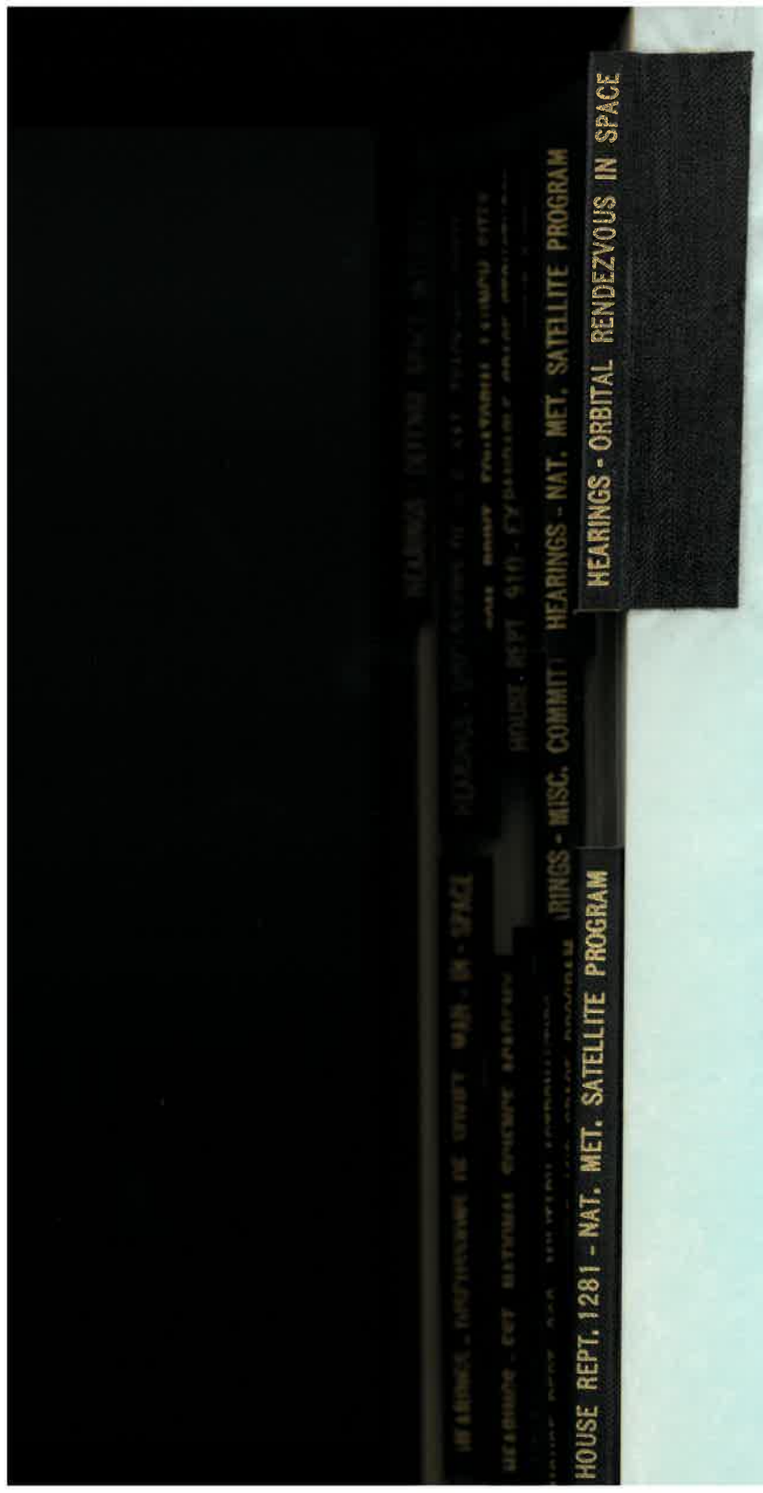

ORBITAL RENDEZVOUS IN SPACE

HEARING

BEFORE THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

EIGHTY-SEVENTH CONGRESS

FIRST SESSION

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ORBITAL RENDEZVOUS IN SPACE

TUESDAY, MAY 23, 1961

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The committee met at 10 a.m., Hon. Overton Brooks (chairman) presiding.

The CHAIRMAN. The committee will come to order.

This morning, gentlemen of the committee, we are considering this subject of "Orbital Rendezvous in Space." This is part of the continuing series of hearings covering the major problems of space flight. Orbital rendezvous is a technique of extreme importance to our growing space program. It relates to the bringing together in orbit two different space vehicles, such as for transferring fuel, personnel, or equipment. It will be a necessity for rotating crews at a permanent space station. It will be important to the construction and supplying of large bases or interplanetary expeditions. It will support future planetary landings. And it has military implications for inspection of unidentified satellites.

Our interest is in a cataloguing of the needs for orbital rendezvous, a general discussion of the means, and an indication of the level of support of the component activities required to make it possible.

The first witness this morning is Dr. Harold Brown, successor to Dr. Herbert York as Director of Defense Research and Engineering in the Department of Defense. He will be followed by Milton W. Rosen, Deputy Director of the Office of Launch Vehicle Programs in the National Aeronautics and Space Administration.

Just off the record.

(Further statement off the record.)

The CHAIRMAN. Dr. Brown, we are happy to have you here to talk to us on a subject that is going to be of increasing importance as the months roll by, that is, "Orbital Rendezvous."

We will be glad to have your statement, and then following that, the committee will understand that you have to leave, and we will release you.

Dr. BROWN. Thank you very much, Mr. Chairman. I deeply appreciate the committee's consideration.

(The official biography of Dr. Harold Brown follows:)

OFFICIAL BIOGRAHY—HAROLD BROWN

Dr. Harold Brown was born in New York City on September 19, 1927. He was educated in the New York City public schools and at Columbia University where he received an A.B. degree in 1945, an A.M. in 1946, and a Ph. D. (in physics) in 1949.

From 1947-1950, he was a lecturer in physics and a member of the scientific staff at Columbia. He held a Lydig Fellowship in 1948–1959. His research during this period was in low energy nuclear physics. During 1945–1950 he was also a lecturer in physics at Stevens Institute of Technology. In 1950, after spending a year in post-doctoral research at Columbia, he joined the University of California Radiation Laboratory at Berkeley, to work on a project aimed at using high intensity beams of particles from nuclear accelerators to produce isotopes in large quantities. In the course of this work he did research on neutron physics and expanded his activities in nuclear reactor designs.

In 1952, when the Livermore site of the Radiation Laboratory was established, he became a staff member there, being appointed a group leader in 1953, division leader in 1955, associate director in 1958, deputy director in 1959, and in July 1960 director of the Lawrence Radiation Laboratory at Livermore. During this period his research interests included nuclear explosive design, applications of nuclear explosives to military and non-military purposes, controlled release of thermonuclear energy, nuclear reactors of advanced design and weapon systems of numerous kinds.

In the past few years he has done research and analysis in the problems of detecting nuclear explosions in various environments, and has participated in a number of studies in the area of arms limitation and control.

He is a member of the American Physical Society, Sigma Xi, and Phi Beta Kappa.

Since 1956 he has been associated with the Department of Defense in a variety of advisory capacities. He was a member of the Polaris Steering Committee from 1956–1958. From 1956 to 1957 he was a consultant to the Air Force Scientific Advisory Board, and has been a member since 1958. From 1958 to 1961 he was a member of the Scientific Advisory Committee on Ballistic Missiles to the Secretary of Defense.

Dr. Brown was an adviser to the U.S. Delegation to the Conference of Experts on the Detection of Nuclear Weapons Tests in Geneva during the summer of 1958, and a scientific adviser to the U.S. Delegation to the Conference on Discontinuance of Nuclear Weapons Tests in October 1958. (Senior scientific adviser from November 1958 to February 1959.) He was also a consultant to the Department of State during the period 1958–1960.

Dr. Brown was a consultant to several panels of the President's Science Advisory Committee from 1958–1960, and was appointed a member of the President's Science Advisory Committee by President Kennedy in January 1961.

He was a consultant to the Aerojet-General Corp. from 1956 to 1961, and was elected a trustee of the Aerospace Corp. in 1961.

In October 1953 he was married to the former Colene D. McDowell of San Francisco, Calif. They have two children, Deborah, 5, and Ellen, 3. The family has its home at 4 Holiday Drive, Alamo, Calif.

STATEMENT OF DR. HAROLD BROWN, DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING, OFFICE OF SECRETARY OF DEFENSE

Dr. Brown. Mr. Chairman and members of the committee:

I welcome the opportunity to appear before your committee today to discuss the problem of space orbital rendezvous. I would also like to say that we are working closely with the Air Force on this problem and this statement is a joint statement of our views.

The concept of purposeful, controlled rendezvous in space by unmanned and manned spacecraft is being studied extensively by the Department of Defense and by the National Aeronautics and Space Administration. Mission applications can be envisioned for rendezvous in conjunction with cooperative or friendly spacecraft, as well as passive or even possibly hostile spacecraft.

From the viewpoint of the Department of Defense, it is conceivable that in the future it may be very desirable to inspect an unidentified space object to determine its characteristics, capabilities, or intent.

This might be done with unmanned satellites capable of orbital maneuvering to intercept a suspicious spacecraft and inspect it by use of sensors. That is, various sensors which can look at the radiations given off by the spacecraft, that can see what it looks like. Cameras are one such—that is, they represent one kind of sensor, though it may not be possible to be sure of the nature of a satellite merely by looking at it. If, for example, it is just a spherical balloon, you can't tell too well what is inside the balloon merely by looking at it. In these circumstances, manned inspection, or the use of more complex unmanned inspection schemes, might be necessary.

Another possible application of orbital rendezvous is to develop unmanned satellites capable of coupling with orbiting elements to perform the assembly of large vehicles in orbit. In this manner, smaller launch vehicles could be used to provide large space stations as an alternative to the use of tremendous boosters to launch large space stations as a unit. In other words, you can either put up a very large space station in one piece, which requires a very large booster, or you can put it up in smaller pieces, using smaller boosters, and then assemble the space station out of the smaller pieces. Similarly, logistic functions could be performed. This might include refueling of operational systems like Advent communications satellites which had "run out of gas," that is, run out of the fuel necessary to maintain their proper position in orbit, or it could be used to refuel a deep space probe from an orbiting fuel station. In other words, one could bring the space probe up to the space station, add fuel to it, and then send it on its distant mission.

