CENTAUR PROGRAM

HEARINGS

BEFORE THE

SUBCOMMITTEE ON SPACE SCIENCES

OF THE

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SCIENCE AND ASTRONAUTICS
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NOTE.—The chairman of the full committee and the ranking minority member, Hon. Joseph W. Martin, Jr., are ex officio members of all subcommittees.

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CENTAUR PROGRAM

TUESDAY, MAY 15, 1962

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE NO. 3 OF THE
COMMITTEE ON SCIENCE AND ASTRONAUTICS,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 2 p.m., in room 214-B, New House Office Building, Hon. Joseph E. Karth (chairman of the subcommittee) presiding.

Mr. KARTH. The committee will come to order.

Dr. Newell, I want to thank you very much for again taking your time to bring before the subcommittee answers to questions that are in the minds of the subcommittee members, and the members of the full committee, in regard to the problems we seem to have been having for well over a year now in the Centaur program.

Dr. Wernher von Braun, we want to thank you very much for taking time from your busy schedule to appear before the subcommittee.

Dr. Newell, I understand you have some other people who will be assisting you in the testimony you are about to give.

Dr. NEWELL. Yes, Mr. Chairman.

Mr. KARTH. And who will probably be giving us information in addition to that which you intend to give.

Dr. NEWELL. That is correct.

Mr. KARTH. I wonder if you would identify those people for the record and the positions they occupy in this program or in NASA.

Dr. NEWELL. I appreciate the opportunity to introduce some of our people here. Sitting with me is Comdr. William Schubert, who is in the Office of Space Sciences as the Centaur program chief.

Behind me here in the back is A. O. Tischler, who has charge of the Centaur engine.

Of course, you are familiar with Colonel Heaton, who until recently was with the Office of Space Sciences in charge of the Launch Vehicle Office in the Office of Space Sciences.

With us also is Vince Johnson, who is acting in Colonel Heaton's spot as acting director of the launch vehicle group in the Office of Space Sciences.

Mr. KARTH. Fine.

I understand you have a prepared statement you would like to make. Please proceed in any fashion you choose. I'm sure the members will want to ask some questions after you conclude your remarks.

Dr. NEWELL. Thank you, Mr. Chairman.

STATEMENT OF DR. HOMER E. NEWELL, DIRECTOR, OFFICE OF SPACE SCIENCES, NASA; ACCOMPANIED BY DEL TISCHLER, WILLIAM FLEMING, COL. DON HEATON, V. L. JOHNSON, COMDR. WILLIAM SCHUBERT, AND DR. WERNHER VON BRAUN

Dr. NEWELL. Mr. Chairman, I have asked that a chronology of the Centaur program be distributed. I think it might be useful to have this placed in the record if you feel it would be useful.

Mr. KARTH. Doctor, there are no objections, and it will be placed in the record.

(The "Centaur Chronological History" is as follows:)

CENTAUR CHRONOLOGICAL HISTORY

August 28, 1958: ARPA Order 19–59 issued to ARDC for development of a hydrogen fueled upper stage for Atlas. USAF Project Manager assigned at ARDC Headquarters.

October 17, 1958: Contract to Pratt & Whitney (P&W) for 18 engines.

November 19, 1958: Contract to General Dynamics/Astronautics (GD/A) for six upper stage vehicles.

December 1958: 24-hour synchronous orbit mission defined as primary Centaur mission.

May 15, 1959: Contract to GD/A for nine sets of guidance equipment.

May 1959: First firing of P&W combustion chamber.

July 1, 1959: ARPA transfers responsibility for Centaur to NASA. USAF Project Manager continues as Project Manager, and contract administration remains as before with ARDC.

July 28, 1959: Contract let for construction of Complex 36 blockhouse.

August 1959: Centaur Project Office moved to AFBMD, Los Angeles, under Centaur Project Manager reporting to NASA Headquarters.

September 29, 1959: Contract let for launch paid and service building at Complex 36.

October 1959: Project progress reassessed and first launch date changed from January 1961 to June 1961.

November 1959: Centaur Project Technical Team established by NASA to review technical elements of program.

March 1960: Centaur Project Technical Team presents report.

June 1960: MSFC established and Centaur Project Manager formally detailed to duty with MSFC.

July 8, 1960: As a result of technical team evaluation, four additional vehicles were added to development program, and additional deep space missions were included.

August 11, 1960: First guidance set delivered by Minneapolis-Honeywell to GD/A.

August 15, 1960: First ground test engine delivered by P&W to GD/A.

November 6, 1960: First dual test of engines at P&W.

November 7, 1960: Explosion on dual test stand at P&W.

November 15, 1960: Checkout started on vehicle C–1.

January 12, 1961: Second explosion on test stand at P&W.

January 30, 1961: Third explosion on test stand at P&W.

January 1961: First launch rescheduled from June to November 1961.

February 1, 1961: Atlas booster 104D delivered to AMR.

February 27, 1961: Atlas 104D erected on stand.

March 1, 1961: Centaur stage C–2 delivered to AMR.

March 14, 1961: Centaur C–2 mated to Atlas 104D on stand.

May 1, 1961: P&W dual test stand reactivated. Successful test accomplished in May.

August-September 1961: Bulkhead leak problem appeared in Centaur stage C–2.

October 31, 1961: Centaur stage C–1 shipped to AMR.

November 4, 1961: Engine preliminary flight rating test completed successfully.

November 1961: First flight rescheduled from November 1961 to late January 1962 due to checkout and testing slippages and delivery delays.

January 1, 1962: Centaur Project Manager returns to USAF duty. Contract administration transferred from USAF, Los Angeles, to MSFC, Huntsville.

January 4, 1962: MSFC requests GD/A to improve internal CENTAUR organization at GD/A.

January 28, 1962: Flights rescheduled to February due to Atlas programer problems.

January 19, 1962: GD/A establishes project-type organization for Centaur.

February 13, 1962: Flight rescheduled again due to Atlas programer problems.

February 20, 1962: Flight rescheduled due to Centaur programer problems.

March 1962: NASA/DOD agreement on Centaur configuration including study of third stage for 24-hour missions. Third stage study begins.

March 16, 1962: Flight rescheduled due to rerun of FACT (flight acceptance composite test).

March 29, 1962: Flight rescheduled due to squib control circuitry revisions.

April 6, 1962: Flight rescheduled due to replacement of hydrogen vent valves.

April 7, 1962: Flight rescheduled due to weather conditions.

April 11, 1962: Flight rescheduled due to drop in Atlas LOX pressure.

April 20, 1962: Flight rescheduled due to ruptured disk in LOX fill line.

April 21, 1962: Flight rescheduled due to reversal of aft disconnect plate firing plug and firing valve plug.

May 8, 1962: F-1 launched. Vehicle exploded 56 seconds after liftoff. Investigation of flight begun.

Dr. NEWELL. Mr. Chairman and members of the subcommittee, it is my understanding that you are interested in investigating more thoroughly certain aspects of the Centaur launch vehicle development program, specifically:

(1) Effectiveness of the management of the program;
(2) Current validity of the technical decisions that have been made;
(3) Schedule slippages and their causes;
(4) Cost increases and their causes; and
(5) General prospects for future success of the program.

To conserve your time, and to provide you with an integrated view of the program, I will discuss these as briefly and directly as I can, attempting to show their relationship to each other and to the environment of the time period during which the events took place. I will not repeat Colonel Heaton's remarks since these are available to you in the record of his presentation of March 19.

Dr. von Braun, Director of NASA's Marshall Space Flight Center at Huntsville, Ala., is here with me, and, following my presentation, is prepared to describe the results of the first Centaur launch conducted last week and to give you his personal estimate of the present status of the Centaur development program and its prospects for success.

I understand also that General Dynamics/Astronautics, the Centaur systems engineering and vehicle development contractor, and Pratt & Whitney, developers of the Centaur engine, will meet with you later this week. They will be able to provide you with more detailed information regarding some of the things that I will only briefly touch upon in my general presentation today.

I know that you will have many questions to ask following my prepared statement and Dr. von Braun and I will be happy to answer these as frankly and as directly as we can.

When the first Russian sputnik was launched in October 1957, only 4½ years ago, the United States had no genuine space program, although there was a satellite effort underway in connection with the International Geophysical Year. The National Aeronautics and Space Administration did not exist. The Advanced Research Projects Agency had not been established. However, there were thoughtful, imaginative men who came forward with recommendations for salvaging our national prestige by establishing a vigorous space vehicle development program.

Among these was General Dynamics/Astronautics. In December 1957, only 2 months after the electrifying Russian success, Astronautics submitted a proposal to the Air Force to develop a pressure-fed, liquid hydrogen-liquid oxygen upper stage vehicle to be used as a second stage on top of the Atlas ICBM rocket which was then under development at Astronautics. Hydrogen was proposed as the fuel because it was then, as it still is today, recognized as the most practical high-energy fuel available for rocket use. Rocket engines using hydrogen and oxygen as propellants can produce a given thrust for a 40-percent longer time duration than can other engines using the same weight of conventional propellants, such as the kerosene-oxygen combination used in Atlas, Thor, and in the Saturn first stage.

This performance advantage is very important to the efficiency of rocket upper stages designed for high altitude Earth orbits or lunar and planetary missions which require tremendous energy for their accomplishment. By its use, the size and, therefore, the cost of constructing and operating launch vehicles to carry a specified load on such missions can be greatly reduced.

Astronautics' proposal was based upon a pressure-fed design because, at the time, the company was not aware of Pratt & Whitney's development of a liquid hydrogen pump which had reached an advanced stage of development for other defense uses. Hearing of the existence of this pump, and recognizing the inherent weight advantage that a pump-fed system has over one which utilizes compressed gases to feed propellants to the engine, Astronautics revised its proposal and, in August 1958, resubmitted to ARPA a proposal for a hydrogen-oxygen upper stage for Atlas using the Pratt & Whitney pump, substantially the vehicle we now know as Atlas-Centaur. ARPA accepted the proposal and assigned its direction to the Air Force, but, due to a desire to reach flight status as early as possible, and to accomplish this within a budget which was seriously restricted in comparison with the space budgets of today, specified that no more than $36 million could be allocated to the work at Astronautics and that a first flight must be attempted no later than January 1961, 26 months from the date of the contract which was signed in November 1958. No interference to the Atlas program would be permitted. To conserve funds and expedite the program, off-the-shelf equipment and existing Atlas tooling and technology were to be utilized as fully as possible.

An associate contract at $23 million was issued to Pratt & Whitney in October 1958 calling for the development of the hydrogen-oxygen engine. The bootstrap system now used with the Centaur engine was proposed by Pratt & Whitney and accepted by ARPA. It was then, and still is, recognized as a highly efficient engine system, superior in this respect to any other in common use, such as the gas generator or gas pressure feed systems, for engines of this general size class.

Six launches were to be conducted at 1-month intervals beginning in January 1961 and ending in June 1961. The initial contract did not provide for the development of a guidance system, but only for studies of the guidance requirements. No specific missions or payload carrying capabilities for the final vehicle were specified. However, the contractor's calculations regarding the vehicle concept proposed indicated that it might be able to place approximately 1,400 pounds of total load into a 24-hour synchronous orbit. This total had to include, of course, basic payload, payload support equipment, instrumentation, and any contingency reserved for unforeseen setbacks.

Considering current allocations of weight for these additional requirements, the initial estimate was consistent with a useful basic payload of about 1,000 pounds. Thus, the project began with a total commitment of $59 million, although it was recognized that additional funds for guidance development, Atlas boosters, and a suitable launch complex would need to be provided at some later date when the requirements were crystallized.

The Air Force assigned an officer as Centaur project manager, with a supporting staff, located at Air Research and Development Command Headquarters in Washington, and the work began. He was an officer with a long background of experience in the missile field and an intimate knowledge of the then little-known technology of liquid hydrogen and of the Pratt & Whitney hydrogen pump development. This same officer and principal members of his staff remained in direct control of the program almost to the present day, returning to other duties in the Air Force as recently as January 1962. We shall return to this matter later.

Astronautics was at the outset, and still is, charged with systems engineering and integration of the entire vehicle program, including engines.

As the project got underway at Astronautics and at Pratt & Whitney, it was obvious that a specific mission had to be assigned to the vehicle to permit the establishment of a logical technical program, especially the guidance system, which was yet to be placed under contract.

To fill this requirement——

Mr. KARTH. If I may interrupt you there——

Dr. NEWELL. Surely.

Mr. KARTH. What year and what time of the year was this decision made?

Dr. NEWELL. The systems assignment?

Mr. KARTH. When did it become obvious that a specific mission had to be assigned to the vehicle?

Dr. NEWELL. This is picked up immediately in the next paragraph.

Mr. KARTH. All right.

Dr. NEWELL. To fill this requirement, ARPA specified in December 1958 that the primary mission of the vehicle would be the 24-hour equatorial satellite orbit, and it was assumed that this very difficult mission would provide a vehicle which would also be capable of less demanding missions such as low Earth orbits and space probes. We still believe this premise was sound.

Does that answer your question, Mr. Chairman?

Mr. KARTH. Yes.

Dr. NEWELL. Fine.

In May 1959, Astronautics let a subcontract to Minneapolis-Honeywell for the development of the Centaur guidance system and Pratt & Whitney accomplished a successful first firing of the engine's combustion chamber only 7 months after date of contract. By July 1959, Pratt & Whitney had conducted its first successful firing of the complete engine using the bootstrap cycle and turbopump feed system and the contract for construction of the Centaur launch pad at AMR was let.

Meanwhile, NASA had been established by the Congress and after many discussions, the Space Council decided to transfer the Centaur project from ARPA to NASA cognizance, based upon the conviction that more Centaurs would eventually be used in support of NASA missions than DOD missions, as they were foreseen at that time. On July 1, 1959, the program was officially transferred and DOD management and funding of the program ceased. The Air Force project manager remained in charge, however, and merely began taking his direction from NASA Headquarters instead of from ARPA, remaining in his same location at ARDC Headquarters in Washington. To avoid any disruption of the rapidly growing program, the original Air Force contracts were retained and NASA control over the program was exercised through the Air Force Centaur project manager and the Air Force contract administrator located in his office in Washington.

Funds for support of the program were provided through transfer of funds between NASA and the Air Force. This funding arrangement continued until January 1962 and worked very well considering its complexity, the chief disadvantage being that an allocation of funds to the program by NASA Headquarters required a substantial leadtime to be processed prior to reaching the contractor through Air Force channels.

The procurement of Atlas boosters to be used as the first stage of Atlas-Centaur was begun in the fall of 1959 through NASA's transfer of funds to the Air Force Atlas procurement office in Los Angeles, a system still in force today. This was done because it was recognized that a separate NASA procurement of Atlases would tend to complicate and disrupt the smooth flow of Atlas ICBM's for defense purposes off the Astronautics' production line.

Upon NASA's acceptance of responsibility for Centaur, the Centaur Management Coordinating Committee was established with members representing NASA, ARPA, and USAF. The purpose of the group, which still meets at approximately monthly intervals, is to provide interested agencies of the DOD and NASA with a common meeting ground for providing broad guidance to the Centaur development, the success of which is so important to both groups.

In August of 1959, the Air Force Centaur project office was moved from Washington to the Air Force Ballistic Missile Division complex in Los Angeles to provide shorter communication lines between the project office, the vehicle contractor in San Diego, and the Atlas procurement office at AFBMD.

During the winter of 1959–60, the program encountered its first significant difficulty. Pratt & Whitney's development was going very well, but additional funds were found to be required if the established engine delivery schedule was to be met. NASA's overall budget was relatively small at that time, and NASA was understandably concerned with expediting other vehicle programs which promised an earlier U.S. space exploration capability, such as Atlas-Able, Thor-Delta, and Atlas-Vega.

The funds required by Pratt & Whitney were provided too late in the fiscal year to meet Pratt & Whitney's requirements, and it became increasingly apparent that a first launch in January 1961 could not be accomplished. As a result, the first flight was rescheduled to June 1961 and the original 1-month interval between firings was changed to a more realistic 2 months.

Also during the winter of 1959–60, NASA established a Centaur project technical team, composed of technical experts drawn from the various NASA research centers and from headquarters, which undertook a thorough study of the program to recommend ways in which it might be improved. This was done because, with the cancellation in December 1959 of the Vega program, Centaur began to be more than an austere experiment in hydrogen technology; it was now looked upon as the vehicle to carry a specific operational DOD satellite (the Advent 24-hour communication satellite) and the newly defined Mariner and Surveyor spacecraft for NASA's lunar and planetary exploration programs.

This change in the basic character of the program obviously warrented a close scrutiny as to the soundness of its developmental pattern in all respects.

The technical team reported its findings in March 1960. The recommendations included a substantial reinforcement of the ground testing program and zerogravity flight tests beyond those supportable with the original austere budget structure.

