of years; to quickly give you my background in this field, I have been in rocket research since 1946 when the first V-2's were brought to this country. I got interested in satellites and space research through the rocket work. As I see it, the primary purposes of satellites and space vehicles are scientific. The knowledge to be gained from satellites and similar vehicles is of primary interest to scientists. Of course, it has great popular appeal. That is why the public is interested in it.

The second point about it is that in order to get up there you need rockets and rockets have military purposes. I think this is why the military are particularly interested in satellites and space vehicles, because we must use rockets to get the satellites and vehicles up there.

I thought very long and hard about some of the other applications for satellites and space vehicles, particularly the military applications, and it is my considered judgment that at the present time I don't see any direct military applications.

I am stressing the word "direct." In other words, I can't see satellites as weapons carriers, bomb droppers, and things of that type. Satellites, however, have a secondary military application from the point of view of reconnaissance, although this is sometimes, I think, presented in a very optimistic way. By this I mean that even if we have a satellite reconnaissance vehicle we will not be able to dispense with any of our other means of reconnaissance and certainly won't put intelligence out of business. Nothing yet can detect a submarine under the surface of the water, not even a satellite. Half the earth is in darkness all the time. That is just the nature of things. A good fraction of the earth's surface is covered with clouds at all times. Finally, there are the old proven stratagems of decoys and camouflage which should work very well for a satellite because it is not a very

intelligent sort of thing. It has only the television camera and not a man. If there is a man up in the satellite, I think its reconnaissance potential might perhaps be increased. This is a point that needs to be investigated. That is one of the reasons why I think we ought to push on with a manned satellite as quickly as possible.

To my mind, the greatest potential of the satellite—to all of us, to the man in the street, to our way of life—is economic. I have no hesitation at all about this. This is my considered judgment on the matter. I feel that the satellite is going to be the vehicle which will make it possible for us to predict weather on a long-term basis. By this I mean predict the weather a season in advance for specific localities, things like wet summers or particularly severe winters, rainfall in particular areas, and things of that type. I don't have to tell you gentlemen what the importance of this is to the economy of our country. If you can make accurate predictions of this type, not only for the farmers but also for the food processors and the canning industry, the agricultural implement manufacturers, the roadbuilding industry, the housebuilding industry, hydroelectric engineers who have to estimate and worry about power requirements, cities which have to worry about water supplies, the resort industry—I think the list is endless, this would be tremendous. How important weather is to our lives is exemplified by so many meteorologists going into business as consultants, and they are being hired to make specific forecasts for industry.

Senator HICKENLOOPER. This will put the Hagerstown Almanac out of business.

Dr. SINGER. Yes; if it is not already. I think, therefore, what was expressed as to hope by President Eisenhower, namely, that space flight serve peaceful purposes, may be extremely realistic.

Then, just to summarize quickly before I open myself to questions, the main justifications as I see them are scientific and, through weather prediction, economic. I, therefore, recommend that we push ahead with selected space-flight projects as rapidly as possible. I have made a little list of the ones that I feel are most appropriate. It goes without saying that we must use rockets which are currently available. Even putting existing rockets together is not easy. One should use existing systems, if possible. Of the list the general presented, the one that attracted me the most was possibility 3. As I recall, that was [deleted] a [deleted] vehicle which can put 50 to 100 pounds in orbit. This should take care of all of our scientific investigations that I can conceive of. That is, the simple scientific investigations. There are very few experiments that require more weight.

A separate category is the meteorological satellite. It requires a very crude television system. This television system can be so crude that one can use just a few photocells to get the effect. I brought along some pictures to demonstrate how crude a system can be used, and still give you results that are meteorologically valuable, and therefore economically valuable. I could pass these around.

Such a satellite would weigh between 300 and 500 pounds. This is the type of picture that a television satellite would get of the earth's surface. The important thing to notice is that you can study the cloud patterns and immediately determine the type of weather over the whole earth's surface. This is something that is not possible

today. Our coverage of the earth's surface is approximately 5 percent. This satellite would make it 100 percent. This type of meteorological satellite in combination with computing machines which can process the data makes the idea of weather prediction really feasible. I think this was first realized and put into words by John von Neumann.

Senator ANDERSON. He had an article in Fortune Magazine, years ago.

Dr. SINGER. Yes. He made a visionary prediction that once we can predict the weather better, it might be possible even to control it.

(Discussion off the record.)

Dr. SINGER. I think this picture is a very accurate picture. The second one is taken by crude television system.

Senator GORE. Doctor, in this second step of controlling the weather, would that not require energy and forces far beyond anything ever dreamed?

Dr. SINGER. Sir, we really don't know the answer to that. We are so far away from even knowing how we would go about controlling the weather that we are not in a position to answer it. It is a hope that we may be able to influence the weather by supplying the proper triggering mechanism which would not involve a lot of energy. But we first have to find out what the triggering mechanism is.

Senator HICKENLOOPER. These pictures are taken from rockets?

Dr. SINGER. No, sir. These are simulated. They are calculated. The original picture was made by Dr. Harry Wexler, who is Chief of Research at the Weather Bureau. This is taken from an altitude of 4,000 miles which is high enough to give you a view of the whole continent, which is really what you would like to have.

Senator HICKENLOOPER. My question is, were these actually taken of the North American Continent?

Dr. SINGER. No, sir, these pictures were calculated.

Senator HICKENLOOPER. There are simulated pictures.

Dr. SINGER. Yes.

Senator HICKENLOOPER. Simulated as if taken at 4,000 miles?

Dr. SINGER. Yes. You see on this picture hurricanes, typical cloud patterns in the equatorial zone; a trained meteorologist can even tell where tornadoes are likely to come. So this type of meteorological satellite not only has importance for long-range prediction, but very accurate short-range predictions. By this I mean of the order of a period of 1 week.

The Atlas vehicle lends itself to constructing really heavy satellites. I would put a number one priority on a manned satellite, a satellite which stays up for perhaps 2 or 3 days to start with, mainly to solve the problem of finding out how a man acts when he is in space, when he is weightless, what his reactions are, is he alert, is he asleep, can he think intelligently, can he observe? These are all physiological problems, things that we cannot simulate on the earth.

Mr. RAMEY. Would you want to start out first with animals?

Dr. SINGER. I am sure you would; yes, sir. The really big problem is reentry, and then recovery. I am close enough to that phase of the work to be able to tell you that the problem is solvable. In fact, two

different engineering approaches have been suggested, and it is a matter of working them out and putting them into practice.

If you take a given propulsion system and if you want to send something very far out, have it escape from the earth, or hit the moon, then you have to reduce the payload somewhat, because it takes more velocity to go far out. It takes about 40 percent more velocity. With the IRBM system or the Atlas system, you should be able to put varying payloads on the moon. The question arises why should you want to do that. I think again the answer would be that you want to put an instrument payload on the moon to find out now something about the surface conditions of the moon. I think you will agree that this has primarily scientific interest to start with. It may conceivably have military importance at some future time, but I don't think we can define this importance at the present time. My feeling is that even scientific justification should be enough to induce us to go into this type of activity, particularly since it can be done for relatively little cost if you use existing rockets.

There are many other types of projects that we can do that are imaginative that don't require very much in the way of equipment. One of the simplest things we can do is to send up a small satellite which blinks all night long. It would be something that you can see visually. It is a trivial thing from a technical point of view. It is important from a scientific point of view. It is important, I am given to understand, from a psychological point of view.

Senator GORE. With respect to the latter, you and I were in Europe at the time of the launching of the first satellite. We felt the impact on public opinion and attitudes. The psychological and political impact was enormous. I am not prepared to know what scientific values might be involved in satellite, et cetera, but I can agree with President Eisenhower's statement in his state of the Union message, that as a nation we had failed to foresee the psychological and political effects of a Russian scientific breakthrough. It is that particular phase which I have some competency to understand that troubles me here, and that causes me to feel the impulsion to press forward in this undertaking.

Dr. SINGER. It is good also that these programs have a direct scientific justification.

Senator GORE. I am not prepared to say they do not. I am prepared to believe that they do, but I have not too much ability to judge in that field.

Dr. SINGER. I am also troubled by the fact that we do not have anything right now with which we can outdo the Russians in the propaganda field. In other words, we cannot at the present time send up anything that is bigger or more spectacular than the sputniks. I think, therefore, that our wisest choice would be to compete in a different area where they cannot compete with us.

One of the proposals that has impressed me most is to send up a satellite which is luminous as a symbol of our intention to press for the peaceful exploration of space to back up the statement made by President Eisenhower. I feel, however, that this should not stop us from pushing ahead with these other space-flight projects I discussed. I think the greater their scientific and economic importance, the more of an impact they will make on the world. If we can show to the

world that we are getting some tangible good out of this—which benefits us and, therefore, ultimately the rest of the world, I think we will be ahead of the game, aside from the fact that it will more than pay for the whole program. I am not capable of estimating in dollars how much accurate weather prediction over long periods of time—say many months in advance—will add to our national income. I have asked people and I have gotten answers which go up to several billion dollars.

Senator GORE. Some people have made references to possibilities which are even beyond my imagination. For instance, it has been mentioned by some that tides could be influenced or controlled. It seems to me that, too, would involve physical forces quite beyond any concept of which I am capable.

Dr. SINGER. I would agree with you. I do not see offhand how one can influence tides in a very simple way or by simple means.

Senator GORE. After all, the moon is a right hefty ball, and it would take a good deal of doing to throw it around or put something in being to compete with it in its gravitational pull.

Dr. SINGER. I think you are right there; yes.

Senator GORE. So even though all of this field may be described as fantastic by some, nevertheless we must pinch ourselves that we don't lose touch with reality completely.

Dr. SINGER. I have given a little bit of thought—since this is the Atomic Energy Committee—of how atomic bombs can be used to help us in our study of outer space. I thought about this before I was invited to the committee. It seems to me that there are many interesting applications for atomic weapons for the exploration of space, things that have not been tried yet. After I developed some of these ideas, I discussed them with several scientist friends of mine. They all referred me to Dr. Teller. I talked to him last week at Berkeley. He was most enthusiastic. Briefly, the ideas are as follows:

If a bomb is exploded outside of the earth's atmosphere, completely new phenomena come into play. The one that interests me the most—I don't think this is classified, because it has not gone through the AEC channels.

Senator GORE. Be careful that it does not get there.

Senator ANDERSON. If it gets there, it will be classified.

Dr. SINGER. If you explode a bomb above the atmosphere, the bomb can set up what I call a magnetohydrodynamic wave. This happens to be one of my fields of study. I am interested in the upper atmosphere and the magnetic effects of the upper atmosphere. What it means is the following. The bomb explosion can jiggle the lines of force of the earth's magnetic field. This wave will travel along the lines of force just like a wave travels along a rope. If you set off an explosion near the North Pole, you should be able to detect this jiggle near the South Pole as the wave comes down, following the line of force. If this is the earth, the lines of force go out into space and come back into the South Pole, just like the lines of force from an ordinary magnet. This is very interesting, because it gives us a means of studying what is out there by setting off an explosion near the earth here and by observing near the South Pole.

Senator GORE. Doctor, how can there be a wave in a void?

Dr. SINGER. That is a very good question. There is not a void. If there were, there could be no wave. There is a very, very tenuous

atmosphere surrounding the earth, the interplanetary gas, and what this essentially would do, among other things, is to measure the density of interplanetary gas, and tell us exactly how many atoms there are in one cubic centimeter of space surrounding the earth, which is a very interesting thing to know. We would estimate that there are several hundred atoms per cubic centimeter. At sea level, for example, the density is 10 million billion times as high—10 to the 19th atoms per cubic centimeter. So it has dropped off by a factor of a million times a billion when we get far from the earth. But it is not too tenuous to support such a wave. I think it would be great fun to do this and look for it.

(Discussion off the record.)

Senator ANDERSON. Doctor, I have to leave for a minute or two, and probably longer. We have just been discussing that when we adjourn, we will probably adjourn to meet again at 2 o'clock or a little earlier, and take the groups that remain this morning to discuss if they could at 2 o'clock. Finally, we will get Colonel Armstrong at a later hour. Is there anybody here who was going to testify from the industry group who would be seriously inconvenienced if we go over to 2 o'clock?

(Discussion off the record.)

Dr. SINGER. I am completely at your disposal, gentlemen. I have nothing special, and I would gladly answer any questions you might want to ask. I want to make you as aware as I can of the great economic implications of the satellites. I think it is very important that Congress realize it, because in my opinion it has such an important effect on our national economy.

Representative VAN ZANDT. Unfortunately, I had to answer two rollcalls, and I missed your testimony. Could you take a minute to bring me up to date on what you said?

Dr. SINGER. Yes, sir. My main point is that we should keep the justification for satellites uppermost in our minds. Once you have a justification, doing the job technically is very simple. You just do it the cheapest way. There are many scientific justifications I see ranging from small satellites from 20 pounds, up to the very large ones which can carry a man. I think it is scientifically important, and perhaps militarily eventually to get a man up into an orbit for a couple of days.

Representative VAN ZANDT. How many pounds would it take to support a man?

Dr. SINGER. Fifteen hundred. This could be done with a standard ICBM rocket, replacing the warhead by a suitable container. That would be a sort of sardine can which fits very tightly around a man and does not give him much comfort, but it is the best we can do. To my mind the economic implication of satellites is very important. I see it primarily as a vehicle for weather reconnaissance, a system of a satellite together with computing machines on the ground which can be used to predict weather on a really long-range basis. By this I mean seasons in advance to predict climatic conditions for specific parts of the country, which would be of tremendous benefit not only to the farmers, but to all the other industries. If you mention any industry, eventually we can find out why they are affected by weather. Eventually we may be able to control the weather. But even prediction is tremendously important.

Representative VAN ZANDT. How far in advance do you predict?

Dr. SINGER. Our best estimate is that you can predict a couple of seasons in advance. As you go out farther and farther, your accuracy gets worse. This is a matter of experience. With some experience the accuracy improves. I don't think one can guarantee 100 percent accuracy in any case.

The satellite gives us a weather reconnaissance vehicle of great potential—we have never had anything like it before. To my mind this is how space flight will really influence our way of life. I don't think the average man is going to be tremendously affected by what we learn about cosmic rays, which happens to be one of my chief interests. I think they are important, but that is because I am biased. I think they will be mostly impressed by things that add to their incomes. I want to be sure that this great potential of the satellite is realized as early as possible so that we do support it adequately.

Representative VAN ZANDT. What is your thinking as far as communications are concerned?

Dr. SINGER. Could you specify?

Representative VAN ZANDT. What effect will a satellite orbiting have on communications?

Dr. SINGER. At the present time, as you know, the range of television is limited because of the television waves which go out of the atmosphere and are not bounced back by the ionosphere. If you had a reflector up there you could bounce back the television waves and you could receive television stations clear across the country. Some people say that is a good thing.

Representative VAN ZANDT. What about jamming?

Dr. SINGER. I don't believe a satellite can jam effectively. This is a matter of power required.

Representative VAN ZANDT. What about photography?

Dr. SINGER. For reconnaissance purposes?

Representative VAN ZANDT. Yes.

Dr. SINGER. I don't think again that this is superior to other systems which are now in existence, for example, a very fast reconnaissance plane, because of the difficulty of recovering the film from the satellite. The proposal to use a television camera on a satellite for reconnaissance may be valid, although I think the resolution which has been claimed for it is a little optimistic. It will not replace other systems of reconnaissance, I should add.

Representative VAN ZANDT. What about detection of critical materials, the location, and so forth?

Dr. SINGER. Of uranium and such things?

Representative VAN ZANDT. Yes.

Dr. SINGER. No.

Representative VAN ZANDT. No value there?

Dr. SINGER. No, sir. In any case, as you know, it is very easy to set up decoys. I think we can discount all so-called direct military applications.

Representative VAN ZANDT. That is my next question.

Dr. SINGER. I am a little worried about the fact that people claim you can drop a bomb from a satellite. If I am on a space station and have a bomb in my hand and drop it, what happens to it? It stays right where it is and keeps going around in the orbit. So in

order to really drop it, I have to toss it out backwards with a speed of 18,000 miles per hour. Then the bomb will appear to stand still in space and drop straight down. While it drops down, the earth turns. It takes quite a while to drop down. I don't see why a bomb carried in a satellite is in any way superior to a bomb carried by an ICBM.

Representative VAN ZANDT. The degree of error would be considerable.

Dr. SINGER. Yes. I see the same problem about the moon. I admit I have not been involved in the thinking and perhaps there are reasons I don't see. It seems to me that a launching site on the moon is just as vulnerable as anywhere else, because if they can see us, we can see them.

Representative VAN ZANDT. Then the primary benefit as I see it would be weather reconnaissance.

Dr. SINGER. Yes, sir; that is the primary. I am measuring in dollars and cents. The scientific benefits you can't measure in dollars and cents.

Representative VAN ZANDT. And the propaganda benefits.

Dr. SINGER. Yes, sir. To summarize, I think we have enough justification, even economic justification, to press for a very imaginative program of space flight. I think all of these programs I have spoken about can be done with existing rockets, without any further developments, or without further substituting of new fuels. The atomic rocket as far as I am able to tell may have great potential for the future. It is my feeling that with the existing rockets we can not put a man on the moon and expect to bring him back again.

Representative VAN ZANDT. That is using chemicals for fuel.

Dr. SINGER. Using what we now have. It may be possible to improve the chemical rockets somewhat. You can always stretch things. It depends on the attitude. If you are an optimist, you can stretch better than if you are not. One also has to see who prepares the report. It is my judgment that about the most we can do with existing rockets—by existing, I mean rockets which we will have in the next year or two operationally—is put one of these sardine cans with a man in it around the moon and bring him back again. Essentially we let the moon bounce him back to the earth.

But landing on the moon is quite a problem. It involves slowing him down in speed so he does not get flattened into a disk, and taking off again involves more energy. If we could make the surface of the moon elastic so he could bounce off and come up again, that would be wonderful but it is not very possible. I see, therefore, a fairly natural cutoff point, if you want to call it that, things that we can do with existing rockets—by this I mean military rockets—and space-flight projects which require special rocket development, in other words, bigger rockets than are now available for military purposes.

Mr. RAMEY. Do you think it is important to go ahead with this longer range sort of thing, including the nuclear at an accelerated pace?

Dr. SINGER. It is a matter of money; isn't it? I am in the following position. It is a matter of weighing the relative costs. If it can be done for reasonable amounts of money so as not to take too much from our defense budget then the answer would be yes. If it means

sacrificing items which our experts consider essential for our defense, then perhaps the answer would be let us not put a crash program on it, but let us keep continuing development. Many of these advanced programs, by the way, involve research. Research can be done on a very cheap basis.

Mr. RAMEY. Do you think there should be more coordination of this more advanced type of research between the military and the various civilian groups that are engaged in the paper studies so that they can get into the experimental development and finally the hardware stage quicker?

Dr. SINGER. I do. I really do. I have the feeling, however, that this is just what is coming about now. In my opinion, the factor which has slowed down our own work in the space-flight field is the long chain between the people who were enthusiastically for such projects, and the people on top who finally approved them. My feeling is that with an agency being set up in the Department of Defense, or elsewhere, which will have top-level direction of all of the activities in the Nation in this field, such approval, if it does come, will come faster, and that is worth a lot.

Another point, too, it will avoid duplicating approaches. The present situation is the following. A contractor goes to a man in an Air Force office who is a good dedicated technical man, typically a lieutenant colonel, and he says, "I have an idea for a system to put us on the moon." He says, "Fine, let us work it out." With proposal in hand, he goes to the Director of his office who may be a full colonel who may give cautious approval, because he is not sure how people higher up will take the matter. Then it is reviewed by the committees and finally it may move up slowly to the top. The Far Side project for a 4,000 mile rocket which I am associated with is a good example. The design was completed 3 years ago. It took $2\frac{1}{2}$ years to move it to the top. The actual doing of it, once the contract was let, took less than 6 months.

There is another thing about this agency concept. Under the old system of operation, there is nothing to prevent another company going to a lieutenant commander in a different office, approaching him with a similar idea. He is a good technical man and sees the advantages to the scheme, and he starts to push it. His commanding officer, say a Navy captain, will approve it very cautiously and forward it. By the time you get into top-level review, you have several competing programs, which may be as far along as development. In other words, there will be a lot of money already in it. Somebody on top is faced with the really awful problem of deciding which one are we going to push. If he has a lot of guts, he will say we will push the better one. If the pressure is on, he will say, "I think we ought to do both to be on the safe side." I think by having this top-level direction right from the beginning we will be able to avoid a lot of duplication.

Representative VAN ZANDT. From the standpoint of the effect on metals, if we could launch a satellite and bring it back to earth the information would be helpful?

Dr. SINGER. I think we should be able to do the following. If we can bring it back again, we might be able to study the effects of meteors on the skin of the satellite. Therefore, we can evaluate the types of vehicles which we will have to build if we want to stay in space for any extended length of time.

Representative VAN ZANDT. Wouldn't that be helpful in our missile program?

Dr. SINGER. I think a properly run space-flight program would be very helpful in the missile program for several reasons. In the first place, it would give us important environmental information. It would tell us what is up there from a scientific point of view, and therefore allow us to design our missiles with perhaps a better factor of safety. We would not have to provide for so many emergencies. Secondly, I think there is a morale problem, too. The people who are working in the missile industry, the topnotch people, are very, very good and dedicated people. A lot of them sincerely believe in exploration of outer space, and it would be a great boost to their morale if they knew that the missiles that they are working on, the guidance system they are working on, all of these items that have direct military significance, could also be used for scientific purposes. I think that is perhaps one of the reasons why the team at Huntsville worked so well. They do not do any actual space flight there, but they keep talking about it, and it has a very good effect on their morale and has kept them together for many years, and has made them work very, very hard on military missiles.

Representative VAN ZANDT. That is all I have.

Senator HICKENLOOPER. Thank you, Dr. Singer.

Are there any additional comments before we adjourn until 2 o'clock?

Colonel ARMSTRONG. I would like to express some disagreement, if I may, if I am not out of order, with some of the things that Dr. Singer has said.

In the first instance, I agree with him wholeheartedly on the scientific approach of the value of a satellite. I question very seriously the scientific value of a 50-pound satellite. In the first instance, you must have something which will gather information, which will either store information and bring it back down to earth, or which will transmit information back to the earth. For the guy who has to develop the electrical power sources, et cetera, to power such equipment, 50 pounds begins to become a pretty ridiculous situation.

On the other hand, I disagree also very violently with Dr. Singer that the military worth of these things is very questionable. [Deleted.] I think these are going to be extremely valuable in gathering [deleted]. In other words, even with the periodic cloud cover, when you have a satellite which makes a trip around the world every 90 minutes, it keeps changing its orbit, if it is dark at one time around maybe the next time around maybe it is going to be light. If there is cloud cover the first 4 or 5 times around, the next time maybe it will get a break in the clouds. [Deleted.] However, these things cost a lot of money to put up. Once you have put them up, you ought to keep them up there just as long as you can. You ought to use them as long as you can.

I think the program which I am going to explain to you this afternoon, which is not any dream in anybody's mind, but metal chips are being cut, solves this problem for us. So in those instances I am in complete disagreement with Dr. Singer.

Dr. SINGER. I think I ought to rebut, particularly since I think I can. If I did not, I would keep quiet. I want to show you the experiment that I have prepared for the Vanguard satellite to measure

the effects of meteor on the satellite skin. This weighs three quarters of an ounce. Most of the scientific experiments that we can think of in the National Academy are similarly very light. If you give me 50 pounds there is an awful lot we can do with that. The transmitters also weigh of the order of ounces and use so little power that the electrical supply can be from batteries. [Deleted.] There are some experiments that require heavier satellites. Probably what you meant is that you could change the orbit.

Colonel ARMSTRONG. Yes.

Dr. SINGER. That sounds very complicated to me. However, I think what I said before still stands. I think there is actual value to reconnaissance from a satellite. It will not supplant other methods of reconnaissance by any means. I think we will still use intelligence. As long as the satellite cannot tell where the submarines are, as long as it is subject to decoys and camouflage which the Russians will use, it is not an ultimate intelligence system. But it is very valuable and should certainly be pursued. I am all for it.

What the actual resolution of the television system is depends on whether you are very optimistic or not. I also have a figure that I can put on this since I have been associated with this program. I don't think it is appropriate to do this here.

Senator HICKENLOOPER. Doctor, do you consider that satellites would contribute to intelligence?

Dr. SINGER. Yes.

Senator HICKENLOOPER. Substantially?

Dr. SINGER. Yes.

Senator HICKENLOOPER. There is no such thing as exact intelligence, is there?

Dr. SINGER. No, sir. I think it would contribute. I think it is valuable.

Senator HICKENLOOPER. It is a matter of relativity. You say that we have an agent in X situation in some foreign country and he sees a certain type of tank or a certain type of something else and reports that, and I think in the main they say that is hard intelligence. It may or may not be. He may be a liar. He may be a double agent. He may be something else. If you can't check intelligence to the point where you get the error down to an absolute irreducible minimum so that anything that would materially contribute to verification of information would be extremely helpful.

Dr. SINGER. I certainly agree. I think it would be an important supplement. This is my real feeling about it as an intelligence system. But it is subject to decoys and camouflage. The situation is about as follows: The satellite can see the ground whenever you can see the satellite. Assuming there is only one up there, there will be many areas which will not be under surveillance for long periods of time, either because the satellite is not overhead, or because of night-time or clouds. Visual reconnaissance is not the only means. Infra-red is another means, although it has rather poor resolution. Electronic reconnaissance is valuable. I don't want to disparage.

Colonel ARMSTRONG. Let me agree with you on one thing. I do not think it will supplant other forms of intelligence, but one very interesting factor is that you cannot fly an airplane over Russia today and take pictures. They don't like this. There was real doubt years ago whether you could fly a satellite over Russia and whether she

would not declare that as an act of war. She solved that question for us and we don't have to worry about it. In peacetime when you cannot fly airplanes over the enemy country to take a look at it, the only way I know of you can look at it is the satellite. That is the only acceptable means.

Dr. SINGER. I think you should assume that the Russians will develop their potential at about the same rate as we, and it is safe to assume that they will develop a reconnaissance satellite and for the same reason we will have to keep up with them, too. It is also reasonable to assume they will develop certain countermeasures to reconnaissance satellites, and we will be forced to do the same.

Senator HICKENLOOPER. I think in any military system, whether peacetime or war, the psychological impact one way or another is a very important factor.

Dr. SINGER. Yes, sir.

Senator HICKENLOOPER. Maybe it has considerable military benefit if we can reverse the question mark that has been created about Russian superiority and the American inferiority on some of these things by getting something going.

Dr. SINGER. Let me stress my own views on the matter. The scientific and economic importance of our satellites and space flight programs will in the long run, I think, be of the greatest value to show to the world.

Senator HICKENLOOPER. I do not minimize that.

Dr. SINGER. The weather satellite, incidentally, is just a reconnaissance satellite, basically, but it can be one with very, very poor resolution. It does not have to be as good as a military reconnaissance satellite.

Mr. TOLL. Colonel Armstrong, wouldn't the Russians have a comparatively easy job of shooting down a reconnaissance satellite since they can measure its course and know just where it will be at a given moment?

Colonel ARMSTRONG. At the moment we have a hard time predicting it is going to be where when. Not only that, but it takes a very, very slight nudge every so often to change the course of the satellite to make it completely unpredictable.

Representative VAN ZANDT. That is true of sputniks I and II.

Colonel ARMSTRONG. They are pretty close in. They would have a little harder nudge, but it does not take much of a nudge up there. (Deleted.)

* * * * *

Senator HICKENLOOPER. Are there any other comments?

Mr. ROTHROCK. I think at this stage it would be extremely dangerous to assume that the satellite is not of great military importance both from the standpoint of reconnaissance and launching. I think the committee should make quite sure that it gets several opinions on a question of this sort, because of its vital importance to the country as a whole.

Representative VAN ZANDT. I understand Colonel Atkinson had something to say.

Colonel ATKINSON. I would like to suggest one point of reference which might be useful in assessing various scientific and technical efforts, and it is a framework in which I think we can hang a number of efforts which are underway.

Over on the right [drawing on chart] we have production, which essentially operates the force in being. That is a deterrent capability which could place America in a strong position. This costs a great deal of money to produce an overall weapon system and retain it in operation.

The next step beyond producing a system is the system development. Before we get to the system development we define a category which is technical development and before we put something into technical development, we have research. The cost factor for research is very small, for technical development it gets larger, for weapon system development it gets very much larger, and for full production it is tremendous.

One of the comments made this morning concerned the length of time it takes to study and consider various proposals that come up with respect to satellites. There is an economic aspect which regulates and controls to an extent what we can do. To put a satellite up is a system type of development. Before that should be done we should be able to demonstrate the capability, and feeding into all these are various research projects where you do not know whether there is anything there or not. We have to back many horses in this area. As something proves feasible, we move it into development.

I think the atomic rocket is in tech development. The key part of tech development is to demonstrate development. It is my understanding that in a short length of time the feasibility will be demonstrated. From the service point of view, it has to maintain a force within limits of cost. From a systems point of view, before we phase in a new system we have to assure ourselves that it is in fact feasible because a stake at this level would involve a large amount of money, and a stake at this level involves smaller, and the research we have to back many horses, and we hope to have a good return.

The second comment I wanted to make was with respect to duplication in the services. We certainly recognize that as a problem. There is a lot of research activity going on in the Department of Defense agencies, and the other agencies of the Government. But in practice we do work very closely on a research basis in coordinating what work is being done in order to cut down unnecessary duplication. In research where a number of projects are very economical compared to the other aspects of it, a certain amount of duplication is desirable. We make every effort to know what the other agencies are doing within the Department of Defense and other Government agencies.

Senator HICKENLOOPER. Colonel, this question of knowing practically nothing about these scientific situations is as I said very often, I can speak freely. I am not mentioning a new idea, and I do not claim it as such, but it seems to me in developing the first atomic bomb and getting a successful bomb, research was essential. It is thoroughly essential. It seems to me as I recall we jumped over several hurdles in the emergency of seeing whether a bomb can go off or not. We did not prove every last ramification or follow every alley or every leadoff in this great vast field. We jumped over certain things and drove for one particular objective, which was attained. I would not for a minute say abandon research at all in any way, shape or form, but is it not possible that maybe two approaches might be taken toward something? Maybe taken vigorous and detailed

step-by-step research which takes a long time when you prove every step. But to have somebody else saying, "I don't know what the answer is right down here," but let us theorize and jump here and see if we can't put two and two together up here and make five out of it in some way.

Colonel ATKINSON. Yes, sir.

Senator HICKENLOOPER. That is dangerous ground, of course, but I think it has been done before. I think if we had proper research on this subject, we would find that many things that have been invented or produced or found to work did not wait on completely proving every last detailed step. Again I say I am not at all advocating any minimization of research in all its phases as it goes along, but it takes a long time sometimes to absolutely prove every step. There might be some system where it is urgent we might jump some hurdles where we thought that reason and judgment and analysis showed that it might be safe to do so.

Colonel ATKINSON. Yes, sir.

Senator HICKENLOOPER. We might fail more times than we succeeded. It might be a wrong idea, but it might work sometimes.

Colonel ATKINSON. Yes, sir. I meant to convey that idea that in backing a number of different approaches in research, we are seeking new knowledge on a number of different types of propulsion systems. The shortcomings are readily apparent. But we feel we have to look into a number of different ones.

Senator HICKENLOOPER. I do not dispute that for one moment. That is not what I am talking about. I would say let research going on carefully and in detail continue, but maybe another team would take some chances.

Colonel ATKINSON. That is quite true.

Senator HICKENLOOPER. I do not know. Maybe it is a crazy idea. I know some people do not agree with me.

Colonel ATKINSON. It is necessary to back a number of horses.

Dr. SLAWSKY. I think in actual fact research has never stopped any one in going ahead and getting a proper solution to a problem. But the vice versa has often happened. The funding of basic research has been stopped to pour money into a practical solution, and never vice versa.

Senator HICKENLOOPER. I understand that. After the first atomic bomb was proven, then we went back into that vast field of unexplored discoveries where certain things had been discovered but not followed out. There was a time when money was not available to get back and do that. So after having attained the practical result, there was a slowdown on scientific research in things that had been left by the wayside on the way up in that particular thing. I do not know that we will ever get to that point.

Is there anything else?

Representative VAN ZANDT. That is all.

Senator HICKENLOOPER. Gentlemen, we will come back at 2 o'clock. (Thereupon at 12:45 p. m., a recess was taken until 2 p. m., the same day.)

AFTERNOON SESSION

The subcommittees met, pursuant to recess, at 2 p. m., in room F-88, the Capitol, Hon. Carl T. Durham (chairman of the Joint Committee) presiding.

Present: Representatives Durham, Holifield, Price, Dempsey, Van Zandt, Patterson, Jenkins, Hosmer; Senators Anderson, Pastore, Hickenlooper, Bricker, Dworshak.

Also present: James T. Ramey, executive director; John T. Conway, assistant director; David R. Toll, staff counsel, and George E. Brown, Jr., staff member for research and development, Joint Committee on Atomic Energy.

Representing the Department of Defense: Gen. Austin W. Betts, Deputy Director for Guided Missiles; Paul Smith, Office of Assistant Secretary of Defense for Research and Engineering; Comdr. M. M. Slawsky, Office of Scientific Research, USAF; Lt. Col. Paul Atkinson, Office of Scientific Research, USAF; Wernher von Braun, Army Ballistic Missile Agency; Homer E. Newell, Naval Research Laboratory; W. G. Stroud, United States Army Signal Corps; Maj. Joseph E. Boyland, Office, Legislative Liaison, USAF;

Representing the Atomic Energy Commission: Col. Jack Armstrong; Commander Moore; Dr. Theodore Merkle, Livermore; Dr. Raemer Schreiber, Los Alamos; K. E. Davis.

Representing the National Advisory Committee for Aeronautics: Dr. John C. Evvard, Lewis Laboratory; Dr. Addison M. Rothrock, Assistant Director for Research.

Others: Dr. Stanley V. Gunn, Rocketdyne division, North American Aviation; Dr. William E. Parkins, Atomics International, North American Aviation; Dr. Sidney Krasik, Bettis Laboratory; Mr. John W. Simpson, Bettis Laboratory.

Chairman DURHAM. The committee will come to order.

This is a continuation of the briefing yesterday on advanced atomic engines for satellites, and I believe Colonel Armstrong will continue. We did not finish with you yesterday, did we?

Colonel ARMSTRONG. No, sir.

Chairman DURHAM. Thank you. You may proceed.

STATEMENT OF COL. JACK L. ARMSTRONG, DEPUTY CHIEF, AIRCRAFT REACTORS BRANCH, DIVISION OF REACTOR DEVELOPMENT, ATOMIC ENERGY COMMISSION

Colonel ARMSTRONG. We have heard a great deal about being out in space, and I would like to keep you out in space for a little bit; but I am also going to try to get your feet back on the ground a little bit, because we are going to talk about things which are not in people's imagination but are coming into being very soon.

The secondary nuclear auxiliary power systems, or SNAP, as it is known, I should perhaps define. If you have a satellite out in space, I assume you put it there for some purpose other than just to be there.

[Deleted.]

The main thing about this is it costs a lot of money to put a satellite up there, and when you have it up there it ought to go on working for you as long as it possibly can. I will admit we were considerably

shaken up on about the 20th day when sputnik kept going beep, beep, beep, because we had computed our own tables then as to how long the batteries could have lasted up there, and we came to the conclusion there must have been something other than batteries in it. Then we made a recomputation on what the possible requirement of this transmitter was, and we finally came to the conclusion 21 days was about the best it could go [deleted]. It actually did quit on the 21st day [deleted] then it must have within it some source of energy to power the equipment within the satellite that is going to do whatever it is you send it out there to do.

Chairman DURHAM. You mean for the purpose of taking photographs or something like that?

Colonel ARMSTRONG. Yes, sir; whether it be a transmitter going beep, beep, beep all the time, as the sputnik did, or whatever purposes you may put the satellite up there for.

When you look at energy, as to what you could use out in this satellite, of course, you are always very concerned with weight. There are several different kinds of energy you can have up there, but electrical energy seems to be the most useful type.

There are several different ways you can have electrical energy; namely, from batteries, from some kind of a chemical generator running up there, a solar battery, or nuclear. Our subject will be on the nuclear-energy aspect.

Our program is to develop a nuclear-energy power source to energize the electric equipment in the Air Force reconnaissance satellite, WS-117-L. In other words, these sources of energy are pointed to a particular system which is now under development in the Western Development Division, and I believe the prime contractor is Lockheed. [Deleted.]

Now, I guess I am going to brag a little bit. You see, some things happened quite a long time before sputnik. We have been working on this proposition for satellites, but we also freely admit, up to about 6 or 8 months ago, every time we started talking about putting money into these kinds of things everybody looked around for the man with the white coat, and we stopped it, suffered accordingly.

In fiscal 1957, our requested appropriated budget was \$3 million. We had several schemes going. We had a scheme of using radioisotopes. We have two schemes of using thermal reactors, and we had a scheme to use a fast reactor.

As we looked these things over as the propositions started coming out of the contractor, it became apparent that the kind of money we could afford in the future—because, after all, we were already thinking about this kind of a budget—we could not afford to run the fast-reactor program, and a fast-reactor program was going on at Los Alamos anyway, so we could learn a great deal from it. So we decided to drop the fast reactor.

Of the 2 thermo reactor schemes going on, 1 was far more interesting than the other. We did not feel we could afford 2, so we dropped 1 of those. So, we voluntarily backed off to \$1.6 million for the fiscal year 1957.

In fiscal year 1958, we asked for \$3 million. The Presidential budget contained \$1.2 million, and there was \$1.2 million appropriated. We actually spent \$2.2 million.

You will remember the other day, when I spoke of Rover, I indicated a million dollars was stolen out of the Rover money in 1958. I think there was a real reason to do this. I think this was very important to keep going, but I would like to give some credit where credit was due. I have some very bright young aids up there, including Commander Moore, who is with me today, and Lieutenant Colonel Anderson, project officer on this, and they hammered on me to do this long before sputnik ever went up, which shows they were really thinking.

We have asked for \$4.6 million in 1959, and that is in the Presidential budget. For the first time, we have asked for construction money in connection with this program, and that is in the 1959 budget.

Representative HOLIFIELD. Both of those will be in the AEC budget?

Colonel ARMSTRONG. Yes, sir. At first, this program was run in the AEC on the reactor side, and the Air Force was appropriating the money to do the conversion equipment that goes with it. This is such a tightly knit little unit, and each piece is so dependent on each other piece, it became obvious it was not the way to run it. So, we proposed to the Air Force, and the Air Force accepted, that we take over the whole job of building this unit with 2 wires coming out of the side of it, with electricity coming out of the 2 wires.

Chairman DURHAM. Haven't they got some funds in the appropriation bill before us today?

Colonel ARMSTRONG. The Air Force?