A number of manned applications are also worth discussing. If large manned observatories become practical, it may be desirable and economical to replace crews periodically rather than replace such large space stations in their entirety at short intervals of time. The value of this technique, of course, depends on how often you have to replace the crews.

Payloads of a certain size and complexity have a limited lifetime because of component failure. It may be claimed that by sending up a man to rendezvous with such a payload to do repairs, the lifetime of the payload could be extended enough to justify the cost of the manned rendezvous. This may be so, but it is too early to tell. Rendezvous may become essential also in the event of emergencies or failure of escape provisions from such space stations. In other words, if you are trying to bring a man down and the vehicle in which he is supposed to be brought down fails for some reason, you may have to send up another capsule and propulsion system to bring him back. You would then have to rendezvous the propulsion system and capsule with the space station where he is.

One particular use of manned rendezvous would be to send the spacecraft (except for the man) up with a very large payload of fuel, instruments, etc., and send the man up separately to rendezvous with it. The man would require a smaller booster which, because it is smaller, is probably older and more standard; simply because it has been in existence for a longer time; it probably has had more work done on it. It will have been tested more frequently for a given expenditure. For these reasons it will tend to be more reliable. So this way of getting a man plus a large payload up may be the correct one. In other

words, the most reliable vehicles will always be smaller ones than the biggest you have, just because the bigger they are the more it costs to try them out, and because of the extreme importance of reliability in the manned part of a mission, it may be desirable to use these smaller vehicles and then attach them onto the larger ones in space; just bringing the man together with the payload which he is supposed to operate.

In this case a failure of the large vehicle, which is more likely than a failure of the small one, merely because the large one is likely to be more complicated and a newer development, will not have disastrous consequences for the man. One can keep on sending up or trying to send up the big payloads until one succeeds, and then send up a smaller booster with a man in it, to rendezvous with the large one.

At this time specific rendezvous requirements and missions are not well defined. Such missions are dependent on the evolution of current space programs, the degree of practicability of intended manned flight, and the technical and economic tradeoffs that emerge as space technology progresses. Nevertheless, because of potential missions and requirements, it is necessary to proceed at this time with the development of the basic elements and techniques necessary to provide a sound base for accomplishing space rendezvous for whatever tasks may be required.

Development is required in areas of guidance and control, orbital propulsion, interception, coupling, remote handling, and sensing devices for identification.

The Department of Defense has under development the Saint program which is oriented toward the problem of intercepting and identifying uncooperative satellites. This program presents many of the problems which I have just outlined and developments are required in those areas in order to make the Saint program a successful one. The National Aeronautics and Space Administration is initiating development efforts oriented toward the problem of intercepting and coupling with cooperative satellites leading toward refueling and transfer operations.

Both agencies are working together closely and effectively through the Aeronautics and Astronautics Coordinating Board to insure that the programs are mutually supporting, that there is a crossfeed of technology, that maximum use is made of common elements and that advanced planning toward possible applications and missions is unified.

Thank you.

The CHAIRMAN. Thank you very much, Doctor.

We appreciate your statement. It gives a lot of new ideas for the committee.

At this time I think we should place in the record at the beginning of your statement your official biography, which we have before us. And, Sam, if you will place that at the beginning of his statement, the committee will appreciate it.

I judge, Doctor, from what you say, that the matter of rendezvous is a matter that has both military and peacetime aspects, is that correct?

Dr. BROWN. That is correct, Mr. Chairman.

The CHAIRMAN. Therefore, both NASA and the military are engaged in the named program?

Dr. BROWN. (Nods.)

The CHAIRMAN. Do you have defined definite limits of your program n the military and does NASA have the same thing in NASA?

Dr. BROWN. Yes, sir, I think there is a quite natural borderline on ne side of which the Department of Defense naturally fits and on he other of which NASA fits.

For example, when one talks about orbiting, or when one talks bout attaining rendezvous for manned purposes, NASA naturally kes the principal role because it has the principal role in the manned xploration of space program.

When one talks about inspecting satellites to see what they contain, ne is naturally worried about possible military uses of such satellites. nd this is, therefore——

The CHAIRMAN. Reconnaissance.

Dr. BROWN. Quite naturally——

Excuse me, sir?

The CHAIRMAN. Reconnaissance.

Dr. BROWN. Well, this is a peculiar kind of reconnaissance. This is econnaissance of other people's satellites to see what they might be p to. Since what you are afraid of is the other man's military satelites, this is naturally a suitable project for the Department of Dense. And as a result, the Saint program is oriented toward that ission, and it is a thoroughly well-defined mission with military pplications. The Department of Defense is doing that one.

Since that is the principal military mission, the Saint constitutes the rincipal Department of Defense approach to orbital rendezvous at his time.

When and if—and this will probably be a long time before it appens—the military gets into such large payloads that they can ustify the use of manned maintenance, then the Department of Defense may logically come into manned rendezvous. But that is not he situation at the present time.

The CHAIRMAN. And that generally provides the lines of demarcaion between NASA and the military?

Dr. BROWN. That is correct, sir.

The CHAIRMAN. Now, this is a rather new program for the mili-ary, isn't it?

Dr. BROWN. The Saint program, if I remember correctly, sir, was alked about by ARPA as long ago as 1958 and -9.

The CHAIRMAN. That is true. The Saint and the Advent program, oo. But the matter of orbital rendezvous is rather a new program, sn't that right?

Dr. BROWN. The idea of orbital rendezvous was talked about in 959, but the Saint program, as such, I believe, did not exist until t least a year later. It was funded, if I remember correctly. Let e see whether I can find the figures. It had small amounts of funds n fiscal 1961, enough to do a study.

The CHAIRMAN. Now, is the Air Force handling this or ARPA?

Dr. BROWN. The Air Force is handling the Saint program, both he booster vehicles and the payload. ARPA is out of the space rogram.

The CHAIRMAN. How about Advent?

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Dr. BROWN. Advent is being handled as a project by the Army. They are to develop the communications payload which goes into Advent.

In accordance with the recent directive from the Secretary of Defense on space programs within the Department of Defense, the Air Force has the responsibility for the propulsion systems and the booster system.

The CHAIRMAN. Now, the orbital rendezvous, you are placing it under the Saint program, are you, and the Advent program?

Dr. BROWN. The Saint program exclusively.

The CHAIRMAN. Exclusively?

Dr. BROWN. Yes, sir.

I mentioned Advent as an example of a system which might at some time make use of orbital rendezvous. But Advent is so far off that this is at the moment merely an example of an applicational use for a rendezvous capability. And I used Advent rather than some other program because that is a Department of Defense program.

The CHAIRMAN. So the matter of the interception, coupling, remote handling, and sensing devices, all come under Saint?

Dr. BROWN. Insofar as the Department of Defense is concerned, that is the program.

Now, the Saint program does not include all of those missions at the present time. It is not that ambitious. The Saint program is confined at the moment principally to the close approach of one satellite or one space craft to another, and the inspection techniques by which one might hope to find out what the purpose and nature of the satellite to be inspected may be.

The CHAIRMAN. Well, at this time what is the size and scope of this Saint program?

Dr. BROWN. The Saint program is being reviewed, sir, so I think probably I can not give a precise number. It is of the order of $20 million, somewhere between 10 and 30.

The CHAIRMAN. It covers about how many personnel?

Dr. BROWN. Well, I will have to make an estimate based on a normal ratio of people to money in such a program. If I do that, I come out with something in the neighborhood of 200–250 people. I am now speaking of the fiscal 1962 program, which of course won't start until July 1 of this year.

The CHAIRMAN. Questions?

Mr. FULTON. Yes.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. When you were speaking of the funding, what fiscal years were you speaking about?

Dr. BROWN. I am speaking of the next fiscal year, the budget for fiscal 1962.

In the past years I think that this was in the stage of a study program.

Mr. FULTON. In order to have satellite rendezvous in orbit, there is actually no invention needed, just technical engineering research and development work, is that not right?

Dr. BROWN. One won't know for sure until one tries some of the things. I would anticipate that this is a feasible program on the basis of techniques that we either know now or can reasonably expect to develop without new inventions.

Mr. FULTON. And then on your statement you had said, on page 3:

> The orbit launched vehicle studies will develop designs of orbit launched vehicles with propulsion systems that should be available in the period of 1965–1970.

Do you mean by your sentence that the designs of orbit launched vehicles with propulsion systems will be available or that the propulsion systems, themselves, will be available by 1965?

Dr. BROWN. Well, since this sentence is actually in Mr. Rosen's statement, the statement that the representative from NASA is going to make, perhaps he should interpret it himself.

[Laughter.]

Dr. BROWN. I think—well, as I read it, sir—and remember, it is not mine—I think he is talking about propulsion systems that will be available.

Mr. FULTON. I am sorry, it was confusing.

You see, another point of it is: Why is the biggest spread 1965 to 1970? That sounds to me as if there will be developing systems through that period, with the first one not operational but at least in an experimental stage by 1965. Would you agree with that?

Dr. BROWN. I would——

Mr. FULTON. I hope you will say yes, because I am going to push you in space activity.

Dr. BROWN. Well, I would say the reason for this large spread is probably that the orbital rendezvous program is mostly still in the conceptual stage, and at that stage it is hard to pin it down. I think that the early period might very well be made, providing that enough push is given on the program.

I think, by the way, that that is a proper thing for NASA to do.

Mr. FULTON. On page 3, at the bottom, the statement reads:

> The work statement for the orbital operation based on Saturn system capabilities study is now in preparation.

What is the target date for completion of that?

Dr. BROWN. I must beg off on that one, sir, because——

The CHAIRMAN. The Doctor's statement is only two pages long. [Laughter.]

Dr. BROWN. We are looking at the NASA statement now.

Mr. FULTON. I know. But the point that I am making is: I am trying to correlate between NASA and the Department of Defense to find how your plans are going on programing compared to theirs.

Are you in close contact with them? Do you know what is going on? Do we have two separate programs, one over here and one over there?

We have seen some evidences of that. And if we are going to get a good team working here, we are going to have to get closer cooperation.

The point I am asking is this.