The infant NASA organization was undergoing adjustments during this same period. It was decided early in 1960 that Dr. von Braun's Army missile group would become a part of NASA and would act as NASA's agent for the development of launch vehicles. The Von Braun group officially joined NASA as the Marshall Space Flight Center in June 1960 and complete responsibility for the Centaur development was assigned to Marshall at the same time. To integrate administration of the project, the Air Force Centaur project manager at Los Angeles was detailed from the Air Force to official duty with NASA to act as the Marshall Centaur project manager, remaining at Los Angeles, but reporting now to the Von Braun group.

The concurrent analyses of the financial and technical validity of the Centaur program generated, in the summer of 1960, a NASA conviction that substantial reinforcement of this program, whose operational importance was growing steadily, was absolutely essential. Consequently, the 6-vehicle program was extended to 10 vehicles, this being considered an absolute minimum to prove out a vehicle design upon which so much of the national space program was beginning to depend. The importance of the program was further enhanced by the decisions of this period that the nuclear rocket program would utilize liquid hydrogen as propellant, and that the upper stages of the Saturn and Nova vehicles would utilize liquid hydrogen as fuel. In addition, the Centaur was selected as the third stage, designated S–V stage, of Saturn C–1.

The new 10-vehicle development program schedule maintained the first launch in June 1961 as previously, but the additional vehicles added at 2-month intervals extended the completion of the development program from June 1962 to December 1962. The ground test program was substantially increased and zerogravity flights to be flown on Aerobee rockets were added to the program. The new estimated total cost of the 10-vehicle development program became $269 million.

The Pratt & Whitney engine was scheduled to complete its qualification for flight tests in December 1960 to support the June 1961 first launch. Pratt & Whitney had completed 230 successful hot runs of single engines on its horizontal test stands prior to its first attempt on November 6, 1960, to fire two engines in a vertical position together (as in the actual vehicle configuration), using flight-type boost pumps and flight plumbing.

Incidentally, all of the ground tests of Centaur engines at Pratt & Whitney and later at Astronautics' new facilities at Sycamore Canyon outside San Diego, and at the propulsion test vehicle stand at Edwards Air Force Base in California, ultilize steam jet ejector systems as part of the test facility equipment to draw a vacuum on the engine during test, thus simulating the space environment for realistic proof of the engine's design.

The first test of two engines firing together was completed without difficulty. A faulty timer prematurely shut off the engines after 6 seconds of running time instead of the 15 seconds that was planned. But no damage to the engines or facility resulted.

On the next attempt, the following day, one engine ignited properly and the other did not. Accumulated propellants from the nonignited engine exploded when ignited by the engine that did fire properly.

A procedural error was made by test personnel, and this was believed to be the cause of the explosion. It was not until two more explosions had occurred in January 1961 that emergency investigations by the engine contractor established that the true cause was that insufficient oxygen for ignition was being presented to the spark igniter when the engines were mounted vertically, despite the previous 230 successful ignitions in the horizontal position.

Once the cause was analyzed, the fix was easy. A small oxygen bleed now serves the ignition process, and we have experienced not one ignition failure in over 700 hot firings vertical and horizontal conducted since the third explosion. We consider that this problem has been solved.

The explosions at Pratt & Whitney had a substantial effect on our schedule. Whereas qualification for flight was to have been completed in December 1960 and engines delivered in January 1961 to support Centaur's first launch in June 1961, engines for the first flight could not be delivered with the corrected ignition system until June 1961, thus slipping our first flight from June to November 1961. Because these engines had not been flight qualified by ground testing, it was decided to make the first launch along a ballistic trajectory, reserving an engine start attempt until near the end of the flight so that any malfunction of the engine, if it occurred, would not cause us to lose the other important objectives; namely, satisfactory separation of insulation panels and nose fairing, satisfactory separation of Centaur from Atlas, orientation of Centaur bottom end toward the sun, and observation of zerogravity behavior of the liquid hydrogen in the vehicle through a televised image.

In February 1961, the Atlas to be used for the first launch was delivered to Cape Canaveral on time to support the intended June

1961 first launch. Since the Centaur stage would not now be ready to fly in June, we sent the second Centaur to the cape prior to its completion and mounted it on the Atlas, making productive use of the unavoidable delay time to match the upper stage with the lower stage electrically and mechanically, to match the entire vehicle with the new launch complex which had never been used before, to generally debug the vehicle and the ground support equipment, to practice loading and unloading propellants into the Centaur, and to allow the new launch crew to practice its countdown procedures.

During these tests in the summer and early fall of 1961, the first evidence appeared that the heat transfer rate across the intermediate bulkhead, separating Centaur's oxygen and hydrogen tanks, was unacceptably high. Something had to be done about it or the vehicle would be incapable of carrying its assigned missions: Advent, Mariner, and Surveyor.

In addition, we had been aware since late 1960 that Advent spacecraft weights were turning out to be heavier than the Centaur could carry even if the bulkhead problem did not exist.

These major technical problems were discussed at length in the Centaur Management Coordinating Committee and within the project itself and culminated in a substantial reprograming action which is only now being completely defined.

Meanwhile, the first flight Centaur completed its cold practice runs at Sycamore Canyon somewhat behind schedule in October 1961 and was delivered to the cape to be mated with Atlas in early November. The 2 months required at the cape for vehicle checkout threw the first launch into late December on the schedule.

In the course of this checkout, we encountered numerous problems with the complex and with the vehicle, getting them ready for launch. As you know, the vehicle was launched on May 8, and failed less than 60 seconds after lift-off.

As always in such cases, an immediate and intensive investigation was initiated by the Marshall Space Flight Center and the contractors involved. Dr. von Braun will tell you about the events leading up to the launch and give you the results so far of this investigation.

On January 1, 1962, pursuant to an agreement with DOD, we transferred the Centaur project office from Los Angeles to Huntsville, and converted the Air Force contracts into NASA contracts, in a program to clean up and streamline the administration of the project. The Air Force officer who had managed the project since its inception returned to his military duties. A new civilian manager has been named at Huntsville.

Also, under strong urging from NASA, Astronautics converted, early in 1962, its internal organization from the traditional matrix organization wherein a project office utilizes personnel located elsewhere under functional department heads, to a projectized organization wherein approximately 1,000 people at Astronautics were brought together under the immediate line authority and supervision of the Centaur program director who is also a vice president of Astronautics. We are convinced that this move will improve the strength of the program from a management standpoint, with resulting benefits technically.

Today, our 2d launch is expected to be accomplished in October 1962, and a 3d at the end of the year, with the 10th launch occurring early 1964. This is a very tight schedule, but we will make every effort to meet it; it is the schedule upon which the Advent, Mariner, and Surveyor people are currently planning their own development programs.

As we now view it, and this new look is based upon a DOD-NASA agreement of early March 1962, the program will pursue a vigorous effort to solve the intermediate bulkhead heat transfer problem, which is amenable to a variety of solutions we will be trying out on the ground in the next few weeks and months; the Centaur will be changed to accommodate only two engine firings in flight, rather than the three originally planned, thus relieving the vehicle of the requirement for a 6-hour coast between second and third burns on the Advent mission; a new third stage or "kick" stage, probably the Surveyor bus, will be provided to substitute for the third burn of Centaur; the ground test program will be increased; the reliability program will be increased; and a second launch pad will be provided for use beginning in 1964 to accommodate the expected 12-per-year launch rate of the operational vehicles following the development phase.

Current estimates are that this will provide a vehicle capable of meeting the payload carrying capability requirements of Advent, Mariner, Surveyor, and others in the 1964 period and beyond.

The entire 10-vehicle development program is currently estimated to cost a total of at least $350 million, of which some $202 million will have been obligated by the Government by the end of June 1962. This total goes beyond the ARPA budget of October 1958, but it should be recognized that the content of the program has also been greatly increased to a level commensurate with what the vehicle is now expected to do in support of a wide variety of important space projects. Moreover, this figure exceeds the $300 million estimate provided to you by Colonel Heaton on March 19. At the time of his presentation, we had not completed our analysis of the additional costs occasioned by the program reorientation decisions of early March 1962 that I described a few moments ago. This analysis has now been completed and resulted in the figure I am quoting today.

While the total cost may appear large in its own context, it is worth noting that the cost is small indeed compared to the cost of any one of our ballistic missiles. We feel the program is now on a sound technical and management footing, as opposed to its early austerity, and will succeed.

There are, of course, technical troubles yet to be met which we do not foresee even now and will not see until we encounter them in future ground tests and in flights. But that, after all, is the purpose of the development program, including the first 10 flights—to uncover problems and then to solve them.

As the Centaur technical program has developed from an austere feasibility investigation to its present status as a major vehicle development aimed at an operational vehicle for highly important space missions, the management of the program has also developed.

The present management, including a well staffed and supported project group at the Marshall Space Flight Center, and project-type organizations in the major contractors, is fully capable of efficiently directing the program.

To summarize:

(1) Centaur started as a financially austere, low-priority experiment in liquid hydrogen for space use.

(2) Its important to the national space program has steadily increased and is now at a high level.

(3) Taming liquid hydrogen to the point where expensive operational space missions can be committeed to it has turned out to be more difficult than anyone supposed at the outset.

(4) NASA has successfully come through its growing pains as a new organization in the Government, and now has a management organization for the Centaur project which is capable of the successful completion of the development program.

(5) The Centaur engine, which encountered testing difficulties in late 1960 and early 1961, is now a highly dependable engine and has completed over 700 consecutive successful hot firings. It has been selected to power the Saturn S–IV stage as well as Centaur.

(6) Between $150 and $200 million more will complete the development satisfactorily, although quite a bit later than was originally thought.

And as I mentioned at the beginning, Mr. Chairman, Dr. von Braun is here to give you his analysis of the events related to the first flight and his prognosis for the program.

Thank you.

Mr. KARTH. Thank you very much, Doctor.

Would you like to proceed now with Dr. von Braun's prepared statement? I would hesitate to offer the committee the opportunity to question at this time because it may get rather lengthy. It seems to me that you should get all of your prepared testimony in, and then the committee members may direct their questions at you or Dr. Wernher von Braun or anyone else that you may have at your side.

Dr. NEWELL. Let us do it that way, then. It seems very reasonable.

Mr. KARTH. Who next to do you have, Doctor?

Dr. NEWELL. Dr. von Braun.

Mr. KARTH. Dr. von Braun, would you take the Centaur seat, please? Do you have a prepared statement?

STATEMENT OF DR. WERNHER VON BRAUN, DIRECTOR, GEORGE C. MARSHALL SPACE FLIGHT CENTER, NASA; ACCOMPANIED BY DR. HANS HUETER, DIRECTOR, LIGHT AND MEDIUM VEHICLE OFFICE

Dr. VON BRAUN. Mr. Chairman, I have a prepared statement, I suggest I read it first and then have some questions.

Mr. KARTH. OK, Doctor. If you will proceed.

Dr. von Braun. With your permission, I brought with me Dr. Hans Hueter, who is director of the Light and Medium Vehicle Office at the Marshall Space Flight Center.

Mr. Karth. Doctor, we are glad to have you with us.

Dr. von Braun. Until very recently Mr. Hueter was program director for both the Agena and the Centaur program, with the Air Force officer repeatedly referred to in Dr. Newell's statement being his deputy for Centaur.

On January 1 this Air Force officer, as Dr. Newell pointed out, returned to active duty with the Air Force and we had to reorganize the Centaur office somewhat. We appointed a new man, Mr. Francis Evans, as project manager of the Centaur project, and he reports to Dr. Hans Hueter direct.

Mr. Karth. Fine. Thank you.

Dr. von Braun. I would now like to read my formal statement.

Mr. Chairman and gentlemen, in this presentation I will review the first flight of the two-stage Atlas-Centaur space vehicle which occurred on May 8 this year. The flight was prematurely terminated as a result of failure of the upper stage. The cause of the failure has not yet been ascertained.

At this time both the Marshall Space Flight Center and General Dynamics/Astronautics, are in the process of detailed analysis and evaluation. Before I go into some of the details of what occurred during flight, I would like to give you a short summary of the mission assigned to F–1, which is our nomenclature for the first Centaur flight, and the history of this particular flight. I do not intend to cover the various program delays discussed previously, but rather the history of the first Centaur missile after it arrived at the Atlantic Missile Range in October 1961.

The Atlas first stage had been at the Atlantic Missile Range since February 1961 together with an unfinished Centaur stage for validation of the launch and checkout facilities. A number of hardware shortages, mainly spare parts, and technical difficulties encountered during vehicle testing and checkout delayed the launch until May. Several launch attempts during the period April to May had to be called off due to either minor technical difficulties which turned up during the countdown and had to be corrected or because of wind conditions prevailing at the Cape at the time.

The F–1 Centaur was launched at 1449 hours e.s.t. on May 8. Operation of all systems appeared normal until approximately 44 seconds after liftoff when temperature measurements on the quadrant I–II insulation panel weather shields on the Centaur indicated an open circuit. Telemetry and film data indicate progressive deterioration after 44 seconds until airframe failure and loss of telemetry of the Centaur stage at 54-plus seconds. Atlas operations failed subsequently at approximately 56.9 seconds.

The exact failure mode or cause has not been determined. A total of 384 measurements were instrumented on the Centaur vehicle. Preliminary analysis indicates that all but five provided satisfactory data. A total of 51 special structural measurements were made during the flight. Generally, data quality was good until the incident at 54 seconds.

The basic objectives of the F–1 flight which was to fly a ballistic trajectory with a flight time of 15 minutes were to—

(*a*) Integrate and prove the performance of the Atlas/Centaur system and the ground-support equipment.

(*b*) Study the inflight performance and evaluate structural integrity of the Atlas/Centaur from launch through separation.

(*c*) Obtain data on Centaur system operations during a short zero-g coast phase as well.

Flight evaluation is not complete at this time; however, significant steps forward have been made in the Centaur program which is the first space vehicle to employ hydrogen. Many vehicle and ground-support equipment system integration problems have been solved and basic engineering needs for handling and launching of a vehicle which uses liquid hydrogen have been proven.

The preliminary evaluation of flight information indicates all Atlas stage systems and the operating systems of the Centaur stage performed normally—Centaur operations including flight control measurements, guidance system performance, electrical systems, and telemetry systems including TV coverage of the interior of the hydrogen tank were normal.

Preliminary evaluation of telemetered data and film indicates premature loss of sections of the insulation which protect the cryogenic propellants of the Centaur stage against aerodynamic heat influx during the ascent period. Whether this relates or how it relates to the final failure of the Centaur stage is not yet known.

A thorough and complete evaluation is currently being made by General Dynamics/Astronautics. All information—telemetry and film—is being analyzed and tests and investigations are being made to isolate the failure or failures and the causes for the failures.

At the Marshall Space Flight Center, the telemetry and film data are being reviewed and studied to back up the findings by General Dynamics/Astronautics. Separate investigating groups are being formed to make evaluations in any particular area of technology as it is isolated to be a concern.

Results of the flight of F–1 at this time do not indicate any major changes to the design, production, and scheduled launch of F–2. No doubt, design changes will be implemented as a result of the complete evaluation of F–1 flight but it is anticipated that such changes will be made on a timely basis.

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The premature termination of the flight was certainly unfortunate and disappointing. However, in spite of all design analysis and ground testing, a number of uncertainties always exist which one has to investigate by flying a certain number of R. & D. flights. Inevitably, these result in some failures.

Dr. von Braun. Mr. Chairman, we brought a film along which will last a few minutes, and with your permission we would like to show it to you. It shows the flight of F–1 from lift-off to the explosion.

Mr. Karth. All right Doctor. Let's do it at this time.

Dr. Hueter. Could you hold a minute. It might be good that you observe this upper part at about 45 seconds when the explosion starts. Before this you see a big cloud developing out of the base of the nose cone and then shortly after you see the explosion.

Mr. Karth. Thank you, Doctor.

Dr. von Braun. I will ask Dr. Hueter to do a little narrating so you will see what is happening.

(Film starts.)

Dr. Hueter. This is the step where the hydrogen gas vents into the atmosphere. The hydrogen gas continues evaporating. This pattern here indicates whether we have a roll movement or not and you will notice during all the flight that the attitude was kept with no deviations in roll or in yaw, but only in pitch as programed. Later on you will notice that the hydrogen vapor is coming out here at the base before the explosion. Also you might observe this area [indicating] where shortly before the explosion a dark spot will develop.