Chairman DURHAM. Yes.

Colonel ARMSTRONG. Not for this unit; no, sir. It is all contained within the AEC budget.

Representative HOLIFIELD. This is all in research and development?

Colonel ARMSTRONG. Yes, sir. The approaches we are taking to these things, we have some requirement from the Department of Air Force as to when they would like these, the electrical energy they would like to have coming out of them, and the time they would like to put them into orbit.

Our first concept is known as Snap I. It is the use of radioactive isotopes as a heat source. The Martin Co. has the prime contract; Thompson Products has the subcontract for the rotating machinery. As I mentioned, we are using cerium 144 as our heat source, inasmuch as the waste stream coming out at Savannah is normally buried, but we are going to separate the cerium 144 and use it. We will get [deleted] electrical energy out of these 2 wires for a period of 60 days. Obviously, with radioactive isotopes decaying over time, this will last considerably longer than 60 days, but we will have to start accepting less [deleted] after that.

(Classified discussion.)

Colonel ARMSTRONG. As you start going up in power, although radioactive isotopes are in the waste stream, it costs you something to get them out. To the extent that one can separate isotopes and find a market, of course, the price will go down. So, yes, sir, there are schemes for using these for power where power is real expensive. I would like to get into some of these applications as I go along.

Senator BRICKER. What is the half life of cerium 144?

Colonel ARMSTRONG. Its half life is 290 days.

There are other isotopes whose half lives are longer, but when you figure out the relative costs and the radiological hazards concerned with them, sir, cerium 144 fits the bill the best. This costs about 7 cents a curie as against polonium which costs about \$10 a curie.

Snap II is the thermal reactor. This is being done out at Atomics International. It has the same subcontractor, Thompson Products, working on this machinery. So we have one contractor who is building [deleted] identical machinery, and we have been able to save quite some money this way.

[Deleted.]

Representative PATTERSON. When was the operation started?

Colonel ARMSTRONG. 1952-53. I might add, we were working on a very, very small budget. Atomics International is so extremely interested in this thing I think you will find a lot of their money in it, because this was carried through to a design critical stage for a total cost of everything—facilities, research, materials, the works—for \$885,000.

Chairman DURHAM. You said they put some of their money in. Why? Couldn't you get the money?

Colonel ARMSTRONG. I was short on money, and Atomics International is extremely interested in this thing, and they have really been willing to cut down to a very, very narrow pencil point on it. We had the utmost cooperation on it.

[Deleted.]

Snap III is a very new one to us. We ran across some work that is being supported by the Navy and we took advantage of this. Its work is with Westinghouse, I think as a result of some Russian work. We are trying to utilize this to provide an extremely light, an extremely small source of power, for something like the Vanguard, or something around that type, and this is only 3 watts of electrical energy for 6 months and will probably weigh not to exceed 10 pounds. This is a very unusual thing, and I think it is something which has a great future.

This is a mixed valence oxide. These little pellets you see here I have actually seen demonstrated. You put fins on one end to cool them, and you apply heat at the other end and electrical energy flows out.

I saw one of these on my office desk with about a dozen of these pellets on it, and they used in this case a propane gas flame on the back side of this. Two wires came out the other side and hooked up to a portable radio and we had music.

Usually a thermocouple is an extremely inefficient way to make electricity. It is a way less than 1 percent efficient. That little gadget is about 8 percent efficient. They feel that the efficiencies can be increased up to 15 percent and, perhaps, to 25 percent efficiencies.

If this pans out, we would then use polonium as a radio isotope for a heat source on one side, and then we would have a very close approximation of direct conversion of atomic energy into electrical energy.

They are so sure of themselves on this that they came in and offered to provide us this unit, 3 watts, in 6 months or a little more for \$25,000. We bought it. This has a great deal of interest for the future. I think, if you will, the chances of getting up to 25 percent

efficiency and using this directly with the reactor in making power right out the side of it—

Senator BRICKER. That is more promising in peaceful uses than anything you have been talking about?

Colonel ARMSTRONG. Yes, sir.

Mr. DAVIS. This is an extremely interesting development, which, incidentally, would apply to conventionally fired engines as well as the nuclear fired ones. It has the interesting property, Westinghouse believes, that this material is not damaged by radiation. If anything, radiation in a reactor might actually improve its properties. Our initial worries about the effect of radiation—while they have not been confirmed, the theoretical people who came up with this also believe that radiation will not damage it.

Chairman DURHAM. It does produce radiation, of course.

Mr. DAVIS. Not this device itself. The reactor will. But the point, Mr. Durham, is that the radiation is not expected to damage this particular device. In my own personal opinion, this is one of the most revolutionary things that has come to our attention.

Chairman DURHAM. Did the Westinghouse laboratories develop that entirely?

Colonel ARMSTRONG. The information I get—and this is hearsay. I have not seen directly the information—is this is a Russian development that has been stumbled on and picked up in this country and being worked on very hard.

Senator BRICKER. How did they find it?

Commander MOORE. I believe a man called Dr. Yoffe (?) in Russia is the recognized expert in this field. It is our understanding that some of the work that Westinghouse is doing is in corroboration of previous Russian work in this same field. This apparently is quite well known in Russia.

Chairman DURHAM. Did the \$25,000 give you full rights to it?

Colonel ARMSTRONG. No, sir.

Mr. DAVIS. Westinghouse did a great deal of this work entirely on their own money, and started this development. Since they have gotten some Navy support for Navy applications and we have been discussing with them support by the AEC. A sizable effort. I do not know now whether we have a contract with them or not.

Chairman DURHAM. I assume there is a patent on it.

Mr. DAVIS. I believe so, yes.

Senator BRICKER. Did this Russian scientist write about it and that is the way you picked it up?

Commander MOORE. Yes. Westinghouse gets a great deal of literature from Russia and have a great many translators.

Senator BRICKER. Is not this the thing we have been thinking about and dreaming about—the direct takeoff of electricity from atomic reaction?

Colonel ARMSTRONG. It is getting close.

Mr. DAVIS. Not quite, because there is still the notion you might be able to get electricity even more directly, in a more direct way out of the reactor. Nobody has come up with the idea yet.

Senator BRICKER. This is moving in that direction, is it not?

Mr. DAVIS. Here you have to get the heat first and convert it into electricity.

Senator BRICKER. But it is done without a reactor?

Mr. DAVIS. No, sir.

Senator BRICKER. It could be done without a reactor?

Mr. DAVIS. It could be done with any source of heat.

Senator BRICKER. That is what I mean.

Mr. DAVIS. But it takes a temperature difference to do it. It is not like a battery which can produce electricity directly.

Mr. RAMEY. It would eliminate the generator?

Mr. DAVIS. This would eliminate the turbogenerator?

Senator BRICKER. It is completely revolutionary from anything we have been thinking about or working on heretofore; is it not?

Dr. Merkle shakes his head "No."

Dr. MERKLE. Thermoelectric effects have been known for a long time. I think Colonel Armstrong made a significant point: It is a matter of efficiency. This new contribution has jacked up the efficiency of thermoelectric utilization a considerable bit.

Senator BRICKER. If you should get up to 25 percent, you are approaching something very practical?

Dr. MERKLE. Being competitive with certain kinds of turboelectric machines, yes.

Colonel ARMSTRONG. This [indicating] will become obsolete if we reach anything like that in efficiency because this is only 8-percent efficient and has all this rotating machinery in it, and rotating machinery in a satellite give you a problem because it acts like a gyroscope and tends to make the satellite drift off.

Chairman DURHAM. And you have to have power.

Colonel ARMSTRONG. If you can have power without any moving parts, you are really in the ballpark.

Senator BRICKER. With a good pitcher.

Colonel ARMSTRONG. Yes, sir.

(Classified discussion.)

Colonel ARMSTRONG. Here are your milestones:

[Deleted.]

Colonel ARMSTRONG. I have been asked to hurry along. This is just some information as to what those are, and I have already covered it.

Here is our developmental schedules, which are more or less covered in the previous charts, but it shows how the power conversion equipment and the reactor equipment meet in these time periods for the tests.

Here is a cutaway of this particular model right here [indicating] which I do not think adds anything more than the model.

[Deleted.]

Representative PATTERSON. Is that going to be in and out of space? You are going out and bring it back?

Colonel ARMSTRONG. This is presumed to go out into space and stay there.

Representative PATTERSON. There is not any possibility of its being rigged up so you can bring it back to earth?

Colonel ARMSTRONG. Yes, these things can be done; but we feel it is wiser to keep it out there, and if you have it reporting what it finds for a solid year, the chances are at that time it will not be the failure of this that will stop it from telling you what it is finding but probably the electronic gear in the system will go out.

Representative PATTERSON. It will eventually burn up?

Colonel ARMSTRONG. It will eventually come back in and burn up.

Representative PATTERSON. How about the hot stuff, the reactor?

Colonel ARMSTRONG. It will burn right up with the rest of it. We will add practically nothing to what is up there already.

Here is the facility that we are building with the two and three test million dollars in our 1959 budget, and this facility has [deleted] hot cells in, and it will be built in such a way that not only the reactor but conversion equipment all will be tested in the same unit, and it can be used as an operational test site for productional units coming on.

Here is the way that the thermocouple conversion unit would look like as I mentioned it. The little thermocouple would be these here, with one end of them against this hot center, which is polonium, the other end on this radiator, held here to cool the other end of them. As I said, it weighs 10 pounds, operates at about 1,500° F. and puts out 3 watts for 6 months.

Now we had a symposium, if you will. We invited people from industry, we invited everybody in the Army and Navy we could think of that were working on things like this, to see if we had some useful purpose for them, and these are just some of the things they came up with that they thought they would like to use these for.

We have had inquiries from the meteorological people. They think it would be quite nice to have something like this scattered over the South Atlantic during the hurricane season which would report back automatically what types of pressures they were sensing so that you could forecast the buildup of hurricanes prior to the time they had actually built up into one.

Where you have a cost of something like \$26 a gallon for diesel fuel up on the DEW line and you have diesel engines running to power radars and like that, it might be cheaper to have this device sitting up there by itself with no people attending it.

The number of things people have thought of for us to use this for is far greater than this list. As I mentioned earlier, the job we are trying to do in operating in a vacuum, in operating without the earth gravitational field, makes our job toughest. If you bring this thing back down to earth and use it where you have substantially large areas of radiator surface for cooling, you have gravity helping, the efficiencies go up considerably and it becomes a much easier job.

But you can just let your imaginations roam and wherever you need electrical energy where it is difficult to get it, this is the way to do it.

Representative PATTERSON. Our imaginations would not roam to the extent, Colonel, that we are going to cripple some of these programs that you have already launched.

Colonel ARMSTRONG. These are side benefits entirely. If this is finished, any other job from that point on is sheer engineering development of this and easier done.

Representative PATTERSON. I think we should certainly use our imagination. In fact, I have the feeling in the past our imagination has been stymied by a great many who were disbelievers in anything in space or anything that was not conventional at the time. But I would certainly hate to see us get into the position where we just roam away from those things that have been proven not only in theory but in actual operation.

Colonel ARMSTRONG. We are not going to allow any of these other applications to interfere with this job. But we have opened up our reports, our information to everybody that we can think of that could have an application for this, and we are more than willing that they take their money and go in any direction they want to.

Representative PATTERSON. I think that is wonderful. I think that should be done. But I would not want to see your particular shop cluttered up with a lot of recommendations that were hypothetical at the time and in such a position they could not even be put on a drawing board.

Colonel ARMSTRONG. We are not letting this sort of thing change our direct course as to what we are trying to do.

Chairman DURHAM. It is classified; is it not?

Colonel ARMSTRONG. Yes, sir.

Representative PATTERSON. I think he means within the services and those who are entitled to that information. Is that not what you mean?

Colonel ARMSTRONG. That is correct. We have stretched a point on this. We have not been too strict on this need-to-know business in distributing this because we feel so many potential users ought to get it in their hands.

(Deleted.)

Chairman DURHAM. You have explained one of the most revolutionary things introduced to this committee in several years.

Colonel ARMSTRONG. I am afraid you people are going to feel I got my needle stuck in my record some place, but this is the first committee I have ever gone before—and God knows I have gone before many—that I felt wanted to do something for me rather than something to me.

Chairman DURHAM. I hope you have better success in this project than we had with ANP in getting cooperation.

Colonel ARMSTRONG. This is part of the ANP project.

Chairman DURHAM. We will certainly help you anyway we can.

Senator BRICKER. Is this SNAP III program the first constructive thing you have picked up from Russian literature?

Colonel ARMSTRONG. In this respect; yes, sir. Yesterday you were very generous in wanting to help us. As I said, my needle is probably stuck in my record, but if you are interested in pushing this ahead, as I am interested in pushing this ahead, I can tell you very frankly I need a couple of million dollars. You cannot stagger along and build 2 or 3 different kinds of units like this on the kind of a budget we have been operating under, and I cannot go on stealing money from other projects to keep it alive. As I said, we have \$4.8 million in the budget to run these for 1958. We asked for a million more than that; it was not allowed. We feel a sense of urgency and are willing to double that and ask for two.

Chairman DURHAM. But you did have to steal money to start the project, I believe, you said?

Colonel ARMSTRONG. We have talked to Dr. Davis and we have talked to the Commission, and I think they are in a mood for us to come forward with a supplemental.

Representative PATTERSON. I think you will find this committee in the mood to accept your supplemental.

Colonel ARMSTRONG. Thank you. As I say, this is something we are cutting metal on; this is no dreamy idea [deleted].

(Classified discussion.)

Colonel ARMSTRONG. That is my story on this thing.

Chairman DURHAM. Thank you very much, Colonel. That is very, very interesting.

[Deleted.]

Chairman DURHAM. Our next witnesses, I believe, are from North American Aviation, Dr. Stanley V. Gunn and Dr. William Parkins. Will you both come around. We are glad to have North American people here. You know what subject we are discussing; just go right ahead please.

**STATEMENTS OF DR. STANLEY V. GUNN, ROCKETDYNE DIVISION,
AND DR. WILLIAM EDWIN PARKINS, ATOMICS INTERNATIONAL,
NORTH AMERICAN AVIATION, INC.**

Dr. PARKINS. I am Dr. Parkins of Atomics International. Dr. S. V. Gunn is here from Rocketdyne. He is the project engineer on the Rover work which is being carried out at Rocketdyne.

When we received our invitation from Mr. Ramey to appear before the committee it was indicated you would like to hear a discussion of the applications of nuclear energy in space flight. So what we have prepared here today is a somewhat general discussion of this subject. I intend to point out what these applications are which we believe are significant and to give a comparison with some of the conventional means for achieving the same objective.

Now this field of the application of energy for space vehicles can pretty well be summarized by the first chart which I have here. We can show that the need for energy in space vehicles divides into two categories. One is the need for propulsion to lift the vehicle, accelerate, change direction. The other is for auxiliary power, the type of thing Colonel Armstrong was just discussing—power to operate electronic equipment, perhaps other equipment needed for the vehicle.

Now in each of these areas, propulsion and auxiliary power, there are really three types of energy which are available to us, and I think only three: Nuclear, chemical, solar. I have shown these in each of the two categories.

As we go through these now I would like to mention the ones which we believe are presently significant methods of utilization. There have been a great many different methods of utilization suggested for these forms of energy, but I think for the purposes of present thinking the ones I will name here are the important ones.

Future developments may show that others compete very well, but at the present time we think these are the most significant methods of utilization.

The first here in the category of propulsion, nuclear propulsion, is a matter of heating a gas in the reactor. This is the type of application for which the Rover project is directed to produce a high thrust, high performance nuclear power plant for propulsion.

One can divide the problem of propulsion of vehicles into really two categories. One is the problem of lifting heavy loads from the earth's surface, perhaps into a satellite orbit where high thrusts are definitely

required. The other problem is that of maneuvering from a satellite orbit, perhaps increasing the velocity to escape speed, perhaps performing other maneuvers in interorbital space, and for this purpose one can use low thrust.

There is a problem, of course, in providing enough propellant, weight of propellant, to carry out some of these missions. The situation on this can be improved if we in some way can increase the temperature at which the propellant is expelled from the vehicle. As you have heard, one way of doing this is to take the approach of accelerating ions rather than to heat gas directly.

There is then another application for nuclear energy, where we have a reactor powerplant to provide the electric power to drive an ion engine. This definitely is a low thrust device but I think may have some importance in future applications.

If we go on talking about these others, chemical is one you are definitely familiar with—the matter of gas being heated by chemical reaction. The hot-combustion products are ejected to provide thrust to the vehicle. This is, of course, a technology which we have in hand at the present time.

The third form of energy, that of solar energy, does not at the present time appear to have any important application for propulsion. There have been suggestion, but I do not think any which are significant at this time.

Chairman DURHAM. There has been work in that field; has there not?

Dr. PARKINS. Yes. I think most of that, however, has been directed to this other purpose, namely, for auxiliary power. Strictly for propulsion, we do not at this time see any importance to solar energy.

Chairman DURHAM. I think the AEC has a research project that has been going for some time. I do not know what the other departments in the Government are carrying on.

Dr. PARKINS. Is this for propulsion?

Chairman DURHAM. I do not know whether it is for that purpose or not.

Dr. PARKINS. There is one special case I might mention. I do not know if this has been discussed before your committee or not. But there may be at some time a need for what we call a satellite sustainer, the matter of having a satellite circulate in the upper atmosphere, but at a low enough altitude where you need to keep putting in a small amount of propulsive energy to keep it going. For that, you have to have some power available, and you might look to these different means for that purpose. In this case, you do not need to carry your propellant—you may use air. And Pluto project, which you heard about yesterday, while intended for quite a different type of application or mission, that reactor concept could be applied where the vehicle breathes air, runs at a low power but high temperature, to provide satellite-sustaining thrust.

You might think about doing the same thing with solar energy, where you have a small heat engine which can, in a way, give you sustaining satellite flight. But I think, when you compare this form of energy with the others, you will find solar energy is not the best way to do it.

If I may go on to auxiliary power and nuclear sources, Colonel Armstrong has just described two of these which I have listed here.

I might qualify this one, in view of what we just said. If it turns out that these thermoelectric effects are deemed important as a means of changing heat energy to electrical energy, one might substitute for the word "powerplant" here, let's say, "thermopile."

But, in any case, these are two heat sources, and it is a matter of converting into electrical energy for auxiliary power.

Here is one conventional type—chemical energy. And, in general, we are talking here about chemical batteries. They definitely have an application, but they are limited in that if you need much power the weight requirements are high.

Solar energy can be used for auxiliary power. There are solar batteries, cells, which receive radiation from the sun, which can convert it to electrical energy directly. These are, of course, of low efficiency.

Then, of course, there is the solar powerplant, where the heat from the sun is concentrated in some way on the boiler and electrical energy is produced from the heat engine.

This, I think, is a summary of the important methods for obtaining energy for space vehicles.

If I could recapitulate. If one is interested in the high-thrust application, where you are lifting large loads from the earth's surface, we have the chemical engine, and we may in the future have a reactor propulsion plant which can perform a similar service, perhaps even to the degree of lifting larger loads than are possible with chemical plants.

If we are in the area of low thrust, or, let's say, we are doing orbital adjustments with some kind of a space vehicle, one could again use chemical energy but, perhaps, to a more limited extent. But here is the place where the ion engine may become important, powered by a reactor powerplant.

Chairman DURHAM. Could I ask you this question: Would it be possible for you to place the vehicle into orbit with chemical and then, by timing, give your nuclear plant a chance to operate, from the standpoint of additional propulsion and guidance?

Dr. PARKINS. Very definitely.

Chairman DURHAM. Would not that be the first step you could take, rather than to depend upon nuclear propulsion initially?

Dr. PARKINS. Exactly. This step, reactor propulsion, is far enough off, I think, that, for boost from the earth's surface, we have to think in terms of chemical engines at the present time. What you do from then on depends upon what mission you want to perform.

One might think of an ion engine, but, as I will explain later, I think the development here is also a fairly long-range one, maybe comparable to what it is going to take to develop a reactor.

We have these applications for propulsion.

When it comes to the matter of auxiliary power, we have these five types I mentioned here. Which one is used will certainly depend upon what the specific requirements of power and life are.

Now, I would like to go ahead and talk about three things: Propulsion by gas heating, by reactor, ions accelerated by reactor powerplant, and then nuclear devices for auxiliary power.

On the first one, the reactor propulsion, I would like to illustrate with an example of the type of plant we might be talking about. This particular illustration is a Rocketdyne version, somewhat modified and scaled up, of the Kiwi A, a type of reactor to be tested by the Los Alamos Scientific Laboratory. It involves using [deleted] a propellant, contained in large tank. Below this we have the reactor plant, and, below, the thrust nozzle where the thrust gases are ejected.

(Deleted.)

I should point out that this really at this time is a conception that the development of this kind of an engine is an extremely difficult task. It is probably the most difficult application for a reactor which has been suggested to date. The temperatures are extremely high, power densities are high, flow rates are high. It is a very difficult thing on which to do experimental work at power.

So I think at best one could only look to this as a development project which would require a number of years and, certainly, many hundreds of millions of dollars; however, if we can achieve it we have something to gain in performance. I believe this point may have been brought out to the committee before.

I have here compared chemical engines and nuclear. I have taken, first of all, the jet fuel liquid-oxygen-type chemical plant, and a somewhat more advanced type of chemical plant using fluorine and hydrazine.

Here are nuclear reactor plants: one using ammonia as propellant, one using hydrogen. Hydrogen is more difficult because it has to be handled as a liquid at low temperature and has a very low density, and it is difficult as far as the handling problem is concerned.

The performance of these different fluids can be illustrated by the specific impulse available. I believe you may be familiar with this term. It essentially indicates the amount of thrust that one gets for a given consumption of fuel. You can look at these numbers as the pounds of thrust you get when you are propelling out the exhaust one pound of propellant per second.

We can see if you can go to a hydrogen nuclear reactor you can gain in specific impulse by more than double. This is not due to temperature so much as it is the fact we are dealing here with a very low weight material which for a given temperature travels at higher speed and gives you more thrust.

If we go then to a metal and we want to get up from the earth's surface to escape velocity, and we would like to have a one-ton payload—with gross weight of the vehicle about 200 tons.

[Deleted.]

Dr. PARKINS. This comparison is even sharper if we look at larger payloads. If we go to 50 tons payload and expect to propel it from earth's surface to escape velocity, this becomes quite impractical. Talking about 10,000 tons initial gross weight of vehicle.

[Deleted.]

Dr. PARKINS. I would like to turn now to the next application of nuclear energy to space flight, and that is a matter of operating a reactor plant to furnish electrical power for ion engine for propulsion.

We start off first of all with a reactor powerplant. I will tell you a little more about that. It does feed power, first of all, to different components of the propulsion system. The reservoir of the propel-

lent is fed to ion source where these particles are ionized. Again we have to have power for that. The powerplant provides a high voltage which can provide an electrical field to accelerate the ion, and these are ejected, giving thrust.

To keep the vehicle neutral we have to also eject some negative charge, and the power, an electron source in the form of cathode, perhaps, a hot filament. This is a much easier problem here. We accelerate within electrical fields of opposite signs and eject them.

There are certainly a number of development problems here. I might say that many of the problems faced were worked on during the war on the electromagnetic project for separation of uranium isotopes. The key problem was one of obtaining intense ion beams.

To go to this new step many new things would have to be done, especially in the way of developing lightweight reliable components.

I might say our company has had under study a small project which involves starting from a satellite orbit and using an ion engine to send an unmanned vehicle on some interplanetary mission for gathering information.

A suggestion here was to use cesium ions as the source of propulsion and to send back information during flight. This project has been called Project Snooper. At the present time it is only supported on company funds and is certainly something that would require many years before it could be brought to fruition. But I think it is the type of thing that could be thought about in terms of space exploration.

If, again, we can achieve the development of a satisfactory ion engine to give us high performance thrust, we can compare with the chemical engine again and see what we have gained. Here I have taken the chemical fuel in the form of a storable liquid or solid propellant compared with an ion engine that might use lithium, 15,000 volts, assuming 100 percent efficient, very difficult to achieve; and an ion engine using cesium at same voltage.

If we go back to specific impulse, pounds of thrust when discharging 1 pound per second per pound of propellant, we have a very large contrast in performance figures: 280 seconds for the chemical fuel, 66,000 for the lithium ions, and 15,000 for cesium. It must be understood we cannot use a flow rate of rate of pounds per second. When dealing with ion development we are limited in the amount of current that can be discharged and dealing with fractions of pound thrust or, if extremely optimistic, perhaps a pound or 2. However, these small thrusts can be applied over long periods.

The weight of propellant required in this case would be, if we are going to send 1 ton from 300-mile satellite orbit to escape velocity, around 5,000 pounds of conventional chemical propellant versus 26 pounds for lithium, 115 for cesium, with real saving in propellant weight.

How much do we pay in that we have to provide electrical energy? This is the electrical energy required for the same missions.

In the case of chemical, of course, we require no electrical energy. With the lithium ion engine we have to over a period of time develop some 950,000 kilowatt-hours. In the case of the cesium engine, somewhat less, around 220,000 kilowatt-hours.

If you have a powerplant available, this can be attractive for a future type of space mission—assuming, of course, one carries out the development of the ion engine.

Now I will turn to the third application, which you heard quite a bit about already from Colonel Armstrong, the matter of providing auxiliary power.

We are dealing here essentially with nuclear heat source, whether it be radioisotopes or whether it be nuclear reactor.

[Deleted.]

Dr. PARKINS. The development problems on this latter were also touched on. I might say that some of the things we have underway at Atomics International—the SNAP II program—involve such things as physics, operating critical assembly to verify critical size of reactor. [Deleted.]

On the matter of fabrication, we are having to develop new types of bearings, partly because of special environment in space. A special kind of pump is being developed, for example, to give a low-weight pump with no seal problems.

As a comparison of what might be done with the various auxiliary power sources I have this chart. I have taken only the five which I have indicated were significant at the present time—at least in our opinion.

I have taken the radioactive source powerplant without any shield; the reactor powerplant, again no shield; the chemical power in this case in a battery. And I have chosen the hydrogen-oxygen type battery, a new one developed by the National Carbon Co., which probably represents the minimum weight battery one could have at the present time for a given amount of power produced.

There is a solar battery, or solar cells which seem to be operating in full sun. And finally the solar powerplant where heat is focused on some boiler and the heat converted to power in a heat cycle engine.

The estimated weights to produce 1 kilowatt of power for 1 year in pounds [Deleted] would be around 200 pounds for the radioactive source powerplant, a little bit more for the reactor powerplant, again no shield included. However, when we come to a battery we are faced with very large weight—20,000 pounds. This is a great deal of power for a battery-type plant.

To get back to the solar cells, around 200, comparable with these others, and the solar powerplant likewise.

If our power requirements are much larger, if we are going to go, say, to 1 megawatt of electrical output for 1 year, some of these methods become impractical. The radioactive source powerplant is one. It requires just too much radioactive material to make this practical. One would go to a different scheme.

The reactor powerplant looks quite feasible in this area. [Deleted.]

The chemical battery, of course, is out of the question; the solar battery, also, because it scales up somewhat linearly with power output required and gets to be too heavy. There may be some application here for the solar powerplant where the heat is focused and used in the heat engine. There are many problems associated with this development.

I think which would be used here would depend very largely on whether a shield was required for personnel. If a shield were needed, one would not work very hard on this type of plant. If it could go unshielded, I am sure this would be more attractive.

This completes my comparison. I might just summarize by saying that for the first application of nuclear power for space flight we have been using a reactor, that of heating gas in the reactor, using the gas directly for propulsion—there is a definite possibility this could be utilized successfully in the future. It is faced with a very expensive and, I think, long development program for success.

In the second area, that of using a reactor powerplant to accelerate ions, this may have special applications where low thrust can be used when high performance is needed, assuming, of course, that the vehicle is already in satellite orbit or in interstellar space. The development problems here again I think are quite difficult.

The third application, that if using nuclear power as a source of auxiliary electrical supply, is definitely in the cards. While there are development problems ahead, I think we can be sure that the development necessary here is much less than either of these two applications. Within 5 years, as Colonel Armstrong indicated, we probably could have operational fairly reliable plants of this type.

That concludes what I have to say.

Chairman DURHAM. Could we have those charts for the record, Doctor?

Dr. PARKINS. We would be very happy to furnish them.

Chairman DURHAM. Thank you. Are there any questions?

Thank you very much, gentlemen.

Representative VAN ZANDT. May I ask the doctor one question? Did I understand you correctly when you said the combination was fluorine and hydrazine?

Dr. GUNN. Yes.

Representative VAN ZANDT. What is hydrazine?

Dr. GUNN. It is a chemical compound, N_2H_4 . It is a chemical that is a model propellant. I mean it can under certain circumstances liberate energy like hydrogen peroxide. It has a density about like water but in combination with fluorine represents about the ultimate performance one can obtain with a chemical system when one is after high-density propellant.

Representative HOLIFIELD. What is the difference between hydrazine and hydrogen?

Dr. GUNN. Hydrogen is the simplest building block of nature. Hydrozene is a molecule composed of 2 atoms of nitrogen and 4 of hydrogen. There is one chemical combination, or there are several that will produce a higher performance, about in the 400 second regime, but these use hydrogen as the fuel and will be characterized by a large bulk and low density. However, the large bulk and low density become increasingly unimportant as the ambition of the mission increases.

Chairman DURHAM. Dr. Gunn, do you have anything further to add?

Dr. GUNN. No, sir; I think he has pretty well summarized it. There is one last point, and that is to reemphasize what I think is the impression you people have gathered here. It is the high performance capabilities of these nuclear systems that make it possible to achieve early substantial percentages of the gross weight of the missile in satellite or earth-escaped missions.

As an example of this, the Vanguard, as we presently conceive of it today, can only place about one-tenth of 1 percent of its gross weight in a satellite orbit. The nuclear hydrogen system which we typified here on one of the charts is theoretically capable of placing around 20 percent of the gross weight of the missile in satellite orbit.

Representative VAN ZANDT. Would you repeat that, Doctor?

Dr. GUNN. The Vanguard, which is being attempted to launch at Florida, is only capable of placing about one-tenth of 1 percent of its gross weight in satellite orbit, 21 pounds for 21,000 pounds of missile. The nuclear hydrogen type of missile which we typified here appears to be capable of placing around 20 percent of its gross weight in satellite orbit. Out of a 550,000-pound gross weight which this 750-pound engine would propel [deleted] over 100,000 pounds appear to be capable of being useful payload in the satellite orbit.

Representative HOLIFIELD. Is there any advantage from the refrigeration angle between the hydrogen and hydrozene?

Dr. GUNN. Hydrozene is a noncryogenic fluid. It is essentially liquid at room temperatures. However, the other counterpart of the hydrozene system, which is fluorine, is very cryogenic fluid, and the problems one has in handling fluorine are also the problems one has in handling liquid hydrogen.

Representative HOLIFIELD. So you do not get away from that problem very much?

Dr. GUNN. No, sir.

Chairman DURHAM. Are there further questions?

Thank you very much.

I believe the next witnesses are Mr. John Simpson and Dr. Krasik of Bettis Laboratory. We are glad to have you down today from Bettis. You know what we are discussing here, and you may proceed as you see fit.

STATEMENTS OF DR. SIDNEY KRASIK, AND JOHN W. SIMPSON, OF BETTIS LABORATORY, WESTINGHOUSE ELECTRIC CORP.

Mr. SIMPSON. Mr. Chairman, we have no formal project in this field, and we are not doing any appreciable amount of work in this field. We do, however, have a number of engineers and scientists at Bettis, and engineers and scientists do let their minds wander through many fields. Particularly in this postsputnik world scientists tend to think about space travel, satellites, and the like.

Many of our people, therefore, more or less on their own have been thinking of these things as this has become more and more in the public mind. I have attempted in talking with some of them to try to coalesce their views into something that might be of interest to you.

I would like to make it clear, however, that I do not pretend to speak with the sureness or the degree of certainty that I would speak to you were I talking about naval propulsion by reactors, because this is a field in which we certainly cannot claim to have any great experience.

We do have a few things, however, that our thoughts have led us to believe are correct. We do believe that a space vehicle can be built in a relatively few years. By that I mean not tens of years but in the order of 10 years.

I believe, and we believe, that the job is a big job, as Dr. Parkins has indicated. It is a tremendous job. It does appear that there are fundamental reasons why nuclear power is a better way of doing it than chemical power, which is primarily associated with the fact that the mass of the propellant being ejected is lower and, therefore, the velocity can be higher. The temperatures can be roughly the same in both cases. It may even be that in the chemicals they can be somewhat higher.

It is quite likely that the mass ratios will be comparable but probably better with the chemicals.

When one scopes out a project such as the gas-cooled reactor that the gentleman from North American mentioned, you can pretty soon see that there are some truly substantial problems. These problems, while they cover all the fields—the field of cryogenics was mentioned, the structural fields, and so forth—the key problems, it seems to us, settle down to being reactor problems. They are problems that have to do with the building of the reactor which is the heat source. This has, of course, been the key problem in many of the other atomic projects.

In the reactor problem, probably the most difficult problem is the reactor kinetics problem, that is, the ability to get the reactor up to the high powers that are required—and they are truly high powers—in a relatively short time, and to be able to control the reactor without mechanical means of control, because the response times required of the reactors would be so fast it would be very difficult to have mechanical means of control.

These things imply a really tremendous knowledge of the reactor physics of the system that you are working on, probably more than is the case with any of the reactors today by at least an order of magnitude.

The reactivity problems themselves are, of course, considerable. In order to get the gas, which would probably be hydrogen, through at the high velocities provision must be made for its free flow. Your ability, then, to get the mass of uranium in that you would like, tightly packed, means that you must go to large quantities of uranium and to rather get you into the higher energy spectrum. So that you have a difficult thing to calculate reactivitywise.

You have to have some structural material, and you have to go away from the thermo in order to compensate for the high cross section of the materials you might use.

I do not want to imply that the more common problems, the thermo problems of running fuel elements at 5,000° or 6,000° absolute temperature—that the thermo stress problems are not also very difficult engineering problems, because they truly are. But I believe that the key problems really are the reactor physics problems and followed next by the thermo problems, and then the structural problems.

I do feel that, if it were really a lot easier, I would be probably worried that the Soviets were already doing it. But it does appear to be something that if you apply yourself to, it can be accomplished.

The reason, as I indicated, why nuclear seems to be better is tied up with the mass of the propellant that is ejected and its velocity. This, then, when you succeed, or if you succeed—and, obviously, anything as developmental as this might not succeed. One does not embark

upon a truly developmental program with a sureness that you will succeed. I do not believe that the A-bomb or the H-bomb or any of the major things were embarked upon with a real certainty of success. But, if you do succeed, as has been mentioned, you put into orbit all of these higher weight vehicles, that can be used to go on into moon travel and the like.

I think that what we have to watch in this field, as in any other, is falling into the trap of setting up the criteria of what it takes to do the job, and then willing, in effect, that it be done and it can happen that way. That is, you can set a mass ratio one must have in order to make a chemical missile or a nuclear missile or anything else go into orbit or go to the moon, and then just assume that that, therefore, can be done. Some of the numbers that get used get pretty high in the percentage of the vehicle that is the propellant.

I believe that if something like this is not done there is a good chance that the Soviets will do it and, having done it, the time it will take us to catch up is just as long as the time that it will take us from now to accomplish the job.

I say this because I believe that the problems are those that would not be worked on except for a missile or vehicle that did have space-travel possibilities. I refer to the reactor kinetics, the reactor physics, and similar problems. Therefore, you do have research going on, and you can simply pluck the fruits of this research off the research tree a few years from now and find you have not really lost that time. In fact, you cannot make it up. It is the sort of thing you either work on or you do not work on; if you do, you make progress.

It is, as I say, conceivable that you might not succeed. But I believe, with a dedicated group of people who have the necessary research and scientific talent, engineering talent, construction talent, it is the sort of job that can be accomplished within the resources of the United States.

That is all I have.

Chairman DURHAM. Are there any questions?

Representative PATTERSON. Yes, Mr. Chairman.

Chairman DURHAM. Mr. Patterson.

Representative PATTERSON. You said, when you were talking about space vehicles, within years—"I do not mean tens of years." What did you mean?

Mr. SIMPSON. The order of 10 years.

Representative PATTERSON. It will be a period of 10 years from now until—

Mr. SIMPSON. I, obviously, sir, have not studied it enough to say whether 8 years, 9, 10, or 12. It is 10 years plus or minus a couple.

Representative PATTERSON. You are basing that strictly on your professional opinion?

Mr. SIMPSON. And looking at the fact that you would have to build facilities to test elements. You would have to build facilities for critical experiments: you would have to build facilities for kinetics experiments; and then stages past that, in which you would have to go to make land tests and so forth. And this assumes success at every stage.

Representative PATTERSON. The reason I ask you that particular question—it seems that this time is a little in conflict in here with other statements that have been made.

Mr. SIMPSON. It takes 4 or 5 years to do most anything, even to build the type of reactor we know how to build these days. I do not know whether you are saying I am in conflict by being shorter or longer in time.

Representative PATTERSON. Longer

Mr. SIMPSON. I guess I am a little more pessimistic by nature than many other people.

Colonel ARMSTRONG. If I may, I think we ought to establish the fact that, perhaps, the gentleman is not familiar with the fact that many of the facilities are already built.

Mr. SIMPSON. That may be.

Colonel ARMSTRONG. The program has been going on 2 years.

Representative PATTERSON. Colonel, I just assumed he was familiar with those.

Mr. SIMPSON. I am not. I am simply speaking as a reactor designer who has been in one field and projecting into another. I do not have access to classified information in this field.

Representative PATTERSON. I did not realize that. I thought you had all of the information.

Then, in the future, Mr. Chairman, I think before a witness testifies here we should know exactly what information has been made available.

Chairman DURHAM. The gentleman is in charge of Bettis Laboratory and built all of the Navy reactors. We are talking about the reactor field, and that is what he is talking about.

Representative PATTERSON. I know, but he still has not had all the information made available to him.

Chairman DURHAM. Have you asked for it?

Mr. SIMPSON. No, sir.

Chairman DURHAM. You had no need for it.

Colonel ARMSTRONG. I think they are on distribution, on our C-84-86 category. I am sure your laboratory has all of our reports.

Mr. SIMPSON. I have been quite busy building Navy reactors.

Chairman DURHAM. He has got another job.

Representative PATTERSON. I was asking questions in a field that was far from yours?

Mr. SIMPSON. Yes.

Representative HOLIFIELD. I believe Colonel Armstrong did give us a figure of about 8 years.

Colonel ARMSTRONG. Yes.

Representative HOLIFIELD. Certainly, in view of the fact you have been working on it a couple of years, from point of time, it would approach the same.

Mr. SIMPSON. I won't argue whether 8 or 10 years.

Colonel ARMSTRONG. No; but the gentleman said facilities would be needed, and these are already being built.

Representative PATTERSON. That is the thing that immediately came to mind.