Dr. BROWN. That is a good point, sir. But the Saturn's system capabilities is their responsibility. And when they have done it, I am sure they will be happy to let us know so we can see how it fits into defense needs.

At the moment the Defense Department does not have a military requirement for systems employing such a booster.

Mr. FULTON. You see, our problem comes up whether these space systems are getting so departmentized that you each know your own fields but you aren't working together as a team.

The point I am trying to bring out here is that unless we have teamwork, we get overlapping and we don't use the research and development of one agency with another. And I am trying to get the picture to see how you and NASA are programing, really, to come up with a joint end-product.

And I hope that you will cooperate, rather than compete, and that, secondly, you won't have preserves where you don't know what is going on across the fence.

It is a very important point to me. I am trying to make a comment, that our experience, some of us, for about 4 or 5 years in these programs, has been that the one hand often doesn't know what the other is doing, on the programing, and they are not using the benefits that are obtained from research in one area to advance the whole program.

I yield to Mr. Bell.

Mr. BELL. May I ask a question, Mr. Chairman?

The CHAIRMAN. I recognize Mr. Bell.

Mr. BELL. This is connected with Mr. Fulton's question.

The CHAIRMAN. Well, Mr. Fulton is going to lose his position.

Mr. FULTON. I just yield for a question.

The CHAIRMAN. Well——

Mr. BELL. I just wanted to know——

Excuse me.

The CHAIRMAN. Surely. The Chairman recognizes Mr. Bell.

Mr. BELL. I just wanted to know, Dr. Brown, whether or not there isn't a Board, a coordinating Board set up between NASA and DOD to inspect and study these problems and how effective and how much work is this Board doing in this direction?

Dr. BROWN. The Aeronautics and Astronautics Coordinating Board, which is a joint group between NASA and the Department of Defense, exists to insure cooperation on these subjects.

I attended my first meeting of that Board, of which I am cochairman, along with Dr. Hugh Dryden, of the National Aeronautics and Space Administration, last week. And to my mind, it was a good example of how coordination should be carried out.

There exist, if I remember correctly, six panels, one of which—or two of which, the unmanned space craft and the manned space craft panels, would naturally be concerned with the orbital rendezvous question.

At the moment, the Department of Defense program in this area, being confined to Saint, is small enough so that there probably is no overlapping or duplication.

Mr. BELL. I think Mr. Fulton's point is a very good one. Because there could be a considerable amount of duplication in the elementary field and many of these other areas.

Dr. BROWN. Yes, sir.

Mr. BELL. And I assume this Board really works at eliminating this duplication.

Dr. BROWN. That is one of its main purposes.

Mr. BELL. That is enough.

Mr. FULTON. There have been stories of previous manned space expeditions in the Soviet. Could you give us a statement whether you have any evidence that prior to Major Yuri Gagarin going up there have been other unsuccessful manned experiments by the Soviets in Space?

Dr. BROWN. I have no information to that effect, sir.

Mr. FULTON. So the answer is completely negative, that we have no information they have lost other men, the way some of these stories are going around?

Dr. BROWN. I can only speak for myself, sir. I have no other such information.

Now, any evidence about this might very well have to be developed in closed session.

Mr. FULTON. Is your Saint program going to be on the basis of a ferry or a shuttle, where you have an ascent rocket and then you have an intermediate ferry or shuttle in orbit, and then that moves out and makes contact with a platform or a station in permanent orbit?

Dr. BROWN. At the moment, and in the foreseeable future as well, perhaps, the Saint program is not directed to rendezvous with a space platform. That is indeed a NASA function, and this is one of the places where there is no overlap.

Mr. FULTON. Yes.

Dr. BROWN. We are looking in Saint at the inspection of one satellite—rendezvous and inspection of one satellite by another. There is no current provision for locking on and boarding.

Mr. FULTON. And you aren't then talking about an intermediate ferry or shuttle station in the military, keeping that in operation?

Dr. BROWN. Not in the Saint program at the moment.

There is talk about maintenance of satellites in orbit, but that is at the moment only in study.

Mr. FULTON. We shouldn't let the record rest that the United States has not been thinking of this space rendezvous, because R. A. Smith in 1951, and Kenneth Gatland in 1951 (both in England), and Krafft Ehricke in 1952 (in the United States), all had very extensive articles, and we have known about it in this particular field.

So I believe we have been making a good basis groundwork for development so far, both here and in Western Europe.

That is all.

Dr. BROWN. Yes, sir. The space rendezvous concept is indeed a very old one, and I think dates back to Professor Oberth in the 1920's.

The CHAIRMAN. Any further questions?

Mr. Anfuso?

Mr. ANFUSO. No.

The CHAIRMAN. I have some questions, if there are no further questions.

I would like to ask you several questions, Doctor, before you get away.

How far away are we from being able to conduct successful orbital rendezvous, and what are the requirements in terms of—(a), size of launch vehicle to carry the necessary equipment and reserve fuel, (b), the need for human pilot or new generation guidance and computer elements, (c), improvements in the world tracking network, (d), precision control of restartable engines, and (e), specialized support-

ing technology such as coupling devices, fuel transfer means, and construction-in-space techniques?

That is quite an order. You have covered some of it, though.

Dr. BROWN. (Laughing.)

The CHAIRMAN. But I thought I would get it in one question.

Dr. BROWN. Yes, sir, it is quite an order. And it is a good question.

I think that we are a couple of years off, perhaps several years off, depending on the pace of the program. It might be as little as a couple of years off, from a completed rendezvous, which includes all of the elements which you mentioned.

In the same program, one is talking about Atlas–D and Agena–B combination, for example, which could put of the order of 4,000 pounds into orbit.

The Agena–B does have a restart capability. And of course one would put the vehicle into orbit and then use its restart capability to home in, having once locked onto the satellite which one is tracking by radar.

The DOD program does not, as I said, have any coupling capability involved in it at the moment. I do know that the NASA people are proceeding with design and thoughts on those questions. As to the tracking from the ground, this depends somewhat on how the rendezvous is accomplished.

The people who are working on Saint, I know are thinking in terms of tracking of the satellite to be intercepted by the other satellite. So within those limits, one might not have to do a great deal more on ground tracking.

The CHAIRMAN. Mr. Rosen, the other day, appeared before this committee and minimized the importance of equatorial or a sea launch base as an alternative to using Cape Canaveral.

NASA then came along and provided this committee with a chart, last month, to indicate that we pay a 5 percent penalty in payload for each 1 degree correction in angle by rendezvousing vehicle.

Can you reconcile those two implied differences of opinion?

Mr. FULTON. Could you state that again, Mr. Chairman, to me? Would you please give your question again? I missed that.

The CHAIRMAN. All right, if the gentleman will attune his ears.

Mr. Rosen was before this committee the other day, that he minimized the importance of an equatorial or a sea launch as an alternative to using Cape Canaveral. Yet, the NASA later on provided this committee with a chart indicating a 5 percent penalty in payload for each 1 degree of correction in angle of a rendezvousing vehicle.

Can you reconcile those two statements?

Dr. BROWN. It would be more convenient for equatorial launches if we had a launching area on the Equator. Having put the very large amounts of money which we have into Cape Canaveral, and thinking about how much additional money would have to be invested in similar facilities if we were to install them on ships so as to get equatorial launch, I think on balance it probably comes out that you take this penalty, which in some cases is rather unimportant, and in other cases can be important, rather than to duplicate the probably hundreds of millions of dollars—yes, several hundreds of millions of dollars, of facilities which exist at Cape Canaveral.

The CHAIRMAN. So you more or less harmonize those two statements, don't you?

Dr. BROWN. Yes—well, yes, indeed. I think on balance, of the additional cost and the additional convenience, I would agree with the NASA position on this.

The CHAIRMAN. You would?

Dr. BROWN. (Nods.)

The CHAIRMAN. That the loss is pretty heavy?

Dr. BROWN. In some few cases.

The CHAIRMAN. Yes. In other cases there is no justification for the additional construction?

Dr. BROWN. That is correct.

The CHAIRMAN. Or acquisition.

Mr. Fulton has another question, he says.

Mr. FULTON. On that particular point, we are in a much more advantageous position than Russia because we are only about 28°30′ away from the Equator, while they are 47°, aren't they?

Dr. BROWN. Depending on how far south in their country they go, that is correct.

It does show—the fact that despite this handicap, they have been able to do all they have, shows that larger boosters can compensate for this difficulty of geography.

The CHAIRMAN. Will the gentleman yield?

If they made a launching from Laos, where would they be? [Laughter.]

Dr. BROWN. In trouble, let's assume. [Laughter.]

Mr. FULTON. Very good.

The CHAIRMAN. Good, Doctor.

Mr. Corman——

Mr. FULTON. Can I just finish?

The CHAIRMAN. All right.

Mr. FULTON. If Mr. Corman will yield.

The CHAIRMAN. You go ahead and finish, Mr. Fulton, and then I will recognize Mr. Corman.

Mr. FULTON. You have spoken of the boosters, Atlas D with Agena B. That would be liquid boosters to get the rocket up to space. But the question comes, when you come to your terminal control actuators, wouldn't you then use solid fuel rockets, just as we do on the Mercury program, on the escape mechanism?

Dr. BROWN. Depending on what you wanted to do, you can use solid rockets. Solid rockets at the moment don't have a restart capability. So the maneuvering had best be done with liquids, if your payload is limited.

Mr. FULTON. As an alternative, could you use electricity on propulsion?

Dr. BROWN. Not for many years.

Mr. FULTON. That is all.

The CHAIRMAN. Mr. Corman.

Mr. CORMAN. Sir, some years ago I heard Dr. von Braun say that the rendezvous in space to launch interplanetary vehicles was in a sense a crutch and that perhaps by the time we had perfected the technique of rendezvousing at all, we would have developed sufficient size that we wouldn't need to for that particular purpose.

Would you comment on that possibility?

Dr. BROWN. I think this is a real possibility.

Actually, rendezvous was invented as a concept in the early 1930's, when specific impulses were very very much lower than they are now and still lower than they could be in the future.

One has to compare the difficulties of rendezvousing in space with the difficulties of getting very large engines or clustered engines so as to put everything into orbit at once. I don't know how this will come out. I think this is a study that is going on. And one wouldn't know and won't know perhaps for a couple of years, several years, which is in fact the most flexible and the least expensive procedure.