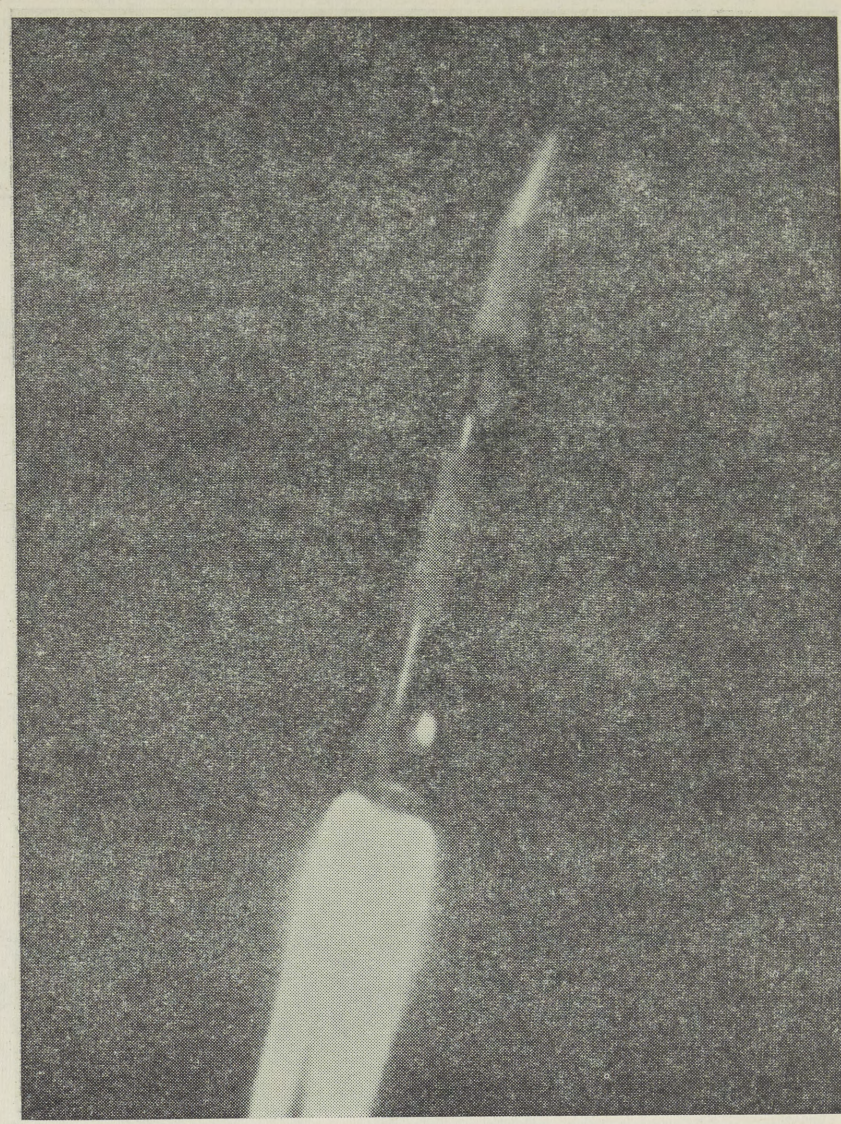
What you cannot see in this film is that the weather shield which connects the insulation panels with the nose cone is flying off, which might or might not be a cause for the explosion later on.

This is the hydrogen vent. You see vapor coming down which is starting after 30 seconds. Up to 30 seconds the hydrogen tank was closed, after 30 seconds on account of the pressure accumulated, the vent was opened.

You might now observe this area here where a small dark spot is developing. It goes awfully fast on this film. I think you can cut it off because the rest of it is quite uninteresting.

In order to explain a little bit more what happened we have a set of slides. In case you are interested we can explain how the steam cloud is developing, also on the second series you see some parts flying away not very clearly.

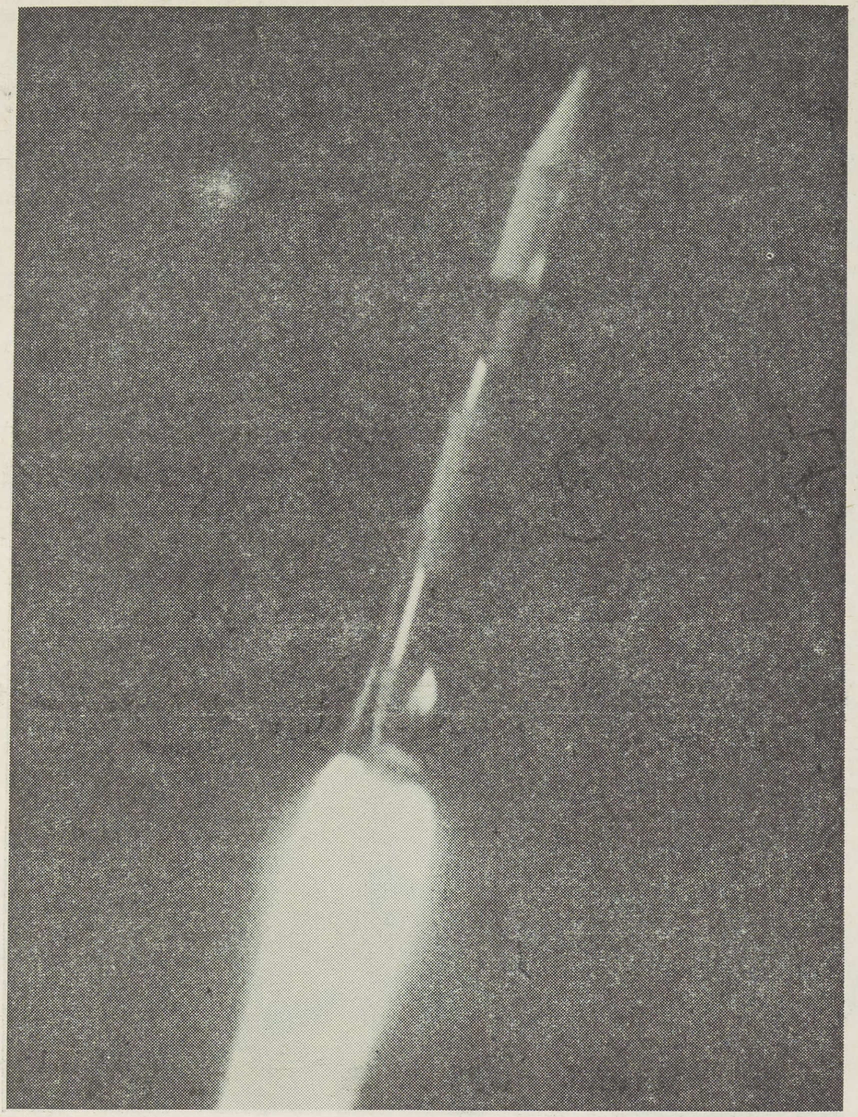
(Slides were shown.)



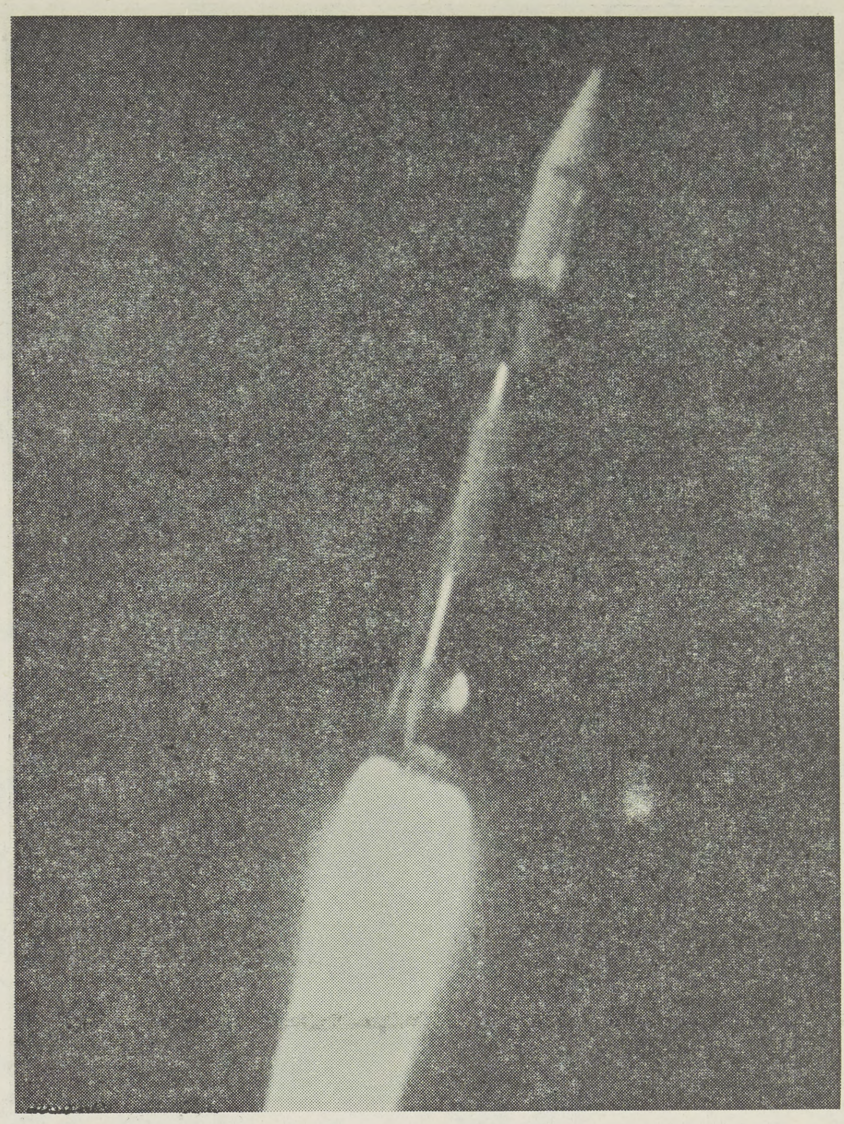
This shows the general shape. I think you have to watch this area here. In this area later on a dark cloud will develop.

This part which you see here is one of the tunnels connecting the upper part of the Centaur with the lower one.

Next slide, please.

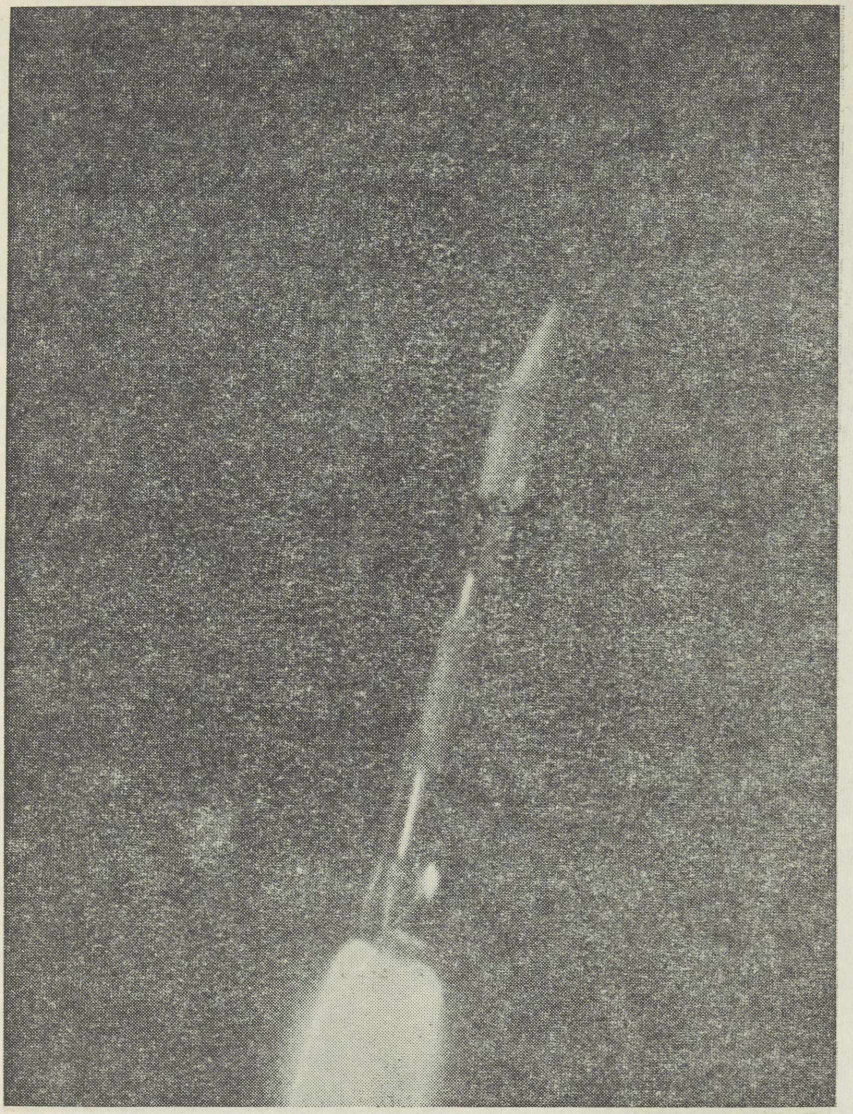


You see here a small dark spot forming.
Next slide, please.

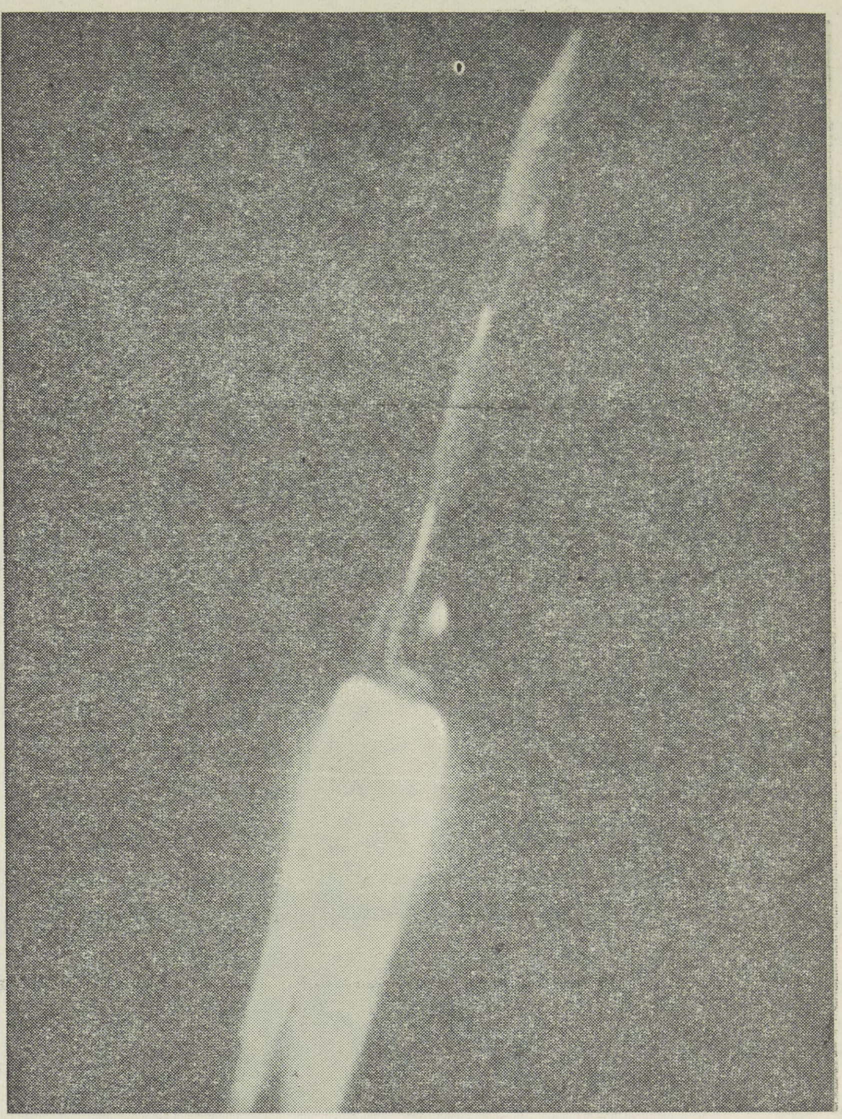


It is becoming larger. The white spot on the left side is the hydrogen vent.