Representative VAN ZANDT. I would like to ask Mr. Simpson if he would tell us how the reactor is coming along at Shippingport.

Dr. SCHREIBER. Mr. Chairman?

Mr. SIMPSON. The reactor went to full power on the 23d of December. It ran for 100 hours and then shut down to make the xenon

transient studies, which, obviously, can be made only a shut-down reactor. Then we have proceeded from that point to make numerous hot tests of all the various systems to more thoroughly understand them, and then we have made critical tests at very, very low, zero power, and are preparing very shortly to go back on the line for power tests. It has performed substantially in accordance with design, to date.

Representative HOLIFIELD. I would like to ask a question, also, a little bit off the line. But we have had some testimony in regard to the modification of three of the planned nuclear submarines to give them missile-launching capabilities. Due to the fact we have got appropriations up—I hear the bell ringing now over there—and it has to do with appropriations in this field, I want to know: Does this mean that the original plan of having these three submarines to be attack-type submarines, in the strict sense of the term, has now been changed for the adaptation for the Polaris missile?

Mr. SIMPSON. I cannot answer that, sir, but I can say from the nuclear propulsion viewpoint, the propulsion plant is identical for both the attack and Polaris.

Representative HOLIFIELD. I will withdraw the question.

Mr. SIMPSON. The propulsion unit is the same.

Representative HOLIFIELD. I see.

Dr. SCHREIBER. Mr. Chairman?

Chairman DURHAM. Dr. Schreiber.

Dr. SCHREIBER. I would just like to make a couple of brief comments slightly in rebuttal to Mr. Simpson on the Rover work. I appreciate his saying that it is difficult, and we have these problems, and we will require numerous ground tests; and I hope that just reinforced our discussion yesterday. At the same time, I do not feel the fast starts of the thermostress problem, and so on, is quite as unknown as would be indicated from strict interpretation of his remarks.

We are well aware these are problems and they are quite different problems from the conventional power reactor. At the same time, they are not unknown; and let's say we are at least at the stage of recognizing these and being able to put in the reactor dynamics. We have actually operated reactors in very much faster periods than this at Los Alamos, but obviously not at these power levels. This problem is recognized. It may be a severe one, but we do not think it is at all insuperable.

Mr. SIMPSON. I agree from what I know and discussed we do not feel them insuperable at all—just difficult.

Dr. SCHREIBER. The other comment is not addressed to you particularly, but there have been words said about the cost of this overall missile program, and I am not here to try to correct this sort of statement. I would like to say simply that in the rather specific reactor study phase which we are in now there is a point, before the commitment of these very large sums of money and after an evaluation of what these can do, that one is not plunged completely on a path toward a large missile development because of the program which is forecast for the next, say, 2 or 3 years.

I think that is all I have.

Chairman DURHAM. Thank you very much, Doctor.

Dr. Simpson, have you finished?

Mr. SIMPSON. Yes.

Chairman DURHAM. Dr. Krasik, do you care to comment on anything?

Dr. KRASIK. I believe Mr. Simpson has covered the ground quite adequately.

Chairman DURHAM. We are very glad to have had you here, gentlemen.

Mr. SIMPSON. Thank you.

Senator ANDERSON. We have two representatives of the Air Force Office of Scientific Research, Dr. M. M. Slawsky and Lt. Col. P. G. Atkinson.

STATEMENTS OF COMDR. M. M. SLAWSKY AND LT. COL. PAUL ATKINSON, OFFICE OF SCIENTIFIC RESEARCH, DEPARTMENT OF THE AIR FORCE

Lieutenant Colonel ATKINSON There has been a great deal of discussion, and presentation of various propulsion possibilities in connection with space flight and other missions. I thought perhaps I could draw together a few ideas and attempt to place them in perspective insofar as what we should be doing.

I have spent time in the development phase of the program in the years past. At the present time I am in the research phase. So I have been on both sides of the fence.

I would like to bring forth the chart we talked about briefly this morning. I hope to clarify why we are concerned with both chemical and nuclear, and what my own personal evaluation would be toward the effort we can feasibly and reasonably expend at this time to perform a mission.

The Air Force mission should really be over on the right [indicating chart] because the Department of Defense is concerned immediately with a force in being. This force in being must be supplied with weapons which can deliver warheads or otherwise provide unquestionably a deterrent, serve a deterrent function. In order to develop those weapons, we have to make absolutely sure that they will perform that mission.

The state of the art, the state of the technology is such that at the present time our forces in being are long-range bombers, and a number of missiles, both strategic and tactical, are getting into operational units. We know they will perform the Air Force mission.

We want to, obviously, produce better weapon systems. However, before we commit ourselves to production of a weapons system we have to make sure that it will be reliable, that it will do the job, and that also it will have the best performance that we know how to produce.

At the present time in the operational unit we may have a certain type of weapon. We are looking into the system development to be able to produce a better weapon just as soon as we possibly can.

Now ICBM and IRBM are in this area at the present time.

Senator ANDERSON. When you say "in this area" what do you mean?

Colonel ATKINSON. They are in the process of weapons system development.

Senator HICKENLOOPER. I do not believe Senator Anderson was here this morning when you explained the chart. I think it would be well to go through and tell him what the chart is.

Colonel ATKINSON. The chart illustrates all the technical and scientific activities underway in the Department of Defense and other Government agencies. This is one framework on which the various activities can be categorized.

Research is essentially seeking new knowledge. A lot of it is undirected. Some of it is directed toward certain areas in which we want to learn more because of various motivations.

Technical development is what we define as "demonstrating the capability."

The weapons system area takes items that have been demonstrated. We know that we can do them, and we start developing them toward a specification along with all the other elements of guidance and control, aerodynamics, structures, warhead, and propulsion, welding all of those together into a system which will perform a mission.

When a system has been developed, or when we see that we are far enough along the road to commit it to production—there is a certain calculated risk in that also we have to take—it goes into production, people are trained, and it usually gets into operational units.

This is a continuous cycle and there is some overlap, but in all of the areas of scientific endeavor and weapons' systems development, there is activity going on across the board.

In general the flow is toward the right. When a new idea in research gives us new knowledge which we would like to try out, we start bending hardware, cutting metal, and also producing a piece of hardware which we hope will show this can in fact be done. When this tech development is over with, when we have in fact demonstrated a certain device, and it has a higher performance, it is a candidate for weapon systems. The systems people are continually casting about for new and improved components and techniques which they feel certain will work; to start marrying these together with the other components into an improved weapons system.

There is another aspect to this: There are only so much funds. This is the economic aspect. We have to have the best for an economical expenditure which the economy of the country can maintain. So there is just so much money. In order to perform the USAF mission, of course, it takes a great deal of funds. But we have to be improving new weapons, we also have to be demonstrating new capabilities, and we have to be seeking new knowledge. And the cost: Research is the cheapest, tech development is probably larger by a factor of 10, roughly, and system development gets into even larger money, and production and operational use takes the very large bulk.

Now the subjects that we have been talking about.

The chemical rocket. Back in the 1920's, Dr. Goddard demonstrated one that flew to 7,000 feet. The work in Germany started in the thirties, I think. And the chemical rocket passed through the tech development stage and through the system stage where we have some weapon systems at the present time. We know enough about chemical rockets that we see we can perform a 5,500-mile mission with chemical rockets, or a satellite mission. It is in the realm of capability—we know we can do it.

Senator ANDERSON. Why do you say we know we can do it?

(Classified discussion.)

Colonel ATKINSON. I think the philosophy they are using is they walk before they run. It is a stepwise process—the philosophy, if we put too many unknowns, too many untried components all together in one missile without a proven reliability in each component, the chance of everything working right the first time is very small.

(Classified discussion.)

Senator ANDERSON. Let me tell you why I say that. I have a headline out of the Washington Evening Star from Friday, January 17—“Navy Polaris Soars in Test Flight.” You and I know there isn’t any Navy Polaris that can soar. [Deleted] and God knows whether it will fly when it is put together. We think it will. But a statement is given out that the Navy Polaris soars in test flight. Then you read down very carefully and it finally says, “The Navy launched a Polaris test vehicle today and for the first time identified it as such.”

When you ask them how much it was, it is a little hard to find out. It could have been one bolt or one nut or one cotterpin. I think it was probably more than that. But the headline to the American public reads, “Navy Polaris Soars in Test Flight.” And an ad of General Electric in the magazines told all about it. The impression they are trying to give is these things work, we know they work.

Well, we were pretty sure of Vanguard, but nobody has yet put one of these together and tested it. So I just wonder if we are justified in saying, until we have tried to fly something that distance, that it will fly that distance.

Colonel ATKINSON. Well, we feel the principle has been proved. The capability in some respects has been demonstrated enough. We can produce thrust of a certain amount from chemical rockets using existing propellants. And the thing that delayed the Atlas program, as I understand it, [deleted].

Dr. SLAWSKY. May I make a remark here?

Senator ANDERSON. Yes.

Dr. SLAWSKY. I am a physicist and therefore no friend of the chemist. But, nevertheless, I think that one might lose track of the fact that our failure is not an argument against chemistry, because I think the Russians put up a chemical rocket.

[Deleted.]

Senator ANDERSON. I will not argue that. But you see here, in order to prove our theory is right, we have to assume they are working with one; and, therefore, to prove we are right, they work. We do not know they are working with one. Theirs might be nuclear propelled. [Deleted.] When we talk about what is orbiting around the earth, we assume there is some sort of battery in it, but we do not know that. Therefore, we assume it is a certain kind of battery and weighs about so much. It is a little bit in the imaginative area, is it not?

Dr. SLAWSKY. I think we are better than that.

Senator ANDERSON. You mean our intelligence is better than that? [Deleted.]

Dr. SLAWSKY. I think we have enough knowledge to be able to make more than just wild guesses as to what it is they have up there. I mean just purely from physical arguments.

Senator ANDERSON. All right.

Colonel ATKINSON. The scope of the effort is planned toward a very strong reliability program in which the engines and components of the ballistic missiles are subjected to literally thousands of tests. That is one reason why in system development in these new type weapons, which are so unbelievably complicated—that is one reason why the expenditure is quite large.

The people who are looking after the systems development, that is, the new weapons, are continually casting about into the tech development area for better capabilities which have been demonstrated. Among those, for example, are certain chemical propellants.

[Deleted.]

Also in this area, but not quite as far along, is the nuclear rocket. That I understand is scheduled to be fired the first time this year. So based on the experience—

Senator ANDERSON. Which one is that?

Colonel ATKINSON. I believe the nuclear rocket Rover.

Senator ANDERSON. Is to be fired this year?

Colonel ATKINSON. In static tests.

Dr. SCHREIBER. It is a quibble of words, sir. We are doing our first test reactor this year.

Senator ANDERSON. That is right. And if it works, you will build a little larger one and try it in a few years and if that works, you may fly it [deleted] a little later.

Colonel ATKINSON. The problems which I think were outlined yesterday showed the capabilities of the Rover is certainly something the systems people will be looking forward toward for satellite applications, particularly where there is a large payload up to an orbit.

The philosophy we have to have is that we back many horses; and since funds are certainly a limitation from many points of view we have to be very careful which components are selected for system development: first, because of the funds, and, second, because if there is a mission to perform we have to make sure we are going to come out with something which will perform that mission.

So the tech development people, on the other hand, are continuously looking into research areas for items which are ready for initial hardware demonstration, not to perform any particular mission but just to demonstrate that it can be done.

[Deleted.]

Another item in the research area right now is the possibility of free radical propellants. Free radical. The definition is a chemical compound of neutral charge with an unpaired electron in the outer orbit.

Now that does not mean very much, but in principle, if we look at hydrogen, for example, as it exists in nature, there are two atoms, each of which has an electron flying around. Now these electrons seek other electrons, and they like to pair themselves in the hydrogen as it exists in nature. If energy is put into molecular hydrogen it tends to separate these two atoms into atomic hydrogen. These are extremely reactive, and they have been stabilized really in trace amounts under extremely low temperatures, approaching absolute zero. However, the performance that atomic hydrogen might offer just by itself is around 1,200 to 1,400 specific impulse.

Now the thing that makes it so attractive is that the range of ballistic missiles, for example, is proportionate to the square of the specific impulse. [Deleted.] This idea is still in research area, and there is a 3-year program in the Department of Defense—Army, Navy, and Air Force—and there is work in the National Science Foundation, the Atomic Energy Commission. And it is all very well coordinated and directed toward seeking new knowledge which might enable us at some future time to start producing these. If we would learn how to stabilize some of these, they are very attractive as propellants.

This is another approach that we cannot neglect. It is just plain not ready for tech development.

Representative HOLIFIELD. It is still in the research stage?

Colonel ATKINSON. It is still in the research laboratory stage. The big problem is to stabilize free radicals.

Another item which has been looked at is the solar ramjet. The systems people wanted to make a feasibility study to determine if, in fact, just the heat of the sun's rays could heat air coming in the front of a ramjet type vehicle. Much in the same way that Pluto has a nuclear heat source, this was a study of a solar source. [Deleted.] So that remains in the research area and we seek more knowledge in the fundamental areas which may contribute toward that.

Recombination of free radicals as they exist in the atmosphere is another one which offers the possibility of using energy which is available in the upper atmosphere, which at the present time we do not know enough about.

There is another area also in ion propulsion, which I think Dr. Slawsky will comment on. There is some effort in this area.

In summary of what I have tried to do, it is to suggest a framework onto which we can hang the various technical scientific development efforts which are underway in this country.

Dr. SLAWSKY. As you know, we were not invited with prepared comments. These are comments and reactions I have had in listening to the discussions, from which I have profited a great deal.

It is our job at the Air Force Office of Scientific Research, ARDC—at least this is my opinion—to be motivated by the needs of the Air Force and to translate them into support of basic and exploratory research. I think Senator Hickenlooper brought the question to my mind, and the fact is there are two ways of solving a practical problem. One is by trial and error; and that solution is a good one because usually it solves all the problems without knowing anything in detail necessarily. The other way of solving it is detailed investigation of all the problems. And the result is that you probably never beat the engineer to the punch, but when he is through he knows how to solve that problem but he does not know how to solve a problem related to it. Our job is to keep the engineer informed about how things work in nature so that he can use his imagination and translate them into actual devices.

Therefore, I feel as though research in ion rocket or photon rocket or any other kind of rockets need not be justified on the basis of its practicability at this time. I think it is justified on the basis that whatever information we get will probably pay for itself in some other application if it is not going to pay for itself in a shape that takes off the ground.

The work that we are supporting is usually slanted that way. We have other contracts with people who are investigating various properties of plasma, which is a neutral gas, where the positive and negative charges in the gas have been separated but not completely separated.

The way I look at it is, in all matter the elementary particles are neutral. In the normal state they consist of negative and positive charges. The first step is to separate them a little bit and make them live together instead of being married, and that is plasma.

The next step is to separate them far apart, and then we get separate ion beams. But both of these fluids, either plasma or ion beams, are of interest to us because it gives us another handle by which we can move the fluid. That is not an easy matter. Normally the only thing you can do with the gas is push it with a piston. If you charge the gas you can push it and pull it with the electromagnetic field. That gives us one more method of controlling the flow of gas.

This has obvious importance for propulsion, also for other things like flight lift, drag, and all kinds of things. So we are pushing our investigation into the behavior of ionized gases—not because we think that the ion rocket is going to replace the chemical rocket but because we think that having another handle on gas is of interest and importance to us.

With respect to the question of chemical rockets versus nuclear rockets, to me those are arguments with respect to the energy source. That is not the whole rocket. The working fluid is also an important part of the rocket. The thing that you kick out of the back end of a rocket is very important.

The question of propulsion, the way we see it, is divided into three areas. One is the energy source. We are interested in all kinds of energy sources because they each have something to offer.

The next area is one where we try to study the mechanisms by which this essentially potential energy is transformed into thermal energy. That is, we make gases hot.

And, finally, we are interested in the transformation of thermal energy into energy of directed stream, which is what we need—a jet—which is what we need to get propulsion.

The question of nuclear versus chemical versus atomic—actually, in mind, there are four sources of energy. There is nuclear, the atomic, the chemical, and perhaps the electromagnetic or solar energy; and each one has its possibilities.

I too like to think that the only limitations on us at the moment are the laws of thermodynamics; that is, everything is possible as far as we know. Not everything is probable. And the things we have to back are the ones that are more probable, and the ones we have to let go are the ones that are less probable. I think as long as things do not violate the laws of thermodynamics, the probabilities are high enough for us to look into them.

Senator ANDERSON. Just one second. If you were going to try to put a manned space ship, rocket, or whatever you want to call it, onto the moon and have it come back again, what fuel would you use? Would you use chemical fuel?

Dr. SLAWSKY. My usual answer to that is that I am a physicist, not an engineer, sir; that these are engineering details.

Senator ANDERSON. What would you do if you were a Member of Congress and neither a physicist nor an engineer and hopeful you might make some evaluation as to whether or not there might be some more effort in the nuclear field since it might be the only kind of propulsion to get a manned rocket to the moon and back again? What would you do?

Dr. SLAWSKY. At the present time my feeling is—I do not think my feeling is any better than yours because I happen to be a physicist—my feeling is that a nuclear energy source gives us the best bet. And the reason I say that is because it looks to me like this has the highest energy density. In other words, the amount of energy per gram of substance looks best in nuclear fuel. However, I do not know if all of that energy can be released. I do not know the efficiency of release of that energy. This is something for us to find out.

Senator ANDERSON. We are betting on trying it.

Dr. SLAWSKY. I think it is worth the bet. I do not feel we ought to throw all the chemists out. I think for some time to be we will have to get off the ground with chemical rockets, and I think we have to get off the ground. But I would bet in the long range on the nuclear powerplant. However, I also should include thermonuclear power.

Senator ANDERSON. I do not want to dispose of all the chemists either. I am very much interested in the Pluto project and I imagine we will need a little chemical help getting that started.

Dr. SLAWSKY. You understand, as a physicist, I am being generous to the chemists.

Senator ANDERSON. Are there any questions?

Representative HOLIFIELD. Do you also agree that for the present, in the present stage, that the best bet would be on supplementary propulsion from nuclear energy and energy for initial propulsion from chemical sources for a satellite?

Dr. SLAWSKY. Are you talking in terms of at present, today, or 2 or 3 years from now?

Representative HOLIFIELD. I am talking in the immediate future. I recognize we have not got the nuclear yet.

Senator PASTORE. Will you ask that question again, Chet?

Representative HOLIFIELD. It seems at the present time we do have the chemical propulsive power developed to a higher point than nuclear propulsive power. Therefore, it would seem also that if you used chemicals to get a mass into orbit that you would need a continuing source of power, and we might look to nuclear propulsive power to deflect it from its orbital ellipse. We look to it for two reasons:

One, it would not have to be so great as your chemical power to get it up there, to guide either sideways or back down to earth, for instance. I am not thinking of going on to the moon. If you wanted to go on and give it additional impulse, you would take it out of orbit and direct it possibly to the moon, unless you hooked on your nuclear propulsion to your initial chemical propulsion to get it away from gravitational attraction so far as possible.

My question was this: At the present time, do you think a combination of the two would be the nearest goal to propulsion into an orbit and then deflection from the orbit?

Dr. SLAWSKY. As I say, my opinion is a guess like yours. Perhaps I have had a little bit more contact, but my feeling is, if you do want something with long duration, I think that probably the nuclear

powerplant would be the better bet, because we do know there is a lot of energy in a nuclear powerplant. How fast you can get it out—I really do not think it has been demonstrated you can get it out quite as fast as a chemical rocket. Although I think that the two are not very far apart.

My feeling is this: that a nuclear powerplant can be developed to take us off the earth probably as well as a chemical one, but it is not as near to us as the chemical plant is. We know how to handle chemicals. At least we know how to handle those better than we know how to build a nuclear powerplant at this time; but I do not think this is going to continue indefinitely.

Representative HOLIFIELD. The advantage of nuclear energy, it seems to me, to use it as a secondary propulsive power in the same vehicle, would be its continuity of release, and also the fact that you would not need as much of it to do the job once you get a satellite into orbit as you need to get it up there.

Dr. SLAWSKY. As was demonstrated by Colonel Armstrong here, I do not know of any chemical system that will run for so long [deleted]. Perhaps somebody can devise one, but I do not know one that will last that long; except perhaps for solar energy, which is there all the time, this look like a pretty good bet. That is as an auxiliary powerplant. You remember it requires relatively little power for the weight it has, but it has a lot of energy packed in it, will run for a long time.

Senator ANDERSON. Are there other questions?

If not, we will hear Mr. Newell and Mr. Stroud.

STATEMENTS OF DR. HOMER E. NEWELL, NAVAL RESEARCH LABORATORY, AND W. G. STROUD, UNITED STATES ARMY SIGNAL CORPS

Dr. NEWELL. My name is Newell from the Naval Research Laboratory.

Mr. STROUD. I am Stroud from Army Signal Corps.

Senator ANDERSON. Do you have a prepared statement?

Mr. STROUD. Mr. Chairman, at the request of General Fields of the Atomic Energy Commission, I called Mr. Ramey this morning to see if the committee would be interested in hearing a discussion and briefing we had with the Atomic Energy Commission this morning concerning a national space establishment which the rocket and satellite research panel is advancing as a proposal for the conduct of a national program for space research.

We would like to see established a national mission to explore and eventually habitate outer space. We have been talking with various people in an effort to put before the various people the concepts, the ideas that the rocket and satellite research panel has for the conduct of space research.

Now the rocket and satellite research panel has roughly a 10-year history and is composed of more or less prominent people in the field of upper air research with rocketry. The panel started in 1946 as the V-2 panel in Army Ordnance, established by Army Ordnance to coordinate the upper air research work that was to be done with V-2's. When we ran out of V-2's the panel more or less dissolved as an official

Government group; and since then, however, it has met as more or less the Nation's group, coordinating group in this field of upper air research. We have no Government charter but I think, as the document we give you will show, the list of membership includes the primary people who have been conducting the Nation's rocketry and missile program over the past decade.

The panel itself was largely responsible for the establishment of the country's IGY—the International Geophysical Year—rocket program, and has played a role in the establishment of the IGY satellite program.

Senator ANDERSON. What is the IGY satellite program?

Mr. STROUD. The Vanguard program, sir, which was designed to be the International Geophysical Year's satellite program.

Senator ANDERSON. By what designation? Did somebody decide that in the military, or where was it decided?

Mr. STROUD. I think the original announcement from the President stated—and this was June 1955—this was a scientific program, scientific in concept and direction, to be the American contribution to the International Geophysical Year, one of our contributions.

Senator ANDERSON. Was not that a different project than the Vanguard?

Dr. NEWELL. If I may give you some of the history—

Senator ANDERSON. I would like to have it. Are you by any chance familiar with World Series? Does that mean anything to you—the project?

Dr. NEWELL. No; it does not.

The Rocket and Satellite Panel developed much of the early planning for the satellite program, and their early planning went into the thinking of the satellite planners in the United States National Committee for IGY.

Senator ANDERSON. World series was project A for the IGY to put a satellite in the air. It was started in July 1955. In furtherance of the President's order it was assigned to Holloman Airbase for a study. Holloman Airbase prepared the first preliminary study in August 1955 under the generic term, certainly, of "World Series," and then submitted its final report in March 1956 [deleted]. That report came into Washington and, so far as I know, vanished from sight, and I have never been able to find any connection with it since. I just wondered how Vanguard got to be the official one when this was the official one supposedly.

Representative PRICE. Vanguard got to be the official one as a result of a special study group setup called the Stewart Committee, and the Stewart Committee threw Jupiter out of the picture and put Vanguard in.

Dr. NEWELL. That is correct.

Senator ANDERSON. When? Go back and give us more history then.

Dr. NEWELL. If I may pick up where I started—

Representative HOLIFIELD. For clarification, I must interrupt you again. I apologize for it.

Dr. NEWELL. Surely.

Representative HOLIFIELD. When you speak of the satellite project, are you speaking of the satellite itself or of the propulsion and the satellite as a unit or separately? This is what I would like to know.

Dr. NEWELL. I am speaking of the science program; so that I am speaking mostly of the satellite, its instrumentation, and its use.

Representative HOLIFIELD. That is what I thought you were speaking of, and that is why I wanted that clarification.

Senator ANDERSON. Is this the thing there is supposed to be a half dozen of in some warehouse?

Dr. NEWELL. Yes.

Senator ANDERSON. I am thinking of something you get up in the sky.

Dr. NEWELL. I will lead into that.

Senator ANDERSON. Good. Go ahead.

Dr. NEWELL. The National Academy of Science then set up an ad hoc group to study the question of whether or not it seemed advisable to include a scientific satellite program into the International Geophysical Year program. This science advisory group operated in January 1955—

Senator ANDERSON. When?

Dr. NEWELL. January 1955.

Representative PRICE. That is right.

Senator ANDERSON. I thought he said the President issued his statement in June of 1955.

Dr. NEWELL. We did this before.

Senator ANDERSON. Good.

Dr. NEWELL. And their deliberations were complete by March of 1955. The answers that the ad hoc committee came up with were:

1. That a satellite program was feasible for IGY; and
2. There were a number of valuable experiments that could be done with such satellites.

Therefore, the National Committee for IGY recommended to the Government through the National Science Foundation that there be an IGY satellite program.

Senator PASTORE. What is the date on that, please?

Dr. NEWELL. This recommendation was in late spring of 1955. It is my understanding that the recommendation was then communicated to the Department of Defense, to the Bureau of the Budget, and to the National Security Council; and this recommendation led eventually to the decision that there would be such a satellite program.

This decision at that time, which was in July of 1955, did not yet involve the decision what launching vehicle would be used. It simply was the decision that there would be an artificial scientific earth satellite program.

The task of putting the satellite in orbit was assigned to the Department of Defense. The Department of Defense then referred the question of what means would be used to the Stewart Committee. The Stewart Committee was chairmaned by Homer J. Stewart of the Jet Propulsion Laboratory, and having on it a number of leading people in the missile and rocket fields.

The committee then considered a number of different ways of getting satellites aloft, including Jupiter-C, which at that time was the basis for the orbiter program, the Vanguard proposal, and others.

The Jupiter-C at that time did not [deleted] among other things have the payload capacity to do the job that the IGY people wanted done. [Deleted.]

The National Academy of Sciences' satellite committee, which was created after the President had agreed there would be an IGY program, came up with recommendations as to the payload, weight, and shape for their satellite program. The Vanguard vehicle came closest to meeting the setup specifications. It also had what was regarded at that time as an advantage of not interfering with any ballistic missile program.

It is my understanding that this is the basis on which the Stewart Committee finally recommended that the Vanguard program be the one to put the IGY satellite in orbit.

Representative PRICE. In order to complete that chronology and make certain we do not leave out any steps in it—actually before the Stewart Committee came into being and before it made any decisions itself, the Army had made definite proposals to the Defense Establishment to place a satellite in orbit with the Jupiter. Is that correct?

Dr. NEWELL. That is correct.

Representative PRICE. And the rest of the chronology, up to a certain point, follows pretty closely and is correct.

Dr. NEWELL. Yes.

Representative PRICE. Then in [deleted] 1956, the Army had a very successful firing of the Jupiter, [deleted] into the atmosphere or stratosphere. And, after that successful firing, successful test, they renewed their proposals to the Defense establishment. Is that not correct?

Mr. STROUD. This is my understanding.

Representative PRICE. And even though at that time—we have testimony in our own files here in the committee, Mr. Chairman, to the effect that we knew at the time that every month we were losing a month in our progress toward success in the satellite program; that, even though they were having all these failures with the Vanguard program, they again rejected the Army proposal. Is that not correct?

Mr. STROUD. This is correct.

Representative HOLIFIELD. Was the commitment of the IGY proposal for the exchange of information between the 80 different nations that were cooperating in the program—was that any contributing factor to the decision to use the Vanguard and not use the Aerobee and the Viking, which had already been used by the Navy in high-altitude tests of different kinds?

I am asking, specifically, Was the obligation to exchange information a factor in that?

Dr. NEWELL. It seems difficult to us to understand why it should have contributed, because it had been generally agreed that propulsion information would not be exchanged. It was only the scientific data we would gather from the satellite that was significant to the IGY.

Representative HOLIFIELD. The reason I asked this is because there was a claim made that the Soviets had broken their vows in the IGY by using a military rocket for propulsion, and that we had not used the military rocket because of the commitment to exchange information. So, this is not a valid statement then?

Dr. NEWELL. It seems hard to believe this would be a contributing factor.

Representative HOLIFIELD. So, there was no commitment to exchange propulsive information with the other 80 nations, but just the end results of scientific information?

Dr. NEWELL. Yes.

Representative HOLIFIELD. Therefore, that particular argument can be shelved?

Dr. NEWELL. I would think so.

Senator ANDERSON. I certainly appreciate this chronology statement you have thus far made. It has been helpful to us. Go right ahead.

Mr. STROUD. If we may pick up, then, I think, with the proposal for a national space establishment, as I say, we have discussed this—the panel group representatives have discussed this with various Government agencies, particularly the National Academy of Sciences, Dr. Bronk, and they have received the proposal favorably and are now considering the adoption of the panel as a committee or a board serving the National Academy of Sciences.

At the same time, the American Rocket Society, which represents the professional talent in the rocketry missiles field, has joined with the rocket and research satellite panel in advancing this proposal as a means for the Nation to accomplish the space research it will need over the next generation.

Representative HOLIFIELD. Excuse me. What was the proposal—to use the Vanguard?

Mr. STROUD. No. This is a basic proposal that we would like to introduce for the creation of a national project whose mission would be the exploration and habitation of outer space.

Representative HOLIFIELD. All right.

Mr. STROUD. As I say, this is the mission of the space establishment. The space establishment we visualize as a civilian—and this means specifically nonmilitary—independent, properly financed Government agency. The financing that we are thinking about, the financing necessary to accomplish the basic research objectives that are so necessary, that seem so necessary, is on the order of \$10 billion during the next decade. In the next 10 years, \$10 billion. This is a problem of no mean scope, but we are concerned with a sizable task.

The basic and general applied research that we wish to have the national space establishment conduct, I think, has been outlined in a series of objectives that we state here.

In order that the United States establish its leadership—regain its leadership, we should say—in space research by 1960 and to maintain it thereafter, we think we should undertake to do the following things:

That we should intensify our program of scientific soundings of the upper atmosphere, as we have been doing it with some 10 years with the high-altitude-research rockets like Aerobees and so on.

We should intensify our scientific and technological development with small instrumental satellites.

Senator PASTORE. When you keep saying “we,” whom do you mean, Mr. Stroud?

Mr. STROUD. I am speaking of this country, our country, the United States.

Senator PASTORE. And whom are you representing now on this recommendation?

Mr. STROUD. The rocket and satellite research panel, the American Rocket Society, and these two groups together comprise the entire professional body of—scientific body and engineering body in this United States. It is in this field of rocket and satellite research.

Senator PASTORE. You are here as a representative of the United States Army Signal Corps?

Mr. STROUD. I am not representing the United States Army Signal Corps. This is my affiliation.

Senator PASTORE. I wanted to clear that in the record. That is the reason why I asked whom do you mean by "we."

Mr. STROUD. I am sorry. I should make it perfectly clear—

Senator PASTORE. The title they have given you here on the agenda is United States Army Signal Corps, and I was wondering for whom you are talking.

Representative PRICE. Could you describe the rocket and research satellite panel?

Mr. STROUD. Yes, sir. I tried briefly, in giving a background history, to show how the panel grew and what the panel membership is. I think the best means is for me to refer you to the membership of the panel itself.

Mr. STROUD. Dr. Delsasso of the Army Ballistic Research Laboratory; Dr. Krafft Ehrlicke of Convair.

Mr. RAMEY. He was invited as a witness for these hearings but could not make it today.

Mr. STROUD. Dr. Kaplan, of the University of California, is Chairman of the United States National Committee for IGY.

W. W. Kellogg, of Rand Corp.

Dr. Newell, of the Naval Research Laboratory, right here.

Dr. W. H. Pickering, who is director of the jet propulsion laboratory of the California Institute of Technology.

Dr. Kurt Stehling, of the Naval Research Laboratory.

Dr. Homer J. Stewart, of the California Institute of Technology.

Dr. Stoughold, of the Randolph Air Force Base and heading the aeromedical research activities of the Air Force.

Dr. Stuhlinger, of the Army Ballistic Missile Agency.

Mr. J. W. Townsend, of the Naval Research Laboratory.

Dr. James Van Allen, chairman of the department of physics at the University of Iowa, and one of the real pioneers in upper air research.

Dr. von Braun, of the Army Ballistic Missile Agency.

Dr. Fred Whipple, of the Smithsonian Astrophysical Observatory, and Director of that organization.

These are not all of the people, but there are about 25 people on the panel, who represent a cross section, we think, of the top competent professional people conducting our upper air research program.

Senator HICKENLOOPER. I would like to ask about a statement you made a moment ago before you started to explain the composition of this group.

As I understood you, you say that one of the purposes of this program is to enable us to regain leadership or regain supremacy in outer space research. Upon what do you base your assumption that we have substantially lost leadership in outer space research?

Do you base that on the fact the Russians have sent up two sputniks to orbit the earth, or is there other evidence or information that we have been pushed downhill by some other country and we are playing second fiddle?

Mr. STROUD. There is considerable evidence—and this evidence comes from our direct personal contacts, such as Dr. Newell and I and others have had with Russian scientists working in this area, and partly from published data. It appears that the Russians have a very strong and a very active program of upper air research and space research; that in setting out as we have with upper air soundings and so on, the Russians have done many things similar to the things we have done, made many of the measurements similar to the measurements we have made, but in a number of areas and a number of instances have gone beyond the things we have been able to do with the means that have been available to us, with the money, essentially, that has been available to the American research groups.

They have, for instance, developed a meteorological rocket which is a standard piece of hardware you can presumably buy off the shelf in Russia for upper air soundings, and use this. We are still working to get a decent meteorological rocket.

I think the best evidence, and the best by far, are sputnik I and sputnik II. These are prime evidences that these scientific groups in Russia have capabilities or have tools that are beyond our immediate capabilities. They put up 185 pounds, not 20 pounds; and they put up some 1,200 pounds, not again the 20 pounds we are right now considering and worrying about.

And our problem, sir, I think is to undertake the kind of program with a civilian scientific directorship with the emphasis on basic research that will enable us to regain the leadership and to maintain it, because the kind of things I point out as sort of highlights and objectives in this kind of program are things that the Russians themselves have talked about, and we see it in their publications, the things they are planning to do. As I pointed out, intensified upper air research program; intensified research program with the smaller satellites available to us, these things should be strengthened immediately.

If we went ahead with the kind of program we feel and the panel feels and the American Rocket Society feels we should have, we could look forward to impact on the moon with nonsurvival of apparatus by 1959.

Senator ANDERSON. How would that be accomplished?

Mr. STROUD. By having a rocket with appropriate guidance system of the size required for us to reach the moon.

Senator ANDERSON. Have you an idea what you would use?

Mr. STROUD. In terms of fuel, these would be chemical fuels. This would be the use of hardware which is now becoming available to us in the military systems—the Atlas system, sir. If we converted a number of Atlas systems to these means, we would be able to hit the moon but we would not be able to have any apparatus survive.

It would not be a gentle landing.

Representative PRICE. When it hit the moon?

Mr. STROUD. When it hit the moon.

Senator PASTORE. Has it not been said here, Mr. Chairman, there is not a chemical today, or is not anything in sight, that would have the power or thrust to send anything to the moon?

Senator ANDERSON. I think the statement has been made, and I added to that that you could not send a ship to the moon and back because that involves going to the moon and landing and coming back. I think that statement was made frequently.

Senator PASTORE. You are convinced we do have the chemical power to do it?

Mr. STROUD. If we would take the military hardware now coming into being [deleted] and convert it to this use, we could by [deleted] lift to hit the moon a piece of American-marked hardware.

Senator ANDERSON. That would be outside the Geophysical Year, however; would it not? It—IGY—would be over?

Mr. STROUD. Yes. We are thinking far beyond the International Geophysical Year.

Representative HOLIFIELD. May I ask for further clarification, would you anticipate a multiple stage of the present Atlas capability? Is that what you are thinking of to take you outside of gravitational pull?

Mr. STROUD. Yes, an augmented system.

Representative HOLIFIELD. Augmented on the third stage or something like that.

Senator DWORSHAK. Why have the Russians made so much progress? Have they been spending more money than we have for development? Or are they just naturally smarter, or have more scientific research, or what? What is your explanation?

Mr. STROUD. I do not know what means they have of making decisions that enabled them to come up with this, but it is apparent that some years ago they started to listen seriously to the scientists.

Senator DWORSHAK. They did not do that in this country?

Mr. STROUD. This is our reaction as scientists, that the people have not been listening seriously.

Senator DWORSHAK. When was the panel created?

Mr. STROUD. In 1946, sir.

Senator DWORSHAK. Is the record clear that those on this panel have, through the available sources and mediums, been endeavoring constantly to alert the Government and leaders in American life to the need of maintaining an aggressive program along these lines?

Mr. STROUD. I think so, sir. There are quite a few documents that the panel has over the years produced.

Senator DWORSHAK. Has it been a lack of money that has prevented us from making the progress we should have made?

Mr. STROUD. I think it was largely a lack of money and, one very important factor, a lack of the proper environment in which the scientific groups can work.

Senator DWORSHAK. What do you mean by that?

Representative PRICE. Laboratories or otherwise?

Mr. STROUD. I think we largely mean intellectual environment with respect to the public and various areas. I think 10 years ago if we stood up and talked about space flight in public we were frowned upon.

Representative PRICE. They would give you a job as a cartoonist.

Senator PASTORE. Even so, if you had the money and facilities, what difference would that make? It is fundamental, is it not, that if the Government had put up the money and made available the facilities,

no matter in what regard you were held by the people of the country, you could have done the job?

Mr. STROUD. I believe so.

Senator PASTORE. So fundamentally it is money and facilities.

Mr. STROUD. Environment effects this—

Senator PASTORE. Getting back to the processes of Government being a long drawn-out thing, the fact of the matter is the people send their elected representatives of the country here to make the decisions, and that is our decision; and if the need is there, we have to meet it. Fundamentally that is where it is. You have not had the money and have not had the facilities. Do you not think we have the scientific know-how in this country?

Mr. STROUD. I am positively convinced of it.

Senator PASTORE. This thing is very simple. We have got the brains in this country. Had we marshalled them and put up the money to do it and shown some will to do it, we could have done it. And that is why we did not do it. We lacked the leadership to do it.

Mr. STROUD. That is right.

Representative PATTERSON. In your opinion there is a possibility of it. Now you have the money, how do you think it can be accomplished?

Mr. STROUD. That is one of the reasons we are here. We are concerned about the fact it is not simply a money problem. We must pull ourselves together in an coordinated effort to do it, and we are advancing a national space establishment as the means.

Representative PATTERSON. It was a money problem, but it is not now?