I think that even if it turns out that rendezvous is not useful overall, it will be useful for some things, such as putting a man up with a reliable booster after one has put up a very much larger payload with a relatively unreliable one.

Mr. CORMAN. Thank you.

The CHAIRMAN. I have a list, Doctor, of possible uses, requirements, benefits and payoffs, and essential ingredients relating to the orbital rendezvous program. I don't know whether you have seen this list. It was given to me by our technical director.

Dr. Sheldon, I think we ought to put this at this point in the record there, if there is no objection.

(The data in question were prepared merely as a check list in advance of the hearings, without necessarily being definitive. They are as follows:)

ORBITAL RENDEZVOUS

Possible Uses:

Refueling of restartable engine devices
Assembly of multibarreled large rockets
Assembly of space stations
Assembly of interplanetary ships
Crew relief in space stations, and space rescue
Repair of expensive long-life satellites
Inspection of unknown satellites
Landings and return at other planets from the main ship

Requirements:

Ability to launch at a particular time
Ability to launch at appropriate places, not always of our own choosing for greater economy and convenience
Ability to establish orbital elements of earlier satellite with great accuracy
Ability to establish very circular orbits when desired
Ability to launch into the same plane with great accuracy
Ability to deliver into an orbit of choice with great accuracy
Ability to home successfully for final close approach without danger of misses or hard collisions
Ability to couple successfully, including provisions for fuel transfer, electrical connections, personnel transfers
Ability to maneuver in cases where the previous device in orbit is maneuvering to avoid contact
Ability for defense against booby traps or other countermeasures

Benefits and payoffs:

Operation of communications and weather satellites of advanced design
Lunar and interplanetary travel perhaps at lower cost for a given large scale operation, or at an earlier date than direct trip operations
Ability to conduct permanent manned and unmanned operations in orbit
Military offensive and defensive systems

Essential ingredients:

Computers
Guidance and control devices
Space tracking and detection networks
Precise propulsion
Sufficient fuel to allow maneuver
Full attention to supporting technology, as for example coupling devices, fuel transfer means, construction techniques.

The CHAIRMAN. And you know how you assembled it.

Dr. SHELDON. Yes, sir, I just made it up.

The CHAIRMAN. I will not make inquiry of the Doctor regarding it.

Dr. BROWN. We would be very pleased to have a copy, sir.

The CHAIRMAN. If you would furnish Dr. Brown with a copy.

Dr. SHELDON. Yes, sir.

The CHAIRMAN. Doctor, I know you have another appointment. We have these hearings which will go on for a number of days—not consecutively, however, because we have yielded this week to the fact that the subcommittees wanted to meet. But we will continue with it. We will furnish you with this copy.

We want to thank you very much, Doctor, for being here. And if there is no objection, we are going to release you now. And we appreciate your fine testimony.

I hope that you over there in your new position in the Pentagon really put everything you have into this space program, that we may properly defend our country and leapfrog the Russians.

We want to thank you again, Doctor, for being here.

Dr. BROWN. Thank you very much, Mr. Chairman.

Mr. FULTON. May I add my comment, too, from this side, we appreciate your task and your experience and we feel you will do a good job in your new responsibility.

Dr. BROWN. It has been a great pleasure, sir.

The CHAIRMAN. Now, the next witness this morning—and here is this list, Dr. Sheldon. You better take it.

Our next witness this morning is Milton W. Rosen, Deputy Director, Office of Launch Vehicle Programs, National Aeronautics and Space Administration.

Mr. Rosen, if you will have a seat, sir.

We notice here that you have a prepared statement.

I think we have already used your biography, showing your background, experience, training, interests and abilities. Therefore, at this time we will not repeat it.

If you will proceed with the prepared statement, the committee will be delighted to hear from you, sir, again.

Mr. ROSEN. Thank you, Mr. Chairman.

STATEMENT OF MILTON W. ROSEN, DEPUTY DIRECTOR, OFFICE OF LAUNCH VEHICLE PROGRAMS, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mr. ROSEN. Mr. Chairman and members of the committee:

I welcome this opportunity to appear before this committee to discuss the significance of orbital operations to the national space program.

70469—61——3

The long range importance of orbital operations was recognized by NASA when studies of ballistic missile interception were followed by studies of satellite interception and space vehicle rendezvous. These studies were initiated within the NASA research centers. Orbital operations begin when we try to maneuver a space vehicle toward a second orbiting space vehicle for one or more purposes. We may want to inspect other satellites, maintain and assemble either manned and unmanned vehicles in orbit, dock and refuel space vehicles, rescue astronauts in difficulty, capture a space vehicle and return it to Earth for inspection, and also launch a space vehicle from orbit.

Although orbital operations will require extensive development to achieve operational capability, two reasons for its importance to NASA are:

(1) By this method, the performance capability of an available launch vehicle could be extended, as a temporary measure, until a direct flight vehicle can be developed, and

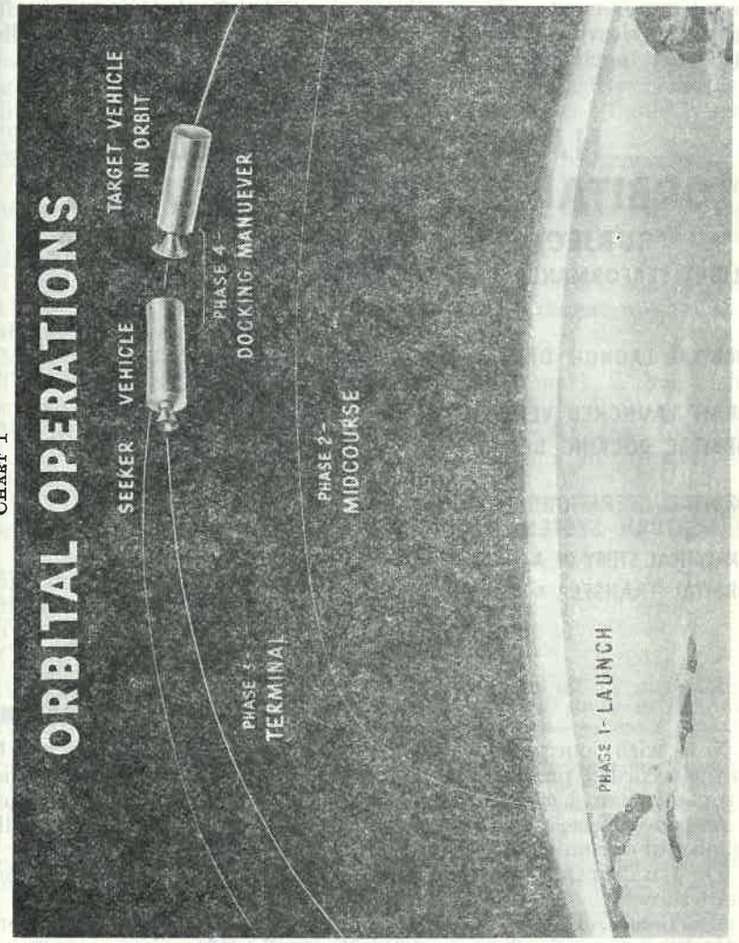
(2) Only by this technique can the NASA objective of a permanent or long-term, manned Earth satellite be accomplished.

The long term Earth satellites will require docking, refueling, assembly, maintenance, repair, and cargo and personnel transfer.

Orbital rendezvous is the name applied to the process of sighting, maneuvering toward and docking at an Earth orbiting target vehicle by a second space vehicle called the "seeker." The rendezvous operation consists—and refer to the chart 1 here—(1) the launching of the seeker vehicle after the target vehicle is in orbit, shown as Phase 1 in the illustration, and (2) the midcourse phase during which the seeker is placed into an orbit close to that of the target vehicle, (3) a terminal guidance and control phase during which the two vehicles are brought into close proximity with the same velocity and attitude and (4) a docking phase when actual coupling maneuvers begin and the two vehicles are locked together.

For many space programs, payload weight is considerably greater than the capabilities of current boosters. As a temporary measure, while developing larger or more advanced booster systems, assembly of components in an Earth orbit and launching an assembled and/or refueled vehicle from orbit could make possible larger payload missions.

CHART 1



The complexity of orbital operations and the many areas of research and development to achieve practical and reliable rendezvous, docking and orbital launch techniques have been examined by inhouse and contracted studies. The difficulty of accomplishing an orbital rendezvous may be considered by comparing it with the job of an anti-satellite missile. Such a missile must coincide with its target in time and space. A rendezvous vehicle must coincide with its target in time, space, velocity and direction to accomplish its objective. These additional requirements add greatly to the task of achieving successful orbital rendezvous. In the next chart the current contracted studies are listed, together with the firms making the investigations.

CHART 2

NASA CONTRACTED ORBITAL OPERATION STUDIES

SUBJECT	CONTRACTOR
FLIGHT PERFORMANCE MANUAL	MARTIN NORTHROP STL
ORBITAL LAUNCH OPERATIONS	VOUGHT DOUGLAS
ORBIT LAUNCHED VEHICLES	CONVAIR
ORBITAL DOCKING DEMONSTRATION	LOCKHEED (STL)
ORBITAL OPERATIONS BASED ON SATURN SYSTEM CAPABILITIES	?
ANALYTICAL STUDY OF A SATELLITE RENDEZVOUS	NAA
ORBITAL TRANSFER & GUIDANCE STUDIES	GRUMMAN CHRYSLER UNIV. OF ALABAMA AUBURN UNIV. UNIV. OF KENTUCKY UNIV. OF NORTH CAROLINA

Now, with your permission, Mr. Chairman, since all of this will be in the record, I propose not to go into detail, on all of these studies. I present chart 2 merely to show the extent of our contracted studies.

As you will see, it involves both industrial corporations and a goodly number of our universities.

The CHAIRMAN. Now, could you tell us in a general way what that chart shows?

Mr. ROSEN. This is a study program that we have pursued very actively during fiscal year 1961—the study of various aspects of orbital operations.

The CHAIRMAN. Let me ask you to straighten it out for the committee. Where you refer to the subject, it is a subject for which contract has been made with the contractor? And you referred to the contractor in the chart?