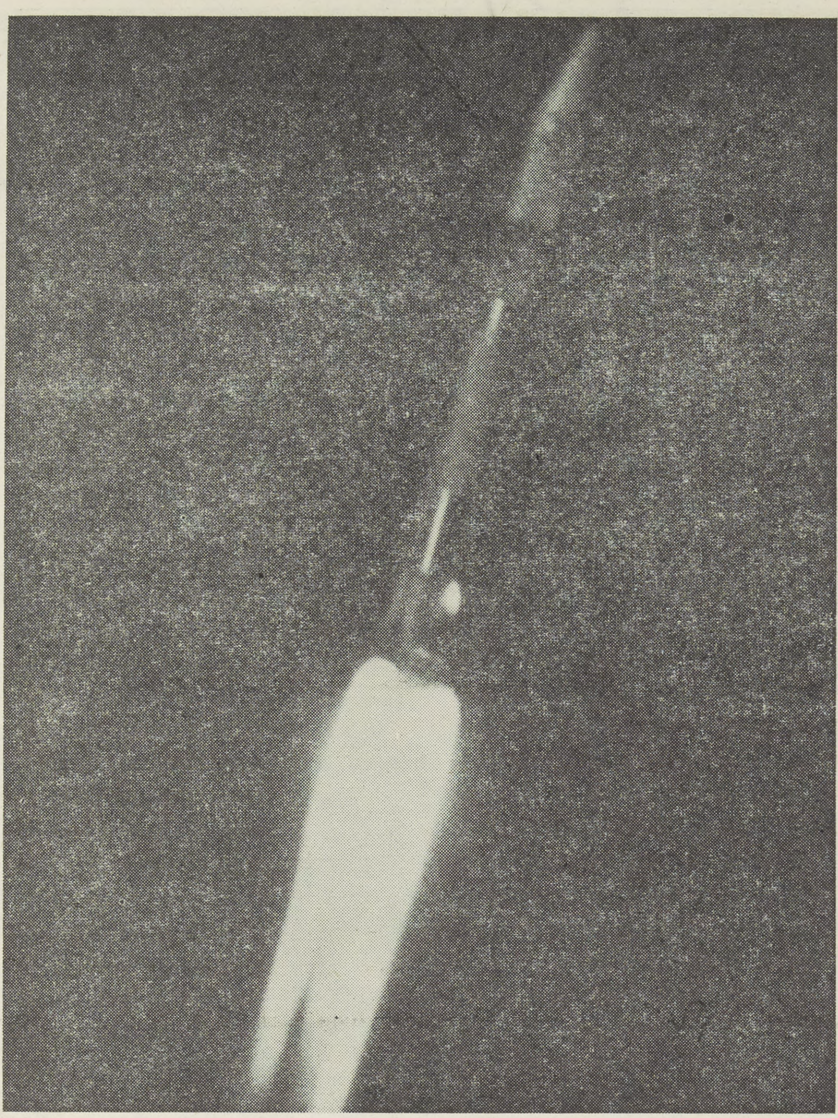
Next slide, please.



It is still becoming larger and extends to the left.
Next slide, please.



Now we see this spot developing downward.
Next slide.



The area is very large which might be partially destroyed. Insulation panels and also vapor coming out.

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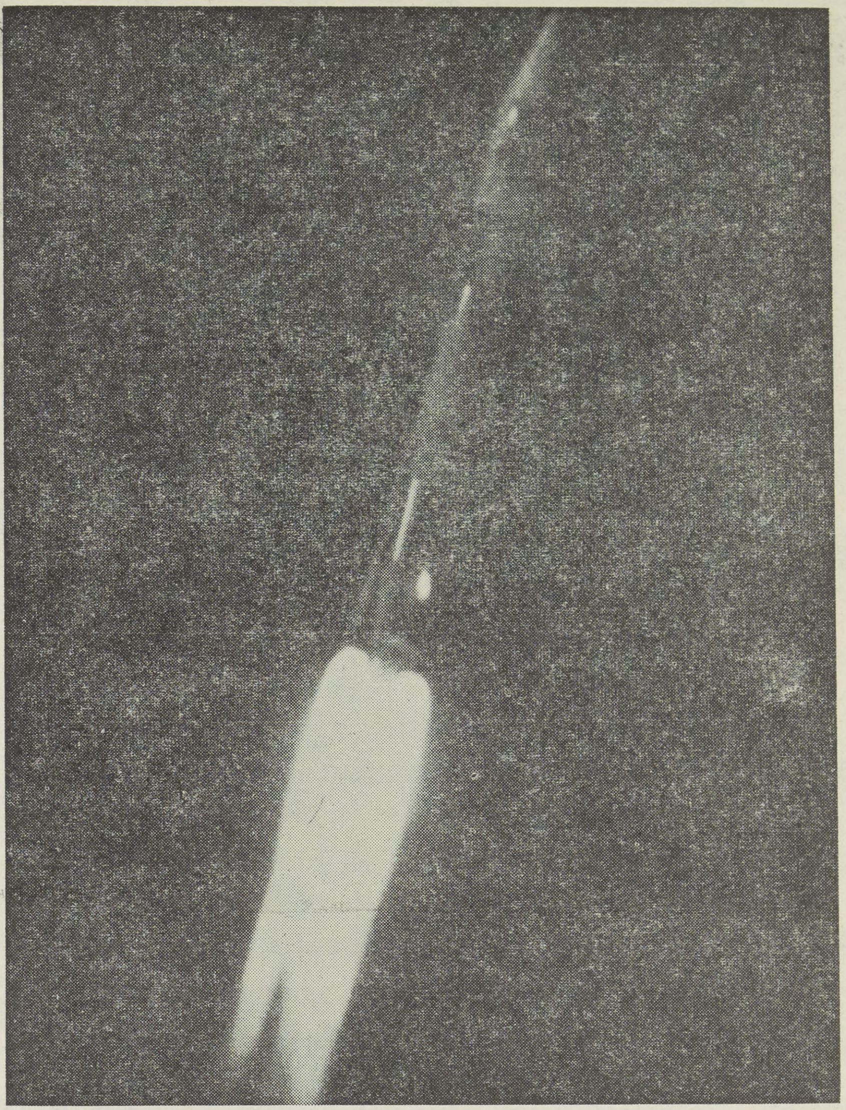
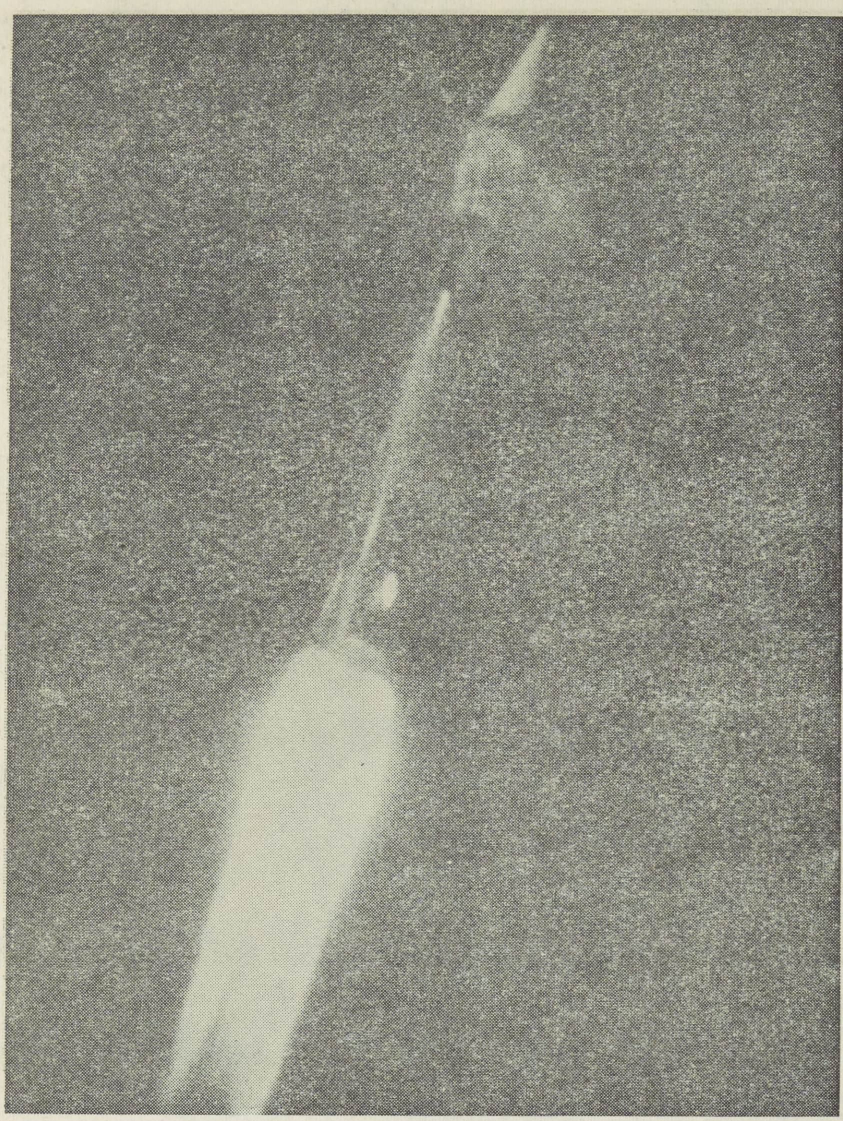
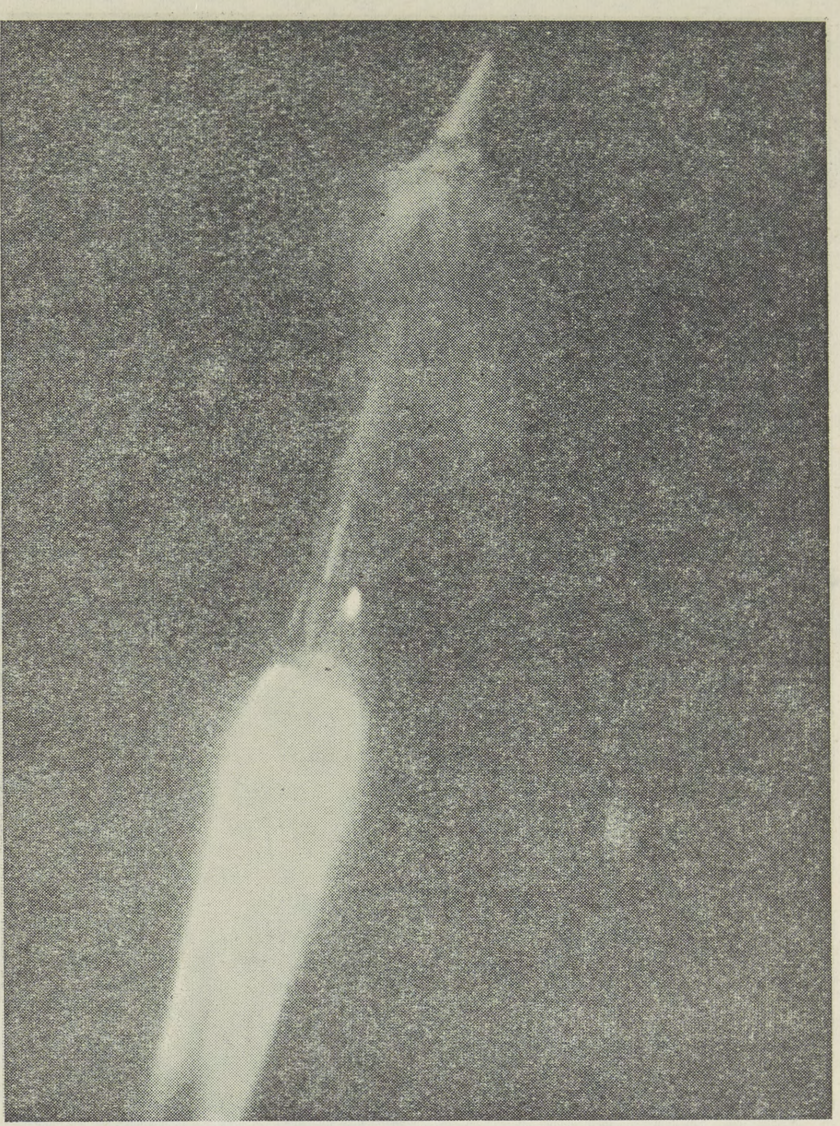


This is hydrogen vapor coming out of the upper part.
Next slide.



The same thing here, the vapor is spreading over all the periphery. Next slide, please.



Now you will see that the upper part of the tank has opened up. You see hydrogen vapor coming out over the whole circumference of the Centaur second stage. You will notice that the nose cone is tilting slightly to the left.

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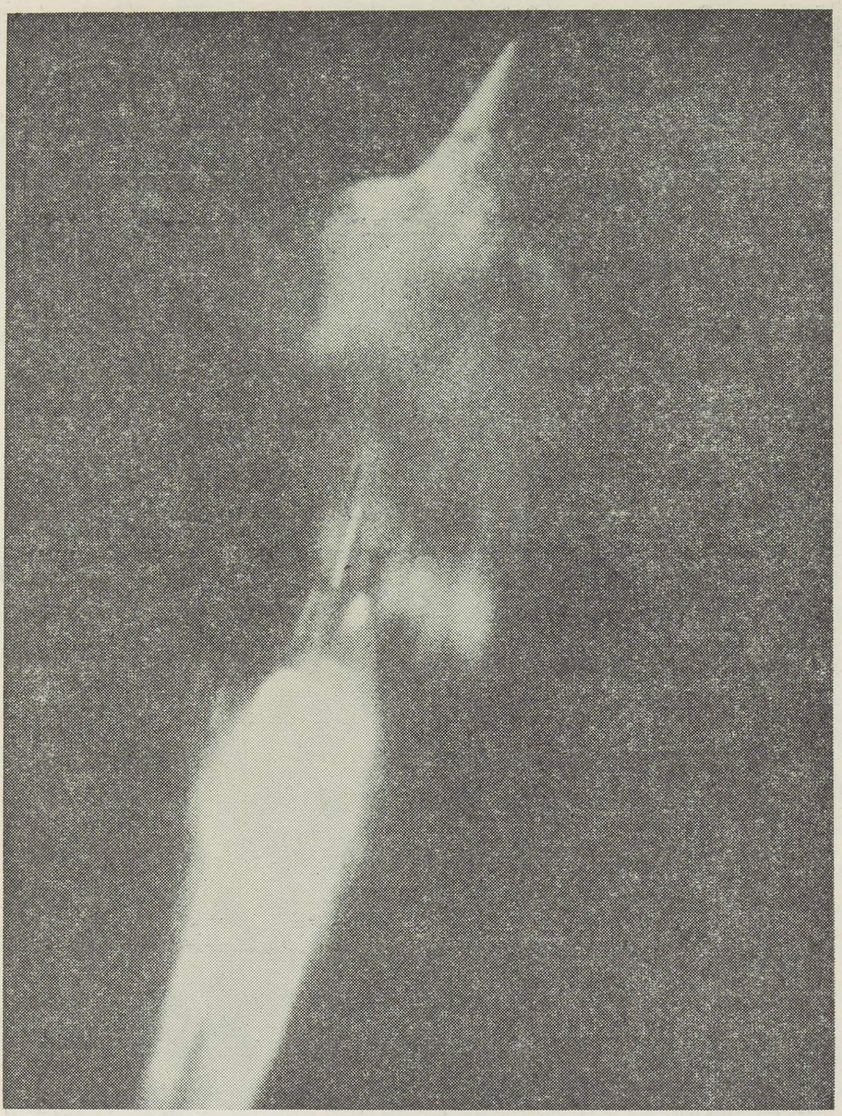
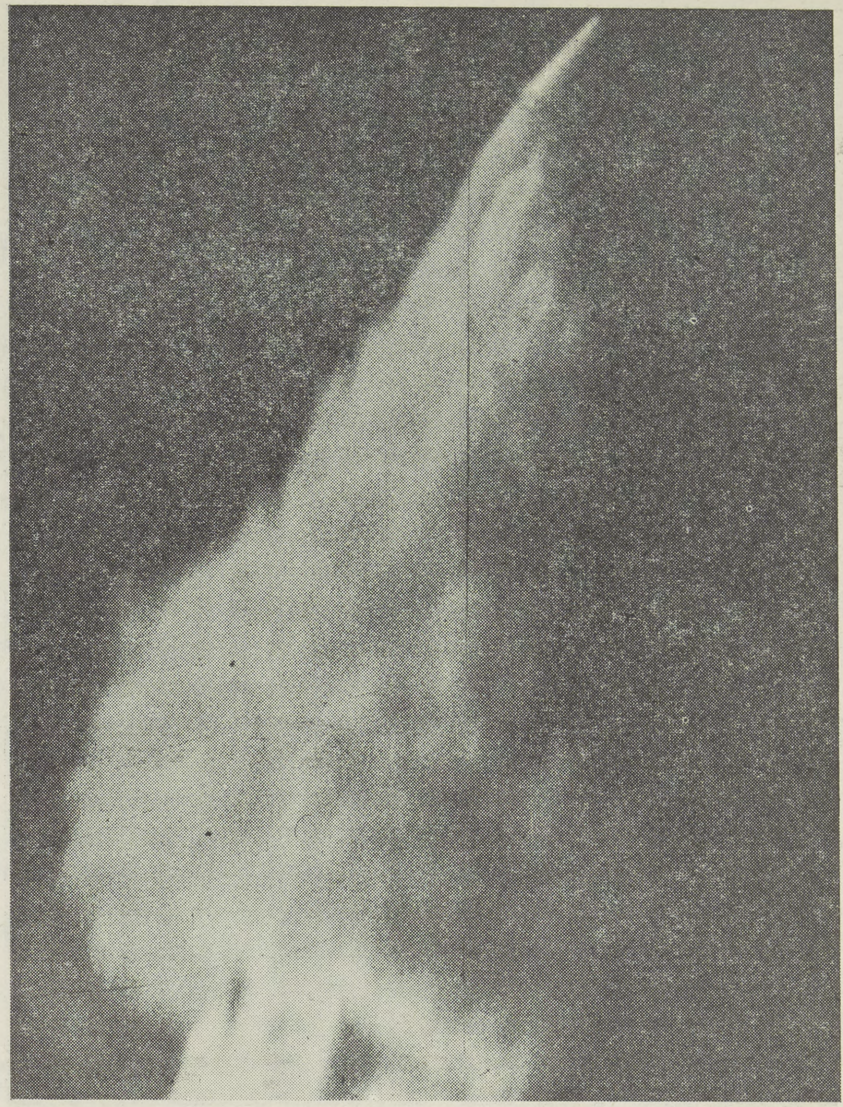


Now the flow of hydrogen downward is quite visible.