Mr. STROUD. It is going to take money, but it is not money alone. We are now faced with the fact that we have a much greater sense of urgency. Even, I think, the scientists themselves have a much greater sense of urgency about the problem.

Representative HOLIFIELD. In the population and Congress also there is a different environment. I remember when the appropriation came for the IGY, when we passed the appropriation there was a lot of opposition to wasting money on the IGY. I remember when Dr. Kaplan came into my office and I took him to John Phillips of the Appropriation Committee. Thank God John saw the light and became one of the strong advocates for the International Geophysical Year appropriation over in the House.

Mr. STROUD. I think the problem we are mostly concerned with, at least I personally, if I may, is what we may do now to regain the leadership I think we should have.

Representative HOLIFIELD. I think you have made a very important proposition here, because what you are in effect saying is that we ought to tackle this like we tackled the atomic program, with a civilian agency to pull this thing together, and regardless of what the projects, or whether in the Army, Navy, or Air Force, where they are, there will be a single agency coordinating this, the same as put the responsibility in a civilian agency on atomic energy. Is that not what you are saying?

Mr. STROUD. Not only to coordinate it—

Representative HOLIFIELD. Coordinate and operate it.

Mr. STROUD. And to operate it.

Representative HOLIFIELD. That is what the Atomic Energy Commission did. They put out contracts all throughout our society. Wherever a segment of our society, whether private industry or the armed services, wherever they could do the job, they did the job.

Senator DWORSHAK. If it had not been for the Russians sending up sputnik and the psychological reaction among the Americans to that development, do you think we would still be coasting along, as apparently you believe we were prior to that time?

Mr. STROUD. I would point out to you, sir, that each and every one of us in the Defense Department, and most of the people doing the upper air research and satellite research work are in the Defense Department, are still struggling with budgets. Right today we still do not have the means to carry out our programs for next year and year after, despite the sputniks.

Senator DWORSHAK. To make available the highly trained scientists or what?

Mr. STROUD. The money.

Senator DWORSHAK. What would you do with the money if you had it? What if you had a billion dollars right there on the table—what would you do with it?

Mr. STROUD. That is a fabulous sum of money.

Senator PASTORE. He would drop dead.

Senator DWORSHAK. What would you do with it to implement what you are telling us? You are doing a good job, but what would you do with a billion dollars? Tell us.

Mr. STROUD. I think we would—specifically you ask?

Senator DWORSHAK. You said you need money. Theoretically I am giving you a billion dollars. What are you going to do with it?

Representative PATTERSON. And you stated it would take \$10 billion.

Mr. STROUD. Over a decade. We could not spend a billion dollars the first year.

Representative PATTERSON. You can answer the question. If you had a billion dollars to use, what do you suggest we could do to accelerate this question? Why do you not try to answer? It is a simple question.

Mr. STROUD. I think Dr. Newell—

Representative PATTERSON. I think I could myself, but you go ahead.

Dr. NEWELL. With the \$10 billion over 10 years, we would ask that an establishment be set up which looks like the following.

It has a strong directorship; it has the independence to determine its own program; it has direct ties to the Bureau of the Budget and to the Congress for supporting its own budget.

We would recommend that this establishment have within itself 1 or 2 laboratories which are concerned with all of the areas of research involved—not to do it all, but simply to have enough competence within its own immediate organization to have the proper guidance, advice, counsel, know-how, to provide direction for the country as a whole.

I would envision that out of the 50,000 people that a billion dollars per year represents, roughly, perhaps 2,000 to 4,000 people would be in the central establishment; that the rest of the work throughout the country would be done through contracts with industry, with universities, with other Government laboratories, and so on.

I would envision that this national space establishment be set up with a strong Advisory Board, or maybe two boards, which would maintain close liaison and cooperation with the Department of Defense, with the Atomic Energy Commission, with the National Science Foundation, and with the National Advisory Committee for Aeronautics.

This, sir, is the sort of organization that we would recommend.

Representative PRICE. Would you have your own national laboratory also?

Dr. NEWELL. We would have 1 or 2 laboratories within the central organization itself. These would amount to 2,000 to 4,000 people.

Senator DWORSHAK. Would all of this be under Government supervision?

Dr. NEWELL. It all would be in the Government.

Senator DWORSHAK. Paid for by the Government?

Dr. NEWELL. Yes, sir.

Senator DWORSHAK. There would be no participation by private industry or enterprise?

Dr. NEWELL. It is our feeling that private enterprise and the universities and the Government should all support this sort of basic research. The major share should come from the Government, but private enterprise should be encouraged to assume its responsibility toward support of this sort of thing because this leads to the things that they eventually will sell.

Senator DWORSHAK. The point I was trying to clarify is this: That the inference could be drawn, if we have been lagging behind it is because there has been a shortage of money and a lack of awareness and insufficient interest in developing this overall program. Now I should like to know whether that full responsibility rests upon the Government, whether it be the executive branch or the Congress, or whether the representatives of that segment of private industry interested in this overall program should assume some of the liability and responsibility for what has been done or what has not been done.

Dr. NEWELL. I think the overall responsibility lies with everyone; that you cannot point to any one group or person and say he is the goat.

I think, for example, that the rocket and satellite panel itself has not taken enough leadership. Some of us were aware of the need for this leadership, but we were too busy with the doing of our immediate problems, and we did not have the sense of urgency that sputnik has now created in us.

I think the Department of Defense has some of the responsibility because basic research always has had to compete at unfair odds with the development of missiles and weapons because of their immediate urgency.

I think that the Congress has to bear some of the responsibility.

I believe, too, that the people in the country have to bear some of this responsibility because they demand more of the consumer products and not so much of the basic research, which is in its doing at the immediate moment of a cultural nature. It is hard for the people to understand, perhaps, that this is important to their children 20 to 50 years from now, just as, for instance, Roentgen's activities that led to the discovery of X-rays, and De Forest's activities that led to the

discovery of the radio are important to us now, although they took place 50 years ago.

Representative PRICE. Why could you not put such an agency under the Atomic Energy Commission?

Dr. NEWELL. You could, sir, but if you put it under the Atomic Energy Commission, you must recognize that the thing we are talking about is as big as the AEC is now; and, therefore, the AEC will have to set up and maintain in operation an operation separate and separately devoted to this activity.

Representative PATTERSON. I missed a point there someplace. Do I understand that this department that you are now recommending would be an overseer of the AEC, the Army, and the Navy?

Dr. NEWELL. No. It would be an overseer of our activities in space research and exploration.

Mr. STROUD. The country's activities.

Dr. NEWELL. It would be parallel to the AEC in the AEC's responsibility for nuclear energy and its output.

Senator PASTORE. Do you really mean that this agency would have to be as big as the Atomic Energy Commission?

Dr. NEWELL. Yes, sir.

Mr. RAMEY. On their numbers of people they do not quite figure out. The AEC's budget is over \$2 billion operation funds a year, and they have 70,000 to 80,000 operating people with their operating contractors.

Mr. STROUD. Yes, sir; but you must remember we are talking about the first 10 years of the life of this agency.

Representative PRICE. Would you not have a headstart with the facilities of the AEC being available, particularly studies on propulsion, and the laboratories being already accessible and available?

Mr. STROUD. You would have a headstart mainly, I think, in the organization of AEC. But the propulsion activities and the nuclear power studies and so forth are only a part of the overall research program that we are talking about. They are a very important part, but only a part.

Senator PASTORE. I think there is a little more to it than that. First, of course, I question—I do not say this with any impertinence—I question the competence of the witness to make the comparison because maybe he does not know everything about the AEC anyway.

Mr. STROUD. I would agree to that.

Senator PASTORE. You have no Q clearance and, of course, you do not know their function, and we cannot talk too much about it here now. We can only give comparative figures which are public knowledge. Their appropriation is \$2.5 billion, and you are talking about an appropriation on a crash basis of \$1 billion, which is not that large.

Do you not think you are going to run into this, if you make these two separate agencies—talking about marshaling your scientific talent. If you are talking about basic research you are going to talk about the same people helping in this whole field of atomic energy. Are you not going to create a competition here that in the long run might be bad for the country?

Dr. NEWELL. No, sir.

Senator PASTORE. I would like to get that on record. I would like to have it explained. In other words, you are talking about people different than anyone associated with atomic energy.

Representative PRICE. Would you be competing with AEC for scientific know-how?

Mr. STROUD. In some areas, but in most areas, not.

The present program that is underway now in the sounding of the upper atmosphere, in satellite instrumentation, in the development of chemical rockets and so forth, involves people who are not in the Atomic Energy Commission program.

If you talk about the development of nuclear propulsion for rockets and of nuclear power supplies, then the Atomic Energy Commission would be involved and the same scientists would be involved.

It is assumed on our part that such an activity would still go on under the AEC, that we would not do what is already being done elsewhere, or what has been properly oriented elsewhere.

I would like to, if I may, clear up some confusion that seems to exist between applied research and development and basic research and the more general applied research which seems to creep in here.

We are talking about a long-range fundamental research program that we feel is essential for this country to undertake to develop the scientific potentiality. The application that will come from this program, the major application, the most important ones, will come 20, 30, 40, 50 years from now. The crash programs, as people speak about, to get a new missile going, a new weapons system, in the next 2, 3, 4, or 5 years are something different. They require a different approach. They require a different type of leadership. They require a different type of atmosphere.

Our proposal to set up the national space establishment is to provide for this basic research, this fundamental research, which by its nature seems to be left out when the crash programs are being discussed. We know that the weapons, the missiles, and those things will get their due attention. They do because of their very nature. But we are afraid that the basic research and the long-range research will not get its due attention unless it is pointed out it needs special treatment, sir.

Senator HICKENLOOPER. May I ask you this, to get straightened out: We have been talking about the Atomic Energy Commission and the organization you are proposing, and we heard right here a moment ago the Atomic Energy Commission is spending \$2 billion a year. The Atomic Energy Commission is not a research organization, it is a production organization, it is an industrial organization.

Mr. STROUD. That is right.

Senator HICKENLOOPER. Certainly it has substantial research which it guides and employs. That is very true. But it is bricks, and mortars, and warheads.

Representative HOLIFIELD. And raw material.

Senator HICKENLOOPER. Which it is producing through contractors, and that takes up the \$2 billion operating expense.

Mr. STROUD. That is right.

Senator HICKENLOOPER. Would you compare the operational activities of the organization your propose. Do you propose it to be a production organization, or do you propose it to be primarily and

overwhelmingly, let's say, from the money standpoint a research organization? If so, if it is, and you propose to spend a billion dollars a year, what will it cost if you go into production on these things after your research and that sort of thing is over?

I do not know whether I made myself clear on this point or not, but I think we are comparing eggs and apples here.

Mr. STROUD. Perfectly clear.

Representative PRICE. The Atomic Energy Commission has a vast research organization and goes into a tremendous amount of basic research, and they spend almost a half billion or three-quarters of a billion a year on research within the Atomic Energy Commission.

Senator HICKENLOOPER. I do not quarrel with that.

Representative PRICE. I am not arguing the point. I merely asked the question, why you could not do it. I do not say they should or could. But I think you ought to at least think about it.

Senator HICKENLOOPER. I thought I made it clear I realize the Atomic Energy Commission does a most substantial amount of research through contracts or one way or another, but the bulk of the \$2 billion they spend is for producing things—it is a manufacturing plant.

Senator PASTORE. I think that is correct.

Senator HICKENLOOPER. I am not complaining about this thing. I want to get some kind of an idea as to what your proposed billion dollars a year is going for. Is it going for production? Is it going entirely for research? Or is it going for research with some preliminary application? What will the billion dollars a year produce for us? That is the point.

Mr. STROUD. Our basic mission and motive will be fundamental research, but to do it we will require vehicle operation fields, facilities.

Representative PRICE. Like the *Nautilus* program.

Mr. STROUD. So that most of our money will go to the support of it—the hardware, the operations that are required to do the research.

Senator HICKENLOOPER. Let me go a step further. Certainly I presume any research organization that gets out of basic research or pure research and gets into the study of applied research or applied physics or chemistry, whatever it is—I presume they have to build a certain amount of gadgetry for tests on your application.

Once you have, let's say, proved that something will work mechanically and you got the preliminary hardware that gives you preliminary proof, do you propose to go ahead and build plants to build these machines?

Mr. STROUD. No, sir.

Senator HICKENLOOPER. That is what I am getting at. The Atomic Energy Commission goes ahead and builds plants to build things and to build current supplies of these things.

How much is it going to cost? I am trying to get at this from an imaginary standpoint. You spend a billion dollars a year on either basic research or certain applied applications of this research. Then you come to a point where production begins. Who produces?

Mr. STROUD. If I may give you an example here—

Senator HICKENLOOPER. Who produces? Not for experimentation necessarily, because I anticipate you probably would produce something for experimentation.

Representative PRICE. For instance, take a space ship. Who would build it?

Senator HICKENLOOPER. After you once proved the theory and proved your application, who would build the space ship in numbers?

Dr. NEWELL. We would build the spaceship for initial exploration, for proving in, but not build it in numbers.

Mr. STROUD. Nor would we build a factory to build the things. We would go to a contractor, say Convair, and say, "Can you build us this airframe?" or to North American and say, "Can you build this engine we need?" or the AEC and say, "Can you produce the nuclear energy plant we need to drive this?"

Representative PRICE. That is identical to the Atomic Energy Commission conducting all the basic research and development on the *Nautilus*.

Mr. STROUD. It is not exactly the same, sir, I think in this way: The AEC does not conduct its own research. The laboratories it has are not immediately in that—

Senator HICKENLOOPER. That is technically correct, but not practically.

Representative PRICE. You said you were going to do a lot of contracting out, too.

Dr. NEWELL. You have to.

Senator HICKENLOOPER. Let me go further. The overall job, with certain exceptions, of the AEC—there is research involved certainly, but one of the great jobs moneywise is to produce nuclear weapons. Now we have got great plants for the production of nuclear components, for the production of fissionable or fusionable material, all financed through the appropriations of the AEC.

Mr. STROUD. Yes.

Senator HICKENLOOPER. True, the AEC will develop things, but they will have some private contractor manufacture them, but that comes out of the AEC's money. You propose to stop at the point where you establish, let's say, a prototype of some kind?

Mr. STROUD. That is correct.

Senator HICKENLOOPER. A proven operational instrument. Then who pays for the production of that in quantities, in your thinking?

Dr. NEWELL. We will never want them in quantity, for one thing. We are not talking about buying them by the hundreds. Initially we will not need these things. Even by 1970, when we are talking about returnable and sizable manned expeditions to the moon, we will not be buying quantities.

Representative PATTERSON. Will you be working in conjunction, for instance, with our present weapons program? No, you will not?

Dr. NEWELL. No, sir. We do not visualize the national space establishment assuming the responsibility for defense of the country.

Representative PATTERSON. I did not say assume responsibilities. I asked if you would be working in conjunction with them.

Dr. NEWELL. There should be and must be, we feel, in order that the defense profit to the highest extent, very close liaison between the national space establishment and the Department of Defense, the closest kind of liaison.

Senator HICKENLOOPER. Let me ask you this then: Do you contemplate that this agency would eventually ripen into a production

agency for the production of the things which your scientific research proved to be not only feasible but practical?

Mr. STROUD. No, sir.

Senator PASTORE. That is not what is bothering me essentially, whether it is going to become a production agency. I do not think anyone envisions that. I think we all understand this is going to be basic research.

This is my confusion at the moment: It has always been said we could not get into an extended accelerated program of building reactors because there is a shortage of engineers, of physicists, of chemists, of scientists. The point I make is this: The minute you create this separate organization—and I am not saying it should not be separate—what I want to know is, will you need the same type of physicists that the AEC will employ, will you need the same type of basic chemists that the AEC might employ, will you need the same kind of basic engineers that the AEC might employ? What you are going to do if we are not very careful and do not get the effort fully coordinated—and this is what is frightening me—we are going to run off in two different directions and spread ourselves so thin we will not get either job done unless you have the proper coordination.

That is what is bothering me, not producing these things: How are we going to spread ourselves so thin with the available manpower that we have that we can utilize it to the best advantage of the country? That is fundamentally the question. If you get 2 agencies and 1 makes a better offer than the other, and you pirate from here and pirate from there, whether we are going to end up behind the 8-ball.

Mr. STROUD. If this were to happen, we would agree with you, sir.

Senator PASTORE. Answer my question. Are there needed physicists, engineers, and chemists that the AEC is now employing?

Mr. STROUD. The answer is no with few exceptions. We point out, with the national program and the proper kind of leadership, that the stimulus that will be provided to our educational system and getting the young people into this field, will more than equal the very small drain we make on the AEC.

Representative PRICE. Also, it was very revealing in the last seminar we had on the reactor program that there is not such a shortage in the nuclear field right now.

Mr. STROUD. The important thing is, for this program, there is not a shortage of engineering and scientific manpower in this country. What manpower we have is badly managed, and we can pick out some very specific examples. They cut off a big program in the missile field and the people do not become available. The company will hoard them, store them up, and prevent them becoming useful.

Senator PASTORE. Is it your considered opinion, then, that the type of expert personnel you will need will in no way interfere with the AEC in the accomplishing of acquirement of expert personnel they might need?

Dr. NEWELL. I believe this very sincerely.

Senator PASTORE. Then you make a strong point.

Representative HOLIFIELD. May I just ask this one question for my own clarification? The thing that you are talking about and envisioning is an overall look at pure science and basic science which goes far beyond the weapons phase we have been hearing testimony on today?

Mr. STROUD. Yes.

Representative HOLIFIELD. And I think a look at the subjects the International Geophysical Year is interested in. I took a look and I was surprised at the many, many subjects they are interested in as a result of their studies this year, which is kind of an indication as to what you are talking about here. Your feeling is that America has never given the prominence and the attention to basic science which has been given, for instance, in Hungary, in Germany, in Russia, and other nations, and that is why today in America our "big idea" men have come from those countries rather than our own country. When it comes to applying, this is a different proposition.

But what you are asking for is acceleration of the basic science program, is it not?

Dr. NEWELL. Yes, sir.

Mr. STROUD. Yes, sir.

Chairman DURHAM. Do you believe that basic research should be Government-directed?

Mr. STROUD. No, sir. But it will be necessary as we go into these areas, as we look forward in the next decade to getting man and machines off the earth—it will get expensive, and it is expensive to the point where the Government must provide the tools to do the work. It is not that the little tiny tube costs money. The scientist in the laboratory with a minimum amount of money can build the tube that will make the measurement. But to get it out in space will cost millions of dollars, and it will be necessary the Government provide the tools and rockets.

Chairman DURHAM. I agree on that. The danger you always run when you ask for Government funds is Government control. I am not a scientist, but I do not look with any favor whatever on Government control of any type of basic research.

Mr. STROUD. I think we would agree with you, sir, but what we need really is leadership—the Government to point the direction and needs in some of these areas.

The AEC, for instance, could not carry out its basic research in basic particles unless the Government provided the funds to build the accelerators. They are fabulously expensive things. But it is the work that the physicists do that is important.

Chairman DURHAM. Do you not get more out of our system in basic and fundamental research, the principle that has been in existence for years, than by Government?

Mr. STROUD. The universities need money to operate, the universities need money to build the tools that the scientists use to make the measurements. This is the thing we are talking about. The billion dollars a year that we are generally speaking of, any large fraction will not go into basic research itself. It will go into creating the tools that the research men need in order to make the measurements where they must be made—in this particular case in the vicinity of the sun, out next to Mars, or wherever it may be. This is where the money is needed.

Mr. RAMEY. Is not that essentially development work, in the sense we talk about in the AEC, of building prototypes?

Mr. STROUD. But we are not suggesting, we feel very strongly that the Government should not do this kind of work. It should not

build, it should not create a plant; it should not build a plant to build airframes or build a plant to build motors. But in this particular case this agency should provide the leadership to say to industry, "We need a 400,000-pound thrust or a million-pound thrust, whatever size engine we need. Here is the money. Develop this engine for us." Here is the kind of leadership we are talking about.

Mr. RAMEY. You are going to have to have somebody to bird dog it like Rickover.

Mr. STROUD. The national space establishment is the thing we are talking about which will provide the Government leadership that is required.

Senator PASTORE. How about the question of classification?

Mr. STROUD. We believe for the best interest of the Nation that this should be a basically unclassified program. Where, however, we need to use military tools, such as military vehicles that become available that are classified, we would maintain classification.

Senator PASTORE. The reason I asked it—that would be a strong argument to keep it out of the AEC.

Mr. STROUD. We should keep it as unclassified as we can possibly keep it if we are to really gain from it.

Chairman DURHAM. I think I agree with you on that.

Representative HOLIFIELD. I think this is a very challenging proposition, and I think we ought to go into it later more fully. But the hour is late and we have Dr. von Braun here, and I suggest at this time, if these gentlemen would step aside for the time being on this very challenging proposition, that we hear from Dr. von Braun.

Chairman DURHAM. Thank you very much. The hour is getting late and you people are available most any time.

Mr. STROUD. Whatever you like, sir. We would like to point out that Dr. von Braun is a member of our panel.

Representative PRICE. They are all of the same group.

Chairman DURHAM. Dr. von Braun, we appreciate your coming back here for this discussion. I know you had a bad day already. I think you can proceed to make your statement now. We will be glad to hear from you.

STATEMENT OF DR. WERNHER VON BRAUN, ARMY BALLISTIC MISSILE AGENCY, DEPARTMENT OF DEFENSE

Dr. VON BRAUN. At the beginning I must apologize. I was not quite prepared for this. I only heard about a half hour ago there was this hearing going on here. I am not quite prepared to make a statement, but I have a statement prepared for a hearing tomorrow at the Vinson committee, and I think part of the statement I could use.

Representative PRICE. I will hear that in the morning.

Senator PASTORE. I am for hearing it now.

Representative HOLIFIELD. I am too.

Dr. VON BRAUN. Referring to the reason why there ought to be a space agency and why we do not now believe this whole project should be handled exclusively in the military is the following:

Looking into the future, we believe that it is necessary to recognize the interrelation of ballistic missiles, satellites, and space travel. The basic elements are the same: Rocket engines, structures, guidance and

control devices, as well as certain ground support facilities. The conquest of space depends on the same resources as the development of ballistic missiles. But this does not mean that it will be a natural and automatic byproduct of the latter. Indeed the very scope of the exploration of outer space is so vast as to simply preclude its being the byproduct or fallout of anything.

We can only meet this challenge if we appreciate and respect the magnitude of this task and discontinue our unfortunate practice of supporting only such research and development serves immediate military objectives.

It is for these reasons that I have advocated a separate space agency which would not concern itself with the development and deployment of missiles but concentrate exclusively on the long-term objectives of space flight and space control.

Now I think one must clearly distinguish in everything involving exploration of outer space between the rocket vehicles and all the other things that are necessary to explore the environment of outer space and making a landing on the moon or something like that.

In the problem of getting the vehicles, it is very obvious that at least for the next 5 years anything we are doing in this area will depend very heavily on hardware developed in the ballistic missile program or the rocket aircraft program and the like. From then on, however, it is to be expected there will be special technical development necessary.

Now my personal feeling is one of the main reasons why we are in such bad shape today in space and space conquest compared to Soviet Russia is the following:

The Air Force has learned through bitter experience in the past, I would say, that instead of just going out and building airplanes and then trying to make military machines out of these airplanes after the airplane itself has been flight tested, thereby discovering that you may not be able to bomb out of the airplane, or put a machinegun in it, or put a reconnaissance camera in it, so that you have to reengineer the airplane to make a weapon out of it—the Air Force has learned a lesson from this, and they have now adopted what they call the weapons system concept.

They say, "We look at the weapons system as a whole. When we are talking about a thing like the B-52 or the B-58 we look at the ground systems, ground equipment facilities, and organization and bombs and everything, and we start cutting out only after we have a very clear concept of exactly what we want, what this weapons system will look like."

This may be an advantageous way of going about this business of building military aircraft, but I think if you apply it to space it is dangerous, and I suspect this is precisely what has happened. The Air Force has said:

"Well, everybody talks about the control of space, but we have no clear concept yet what future space warfare will look like, what forms it will take, how you can bomb from orbit, how you can reconnoiter from orbit, what kind of equipment it will take, et cetera. And, since we do not understand the concept clearly, we do not start cutting hardware."

So they study and study and accumulate an impressive array of reports studying the system, but, in the meantime, they do not do

anything about the hardware. And one fine day—I think the time has come, should have, several years ago—you discover no matter how you do it, if you want to bring people into orbit and return, they will have to have a big rocket-booster engine, 500 or a million pounds thrust, and they take 5 or 6 years to develop. If you start developing these engines only after you comprehend the weapons concept and weapons system, you wind up with a perfect solution 5 years too late.

Chairman DURHAM. I think we have had a little experience along that line.

Dr. VON BRAUN. And I think, if we settle for 80-percent perfection but get busy, we will be better off. This is precisely what the Russians have done. They probably do not understand space warfare and all of its ramifications and implications, either, but they have the vehicles to get up.

So I think it is very dangerous to say you always have to have a military requirement; first, you have to understand your weapons system completely.

I think the atomic bomb is the very best example I could think of. The atomic bomb was not conceived because some ordnance officer established a requirement for bigger bang per pound. It started the other way around—that somebody with pad and pencil dreamed up something about the relations between matter and energy, not even having a bomb in mind.

I think in this space thing we are very much in the same situation today, that so many people are trying to put the cart before the horse.

Chairman DURHAM. Are there any questions?

Representative PRICE. What was the maximum altitude you got out of V-2's way back in 1946 at White Sands?

Dr. VON BRAUN. Going straight up, maximum altitude attained was 135 miles.

Representative PRICE. Back in 1946?

Dr. VON BRAUN. Yes.

Representative PRICE. Did not you do some photography in some of those tests?

Dr. VON BRAUN. Yes, sir.

Representative PRICE. What was the maximum altitude at which you took photographs?

Dr. VON BRAUN. I have seen pictures taken from about 60 miles up—the Viking.

Dr. NEWELL. The Viking had pictures from 158 miles, and one of the Navy's earlier efforts in V-2, about 1947, pulled in pictures about 100 miles up.

Representative PRICE. How much range do they take in?

Dr. NEWELL. They were primarily directed toward horizon studies; that is, getting the aspect of the vehicle from a study of the horizon and the earth. So, it covered a large segment of the earth and was not directed toward being able to see specific objects on the surface.

Representative PRICE. Was it a good enough test so that you know, by the process of enlargement of the area, which area you could almost pinpoint anything from any height?

Dr. NEWELL. Yes.

The Viking 10 that went to 160 miles got some really magnificent pictures in infrared of the regions of New Mexico that surrounded

the White Sands Proving Ground. These have been published, and form the basis for many of our optical studies looking back on the earth. Here you can see—from 160 miles you can see the Army base, the airfield at El Paso, the city of Los Angeles, and that sort of thing.

Chairman DURHAM. Dr. von Braun, what do you think of nuclear power for outer-space propulsion?

Dr. VON BRAUN. My knowledge in this nuclear-propulsion field is limited to the project conducted in Livermore. I was visiting out there about a year ago when Dr. York showed me [deleted] experiment and everything going on for Project Rover.

The demonstration that was given to us at the time indicated that nuclear power for vehicles taking off from the surface of the earth becomes attractive only if you go to very large units and very large payload capability. [Deleted.]

My personal conclusion out of this presentation was that, while it should be definitely possible to build a reactor of, say, 800,000-pound thrust, while the technical difficulties could probably be solved, the gain, taking into the consideration the difficulties to which you go, was kind of dubious to me, and it appeared to me that a better and simpler and smarter way of going about this whole business of atomic propulsion for rockets would be to completely refrain from building a huge rocket engine capable of taking off from the ground, but use these rocket engines only at higher altitudes, either at intermediate stages of multistaged rockets, or departing from rockets and going to the Moon or Mars or someplace else, but not to use them for takeoff from the ground.

You have a two-stage rocket, for example, that you boost up with liquid or solid chemical and start your reactor engine only several miles up, and your gamma-radiation danger surrounding the facility is nil. If you have a misfire, the chances are it will fall into the ocean and we can forget about it. We do not have the problem of contamination of launching sites, because you do not turn on in the launching sites, and you work on a much smaller energy level to begin with, because the entire unit is smaller, being the top stage of the bigger rocket underneath.

So my personal feeling is, as far as fission power is concerned, it would be better and smarter to establish a requirement for rocket engine with a large thrust that can be used in second or top stage of a rocket but not for departure from the ground, or something that can depart from an orbit.

I think things look very different with fusion rocket power. This may be a little more fantastic. I mean a fission rocket can be built today and it is a question of engineering. With a fusion rocket engine we are still working in the advanced research area. But I believe that out of these approaches presently being used in the Stellerator project and out of all of these efforts—I believe and am personally optimistic that sooner than many people think we will have a fusion rocket. That rocket, of course, will be something else. That can take off from the ground, and with that thing maybe you can go in one stage to the moon, of course.

I believe there are a lot of promising things going on in the combination of plasma research conducted quite a few places. For example, by Dr. Thonony in Los Angeles. There is a lot of promise in this area.

Chairman DURHAM. Are there any questions?

Dr. VON BRAUN. I could not tell you how to build one.

From discussions I have had with people who know more than I do about, I think there is quite a little bit of optimism in this area.

Colonel ARMSTRONG. Mr. Chairman, may I make a couple of comments?

Chairman DURHAM. You may have that privilege.

Colonel ARMSTRONG. Gamma radiation is a problem but not quite as extensive as Dr. von Braun was indicated. The problem of a misfire is indeed a problem. There is no question about it. But considering that your reactor under the conditions of a misfire has only run for a very few seconds, the buildup of fission products is indeed extremely small, and should this return to earth indeed you do have some radioactive fragments.

If I may say so—and I do not say it facetiously—if I had my choice between standing underneath a few fission products and a very large tank of fluorine, I consider the latter extremely worse.

If I may also say, this business of moving people a mile away, believe me, it does not take any more concrete to protect you from the gamma radiation coming out of a nuclear rocket than is used today to fire Dr. von Braun's vehicle and protect the people from the vehicle falling on their heads. The same amount of concrete protects you from iron falling on you as protects you from radiation coming out of the reactor.

These problems have been thrown up many times in the past. I would like to turn this over to Dr. Merkle, who is intimately associated with this problem, and see if he does or does not substantiate my remarks.

Senator PASTORE. Before you do that, what is your comment with reference to the suggestion by Dr. von Braun in response to a question asked by Mr. Holifield a short while ago about separation by chemical action and then start off your reactor?

Colonel ARMSTRONG. It was very early in the game when we started worrying about Rover—the first proposal we thought up was to take a chemical booster and use that for the first stage and use the nuclear system for the second stage. We very quickly found out this is a real poor way to do this. All of the problems that we were trying to solve by using chemistry as a first stage were not real problems at all, because when you start this thing up and fire it, it is with you such a short time that the amount of dirtying up of the rocket stand is really conjectural.

Senator PASTORE. If it works. What if it fell out?

Colonel ARMSTRONG. As I say, the problem is no worse than the chemical system that falls back in your face too.

Representative HOLIFIELD. Wait a minute. Let's explore that a moment.

Chairman DURHAM. I might say to Dr. von Braun we have had a very free discussion here.

Colonel ARMSTRONG. I am not criticizing him. Please do not take any of my remarks as criticism. I think Dr. von Braun stated his case very clearly. I think he had a briefing with Dr. Merkle here a year ago. We have learned a lot in a year.

I think any comments I might make about Jupiter that I saw a year ago might not be any more substantive.

Representative PRICE. In other words, many of the things he had doubts about—

Colonel ARMSTRONG. We also did at that time.

Representative PRICE. Some of those things, at least, have been corrected in the last year. Is that right?

Colonel ARMSTRONG. Yes.

Representative HOLIFIELD. Will you not agree with me, Colonel, that when you compared the fallback of a fission rocket to the burning of the fluorine, when the fluorine gets through burning you do not have a contaminated area?

Colonel ARMSTRONG. Oh yes, you do, sir. Fluorine is a real nasty actor when it gets through coming down, and I should like to compare it in many respects to World War I gases that were used.

Representative HOLIFIELD. Do you mean to say it has the persistence that a gamma-radiated area has?

Colonel ARMSTRONG. It is extremely deadly poison.

Representative HOLIFIELD. But does it have the persistence?

Colonel ARMSTRONG. If you just assume that you have quantitatively as many fission products as you have quantitatively fluorine, then the persistence is definitely in the radioactive material. But fortunately this argument falls flat when you realize that you are starting out with a clean reactor with no fission products and they build up over the time it is running. If it only runs for a very short time and falls back to the ground, the amount of fission products which have been created are extremely small.

Representative HOLIFIELD. Comparatively speaking.

Colonel ARMSTRONG. It is not as big a job by far as what we do every year out in Nevada. We build a tower, blow it up, and go out with a road scraper and scrape it away, and go out and build another tower.

Dr. MERKLE. I would like to begin by complimenting Dr. von Braun on his memory of that briefing. He has retained pretty much all of the things that we said almost exactly right with the one exception of the specific impulses.

It is certainly true there is fission activity in the reactor. It is not necessarily so the fission activity comes out of the reactor. It depends entirely on how it is built. At the present stage of the game I do not believe Dr. Schreiber, if he were here, would guarantee to either keep it all in or make it all come out. We just do not know how well these materials will behave yet.

So from contamination on the ground from the blast of the rocket two things apply:

1. If your material development is good, you may find yourself exhausting very little fission fragment activity anyway;
2. Even if you do exhaust, the rocket spends a relatively short time near the launching site. And the arguments brought up by Colonel Armstrong are correct: It is not hard to decontaminate the stuff lying on the surface. The bomb experience kind of points out how you do that. So much for fission fragments.

Representative HOLIFIELD. Stop there one moment and let me ask a question. If your chain reaction starts in your rocket and fails to

have the propulsive power to carry the rocket on up and it falls back, is it a fact that the chain reaction stops automatically or does it continue?

Dr. MERKLE. This will depend on the circumstances of the misfire quite obviously. Like any other kind of accident, the interesting part is you do not know you are having it until you are having it. Either could happen, depending on certain circumstances.

On the matter of gamma radiation that comes out of the reactor and the neutrons during the acceleration period, it is certainly so that for a particular design point we were considering at the time of your visit—which was a 300,000-pound launching weight vehicle, [deleted] megawatt reactor—personnel to be safe from direct radiation during 300 seconds of acceleration had to be better than a mile away from launching point if unprotected. However, it is also so this is a transient radiation situation, and the blockhouse business, as Colonel Armstrong pointed out, will more than adequately protect the personnel from radiation. I do not believe you leave too many people around within a mile of anybody's big rocket when you shoot it. So I think that is kind of an unimportant point.

So I think one can effectively dispose of two major hazard questions. They are by no means catastrophic, no more than troublesome ones, when compared with rocket technology.

The question of heating of mechanical structures close to the reactor you have remembered quite well. It is certainly so on the heating problem of structures. It is not, on the other hand, a particularly fantastic cooling problem and prevails only in the immediate neighborhood of the reactor. One must not go away with the impression of the top end of the rocket being melted by gamma rays. It is not so. It is within a matter of a few feet of the reactor sides and faces you have this heavy heat deposition, and it depends upon the type of materials located there. The particular one you quote happens to be for certain tungsten springs we were considering in the design at that time. It is true we had to pump hydrogen through the neighborhood of the springs to cool them. I do not believe it is insurmountable. I believe the people from North American here today can say more about the cooling. But it is a problem that does have to be considered.

That really is enough for me to say about the cooling phase of this.

There is one other question, which Dr. von Braun did not raise, and that is, if you wish to put individuals in a nuclear rocket and launch that nuclear rocket from the earth's surface, then you have a bit of problem with shielding, and I suspect the committee is familiar with this problem under the guise of nuclear aircraft propulsion. The reason you have this difficulty is largely because of the scattering of gamma rays and neutrons in the air. So we did seriously consider, if you were to transport personnel in a nuclear rocket it would probably pay to use large dry propellant boosters to lift that rocket to altitude of about 50,000 or 60,000 feet before turning on the reactor. Just to lift it. I do not care whether you gave it any velocity or not. At that altitude there is not any scattering to speak of from radiation from the reactor back into the crew compartment. And you can shadow shield that compartment, and that is very much

lighter than trying to wrap either the crew compartment or the engine in lead.

So if you are thinking of lugging people with a nuclear rocket launched from the earth's surface, then you probably would want to boost to some high altitude before cutting in full nuclear power.

The advantage, however, for the hydrogen nuclear rocket is one I think Dr. von Braun fully appreciates, and that is specific impulse is [deleted] instead of something much lower, and enables you to have a much more favorable mass ratio, which is particularly important if you wish to go to the moon and back again. If you wish to go to the next county it does not pay probably to go to all this fuss. If you just wish to go from here to Moscow it is doubtful. But if you wish to lug a big object to an orbit, it probably does pay you to go to all of this fuss.

This is essentially the text of the argument given by Colonel Armstrong yesterday morning. I think I am almost beginning to believe it myself.

Chairman DURHAM. Dr. von Braun, it is getting late. What do you think of the urgency of going into this problem of space at the present time?

Dr. VON BRAUN. Strictly from the military point of view, I look at this space challenge a bit as follows: I think we have reached the point, technologically speaking, with respect to our capability of going into space people had shortly after the discovery of the compass. For a short time people could not go out on the ocean without referring to landmarks for navigation. Of course, all of a sudden the wide oceans became a great challenge to all nations that had coastlines—the Portuguese and the Spanish and the British and the French, everybody going out and discovering new lands and raising their flags on new land and starting colonies. And then very soon, in order to protect the colonies and to protect their shipping lanes, they had to build navies.

I think there is a certain parallelism here, that we can rest assured the Russians, at least, will go into space, and I think we may find ourselves in a rather embarrassing situation of finding the Russians have raised the Red flag on the moon and saying "The entire moon is ours."

Even legally it is not quite clear whether they are right or wrong in this case, who really owns it.

Chairman DURHAM. Who gets there firstest with the mostest.

Dr. VON BRAUN. As to the utility, what good is the moon to begin with, it is a little bit of a question like Antarctica. We have a lot of various groups living in those parts. Nobody knows exactly what it is good for, but everybody has an inkling they have to deny it to the other guy and at least have a foothold in there because somebody may discover something there someday.

Chairman DURHAM. We certainly appreciate the discussion. Of course we will be continually calling you back here because this problem will be with us for some time to come.

(Whereupon, at 5:50 p. m., the subcommittee adjourned.)

OUTER SPACE PROPULSION BY NUCLEAR ENERGY

THURSDAY, FEBRUARY 6, 1958

CONGRESS OF THE UNITED STATES,
SPECIAL SUBCOMMITTEE ON OUTER SPACE PROPULSION,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D. C.

The subcommittee met at 2 p. m., pursuant to notice, in room 304, House Office Building, Senator Clinton P. Anderson (chairman of the subcommittee) presiding.

Present: Senators Anderson, Gore, and Hickenlooper; and Representatives Holifield, Price, and Hosmer.