Mr. ROSEN. That is right.

The CHAIRMAN. That means that you have a contract with those people to do the job indicated by the subject matter.

For instance, flight performance manual. It doesn't show the amount of the contract or the scope or size or anything of that sort.

Mr. ROSEN. No.

The CHAIRMAN. Do you have an amount?

Mr. ROSEN. I can give you a figure for the total effort. This total effort in fiscal year 1961 amounts to $871,422.

These are generally small contracts, of less than $100,000 each. We tried to get a very broad spectrum of talent and opinion, by spreading the contracts among many qualified contractors and universities. All of this work is administered by our Marshall Space Flight Center.

The CHAIRMAN. All right, sir. Go right ahead.

Mr. FULTON. May I compliment you on spreading the contracts?

The CHAIRMAN. Well, now, wait just a minute. That doesn't mean you have spread the contracts. It means you have broken down the subjects and given to each company a specific subject for a contract.

Mr. ROSEN. This is true, Mr. Chairman.

I think you will note that in some cases we have several contractors for one subject, where we would like to get different approaches and different opinions.

Mr. FULTON. That is the point.

The CHAIRMAN. Where you have that question mark, is that what you mean?

Mr. ROSEN. No, the question mark refers to the fact that this one study is not yet contracted. The work statement is in preparation and should be available in a few weeks.

Mr. FULTON. May I comment for Mr. Hechler that they got awfully close to West Virginia, and all around it, but just missed it. [Laughter.]

Mr. MOELLER. What about Ohio?

Mr. HECHLER. I thank the gentleman.

The CHAIRMAN. Mr. Rosen.

(The portion of the statement not read follows:)

The flight performance manual contractor will organize all the engineering information needed in studying how to get from the launch site to an orbiting vehicle. The result will be an engineering manual for use by space vehicle designers and mission analysts.

The purpose of orbital launch operations studies is to obtain engineering standards and cost estimates for orbital launch operations. The study will consider the assembly of the vehicle in space, assembly and operation of the launch facility, operation of all equipment necessary for launching, refueling, communications, tracking, cargo and personnel transfer.

The orbit launched vehicles studies will develop designs of orbit launched vehicles with propulsion systems that should be available in the period of 1965–1970.

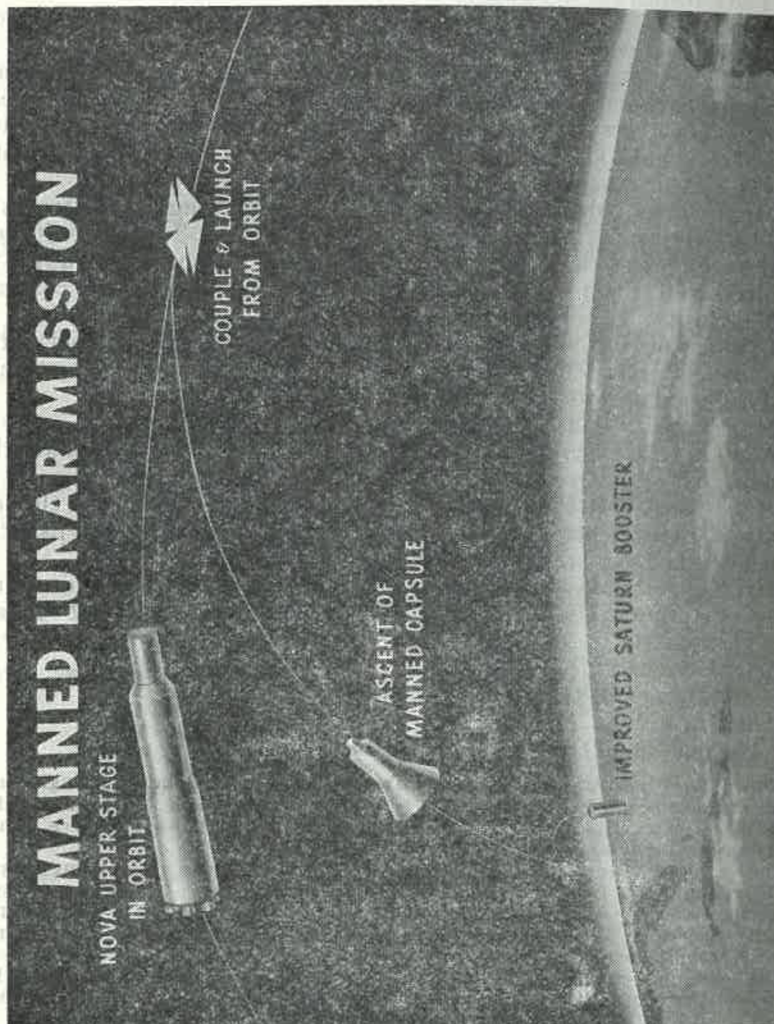
The orbital docking demonstration study leads most directly to a program of experiments in space. It is a design study for joining the payloads of two test vehicles in orbit, in a manner that they become a single operating unit. The purpose of this study is to define a method of demonstrating orbital rendezvous, docking and refueling.

The work statement for the orbital operation based on Saturn system capabilities study is now in preparation.

The analytical study of a satellite rendezvous will estimate the possible position and velocity errors to be considered for orbital transfer maneuvers.

The objective of the orbital transfer and guidance studies is to develop guidance theory for various tasks for space flight.

CHART 3



Mr. ROSEN. One example of the possibilities of orbital operations techniques as applied to the manned lunar landing objective is illustrated in the next chart. (No. 3.) An important aspect to the manned lunar mission is that of "man rating", which requires a launch vehicle sufficiently tested to assure reasonable reliability. The improved Saturn with "man rated" performance is not large enough to accomplish the lunar mission by a direct flight. The Nova vehicle, capable of direct flight, will require considerable testing to achieve a "man rated" status. However, the Nova booster could be launched early in the program as an unmanned carrier. One of the many possibilities which develops from these considerations is the use of orbital operations to achieve a relatively safe manned lunar flight without the risk of flying a man on an experimental Nova vehicle. As a temporary measure, until the Nova vehicle can be thoroughly "man rated", orbital rendezvous may be employed. A possible solution is to place an early non-man-rated Nova vehicle in a parking orbit, as seen at the left. If the Nova lower stages are successful, the upper stages become the target vehicle in an orbital operation. The manned capsule is now launched by the man-rated Saturn and rendezvous with the Nova upper stages is accomplished. The manned capsule and upper stages of Nova are locked together and a launch from orbit will carry the man to the Moon with sufficient payload to accomplish a soft landing and return to Earth. The experimental Nova, in this case, places the "truck" in orbit and the man-rated Saturn carries the manned "cab" into space, where the two are combined and launched to the Moon from the Earth orbit.

Another illustration of the use of orbital operations to accomplish manned lunar landing, makes use of launch vehicles smaller than Nova. In this case a series of approximately six Saturns are launched to carry and transfer fuel and finally a manned capsule to an orbiting Saturn upper stage. The space refueled stage, with the manned capsule attached, is then launched from orbit to the Moon. Sufficient fuel is carried to permit a soft landing on the Moon and return to Earth. By this method a smaller and less expensive vehicle than the Nova is employed, but the mission requires many of the smaller vehicles and the successful development of the orbital operations is involved. The operational complexity of this approach raises many questions regarding its reliability and the time to achieve it.

The Apollo manned flight program anticipates flight training in orbit. In the event an orbiting capsule is disabled and is incapable of making a safe descent, it would be desirable to launch a rescue vehicle to save the crew. The rescue vehicle would rendezvous and attach a powered capsule to the disabled vehicle, and then return the crew safely to Earth.

I personally believe that this is one of the strongest justifications for the entire subject of orbital rendezvous.

Consideration of the manned permanent space laboratory illustrates other examples of orbital operations which should be developed. It is possible that the size of the space laboratory will require that it be assembled in space. This would be accomplished by launching components into orbit and docking and coupling them to the units already assembled. After the structure is assembled, crews will be carried by seeker vehicles similar to the ones which carried the struc-

tural units; rendezvous and docking will be accomplished and the men transferred to the space laboratory. Periodic relief of the crew by new teams will be accomplished by similar maneuvers. Similarly, maintenance equipment and supplies will be periodically delivered to the laboratory. Of course, this is [redacted] time in the future, but we must start now to develop the techniques that will make it possible.

In summary, orbital operation techniques are essential for permanent manned space laboratories and for extensive manned space operations. Further, by means of these techniques, as a temporary measure until larger boosters are developed for direct flight, an order of magniture increase in the mission capabilities of existing launch vehicles can be realized.

I would like, Mr. Chairman, to make one additional comment to the prepared statement. What I have said about orbital operations does not lessen the need for a direct flight vehicle, such as Nova, if we are to achieve a manned lunar landing as soon as practicable.

As I have pointed out in my prepared statement, orbital rendezvous must be developed for many other purposes.

I am available, Mr. Chairman, for any questions.

The CHAIRMAN. Thank you, Mr. Rosen, for your statement.

I judge from accepting your statement in globo that really what you envision is the general use of space for transportation and travel.

Mr. ROSEN. Yes, sir.

The CHAIRMAN. Now, you refer to the use of manned space laboratories, specifically, in your summary. Then you in a general way cover the field of extensive manned operations.

Could you be a little bit more definite in what you have in mind in extensive manned space operations?

Mr. ROSEN. I should think that such operations would center about investigations in the vicinity of the Earth, for which the permanent manned space laboratory would be useful.

Here we are observing the Earth and the regions around it with large amounts of equipment. It would be a function that would go on for I believe many years, and be extensively supported.

When we look out farther into space, the orbital area can serve as a staging area for further expeditions, to the Moon and eventually to the planets.

We have to look forward to both aspects of space, as a region to investigate in itself and also as a staging area for further exploration.

The CHAIRMAN. So that this gives you the opportunity, this development, to move either nearer to the Earth in space or move further out to deeper space?

Mr. ROSEN. Yes, sir.

The CHAIRMAN. Any questions?

Mr. FULTON. I do have.

The CHAIRMAN. Mr. Fulton has a question.

Mr. FULTON. May I compliment you, because you have more specific plans than the Department of Defense.

On page 2 of Dr. Brown's statement, he says—

At this time, specific rendezvous requirements and missions are not well defined.