Next slide, please.

When you see the picture the first time you wonder why you don't see flame immediately.

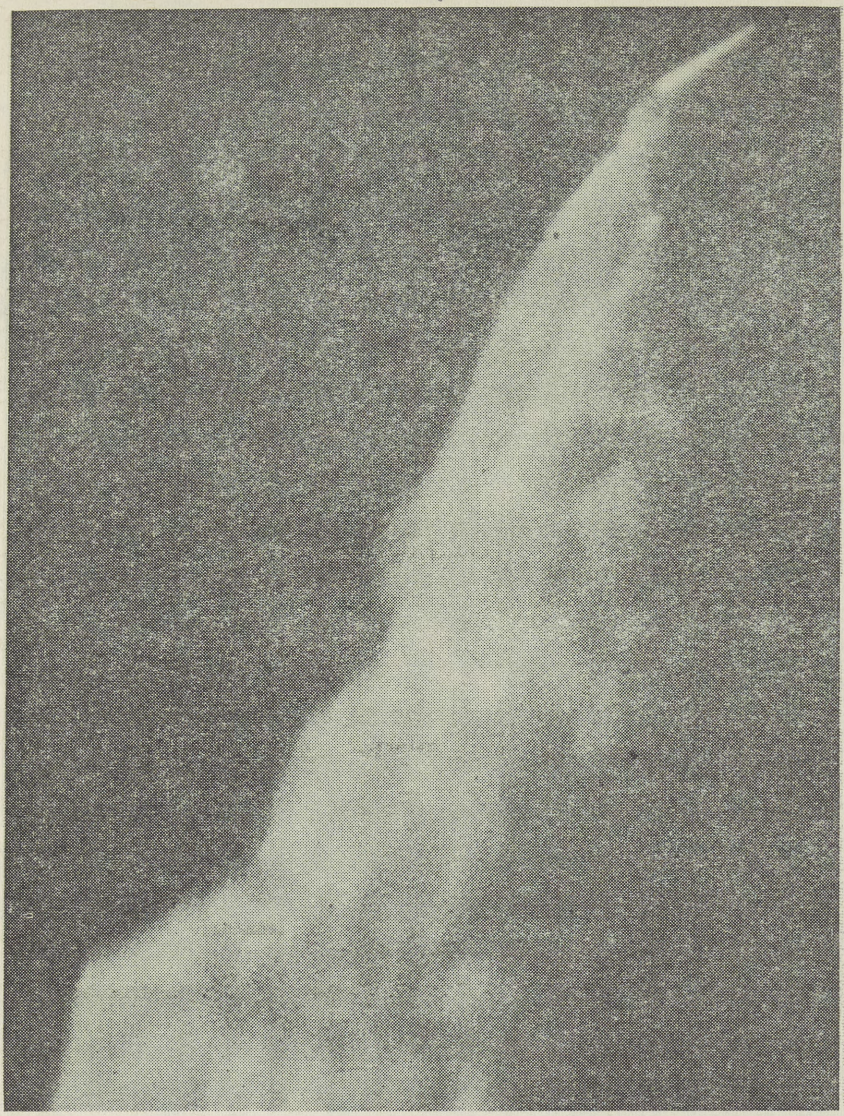


You see even the clouds coming down to the vernier engine and the main engine of the Atlas, and since we are still in relatively dense atmosphere you could expect that the whole thing explodes much earlier being ignited by the exhaust flames. But very probably the hydrogen is expanding much more forward. What you see down here is only the condensation of the moisture in the air.

You still see this big vapor cloud and still no explosion on the Centaur, but you see the nose cone is considerably tilted.

Now the whole missile is enveloped.

Next slide, please.



I think the next picture is the explosion. As far as the explosion is concerned, it is interesting that the explosion started in the middle of the Centaur, very probably since by that time the structure is quite destroyed and the LOX tank is opening up and we have an explosive mixture. This is in the middle of the Centaur.

Mr. KARTH. Doctor, we have been aware of the fact that we have had three specific problem areas with this vehicle, (1) the ignition of the engines, (2) the electrical mating, and (3) the hydrogen leaks in the bulkhead between the tanks.

Now, is it your opinion that any one of these three problem areas caused the failure of the first test flight, or do you think it is something other than the three major problem areas that we have experienced ever since we started with Centaur?

Dr. VON BRAUN. It may be a little premature at this time to make a final statement, but all indications are that what happened here is that part of the insulation was destroyed, rose to the transsonic speed, thereby exposing part of the hydrogen tank through the aerodynamic slipstream outside. So it was actually a structural failure of a heat insulation panel that initiated the whole failure.

Mr. KARTH. And this was close to the time when it was reaching its maximum Q, isn't that correct? Maximum Q was reached at about 50 seconds, and at what stage did the Centaur blow up?

Dr. VON BRAUN. It was very shortly before passing mach 1 sound speed.

Dr. HUETER. I think the maximum Q was around 57 seconds, and this happened around 50 seconds.

Mr. KARTH. The maximum is reached at what time?

Dr. VON BRAUN. Seven seconds later.

Dr. HUETER. The explosion happened at 54.7 seconds and the destruction apparently happened at around 50 seconds. The explosion is at approximately mach .98.

Mr. KARTH. So you are considering a structural failure, I suppose, at this time.

Dr. VON BRAUN. When a large rocket approaches sound speed it is always somewhat critical from the point of view of aerodynamic buffeting. Even our astronauts reported in the Atlas flights that there was a period of rough going, as they put it. Once this period was safely passed, things smoothed down again.

Mr. KARTH. Doctor, I notice in your testimony on page 1 that the latest delay was caused by a number of hardware shortages, mainly spare parts. Who is responsible for this? You mean we had no spare parts for the Centaur vehicle?

Dr. VON BRAUN. This had something to do with the funding level available for the program. As was pointed out by Dr. Newell, this whole program started as a shoestring program and grew gradually from what was originally a feasibility demonstration of flying a liquid hydrogen upper stage into a full-blown program supporting a great number of NASA space exploration missions. The program probably grew a little faster than the funding reserves backing it up and as a result we were always short of spare parts early in the program.

This situation has been remedied. In the meantime, we are still suffering from the aftereffects of this situation.

Mr. KARTH. I want to go back just a little earlier than the last half hour of testimony. Who chose Pratt & Whitney originally as the engine contractor?

Commander SCHUBERT. If I may answer that.

Mr. KARTH. Commander Schubert.

Commander SCHUBERT. It is our understanding, although none of us here was associated with the program at that time, that the choice of astronautics for the vehicle integration and vehicle development work, and the choice of Pratt & Whitney as the associate contractor for the engine were made by the Advanced Research Projects Agency as part of their administration of this program at that time.

Mr. KARTH. How much experience did Pratt & Whitney have with rocket engines at the time that they were chosen to be the engine contractor? Could you tell the committee?

Commander SCHUBERT. Well, it is my understanding that they had never built a large rocket engine before that time. However, they did have qualifications which other contractors in the country did not have in respect to this particular problem, namely long experience in the utilization and storage of liquid hydrogen in connection with previous non-rocket-type programs for the Department of Defense.

Mr. KARTH. Let me ask you this: Did that ever develop as a major problem area? I mean is that one of the areas that we have had difficulty with?

Commander SCHUBERT. Yes, sir; I would say that is one of the major problems of this program.

Mr. KARTH. Handling of the hydrogen.

Commander SCHUBERT. The handling even on the ground of liquid hydrogen is a problem although we haven't any great trouble in that area.

Mr. KARTH. You haven't experienced any delays as a result of the problem in this area, have you?

Commander SCHUBERT. No, sir, not that I know of.

Mr. KARTH. How much time was lost as a result of Pratt & Whitney having to develop a learning curve in this area of rocket engine development?

Commander SCHUBERT. I would say we haven't lost any substantial time on that account. They came into the program as one of the few industrial contractors with knowledge in this area.

Mr. KARTH. Not in the manufacture of rocket engines, though.

Commander SCHUBERT. No, sir; but in the hydrogen technology which was perhaps the more advanced element of the program as distinguished from the mere construction of combustion chambers as such. They had built a successful hydrogen pump as was mentioned, prior to their entrance into the program. This was, we felt, a leg up on the problem, that being an important component of the entire engine.

Mr. KARTH. Who was the director of the Centaur program at that time?

Commander SCHUBERT. Lieutenant Colonel Seaberg, the Air Force Centaur project manager, was assigned to the project at the outset and remained with it until this last January.

Dr. NEWELL. Mr. Chairman.

Mr. KARTH. Dr. Newell?

Dr. NEWELL. It is my understanding from my rocket engineering friends that the development of an engine of this type from start to successful proving in of the engine in 3 years is quite a good accomplishment. So this would seem to bear out Commander Schubert's comments here. Not much time has been lost.

Mr. KARTH. Well, most of the programs have been done in that time or less, haven't they, Dr. Newell?

Dr. NEWELL. I must turn to the rocket people.

Mr. KARTH. I am talking about engine developments, booster systems. How long, Doctor, has it taken you to develop Saturn to the stage where you now have it? To the best of my recollection we haven't had a failure.

Dr. VON BRAUN. The engine we use in the Saturn is actually about 6 years old. We are still improving it today. But Pratt & Whitney's record in developing this A-3 engine, RL-10 as we call it, is actually quite remarkable. They have had their setbacks, but they did remarkably well considering the fact they never developed a rocket engine before. I can only confirm what Commander Schubert said here. At the outset, most people agreed once you can get liquid hydrogen and liquid oxygen in a combustion chamber your problems are over.

The problem is to get them to that point. So the emphasis was really on handling and fueling and these kinds of things and Pratt & Whitney had developed a hydrogen-powered aircraft turbojet engine for the Air Force which gave them quite a little bit of background in this particular area, in the opinion of our people at that time, it weighed at least as heavily in their favor as the lack of rocket engine development weighed against them.

Mr. KARTH. Doctor, how long did Colonel Heaton act as the project manager for Centaur?

Commander SCHUBERT. I think I answered that, sir. Until January of this year.

Mr. HAMMILL. No; the chairman is inquiring about Colonel Heaton, not Colonel Seaberg.

Commander SCHUBERT. I am sorry.

Dr. VON BRAUN. I have the exact chronology here.

Dr. NEWELL. The question perhaps implies a misconception. Colonel Heaton has been in charge of the launch vehicle group, but the project manager for Centaur has been the Marshall Space Flight Center shortly after we took it over. So we had first Colonel Seaberg, and then Colonel Seaberg reporting to Marshall during the transition phase and then from that point on Marshall Space Flight Center.

Mr. KARTH. So you had what, three different managers? Use your own language for the nomenclature, but is it fair to say three different managers of the Centaur project, Dr. Newell?

Dr. VON BRAUN. Colonel Seaberg came on board right at the outset. He was actually appointed Centaur project manager when ARPA established the program and gave the Air Force program management. He handled this at first out of his office at ARDC in Washington, then later he was transferred locally to the Space Systems Division in Los Angeles, but still with his entire staff and as an Air Force officer, and when NASA took over the Centaur management, he was kept on board working for NASA.

NASA took over Centaur management about a year before we became Marshall Center. Our Huntsville organization used to be an Army installation until the first of July 1960, and the assignment of the Centaur project to NASA took place about a year earlier.

Dr. HUETER. First July 1959.

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Dr. von Braun. Exactly 1 year earlier.

At this time Colonel Seaberg reported to Mr. Milton Rosen, who was Launch Vehicle Director at NASA. When we became an element of NASA and General Ostrander was appointed head of the launch vehicle development, he said, "I want a field center to run these projects."

So Colonel Seaberg was attached to Marshall. But at the same time it was quite clear that he would retain management, and so he stayed in Los Angeles and actually ran the program out of Los Angeles. So as far as the Centaur program management is concerned, there was very little change. He was in it right from the beginning and actually stepped out only on the 1st of January 1962. However, the people to whom he reported changed several times.

Mr. Karth. In other words, the headquarters people changed several times?

Dr. von Braun. Yes.

Dr. Newell. Yes.

Mr. Karth. Why don't you just follow this sequence very briefly for the record?

Dr. von Braun. Do you want me to read a chronological sequence of how this developed?

Mr. Karth. Is this what you are talking about, the chronological sequence?

Dr. Newell. Yes.

Mr. Karth. That marked progress or lack of progress in the Centaur program, or the development of the vehicle? I was wondering if you could just give me the changes that took place in the headquarters group.

Dr. von Braun. Yes. Well, I think I mentioned already that it all started with ARPA, assigning program management for Centaur to the Air Force. The first ARPA order was let in August 1958. And then certain follow-on contracts, like the contract to Pratt & Whitney and General Dynamics, followed.

Mr. Karth. Well, then, whose responsibility was it for selecting the contractor at that point, or the contractors? Was it the Air Force's responsibility? Did they do the selecting or did ARPA do the selecting?

Dr. von Braun. As far as I know, I wasn't in the program at that time, ARPA selected the contractors, and I mean both the vehicle contractor and the engine contractor, and instructed the Air Force to proceed with these two contractors.

Dr. Newell. That is right.

Mr. Karth. All right, continue, Doctor.

Dr. von Braun. In July 1959, responsibility for Centaur was transferred to NASA, but Colonel Seaberg remained U.S. Air Force project manager, and the only difference was that he now reported to Mr. Rosen, who acted as NASA program chief.

Mr. Karth. How many of his team were transferred with him?

Dr. von Braun. Colonel Seaberg always had three key officers, all three Air Force majors with him, and he had a number of civil assistants and secretarial help. The entire staff amounted to eight people.

Mr. Karth. And the total of eight was transferred to NASA?

Dr. VON BRAUN. The total of eight was transferred to NASA. But they remained physically in Los Angeles.

Mr. KARTH. Yes; I understand.

Dr. VON BRAUN. This was in July 1959, that Seaberg reported in to Rosen.

Now, about a year later, in July 1960, Marshall became an element of NASA; in other words, our group in Huntsville was transferred from the Army to NASA.

Mr. KARTH. That same team then was transferred again to Marshall Space Flight Center?

Dr. VON BRAUN. Yes. At about the same time General Ostrander came on board to become head of NASA's Launch Vehicle Office here at NASA Headquarters, in the Washington office. He became my boss. And when he took over he said, "I would like to attach Colonel Seaberg and his eight people to the Marshall Space Flight Center in Huntsville, rather than having them report to headquarters direct."

He couldn't have done that any earlier, because there was no launch vehicle center in NASA. This engineering capability in the launch vehicle area was nonexistent in NASA, which was one of the reasons that NASA wanted our Army group at that time.

Mr. KARTH. Now, Colonel Seaberg reports to General Ostrander, or does he still report to Rosen?

Dr. VON BRAUN. No, when Ostrander came on board, Rosen became assistant to Ostrander and Marshall reported to Ostrander. He was my direct superior. I was in Huntsville and he became my Washington superior. And he decided, "I want Seaberg from now on, instead of reporting into headquarters direct, I want him to report into my field center in Huntsville."

That is how we inherited Colonel Seaberg and his group at Marshall.

Mr. KARTH. Once Colonel Seaberg got to Marshall, then whom did he report to?

Mr. VON BRAUN. He reported to Mr. Hueter, whom we appointed as Director for light- and medium-launch vehicles. Along with Centaur we inherited the Agena program, both the Thor-Agena and Atlas-Agena. I appointed Mr. Hueter as systems manager for all these lighter vehicles, as compared to the Saturn and the heavier ones. So we established a light- and medium-vehicle office, and it was only logical to attach Colonel Seaberg to this group.