Also present: James T. Ramey, executive director, John T. Conway, assistant staff director, David R. Toll, staff counsel, and George E. Brown, Jr., staff member for Research and Development, Joint Committee on Atomic Energy.

Representative HOLIFIELD. The subcommittee will come to order.

Chairman Anderson has been delayed with a downtown engagement, and has asked me as acting chairman to open the meeting and read a statement which was prepared for the chairman.

This hearing represents a continuation of the Joint Committee's long interest in the subject of atomic propulsion for missiles, and outer space vehicles for peaceful purposes. The committee has been interested in, and has actively supported, the AEC's Rover project for several years. The Rover project is for the development of a nuclear rocket of great thrust. The committee has also been interested in the Commission's project for the development of auxiliary atomic power for satellites and space vehicles.

Early this session the committee, through its research and development and military application subcommittees, held a series of hearings in executive session to receive briefings on Project Rover, auxiliary atomic power for satellites, and more advanced concepts for outer space propulsion.

Witnesses included scientists from Los Alamos and Livermore Laboratories and representatives from the AEC Aircraft Reactors Branch; scientists from the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics in Cleveland; representatives of the Defense Department Office for Guided Missiles and Air Force Office of Scientific Research; industry and university scientists; and representatives of the Rocket and Satellite Research Panel from the Army Ballistic Missile Agency, Naval Research Laboratory, and Army Signal Corps.

At this point I would like to insert in the record a staff summary of the major points discussed in the briefings.

(The document referred to follows:)

No. 122, for immediate release, February 4, 1958.

From the Offices of the Joint Committee on Atomic Energy.

The first of a series of public hearings on the peaceful development of outer space will be held on Thursday, February 6, by the Joint Committee's Special Subcommittee on Outer Space Propulsion, it was announced today by Senator Clinton P. Anderson, chairman of the new subcommittee, which held its first meeting yesterday. The hearings will cover legislation on outer space development recently introduced in the House and Senate by Representative Carl T. Durham, chairman of the Joint Committee, and by Senator Anderson who is vice chairman of the full committee. The subcommittee will also consider pertinent sections of bills recently introduced by two other members of the Joint Committee, Senator Albert Gore and Representative Chet Holifield.

Representatives of the Atomic Energy Commission are scheduled to appear before the subcommittee at the February 6 hearings to give their comments on the proposed legislation and to present their views on the desirability of providing additional funds for Project Rover to stimulate progress in the peaceful development of the nuclear rocket for space propulsion. Further public hearings, probably extending into the month of March, are being planned by the subcommittee to provide an opportunity for all interested agencies, organizations, and individuals to present their views.

During its first meeting, the new subcommittee reviewed expert testimony on the nuclear rocket program (Project Rover), nuclear ramjet program (Project Pluto), auxiliary atomic power for satellites, and more advanced concepts for space propulsion which was presented to the Joint Committee in executive session on January 22 and 23. It was the general consensus of the subcommittee that nuclear propulsion offers the best prospects for space vehicles carrying large payloads for long distances. A summary of some of the major points covered is attached.

SUMMARY OF BRIEFINGS ON SPACE PROPULSION

BACKGROUND

Joint meetings of the Research and Development Subcommittee and Military Applications Subcommittee were held on January 22 and 23, 1958, to receive briefings on the nuclear rocket program (Project Rover), the nuclear ramjet program (Project Pluto), auxiliary atomic power for satellites, and more advanced concepts for outer space propulsion. Witnesses included scientists from Los Alamos and Livermore Laboratories and representatives from the AEC Aircraft Reactors Branch; scientists from the Lewis Flight Propulsion Laboratory of the National Advisory Committee for Aeronautics in Cleveland; representatives of the Defense Department Office for Guided Missiles and Air Force Office of Scientific Research; industry and university scientists; and representatives of the Rocket and Satellite Research Panel from the Army Ballistic Missile Agency, Naval Research Laboratory, and Army Signal Corps.

MAJOR POINTS COVERED

Following were some of the major points discussed in the briefings:

(1) During the course of the discussions it was emphasized that we should define and develop a national program to explore and utilize outer space.

(2) Various missions for space vehicles were discussed such as weather predicting, aides to navigation, communications, and trips to the moon and the planets. It was pointed out that there is a good possibility of utilizing a space vehicle to make long-range weather predictions (one or two seasons in advance). Such information would be of great economic value, particularly in the field of agriculture.

(3) It was emphasized that in making plans for development of outer space propulsion a distinction must be drawn between short- and long-range objectives and programs. Chemical rockets are undeniably at a more advanced stage at present than nuclear, but nuclear may be the best long-range bet, particularly for large payloads traveling long distances. It was pointed out that AEC's nuclear rocket project will provide the basis for large-scale outer space propulsion.

(4) In comparisons between nuclear and chemical propulsion it was pointed out that the specific impulse for nuclear rockets (i. e. pounds of thrust produced for each pound of propellant consumed per second) could be more than double that for the best chemical rockets. Whatever the relative advantage of one over the other for the "blasting off" engine, it was the general consensus that an atomic energy source of long endurance would be needed for propulsion once the vehicle leaves the earth's atmosphere. Perhaps a combination of chemical and atomic might prove to be the most practical approach in the foreseeable future. A new type of propulsion, known as ion propulsion—with a nuclear powerplant to supply the energy for the ion propellant—was suggested as a possible means for powering and controlling the direction of a vehicle once it is in outerspace.

(5) In view of the rapid advances being made by the Soviets in the field of chemical missiles—and their assumed work on the nuclear rocket—witnesses stressed the urgency for the United States immediately to embark on a vigorous program of research and development to achieve an outer space propulsion capability at the earliest possible moment. Chief problem, initially will be to find out which avenues of research are worth exploring and equally important, those which are not. We must also coordinate the existing efforts and talent which are widely diffused throughout the country.

(6) It was generally agreed that efforts to compete effectively with the Soviets in outer space propulsion will require a large scale developmental program and large outlays of funds, running into billions of dollars.

(7) The Committee was briefed on various plans for organization and administration of an outer space development program. It was noted, in this connection, that the Atomic Energy Commission, and particularly Los Alamos, Livermore and the national laboratories, have certain advantages over other groups in that the laboratory facilities are already in existence and are staffed by experienced scientific teams who are actually working at the present time on projects which have a direct relation to atomic propulsion for space travel.

(8) The consensus was that whatever administrative body is eventually set up, either within or outside the AEC, it is desirable that clearcut civilian control be established over the development program. It was further emphasized that close teamwork would be required between civilian development and progress made under the Department of Defense.

Representative HOLFIELD. The Joint committee believed that the problem of the development of outer space propulsion for peaceful purposes was of sufficient importance to merit the establishment of a separate Subcommittee on Outer Space Propulsion. I would like to insert Chairman Durham's announcement at this point in the hearings.

(The document referred to follows:)

No. 115, for immediate release, January 23, 1958.

From the Office of the Joint Committee on Atomic Energy.

Congressman Carl T. Durham, Chairman of the Joint Committee on Atomic Energy, announced today the names of Committee Members appointed to the Subcommittee on Outer Space Propulsion. These Members are: Senator Clinton P. Anderson, Chairman; Senators Henry M. Jackson, Albert Gore, Bourke B. Hickenlooper and John W. Bricker; Congressmen Chet Holifield, Melvin Price, James E. Van Zandt and James T. Patterson.

In making the announcement Congressman Durham emphasized the importance of a vigorous program of outer space development to the Nation's prestige and security, and stressed the desirability of establishing civilian guidance and control over the development program.

At the same time, Senator Anderson, vice chairman of the joint committee and new chairman of the subcommittee, emphasized the need for peaceful international cooperation in the development of outer space vehicles and voiced the hope that in the years to come some means may be found through which such peaceful cooperation among the nations of the world can take place.

Representative HOLFIELD. Today's hearing will begin discussions on an unclassified basis of our current status and future prospects of nuclear rocket propulsion and the peaceful development of outer

space by means of atomic propulsion. Among the subjects to be discussed will be proposed legislation introduced by Chairman Durham, Congressman Holifield and myself this past week providing for civilian control of outer space development, with responsibility for such development placed in the Atomic Energy Commission. (S. 31117) and (H. R. 10271).

The subcommittee will also consider pertinent sections of bills recently introduced by two other members of the Joint Committee, Senator Albert Gore and Representative Chet Holifield.

The proposed legislation is designed primarily to serve as a basis for discussion of the complex issues involved in the development and control of outer space, not as a definitive version of the law which may eventually be enacted. These issues include the question of short- and long-term objectives and the technical aspects of the various means of space propulsion, including nuclear and chemical. They also include the question of what type of organization appears best suited to peaceful outer space development, and evolving relationships between civilian and military agencies responsible for developmental work.

Finally, we must consider the need for added support of current projects, such as the nuclear rocket and the capabilities of existing laboratories to take on the future job of outer space development. We must make sure, in this regard, that whatever plans are adopted, there will be no interference with, or slowing up of, projects already underway which are essential to the national defense and security as well as peacetime development.

We are glad to have with us today at our first public session Chairman Strauss and the other Commissioners and AEC representatives who will present their views on civilian outer space development and a description of what the Commission and its facilities are working on which may provide a useful contribution to outer space propulsion. In this connection, I would like to read from a letter written to Mr. Strauss as to the topics we wish to cover:

- (1) What the Commission is doing, on an unclassified basis, that may have utility for outer space propulsion. This would presumably include the Rover and associated projects.

- (2) What general project areas could utilize additional funds to help accelerate developmental work in the Rover and related programs.

- (3) What advanced outer space propulsion concepts are worthy of consideration, and comparisons between nuclear and chemical propulsion.

- (4) Whether present AEC facilities such as Los Alamos, Livermore and the national laboratories are adaptable to outer space development work.

- (5) What type of organizational arrangement appears to be best for peaceful outer space development. Specifically (a) the role of civilian agencies; and (b) how the Commission cooperates at present with the military.

I would like to emphasize the subcommittee fully recognizes and would like to make clear to all concerned that AEC is testifying at our request and obviously has not had an opportunity to obtain Bureau of Budget clearance for its views. Moreover, we also recognize that

AEC has made no overtures to assume the responsibilities for outer space development contained in our bills, although I hope that AEC would assume them if Congress so directs.

Mr. Strauss, I understand you will lead off this morning and that the Commission's General Manager, General Fields, Mr. Davis and Colonel Armstrong, and other members of the Commission staff are present to answer detailed questions.

Will you please proceed, Mr. Strauss?

STATEMENTS OF LEWIS L. STRAUSS, CHAIRMAN OF THE ATOMIC ENERGY COMMISSION; K. E. FIELDS, GENERAL MANAGER; AND COL. JACK ARMSTRONG, DEPUTY CHIEF, AIRCRAFT REACTORS BRANCH, ATOMIC ENERGY COMMISSION

Mr. STRAUSS. Chairman Holifield, I think the entire Commission is here today, and we are here as you have said, to comment insofar as possible on the several matters set forth in Chairman Anderson's letter of the day before yesterday.

Because of the short time which has elapsed since the legislation that is under consideration was introduced, we have not been able to complete formal comments on these bills nor, as you have also observed, have we been able to consult with the Bureau of the Budget as is the required procedure.

I would also like to thank you for having made it clear at the outset that our appearance today is in response to your invitation, rather than being in the nature of volunteered testimony. It is important to us that you have said this, so that we be not cast in the role of special pleading as claimants to have the responsibility for the national outer space program.

This is said in no sense of false modesty, for we do have outstanding personnel and outstanding laboratories, and we have a very good record, ever since the Commission was organized of cooperation with the Department of Defense and the three services which compose it.

But as you undoubtedly know, at his press conference yesterday morning, the President indicated that he had discussed with his scientific advisers a study to be made which would include a program of a time schedule of accomplishment and also how the executive branch should organize for this enterprise.

Representative HOLIFIELD. I might interrupt at this time, Mr. Chairman, to say that as you know, this meeting was scheduled before the President's press conference, and also before the action taken by the Senate yesterday on legislation.

Mr. STRAUSS. I am unfamiliar with the latter, and if in the course of my remarks that ignorance is disclosed, I would simply like to have you know that I have not seen the Congressional Record for yesterday and I do not know of the action.

I would like to begin by saying that, as I see it, there are three issues before us as a Nation in connection with the development of outer space, and the first is whether or not it should be undertaken. It seems to me that question is easy to answer and the answer is that it must be done if for no other reason that when men have reached this point in the development of science—a point of determining that a new and radical venture is possible—men will do it.

We are at a point in the exploration of outer space perhaps analogous to the exploration of the world in the 15th century. The expedition of Columbus was designed in the hope of finding passage to India. Something far more valuable was discovered, and so it is impossible to predict what new knowledge and what new benefits will accrue from the exploration of space. But only the most hardened skeptic, I think, would discount the fact that things of great importance to men will be the result of it.

The second point is the scope and the priority of the enterprise. In this, it seems to me that you will want to consider the fact that the project may be divided into short-range and long-range objectives, and that these aspects may call for quite different approaches.

I also mentioned priorities because there must be a determination of the degree of effort, money and skill that is to be devoted to this project, and the effect upon other programs. Programs perhaps more immediate and more urgent in defense requirements require very large outlays of time and money and skills. This is a determination which will have to be made at the very highest levels.

Finally, the third point has to do with method and organization. Since, as I have indicated, the President will have this under consideration when he receives the report which he has requested, it would not be fitting for me to suggest that one agency or another or a completely new agency would be clearly logical as the designee for this responsibility. But it does seem to me that the selection of the agency is perhaps of less importance than a clear delineation of responsibility.

The placement of responsibility, then, will be absolutely clear-cut, and I think that will be the result and I am confident that will be the result of the studies now being undertaken at the President's direction. That is of the greatest importance.

I will now, Mr. Chairman, if you wish, direct comments to the specific points which were outlined in the letter of February 4, and for the purpose of understandable continuity of narrative, I have rearranged them so as to answer them in the following order: The first, third, the second, and the fourth and the fifth.

My colleagues are here to supplement my testimony, also the General Manager of the Commission, General Fields, and Colonel Armstrong, who has been particularly charged with following the program of nuclear rocket development.

I am sure that you understand from the testimony which has been presented on an earlier occasion in executive session that we will not be able to respond freely to all questions in this hearing that might occur to you.

I will repeat the questions for the benefit of those of you who may not have the letter before you. It was this: "What the Commission is doing on an unclassified basis or that may have utility for outer space propulsion. This would presumably include the Rover and associated projects."

My comment is that specifically the Atomic Energy Commission in its Rover program is directly contributing to the propulsion program and the secondary power program required for outer space objectives. The Commission is also investigating and at the proper time will expand its effort on ionic propulsion which may require a nuclear source of primary energy.

Indirectly, many of the programs in the Commission contribute toward space travel if the basic assumption that nuclear propulsion is the most practical means is a valid assumption.

Later in this testimony, perhaps Colonel Armstrong would discuss what is our present thinking as to the relative efficiency of nuclear versus conventional fuel for such propulsion, but these are only speculations as of now.

The third question is this: What advanced outer space concepts are worthy of consideration, and what are the comparisons between nuclear and chemical propulsion?

As was explained to you in executive session by members of the staff, and representatives of our Los Alamos and Livermore Laboratories, there are several approaches beyond the present Rover program which we think are worthy of consideration but which are much longer range.

Ionic propulsion, to which I have just referred, is one of course. This would appear to require a nuclear power source. However, the conversion of nuclear energy to electrical energy to make possible an ionic propulsion device would require considerable weight, and until this is overcome we think ionic propulsion is probably not within the feasible range. It is early to be making comparisons between chemical and nuclear propulsion systems as we have, of course, not yet proven that a nuclear system will, indeed, work.

We have, however, made extensive studies on the assumption that nuclear systems would work, and on this assumption it appears that nuclear systems would be very attractive, particularly where large payloads in space travel are concerned.

You are familiar with these figures, as I understand they were a part of the testimony in executive session.

I now return to the second question: What general project areas could utilize additional funds to help accelerate developmental work in the Rover and related programs?

My comment is that, as has been discussed with the full committee in closed session, the additional funds which we are contemplating on Rover and a smaller program called Snap are those which we can reasonably expect, not necessarily to accelerate but rather to assure the work in those areas. In this respect, the only real acceleration which can be achieved involves a relatively large degree of risk, but not risk in the sense of physical hazard.

This acceleration, with its attendant risk, would entail the spending of large sums of Air Force money for those components of the system beyond the reactor so that we would be off to a running start with the reactor when it has proved feasible. The risk here is that the direction one might choose to go might prove to be the wrong direction should the reactor either fail or be achieved in an entirely new manner.

Question No. 4 is this: "Whether present AEC facilities such as Los Alamos, Livermore, and the other national laboratories are adaptable to outer space development work?"

My comment is that although we have not had time to really think this one through, our opinions at this time relative to the adaptability of the Los Alamos and Livermore Laboratories to outer space development work might be summarized as follows:

First, they are presently engaged in certain particular projects that are and will contribute to outer space development work. The scope of these projects is not now interfering with the primary mission of these laboratories, and a moderate expansion appears possible within the present framework of the laboratories' organization, facilities, and missions.

Second, the present and foreseeable weapons program in those laboratories is of the utmost importance to the defense and security of the United States, and must not be allowed to suffer. Both laboratories are required for the accomplishment of this mission, that is to say, we would not think of taking either one of them out of the weapons business and devoting it to this purpose without seriously impairing the weapons situation.

Senator ANDERSON. When you say that work must not be allowed to suffer, I believe that Dr. York has recently been asked to do some special work in this space field.

Mr. STRAUSS. He has.

Senator ANDERSON. I am sure that you would agree, as I would agree, that the work at Livermore, however, is not being impeded, and that the work is going ahead on a fine basis with excellent people working it out, and that Dr. York's contribution can be made in addition to the things that Livermore is now doing.

Mr. STRAUSS. I would have to express the personal hope that the work he is now doing in addition to his work as Director of the Livermore Laboratory will be of a temporary character, Mr. Chairman, and that he will not be permanently withdrawn from the direction of the laboratory.

Senator ANDERSON. I would agree with that. I think that his work is of very high caliber at the laboratory, and that he should not be disturbed for a long period. But certainly for a brief survey, he is available, and he is doing a fine job.

Do you not also feel that the work being done at Los Alamos Laboratory on Project Rover is done without harm and probably with great help to the weapons program generally, and the two fit together?

Mr. STRAUSS. I think there are many places where they compliment one another. Obviously, in the sort of program that I suppose is in your minds, as it is in mine, for a more aggressive attack on the outer space program that we are thinking about, very greatly accelerated effort which, in whatever laboratory it is placed, will be far beyond anything that is presently in operation.

I return to Dr. York for a moment to say that he is not totally withdrawn from the laboratory, and he is spending about half time there, and about half time as a consultant or a member—I believe a member—of Dr. Killian's committee.

Shall I continue?

Senator ANDERSON. Yes, please.

Mr. STRAUSS. The reassignment of all weapons programs to one laboratory and the utilization of others for outer space development would work serious impairment in the prosecution of the weapons development program. I am sorry if I am repeating myself.

The other laboratories at the University of California, Oak Ridge, Argonne, and Brookhaven can be viewed somewhat differently. The primary missions of these laboratories are not as directly identifiable

with the national security as are the two major weapons laboratories. They in all probability contribute now and will contribute in the future to certain aspects of outer space technology.

If the Commission were assigned outer space responsibilities, these laboratories could probably take on some additional work in the early phases of the project without appreciable disruption of their current programs. However, at this time it is too early to forecast what part they could play in a space development program on a long-range basis.

The fifth question is this: "What type of organization arrangement appears to be best for peaceful outer space development? Specifically (a) the role of civilian agencies; and (b) how the Commission cooperates at present with the military.

With respect to part (a) of that question, Mr. Chairman, before you came in I had discussed the fact that since the letter has been written and received by the Commission, the President yesterday indicated that he had asked his Scientific Advisory Committee to work up a schedule of accomplishment and to recommend a method of organization in order to achieve it. I think it would be inappropriate, therefore, for me to comment on (a).

Senator ANDERSON. I think I would agree with that, in view of what has taken place. These things happen so rapidly that we cannot anticipate, in the letter you write one day, what might happen the next.

Mr. STRAUSS. Mr. Holifield, who was presiding in your absence, referred to action taken in the Senate yesterday with which I am not yet acquainted, and I remarked that if something that I might say in the course of this testimony was inappropriate in the light of that, I hoped you would be charitable.

Senator ANDERSON. I am sure I can say to you that the Senate has passed a resolution that would provide that all resolutions and bills related to outer space be referred to a special committee, as soon as we establish one. But I am certain that everybody connected with that would recognize that the bills before the joint committee include a House bill, and the House action can be taken quite independently of the resolution which was introduced in the Senate which is purely a Senate resolution.

Therefore, I hope that no one in the Senate will take offense and I am quite sure no one will, at your testifying on a House resolution which is properly before this committee at the present time. I will say that now so that if there is any later objection to it, I will say that it is my fault and not yours.

Mr. STRAUSS. With reference to the second part of the question, how the Commission cooperates at present with the military, it gives me a great deal of pleasure to talk about this.

When the Atomic Energy Act of 1946 was being considered by the Congress, and as it finally emerged as law, it provided for the establishment of a statutory committee known as the Military Liaison Committee with which the Commission was to maintain a close and continuing contact. That reminds me that in the hearings for confirmation of the original Commission in February, I think, of 1947, the late Senator Vandenberg, a member of the committee, asked how we intended to cooperate with the Military Liaison Committee.

A member of the Commission said, "We will have to live in the same suit of clothes." That was an awkward attempt to indicate that we would really have to be in continuous and close contact. The Military Liaison Committee maintains offices with the Commission. We meet on a reasonably regular basis, once a month, but we see each other daily.

I do not think it is an exaggeration to say that there is some contact at the staff level daily, and frequently several times a day. There is mutual respect between the Commission and the members of the Military Liaison Committee, and I cannot recall in the 11 years of the Commission's existence—and about eight of them I have been on the Commission—a substantial difference of opinion which continued overnight. They have always been ironed out in mutually agreeable debate.

I would suspect, therefore, that the relationships between the Commission and the Department of Defense, however the responsibility for this enterprise fell, would facilitate the accomplishment of the objective. It would not make any difference to the Commission.

Senator GORE. Mr. Chairman, in view of scientific testimony and statements which I have read and heard to the effect that chemical fuels had certain limitations on their development of thrust and because of the very nature of chemical fuels, I have felt that if this country ever conquered outer space it would do so by proper utilization of nuclear energy.

My opinion is not based on too much knowledge, but I know a few basic elementary facts, plus testimony I have heard. Would you be willing to discourse briefly upon the advantages possessed by nuclear fuels and energy from nuclear action over chemical fuels for large-scale propulsion of a space vehicle?

Mr. STRAUSS. Senator Gore, I think in order to give you a more meaningful answer, I will ask at this point to put Colonel Armstrong on the stand. But I will say this: Propulsion either in our own atmosphere or outer space is a reaction as the result of the waste or ejection or expenditure of matter.

Rockets and chemical propulsion expends very large amounts of it. Rocket motors weigh very much, and burn enormous amounts of fuel, and burn it quickly. The periods of time for which they are operative is quite small.

Senator GORE. And must have other chemicals present for oxidation.

Mr. STRAUSS. That is true. The liquid-fueled motors that we have, I believe, do require liquid oxygen or something of the sort. I am not an expert and I cannot testify as to that.

I do not think that we are in a position, as of this moment, to give you any hard facts as to the relative advantage of nuclear propulsion as against chemical propulsion because we have not perfected a nuclear rocket motor. We have been working on it for some years, as you know. But at this point, if I might, I would like to ask if Colonel Armstrong would simply stand and give you an answer to that question.

Senator ANDERSON. When you identify yourself for the record, would you also indicate whether you wear two hats, and you had some connection with the Department of Defense as well as the Atomic Energy Commission?

Colonel ARMSTRONG. I am Colonel Armstrong, and I am assigned to the Aircraft Nuclear Propulsion Branch of the Atomic Energy Commission, and as such, I do wear two hats in that this is a very closely coordinated effort between the Atomic Energy Commission and the United States Air Force.

So we do have a single management concept where I am responsible for expending the AEC's good money, on those things which are of primary interest of the Atomic Energy Commission and the coordinated program in the Air Force with its contractors on the Air Force side.

Senator ANDERSON. As I listened to Senator Gore's question, it seemed to me that he was saying that it appeared to him that chemical propulsion for certain tasks might have limitations, because of the very tremendous amounts of fuel that would be consumed and the necessity for carrying along accompanying chemicals.

Senator GORE. And rapidity of burning.

Senator ANDERSON. Could you, within the proper limits of classification, which I know you will carefully observe, indicate that if we could achieve nuclear propulsion for certain large tasks, it might have advantages? I am not referring now to a missile the size of the Atlas, although we might get into that, too, very profitably.

But let us start first with a missile that might be above the Atlas in size or a proposal that people are constantly making of a mission to Mars. If you were going to go to Mars and come back, or if you were going to go to the moon and come back, and not just putting a 300-pound missile on the moon as someone suggested—are there advantages theoretically, at least, in nuclear propulsion?

Colonel ARMSTRONG. Senator Gore asked quite a mouthful of a question, which is going to be rather difficult to answer very quickly.

Senator ANDERSON. You go right ahead.

Colonel ARMSTRONG. I should like to preface my remarks with this statement: We have in the Air Force—and wearing my other hat if I may—conducted some studies with very good contractors to determine the performance capabilities of a rocket which would be propelled by nuclear means. Naturally, as Mr. Strauss has stated, we haven't perfected a nuclear system as yet.

So one must start out on the presumption that such a thing will be successful, and then do your computing from that point. So to that extent you may weigh these figures for what they are worth.

I think that I should also state that perhaps this is a great deal my own personal opinion, because I am sure you can find as many proponents of this system as you can find opponents to it, and there are real, honest disagreements between them, basic disagreements as to which is the better under which circumstances.

With that very long hedging, I guess I will try and answer the question. In a chemical rocket, there must be two fluids carried along. You do not have to carry two, but the normal way is to carry two. One is a propellant and one is an oxydent. You effectively mix the two together, and burn them. By burning them you get a thrust out of the nozzle which causes the missile to depart the surface.

In a nuclear rocket, basically what you do is substitute nuclear heat for a flame. Therefore, you carry only one propellant along with

you, and instead of having a burning, you heat the propellant with the heat of the reactor.

Now basically, this saves you weight. There is another term that I must use, but I do not care to get into it too deeply, but as propellents are heated up and exhausted through a nozzle, the thrust which they will give you is measured in a term known as specific impulse.

Specific impulse is a measure of the thrust that can be derived from 1 pound of propellant burned in 1 second. It appears at this moment that the upper limit that can be obtained from whatever exotic chemical you might put together is somewhere in the range of 360 to 400.

I leave this open-ended because there are real arguments as to which of the ends are correct. The possible specific impulse that you can get from a nuclear rocket starts out at a factor of about 2-to-4 beyond this. So if you will accept that, you are starting out.

Senator GORE. You said 2-to-4 beyond that.

Colonel ARMSTRONG. A factor of 2-to-4.

Senator ANDERSON. Twice to four times; somewhere in that general range.

Colonel ARMSTRONG. Yes, sir, and so if you will accept the premise that the nuclear rocket, if successful, weighs less in its dead weight than a chemical rocket to start with, and produces a thrust which is considerably greater, then I think I would rest my case that the payload or the distance which you can take it is obviously larger.

Senator ANDERSON. When Mr. von Braun was testifying before the committee, and I think publicly as well, he said that to put up the type of missile we are discussing, we might need a lift that went up to a million pounds. Without trying to determine whether von Braun is right or not, and without trying to get into too many things, would it be your opinion, based upon the estimates and studies that you have made, and I realize this is a matter of opinion, that to get to a fuel with a specific impulse of 1,000, one very definite route we must explore is the nuclear route?

Colonel ARMSTRONG. I think this is correct.

Senator ANDERSON. Would you have any hesitancy in saying whether it is your opinion that that is probably the most promising route when you get to 1,000? If that is improper for you to answer, I assure you I would not want you to do it.

I am merely trying to say, and I am sure it means to members of this committee who have heard lots of testimony, that we should be giving the Atomic Energy Commission every opportunity to try to get to this thrust of 1,000, because it may be the surest way in the long run.

The other may be possible also. It may be as Admiral Strauss referred to a moment ago; there may be 2 or 3 ways to get these things done. I am not trying to say that the proposals of anybody else are impossible or anything of that nature, but does this not look to be a very promising route by nuclear propulsion?

Colonel ARMSTRONG. Yes, sir; it does, and I do not think that I find any opposition to going this route. In fact, I have had a great deal of encouragement from the Commission in going this route.

Senator ANDERSON. I am sure you have from the Commission, but have you not had from other scientists?

Colonel ARMSTRONG. Yes, I have.

Senator GORE. Colonel, were you coming to the point of mentioning the difference in the dependability of a nuclear reactor compared to a motor activated by chemical fuel as a source of consistent heat, or inconsistent heat, or heat at varying intensity?

Colonel ARMSTRONG. This is not quite that connotation when we speak of reliability, and here I am afraid my opinions are strictly personal. I have the very firm conviction that obviously the less parts you have, the less trouble you can expect.

As is well known, chemical rockets are usually made up in stages. Each stage burns and in its time drops off, and the second stage takes over. The type of thing that we talk about is a single-stage device.

So I cannot help but believe that one piece of machinery is bound to be more reliable than two or more pieces of machinery. This is strictly my personal opinion.

Now, there are some adherents of this. It is only again my opinion, in the nuclear system where the basic energy available to you is relatively unlimited, that you can get an engine which to all intents and purposes has more thrust than is required to do the particular job.

Senator GORE. When you say the source of energy is relatively unlimited, is it not true that a small amount of fissionable materials can provide, and will provide, large amounts of heat or energy over a considerable period of time?

Colonel ARMSTRONG. I do not want to mislead you with my answer, in saying "yes" to that. You must realize that when a rocket leaves the ground, working against the force of gravity and the drag of air, it must expend a tremendous amount of energy in a very short time.

To do this a large amount of propellant must be heated very quickly, and discharged. To all intents and purposes, and I guess you can go back to Professor Einstein's theory, that E equals MV^2 , and this is your answer. It takes a large amount of energy to get out of the earth's atmosphere and the earth's gravitational field.

To do this, a large mass of material must be speeded up to a high speed and shot out the rear end of this. Now, it matters not at all that you have a tremendous amount of energy for a long, long period of time because you are stuck with the amount of propellant that you can carry. Once that propellant is gone, it matters not at all how much longer the reactor lasts because you get no more thrust.

Now, conversely, once you are in space, then the amount of thrust that is required to move you around is very, very small. Therefore, you can attack this from another viewpoint. That is to have a very, very small mass of material accelerated to an extremely high velocity and this is where the ionic propulsion scheme fits into the scheme of things, as Mr. Strauss has indicated.

But this is going to require a major breakthrough, believe me, because the weight of the machinery to convert heat into electricity and electricity is a must in ionic propulsion, is an extremely heavy thing.

Senator GORE. But it is this source of supplementary, although relatively smaller, energy that would provide maneuverability and controlled mobility once you are in space.

Colonel ARMSTRONG. Yes, sir. This is one way of doing it; yes, sir.

Senator ANDERSON. Colonel Armstrong, people ask if we put up a space ship, what it would it look like? I am not going to ask you that question. I am only going to ask you for background information.

When you try to deal with the other services in the development of a nuclear-propelled airplane, does the Atomic Energy Commission try to design the airframe or do you, in cooperation with the military group, permit them to go ahead with the design of it?

Colonel ARMSTRONG. This is strictly a cooperative effort.

Senator ANDERSON. I know it is, but I want to get that into the record. In the Atomic Energy Commission, there is a great deal of responsibility reposed with reference to the development of nuclear-propelled airplanes. So far as you know, the Atomic Energy Commission, and perhaps Admiral Strauss could answer this, has left to the Air Force a great deal of designing work in the actual type of plane into which this power would be finally put.

Colonel ARMSTRONG. That is correct. Your statement is absolutely correct, and the Air Force is charged with the responsibility for the airframe.

Senator ANDERSON. And on my own responsibility, I would say that no person from the Air Force has ever complained that he has had the slightest interference from AEC because the 2 programs were fitted together by the 2 agencies. I think they have been very happy with the cooperation they have had.

Now, with reference to project Rover, if the Atomic Energy Commission develops a powerplant for it, a nuclear powerplant for it, would it expect to develop the airframe in which it might be carried off into space?

Colonel ARMSTRONG. The present frame of reference that we are working in is that beyond the reactor, the responsibility for the balance of a rocket is that of the Air Force.

Senator ANDERSON. I am happy to have you say that. I knew it, and I am merely trying to say that there is no trouble with that. You work with these agencies steadily all of the time.

Colonel ARMSTRONG. It works beautifully.

Senator ANDERSON. Therefore, if it were to be said that the surest way—and this is not your testimony, now, but it is mine—if the best bet for getting to a planet and back was by a device that had nuclear propulsion, it would not be difficult for the Atomic Energy Commission to cooperate with any agency in the development of the structure into which the nuclear propulsion unit might be fitted?

Colonel ARMSTRONG. This is getting away off into who gets which responsibilities, beyond that which I have right now, Senator.

Senator ANDERSON. I probably said it badly.

Representative HOLIFIELD. Would it be well to point out at this point that this system that the chairman has just mentioned in regard to an aircraft, nuclear aircraft project, was applied in the construction of the Nautilus? The AEC took care of the nuclear reactor portion of it and the Navy took care of the hull and the fittings that went along with it, and also the maritime ship that has been authorized, so far, and the carrier, I suppose.

Colonel ARMSTRONG. That is the way we are working with Rover and Pluto.

Senator ANDERSON. It has occurred to me that the probability of interplanetary flight, and flights to the moon, or flights to a particular planet, will have to depend some day upon nuclear propulsion. That is not a scientific appraisal, but it is just my own guess after listening to a lot of witnesses.

If it should develop that the best way to get there and back was by nuclear propulsion, if the Atomic Energy Commission had developed the system of nuclear propulsion, there would be no difficulty in designing a frame to carry it, because you do work with organizations steadily in that regard.

Colonel ARMSTRONG. I am sorry, Senator, but I get confused at this last part of this question, because in the present framework that I am in right now, where the Air Force has a definite responsibility to build a rocket to do a particular mission, and the AEC has a definite responsibility to provide a propulsion system for that rocket, my answer to you is yes, sir, that is exactly the way it would go and I can see no difficulty with this.

I must for the moment bring out my blue suit and put it on and say this is what I would be doing in the Air Force.

Mr. STRAUSS. Senator, I think the question is beyond the Colonel's competency, and I will answer it for the Commission by saying yes.

Senator ANDERSON. Thank you. I am sure that I agree. I will put it this way: There are many people, who believe that if you are going to have interplanetary travel, you must have some sort of nuclear propulsion which would have to be developed naturally through the Atomic Energy Commission.

Now, everything I have seen would indicate that if that were to be developed by the Atomic Energy Commission, the type of buggy in which it would ride would not be very hard to develop because you would turn it over to the people particularly equipped to do that.

Mr. STRAUSS. It might be very difficult to develop. The problems connected with other parts of it than propulsion might approach the magnitude of the propulsion problem. I would not want to discount them by any means. But I do not see any difficulty in the kind of cooperation that you have referred to.

Senator ANDERSON. That is what I really wanted you to say.

Now, Colonel Armstrong, the task of making an atomic bomb from what we knew about fission many years ago was a relatively difficult one, and the task of making a hydrogen bomb with the atomic bomb technology was rather difficult.

Would you care to say whether your contacts with individuals who have worked in those fields leads them or you to believe that the task of nuclear propulsion is easier or more difficult than the work of developing of the hydrogen bomb and the atomic bomb?

Colonel ARMSTRONG. Senator, I am awfully prejudiced on this project.

Senator ANDERSON. I know it; that is why I asked you the question.

Colonel ARMSTRONG. I have such confidence in the people at Los Alamos and I have seen them do such spectacular things, and things I would not even believe when I was first in the bomb business, that to me this is a *fait accompli*.

I know they are going to do it. If they do not, I am going to be awfully disappointed in them, but to compare as to which was the

harder job, I can only lean on the words which you heard yourself in the closed testimony, that in the opinion of Dr. Bradbury, he would say that the nuclear rocket was an easier job at this stage of the game.

It appears that the problems are less involved. I am not really competent to answer the question.

Senator ANDERSON. I realize that. I only wanted that testimony because some people have said, "Oh, yes, the way to do it is by nuclear propulsion, but you never can get nuclear propulsion." It was certainly the feeling among the people who testified that this would not be a more difficult task than some of the other tasks they had.

Colonel ARMSTRONG. If I did not think it was possible, obviously I would quit.

Senator ANDERSON. Do you have additional statements?

Mr. STRAUSS. I have completed my statements.

Senator HICKENLOOPER. I just wanted to ask this question, Colonel: When you say not quitting, necessarily your own opinion, but that of others working in the field, that it probably is less difficult to solve this nuclear propulsion problem in a rocket than it was to build the original bomb, do you mean that based upon the vast knowledge which we have acquired in building the bomb, the first one, and the atomic science up to date, with that broad base then the step from what we know now to the creation of an atomic propellant machine is less difficult than when we started from scratch back in the original theoretical days of the bomb?

Colonel ARMSTRONG. I think that is half of the answer, sir. I think the other half of the answer is that there are less uncertainties involved in nuclear propulsion.

Senator HICKENLOOPER. I think that would be involved in the broad base of knowledge which we have acquired. We have acquired certain things during this time.

Colonel ARMSTRONG. We have a theory on nuclear propulsion which seems quite reasonable. At one stage in the nuclear bomb business, we did not even have a theory.

Senator HICKENLOOPER. Well, apparently I did not make myself clear. That is all.

Senator ANDERSON. I think he is trying to get you to say the same thing I was; that this looks like an easy job.

Colonel ARMSTRONG. It is not an easy job.

Senator ANDERSON. But you are very confident of the outcome?

Colonel ARMSTRONG. Yes, sir.

Senator ANDERSON. That is what is important to us.

Colonel ARMSTRONG. This is a real difficult job, and let me clear up the fact that I do not think it is easy. I think it is a very difficult job.

Representative VAN ZANDT. Admiral Strauss, in connection with expanding the existing facilities to take care of this project, is it not proper to say that the support facilities are already in existence at Livermore, Los Alamos, and Oak Ridge.

Mr. STRAUSS. Mr. Van Zandt, that is true. I think also that there are support facilities in other laboratories that are not laboratories of the Commission. I put in a plug a little earlier in my testimony for our laboratories, because I think that they are quite exceptional, and I think the staff at our laboratories are remarkable people.

This is perhaps due to the fact that I am more closely associated with them than very competent men in other Government laboratories.

But you are correct; to a very considerable extent, support facilities are in existence; not all that would be necessary.