He says further—

Nevertheless, because of potential missions requirements, it is necessary to proceed at this time with the development of the basic elements and techniques necessary to provide a sound base for accomplishing space rendezvous for whatever tasks may be required.

And I emphasize that last "for whatever tasks may be required."

Now, at the end of Dr. Brown's statement he has said—

Both agencies are working closely and effectively through the Aeronautics and Astronautics Coordinating Board to insure that the programs are mutually supporting, that there is a cross feed of technology, that maximum use is made of common elements and that advanced planning toward possible applications and missions is unified.

When it came to the questioning, however, he knew nothing of your program nor of your dates. And he was not able to say what you meant when you said, on page 3 of your statement—

The Orbit Launched Vehicle studies will develop designs of orbit launched vehicles with propulsion systems that should be available in the period of 1965–1970.

He was unable to say whether that was the designs, the experimental vehicles, or the operational vehicles.

Now, that, to me, again brings up the point of the separate compartments that space is assembling to get itself into between the military and the peaceful uses of space.

Will you please tell us, in your statement on page 3, what you mean by that statement, and why there is the spread of really six years, from 1964 through 1970, in that one paragraph?

Mr. ROSEN. Well, Mr. Fulton, I believe we could have been more specific.

In that period of time the type of propulsion we refer to is electric propulsion.

As Dr. Brown pointed out, and we agree, we would begin to have some useful electric propulsion systems in that time period.

Mr. FULTON. I am glad to hear that. Because he had put it so far in the future. He had been unable to say when it would be when I brought up the question of electrical propulsion.

Is that your design or is that the experimental or an operational vehicle, that will be available in 1965?

Mr. ROSEN. No, I would not call it an operational vehicle.

What we are trying to do in this study is to have some of our contractors look at the type of vehicle you would design to use electric propulsion for orbital operations and rendezvous.

Mr. FULTON. So you could be having experimental vehicle shots by the year 1965?

Mr. ROSEN. Yes.

Mr. FULTON. Looking forward to operational characteristics by 1970, at the latest?

Mr. ROSEN. That is substantially true.

I would want to hedge that a little bit by saying that we would do the experimental work during this 5-year period and look for operational use in the next decade.

Mr. FULTON. Now, Robert Roberson has spoken of having these clusters of terminal control actuators that are solid propellants.

If we had a program on solid propellants as well as the electrical propellants for this rendezvous-making, wouldn't we be wise to have that second program as a backup?

Why wait for electrical propulsion? It is going to take us 9 years, and in all probability 10 years, when we have at hand on the Mercury escape mechanism a solid propellant booster that works?

Mr. ROSEN. I think the reasoning behind it runs in this manner, Mr. Fulton:

We have solid rockets now that could be used in orbital operations, but we have not developed the orbital operations techniques. We haven't developed the techniques of operating in orbit that could use these rockets.

Mr. FULTON. The point is:

Don't you need a backup program for solid propellant fuels, rather than waiting for the invention and the development from about 4 kilowatts to 300 kilowatts on electrical propulsion?

Mr. ROSEN. I firmly believe—in fact, I can say with assurance that both solid and liquid rockets will be available, and some are available now, to perform orbital rendezvous, as soon as we have worked out the techniques of orbital rendezvous.

Now, the reason for considering electric propulsion is that we hope it will be available by the time we have worked out the orbital techniques. It is very much more efficient. It can operate for longer periods. It would require less fuel. It would enable us to do many more things.

Mr. FULTON. Is your program based on a ferry or shuttle, in intermediate orbit, or do you just make the ascent and go to the immediate rendezvous with an upper stage orbit?

Mr. ROSEN. I am not sure, sir, what mission you are referring to.

The CHAIRMAN. Would you repeat that question? [Laughter.]

Mr. FULTON. The question is this: Do you just use an ascent rocket that goes up to rendezvous with a high level orbit vehicle or do you use the intermediate orbit that is up there, like the space platform, and your ascent rocket goes up to rendezvous with this ferry or shuttle platform that is in a lower orbit, and then that moves on up and meets with the higher orbit?

Do you use the intermediate orbit stage?

Mr. ROSEN. Well, sir, when you say "Do you use"—of course we are not actually doing any of this operationally. What you have described——

Mr. FULTON. I realize that. But I say in your thinking. That is what we are talking about. How are you going about it? Nobody has said it.

Mr. ROSEN. My answer would have to be Yes. We have to consider the method that you have outlined. It is one of many methods that we are considering and studying, to find out which is the best to employ in orbital rendezvous.

Mr. FULTON. How soon could we have that intermediate space platform in operation?

Mr. ROSEN. Well, actually, it is going to be some time before we are rendezvousing vehicles. What is required in this area is a very strong program in technology.

Now what I have shown here is the first step, that is, to study the problem and find out what we should be doing and how we should do it. Then we have to develop the hardware. And this consists of a lot of small gadgetry—couplings, methods of transferring fuel. Much of this can be done on the ground, without using expensive vehicles.

It is this area of work that we are about to enter, and this is really the most important area for the next year or so.

Mr. FULTON. How much money did you ask the Bureau of the Budget for in your presentation for fiscal year 1961? What did you receive? How much has the Kennedy Administration indicated they will give you on your present presentation, for 1962?

Mr. ROSEN. We asked for approximately $1 million in fiscal year 1961 and received that amount, most of which, as I have indicated, has already been committed.

We have doubled the amount in fiscal year 1962. We have asked for $2 million, most of which will go into the area of technology that I referred to.

Mr. FULTON. What has the Bureau of the Budget allowed you?

Mr. ROSEN. Our request has been allowed and is presently in the bill before Congress.

Mr. FULTON. You speak of the strong program for these purposes. How much money would you require in 1962?

Mr. ROSEN. To have a really aggressive program, I should like to see the number increased to about $8 million.

Mr. FULTON. And that could be well used without waste and without a crash program?

Mr. ROSEN. I believe so.

Mr. FULTON. How much would that advance the program in time as an end result, by having this boost from $2 million in 1962 to $8 million?

Mr. ROSEN. It is very hard for me to give an exact time scale.

Mr. FULTON. But it would advance it substantially, would it not?

Mr. ROSEN. I think it would advance it substantially. I could not say it will advance it an entire year. But it would advance it a substantial part of a year.

Mr. FULTON. That would be worthwhile for the security of the United States as well as for our advance in science, would it not, in peacetime use?

Mr. ROSEN. I would agree, sir.

Mr. FULTON. Thank you. That is all.

The CHAIRMAN. Questions?

Mr. HECHLER. Yes.

The CHAIRMAN. Doctor.

Mr. HECHLER. Did I understand you to say, Mr. Rosen, in response to Mr. Fulton, that 1970 was the approximate target date for achieving orbital rendezvous capability?

Mr. ROSEN. No, Mr. Hechler. I didn't mean to imply that.

My answer was in response to the item on page 3, which concerns only one study, where we are looking at the application of electric propulsion to rendezvous. And in that respect I said by about 1970 we could have rendezvous systems using electric propulsion.

But I think we could have rendezvous systems using the more conventional liquid and solid propulsion earlier.

Mr. HECHLER. I see.

In all of your study, what would you say is really the most difficult thing to lick in this whole problem that you are attacking?

Mr. ROSEN. I would have to say that there are many difficult problems, principally because we haven't much experience in them.

The interception problem, which is—and I support what Dr. Brown said—being most actively pursued by the Department of Defense, is a difficult problem, probably more difficult than the one we are more actively pursuing, which is the docking problem. They have to do their job first, intercept and get close, before we can talk about docking.

In comparison to building a large rocket, where we have a background of technology, we are very lacking in technological background in rendezvous. We just haven't tried rendezvous operations.

So there is a lot to be learned in orbital rendezvous before we can do something practical. Nevertheless, as I have tried to point out, the gains and the returns from it will be very great.

Mr. HECHLER. Maybe one of your most difficult problems, then, is to try to identify what is most difficult. [Laughter.]

Mr. ROSEN. I think you are right.

Mr. MOELLER. Mr. Chairman.

The CHAIRMAN. Mr. Moeller.

Mr. MOELLER. I would like to ask the doctor if you are planning anything beyond inspection rendezvous? What about inspection of planets, et cetera, for possible military bases and so forth? This is a bit farther on, but are you thinking of such things also?

Mr. ROSEN. We have a program for unmanned planetary exploration, but it isn't involved in the rendezvous program. The idea there is to merely send a vehicle out toward the planet and have it pass close to the planet to observe it.

I have been talking here about the rendezvous of two of our own vehicles. The planetary mission is a different type of rendezvous and is not really germane.

Mr. MOELLER. I understand. But this other is in the making, or has it already been developed?

Mr. ROSEN. Yes. We hope in 1962 to send one or two vehicles to the vicinity of Venus.

Mr. MOELLER. For inspection purposes?

The CHAIRMAN. In the vicinity of what?

Mr. ROSEN. Venus, the planet Venus.

Mr. MOELLER. How soon are you going to hit close to the Moon for inspection?

Mr. ROSEN. Well, we have four attempts scheduled for this year, the first to start in July or August.

Mr. MOELLER. For inspection purposes?

Mr. ROSEN. No. This is a scientific test. The payload has been described before this committee. It is called the Ranger. We will attempt to take photographs of the Moon and also to land a seismograph on the surface of the Moon to get seismic data.

Mr. ANFUSO. Mr. Chairman.

The CHAIRMAN. Mr. Anfuso.

Mr. ANFUSO. What happened to the Russian satellite that took photographs of the Moon? Is that still up there?

Mr. ROSEN. I must say, Mr. Anfuso, I haven't checked it recently. The satellite, if it is still up, is inactive. It was in a highly elliptical orbit and did return and pass around the Earth. I can check and add it to the record. I am not certain at this point whether it has come down.

Mr. ANFUSO. Would you add it to the record?

Mr. ROSEN. I will.

In answer to Mr. Anfuso's question re Russian satellite which took photographs of the moon, "Is that still up there?"—

Lunik III or 1959 Theta launched 4 October 1959 to photograph far side of Moon. Presumed down mid-April 1960.

The CHAIRMAN. Mr. Rosen, I would like to ask you a few questions.