Mr. KARTH. And is that the present management chain of command for Centaur?

Dr. VON BRAUN. Until the 1st of January it was this way; Seaberg was Hueter's deputy for Centaur, you might say, with his group, but physically located in Los Angeles.

On the 1st of January this was changed; Colonel Seaberg was called out by the Air Force, put back on active duty with the Air Force, and we appointed a new man, Mr. Evans, to take Colonel Seaberg's former role. At the same time we terminated the management out of Los Angeles, because we always felt that we didn't have sufficiently intimate liaison, shall we say, between our place in Huntsville and this office in Los Angeles. So Mr. Evans, who is now manager for Centaur, operates out of Huntsville.

Mr. KARTH. Is there any reason why it was not brought to Huntsville sooner than it was, Doctor?

Dr. von Braun. Sir, we have recommended it several times, but the Air Force contracting office was in Los Angeles and the idea was opposed.

Commander Schubert. Perhaps I could help answer that.

Dr. von Braun. Yes.

Commander Schubert. Until January 1 of this year, sir, the Centaur contracts remained Air Force contracts, as they had been at the outset. This was never disturbed.

Mr. Karth. You mean NASA was just paying for it?

Commander Schubert. Paying for it and applying technical direction, sir. But contract administration, that is, the paperwork associated with negotiating contracts and establishing them, remained an Air Force service provided to the program.

Mr. Karth. What did this have to do with the contracts? What did this have to do with the assignment of the people in California or in Huntsville?

Dr. von Braun. Let me explain, sir. The contract administration, being an Air Force service to the program, was carried out in Los Angeles, by the Ballistic Missile Center, as it was called, which was the procurement side of the Ballistic Missile Division in Los Angeles. It was thought to be desirable that Colonel Seaberg, the technical manager for NASA, should be located in the same locality geographically with his contract administrator.

Mr. Karth. Except the people who were in charge of the program didn't agree with him.

Dr. von Braun. Sir, one could really argue the case.

Mr. Karth. Doctor, I am just wondering why the Air Force should have veto power over your recommendation in this instance when this group had been transferred to NASA, is under the direction of NASA, and NASA is picking up the tab.

Now, you try to explain that to me for the record, will you?

Dr. von Braun. Yes. Sir, the situation was the following: The Astronautics' plant in San Diego was built up by the Air Force originally for the Atlas ICBM program. There was, of course, an element of a possible disturbance on the part of NASA running a separate program within that same Air Force plant that was handling this high-priority defense project, the Atlas ICBM.

It is for this reason that the Air Force, in order to avoid any disruption, volunteered to render contract management services to NASA for the entire Centaur program, simply in order to avoid the two independent Government agencies going into the same contractor's plant. NASA readily agreed to this and thought this was a very fine arrangement, that the Air Force offered this service. So we bought that.

Now, what one can argue is, and what we did argue, indeed, was whether the technical men who had to monitor the program for the technical side should stay with the contract managers, or should stay in an environment where they would have the benefit of learning from other programs, also, and this environment we could offer in Huntsville.

The decision was finally made in favor of leaving the project manager in Los Angeles. But I think recent events have shown that we must get a little more technical inputs into these project managers, and for this reason it was changed on the 1st of January, 1962.

Dr. HUETER. May I describe, Mr. Chairman, shortly, how difficult the situation was at that time with the Air Force?

Mr. KARTH. How difficult from what standpoint?

Dr. HEUTER. For managing it. Let's say the contracting office was at Los Angeles. The Air Force contracting office had approximately 15 people.

Mr. KARTH. Fifteen, sir?

Dr. HUETER. Fifteen people were working for Colonel Murphy, who was the contracting officer for the Air Force. Simultaneously, during this period, of course, there were a lot of changes coming up in the contract. In an R. & D. contract, there are always a lot of things you recognize and want to modify which require a lot of engineering changes which have to be processed, negotiated, and so on.

So when the project was assigned to Marshall we faced immediately the dilemma that we would like to see the technical manager in Huntsville so that he could have the benefit of the Marshall technical support. Otherwise, he had to continuously keep in contact and advise Colonel Murphy as the contracting officer in his negotiations with Astronautics. So it was actually impossible at that time to transfer him.

We had to develop two offices, let's say, my own office here with a lot of technical people——

Mr. KARTH. Doctor, when was the first request made for the transfer of Colonel Seaberg's personnel from California to Huntsville? When was that request first made?

Dr. HUETER. We discussed it seriously in March 1961.

Mr. KARTH. And when did the transfer take place?

Dr. VON BRAUN. July 1960, the Centaur project office was formally attached to Marshall, with the explanation there is a very capable technical management group out in Los Angeles and they actually do the work——

Mr. KARTH. When did you recommend that the technical team be transferred to the physical location of the Marshall Space Flight Center?

Dr. VON BRAUN. I would say approximately half a year after we were assigned this team and we began to realize that we couldn't be effective enough.

Mr. KARTH. Then how long did it take to meet the request that you made? How long did the Air Force take before they agreed with the request?

Dr. VON BRAUN. It was finally changed on the 1st of January, 1962.

Mr. KARTH. So what are we talking about, 6 months?

Dr. HUETER. Six months, approximately, after the decision was made.

Dr. VON BRAUN. Approximately 1 year, Hans. We were assigned responsibility for Centaur on the 1st of July, 1960. And I would say we first suggested to have Colonel Seaberg moved physically to Huntsville in early 1961.

Dr. HUETER. Right.

Dr. VON BRAUN. About half a year later. And by the end of 1961 or toward January 1962——

Mr. KARTH. We are talking about 12 months rather than 6 months?

Dr. VON BRAUN. Yes, sir.

Mr. KARTH. Now, in your opinion, were there any delays as a result of the technical team being in California rather than being in Huntsville, Ala., where they would have had the advantage of all of the technological development that you people have accomplished in the so-called liquid propellant field? Would you attribute any of the delay—I want your very candid answer—would you attribute any of the delay in this program to that refusal on the part of the Air Force to transfer the management?

Dr. VON BRAUN. Sir, I think the word "delay" may not describe the problem too well. I think what we felt was lack of depth of penetration of the program on the part of Government personnel, in very general terms. We believed that this staff of eight people—they were all very competent people, no question about it, but eight people is just an inadequate coverage on the part of the Government, no matter whether it is NASA or the Air Force, to stay on top of a program of this magnitude, involving engine development going on in Florida and vehicle development in southern California and static testing in——

Mr. KARTH. Doctor, as long as they were there, though, instead of being at Marshall Space Flight Center, you couldn't complement the eight with any additional technical help.

Dr. VON BRAUN. That is correct.

Mr. KARTH. Or technically capable personnel at Huntsville, could you?

Dr. VON BRAUN. That is precisely the reason why we recommended to move the management to Huntsville, because we felt we could provide for more depth to our Government penetration of the program.

Mr. KARTH. All right, you use "penetration" and "depth" and I will use "delay." Now, how much time did we lose because we didn't have this depth and this penetration that we would have had if these people had been at Marshall Space Flight Center instead of in California?

Dr. VON BRAUN. Well, sir, I could not make a flat statement that this first flight would not have exploded——

Mr. KARTH. I have a great deal of confidence in your judgment. Why don't you give me your best evaluation?

Dr. VON BRAUN. I think we could have provided more protection against such occurrences by simply appraising potential problem areas better. This has always paid off very handsomely in other projects.

Mr. KARTH. Doctor, let me interrupt to present Chairman Miller of the full committee.

Dr. VON BRAUN. Yes, sir.

Mr. KARTH. I think you have met Chairman Miller.

Mr. MILLER. Doctor, you spoke of a Colonel Murphy, I believe it was, in California?

Dr. VON BRAUN. Colonel Murphy was the contracting officer.

Mr. MILLER. He had 15 men?

Dr. VON BRAUN. He had 15 men; yes, sir.

Mr. MILLER. What were these people? What were their activities? How would you classify their work?

Dr. VON BRAUN. Contracting people, negotiators.

Mr. MILLER. Nontechnical people?

Dr. VON BRAUN. Nontechnical; yes, sir.

Mr. MILLER. How many technical people did you have in California?

Dr. VON BRAUN. The technical staff was limited to Colonel Seaberg and his staff, which was a total of eight personnel.

Dr. HUETER. May I correct you? When I quote the number of 15 people that were there, by that time we had not only the 8 people in Los Angeles under Colonel Seaberg, but we also had some people already working in Huntsville. So, to answer your question, about 30 technical people were working with 15 contracting people at that time.

Mr. MILLER. There were actually only eight people having direct day-to-day contact with the hardware?

Dr. VON BRAUN. Sir, this is the way it started out, and as we——

Mr. MILLER. I mean up to this time.

Dr. VON BRAUN. Yes, sir.

Mr. MILLER. Is this right?

Dr. VON BRAUN. Yes, sir.

Mr. MILLER. Then, as you took it over, you wanted more technical people?

Dr. VON BRAUN. Sir, even with the management in Los Angeles, physically located in Los Angeles, it became obvious to us in Huntsville that we were heading into difficulties. There were these explosions at Pratt & Whitney. So, after this happened, we sent a larger group of propulsion people into the Pratt & Whitney plant at West Palm Beach to analyze jointly with Pratt & Whitney personnel their quality control methods, their testing procedures, their safety procedures, the measurements they were taking, and all these things.

Mr. MILLER. That is it.

Dr. VON BRAUN. And exposed them to our propulsion people.

Mr. MILLER. Now, how long were these eight people working on this project, over how long had these eight been doing the supervision before you began to add to them?

Dr. HUETER. Until July 1960.

But may I clarify for you, Mr. Chairman. These eight people were in daily contact with the hardware, but they had also the resources of NASA, like the laboratories in Lewis, in Langley, which, in case of difficulties, were called in as advisers. Only those eight people prior to July 1960 were the daily contact with the hardware, as you expressed it.

Dr. VON BRAUN. Full-time Centaur staff.

Mr. MILLER. I was just wondering whether eight people over any period of time was sufficient to guarantee quality control on a project this size. Do you think so?

Dr. VON BRAUN. No. We felt all along——

Mr. MILLER. Isn't that part of the trouble we are in right now?

Dr. VON BRAUN. Yes.

Mr. MILLER. We lack quality control.

Dr. VON BRAUN. Yes.

Mr. KARTH. Mr. Chairman, if you would yield at this point—Dr. von Braun, how many people do you now have assigned to the project?

Dr. VON BRAUN. Approximately 140.

Mr. MILLER. How many of those are highly qualified technicians?

Dr. VON BRAUN. Could you break that down?

Dr. HUETER. I can only estimate it.

Mr. MILLER. An estimate.

Dr. HUETER. Approximately 100 to 110, the rest would be contracting people.

Dr. VON BRAUN. I have it here in detail.

Dr. HUETER. Not broken down in technical versus contracting.

Mr. KARTH. Mr. Chairman, you developed how long eight people were actually doing the technical work in this area, since 1959, was it not?

Mr. MILLER. They had eight people.

Mr. KARTH. Until the first of this year.

Is this correct for the record?

Dr. VON BRAUN. Sir, I have a breakdown here to answer your question.

For the fourth quarter of fiscal year 1962, which is today, the total is 139 Marshall personnel that are working on the Centaur. Of these, 10 men are full-time quality control people in the sense, not that they inspect parts, but they set up the machinery in the plants where, with the support of professional Air Force quality inspectors and also corporation inspectors, quality assurance is built up.

Mr. KARTH. They set up standards that they are inspected by, is that right?

Dr. VON BRAUN. Inspection and methods.

Mr. MILLER. They inspect the inspectors.

Dr. VON BRAUN. Precisely, and set up the procedures.

We have 19 propulsion and vehicle engineering people. These are engineering types with backgrounds in rocket engine development as well as overall vehicle system engineering.

We have nine guidance people, and guidance includes also telemetry and networks.

Then we have 24 people in Cape Canaveral, our launch operations directorate, who familiarize themselves with the launch procedures and went through the procedures in Cape Canaveral jointly with General Dynamics/Astronautics, Pratt & Whitney, and also Honeywell personnel in the guidance area. That is 24.

Then we have nine people at present in the procurement and contracts area, because after the 1st of January we have taken over contracting in our own procurement office at the Marshall Space Flight Center.

In other words, this old relationship with Colonel Murphy on the west coast, whereby the Air Force renders contract service, is being terminated, and we had to furnish nine men to do that.

Then we have 15 men in the so-called aeroballistics area. These people deal with wind loads, heat transfer, dynamic behavior of the vehicle, flutter analysis, and things of this nature.

Then we have 1 in our computation division, and finally 52 that work directly for Dr. Hueter and Mr. Evans in the Centaur project office. In other words, they are the direct line people who handle the day-to-day affairs of the Centaur program, using the services of the other divisions.

Mr. KARTH. Is that the total of 139?

Dr. VON BRAUN. That is a total of 139.

Mr. KARTH. All right.

Dr. Newell, I couldn't help but notice in your presentation on page 13 this language:

On January 1, 1962, pursuant to an agreement with DOD, we transferred the Centaur project office from Los Angeles to Huntsville and converted the Air Force contracts into NASA contracts in a program to clean up and streamline the administration of the project.

Would you amplify on that?

Dr. NEWELL. Yes, Mr. Chairman.

Mr. KARTH. Will you tell us about these contracts, what kind of condition they might have been in, where you disagreed, how you changed them, and the general language you may want to use in reference to cleanup and streamlining the administration of the project? Will you explain at length what you are talking about here?

Dr. NEWELL. I would like to submit this information and then turn to Commander Schubert to carry on from that point since he has been in close contact with it.

The following contracts were involved in the transfer:

Air Force No.	NASA No.	Type	Contractor	Purpose
AF-18(600)-1775	NAS8-2664	CPFF	Astronautics	6 Centaur stages.
AF-04(647)-815	NAS8-2543	CPFF	do	4 Centaur stages.
AF-04(647)-924	NAS8-2666	CPFF	do	Adaptation of Mariner and Surveyor.
AF-04(695)-2	NAS8-2540	CPFF	do	Spares program.
AF-04(695)-50	NAS8-2665	CPFF	do	Complex 36-B design criteria.
AF-18(600)-1887	NAS8-2532	CPFF	do	4 dummy Centaur stages for Saturn.
AF-18(600)-1774	NAS8-2691	CPFF	P-W AC	24 hydrogen/oxygen engines.
AF-04(647)-648	NAS8-2690	CPFF	P-W AC	Additional and uprated engines.

The condition of the eight transferred contracts varied. Three received only minor administrative changes such as location of contract office and source of payments. One had 40 outstanding contract actions and another 5. AF-04 (647)-924 was a letter contract and still is; it is still being negotiated. The two Pratt & Whitney contracts were rewritten. AF-18(600)-1774 was the original engine contract and was rewritten in the light of the increased scope and definition of the overall program. AF-04(647)-648 was rewritten to include both the Centaur engine specification and the Saturn engine specification, which are similar, but different in minor respects. This was done to accomplish the development of a single RL-10-A-3 engine to serve both Centaur and Saturn, to reduce cost and increase reliability of the engine.

There were no disagreements with the engineering program defined by the contracts, but it was desired to cut down the amount of work involved in formalizing contract changes, which are very prevalent in R. & D. activities. NASA will attempt to streamline the change process as much as possible.

All contracts were amended to show the new contracting office and source of payments. As noted above, two contracts were rewritten to bring them up to date and reflect new requirements. Both NASA and Air Force contracts are based upon the general provisions of the Armed Services Procurement Regulations.

Mr. KARTH. Let me ask you this question: Are you familiar with a full explanation of this?

Dr. NEWELL. I am not personally familiar with it, since I was not associated with this at that time, but Commander Schubert is.

Mr. KARTH. All right.

Dr. NEWELL. I would like, though, before we get into this, to correct a false impression that may have been developed in the previous discussion that relates to this.

We should not leave the impression in the record that the Air Force is the culprit here in this question of whether Colonel Seaberg was left in Los Angeles or moved to Huntsville. Colonel Seaberg was assigned to NASA. So any decision as to whether he was left in Los Angeles or moved to Huntsville rested with NASA.

I think this should be made clear.

Mr. KARTH. Let me ask you this question, then, before we get into an explanation of this language: Who, then, in NASA, refused to grant the request that was made by Dr. Wernher von Braun that the team be transferred from California to Huntsville?

Dr. NEWELL. Well, this was caught up in the activity of the times. It was about this time that the question of the manned flight project for landing men on the Moon was introduced, and discussions were underway as to where management of the Centaur program should be, and as to the relationships between the Centaur and Saturn and Nova programs.

It is in the process of those discussions that a certain amount of indecision as to whether Seaberg and his office should be transferred resided at headquarters.