Representative VAN ZANDT. Is it not true that at Livermore, and I think again at Los Alamos, studies have been made by physicists concerning space?

Mr. STRAUSS. There have been such studies on a somewhat informal basis. They have not had that specific responsibility. As a matter of fact, Dr. York has probably told you things that he has done, and his group have done in that connection. I would not want to particularize them more than that.

Senator ANDERSON. Dr. Merkel has also been in that, and Stanuland said he had a little chance to stop and think again in his pleasant duties, which he enjoyed.

Representative HOLIFIELD. Do you find a feeling of enthusiasm and a desire to get into this field on the part of the nuclear scientists?

Mr. STRAUSS. I have not heard any of them express skepticism. Enthusiasm—I do not know how to define that, but for example, today I met with Dr. Ernest Lawrence who has not been directly concerned with it except that he is the director of the Berkeley Laboratory, and he has sort of an overall responsibility for it. He is a man of very distinguished accomplishment.

He expressed the view, and I read him these three points of mine, and on the first point, the question as to whether or not we had the responsibility as a Nation to go ahead with this, and he said, "Absolutely and unqualifiedly, it must be done." Irrespective of an immediate goal in the way of gain. Perhaps it is not fair to quote a man who is not present.

Senator ANDERSON. I think it is. You would say, would you not, that Dr. Lawrence, in addition to the brilliant work he has done in this country, has had an opportunity to become quite familiar with Russian science, and after the Geneva conference a couple of years ago, he did some traveling in Russia, and renewed acquaintances with a great many, and formed some impressions as to the abilities and standards of scientists working in Russia, and therefore, he probably is a very good witness to testify as to whether this is something that should be undertaken.

Mr. STRAUSS. He has enthusiasm—I will go back to Mr. Holifield's word—for the short-range project. He feels that we cannot afford not to do it in face of the existing situation.

Representative VAN ZANDT. Admiral, with the knowledge we have of outer space development, would you suggest we tackle the problem through a Manhattan district project?

Mr. STRAUSS. Mr. Van Zandt, there I would like to reserve my answer because of the fact that, as I indicated earlier, the President has named a group or is about to name a group to advise him on this. I think perhaps as a member of the team I ought not to particularize on that. I hope you will not press me on that.

Representative HOLIFIELD. Mr. Strauss, are you familiar with the bill which Mr. Anderson and some other members of the committee have introduced, Congressman Durham and I introduced a bill like it, and—

Mr. STRAUSS. I have read it; as I testified, I have not had an opportunity to give it detailed study. I believe it was only introduced last week, I think.

Representative HOLIFIELD. Yes. I want to direct your attention to the organizational setup in this bill, and not for the purpose of getting you to express approval of this bill, but strictly from the standpoint of the feasibility of the setup.

Beginning with the program, section 242 on page 2, section (b), it says:

There is hereby established within the Commission a Division of Outer Space Development, which shall administer the Commission's activities under this act.

Now, the question I ask, at this time—the Atomic Energy Commission is divided into divisions, is it not?

Mr. STRAUSS. Yes, sir.

Representative HOLIFIELD. How many existing divisions do you have?

Mr. STRAUSS. We just created a new one the other day.

Mr. FIELDS. Of the nature you are talking about here; I think we have eight.

Mr. STRAUSS. You are thinking of program divisions, instead of administrations.

Representative HOLIFIELD. There are eight at the present time and the present law allows you to have how many?

Mr. STRAUSS. Ten, in addition to DMA.

Representative HOLIFIELD. This would fit in very nicely to complete the 10.

This is in line with the organizational structure, and as far as that is concerned, no new legislation would be needed to permit the establishment of such a division if the President should order it?

Mr. STRAUSS. We would probably come back to you, Mr. Holifield, for some money, and the opportunity to increase the salaries of our division managers and pay them a living wage.

Representative HOLIFIELD. The section 243 seeks to set up an Outer Space Advisory Committee; and does this not parallel to a certain extent the Scientific Advisory Committee?

Mr. STRAUSS. Yes. In the course of the comments which we will formally present on this bill, I would take exception to that as being invisible and that it would duplicate the work, I think, to a considerable extent, of the General Advisory Committee and I would urge you to take the position that the General Advisory Committee should be composed of men of sufficient competence to advise the Commission on that.

Representative HOLIFIELD. And have that burden one of the burdens of the General Advisory Committee rather than a special advisory committee?

Mr. STRAUSS. That is right. The Commission may be overburdened with advisory committees; except on an ad hoc basis, that could be so.

Senator ANDERSON. Could I break in there, and explain the reason that paragraph was put in was that people had come to me and said, "Although it is fine to put a great deal of the responsibility on the Atomic Energy Commission, somewhere in this, why do you not make provision for having representation for the NACA and maybe the National Science Foundation?" I put this in as a paragraph on which we might have testimony, as to whether there was need to have specific mention of NACA or the National Science Foundation, or the

National Academy of Sciences, so that if we had long hearings upon the bill, which were then contemplated, and may still take place, we would have a chance to find out if an additional group other than the advisory committee to the Atomic Energy Commission might be necessary.

This was an exploratory paragraph, and nothing else. I am glad to have your early comment on it.

Mr. STRAUSS. As a matter of fact, this is an opportunity to see whether my colleagues feel differently about this, because I have not had a chance to consult them on it.

Dr. LIBBY. There is a point of having competent advisers. They might be members of the GAC. I sympathize with the chairman's point that we have a very fine committee in the general advisory committee, and I have great confidence in them, and they do a great deal of good.

I think that they might have, if this responsibility were given to us—we might pay special attention that the members include some of these people that you have in mind, Senator.

Senator ANDERSON. I recognize the general advisory committee is excellent for the work that has heretofore been placed upon the Atomic Energy Commission. I only felt if you were going off into the other uses you might want to have different persons advising you than the members of the present General Advisory Committee contemplated under this bill for space exploration.

It was only for the purpose of exploring to see if there were additional groups that might need to be brought in that this was put in there.

For example, I think everyone will concede that the National Advisory Committee on Aeronautics has done good work on the research of the aviation industry and its associated lines, and you might want to say in order to bring them into full contact with it, we would like to have their advice on this particular phase of the program, but might not want to put them in as general advisers to the Atomic Energy Commission on the development of atomic energy: that is, power plants, and nuclear warheads, or whatever it might be.

There might be that distinction. I do want to explain, Mr. Chairman, that is the only reason it is in the bill, so you might consider that possibility.

Colonel Armstrong, have you finished your discussion as to the differences that Senator Gore asked you about, between chemical and nuclear?

Colonel ARMSTRONG. Yes, sir.

Senator ANDERSON. We did not want to cut you off, because we get off into tangents. Might I ask you one further question: The Jupiter-C that was able to put the satellite in orbit the other day is reported to have been a four-stage missile. Would a nuclear-propelled missile, as you envisage it, need to be more than a one-stage missile?

Colonel ARMSTRONG. This is not an easy question to answer. It would depend entirely upon the mission that you intended this thing to go on.

If you are talking about putting a satellite in orbit, then the answer to your question is no; one stage would be sufficient.

Senator ANDERSON. If you were going to propose putting a 300-pound missile on the moon, that still is within the range of capability

of a one-stage missile, as you are contemplating it, and I am not trying to get a final scientific answer. You could think about a one-stage missile?

Colonel ARMSTRONG. In that kind of weight range, yes, sir. Again, now, these are personal opinions, believe me.

Senator ANDERSON. We tried very hard to say that we would recognize that this is a sort of exploratory meeting in which you are giving some guidance as to the direction in which the committee might go and these have to be personal opinions and not binding upon you, and I am sure you would not want them binding upon the Atomic Energy Commission.

This is an attempt to get information, and I want to repeat that the Atomic Energy Commission under this sort of uncertain circumstances might come ahead and help us in this testimony and I think it is very fine.

We did request at one time an unclassified chart comparing the thrusts of nuclear and other sources. I still do not know whether it is permissible.

Mr. STRAUSS. We tried one out and I looked at it last night, Senator, and we decided that we had better stick to the classified one that was presented.

Senator ANDERSON. I was just about to say to you that we recognize the difficulties of it, and if you feel that that is what it should be, we certainly withdraw the request.

Representative VAN ZANDT. Colonel, in your thinking, would it be possible to get a space platform into the stratosphere and from a space platform launch nuclear-powered missiles with unlimited cruising capabilities, not only to land on the moon, but to make the circuit of Jupiter and Mars?

Colonel ARMSTRONG. The "filling station in the sky" concept has never appealed to me particularly. These things have been talked about. Here, of course, is where your ionic propulsion device might come in, that you would establish on orbit, some large space station, and then you could, because you need no large quantities of propellant, use this as a departure and return point.

Representative HOLIFIELD. Colonel Armstrong, Senator Anderson questioned you in regard to a one-stage nuclear vehicle. Has there not been some thinking that we might use the known means of propulsion, chemical propulsion, to raise the satellite to the orbital ellipse, and then even with a much less effort and with less thrust assist from nuclear chain reaction power give it a push and give it mobility and maneuverability from a guided standpoint after it had attained its orbital ellipse?

Colonel ARMSTRONG. This present concept of Rover does not lend itself to this type of an idea. You are speaking of some type of strange propulsion such as ionic propulsion?

Representative HOLIFIELD. I was thinking of nuclear propulsion, maybe with not adequate thrust to lift a heavy object from the ground, but with adequate thrust to provide guidance to different altitudes and in different directions, once it attained orbital height.

Colonel ARMSTRONG. This is a natural outgrowth, but at the moment our problem and our energies are directed toward getting off the earth. This is what we are pointing at at this time. So I cannot

answer your question definitively and tell you what the benefits would be because I have never studied it.

Representative HOLIFIELD. It could be a shorter range possibility, possibly, than the other.

Colonel ARMSTRONG. I do not know, sir.

Senator ANDERSON. Are there any other questions?

Representative PRICE. Colonel Armstrong mentioned ionic propulsion and since it is an unclassified matter, he might elaborate a little on it.

Colonel ARMSTRONG. Well, the theory of it is rather simple. Of course, like anything that is away off in the distance it is quite easy to talk about it.

If you will compare it with your television tube in your set at home, a television tube is an ionic gun. Or, look at this as being an accelerator with an open end on it. What you do is, you boil ions of metallic surface and you accelerate them in a magnetic field, to very high velocities, and discharge them through an orifice, and this gives you a small measure of thrust.

Now, in obtaining ions, and accelerating them in a magnetic field to the point where they get this much speed takes a tremendous amount of electrical energy, as your familiarity with accelerators will tell you, and if you put your hand in the rear of your television set, you will find out that there is quite a bit of electrical current there.

To do not know that I can define an ion really.

Representative PRICE. I have another question that may have been asked while I was out taking a telephone message, but that is, for the sake of the record, to establish the length of time that the Atomic Energy Commission has been engaged in study and research and development of nuclear propulsion for rockets.

Colonel ARMSTRONG. It is 3 years of concerted effort, but there had been some studies made by the laboratories before that.

Senator ANDERSON. Could you give that a little louder?

Mr. STRAUSS. Three years of concerted effort, but there had been studies made by the laboratories that antedates that.

I think, as a matter of fact, it would be rather difficult to establish the date of its beginning. Undoubtedly that was in conversations between individuals, but there have been three years of work on it in which money has been spent, which is more to the point.

Representative PRICE. Considerably more time was spent on study and consideration and research and development on aircraft nuclear propulsion, is that right?

Mr. STRAUSS. Yes, the aircraft nuclear propulsion program is of greater antiquacy.

Representative PRICE. That is about 12 years?

Mr. STRAUSS. Not that long.

Representative PRICE. 1946 was the first year when consideration was given to it?

Mr. STRAUSS. I am sorry. The Commission began operations on November 1, 1947, and at that time we did not have as a project aircraft propulsion.

Representative PRICE. But I was trying to get the number of years in which nuclear propulsion had been under consideration and study that antedated the Commission. It began at Oak Ridge in 1946 before the Commission took over.

Mr. STRAUSS. I would have to supply that for the record, Mr. Price, because I do not remember, but as you say it is over a considerable period of time.

Representative HOLIFIELD. All of your studies for nuclear propulsion for aircraft has been valuable for the missile study?

Mr. STRAUSS. Not all of it, but some of it, surely.

Representative PRICE. That is all.

Senator ANDERSON. I was going to say I heard there was a chemical term, "free radicals." Would that apply to people who start talking about trips to the moon?

Colonel ARMSTRONG. I am sure there are more free radicals in people than there are in chemistry.

Mr. RAMEY. On your explanation of ion propulsion on the large amounts of electricity needed, is the theory there that you would need a nuclear reactor of moderate size to provide that electricity in outer space?

Colonel ARMSTRONG. It is not an absolute must, no, but if you want electrical energy out in space for a long time, I don't know of any other way of getting it other than supplying it through a nuclear sense, because any means of batteries, or engines, is obviously not going to run but a very short time. I would say, "Yes" to your question; nuclear is where you begin.

Senator ANDERSON. Admiral Strauss, do you care to just estimate some of the agencies that are certain to be in this general field of work?

Mr. STRAUSS. I think they have all been named, that I would think of. There is the National Science Foundation, the National Advisory Committee for Aeronautics, the Department of Defense, obviously.

Senator ANDERSON. Would you not include the Department of Commerce, because of the weather importance that would be connected with this?

Mr. STRAUSS. I would think so. As a matter of fact, it is hard to think of any part of the establishment that does not have some interest in it. I am reminded that many years ago—more than I care to remember—I was looking over some old navy correspondence dating from 1890, and someone suggested the formation of a Bureau of Electricity, which was then fairly novel application, and it was defeated on the general idea that eventually electricity would be used by everyone.

I suspect that atomic energy if it has not already demonstrated the fact, will be of importance to all parts of the establishment.

Senator ANDERSON. I had a discussion once with reference to the future of the Joint Committee on Atomic Energy. Someone pointed out that the tasks it had assumed in a day of secrecy might change when there might not be any secrecy, and when we deal with the propulsion of a locomotive that is something that might also be considered in the Committee on Interstate and Foreign Commerce in the Senate, for example.

When we deal with the development of nuclear propelled merchant ships, that also might come to a standing committee, for example, the Merchant Marine and Fisheries Committee of the House. Then, when you deal with all of these other manifestations, you get a cross-current of all kinds of committees.

Is that not likely in the wide scope that would be involved in studies of space propulsion, that while the propellant might need to be developed by the Atomic Energy Commission, that the Atomic Energy Commission would certainly touch the Department of Commerce and the Department of State, and all of these various departments in the fulfillment of an entire program.

Mr. STRAUSS. I am glad that you mentioned the State Department. I had not mentioned that, and it is an agency that has a very obvious interest in what is done. The Department of the Interior in the matter of its mining responsibilities is another one. There is scarcely an agency—and I have not been able to think of one—that has not an interest in this.

Senator ANDERSON. I stopped because it was suggested that you might wish to discuss the need for acceleration of Rover. I had a feeling that this was probably not the best place to discuss that. We would be happy to discuss it if you felt it should be.

Mr. STRAUSS. I would prefer, Mr. Chairman, that that would be on another occasion.

Senator ANDERSON. May I, at this point, just read in a few of the points that we covered.

This was in a press statement that was issued from the committee:

(1) During the course of the discussions it was emphasized that we should define and develop a national program to explore and utilize outer space.

(2) Various missions for space vehicles were discussed such as weather predicting, aids to navigation, communications, and trips to the moon and the planets. It was pointed out that there is a good possibility of utilizing a space vehicle to make long-range weather predictions, 1 or 2 seasons in advance. Such information would be of great economic value, particularly in the field of agriculture.

(3) It was emphasized that in making plans for development of outer space propulsion a distinction must be drawn between short and long-range objectives and programs. Chemical rockets are undeniably at a more advanced stage at present than nuclear, but nuclear may be the test long-range bet, particularly for large payloads traveling long distances. It was pointed out that AEC's nuclear rocket project will provide the basis for large scale outer space propulsion.

(4) In comparisons between nuclear and chemical propulsion it was pointed out that the specific impulse for nuclear rockets (i. e., pounds of thrust produced for each pound of propellant consumed per second) could be more than double that for the best chemical rockets.

We tried, as you did, to be somewhat careful in the figures that we might use there, but we are trying to get just a general idea of what could be done.

Whatever the relative advantage of one over the other for the blasting off engine, it was the general consensus that an atomic energy source of long endurance would be needed for propulsion once the vehicle leaves the earth's atmosphere. Perhaps a combination of chemical and atomic might prove to be the most practical approach in the foreseeable future. A new type of propulsion, such as ion propulsion—with a nuclear powerplant to supply the energy for the ion propellant—was suggested as a possible means for powering and controlling the direction of a vehicle once it is in outer space.

(5) In view of the rapid advances being made by the Soviets in the field of chemical missiles—and their assumed work on the nuclear rocket—witnesses stressed the urgency for the United States immediately to embark on a vigorous program of research and development to achieve an outer space propulsion capability at the earliest possible moment. Chief problem initially will be to find out which avenues of research are worth exploring and equally important, those which are not. We must also coordinate the existing efforts and talent which are widely diffused throughout the country.

(6) It was generally agreed that efforts to compete effectively with the Soviets in outer space propulsion will require a large scale developmental program and large outlays of funds, running into billions of dollars.

(7) The committee was briefed on various plans for organization and administration of an outer space development program. It was noted, in this connection, that the Atomic Energy Commission, and particularly Los Alamos, Livermore and the national laboratories, have certain advantages over other groups in that the laboratory facilities are already in existence and are staffed by experienced scientific teams who are actually working at the present time on projects which have a direct relation to atomic propulsion for space travel.

(8) The consensus was that whatever administrative body is eventually set up, either within or outside the AEC, it is desirable that clearcut civilian control be established over the development program. It was further emphasized that close teamwork would be required between civilian development and progress made under the Department of Defense.

I will say to you that the hearings were of great interest to the committee and I think that the Atomic Energy Commission is entitled to the praise of the committee for the bold thinking that was demonstrated by the people sent in from the Atomic Energy Commission, not only members of the Commission, but members of the staff.

They came in from various laboratories and various agencies. I only regret that security precautions do not permit the committee to publish in full those hearings because I think they would be very reassuring to the American people.

If there are no further questions, thank you very much, Mr. Chairman and members of your group for being here today.

(Whereupon, at 3:30 p. m., the hearing was concluded.)

APPENDIXES

APPENDIX 1

[S. 3117, 85th Cong., 2d sess.]

A BILL To amend the Atomic Energy Act of 1954, as amended, to provide for outer space development through the peaceful application of atomic energy, and for other purposes

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as "The Outer Space Development Amendment of 1958".

SEC. 2. The Atomic Energy Act of 1954, as amended, is amended by redesignating chapter 19 as chapter 20, and inserting a new chapter 19, reading as follows:

"CHAPTER 19. OUTER SPACE DEVELOPMENT

"SEC. 241. PURPOSE AND POLICY.—It is declared to be the purpose and policy of the United States—

"a. to achieve the development and control of outer space for peaceful purposes by the United States and all friendly nations working cooperatively to promote scientific progress and the security and welfare of all nations and peoples of the earth.

"b. to accelerate the civilian development of outer space propulsion, including appropriate energy-producing reactors and engines, vehicles and platforms, and all other related components and activities.

"SEC. 242. PROGRAM.—

"a. The Atomic Energy Commission is authorized and directed to exercise its powers in such a manner as to accelerate research and development on outer space propulsion, including appropriate energy-producing reactors and engines, space vehicles and platforms, and all other related components and activities.

"b. There is hereby established within the Commission a Division of Outer Space Development which shall administer the Commission's activities under this Act. The Division shall be under the direction of an Assistant General Manager who shall be appointed by the Commission upon the recommendation of the General Manager.

"c. The Commission, to the fullest extent practicable, shall utilize existing atomic energy laboratory installations, and other Government installations, personnel, and services, provided that the Commission shall retain full authority for the planning, direction, and overall budget control for such programs and projects.

"SEC. 243. OUTER SPACE ADVISORY COMMITTEE.—There is hereby established an Outer Space Advisory Committee (hereafter referred to as the "Committee") which shall be composed of seven members appointed from civilian life by the President with the advice and consent of the Senate. The Committee shall be responsible for reviewing and advising the Commission, the President and other Government agencies, the Congress, and the public as to the adequacy of proposed programs and the status and results of projects undertaken to carry out the purposes of this Act.

"SEC. 244. INTERNATIONAL LABORATORY FOR OUTER SPACE PROPULSION.—The Commission, with the general policy guidance of the State Department, is authorized and directed to undertake to negotiate and execute an agreement with cooperating nations for the establishment of and participation in an international laboratory for outer space propulsion.

"SEC. 245. NATIONAL LABORATORY FOR OUTER SPACE PROPULSION.—In order to carry out the purposes and policy of this Act, and consistent with the provisions of section 242 (c) and 244, the Commission is authorized to establish a national

laboratory to serve as a domestic center for research and development on outer space propulsion and related activities."

Sec. 3. Section 202 of the Atomic Energy Act of 1954, as amended, is amended in the following particulars, as follows:

a. At the end of the first, fourth and fifth sentences add the following: "and outer space propulsion."

b. In the sixth sentence following the words "atomic energy" add the following: "or outer space propulsion."

Sec. 4. The sum of \$50,000,000 is authorized to be appropriated or otherwise made available to finance initial operations and construction to carry out the provisions of this amendment.

STATEMENT BY SENATOR CLINTON P. ANDERSON, IN THE UNITED STATES SENATE,
MAY 6, 1958

Mr. President, under the leadership of the distinguished majority leader, Senator Lyndon Johnson of Texas, there has been a meeting of the Senate Special Committee on Space and Astronautics, of which he is the chairman, to hear Dr. James Doolittle who is vice president of the Shell Oil Co. and Chairman of the National Advisory Committee on Aeronautics, in conjunction with Senate bill 3609.

This marks the beginning, as far as the Senate is concerned, of hearings which can be of enormous importance to the United States. Without attempting to go into details, I can surely say that some of us who have been serving on the Joint Committee on Atomic Energy are extremely interested in the hearings and the conclusions which the Congress and the country will finally reach. We have been attracted to the possibilities of space flight and to the possibility that manned vehicles can travel between the Earth and the Moon, Mars and Venus, and the possibilities of interplanetary and interstellar travel are extremely attractive. We have had much testimony to the effect that a manned flight back and forth between the Earth and Mars, for example, can only be possible through the medium of nuclear propulsion and we, therefore, have an extremely alert interest in who shall direct the research looking toward that eventuality.

As I shall probably say many times during the hearings, it is strange that the bill recommended by the President makes no mention whatever of nuclear propulsion. That fact alone will cause a great many people to stop and wonder whether we will orient our course toward ultimate success or certain failure. Once the hearings start, I hope to give undivided attention to that question. Therefore, I thought it might be well, on the opening of the hearings, to say a few words about previous problems and specifically the problems of the bill which came from the Bureau of the Budget in order that some of the points I raise may be in the minds of the members of the committee as they examine the testimony of Dr. Doolittle and those who will follow him on the witness stand.

On October 4, 1957, our illusion of scientific superiority was shattered and the advent of the space age found us without policy or program. As a Nation, we did much soul searching and found that our own space exploration programs had been treated lightly at the highest levels, while the Soviets had been engaged in long-time planning and programing.

As early as 1955, the Soviet Union had established a commission on astronautics with specific responsibilities and power to direct scientific laboratories and research centers to work on outer space development. They had a program. They seemed to know where they were going. Now, almost 4 years after the founding of the Soviet space agency, the President has forwarded a message and a legislative proposal for the beginning of an astronautical program in the United States.

The proposal calls for the creation of a new outer space agency built around the present National Advisory Committee for Aeronautics. The Congress has responded promptly and is now holding hearings. Of course, much more could have been done in these 8 months and earlier, under existing law, but this is now somewhat irrelevant.

In approaching outer-space legislation, we must first examine the reasons why and explain to ourselves and the public the need for appropriating funds for the development of satellites, space vehicles and for the later exploration of outer space. To date many reasons have been proffered but I have seen few concise explanations.

The reason why is a dynamic composite of many things all of which surround our destiny as a leader among nations.

The primary reason why we must have an astronautical program is to explore the vast unknowns of the universe and harvest its scientific information. The material value of such knowledge is difficult to measure but we have learned over the centuries that knowledge once applied to practical usage pays dividends a millionfold. When Dr. Einstein wrote to President Roosevelt and suggested what was to become the atom bomb program, who would have anticipated today's widespread industrial and medical uses of isotopes, atomic power or ships that can sail the oceans for years on their original charge of fuel?

An outer-space program offers us much knowledge in meteorology, biology and astronomy, and within these and the many sciences there is much we will learn. In a more material sense, man would learn about the resources on the moon and the planets with a view toward their use after we have exploited the scarce resources of this world. This much is certain, exploration of outer space will afford us the priceless opportunity of looking at our own planet in a detached but highly advantageous position—a position man has long dreamed about and now finds within his grasp.

We should also have a program for purely military reasons. Some have said that the planet could be controlled, in military terms, from outer space, but this may be an overstatement. The weight of opinion is that the main military value of satellites or space vehicles would be reconnaissance. When we remember that the allied armies stopped before Monte Casino for 5 months because a single reconnaissance point supported the enemy forces, we can assess the magnitude. A reconnaissance point in space could monitor the positions of armies, aircraft, shipping and particularly the position of all missile launching and storage sites on earth.

Recently the President's Scientific Advisory Committee, whose chairman is Dr. Killian, published a report entitled, "Introduction to Outer Space." This report spoke of the military applications of space technology in the same terms of communications and reconnaissance but it minimized the risk of actual bombardment from outer space. Since then Dr. Wernher von Braun has taken issue with the report, stating that actual bombardment of the earth is quite conceivable from space satellites and vehicles. We might well add then, another military usage—that of strategic bombardment.

But we have learned with our atom and hydrogen bombs that the possession of a highly advanced weapon system alone does not assure the peace. To plan the usage of outer space for military advantage alone merely broadens the armament race and emphasizes preparation for war. But, the science of astronautics offers much more. It can be an avenue to peace and international accord. Here the major powers of the world might work together, and plan joint scientific ventures. There is an esoteric quality to outer-space exploration and once man's mind is lifted from his own planet and into the universe he might well forget his hatreds and work for human knowledge and understanding.

These are the reasons why we should promote the science of astronautics in the United States and have a national program.

The Congress now must decide what kind of a program there will be—whether it will truly be under civilian or military control—its size and scope—and what policy will be set to guide the executive branch.

The President has proposed a civilian agency and is to be congratulated for his enlightened approach. His concept should be accepted, for the arguments in favor of real civilian control, particularly if we are to consider this work as an avenue to peace, are indeed strong. But the mere calling for a civilian agency is not enough, because in practice, the military could dominate this field if we do not spell out the scope and power of the civilian jurisdiction.

I understand that following the President's decision in favor of a civilian control, the Bureau of the Budget was asked to prepare draft legislation embodying his concepts. This legislation was prepared and forwarded to the Congress but there is substantial conflict between the President's purposes and the draft received by the Congress.

I need not remind you how many times the Congress has rejected the exact wording of drafts prepared by attorneys in the executive branch and referred to appropriate committees along with the Presidential messages. Surely no one would look upon our failure to do so now, if indeed we do revise the Bureau of the Budget bill, as evidence of discord on this subject.

In fact, the same situation prevailed with the Atomic Energy Act of 1954. The Congress and the Executive were of the same political party then, and there was an intimate working relationship on atomic energy matters. When the decision was made to amend the 1946 Atomic Energy Act and permit private industrial participation, attorneys in the executive branch of Government prepared a draft proposal. The then chairman of the Joint Committee on Atomic Energy, Representing Sterling Cole, decided that this proposal did not spell out the agreed upon objectives and the proposal was discarded. A vastly different draft was prepared in the Congress but it was soon accepted by the Executive as an administration bill.

I believe that the draft outer-space bill which the Bureau of the Budget has prepared presents the same problem and hope that my comments on some defects will be accepted as constructive criticism. To cure these defects, revisions are needed, and perhaps a completely new bill must be written. Specifically, the problems are these:

The Bureau of the Budget tried to modify the existing legislation under which the National Advisory Committee for Aeronautics operates and make it into a bill for the Outer Space Agency. But the two concepts of the NACA and the Outer Space Agency are not compatible. They are at variance because the present NACA is essentially a research study and service group. It was created to carry on research for the military aviation branches, for the Civil Aeronautics Authority and in some respects for aircraft manufacturers. The NACA has never worked on or directed a complete project such as building the *Nautilus* or an ICBM. It merely studies a small phase of a project and lends advice to the agencies responsible for the project itself. Hearings by the Joint Committee on Atomic Energy revealed that NACA does no hardware development work.

The new agency envisioned in the President's proposal would direct whole projects and use contract powers to a great extent. It would not be just a study group.

The NACA works through committees. On top of the agency, there is a 17-man committee made up of Government representatives and men from private walks of life. In addition to the main committee, there are many subcommittees, often in excess of 20, which are also composed of industry and Government people, both military and civilian.

In the new agency where important contracts would be awarded, the public interest would seem to reject such ill-defined, commingling of Government representatives and private parties. The appointees from private life would serve without compensation and, despite the utmost discretion in appointments, the potential at one time or other for conflicting interests surely seems great.

In this regard, I am most distressed by one provision of the Bureau of the Budget bill. While the bill incorporates NACA into the new agency, the present NACA law providing for a 17-member committee of which 10 are appointed from the Government and 7 serve without compensation from private life, was changed. In modifying this law the Bureau of the Budget attorneys reversed the representations and chose to have 9 persons, the majority of the committee from private life, and only 8 from the Government. We find then, that the Bureau of the Budget not only failed to be concerned over the commingling of private and Government persons in an agency with the power to contract on specific projects but they also (and obviously with deliberation) placed the majority control of the agency in the hands of private persons. They would divest the Government of control over the most dynamic program of this century.

I believe that these draftsmen from the Bureau of the Budget should be called before a committee of Congress to explain why they deliberately chose to change this provision.

At the same time I would like to hear why their bill makes provisions for the acceptance of gifts by the agency from private sources.

I do not mean to impugn the integrity of the Bureau of the Budget representatives nor suggest improper motives. I believe, however, that explanation of their thinking could help the Congress understand why the jurisdiction over outer-space matters should not be controlled by appointed Government officials, confirmed by the Senate, rather than by private parties.

Even if there were not this odious characteristic of private control, I would be at a loss to understand how 17 men can be truly responsible for the conduct of such vital work. While it is true that the Bureau of the Budget bill has the 17-man committee deciding upon only 4 subjects, these 4 topics go to the

very root of the agency's affairs. The 17-man board would have referred to them all policy, program, budget, organization, and major personnel matters. With that much power of decision, they obviously would control the agency.

One of the major problems in the United States in our advanced scientific and technical programs has been our inability to fix responsibility for success or failure of projects. Only in programs such as Admiral Rickover's work on the nuclear navy has the Government been able to pinpoint responsibility. We have a broad body of experience to teach us that if we are to launch successfully large size satellites and space vehicles and to explore outer space, the agency we create should be constituted in such a way that someone is responsible.

Many experts have testified on the use of atomic power for launching and propelling space vehicles. The evidence seems overwhelming that any vehicle of substantial size and range must depend upon some form of nuclear energy as its propulsive force. If we contemplate the ability to maneuver in outer space or have round-trip explorations of the moon and other planets, nuclear energy must play a part. In terms of launching vehicles, thrusts of over 1 million pounds suggest the use of nuclear power. Soviet technical authors have not ignored this prospect and most recent works discuss the uses of nuclear power on space flight.

We should not delude ourselves that we have anything to hide from the Soviets for they are obviously many years ahead. Recently I was examining an interesting little booklet, entitled: "Application of Atomic Engines in Aviation." It was published last November by the Military Press of the Ministry of Defense of the Union of Soviet Socialist Republics and has recently been translated by the Air Force.

On page 166 of this booklet there is an interesting passage regarding the relative desirability of nuclear and chemical fuels for the propulsion of interplanetary vehicles. And I quote:

"At present, thanks to the progress made in nuclear physics, to the development of a rapidly progressing science of atom power, and to the creation of an atomic industry, we have come close to the solution of the problem of making use of atomic energy in rocket engineering.

"However, even today, many scientists believe that the first interplanetary trip by man will not be made with nuclear but with conventional chemical fuel. Another, and in fact, much larger group of contemporaries hold that interplanetary flights are impossible with conventional chemical fuel and that a more powerful source of energy such as nuclear energy would have to be used * * *"

Then if you turn to page 179 of this Russian booklet under the heading of "Conclusions," you will find this interesting passage:

"The question as to the necessity and possibility of applying atomic energy in aviation has already been given a positive answer and solution. This is primarily demonstrated in the directives of the 20th Congress of the Communist Party of the Soviet Union, which indicate the need to develop atomic engines for transport purposes."

I don't think that there can be much doubt that the Soviet Union is going ahead full blast with the development of nuclear propulsion for space rockets. The material in this little booklet leaves very little doubt on that score.

Despite this evidence, not enough is being done in this country to develop this technology of nuclear power application. For several years now, there has been a modest program for the application of nuclear power to military missiles, but this program has been so impeded by budget limitations it cannot test promising ideas. Dr. Norris G. Bradbury, director of the Los Alamos Scientific Laboratory, has to cook his pot too far back on the stove.

Within the atomic energy program, there are major Government laboratories employing some of the best scientific and engineering talent in the land—men deeply dedicated to the public good. Less than 1 percent of all these scientists and engineers have even had the opportunity to study the role of nuclear power as applied to missiles, much less outer space. Few have even had access to the technical information on nuclear missile work. We may feel certain the Soviet atomic scientists and engineers have not been denied this opportunity, particularly when we consider that the Soviet Commission on Astronautics can place requirements on such laboratories as it chooses.

And yet, between the time of the Soviet Sputnik and now, no one, outside Congress, has called upon the Atomic Energy Commission to increase its effort and no requirements have been placed upon them to conduct broad studies on

outer space propulsion. The President's bill and message is completely silent on atomic power and it may be that little thought has been given to the subject.

Of course, no new legislation is needed to start studies of atomic power application now; in fact, by simple administrative order, it could have started yesterday and it could start today. Only modest appropriations would be required because all of the facilities exist and the people are already employed. There would be no expenditures for components or hardware—only for study time. It seems incomprehensible that the order has not been given to start 4 or 5 of the major Government laboratories on broad studies.

On May 1, Dr. James Von Allen at the University of Iowa reported in connection with International Geophysical Year (IGY) research that unidentified forms of radiation might exist in the form of a belt many hundreds of miles outside the earth's atmosphere. Newspaper stories on this suggest that this could prove to be a barrier to manned satellites and a temporary hazard through which space vehicles would have to pass. The discovery does not affect the probability of travel, but the discovery does point up the fact that the laboratories who have the most experience with radiological hazard, those of the Atomic Energy Commission, should be utilized to the utmost in outer space research.

The discovery also emphasizes the desirability of nuclear propulsion because one of the difficulties with nuclear propulsion is the necessity for shielding against radioactivity. If it is necessary to shield a space vehicle against the newly discovered radioactive belt anyway, we might just as well use the most powerful propulsive force we have available. We can well remember as we evaluate this, that the U. S. S. *Nautilus* has inside of it a source of radioactivity which could kill all of the ship's occupants in a matter of moments. The laboratories of the Atomic Energy Commission learned how to permit men to live in this environment and, in fact, be free from radiation. These same Atomic Energy Commission laboratories can solve the problems of human health from radioactivity in outer space and from proximity to nuclear propulsion plants on space vehicles.

The Bureau of Budget draft bill is silent on the international aspects of astronautics. The omission is indeed strange when we think of this science as a force for peace and see the ample provision for military representation in the agency. Certainly the Congress will wish to assure itself that there are strong policy and substantive provisions on the subject and assure, at the very minimum, that the Department of State is informed of the activities of the agency so that they can approach international conferences intelligently.

The Bureau of the Budget's legislative proposal contains no section on patents. Its silence leaves patent awards in the hands of the new space agency. Since the Bureau of the Budget's bill provides for the majority of the board controlling the agency to be from private life, one would wonder what thought was given to protecting the Government's interest in the patent rights arising out of contracts for research and development of outer space components. I am sure most Members of Congress remember the many weeks of debate over the patent clauses of the Atomic Energy Act when a few of us insisted upon protecting the public interest in the atomic energy field with appropriate patent provisions. Any legislation the Congress now approves for space should have similar provisions.

At present, the National Advisory Committee on Aeronautics is required to come before Congress and obtain specific authorizing legislation before they can construct new facilities or expand existing ones. When the draftsmen at the Bureau of Budget incorporated the present NACA structure into their bill they deleted this provision.

When we consider that the United States has billions of dollars invested in laboratories and other facilities spread all over the United States, Congress should have the opportunity to see how existing facilities, particularly those at the Atomic Energy Commission and the Department of Defense laboratories, are being utilized before they permit the expenditure of funds on new laboratories and plants. I feel certain that Congress will wish to make provision for authorizing legislation in any law on outer space which is enacted.

In 1946 when the first Atomic Energy Act was being considered, there was much controversy over military versus civilian control. The debate ended with a proposal by the late Senator Vandenberg providing for a military liaison committee to the Atomic Energy Commission which would keep the military informed of atomic energy progress and through which the military

could place requirements upon the Atomic Energy Commission. The wisdom of Senator Vandenberg's compromise has been proven, and the Atomic Energy Commission has more than fulfilled the most optimistic anticipations of the Department of Defense in terms of atomic weapons.

The Vandenberg provision worked, because it distinguished between the domains of the civilian and military agency. Under the Bureau of Budget proposal and within the NACA-type framework, military personnel would be so commingled in the agency that there would be no demarcation between its civilian and military character. This hybrid could be utterly confused in its purposes.

But even more important than this, is the problem of deciding what aspects of outer space should be under civilian control and what should remain within the military. Of late, we hear that most of the funds for space research would still go to military agencies even though a new civilian agency may come to being. For fiscal year 1959, the Budget Bureau had requested \$480 million for a military space program and only \$100 million for a civilian program. In fact, a one-time Presidential adviser recently stated that if most of the money is to be allocated for military space research, it might be better to just forget about creating a civilian agency. Apparently, he thought that talk of a civilian agency in the administration is only so much window dressing to hide the true intention of continuing a purely military program.

Despite the fact that the President has forwarded a message and legislation to Congress, no civilian program has been outlined so far. Discussions to date indicate that under present plans, the bulk of outer space research and development would remain within the Department of Defense. This expectancy is fortified by the April 2d memorandum from the White House to the Department of Defense and the Presidential Advisory Committee on the subject. It said the civilian agency would be responsible for all space programs "except those peculiar to or primarily associated with military weapons systems or military operation."

If the words of this memorandum are to supply the demarcation between civilian and military control, it would be a farce to call this a civilian program. So few things in modern life could not be described as "peculiar to military operations" that if the same test were used in the rest of our national affairs, we would have a military dictatorship.