You referred to the need, in your opinion, of additional money for this program. What priority do you have on the program?

Mr. ROSEN. It is a program that we push aggressively. We have taken strong steps to commit the funds that we did get this year. But from the point of view of formal priorities, I must say it cannot rank with the DX priorities we have in Mercury and Saturn, which, at the moment, are our two highest priority projects.

The CHAIRMAN. Well, so it doesn't have the DX priority. Does it have the D priority, without the X, or what is the next grade of priorities?

Mr. ROSEN. I am not aware that we use any priority system, other than the DX, which, as I understand, helps us in contracts and procurement of materials. Other than these two projects, we class our remaining projects in the same category, and we push them as vigorously as possible.

The CHAIRMAN. Well, now, you referred to the need of additional funds. Would you use those additional funds for technological purposes? You referred to the many technological features that had to be developed for this program. Of what would that consist?

Mr. ROSEN. Yes, Mr. Chairman. That is the purpose for which we would use the additional funds.

It would consist of design and development of systems for capturing a target vehicle, if you were within, say a mile of it.

Now there are a number of possible ways of doing this. You can acquire the vehicle, home on it electronically and guide toward it, under propulsion. Another system we are looking at is one which involves shooting out a line, much in the nature of rescue operations of a ship stranded off a coast—that is, shooting out a line which snags the target vehicle. Then the two vehicles are pulled together.

After you have brought the vehicles together, you have to make connections, and you may have to transfer fuel. All of the needed devices have to be developed, and tested on the ground.

One of the more fruitful areas that we can look to for some experience in this field is the area of aircraft refueling. And I think we can borrow from their technology.

The CHAIRMAN. You mean the tanker aircraft?

Mr. ROSEN. Yes, sir.

The CHAIRMAN. You just put out a nozzle there and one will fly above the other and release the fuel. Let gravity do it. But you have no gravity up there to do it.

Mr. ROSEN. That is right.

We have many problems that make our job more difficult: The absence of gravity and an almost complete vacuum.

Nevertheless, they have a lot of experience and we propose to learn from their experience.

The CHAIRMAN. Well, would you build new plants for this, or will you let this technological development out on contract?

How would you in your mind do that?

Mr. ROSEN. Mr. Chairman, these would be small contracts, distributed to a large number of companies in small jobs, all of which can be done in existing plants with existing facilities.

The CHAIRMAN. So no additional facilities would be needed?

Mr. ROSEN. Not at the present time.

The CHAIRMAN. Do you have your planning covering that?

Mr. ROSEN. We have a list of projects that we would like to undertake in general. We don't have specific projects outlined.

In other words, we know the areas of work that we would like to undertake.

The CHAIRMAN. How long would it take you to get your planning down to date?

Mr. ROSEN. We could have specific work statements generated in a few months. Our general policy has been not to commit all of the money at the start of the year, but to spread it out through the year and go carefully into each project.

The CHAIRMAN. Would you proceed with all of these, or just pick out one that you feel is more important than the other, to first proceed with?

Mr. ROSEN. We would proceed with the ones we think are most critical and most important first. The funding would be spent during the course of the fiscal year.

The CHAIRMAN. Does the rest of NASA share your views?

Mr. ROSEN. Generally, yes.

The CHAIRMAN. They have.

Why wasn't a recommendation made, then, for this additional funding?

Mr. ROSEN. Well, I must say that recent events have generated a more pronounced interest in space. Those of us who are proponents of this field have always thought orbital operations should be supported more strongly. Now we are beginning to get wider support.

The CHAIRMAN. Well, you think you are getting wider support on all space, don't you?

Mr. ROSEN. Yes, sir.

The CHAIRMAN. There is a greater public understanding of the importance of space developments. And the recent developments, at Cape Canaveral and then throughout the world, have helped a great deal.

But you didn't anticipate that, is that your answer, and therefore you didn't make a recommendation?

Mr. ROSEN. We had programing plans to move forward more aggressively. As always, you have to work within a total budget. Within the total budget that was brought forward in the NASA bill, I feel that orbital operations did achieve its proportionate amount.

If we can talk in terms of a larger budget, I think orbital operations should be one of those areas that receive more aggressive support.

Mr. FULTON. Mr. Chairman.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. You would then recommend to this committee, as you have, that the $6 million additional, making $8 million for the rendezvous program, be put in the 1962 budget?

I might say parenthetically that we individual members would take the responsibility for pushing and proposing that. But you are simply at the point here of recommending.

Now, do you firmly recommend that?

Mr. ROSEN. Yes, I firmly recommend it.

Mr. FULTON. Thank you.

The CHAIRMAN. But you don't give any priority on your recommendation. I think that is—that is your big problem, that you don't come down here and say this additional spending should be done by priority.

Mr. FULTON. No. I don't think that that is inherently necessary. Once we know that they need this general magnitude of funds, they can then marshal their own resources if they have the funds. I believe that is the basis.

Mr. ROSEN. Yes, Mr. Chairman, I just can't say that this has top priority. There are a number of other things that are more important.

The CHAIRMAN. Where the funds are more badly needed than this area, is that right?

Mr. ROSEN. That is correct.

But I think we can have a program in which this can be an important element and should be an important element.

The CHAIRMAN. I think it should be, too, an important element.

Mr. Randall.

Mr. RANDALL. A question, sir.

Along this budget line, has Mr. Webb, the Administrator—does he share your views in this importance, or has this been—I assume all this has come about since you were before us earlier on the authorization bill.

Mr. ROSEN. Well, I haven't talked to Mr. Webb personally, but I would assume he——

Mr. RANDALL. Then your immediate superior shares your view there. Who is your immediate superior?

Mr. ROSEN. General Ostrander.

Mr. RANDALL. I see.

Mr. ROSEN. Yes; I have talked to him, and he definitely shares my view.

From the point of view that Mr. Webb is in general agreement with our approach to this, I would assume that he shares it.

Mr. RANDALL. Mr. Rosen, at the end of your prepared statement you made reference to some other type of engine or some other type of booster. I didn't get the name of it. Do you recall what it was?

Mr. ROSEN. I believe I referred to the Nova.

Mr. RANDALL. No. It was "Melba"—does that sound right? It sounded to me like—I had never heard the expression used in any of the hearings.

Mr. ROSEN. I am sure I mentioned the Nova at the end of my statement.

Mr. RANDALL. All right.

Now, at the bottom of page 1, you refer to the real objective being a permanent or long-term manned Earth satellite. And I find no reference in there as to what are the advantages of that, or why is that so important. Is it because the instruments would be changed as a new one is orbited, or what is the reason?

Mr. ROSEN. Well——

Mr. RANDALL. It is obviously important, but you don't set out or spell out why a permanent satellite is so important.

Mr. ROSEN. There are a number of reasons.

You might say that right now, by sending up satellites repeatedly, we are not using our equipment most efficiently.

Now, if we could put an astronomical telescope in space, put radio transmitters in space, put devices which observe the weather in space, and use them continuously, merely by sending men up to operate them, we would be getting a more efficient use of our equipment.

Now, in order to do this, one of the methods that has to be developed is rendezvous.

I am talking about something that may be a decade away, but I think we should look forward to a mode of operation which doesn't require us to put up 20 or 30 satellites every year when one——

Mr. RANDALL. Is it an economy measure then? Would it result in an economy?

Mr. ROSEN. Not only more economical, but more efficient.

Some observations take a long time. And you would want to have a permanent station to make them.

Mr. RANDALL. All right.

The CHAIRMAN. Somebody else had a question here?

(No response.)

The CHAIRMAN. I heard, Mr. Rosen, extensive suggestions made a year or 2 years ago in reference to the possibility of salvaging the booster as a matter of economy and then using it repeatedly.

What has been done in that direction? Has anything been done?

Mr. ROSEN. Yes. We have a program directed at attempting to recover the first stage of the Saturn. This is probably our biggest and most expensive stage at the moment.

We actually have two contracts out. One of them is with Ryan Aeronautical. I don't recall at the moment the other. But I would like to supply it for the record to be fair.

In answer to Hon. Overton Brooks' (chairman) question re second contract on booster recovery studies—

North American Aviation is the second contractor on the current booster recovery studies.

Mr. ROSEN. They look into the possibility of recovering this first stage with a para-glider, as it is called. That is a device that was developed by one of our scientists at Langley Research Center and is referred to by his name. It is called the Rogallo wing.

This is in the early stages of development. We are making studies of it, and at Langley doing some experimental work in wind tunnels. It shows some promise of being successful.

Mr. MOELLER. Mr. Chairman——

The CHAIRMAN. When the booster is sent up, the Rogallo wing will appear and glide the booster back to the surface of the Earth?

Mr. ROSEN. Yes.

Mr. MOELLER. Will the gentleman yield?

The CHAIRMAN. Mr. Moeller.

Mr. MOELLER. Why are the considerations only for the Saturn? How about others, or don't we have first stage boosters that could be recovered?

I mean will the majority of them be single use operations?

Mr. ROSEN. If I understand your question correctly: Why is only the Saturn being considered?

Mr. MOELLER. Yes, for recovery.

Mr. ROSEN. The reason we are considering the Saturn is because it is the largest and most expensive vehicle, so the pay-offs from recovery would be the greatest.

As the vehicles get smaller, it becomes a matter of economics, whether it is worth going to all the trouble—and it is quite a bit of trouble—to recover the vehicle.

So in starting out, we feel we should attempt to develop the method for the vehicle that will give us the greatest economic return if we recover it.

Mr. FULTON. Could I——

The CHAIRMAN. Mr. Corman.

Mr. CORMAN. Mr. Rosen, I read recently of studies made by the Marquardt Co. for a ramjet plane that would have the capacity to reach orbit and return and land, not unlike an airplane.

Are you familiar with their studies, and do they hold any promise from your point of view?

Mr. ROSEN. I am not personally familiar with it, but people on my staff keep a very close watch on all new proposals.

We have repeatedly looked at boosters which partake of the nature of an aircraft that can take off from a landing strip and go into orbit and then return.

Thus far, none of these have had either the performance or a cost that is competitive with the conventional vertical rocket. But sometimes they get rather close. It is a field that we have to watch continually. Thus far, all our economy studies show the vertical rocket to be superior.