Mr. KARTH. Who had the responsibility of making that decision, Doctor?

Dr. NEWELL. That, at that time, was under General Ostrander's office.

Mr. KARTH. And General Ostrander was from what branch of the service?

Dr. NEWELL. The Air Force.

Mr. KARTH. Now, I didn't draw any erroneous conclusions, at least I didn't think so. I thought Commander Schubert had made that statement, rather than my making it.

Dr. NEWELL. Well, I just didn't want it to show that way on the record.

Mr. KARTH. Now, if you would like to proceed, Commander, to explain this language on page 13, I would appreciate it.

Commander SCHUBERT. Yes, sir.

As I understand your question, it is that if moving the technical management of the project and its contract administration to Marshall on January 1, 1962, was deemed a cleaning up and streamlining of the project, why was it not done earlier. Is that correct, sir?

Mr. KARTH. I want an explanation of what you mean by the words "cleanup" and "streamlining the administration of the project." What was wrong with it to cause this language to be used, and, depending upon what was wrong with it, why wasn't the decision made earlier?

Yes, sir; if you can be as complete and as thorough on this for the record, we would appreciate it.

Commander SCHUBERT. I will do the best I can.

Mr. KARTH. Do you have a copy of the testimony?

Commander SCHUBERT. Yes, sir.

Mr. KARTH. All right. You know what language I refer to.

Commander SCHUBERT. If I may go back historically for a moment. I think we have made it clear here today that when the project began it was on an austere financial basis. Its scope was extremely restricted. Its objectives were short range, compared to the program that we now are dealing with.

It has grown in importance since that day, and the dependence of the national space program upon it has grown during the whole period since October 1958 when it began. When it began it was an experiment to prove or disprove the feasibility of hydrogen as a space propellant.

It was staffed at that time in a manner which I assume ARPA and the Air Force felt was commensurate with its restricted scope and restricted financial budget. Colonel Seaberg was assigned to it at that time with the three Air Force officers who assisted him until just the beginning of this year.

Mr. KARTH. Commander, let me just for the purpose of the record say at this point that I would respectfully disagree that the Congress starved this project to death after having appropriated some $200 million toward it. In my opinion, this isn't starving a program to death. So we might just have a difference of opinion as to what is not proper funding. But you go ahead.

Commander SCHUBERT. I didn't make my intent clear, sir.

At the beginning of this program it was budgeted at $59 million total. It had a considerably lower budget with considerably restricted objectives compared to the program today, into which we have so far put $200 million.

I think the staffing of the program at the beginning, as apparently the Air Force and ARPA also thought, was adequate to its then purpose.

As the program grew, and as Colonel Seaberg's office gradually grew with the program, he moved out to Los Angeles in the fall of 1959, which was just a few months after NASA assumed leadership of the program.

When he became a part of the Marshall Space Flight Center, which was in June of 1960, the program had already taken on an increased scope. I think we all agreed in NASA that his staff needed some beefing up, that he needed more people to do this larger job.

As Dr. Hueter received personnel vacancy ceiling points that permitted him to hire people for the purpose, he placed in Colonel Seaberg's office in Los Angeles additional people. He brought in at least one man from the Lewis Research Center, I remember, and from some of the other NASA research centers, and by the end of 1960 I think Colonel Seaberg had more than his original eight people.

Dr. HUETER. Yes.

Commander SCHUBERT. He eventually grew to a total of about 15 technical people at Los Angeles by January 1, 1962.

At the same time, Colonel Murphy, who was sitting in the offices adjacent to his, had about 15 people to handle the contract problems. So that at Los Angeles or at the contractor's plants——

Mr. KARTH. Now, let me just interrupt, if I may.

Commander SCHUBERT. Yes, sir.

Mr. KARTH. The 15 people were technical people and they weren't concerned with this day-to-day contract work that someone else talked about here a while back; is that correct?

Commander SCHUBERT. Colonel Seaberg's office in Los Angeles consisted of 15 people, including secretarial personnel, to help him with the technical direction of the program.

In an adjacent office was Colonel Murphy, Air Force contracting officer, with about the same number of people. So that a total of 30 people existed under Colonel Seaberg's——

Mr. MILLER. Just to keep my mind clear, 15 of these, though, were clerical people who had no technical competence whatsoever, that was Colonel Murphy's staff?

Commander SCHUBERT. Yes, sir; they were not involved in the technical direction of the program.

Mr. MILLER. Then you had 15 people including the clerical personnel.

Commander SCHUBERT. Yes.

Mr. MILLER. Among whom were the technical personnel.

Commander SCHUBERT. We had about eight technical personnel and the remainder secretarial and administrative.

So that during this period as Colonel Seaberg's office was built up on the west coast, he was, as I believe Dr. Hueter mentioned, drawing also technical assistance from the NASA research centers as required, and also had available to him the Marshall Space Flight Center technical divisions, albeit at 3,000 miles distance, which perhaps was a disadvantage from a communications standpoint. I think we all recognize this.

However, it was deemed by NASA management desirable during this period to leave Colonel Seaberg in Los Angeles because Colonel Murphy was providing contract services in his Air Force office at that location.

The technical manager and the contract manager should be close together to provide clean administration.

Mr. KARTH. You explain to me what you mean when you say "contracting services." I want to know what this includes, Commander.

Commander SCHUBERT. Lieutenant Colonel Murphy, as contracting officer, had the function of preparing and signing letters to the contractors requesting proposals whenever Colonel Seaberg, in the name of NASA wished a technical addition or change to be made.

Mr. KARTH. Yes.

Commander SCHUBERT. Colonel Murphy then received from the contractor the proposals that he had requested. He had negotiators on his staff who were experienced in the analysis, including cost analysis, of such contracts, and in assuring that the proposal prior to becoming a contract contained the required standard statements, so that the contract was properly put together from an administrator's standpoint.

These were reviewed by Colonel Seaberg in the adjacent room in NASA's name, approved or disapproved, and then Colonel Murphy would see that the proper contract was written and signed by both parties in the proper manner.

Mr. MILLER. Purely administrative matters?

Commander SCHUBERT. Yes, sir, he had no technical responsibility.

Mr. MILLER. No technical responsibility?

Commander SCHUBERT. It was very clearly established on the transfer of the program to NASA, that the Department of Defense, specifically the Air Force, had no further technical control of this program as of July 1959.

There was an arrangement on paper between General Schriever and Dr. Glennan of NASA at that time to this effect.

Colonel Seaberg was very much a part of NASA, on duty with NASA in the same way that I, as a naval officer, am on duty with NASA, a complete member of the team without any restrictions.

Mr. KARTH. Now, Colonel Seaberg had years of experience with this project.

Commander SCHUBERT. Yes, sir; he started it.

Mr. KARTH. Yes.

Could you tell me why his services were discontinued?

Commander SCHUBERT. His services?

Mr. KARTH. Yes; as head of the program.

Commander SCHBERT. Well, we had been on it since October 1958 when it began. By October 1961 he had completed a 3-year tour, which, in all such details of military people to NASA, is considered a normal period.

A military officer coming to NASA for a while leaves the normal career pattern of his mother service, and it is generally thought desirable by both his mother service and NASA that he should not remain too long away from his mother service, but after a period of 3 years should get back into his normal military duties to further his own professional military career, which is reasonable.

An extended tour beyond 3 years has to be a matter of special agreement between NASA and the service from which he came. So it was normal for Colonel Seaberg to return to the Air Force at the end of last year.

Now, I believe you were asking a question in regard to his location.

Mr. KARTH. Primarily that problem of streamlining the administrative function.

Commander SCHUBERT. Yes, sir.

We thought he should stay in Los Angeles because contract administration was in Los Angeles and we accepted, for the time being, the 3,000-mile line of communication between himself and his immediate superior, Dr. Hueter, at Huntsville.

As the program grew in scope and in importance, and it has been steadily growing to this day, it became clear, I think, to everyone in NASA that this 3,000-mile communication link was a disadvantage to the program and we should do something about it.

So, early in 1961 discussions began and by mid-1961 the decision had been made and agreed to that Colonel Seaberg's function would move to Huntsville so as to have the benefit of Dr. von Braun's technical divisions as we have described.

At the same time it was decided that the contracts would be converted from U.S. Air Force to NASA contracts, and this contracting function, which Lieutenant Colonel Murphy had provided for the first 3 years of the program, would also move to Huntsville, so that we would have the ideal situation, you might say, from a management standpoint: Technical management at Huntsville where the technical backup existed and contract administration at Huntsville in the same location. It took a number of months to transfer the contracts from the Air Force to NASA because of proposals that were in process and had not yet been accepted, but we finally did accomplish it late last year and now feel we are on a sound management basis in this respect.

Mr. KARTH. What kind of contracts do we have with General Dynamics/Astronautics and Pratt & Whitney? Are they cost plus incentive fee contracts?

Commander SCHUBERT. Cost plus fixed fee in each case.

Mr. KARTH. Cost plus fixed fee?

Commander SCHUBERT. Yes; and have been since the beginning.

Mr. KARTH. Mr. Chairman?

Mr. MILLER. No.

Mr. KARTH. Mr. Randall?

Mr. RANDALL. On page 3, Dr. Newell, of your statement, it says:

> Astronautics proposals was based upon a pressure-fed design and this company was not aware of Pratt & Whitney's development of a liquid hydrogen pump.

Then in the next sentence you say:

> Hearing of the existence of this pump.

Well, now, this looks like an omission of something to me, at least, that that should have been. Is there anything being done to prevent a repetition of something like that? In other words, first I will ask you: There is some delay right there, whether we call it in the words of Dr. von Braun, whether we call it delay, wasn't that responsible for some of the delay in the success of this project?

Dr. NEWELL. This was, you understand, before the project ever began. In the initial proposal to ARPA the Astronautics proposal was based on the pressure-fed design. Then in the exchange that went on, as I understand it, and I wasn't there and some of the other people may have to correct me here, the existence of the pump-fed system was brought forward and Astronautics altered its proposal to include the pump-fed system.

Is this correct?

Commander SCHUBERT. That is correct. It was during the proposal phase before the contract was let, in November 1958. The reason for this lack of knowledge at Astronautics lay entirely in the Department of Defense security requirements. The work that had been going on at Pratt & Whitney was a highly classified program at the time, extremely highly classified, and Astronautics, not being a part of this program, would not normally know about the existence of it.

Mr. KARTH. Who endorsed this bootstrap principle, Commander?

Commander SCHUBERT. Well, that was finally proposed to ARPA in the middle of 1958, and ARPA accepted it as the engine system concept.

Mr. KARTH. Who was at the head of ARPA at that time, Commander?

Commander SCHUBERT. I think it was Mr. Johnson at that time, sir.

Mr. KARTH. I am sorry, Mr. Randall.

Mr. RANDALL. That is all right, Mr. Chairman.

Well, the explanation notwithstanding, Astronautics was charged with the system's engineering and yet at the same time Pratt & Whitney were working on a phase of the overall contract, isn't that true?

Commander SCHUBERT. No, sir. The contract was not let until the fall of 1958, after this interchange of information. General Dynamics was advised by ARPA of the existence of the Pratt & Whitney work in the early summer of 1958, and this was the basis of their resubmission of a new proposal, which ultimately became a contract in the late fall of that year.

Mr. RANDALL. Well, on page 6, bottom paragraph, you say—

On July 1, 1959, the program was officially transferred and DOD management and funding of the program ceased.

The Air Force Project Manager remained in charge, however.

Now, we have gone all down the line, the difficulty in connection with Colonel Seaberg, and coming back, and his final return to a tour of duty.

When was the effort first made by NASA to get in complete charge of the program? I don't know that that is the wording I am trying to put. You continued to let the Air Force carry out their contracts, didn't you? Wasn't that true because you say down here:

To avoid any disruption of the rapidly growing program, the original Air Force contracts were retained.

Commander SCHUBERT. I think I can explain that, sir.

Mr. RANDALL. All right, I wish you would.

Commander SCHUBERT. NASA itself was established in 1958. When NASA accepted the Centaur program from ARPA, NASA was still an infant organization. Its headquarters were still in the process of being staffed with properly qualified people.

It had not, in July 1959—I am sure the judgment was at that time—the capacity to take over contract administration of this program at that time.

And as Dr. Newell pointed out, it was additionally thought that it might be disruptive if we did take it over, in view of the fact that it was a going contract, already underway, under Air Force auspices, apparently operating harmoniously on this basis. It was not until the Marshall Center, under Dr. von Braun, became a part of NASA in July 1960, with the capacities that his organization brought to NASA, that we began to feel capable of discussing the possibility of taking it over in its entirety and not relying on the Air Force services, which I should add were adequate while they were being provided. We had no argument.

Mr. RANDALL. Of course, Commander, I'm very glad to accept that as an explanation: The fact that NASA came in in the fall of 1958 and we are talking about a time here in July of 1959, but at page 7 you show that this continued clear up until January 1962, this same arrangement.

Commander SCHUBERT. It was in 1961, early 1961, I think, that we made the decision that we should move, and it took a number of months to accomplish.

Mr. RANDALL. Then I ask you why wasn't this change consummated earlier? It says here January 1962, it worked very well considering its complexity, the chief disadvantage being an allocation of funds, which you admit there was a disadvantage there. Why all of that period of time during 1961 and 1960?

Dr. VON BRAUN. Could I say something about this?

What is now the Marshall Center became part of NASA only in July 1960 and it took us, of course, several months until we began to understand our new role within the NASA organization.

At first we were simply told, among many other things, that you will have the Centaur, but the Centaur is in very good hands. They do that out there on the west coast and there is a very effective technical and contract management organization at work.

At the beginning we felt our way into this situation. We cannot start criticizing and making proposals as to how to improve a structure that you don't understand yourself.

Mr. KARTH. What made you change your mind, Doctor?

Dr. VON BRAUN. So we observed for a while.

Well, we noticed that this program needed a little more depth and technical coverage. On the other hand, we found ourselves not in a very good position in bringing our inhouse experience to bear when the technical management was 3,000 miles away.

Mr. KARTH. You felt it wasn't proceeding as it should, didn't you?

Dr. VON BRAUN. Well, shall we say we felt that we ought to make a greater contribution by bringing our own technical experience a little stronger to bear on this project and there was a liaison problem between us and the technical management located on the west coast. And when we made the proposal at first to locate there in Huntsville, we were told and I think with very good reason, by NASA headquarters, that the disruptive effect of pulling the technical people away from the contractual people may hurt the program more than whatever little input we could provide from Huntsville would help the program. So I think quite honestly the question could be argued. But now in the meantime the Centaur program grew——

Mr. KARTH. Doctor, which way would you argue it if you were called upon to do so?

Dr. VON BRAUN. Well, I had argued right in the beginning in favor of moving it to Huntsville, but I must confess and admit that my position wasn't a very strong one because the counterarguments were quite good. Only as the program grew in magnitude and became an ever-growing percentage of the entire effort of astronautics in San Diego, it became pretty evident that we should no longer be a junior partner and an appendix in this thing, but we should really get in.

At the same time, of course, we had a few technical setbacks which made it very obvious to all of us that more penetration by technical people was desirable and so throughout 1961 the consensus of opinion in NASA changed more and more toward the direction of doing a complete job and even abolishing Air Force contract management. That was finally done in 1961, but it took some organizational preparation on our part to do it. For example, I didn't even have the procurement people early in 1961 to take over Colonel Murphy's function. We had to hire these people, train them, send them out to the west coast for indoctrination. The thing could have been conceivably a little faster but I doubt it could have been done abruptly in early 1961.

Mr. KARTH. Would the gentleman yield for one question?

Mr. RANDALL. Yes.

Mr. KARTH. Dr. Newell, on page 13 at the bottom you say also under strong urging from NASA astronautics converted from a matrix organization to a projectized organization.

Dr. NEWELL. Yes.

Mr. KARTH. Why did you have to strongly urge this change before it was done? Had you urged previous to this time that something be done in probably less significant terms than that which you use in your testimony?

Dr. NEWELL. The strength of our urging was based on our feeling that this program had grown to a point where it demanded a projectized type organization, and a letter went out from Dr. Hueter to Astronautics requesting them to do this.

It was our feeling that the time had certainly come to give the direct attention to this program that only a projectized type organization could do.

I may say it is my understanding that Astronautics was also considering this at the same time. So the words "strong urging" simply mean that we were convinced it had to be done, not necessarily that Astronautics was saying they didn't want to do it.

Mr. KARTH. You say not necessarily. Were they up to that point?

Dr. NEWELL. It was my understanding that they did want to do this. Perhaps Dr. Hueter would like to comment.

Mr. KARTH. Is this right, Commander?