The military viewpoint had its ultimate expression in the recent testimony of Maj. Gen. Bernard A. Schriever, who said that the development of space weapons must take priority over nonmilitary space exploration and he inferred that a civilian agency could not supply the military with the weapons systems for outer space that is might need.

Of course, we have all seen that the civilian Atomic Energy Commission has been more than competent in supplying weapons to the military, and many of our international problems of late with hydrogen bomb tests spring from this very success.

Mr. Simon Ramo, of the Ramo-Wooldridge Corp., a private company, recently said that 90 percent of the space program of the United States must remain under military control and direction for the security of the Nation. Mr. Ramo's comment is of great interest and might be indicative. Some years ago the Air Force found it lacked the management talent to administer the Intercontinental Ballistic Missile Program and assigned management of most of the Government's interest to the Ramo-Wooldridge Corp. The management of missiles has vested in the Ramo-Wooldridge Corp. for some years and the rate of progress and success has been somewhat questionable.

In drafting any new legislation, Congress might want to look at this arrangement, whereby a private company more or less acts as Government representative, placing contracts for research and development and the procurement of components. I can fully understand why Mr. Ramo would object to a new agency which might exercise some control over the Government's funds and direct the Government's program. I can well understand his fear that before many months passed, he might have to deal with a tight-fisted civilian administrator.

In the enactment of any legislation, the Congress might well look for a proper definition of what should remain in the Defense Department and what should be in the civilian agency. I believe a clear definition is readily available. The Defense Department should retain jurisdiction over missiles which are fired from earth or its atmosphere and return to a target on earth in a ballistic flight. Anything which goes beyond this and into orbit or travels into outer

space should go to the new agency. The record of the Department of Defense in developing satellites and mechanisms which go into orbit is hardly a record of success. They would be pressed to make a case that they have such an interest in this field that jurisdiction could not be given to a civilian agency. But even if they had progressed with their research and development we have the classic precedent of the Manhattan Engineering District and the Atomic Energy Commission where a fully matured program was transferred to a civilian agency and progress was accelerated rather than impeded.

I am convinced that no program worthy of the United States can possibly evolve out of the presently confused Pentagon. At the moment they have jurisdiction but we learn that no requirement has been fixed for a space vehicle. As you know, without a requirement, no Government work is being done in this area.

The draft legislation of the Bureau of the Budget provides for the new agency to report to the President annually. This is a strange provision because one would expect the President to be kept informed on what is taking place within his executive family. The channel in which reporting breaks down is between the Executive Branch and Congress. While it is called upon to appropriate billions of dollars of public money, Congress must often proceed with the scantiest of information. It would have been more thoughtful of the draftsmen to provide some reporting mechanisms to Congress but surely we can arrange in our committees to provide for a semi-annual report to us.

The Bureau of the Budget's draft provides criminal penalties for disclosures of information and violation of the Space Agency's security regulations. We have learned that penal provisions of a substantive nature in new laws weaken the basic statutes like The Espionage Act of 1917 and The Atomic Energy Act of 1954 and confuse an already confused field.

In a more positive sense, I think the provision is unwise insofar as it accents security provisions rather than encourages the new agency to conduct its scientific and technical research to the fullest extent practicable in an atmosphere of free information exchange.

In the atomic energy program we learned that the strongest of security measures and building forts around our laboratories did not halt scientific progress elsewhere in the world. The delusion cost us many millions, if not billions of dollars, and as I look back upon it, I only wish that this money had been spent on basic research. If it had, the benefits which would have accrued to the United States would have been vast.

Mr. President, I have been generally critical of the legislation which has been sent to us and if I were to close at this point, I probably would have offered little of constructive value to guide us in the establishment of an astronautical agency. I may have told you too much of what we should not do rather than what we should do.

Our national astronautical program should be far broader than anything contemplated today. I would provide for utilization of any appropriate Governmental scientific or research facility through the placing of requirements or work directives by the Space Agency on the appropriate Government agency.

Within the atomic energy program, a subject with which I am most familiar, an almost unlimited reservoir of scientific and engineering talent, exists. The Atomic Energy Commission probably should not have jurisdiction over the outer space program as such, but the legislation should provide a mechanism whereby the Space Agency can place requirements on the major laboratory facilities of the AEC.

The Congress should establish the policy that this new agency not build new facilities or laboratories but that they utilize existing facilities to the utmost. They can do this without sacrifice of jurisdiction by placing requirements on existing agencies. If we think this will be difficult to administer, appropriate liaison committees can be established along the lines of those in the atomic energy program which have been so successful.

The Space Agency itself should start as a small Agency. Whether 1 man should be in charge or whether there is a 3- or a 5-man commission is a matter for further study, but the top leadership should be limited in number certainly to no more than 5 and preferably to a lesser number. The people on top should be full-time Government administrators confirmed by the Senate and prohibited from having outside interests. If such deprives the Agency of broad technical advice, provision can be made for such scientific advisory committees as is necessary.

Our statement of policy should call for international negotiations which seek international agreement to deny the use of outer space for military purposes and provide for mutual scientific cooperation.

We should seriously consider whether or not it is appropriate to graft the new Agency on to the existing framework of the NACA because of the great variance between what the new Agency must do and the long existing pattern of work in which the NACA is engaged. I feel that an entirely new agency should be established with power to place requirements for scientific study and work upon the NACA rather than work within its structure. Were we to take this approach we would also avoid the conflicts of interest inherent in the NACA committee structure where industry and military personnel are so much in command.

We must study the problem of inventions and discoveries and find language which protects the Government interest and yet equitably awards to inventors the exclusive right to profit from their work.

I am confident that each Member of Congress will take time to study this problem and if we do this, the proper agency structure and policy will evolve. We have learned a great deal in recent years on how and how not to prosecute scientific programs and undoubtedly we will be able to provide for a responsible and effective Government agency which will harness our very great resources in scientific and engineering talent.

When future generations consider the secrets of the universe as commonplace and when the domain of human reason reigns over outer space, many may look back upon this Congress and speak highly of its wisdom. Before many weeks pass, we will have the chance to inaugurate the effort which one day will be a priceless heritage to those yet unborn.

REMARKS OF SENATOR CLINTON P. ANDERSON, IN THE UNITED STATES SENATE,
JANUARY 16, 1958

Mr. President, the people of America have so much interest in the possibilities of a satellite, a spaceship, or even a long-range intercontinental ballistic missile that I feel it important there be some discussion of the progress we are making in the general field of nuclear propulsion as it might be related to missiles or satellites.

To begin, we would of necessity be discussing what has been called Project Rover. This is the code name for our project for nuclear rockets to propel long-range missiles and possibly satellites. I want to make an attempt to indicate what happened to slow down Project River, why we are not making very much headway in the study of nuclear propulsion as far as missiles, airplanes, and satellites are concerned, and what we may do to increase the tempo of our activities in this very important field.

This is not an attempt to become involved in arguments as to the policies that may, or may not, be involved in nuclear propulsion. I am going to try to recite the facts and people can make their own political conclusions from them. Personally, I think we will be better off if we avoid some of the political discussion that could be indulged in, and devote our time to deciding what steps America must take if we are not to lose both the psychological and the military values that are involved in this whole program.

I want to go back to July 1956. At that time Project Rover was adequately financed for the ensuing fiscal year 1957, involving many millions of dollars for construction and operations. We had had a problem in the Joint Committee on Atomic Energy. The Atomic Energy Commission had appeared in a special meeting in late June, had testified that it needed some additional money for construction, and had received over \$9 million in additional funds through the following steps:

On June 22, 1957, the Atomic Energy Commission came up before the Joint Committee, at the AEC's own request, to ask for the added \$9 million which they said was urgently needed to push ahead the Rover program. In response to this urgent plea the Joint Committee immediately approved authorization of the extra funds and I remember that I personally made a special visit to the Senate Appropriations Committee the same day, I think it was a Saturday, to ask that the money be made available to AEC. The Appropriations Committee duly approved this request and the money was appropriated.

It is my understanding that the initial AEC request for operating funds for fiscal year 1957 was cut down by about \$4 million. Of course, we were then

going through a period of study, and were attempting to learn what the future of nuclear propulsion would be insofar as ballistic missiles and satellites might be concerned.

At that time, Mr. Edgar Murphree, connected with the Standard Oil Company of New Jersey, was a guided-missile czar. At least that was his title. He appointed a committee under the chairmanship of General Loper, who is chief of the Military Liaison Committee. There were 10 members on the committee:

Herbert B. Loper, chairman, Nuclear Rocket Propulsion Committee, Assistant Secretary of Defense (Atomic Energy).

J. B. Macauley, special assistant to the Assistant Secretary of Defense (R. and D.).

J. H. Sides, rear admiral, USN, deputy to the special assistant to the Secretary of Defense for Guided Missiles.

Dr. Clark Goodman, Assistant Director for Technical Operations, AEC.

A. R. Lueddecke, major general, USAF., Chief, Armed Forces Special Weapons Project.

Leland S. Stranathan, major general, USAF, Director of Development Planning, DCS/DEV.

D. J. Keirn, major general, USAF, Chief, Aircraft Reactors Branch, AEC.

Dr. Herbert F. York, director, University of California Radiation Laboratory, Livermore.

Dr. Homer J. Stewart, California Institute of Technology.

Mr. Allen F. Donovan, Ramo-Wooldridge Corp.

The terms of reference of the Loper Committee were to determine the prospects of meeting the original requirement for testing the rocket's nuclear powerplant by a certain date within the next few years. The exact date, I am told by the Defense Department, is classified.

The Loper Committee made a report and I am not desirous of questioning in any way the wisdom of that report. I do, however, point out that they indulged in a somewhat difficult task. They were charged with the responsibility of determining the prospects of the application of nuclear propulsion to an intercontinental ballistic missile, and to discharge that responsibility, the Committee felt that its members should compare the potentials of nuclear propulsion and chemical propulsion devices, which might become available in the same time period. That was a pretty tough assignment.

We knew a lot about chemical propulsion because we had had a good many tests of small chemical devices, and when the Loper Committee attempted to predict from these early tests—what the properties and capabilities of a superchemical fuel might be in a couple of years—there was no assurance that the estimates were to be correct. The Committee members merely did the best that they could to determine what might be the final estimate of propulsion by a superchemical not yet developed.

On the other hand, they also had to estimate how nuclear rocket propulsion might work. And this was a shot in the dark. We had never attempted to develop the extremely high temperatures which would naturally accompany nuclear propulsion. Likewise, we had no device in which we had tried to check its lift properties. So in the end, the Loper Committee had to guess how a nuclear rocket propulsion device might work. And I do not criticize it for guessing, because that was the purpose of its appointment. In any event, the Loper Committee concluded that the AEC should engage in a "prompt effort to demonstrate the technical feasibility" of the project by a specified date within the next several years and should continue at the then existing rate and scale of effort.

At an earlier time in one of our hearings, I developed the fact that Project Rover, which is the nuclear rocket propulsion project, was decelerated by the Department of Defense, and that it was the decision of Mr. Murphree to cut back the Rover program even before a formal Loper report was issued. This was discussed at a meeting of the Joint Committee on Atomic Energy on January 28, 1957.

I therefore wish to point out that Mr. Murphree, who had spent his life with chemicals and chemical fuels, and gasoline and similar substances, cut back Project Rover before the Loper Committee had given him advice as to whether or not Project Rover should be cut back.

Now I think we need to bear in mind that the decision of Secretary of Defense Wilson did not carry out the recommendation of the Loper Committee. In fact, General Loper wasn't even consulted before the decision was made. The

report was ignored by Mr. Murphree and a letter, dated January 12, 1957, was prepared to the AEC for Secretary Wilson's signature which largely negated the original requirement which had been received from the Department of Defense, and established a requirement to demonstrate the feasibility of nuclear propulsion for an application not yet really known. No time was indicated when this should be done, and the words "a modest effort" were used instead of the recommendation that it be done promptly. In other words, there is a big change from a "prompt" determination to a "modest effort" to check it out.

The Department of Defense could help clear up this whole situation if it would release the Loper report. I believe that the original requirement was to demonstrate the feasibility of an engine involving nuclear propulsion on a short-time scale. I think that the present goal is far from that. We hope to see a first preliminary test of one of the devices in the next year or two and if it works, we can then proceed to move on to other tests. It will be well into the 1960's before there is a real test of the power plant that might be used in nuclear propulsion. In any event, the target dates for the project have had to be moved back—and by that I mean delayed—at least 2 years, and maybe more.

This cutback had its significance in the dollars that were assigned to this sort of work. The flow of fiscal 1957 funds for AEC work in nuclear rocket propulsion was held back by the Bureau of the Budget pending the Loper report. That meant that from July 1956 until January 1957 the Bureau of the Budget withheld almost all the operating and construction funds allocated for this work. This involved many millions of dollars. Now they allowed some money during this holdup period. They allowed the AEC group interested in the rocket program to go ahead on a month-to-month ration, but they were not allowed to spend any of the construction money, except \$1 million, which went into the laboratory at Livermore, and there was a little money that went into the design of certain facilities for the Nevada Proving Grounds. But this money for design work was in reality wasted because AEC could not subsequently use the plans which had been prepared and had to junk them and take an entirely new set of plans and go to work.

In the early part of January 1957 the Bureau of the Budget on the basis of the letter from Secretary Wilson saying that "a modest effort" should be made, reduced the construction funds \$10 million from the total appropriated by the Congress and approved by the President. Well, a million dollars had already been spent at Livermore, so that had to be subtracted from the remaining funds. The operating funds at that time were cut by nearly \$6 million. That, of course, meant that the work could not proceed at both Livermore and Los Alamos, and the AEC therefore had to choose the laboratory that seemed to have the most capability and the best approach to the problem, and cut out work on Rover at the other laboratory. The decision was reached to go ahead at the Los Alamos Scientific Laboratory and assign certain other work to the Livermore laboratory. There just wasn't enough money for both laboratories to operate, and I want to suggest now that I think it would have been well if both laboratories had been allowed to proceed.

Anyhow, Project Rover was assigned to the Los Alamos Scientific Laboratory the end of January 1957, and another related project under a classified code name was assigned to Livermore. Incidentally, this is a very promising project, and nothing should be allowed to interfere with the progress that is being made and can be made on that. The money that had been spent at Livermore, and the group of people who had been brought together for Project Rover at Livermore were identically the kind of facilities and the types of people needed in this other classified project and, therefore, the effort which was going on at Livermore on Project Rover could be successfully and properly diverted to work on this project, and this was done and I think successfully.

The budget for fiscal 1958 did not allow any more funds for construction for Rover because of the late date of getting started on the 1957 funds. Obviously, since the Atomic Energy Commission could not commit all these funds in the few remaining months of fiscal year 1957, asking for more funds for fiscal year 1958, which obviously could not be spent, would have been a little absurd. The AEC was allowed an operating budget for fiscal 1958 which was a little less than that for fiscal 1957. The ground rules for 1959, which were indicated to AEC, were that efforts were to be carried on at approximately the same level as 1958. The net result has been the moving back or delaying of the target date for

demonstration of feasibility by at least 2 years from that which was set out in the directive to the Loper Committee.

Now I have had it reported to me that the AEC had planned to accelerate the Project Rover expenditures and had planned to use for fiscal 1958 about \$20 million more than has actually been allotted. I believe that the planning experts, or those in charge of the program at AEC, would admit that that was about the 1958 figure which they hoped to reach. Of course, Livermore was included in the program at that time and when the Bureau of the Budget clamped down unilaterally in January of 1957, AEC's original planning figure was completely unrealistic and, therefore, it had to be abandoned.

I know we have a fiscal 1959 budget before us and I suppose that the dollars for the Rover program will be carried in that somewhere and will be revealed in time to the Joint Committee on Atomic Energy and to other proper Members of the Congress. But it undoubtedly won't request added authorization for construction money because the original authorization which was in the 1957 budget has never been withdrawn from the books. The AEC has a \$10 million authorization left over from the previous cutbacks and if they go ahead with their present plans, this construction work will probably stay well within the authorization figure.

I do not wish to be understood as saying that there are no other funds for the nuclear propelled rocket program because the Air Force does have some money for this purpose. In 1957 it was authorized to spend a few million dollars and then again in 1958 an additional few million dollars on the studies and development of airframes, tanks, pumps, etc., associated with the nuclear-propelled rocket. AEC will probably not have the responsibility for the airframe that undoubtedly should belong with the Air Force, but these groups have been working well together and I think that they will probably continue to get along very nicely.

The important point for some of us to remember is that a missile to go to the moon, for example, or a vehicle to travel in outer space, can't just be suddenly concocted out of a bucket load of chemicals. I do not hesitate to say that on the basis of information I have gathered from scientists, I do not believe we will ever have a missile capable of going to the moon and back again unless it be nuclear propelled. Bear in mind that it will take about 3 million pounds of lift, according to those who have done some calculating, to get a missile off the ground that is capable of going to the moon. If that estimate is accurate, we now have no engines that will give anywhere near that amount, even when you group a great battery of them together in a single device like the Atlas, and if we can't get more than that from the Atlas engines, we would surely have a hard time in building a chemically fired engine that would give a lift of 3 million pounds. So when people talk about putting manned missiles or space vehicles on the moon, they are probably talking about waiting until we attain nuclear rocket propulsion, and that is why it is important to speed up nuclear propulsion in this country.

If we think that there are certain psychological advantages in space travel, interplanetary travel, and journeys to the moon or in the setting up of space platforms, then by all means we should be pushing the work in the development of nuclear rocket propulsion.

Furthermore, there is a possibility, and I list it only as a possibility, that we may find that even a 5,000-mile intercontinental ballistic missile will have to be nuclear propelled if it is going to have great reliability. I can conceive of our learning that the Atlas and Titan, well designed though they may be, will have some possibilities of failure and will not be as reliable as we want them to be. You just can't send up missiles with nuclear warheads unless you are sure they are going to reach the target for which they are intended and won't drop onto some friendly land between America and the target zone. So we will want to be careful that each will reach its intended target.

Therefore, in order to press forward vigorously and effectively in developing nuclear rocket propulsion we need a program that has clear objectives, even if they can't be too precise at this stage of the game. We also need clear lines of authority and steady support for the program so that it can be pursued to a successful conclusion at the earliest time.

In brief, I hope we don't get into the same fix we have been in for over 10 years with the aircraft nuclear propulsion program. Beginning with the old NEPA project in 1946, the ANP program has been characterized by ups and downs in funding, by on-again-off-again planning, and by an administrative

setup that has been just short of chaotic at times. As far as I can see there never have been any real clear objectives nor have the contractors been able to find out where the program is going from year to year. In 1953 Secretary Wilson attempted to kill the project outright but thanks to the intervention of the Joint Committee on Atomic Energy—and particularly through the efforts of Melvin Price and the late Carl Hinshaw of the other House—it was kept going somehow. After 10 long years of this merry-go-round, it now appears that the project is once again getting back on its feet. But it's been a long and costly wait.

The point is that if we really need nuclear rocket propulsion for missiles and for space travel—and I think we must have it—we are going to need some clear-cut objectives to aim for and a well-administered program to see that we get these promptly. Prospects of developing space platforms and taking trips to the moon give a whole new dimension to our life and we must be prepared to cope with the situation.

One of the most important factors in whether we succeed or fail in this new era is how well we organize and conduct our scientific development efforts. It seems logical to me that since flight into space will require some form of nuclear propulsion, one alternative to be considered is to have the Atomic Energy Commission and some of its laboratories like Los Alamos take on the development job. This would have the advantage of utilizing going organizations who are familiar with the kind of work which will be required.

Another alternative would be to set up a separate Government agency, under civilian management, in which centralized responsibility would be vested for space development plans. Such an agency could proceed to coordinate scientific efforts on space development throughout the country and oversee the construction of facilities for its own research and development work.

At this point, Mr. President, I would like permission to insert in the record at the end of my remarks an excellent study on the formation of a "Space Commission" and a prospective on Space Research in operation which were prepared by a special committee of the Los Alamos, N. Mex., chapter of the Federation of American Scientists.

Whatever steps are taken, I would expect that the Joint Committee on Atomic Energy will be taking an active and continuing interest in this matter.

Mr. President, this subject is not new with me or with the other members of the Joint Committee. Back in June and July of 1955 I sent two letters to the President, cosigned by the junior Senator from Washington, Mr. Jackson, who is chairman of the Military Applications Subcommittee, emphasizing the importance to the Nation's future strength and security of a vigorous program—on a wartime footing—to develop an operational ICBM at the earliest possible moment.

On April 6, 1956, I spoke to the Sixth Annual Conference on High Energy Nuclear Physics at Rochester, N. Y., and I would like to quote several comments from that talk:

From page 4:

"Moreover, we should not restrict ourselves merely to consideration of hazards implicit in wars of annihilation with atomic weapons. In technology applied to military ends, novelty is ever a prime goal * * *

From page 10:

"* * * we may think of climate control or worldwide weather modification. Recent advances in meteorology suggest that efforts in this direction may produce useful results sometime in the future.

"Another example on a large scale which inevitably crosses national boundaries is the project to send a rocket into outer space. Purely from a geographical viewpoint, efforts to send missiles and ultimately passengers to the moon and the nearby planets are of worldwide interest. While the intensely nationalist feelings characterizing international relations on our planet at the present time suggest that we may even see, as a result of interplanetary travel, an extension of the competitive colonialism which the last century saw for the backward areas of this planet, the prospect of seeing different sections of Mars staked out by different national governments of this earth seems on the face of it ludicrous. Are we trying to play God and develop a new planet in our own image and likeness? A much more rational and probably more productive basis for the exploration and development of other worlds would be under an organization which properly reflects the common interests of all the peoples of this earth in such development. The Man in the Moon belongs to the children

of every country, is a part of their dreamworld, and if reached by spaceship, might better remain the property of all.

"Returning now, however, from the fanciful and the future to the more immediate problems of initial efforts to get a spaceship away from the earth, we recognize hazards of a rather sever sort which may arise as a result of the erroneous function of a space missile intended for the moon but which instead, through defective mechanism or planning, lands on the territory of another nation. If such a nation were at that time in an advanced state of tension in anticipation of a possible attack, this simple error might touch off the spark of world conflict.

"Which brings me to the competitive race to develop an intercontinental ballistic missile. We in the American Congress have already learned that it would be a drain on all our budgets if that race should set a pattern in the whole field of space conquest. Russia and this country are working at high speed toward the attainment of an intercontinental ballistic missile, called by many 'the ultimate weapon.' Yet, if the missile were to be attained almost simultaneously and prove to be as accurate as now forecast, if indeed it could carry atomic warheads with a striking power of several kilotons and place them within the area of a small circle, then no city in the world is safe, no jet interceptor can police the skies and no highway can promise egress from the affected area. In that day the people of the earth would banish the weapon as poison gas was outlawed in World War II, but only after the expenditure of fantastic sums of money, materials, and scientific skills.

"Might it not be better to examine the chance to use space conquest as another project for an international laboratory? If we will never use this weapon once we achieve it, might it not be set aside as one segment of world-wide competition that could be surrendered to the effort to halt the race for a full arsenal of atomic arms in every land?"

From page 15:

"It is to that problem that I have directed these words. If the great powers find themselves in an atomic stalemate today—and I think they do—it is a carryover of patterns of 'national security' which modern science has rendered obsolete. The military techniques which might emerge from the new areas of technology that I have been discussing can make the stalemate no worse. Already it is at a level in which any major power can precipitate almost total destruction upon an adversary (and in return upon itself) if it should make so tragic an error in judgment. Yet there is the danger that if these new areas of technology are developed in secret, some nation which at some future time is led by reckless rulers, may feel that it has gained so great a lead in some field of science that it may dare to launch an attack for world conquest. While this error in judgment will almost certainly be answered by mutual annihilation approaching totality, every effort must be bent while still we have the chance to prevent such dreadful miscalculations from occurring. Scientists, it seems to me, might suggest to the statesmen that modern technology could make the greatest contribution to the security of great powers if statesmen would move as far as possible from the secret competitive development of technologies under which we have largely operated in recent years. The scientists might urge, indeed, that the race for atomic arms could best be halted by having new fields of science developed jointly by all nations."

It is that theme which I am happy to see stressed by so many leaders today.

APPENDIX 2

ASTRONAUTICS: DEPARTMENTS AND AGENCIES OF THE EXECUTIVE BRANCH OF THE UNITED STATES GOVERNMENT WHICH MIGHT BE CONDUCTING RESEARCH IN CONNECTION WITH OUTER SPACE CONTROL

(A preliminary report by the Library of Congress, Washington, D. C.)

Within the time available it was possible to use only published sources of information which in this case are far from adequate. Those subdivisions of executive departments and agencies which, by title, appeared to be devoted to aeronautical research in general, guided or ballistic missiles, special weapons, special projects, geophysical sciences, nuclear propulsion and propellents, powerplants, and aerodynamics are included in the following table.

It is suggested that a request might be made by the chairman of the subcommittee, addressed to the heads of the different departments and agencies, asking for special information as to those units of the organization engaged in astronautical research and development. There does not appear to be any other source from which this information can be derived, and it undoubtedly would be compiled at the request of the chairman of a congressional subcommittee.

DEFENSE DEPARTMENT

Office of the Secretary:

- Assistant to the Secretary (Guided Missiles).
- Assistant Secretary (Research and Engineering).
- Secretary, Research and Engineering Policy Council.
- Director of Guided Missiles.
- Director of Science.
- Defense Science Board.

The following committees, etc., are in the Department, probably in the Office of the Secretary:

- Advanced Research Projects Agency.
- Guided Missiles—Research and Engineering Coordinating Committee.
- OSD Ballistic Missile Committee.
- Sciences—Research and Engineering Coordinating Committee.
- Scientific Advisory Board.
- General Services—Research and Engineering Advisory Panel.
- Guided Missiles Intelligence Committee.
- Armed Forces special weapons project.
- Deputy Chief of Staff, Technical Services,

AIR FORCE

Office of the Secretary:

- Assistant Secretary (Research and Development).
- Administrative Assistant.
- Research and Analysis Division.

Chief of Staff:

- Office of the Chief Scientist.
- Assistant Chief of Staff for Guided Missiles.
- Scientific Advisory Board.
- Deputy Chief of Staff (Development).
- Director of Development Planning.
- Rand Project Office.
- Research and Analysis Division.
- Director of Research and Development.
- Deputy Chief of Staff (Plans and Programs).
- Aircraft and Guided Missiles Programing Division.

Air Force Office of Scientific Research:

- Chief of Scientific Research.
- Deputy Commander/Sciences.

Major commands: Air Research and Development Command.

ARMY

Office of the Secretary: Director of Research and Development.

Chief of Staff, United States Army:

- Director of Plans and Programs.
- Plans Division.
- Special Projects Branch.
- Guided Missile Section.
- Deputy Chief of Staff for Military Operations.
- Guided Missiles.
- Office of Research and Development.
- Director of Research.
- Research Division.
- Geophysical sciences.
- Physical and engineering sciences.
- Director of Special Weapons.
- Atomic Division.
- Army Ballistic Missile Committee.

Chief of Ordnance:

- Industrial Division.
- Guided Missiles Branch.
- Office of Program Coordination.
- Guided Missile Coordination Branch.
- Ordnance Research and Development Division.
- Guided Missile Systems Branch.
- Nuclear and Special Components Branch.
- Guided Missile Section.
- Research Branch.
- Ballistics Section.
- Research and Special Projects Section.

NAVY**Office of the Secretary of the Navy:**

- Assistant for Research.
- Assistant Secretary (Air).
- Research and Development Review Board.
- Naval Advisory Committee on Scientific Personnel.

Executive Office of the Secretary:

- Naval Research Advisory Committee.
- Office of Analysis and Review.
- Assistant Director for Program Appraisal.
- Office of Chief of Naval Research.
- Assistant Chief for Research.
- Naval Research Laboratory.

Bureau of Aeronautics:

- Assistant Chief for Research and Development.
- Research and analysis officer.
- Aircraft Nuclear Propulsion Division.
- Guided Missiles Division.
- Powerplant Division.
- Assistant Director for Propulsion Systems and Components.
- Research Division.

Marine Corps:

- Deputy Chief of Staff (Research and Development).
- Division of Aviation.

Chief of Naval Operations, Office of the Chief:

- Deputy Chief (Air).
- ACNO (Air).
- Air Warfare Division.
- Assistant for Research and Development.
- Aviation Plans Division.
- Guided Missiles Division.
- ACNO (Research and Development).
- Atomic Energy Division.
- Development and Production Branch.
- Nuclear Power.

Bureau of Ordnance:

- Research and Development Division.
- Director of Ordnance Sciences.
- Assistant for Aerodynamics, Hydrodynamics, and Ballistics.
- Assistant for Propellants and Propulsion.
- Ammunition and Special Weapons Branch.
- Propulsion Branch.
- Air Launched Guided Missiles Branch.
- Technical Division.
- Missile Branch.

Bureau of Ships: Assistant Chief of Bureau for Nuclear Propulsion (Rickover).

EXECUTIVE OFFICE OF THE PRESIDENT

- Science Advisory Committee.
- Special Assistant for Science and Technology.

INTERDEPARTMENTAL COMMITTEE ON SCIENTIFIC RESEARCH AND DEVELOPMENT

DEPARTMENT OF COMMERCE

Weather Bureau:

Cooperation under the United States National Committee of the IGY; work with the Atomic Energy Commission at the Nevada test site; work with Federal Civil Defense Administration. No published indication of current research in outer-space problems, but weather research is a part of these problems.

Bureau of Standards:

Cooperation under the United States National Committee of the IGY. The Bureau is equipped to work on various aspects of astronautics as, for example, conducting tests on the properties of material.

ATOMIC ENERGY COMMISSION

Assistant General Manager (Research and Development):
 Director, Division of Research.
 General Advisory Committee.

NATIONAL SCIENCE FOUNDATION

Assistant Director for Mathematical, Physical, and Engineering Sciences.
 Head, Office for the International Geophysical Year.
 Head, Office of Special Studies.
 National Science Board.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Associate Director for Research.
 Assistant Director for Research (Aerodynamics).
 Assistant Director for Research (Aircraft Propulsion).
 Assistant Director for Research (Aircraft Lands and Structures).

SMITHSONIAN INSTITUTION

Astrophysical Observatory.

QUASI-OFFICIAL

National Academy of Sciences—National Research Council.

MULTILATERAL INTERNATIONAL ORGANIZATION

World Meteorological Organization (N. N.).

DOROTHY SCHAFFTER,
Senior Specialist in American Government.

SPACE TRAVEL IN PERSPECTIVE

Legislative Reference Service, the Library of Congress, Washington, D. C.

INTRODUCTION

The growing popular and governmental interest in space travel requires assessment of its prospects and potentialities before that aspect which relates to congressional policy can be delineated. Although there are some doubters, most scientists are confident that the time will come when men will learn to travel across the distances of interplanetary space, and some think that, in time, interstellar space will be crossed, too. The real question is whether this is the time that such efforts should be pushed, and whether there are potential gains worth the costs of pushing such developments. A further factor which must be weighed is whether this is a decision the United States can make in vacuo or whether if this country fails to exercise leadership others may not develop techniques inimical to both the long range and the fairly immediate interests of this country.

There was a time when this planet was viewed as a very large place, almost too large to be knowable, always with new lands and strange inhabitants to

be discovered. It was also viewed as the center of the universe, the point around which the stars, the planets and the sun revolved. Since then, improvements in transport have made it possible to travel around the globe in a few hours, and no really new lands remain to be discovered. We can already foresee the day when many important resources are going to be in short supply at any reasonable cost.

Our knowledge of our place in the physical universe has undergone great change. Optical and radio astronomy have pushed out the frontiers of the observable limits of this system. Cosmologists have presented better and better hypotheses of the fundamental development of the universe. There have been strong interactions among the various fields of knowledge including mathematics, geophysics, nuclear physics, and astronomy to the mutual benefit of all. For example, the hypotheses for explaining the energy output of the sun have led to development of fusion energy processes on earth.

By today we know that our planet is one of the smaller planets revolving around a minor sun in a galaxy of about 100 billion suns which we call the Milky Way. Our telescopes tell us there are about a billion galaxies within the distance radius of the several billion light-years we have been able to detect so far. Each time a better telescope is constructed, an even larger portion of the universe is disclosed.

It is still a moot question whether the universe is limitless, whether the universe is expanding from a single primordial explosion, or whether the process of creation is continuous. Our scientific advances are now rapid enough that we may be able to find partial answers to some of these questions in the foreseeable future.

There was a time that the most popular theory for the creation of planets required a near collision between two stars, a relatively rare event in the vastness of space, and one which would make rather unlikely duplication of conditions found on earth. Currently acceptable theories for the formation of stars from an original gas in space, however, allow for the possibility that planets are not uncommon. Most stars are too far away for current astronomical confirmation of this newer hypothesis, although now that a very few cases have been found of enormous planets close to other suns, some confirmation is presented. It is no longer considered extreme to conclude that there are probably many billions of stars with planets similar to those of our own solar system, and there can be countless numbers providing environments favorable to the development of life as we know it. Here we depend upon the incomplete work of the biologists for more insight into the processes by which life is created. There is no scientific reason for doubting on the basis of recent research that life will appear sometime in the course of millions of years when the right environment is presented.

Perspective then is required to understand that whatever our destiny may be as a race, it would be extreme egotism to believe that we are the only life form capable of rational thought within all the vastness of space. Our studies show suns at all stages of development, and over billions of years, even the planets of our solar system have undergone considerable changes. As purely a working hypothesis, there may be as many millions or billions of planets supporting forms of life in a higher stage of development than man as there are in lower stages, whether in their specific forms they bear any resemblance to man or not. It is worth noting, too, on the cosmic time scale, that only in the last few seconds so to speak has man flashed briefly into existence and in the last moment accomplished what we know about through the few thousand years of recorded history. Unless we are destroyed by some misadventure, the millions of years which lie ahead afford opportunities for the growth of knowledge and power which may be inconceivable today. Our limited experience to date already has made clear the fallacy that all knowable knowledge is already in our hands.

With the rapid acceleration in growth of scientific knowledge which the last century and particularly the last few decades have brought, we then face the question: Is ours the generation which will continue the age of exploration beyond the surface of the earth to other worlds? Is it presumptuous for us to consider such a policy? Or should we stick to obvious, earthbound problems which are immediate in their economic return? The present state of knowledge and the activities of other nations are removing already the freedom of choice which would let us delay these questions for a later generation to face. Soviet sputniks already have been launched into space, and ballistic missiles which are subject to the physical laws of space are already influencing international strategy and military budgets.

But what lies ahead will not come easily and automatically; an enormous effort will be required, with a coordinated attack running the whole gamut of scientific knowledge. It is the purpose of this brief paper to suggest the general dimensions of the problems ahead, viewed from the perspective of today.

CURRENT STATE OF THE ART

Some scientists contend that the appearance of sputniki in the skies is not particularly significant because they were placed in orbit through no new scientific principle. This is, of course, exaggeration through minimization, but is a way of saying that the basic principles of space flight have been known a very long time. The engineering of these principles into concrete results has been one of the great technological victories of our times, and more than anything else has awakened the general public to the research and development long under way in many countries which finally culminated in successful launchings. What the Russians and Americans have done will be done by many others in time, although the expense of such a program is considerable.

We are to the place where development of these same principles and techniques will in the near future provide earth reconnaissance vehicles, both unmanned and manned, and probe vehicles capable of travel to the moon and possibly other planets. With a less definite timetable, we can foresee the construction of a large space station, whose uses will be discussed presently. New types of powerplants making possible more ambitious travel can be foreseen, but when they will come is partly a question of willingness to support broad-based research leading toward them, and partly dependent upon unexpected breakthroughs which cannot be predicted in advance. It is worth noting that even the unpredictable breakthroughs presuppose well-financed research in many directions.

It is important to recognize at the outset of any analysis, that many of these projects are mutually supporting. Simultaneous development of ballistics missiles, nuclear reactors, thermonuclear power, computer technology, high energy physics, solid state physics, low temperature research, astronomy, space medicine and psychology, photosynthesis and hydroponics, and a host of other activities will advance both the military arts and science in general, with its peacetime intellectual and economic goals.

It seems fair to conclude that, with varying degrees of support and a rather limited degree of coordination, some work is going on in all these fields of research which will bring space travel. What is required to support a space program is a greater coordination of efforts, including freer exchange of information, and a more consistent flow of funds geared to push ahead steadily on all the fronts required. Also required is a public appreciation of the stakes involved, and the long-run support of a climate in which potential contributors to such a program are going to be encouraged to gain the training required.

Undoubtedly, there are many unforeseen problems still ahead of us, but we can, even today, see the general dimensions of the research and development necessary to successful travel away from the earth.

CELESTIAL MECHANICS

Study of the motion of heavenly bodies, including their apparent interaction on each other, has demonstrated the general roles of gravity and centrifugal force in the movement of objects in our solar system, long before their cause has become known. We have been able to apply the data known from experiments in physics to calculating the mass of each of the planets, and the rules even have been well enough established that the existence of Pluto was predicted before it was found by telescope. The man in the street now has been given proof of the long identified principle that an object can circle the earth almost indefinitely if it is in a path largely outside the atmosphere, and has enough momentum that its ballistic free fall toward the earth under the force of gravity is balanced against this inertial centrifugal force to keep it in an elliptical orbit.

It has been possible to calculate just what speeds are sufficient to counterbalance the force of gravity for escape from each of the planets, and, correspondingly, to land on them, which, in the absence of atmospheric braking, takes an equal amount of force. We know that an object in free fall around a larger body is in effect "weightless," so far as a passenger would be aware, unless this object's own rotation supplied a centrifugal force equivalent of weight.

In similar fashion, the earth is in free fall around the sun, and its orbital speed counterbalances the gravitic pull of the sun. This makes it free of the weight

of the sun, but is, itself, large enough to exert what we have defined as a 1 g. pull on or near the surface. Fortunately, as we consider possible travel from one planet to another, we can note that a space vehicle has a free gift of the earth's orbital speed, providing most of the momentum required for such travel. The principal energy expenditure required is that to rise from the surface into a free-fall orbit around the earth, and later, to reach the surface at the destination, unless atmospheric braking is practical. The greater part of the travel from one planet to another is performed by moving millions of miles in free fall around the sun in a huge eccentric ellipse tangent both to the orbit of the earth and to the orbit of the destination planet. The only power required for most of the trip is that needed to correct any earlier miscalculations of course. Although actual tests may disclose unforeseen problems, the general principles are not really in doubt, and the work that lies ahead is not primarily one of proving that celestial mechanics are understood, but of engineering systems.

ASTRONAVIGATION

Navigation on the surface of the earth and in the atmosphere is relatively simple, although many complex devices are in development to improve its certainty. In space, many of the same techniques can be used, but require refinement, greater accuracy, and involve more variables. Celestial guidance is made easier by the absence of cloud cover at all times, and, within our own solar system, stars will continue to maintain their relatively fixed positions. However, establishing position is more complex because there is no fixed plane of reference as on earth. Disorientation of space crews may be acute, and automatic inertial guidance of far greater accuracy than is now available will be very helpful. Further work in radio and radar triangulation and ranging will also be required, particularly on close approaches to other bodies in space. Clearly, there are many areas requiring more research.