Mr. CORMAN. Thank you.

Mr. FULTON. Mr. Chairman.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. You had some statements, on page 3 of your own statement that you read:

The work statement for the orbital operation based on Saturn system capabilities study is now in preparation.

What is your target date in relation to that?

Mr. ROSEN. The work statement should be completed in June.

Mr. FULTON. On page 4, at the top of your statement, you say—

The analytical study of the satellite rendezvous will estimate the possible position and velocity errors to be considered for orbital transfer maneuvers.

When will that analytical study of a Saturn rendezvous be available?

Mr. ROSEN. This I would have to check, Mr. Fulton. That study is now on contract. I don't have the completion date at the moment.

But I could get that.

In answer to Mr. Fulton's question re analytical study of satellite rendezvous—

Results of the analytical rendezvous study scheduled for January 1962.

Mr. RIEHLMAN. Will you yield?

Mr. FULTON. I yield.

Mr. RIEHLMAN. In order to see the advance in this program, I think it is important that we have the target dates on the studies that you have with the universities.

Mr. FULTON. That is correct.

Mr. RIEHLMAN. Doesn't it depend on the result of the studies that you have already contracted for?

Mr. ROSEN. I can tell you in general. And I could give you a list of all the completion dates.

In general these studies are for about 8 months duration. Some of them may be for a year duration.

Mr. RIEHLMAN. Well—

In answer to Messrs. Fulton and Riehlman's question concerning NASA orbital operation program dates and amounts, a chart is attached.

NASA contracted orbital operation studies

Subject	Months	Completion	Contractor	Cost
Flight Performance Manual	6	May 1961	Martin	0
			Northrop	$57,380
			STL	92,620
Orbital Launch Operations	6	June 1961	Vought	112,156
			Douglas	92,165
Orbit Launched Vehicles	6	September 1961	Convair	58,000
Orbital Docking Demonstration	6	July 1961	Lockheed (STL)	100,000
Orbital Operations Based on Saturn System Capabilities.	6	December 1961	(?)	100,000
Analytical Study of a Satellite Rendezvous.	12	January 1962	NAA	60,000
Orbital Transfer & Guidance Studies	12	do	Grumman	54,601
			Chrysler	30,000
			Univ. of Alabama	26,000
			Auburn Univ	24,000
			Univ. of Kentucky	32,500
			Univ. of North Carolina	32,500
Total				871,422

Mr. FULTON. On the development of your—

Are you through?

Mr. RIEHLMAN. Go ahead.

Mr. FULTON. On your development of the manned permanent space laboratory, what is your target date on that?

Mr. ROSEN. Again, I would have to supply that for the record.

In answer to Mr. Fulton's question re dates of a manned permament space laboratory—

The Apollo spacecraft will be adaptable as a manned Earth orbiting laboratory and could be accomplished in the next five to seven years. The next step would be a permanent manned space station which could be accomplished in the mid 1970's.

Could I give you a list of the completion dates for all of these studies?

Mr. RIEHLMAN. I think that is important, because I repeat what I said a moment ago. Our advance in this program is going to depend upon the completion of these studies and the analysis of them and the contracts that are going to be let after that.

Am I correct in that observation?

Mr. ROSEN. That is very true, sir.

I think I can say that every one of these studies would be completed during the next fiscal year. They have been started during the present fiscal year and would be completed during fiscal year 1962.

Mr. FULTON. Now, the—are you through?

Mr. RIEHLMAN. Yes.

Mr. FULTON. The next point is this: When you have vehicles that are going at least 17,500 miles an hour and bring them together, actually because of relative motion you can bring them together when they are moving at that same relative speed with no more of a bump than a boat coming into a dock or to a car coming up close to another automobile. There is no particular problem of the amount of speed they are both traveling at. Because you can make a docking relatively easy, can't you?

Mr. ROSEN. That is very true, sir.

The CHAIRMAN. The point is——

Mr. FULTON. They can bump and bounce off with no particular jar.

Mr. ROSEN. Except the——

Mr. FULTON. That is if their courses are not too transverse.

Mr. ROSEN. Yes. In principle, you are certainly right.

However, since you are maneuvering in three dimensions, I think the problem is more difficult.

Mr. FULTON. Now that brings me up to my next point.

You have spoken in your statement in here simply of rendezvous in orbit. Why not rendezvous in straight line flight, leaving the orbit, so that you have either bursts of thrust or a continuous thrust that gives an acceleration, so that one vehicle overtakes the other in continuous straight flight.

How about that?

Mr. ROSEN. It is certainly possible. It is an alternative we have looked at.

It seems to us, however, that an orbit close to the Earth is about the best place to do rendezvous operations, for a number of reasons.

First, it is more easy to observe the operations from the Earth, if you are close to the Earth.

Second, if men are involved, we want them to be able to get back easily. It is easier to get back from an orbit close to the Earth than from far out or when they are traveling at escape velocity.

So merely from an operational point of view, it would appear that a close orbit is about the best place to conduct rendezvous operations.

Mr. FULTON. But the experience we have had in the military has always been a continuous straight line flight on refueling operations, has it not?

Mr. ROSEN. I am sorry, sir. Would you repeat that?

Mr. FULTON. Our experience with the military has always been so far, a continuous straight line flight in fueling operations, has it not?

Mr. ROSEN. Yes. I would like to say that when you are in orbit, it has all the elements of continuous straight line flight.

Mr. FULTON. But the difference, I might say, is this. If you are in an elliptical orbit rather than in annular orbit, you have a varying speed. And to bring those two vehicles together in a coplanar orbit at a different apogee and a different perigee for each is really a good problem in analytical geometry.

If you are in annular orbit, a circular orbit, with the same continuous speed, that is to me one type of a problem. But when you try to intersect two eliptical orbits that are first not coplanar and secondly they don't have the same apogees or perigees, I think you have a much more difficult problem, even though you are just taking a shot at it with an ascent rocket.

Mr. ROSEN. That is very true, the equations of motion and the guidance equations for making an encounter are somewhat complicated.

But you have the great help of the Earth near you. Observations can be made from the surface of the Earth. You can use features of the Earth as a reference.

It seems to us much more difficult to make a rendezvous far out in space than it does close to the surface of the Earth.

Mr. FULTON. My final point is this: Would it be possible to pick a point in space where you know the coordinates and then take an exact point in time and have your vehicles meet at that same exact time and that same point in space at a trajectory that is not too transverse, so you wouldn't get a collision course?

Mr. ROSEN. I would say it would be rather difficult, in the first place, to identify any point in space with coordinates, and second to have two rockets, particularly if the point were some distance from the Earth, reach it at the same time.

Mr. FULTON. That is all, Mr. Chairman.

The CHAIRMAN. Mr. Bell.

Mr. BELL. Mr. Rosen, you indicated that you felt that your budget could be properly increased to $6 million and would be of great benefit for the program on the rendezvous orbital vehicles.

Mr. FULTON. By $6 million?

Mr. BELL. By $6 million.

Didn't I say—I meant to say about $6 million.

Now you also said that you felt that maybe there were other areas which were of more importance that should be, I assume, increased, too. Would you like to tell us what other areas you think should be increased also, that are perhaps more important than this particular orbital rendezvous program?

Mr. ROSEN. That sounds almost like an invitation to review the entire NASA authorization and take care of all my friends in NASA. [Laughter.]

Mr. BELL. I was thinking mostly of areas that are somewhat connected with this project.

Mr. ROSEN. Yes.

The CHAIRMAN. I think in all kindness to the gentleman's question—and I know his inquisitive mind—I think we would be making a mistake on this committee to review it. Because it would just give us trouble later on on the floor.

Mr. FULTON. The question is too good.

Mr. BELL. Mr. Chairman, I withdraw my question.

The CHAIRMAN. I would hesitate. I would want to ask this question, because we have in that bill an increase there, under large vehicle technology, from $15 to $23 million, which is an increase of $8 million, and this money is being given for new in-orbit rendezvous techniques for refueling of spacecraft, advances in the development of maneuverable spacecraft.

Why couldn't that $8 million be used in whole or in part for some of the gentleman's recommendations?

Mr. ROSEN. Mr. Chairman, I am not sure I identify the particular item in the budget you referred to.

The CHAIRMAN. It is under large vehicle technology, an increase from $15 million to $23 million. It is additional money here, which will permit the development of new in-orbit rendezvous techniques for refueling of spacecraft, plus advances in the development of maneuverable spacecraft.

Mr. FULTON. Isn't that your booster program, based on the Saturn project?

The CHAIRMAN. No, it is not based on the Saturn project.

Mr. ROSEN. I think the Chairman is probably referring to the same thing that I am hoping we will obtain.

I was referring initially to our advance technology budget of $15 million, in which $2 million was set aside for orbital rendezvous. I spoke of the desire to have that increased to $8 million.

The CHAIRMAN. Could you use some of this money for that same purpose that you referred to?

Mr. FULTON. Why don't we have them check it and let us have a statement on it? I would rather have that than get something off the cuff.

The CHAIRMAN. Well, all right. Can you do that?

Mr. ROSEN. I will do that.

The CHAIRMAN. All right, let the record show it there. We would like to have an answer within a reasonable time, however.

In answer to Hon. Overton Brooks' (chairman) question regarding additional funds for orbital rendezvous—

With regard to the item on page 85 of House Report No. 391 referred to by the Chairman, it is clearly the intention of the committee that part of the increase in authorized funds would be applicable to the development of orbital rendezvous techniques. In view of this, I wish to reiterate that the additional funds, if we obtain congressional approval of an appropriation bill reflecting the funds authorized by this committee, would substantially strengthen and advance the development of orbital rendezvous techniques.

The CHAIRMAN. Are there any more questions?

(No response.)

The CHAIRMAN. I want to say again that we did have several days of hearings scheduled for this particular purpose here today. But we have cancelled those on account of the press of time.

If there is no further business this morning, then, the committee will stand adjourned.

Mr. ROSEN. Thank you, sir.

Mr. FULTON. When is our bill scheduled, what day?

The CHAIRMAN. The bill is coming up probably Thursday morning. It could come up late Wednesday. Hold yourself in readiness. Stand by.

(Whereupon, at 11:50 a.m., the committee adjourned to meet again at the call of the Chair on another subject.)

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