POWERPLANTS

With the present state of knowledge, travel in "empty" space affords more limited opportunities for propulsion than on the surface of the earth or in the atmosphere. Whatever momentum an object has is maintained indefinitely except as collisions with other objects absorb part of this energy or deflect it from its previous course. The pull of gravity, which is a mutual attraction, affects the shape of the path the traveling object pursues, and, of course, if the momentum is not sufficient, two approaching objects will be drawn together, with most of the additional movement caused by gravitic pull occurring in the lesser object. Fortunately, an initial push from a launching on the surface of the earth is not the only chance to alter momentum deliberately. The principle that every action has an opposite and equal reaction provides the basic means for altering both speed and direction of momentum in space. A leap into the air from the surface, in effect, pushes the earth backward, but its own mass is so great compared with the man or machine being pushed away from it that it is, to all accounts, stationary. A jet aircraft, on the other hand, pushes out a fast-flowing exhaust which, measurably and obviously brings a reaction, and it is not so much the pressure of this exhaust against the air that pushes the plane ahead as it is the reactive force. This is proven by the rocket, which, unlike the ordinary turbine engine, carries its complete fuel supply with it and still leaps forward when its exhaust is shot to the rear, even in empty space. The amount of reaction depends upon the mass and the velocity of the rocket exhaust in relation to the mass of the rocket itself—a faster exhaust gives a bigger forward reaction to the rocket.

The obvious big problem with chemical fuels is that there are fairly well-established limits to the exhaust velocities which can be obtained, and so much fuel is required for any prolonged amount of thrust that the weight of fuel must be added to the weight of the rocket, and the amount of forward velocity resulting from thrust is limited. However, as the fuel is burned, the rocket will accelerate faster and faster until the fuel is gone. There are enormous practical difficulties in finding the best combinations of fuel which provide a maximum of thrust with a minimum of weight, and which at the same time are reliable and manageable. Years of development lie ahead, but the general limits are already foreseeable. Some help is provided by the trick of multiple stages for the rocket. When an initial rocket has used its fuel, the payload can be given an even better kick ahead again by dropping the empty and now useless casing of the initial rocket at the time a second, smaller rocket is fired.

Use of several steps allows the accomplishment of high momentums that otherwise would be very difficult to achieve. But, even here, the research ahead is largely one of engineering for the greatest economy in dead weight, and finding materials which will withstand the temperatures and pressures associated with the greatest exhaust velocities obtainable.

For the foreseeable future, improved chemical rockets probably will be required to raise cargo and passengers from the surface to some orbit above the atmosphere. However, for extensive and frequent travel away from such an immediate orbit, chemical rocket fuels have presently known limits that would make travel to other planets possible only at rare intervals and at enormous logistic costs in ferrying fuel reserves up to orbit to refuel the long-range space craft.

There are potentially at least two tricks usable in the future which may add to the value of chemical rockets. One is the discovery that in the upper atmosphere there are free radicals created by solar radiation, and possibly a ram jet could scoop up enough to use as a fuel of greater efficiency than ordinary gas molecules will provide. The most immediate use may be in a fast-moving satelloid relatively close to the earth, but there may be ways of collecting this fuel for use in space rockets before they depart from the vicinity of the earth, too. A second possibility, ultimately, may be to refuel a chemical rocket from the supposed methane atmosphere which is tentatively credited to Titan and to some of the larger planets of the solar system.

But we are pretty well forced to the conclusion that, as difficult as the techniques may prove to be, some application of nuclear energy may be vital to any regular travel to other parts of the solar system, and, certainly, to any travel outside the solar system short of expeditions measured in terms of thousands of years.

APPLICATIONS OF NUCLEAR POWER TO SPACE TRAVEL

The great advantage over chemical fuels enjoyed by nuclear fuel is that it represents a relatively small weight in itself for the energy it can develop. But there are enormous difficulties in finding a good way to use this energy; it is only the limitations of chemical fuels which makes it not only desirable, but essential.

In the first place, the weight of a reactor is still so great that only in a very large space vehicle would it represent a bearable cost, as compared with using a chemical-fuel rocket. Secondly, biological shielding, and, indeed, protection of other components of the rocket could represent another acute weight problem unless the rocket is so elongated that a crew could be quite remote from the reactor. There are new problems of cooling in a rocket in space which are more acute than those on the surface of the earth or even in a nuclear-powered aircraft.

But the real challenge is in finding an efficient way to utilize the nuclear energy. It is not possible to construct simply a bomb with an open end. An uncontrolled nuclear explosion is so great, with its force moving out in all directions, that a spaceship would be vaporized. Even if it were not, the sudden application of great thrust would apply so many gravities to the crew and equipment as to negate the purpose of building the ship.

In a primitive but conceivable plant, the nuclear reactor might be used simply to heat such a conventional fuel as hydrogen or some other material which could be expelled at maximum velocity from the ship. For significant thrusts to be developed, the reactor and jet exhaust would have to operate at very high temperatures and pressures, possibly beyond the capabilities of present metals and ceramic materials. The possibility of a pulsing reaction might overcome the heat problem. Such a nuclear rocket would have an advantage in that the source of its energy could come from a small nuclear fuel supply rather than from less efficient (in weight) chemical reactions. But the necessity still to carry a conventional material to be heated and expelled would limit the capabilities of such a spaceship. The choices of using thermal or fast reactions, and of using solid or gaseous reactors are technical problems outside the scope of this elementary review.

THE ION ROCKET

Under study is another way to obtain reactive force from a nuclear powerplant in a spaceship. Instead of relying on the expansive force of heat from a reactor to accelerate the propellant, the reactor might be used as a source of electricity. The electricity could be used to create an electrostatic or electromagnetic field to propel ions at a very high exhaust velocity. In terms of present knowledge,

however, the weight of equipment to generate electricity would be so great as to overwhelm any advantage from rapid acceleration of ions. A large research effort would be required to find shortcuts in creating ions and then exhausting them at great speed. Eliminating the thermal and mechanical stages to generate electricity directly from the nuclear reaction would prove of tremendous value.

An alternate approach which would be applicable in this part of the solar system would be solar heat, collected by photocells, thermopiles, or by boiling (to create mechanical power) to generate electricity.

It may be that all early ion rockets, whether using nuclear fuel or applying solar energy will be useful only for delivering small amounts of acceleration over long sustained periods of time, clearly not helpful in overcoming the heavy load of takeoff from the surface of a planet or returning to the surface.

It may turn out that the best foreseeable form of power will be some application of the thermonuclear principle now under development, particularly if it is possible to achieve direct translation of the reaction into electric energy. It might prove possible to save some of the weight and perhaps shielding now associated with fission reactors.

OTHER PROPULSION SCHEMES

Some other rather ingenious proposals have been made, but their degree of practicality remains to be tested as is true of the better prospects already discussed.

One idea calls for the construction in outer space of huge surfaces covered on one side with a very thin layer of some powerful beta emitter such as strontium 90. The theory is that emission in one direction will be absorbed by the radiating surface as heat, while random emission away from the surface will provide a small amount of thrust. It may be that enough material to supply useful thrust would also create so much heat in the radiating surface as to be impractical. In any case, this is clearly a means which could supply only a very low increment of speed.

PHOTON POWER

Another scheme for building a very large surface for propulsion purposes in a spaceship would call for the gentle but sustained pressure of photons from the sun to power a ship in the same way that a sailing vessel on earth employs the pressure of the wind. In combination with some other power source, it might be possible to choose any vector for travel desired. This is another scheme of rather limited applicability.

Of conceivable use someday is the photon rocket. If the secret is ever discovered for the total conversion of matter into energy, the ultimate in exhaust velocities would be obtained—the speed of light. This is the only such power presently conceivable which opens the prospects for fast interstellar or even intergalactic travel. Only a great research effort is seen as even offering the hope that such propulsion can be achieved, and it, too, might be useful only for slow acceleration over time rather than direct planetary takeoff.

The presently apparent avenue to search for a system of total conversion is in high energy physics as exemplified by the big accelerators in use and projected in several countries. Discovery of right- and left-hand spin in elementary particles and opposite entities for each ordinary kind of particle may lead to some means of their creation. Then bringing them together will release energy in the way that an electron plus a positron disappear to create photons.

ENTIRELY NEW APPROACHES

There is tremendous interest in research on gravity. Any popular hope that a workable gravity screen or antigravity force can be found seems unlikely today. Whether the power output of a nuclear reactor ultimately can be applied to influencing gravity rather than operating a rocket is not supportable in theory today. If it turns out that some presently unknown scientific principle allows influencing the force of gravity, the possibility of overcoming the problems of inertia are presented. If everything in a spaceship were simultaneously accelerated in like degree, the current limitations on number of gravity-forces-equivalent withstandable would be removed. It is important to emphasize there is no work underway which offers real hope of this, despite the interest in the technique, and the research being done.

BIOLOGICAL ENVIRONMENTS

An enormous field for investigation is that relating to adapting spaceships and men to the environment in which they will be found so that survival will be possible. Some of the problems are obvious.

We must learn even more about maintaining a proper air supply in a spaceship. The nuclear submarine gives some experience, but stays down for a shorter period in ordinary use, has fewer weight limitations, and conceivably could draw on the ocean itself for replenishment. A spaceship faces more acute problems, but they are not insurmountable. Short satellite flights are manageable now. Longer flights into space might involve complicated recycling with use of a plants or algae to take up carbon dioxide and return oxygen. All waste products and water vapor would have to be recovered and reused on any extended voyage.

Control of pressure could be acute in any large, lightly constructed spaceship, and protection would have to be afforded against explosive decompression.

Temperature control is another problem. It can probably be solved fairly readily, but experimentation will be required. Combinations of light and dark surfaces, adjustable as needs dictate, will be required to control the amount of heat absorption from the sun and radiation of any excess heat from the spaceship.

Food supply problems are manageable on short flights, but any extended trips either carry a great weight penalty or require complicated chemical reprocessing of wastes to renew the food supply with a minimum attrition loss.

Acceleration and deceleration problems will continue to require research. We have some data as to how many gravities can be withstood by men for what periods of time, and most practical plans for space propulsion do not exceed these limits. A brief high-g takeoff or landing may suggest the absolute necessity for automatic controls if the crew is weighted down in a strapped, reclining position. Anyway, things may happen too fast and a man may be too disoriented to do much useful manual manipulation.

Once any spaceship is in free fall and is "weightless," a new physiological problem is presented. Brief exposure of a few seconds duration is not enough to tell us what the prolonged effects will be. What if anything it may mean in disorientation and nausea is not yet well known. It may have therapeutic uses in time for some medical conditions, but prolonged exposure may require special measures of exercise for the time of return to normal earth gravity. Although eating and drinking techniques may change, it is believed that peristaltic action rather than gravity is the essential part of the digestive process.

Meteors are not expected to be an insurmountable hazard. Ones large enough to wreck a spaceship are expected to be very rare. Those common enough to hit the ship frequently, are expected to be so small they would probably vaporize on hitting a meteor bumper shield. Even if an occasional pinhole puncture occurred, sealing the hole should be possible before the ship is seriously threatened. The thin cloud of gas which may be common in many parts of space is expected to be a problem only at speeds close to that of light.

Cosmic rays give some more concern, but although such radiation is harmful, only on-very long flights would exposure be serious enough to be debilitating in some obvious way, if then. This is an area where much more research will be necessary before definitive answers are available.

Lengths of voyages are an added factor of concern in several respects. In the first place, supplies of food, water, and air, and the proper maintenance of all equipment must be adequate. In the second place, much more needs to be known about psychological problems. Will disorientation or claustrophobia be a factor, and how will crews get along together in confined spaces? Voyages which go farther away than Mars and Venus begin to involve more difficult questions as the time for trips shifts from months to years, unless better propulsive means are found.

Travel to other star systems involves many unexplored questions about time. Even at very high speeds, voyages might vary from close to a working lifetime as a minimum, to centuries or thousands of years as a maximum depending on the propulsion used. There is theoretical support for the concept that a voyage close to the speed of light might compress time as experienced on the spaceship so that both the monotony of the trip and the biological aging of the crew would be limited. But even if speed approached that of light, the minimum earth time required for a round trip to the nearest star would be about 9 years, with no allowance for acceleration and deceleration. At such a speed, however, the crew might experience the trip as if it had occurred in a matter of days.

One calculus for a voyage around the known cosmos is that such a trip at al-

most the speed of light would seem like about 33 years to the crew, but in earth time require 10 billion years, making the return to earth as it was known very much out of the question.

Even if very great speeds are never reached, today's chemical fuels could launch a ship on its way with sufficient momentum to leave the solar system. Such a ship would have to be a self-contained world of enormous size in which many, many generations would be born and die before the one-way ship could reach some ultimate destination, which might or might not prove hospitable.

Possible lines of development for very long trips may include some form of hibernation or suspended animation. Another speculative means for covering very long distance travel might even include sending frozen human germ cells which after long centuries would about 30 years out from the destination be reactivated to grow children who would be trained by cybernetic machines so that by the time of arrival they would have reached trained adulthood. This is very speculative, but not outside the area of possibility for the future.

END USES OF SPACE TRAVEL

Using the means of rocket propulsion, following ballistics trajectories, a limited form of space travel is provided by point-to-point movement over the surface of the earth. This has obvious military uses to deliver nuclear and thermonuclear warheads. It is expected in time that even passenger transport by such means will become possible. This would call for a rapid rise into space, followed by a long glide back through the upper atmosphere until the destination was reached. The Russians have already announced they plan such trips between Moscow and Peking, and later hope for 16-minute to half-hour flights to New York. The technique was proposed in 1948 by Dr. H. S. Tsien then at California Institute of Technology and now back in Red China.

Such rocket flights may also be used in time for reconnaissance, and as a step in training for other flights into space.

The earth satellite vehicle in unmanned, instrumented form has already showed its usefulness in collecting data on cosmic rays, temperature, radio propagation, shape of the earth, location of places, meteor activity, as well as demonstrating the practical application of long-established theoretical principles. In a sense, the Explorer in the first 3 or 4 days supplied the United States with more information about space than a decade of high altitude sounding rocket shots.

Better satellites in the future will continue to supply more information for later manned flights. With television and cameras, reconnaissance of the surface and weather reporting will become possible. Some better astronomical views will be possible. Opportunities will be provided to learn more about re-entry techniques. Placed farther out, such vehicles can appear stationary in relation to the surface of the earth, and serve to relay television and telephone across oceans.

The manned satellites which will combine the experience of such aircraft as the new X-15 and the unmanned satellites will greatly increase the amount of knowledge and experience available about space flight in a very few years. The work being done on the ground now by way of preparation on the biological environment problems is most important to later success, as are the balloon flights at very high altitudes for extended periods.

Probe vehicles traveling farther afield are within the range of present-day technical possibility, although a considerable research effort will be required, particularly on remote communication devices. Such unmanned vehicles should bring back the first photographs of the far side of the moon and close views of Mars and Venus. At some point, though at much greater costs, it should be possible to construct unmanned devices capable of landing on the moon and on Mars and Venus, later taking off again. The fuel requirements, however, will be very heavy. It has been suggested that it may be easier for men to travel to Deimos, and Phobos, which circle Mars, than to attempt a landing on our moon. Unmanned devices are likely to precede any planetary landings by men.

Considerable attention has been given to the uses of large stations in space, orbiting around the earth. Indeed, such stations may be a necessary point of departure for expeditions traveling to the moon or to other planets, particularly if chemical rockets must lift materials into orbit before the assembly of a long-distance spaceship, possibly with nuclear power, is attempted.

Such a satellite station, which is well within the realm of possibility given a willingness to make the effort, can be used for extended reconnaissance and study, as small and cramped satellite vehicles up for only a few laps cannot.

Developed as part of a system wherein the initial stages are recoverable and the final stages can be incorporated directly into the construction of the station out in orbit, a very impressive station in time can be created. There is debate as to its military usefulness as a launching platform for missiles and its vulnerability to attack, but there is little debate about its importance to peaceful development of space travel. As one example, prolonged study of Mars from a good-sized telescope in a satellite station would resolve questions about that planet in advance of attempting a trip there to a degree that can never be done from the surface of the earth. Secondly, the flight to Mars would be relatively easy if a work assembly and fueling base already existed in free fall around the earth.

Manned trips to circle the moon and to circle Mars and Venus are likely to come about before landings on any of them. Ultimate landings on the moon first for preliminary exploration and later for a permanent station are to be expected. The moon in time will afford a bigger research laboratory for scientific studies of astronomy, high vacuums, and many other subjects, as compared with an artificial satellite. Retreat below the surface for permanent stations will afford some protection not readily available on the surface. The moon offers real advantages as a military base. With its characteristics of low gravity, almost no atmosphere, and with the same face always turned toward the earth, its bases would have to be destroyed by any aggressor before he could count on victory on earth against the moon base owner. But to attack the moon bases would require several days in flight, and watchers on the moon could take defensive measures before the incoming rockets arrived, or in any case, could launch their own attacks against the aggressor country. This virtually insures a retaliatory capability and limits the use of surprise attacks.

If there is successful development of some of the more exotic means of propulsion outlined in this paper, particularly nuclear power, there is some hope that bases may be developed for economic and scientific purposes on Mars, possibly Venus, and perhaps on such moons as Titan and Gannymede. There is less prospect that the high-gravity, turbulent, and bitter-cold larger planets will be of direct use as bases. What advantages will flow from bases on any other planet cannot be judged conclusively today, but the dividends may be very surprising. At the very least, we may be able to learn more about the universe and the adjustment of life forms to different environments particularly if estimates are correct that Mars has at least simple lichens growing some places.

Interstellar travel is probably more remote and it may be that decades or centuries of interplanetary travel will be completed before any serious attempt is made to travel away from our solar system. Viewed in astronomic time rather than in terms of recorded history which is very brief, interstellar travel can be thought of as being almost just around the corner from today. The current answers to questions of its value must be philosophic rather than absolute. Years of improved astronomical observation from the moon may eventually give us images of other planets accompanying other suns, a helpful prelude to any enormous investment in such long distance travel. The heroic measures in biological terms required to undertake such a trip have been discussed.

If coming decades do not give us a very fast space drive, sending an unmanned spaceship to another star system may be the course followed. It might be that a very completely equipped automatic ship would travel for a thousand years to its destination for survey work, take pictures, record data, and even collect samples, then make a return voyage after orbiting planets if it found them. It would be 2,000 years before direct benefits would be returned to earth.

ULTIMATE CONSEQUENCES OF SPACE DEVELOPMENT

It would be a bold person who would venture an opinion on the ultimate consequences of space travel. But even this outline of problems suggests some radical changes in outlook required of the general population and the Government if projects suggested are to come to fruition. In a simple parallel, however, many reasons could have been found 5 centuries ago for not exploring the Atlantic Ocean.

Certainly there are short run, intermediate, and long range consequences which will follow attempts to explore space. In the immediate short run, foreign developments of space techniques can have both military and strategic political effects disastrous to the United States unless this country exercises its own abilities in this field. This short run need will have its effects on the budget, on requirements for scientists and scientific education, and upon the kind of

research effort the country must make. In the intermediate span, the military consequences and requirements may expand in directions difficult to foresee today. As our knowledge of space increases, and it comes time to implement more ambitious programs, the United States and other countries may find that a sizable amount of resources and trained manpower will be absorbed in this work. Presumably by that time, new and unexpected benefits will begin to flow back. For example, a costly moon base developed with chemical rockets may provide the laboratory for developing ionic rockets in its near vacuum, and it may be the place to build marvels of complex computers and communications equipment based on cryogenics that would astound us today.

As one looks to the very distant future, mastery of space travel may be matched by mastery of our environment so that we relocate planets to improve their climates and give them new atmospheres so that they are useful to man. Ultimate mastery of high speed space travel may bring us mutually advantageous trades of knowledge with other forms of intelligent life, and the opportunity to start colonies of men in varied locations to forestall some ultimate destruction of mankind or his descendants in the physical destruction of the earth itself either in an accident or when our sun ultimately runs down or explodes as a nova, if it does.

There are many problems which face mankind other than conquering space. But now that the limits of our own planet are so well known, the opportunity to channel our energies into new directions may be good for our continued aggressive adjustment to our changing environment, as well as revealing knowledge of the universe which in itself represents some further understanding of our reason for being and sense of mission in this universe.

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ADDENDUM: SOVIET INTEREST IN SPACE TRAVEL

Legislative Reference Service, The Library of Congress, Washington, D. C.

In September 1951, the Second International Congress on Astronautics was told by H. K. Koelle that it was an open secret that the Russians were racing the West to establish a manned station in space 300 miles up.

On October 1951, Red Fleet reported a plan for a Soviet rocket ship to the moon weighing 1,000 tons and powered by 20 liquid rocket engines. The estimate was that it could be ready in 10 to 15 years.

American Aviation reported in November 1953 that experimental Soviet rocket planes had reached a speed of 1,700 miles per hour.

In April 1954, the Central Aviation Club of Moscow formed an astro-aviation section. A. A. Shternfeld foresaw as not difficult the construction of a space station. In May 1954, at a meeting at the Hayden Planetarium, American scientists warned of the psychological effects of an early Soviet success in putting up even an unmanned satellite. There were warnings that the Russians already had a rocket powerplant for an intermediate range ballistic missile.

Russian drawings of how they planned to build space vehicles were fairly common by 1954 in a number of their publications. They also were talking of passenger-carrying rockets which could follow ballistic trajectories on long trips across their country in a matter of minutes.

By April 1955, the Russians were talking about sending remote controlled tanks to the moon to carry on exploratory work.

In September 1956, the Soviet radio announced that plans were complete for building a rocket with a weight of 2,200 pounds for a flight to the moon and back. American scientists doubted the veracity of the broadcast.

A Soviet proposal of May 1957 advanced the idea that it would be easiest to launch space vehicles by using a turbine-powered mother craft (or two) before an ultimate rocket was fired.

In June 1957, Ehlebtsevich, chairman of the technical committee on rocket guidance, predicted that by the early 1960's, unmanned reconnaissance of the moon would begin, with the first human landings 5 to 10 years thereafter. He foresaw the first Mars probe rocket sent between 1965 and 1971. The Mars expedition would involve 6,000 tons of equipment and fuel.

On October 1957 after Sputnik I went up, the Russians repeated their claim that they expected to send an instrumented rocket to the moon. An unnamed American expert said this was far from realization, as it would take a rocket

assembly as large as an ocean liner. However, Lloyd Berkner was quoted a few days later as considering the possibility of such a Soviet shot not at all unlikely. This was also the reaction of J. Allen Bynek.

By November 1957, the Russians had revealed that they were doing research on photon rockets, to allow travel at close to the speed of light, but no timetable was announced for expected application.

In December 1957, the Russians showed sketches for the first time of a purported actual rocket ship to carry a man at speeds up to 10,000 miles per hour. It is not clear what stage of construction has been reached.

In January 1958, western news services carried a false story through a misunderstanding that a Russian man had already been shot 184 miles into space, to return by parachute braking.

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ASTRONAUTICS: SELECTED LIST OF SOCIETIES AND ASSOCIATIONS WITH PRINCIPAL OR PERIPHERAL INTEREST IN SPACE TRAVEL

Legislative Reference Service, the Library of Congress, Washington, D. C.

(NOTE.—This list has been compiled from two principal sources: (1) The New York Times Index for 1956 and 1957 was scanned for names of societies and associations which appeared under the headings "Astronautics" and "Outer Atmosphere." (2) The Encyclopedia of American Associations (Detroit: Gale Research Co., 1956, 306 pp.) was consulted, with particular attention to section II, scientific and engineering associations, pp. 121-134, and additional titles were obtained.)

(Attached is another list of astronautical and rocket societies comprised principally of foreign associations which appeared in a publication by the British Interplanetary Society, *Realities of Space Travel: Selected Papers * * **, edited by L. J. Carter (London: Putnam, 1957, 431 pp.))

American Association for the Advancement of Science, 1515 Massachusetts Avenue, Washington, D. C. Dr. Dael Wolfe, executive officer.

American Association of Engineers, 8 South Michigan Avenue, Chicago, Ill. M. E. McIver, national secretary.

Professional organization of engineers (all fields). Has 23 local groups. American Association of Variable Star Observers, 4 Brattle Street, Cambridge, Mass. Mrs. Margaret W. Mayall, recorder.

Amateur and professional astronomers who gather and record astronomical data.

American Astronautical Federation, care of Aero Service Corp., 236 East Courtland, Philadelphia, Pa.

A federation of five local societies to advance space flight.

American Astronautical Society, 516 Fifth Avenue, New York, N. Y. Norman V. Peterson, president

Scientific organization devoted to development of astronautical sciences, dealing with all aspects of space travel, planning, and theory. Has two local groups.

American Astronomical Society, McMillin Observatory, Columbus, Ohio

Professional society devoted to astronomy, astrophysics and related sciences.

American Rocket Society, 500 Fifth Avenue, New York, N. Y. James J. Harford, executive secretary.

Professional scientific organization devoted to advancement of jet propulsion and guided missiles. Has 27 local chapters.

American Chemical Society, 1155 16th Street NW., Washington, D. C. Alden H. Emery, executive secretary.

Professional society of chemists and chemical engineers. Has 149 local groups.

American Institute of Chemical Engineers, 25 West 45th Street, New York, N. Y. F. J. Van Antwerpen, secretary

Has 54 local groups.

American Institute of Chemists, 60 East 42d Street, New York, N. Y. V. F. Kimball, editor

American Institute of Electronics Engineers, 500 Fifth Avenue, New York, N. Y.
 American Institute of Physics, 335 East 45th Street, New York, N. Y. Henry A. Barton, director

"Advancement and diffusion of knowledge of the science of physics."

Membership includes local, regional, and national scientific societies. Publishes nine scientific journals.

American Mathematical Society, 80 Waterman Street, Providence, R. I. Dr. J. H. Curtiss, executive director

Professional society promoting the interests of mathematical scholarship and research.

American Meteorological Society, 3 Joy Street, Boston, Mass. Kenneth C. Spengler, executive secretary

A scientific society. Sections include agricultural meteorology, air pollution abatement, climate, forecasting, hydrometeorology, radar, meteorology, and others. Has 36 local branches.

American Psychological Association, 1333 16th Street NW., Washington 6, D. C. Fillmore H. Sanford, executive secretary.

American Society for Metals, Cleveland, Ohio.

Association of Universities for Research in Astronomy, Phoenix, Ariz.

Astronomical League, 4 Klopfer Street, Millvale, Pittsburgh 9, Pa.

To promote astronomy and further observational and computational studies.

Astronomical Society of the Pacific, San Francisco, Calif.

Coordinating Research Council, 30 Rockefeller Plaza, New York 20, N. Y. M. K. McLeod, Manager.

Directs scientific research on fuels, lubricants, and equipment powered by internal-combustion engines.

Federation of American Scientists, 1805 H Street NW., Washington 6, D. C. Dr. Donald J. Hughes, chairman.

"A nationwide organization of scientists in all fields concerned with the interachone of science and society." Has 6 local groups.

Institute of Navigation, University of California, Los Angeles 24, Calif. George J. Hider, executive secretary.

Meteorologists, engineers, pilots, military personnel, and others interested in air and sea navigation. Has 5 local groups.

Institute of Radio Engineers, Inc., 1 East 79 Street, New York 21, N. Y.

Institute of the Aeronautical Sciences, Inc., 2 East 64th Street, New York 21, N. Y.

International Astronautical Federation, Baden Switzerland.

International Mars Committee, Lowell Observatory, Flagstaff, Ariz.

National Investigations Committee on Aerial Phenomena, Washington, D. C.

A nonprofit organization to provide the public with a "broader understanding of such aerial phenomena as unidentified flying objects and the technical problems of space flight."

National Society of Professional Engineers, 1121 15th Street, Washington, D. C. Paul E. Robbins, executive director.

Professional organization of all types of engineers. Has 350 local groups.

Operations Research Society of America, Mount Royal and Guilford Avenues, Baltimore, Md.

To further the science of operations research.

Plastics Engineers Association, 122 East 42d Street, New York 17, N. Y.

Radiation Research Society, care of Nuclear Science & Engineering Corp., Box 10901, Pittsburgh 36, Pa. A. Edelmann, secretary.

Scientific organization interested in the study of radiation effects.

Reaction Missile Research Society, Box 1199, State College, N. Mex.

Studies rockets and jet propulsion.

Scientific Research Society of America, 56 Hillhouse Avenue, New Haven, Conn. Donal B. Prentice, director, treasurer.

"To encourage original investigation in science, pure and applied." Has 36 local groups.

Society of Automotive Engineers, 29 West 39th Street, New York 18, N. Y. John A. C. Warner, secretary.

Professional engineering society. Has 43 local groups.

Society of Plastics Engineers, 34 East Putnam Avenue, Greenwich, Conn. P. J. Underwood, executive secretary.

Has 34 local groups.

United States Rocket Society, Box 271, Pittman, Nev. R. L. Farmsworth, president.

Scientific society pioneering promotion of rockets and interplanetary exploration and penetration.

DOROTHY M. BATES,

Analyst in American Government, Senior Specialists Division.

LIST OF ASTRONAUTICAL AND ROCKET SOCIETIES

- Agrupacion Astronautica Espanola (A. A. E.), Av. Generalissimo Franco, 377, 2°, Barcelona, Spain
- American Astronautical Society, Inc. (A. A. S.), 516 Fifth Avenue, New York 36, N. Y.
- American Rocket Society, Inc. (A. R. S.), 500 Fifth Avenue, New York 36, N. Y.
- Associazione Italiana Razzi (A. I. R.), Piazza S. Barnardo, 101, Rome, Italy
- British Interplanetary Society (B. I. S.), 12 Bessborough Gardens, London, S. W. 1, England
- Chilean Interplanetary Society (C. I. S.), Casilla 1740, Santiago, Chile, S. America
- Commission on Astronautics, Moscow Academy of Sciences, Moscow, U. S. S. R.
- Dansk Interplanetarisk Selskab (D. I. S.), Postbox 31, Copenhagen, K, Denmark
- Deutsche Arbeitsgemeinschaft für Raketentechnik (D. A. R.), Erlenstrasse 67, Bremen, Germany
- Deutsches Raketen & Raumfahrt-Museum e. V., Reinsburgstrasse 54, Stuttgart, W., Germany
- Egyptian Astronautical Society (E. A. S.), care of CERVA, P. O. Box 33, Heliopolis, Egypt
- Gesellschaft für Weltraumforschung e. V. (G. F. W.), Neuensteiner Strasse 19, Stuttgart-Zuffenhausen, Germany
- Japan Astronautical Society (J. A. S.), No. 92, 2-chome, Nobuto-machi, Chiba, Japan
- Nederlandse Vereniging voor Ruimtevaart (N. V. R.), Anna Paulownaplein 3, s'Gravenhage, Holland
- Norsk Astronautisk Forening (N. A. F.), care of Storgt. 37, Oslo, Norway
- Osterreichische Gesellschaft für Weltraumforschung (Oe. G. F. W.), P. O. Box 192, Vienna VII, 62, Austria
- Polskie Towarzystwo Astronautyczne (P. T. A.), Pl. Jednosci Robotniczej Politechnika Gmach Glowny, pok. 218, Warsaw, Poland
- Schweizerische Astronautische Arbeitsgemeinschaft (S. A. A.), P. O. Box 129, Basel 3, Switzerland
- Sociedad Argentina Interplanetaria (S. A. I.), Tucuman 950, Buenos Aires, Argentina, S. America
- Sociedade Interplanetaria Brasileira (S. I. B.), Caixa Postal, 6450, Sao Paulo, Brazil, S. America
- Société Française d' Astronautique, 7 Avenue Raymond Poincaré Paris 16°, France
- South African Interplanetary Society (S. A. I. S.), P. O. Box 2330, Johannesburg, South Africa
- Swenska Interplanetariska Sällskapet (S. I. S.), Grev Turegatan 55, Stockholm Ö, Sweden
- Yugoslav Astronautical Society (Y. A. S.), ul. Uzun-Mirkova 4/1, Postfah: 872, Belgrade, Yugoslavia

(Source: British Interplanetary Society. *Realities of Space Travel: Selected papers of the British Interplanetary Society.* Edited by L. J. Carter. London: Putnam. 1957. 431 p. At pp. 419-420.)

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APPENDIX 3

BACKGROUND INFORMATION ON LOS ALAMOS AND LIVERMORE NUCLEAR PROPULSION
 PROJECTS AND THE STATIC TEST AREA BEING DEVELOPED AT THE NEVADA TEST
 SITE

Released by AEC on March 6, 1958

Scientific theory that nuclear energy can be superior to chemical energy for long-range propulsion of manmade vehicles through the atmosphere or particularly through outer space evolved soon after the fact of controlled fission was demonstrated. In early 1955 the Atomic Energy Commission decided to go ahead with formal research programs to determine the feasibility of nuclear rocket propulsion systems for atmospheric and space vehicles. Programs were assigned to the Los Alamos Scientific Laboratory and the University of California Research Laboratory, Livermore, Calif.

Planning began for field facilities where laboratories could test reactor designs. Isolation is desired because experiments might result in discharge of measurable amounts of radioactive particles into the atmosphere and might result in some ground contamination. The Nevada Test Site was considered ideal for such a site because of existing facilities, such as housing and feeding accommodations at Mercury; because the existing Las Vegas branch office and its several contractors could provide administrative and site services; because Government-owned wasteland was available in the area; and because it was within reasonable traveling distance from Los Alamos and Livermore. A 12.2 by 39.6-mile portion of the Air Force Las Vegas Range was transferred from the Air Force in 1956 to the Commission. It is immediately west of Nevada Test Site. The Jackass Flats portion of new addition was designated as the site for the installations to support both the Los Alamos and the Livermore programs. One section is designated "400 area" for Los Alamos and another "401 area" for Livermore. Initial contracts for roads and water wells to serve both areas were let in spring 1957. Another section of the new addition has not yet been named, but was set aside for possible future testing of experimental reactors.

In early 1957 the nuclear rocket-propulsion project was restudied from the viewpoints of national urgency, money requirements, and use of personnel and facilities. As a result, it was determined that the Los Alamos Scientific Laboratory was to continue with a program related to nuclear propulsion of rockets (Project Rover), and the Livermore Laboratory was to continue with a program for nuclear ramjet propulsion systems (Project Pluto).

PROJECT ROVER

Project Rover is a Los Alamos study to determine the feasibility of using nuclear power to propel rockets.

Advantages of nuclear propulsion

Essential advantages are increased payload and essentially inexhaustible source of energy.

Staff members at Los Alamos feel that nuclear propulsion systems toward which they are working would have many advantages over chemical systems for vehicles designed to escape from the earth's gravity field and travel in space.

Project Rover was undertaken by Los Alamos Scientific Laboratory initially on fairly modest scale. Work is spread over several of the Laboratory's divisions, with most of the design work concentrated in N Division, which was formed for this purpose. Leader of N Division is Rainer E. Schreiber and alternate division leader is R. W. Spence.

Nuclear rocket propulsion system studies at Los Alamos Scientific Laboratory are still in the research and development stage. During studies so far, various concepts have been evolved, and some have been promising enough to justify incorporating into detailed design studies. One or more reactors based on early design studies are to be tested at the Nevada Test Site.

Information gained in Nevada tests is expected to help in formulating more advance design concepts which may lead to construction of prototype nuclear propulsion engines for rockets.

LASL is working only on reactor-propulsion systems, not on the rockets or missiles they would propel aloft.

Schedule of field experiments.—First tests of reactor systems at NTS are now scheduled late in 1958. Chairman Strauss has said that flight tests of rockets propelled by nuclear powered systems are probably somewhat more distant than 2 or 3 years from now.

Rover installations in 400 Area.—Approximately \$10 million will be committed, largely through open-bid contracts, for Rover facilities at Jackass Flats. Under construction are three major groups of buildings and facilities with supporting roads, water wells and lines, smaller buildings, railroad trackage, electrical power supply feed lines and transformers, and a tank farm.

The following are facts on the three areas being developed, and the status of construction:

Control building area.—The major structure being erected is the control building, with a floor area of 9,700 square feet. The building will house the controls and instruments for operating and recording tests to be performed in the test cell area which will be described subsequently. The control building is being constructed of reinforced concrete. Other buildings in the same area, including a generator station for standby power, an administration building, two warehouses, a cafeteria, and a small guardhouse, are being constructed of steel and aluminum components so they can be moved elsewhere if they are no longer needed for the Rover program. J. A. Tiberti Construction Co., of Las Vegas, is building the control building area facilities under a fixed-cost contract of \$815,572.

Mechanical assembly-disassembly building

This is a massively constructed concrete structure with 30,000 square feet of floor area where work will be performed, as indicated by the name, on assembling and disassembling reactors and reactor components before and after tests. The building will include shielding and facilities for remote handling of large assemblies which have become radioactive in tests. Located nearby will be a small office and warehouse building, and a guard building. Sierra Construction Co., Inc., of Las Vegas, is contractor for the building, under a fixed-cost contract of \$2,058,355.

Test cell area

The test cell itself is being constructed of reinforced concrete, with a floor area of 1,680 square feet. Reactors and reactor systems to be tested will not be housed in the cell, but will be supported on a railway car backed up to the cell, and will be connected to receiving instruments inside the test cell, which will transmit needed information to recording instruments in the control building, which is about a mile and a half away. The railway car bearing the re-

actor can be moved by a remotely controlled locomotive over a railway line to the shielded portion of the mechanical assembly-disassembly building. Also being constructed in the test cell area are a propellant storage area, water storage tanks, and other facilities. Contractor for the test cell and tank farm is the Petroleum Combustion & Engineering Co., of Los Angeles, at a fixed-cost contract price of \$1,209,000.

PROJECT PLUTO

Studies to determine the feasibility of applying heat from a reactor to ram-jet engines will be extended to the Atomic Energy Commission's Nevada test site in the near future. Experimental and theoretical work on such an application is being conducted by the University of California radiation laboratory for the Commission at Livermore, Calif.

The work, under the direction of Dr. T. C. Merkle, leader of the R division of the laboratory, is related to research on propulsion of missiles. A ram-jet can operate only within the earth's atmosphere as contrasted with a rocket which can travel in free space. Also associated in the program is Atomics International, a division of North American Aviation, Inc., at Canoga Park, Calif., where basic research into reactor materials is being conducted.

Construction at Nevada will include a high-temperature critical facility and control building, other assembly and shop structure, and utilities. It is expected that invitations for bids on work will be issued in March.

Approximately \$1,200,000 will be expended for this construction.

In studying the possibility of using a high-temperature, gas-cooled reactor as a source of heat for ram jets, scientists state that the information developed will be useful in civilian power production.

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