Commander SCHUBERT. I think the timing of the change is related to a change in the character of the work going on at Astronautics itself. When Centaur first started, it was funded at a low level as we have described. It was a very small, exceedingly small portion of the total job being done at Astronautics.

The Atlas development program at that time was in full swing, but since the beginning and culminating in late 1961, Centaur has been growing in importance. The Atlas program has reached the production phase, the development effort has begun to wane. Therefore, the importance of Centaur at Astronautics compared to the total work there has increased. When you have a company that is largely a one-project company, the type organization they use was well designed for its purpose, with functional department heads operating under a single leadership.

When a company becomes a multiple-project company, and this is apparent in much of the aerospace industry, then it sometimes becomes desirable to provide project-type organization so that a large program can receive the exceedingly intimate correlation that the parts of it require within the company.

Mr. KARTH. Commander, by matrix you actually mean that these people were scattered around in several different departments and were kind of working—maybe this is language too strong to use—working on a hit-and-miss basis on the project, rather than having a centralized group of people concentrating 100 percent of their time on that project under one particular, one central head?

Isn't this the difference between the matrix and the projected organization?

Commander SCHUBERT. When Centaur began, the low level of effort was consistent with the type of organization that was being used to prosecute it.

Mr. KARTH. It wasn't so low that you couldn't have assigned three or four men permanently to the project?

Commander SCHUBERT. There were many men assigned permanently, but the characteristic of the matrix organization is that

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these men are located at different locations, different offices in the company, different buildings even, in some cases, and are not in a single room together under a single leadership.

Mr. KARTH. Let me ask you this question: If you had it to do all over again, starting from scratch, knowing what you know now, would you have allowed the matrix organizational system to function as long as it did function in General Dynamics/Astronautics? Would that be good business, in your opinion?

Commander SCHUBERT. If I look at it as a Centaur man only, I would naturally prefer that Centaur should get the projectized treatment at an earlier date than it got it, but——

Mr. KARTH. This is the best system; isn't it?

Commander SCHUBERT. Well, looking at it as a taxpayer and realizing the importance of the Atlas program to the Nation, trying to weigh this against the early, relatively low importance of the Centaur project, I would have been satisfied in the early days to have the organization as it was, as the best way to operate in the broad sense.

Mr. KARTH. I am not asking you to admit past mistakes. I just say if you had your "druthers" right now and you had the whole program to do over, wouldn't you pick the projectized organizational system 100 times out of 100 for a project such as this?

Commander SCHUBERT. I would not, in October 1958.

Mr. KARTH. Now?

Commander SCHUBERT. Now I would and we did and it is implemented.

Mr. KARTH. Don't you think this should have been done a little sooner than it was though, Commander, for the record?

Commander SCHUBERT. I would wish that it could have been done earlier, but considering the problems of a large organization and of making substantial adjustments to it, such as this required, I don't think it was done at an untimely point.

Mr. KARTH. You are even making it difficult for me, Commander. Dr. von Braun, what is your answer?

Dr. VON BRAUN. Well, I think Commander Schubert put it very well, that at the beginning the problem was certainly quite different. Atlas was absolutely the senior project in Astronautics, and Centaur was a little appendix.

Looking at it from the Centaur standpoint, we would have liked all along a stronger Centaur organization, but there were some serious internal problems in Astronautics in implementing this desire early. I personally would have wanted them to do it sooner, there is no question about it, but I appreciate their problems.

Mr. KARTH. Dr. Newell?

Dr. NEWELL. Without attempting to be defensive and recognizing all the qualifications I could put in on it, I would like to have seen it done earlier.

Mr. RANDALL. I don't know that I have heard the answer, Dr. Newell.

Dr. NEWELL. I would like to have seen it done earlier from the point of view of the Centaur project.

Mr. RANDALL. Everyone would have wished to have seen it done earlier. Then we are talking here, before we get to the matrix, back on page 7 you say that there was a management coordinating committee. I don't know that you show the date when that was established. When was that established?

Commander SCHUBERT. July 1959, sir. At the time NASA assumed responsibility for the project.

Mr. RANDALL. Fine.

At all times from 1959 until we scuttled the matrix-type organization into the project and all the while this was growing from a modest, austere program to an important project, I believe this coordinating committee was meeting every month?

Commander SCHUBERT. Yes.

Mr. RANDALL. Where are the minutes, where is the agenda, where is that available? What was done in that committee on this very thing we are talking about?

Commander SCHUBERT. We have a complete set of the minutes at headquarters and they could be provided to you.

Mr. RANDALL. Were the topics of discussion as we have discussed this afternoon, the change from the matrix, the change of Colonel Seaberg and these things, was that in discussion monthly?

Commander SCHUBERT. I wouldn't say at every meeting it was brought up; no.

Mr. RANDALL. I would like to have a copy of those minutes if they are available; at least made available, to the committee, to see what had been done along the line, instead of looking back now as to what would have been preferable.

Commander SCHUBERT. If I may say so, sir, the function of the Centaur management coordinating committee was really not associated with the internal management of the program by NASA. Its purpose, rather, was, at a higher level, to bring together the interested parties of the Army Advent management agency, the Air Force, who was responsible to provide launch vehicles for Advent, the Department of Defense and the NASA people, to work out interagency interface problems, if you will, rather than internal NASA problems that NASA could solve itself.

Mr. RANDALL. That is quite well recognized, but I thought one of these problems was the question of these contracts going forward in the name of the Air Force and you say "broad guidance," the purpose was broad guidance of the entire Centaur development and certainly was—NASA was a party to that team as well as DOD and ARPA; isn't that true, all the while, in the committee?

Commander SCHUBERT. Yes, sir; but NASA was in direct control. The DOD members represented an advisory capacity rather than a direct executive capacity since NASA had the entire responsibilty for the program.

Mr. RANDALL. What is your title, Commander?

Commander SCHUBERT. I am called Chief, Centaur program, here at NASA Headquarters.

Mr. RANDALL. You are on loan from the Navy?

Commander SCHUBERT. Yes, sir.

Mr. RANDALL. You are at Huntsville?

Commander SCHUBERT. No, sir; Washington.

Mr. RANDALL. Washington. How long have you been with NASA?

Commander SCHUBERT. I was detailed to NASA from the Navy Department in September 1959, became Centaur program chief, now under Dr. Newell's Office of Space Sciences, in January of 1960.

Mr. RANDALL. Under the ordinary 3-year tour of duty this September you will be going back to naval service?

Commander SCHUBERT. Yes, sir.

Mr. RANDALL. Whatever happened to General Ostrander?

Commander SCHUBERT. He returned as deputy commander of the Ballistic Systems Division, as it is now called, in Inglewood.

Mr. RANDALL. Before I get to some other questions, Dr. Newell, you describe over here the Aerobee rocket used for—I guess that must have been a static test.

Dr. NEWELL. No, sir; those were flight tests.

Mr. RANDALL. Flight tests? How does that work?

Dr. NEWELL. The Aerobee is a small sounding rocket about 20 feet in length which can carry 150 pounds up into the 200 kilometer regions, 120 miles or so, and has been used to carry experiments to determine the behavior of the hydrogen propellant under zero gravity conditions for the short period of time of the Aerobee flight.

Mr. RANDALL. Dr. von Braun, referring to the very first part of your statement, the chairman mentioned about the hardware shortages, mainly spare parts. We have been talking about an austere program, but at no time have we been talking of less than the—at the very beginning I think it was $36 million and then $59 million and now finally $220 million, and you say the total cost will be $350 million.

Do we have enough funds now to prevent anything like that happening? Why did that happen?

Dr. VON BRAUN. Sir, as it was said repeatedly in this meeting the program started out with the intention of demonstrating the feasibility of a liquid hydrogen-liquid oxygen rocket, and as the feasibility, at least on paper, became more and more obvious, the programs were generated within NASA for payloads to be carried by Centaur and the program probably grew on paper a little faster than the funding resources to support it and so there was a period when all we could buy was assigned essentially to flight testing and maybe not enough for spare parts.

Mr. RANDALL. It is a question of terminology. What do you mean by spare parts?

Dr. VON BRAUN. Spare parts mean, for example, where you have a guidance computer for flight No. 1, one for No. 2 and one for No. 3, that you have one additional guidance computer that isn't assigned to any of the flights and is just standing by and available for either laboratory tests or for launching attempts, so we can slip in a spare.

Mr. RANDALL. But that was a source of delay; is that right?

Dr. VON BRAUN. It was a source of delay.

Mr. RANDALL. And how much delay?

Dr. VON BRAUN. It has delayed several launch attempts at Canaveral. I think we can substantiate that here.

Mr. RANDALL. Three months, 6 months?

Dr. HUETER. No; it was a matter of delaying the launch from December until May. It is one of the items, on account of a spare part not being available in time.

Mr. RANDALL. I have just one more. The hour is late. I would like to put in the record the reason, or at least so far as I am able to determine, one of the reasons, for this hearing, other than the overall importance of the Centaur development.

I believe, Mr. Chairman, it was over in the George Washington Inn, Dr. Newell one morning we were discussing the Mariner program and we learned that there was a cancellation of one of the big Mariners, not the Mariner-R, the larger Mariner.

This all ties in and fits in very closely with our manned space attempts. We sort of developed over there that the purpose of this whole thing was to try to lay the groundwork, sort of like the football team, the line before the backfield can start moving. But here is what we found over there, that because of this delay that we weren't able to use one of our Mariners that would have given us much more information maybe, or at least we thought it would give us much more information, and had to go back to the Mariner-R, put in a lighter vehicle and went off of schedule and here we had all the while been—what was it—between $4 and $5 million setting out here and the big Mariner which, so far as we know yet because of all the preparation, was an outright net loss, not recoverable even in the sense that you recover some information or some experience from a misfire like we did this morning.

That is, I think, one of the reasons why we are here.

I simply wanted that for the record. The chairman can make any additional comment he wishes.

I have just one more question.

On page 15 you suggest that it will cost 350 million, of which some $220 million have already been obligated by the end of June, 1962. Is that in fiscal 1961? Has that much already been obligated?

Dr. NEWELL. That is fiscal 1962, sir.

Mr. RANDALL. Fiscal 1962 I mean, yes, June 30.

Dr. NEWELL. Yes, almost all of that has been obligated, it will be by the end of this fiscal year.

Mr. RANDALL. That is all, Mr. Chairman.

Mr. KARTH. Dr. Newell, I notice on page 6, we have repeatedly talked about Centaur not having been assigned a specific project or a specific job. I notice that ARPA specified in December of 1958—this is about the same time that NASA was formed—the primary mission of the vehicle would be the 24-hour equatorial satellite orbit, and this is a major portion of its job today. In addition to that, of course, you have Surveyor and Mariner, but Advent is one of the big jobs that this thing was supposed to do, and way back in 1958 we made the decision.

Then on page 8 I notice, with the cancellation in December of 1959 of the Vega program, the Centaur took on additional responsibilities, Mariner and Surveyor. Now, I just didn't want the record to show that these jobs that Centaur now has to do and that have been assigned to it are things that developed very recently. This goes way back to the initial stages of the program, doesn't it?

Dr. NEWELL. Well, Mr. Chairman, the main point to bring out here, I think, is that the initial assignment of a 24-hour equatorial satellite orbit capability did not have the same operational requirements, same scheduling requirement as it assumed the moment you said "Well, we will use this capability for Advent." Until that time one could go along, accepting schedule slips without embarrassing any program of an operational nature.

This is simply a development specification. It is like saying: We will develop a sounding rocket to go to 200 miles. You might say a 200-mile flight is its mission. But that doesn't become embarrassing until you say you are riding a specific payload on that at such and such a time.

So the difficulties in programing began to arise when we said we will fly Advent on this, we will fly Surveyors on it, we will fly Mariners on it. That then began to apply constraints to the development program that had not existed in the early part of the effort.

Commander SCHUBERT. May I add to that, sir, if you don't mind?

Mr. KARTH. Yes, Commander.

Commander SCHUBERT. An additional item of information or data that came along later was how much would these payloads weigh? It wasn't until well along in the Centaur program that a weight was established for the Advent satellite or a specific weight for the Surveyor or specific weight for the Mariner. Their development programs, you see, were going on concurrently with the development of the vehicle, itself, and until they progressed awhile——

Mr. KARTH. While that was happening, Commander, if I may interrupt here, Centaur's anticipated capability was going in the other direction, wasn't it?

Commander SCHUBERT. It was.

Mr. KARTH. I mean so you had kind of a disastrous effect, you had the jobs becoming heavier and you had the capability of the vehicle going down?

Commander SCHUBERT. I wouldn't characterize it as disastrous, because we now feel——

Mr. KARTH. Well, it isn't good.

Commander SCHUBERT. No, sir; it is not good. But it is also not uncommon. Vehicles, characteristically, get heavier and perform less well as they progress from the brochure proposal stage to the hardware stage.

Mr. KARTH. My point is that this is one of the problems that we have with Centaur now insofar as the programs that are assigned to it.

Commander SCHUBERT. Yes.

Mr. KARTH. And the job that Centaur was originally scheduled to perform?

Commander SCHUBERT. Yes. And the program we now wish to go forward with, we feel will meet these requirements. We have made adjustments in our vehicle development to accept these new data, these new requirements.

Mr. KARTH. Dr. Newell, on the bottom of page 11, you talk about the engines "had not been flight qualified by ground testing." Now, isn't this the contractor's responsibility? Shouldn't they have flight qualified this vehicle by ground testing?

Dr. HUETER. May I answer this, please, Mr. Chairman?

Mr. KARTH. Yes.

Dr. HUETER. At that time, after the difficulties which we had with the Pratt & Whitney engine in November, because the flight qualification means a certain number of tests without any flaw, and because certain modifications had to be made with the ignition, the flight readiness testing was moved into 1961, but in the meantime the F-1 missile had to proceed and we had to have some engines.

For that reason we made the decision to take test engines rather than wait for the final engines with a flight test rating, for we had other missions with the first missile anyway; structural and control missions which we wanted to find out at an early time. At the time the decision was made we didn't know whether it would take us 2 or 6 months until we really had flight qualified engines available, but we wanted to go ahead with the flight test program.

The delay was actually caused by the explosion in November 1960.

Mr. KARTH. I see. The heat transfer rate, for example, which was an unacceptably high one, through the bulkhead between the two tanks, was this a contractor deficiency, was this a slip-up on his quality control?

Dr. HEUTER. No.

Mr. KARTH. This was the result of a poor weld, wasn't it? Isn't this how the gas escaped from the hydrogen tank and permeated the vacuum that acted as the insulation between the two tanks? Whose fault is this?

Dr. HUETER. I wouldn't call this a failure; this is something you have to expect in the program because of its development nature, Mr. Chairman. We were fortunate up to that time that actually nothing happened. But when we went into real tests and filled it with cryogenics, a leakage developed. Unfortunately, this bird is so sensitive that when a leakage develops it hits you pretty hard since immediately you have a large heat transfer. I wouldn't call this a failure of the contractor, but rather what you can expect during development.

Mr. KARTH. But this is a very mechanical operation, isn't it, Doctor? It was a weld that caused the leak?

Dr. HUETER. No, it is not a weld, no. You have, apparently, not the proper picture—as I see it, at least.

Mr. KARTH. This tank is not all one piece, is it?

Dr. HUETER. This is a balloon-type structure, which goes through a lot of stresses.

Mr. KARTH. And parts are welded?

Dr. HUETER. It is not an individual welding which went wrong, but the general design which has to be improved by better expansion joints and better supports.

Mr. KARTH. I see.

Dr. HUETER. But it is not a matter of quality control that we have this problem at the present time.

Mr. KARTH. Doctor, do you think the contractors have done a good job on Centaur?

Dr. HUETER. Well, let's say when you have some hindsight you always have the feeling you could have started it differently, and I still do not question the design. Maybe with more monitoring and ground testing we would have detected it earlier. I feel we would have gone through that cycle of step-improving the design, but it may be that we could have started it earlier.

Mr. KARTH. Then is your answer to my question that they could have done a much better job?

Dr. HUETER. If we would have supported them with more money, we could have probably done better ground testing, earlier ground testing. But, on the other hand, you have to consider also that this type of bulkhead was used in the Atlas and they had very good results.

So there was not immediately a need for doubting that this design was 100 percent.

Mr. KARTH. But you are not very happy with it, are you, Doctor?

Dr. HUETER. Certainly not yet, no. But we were all surprised that it came up.

Mr. KARTH. You are not very happy with the bootstrap principle that is applied to the engine, are you, really?

Dr. HUETER. No, I would say we are very happy with—let's say the bootstrapping is an acceptable thing and this is the least of our worries during development.

Mr. KARTH. You would rather have gas generator, though, wouldn't you?

Dr. HUETER. No; I wouldn't even say that, because the Centaur missile is a relatively small missile nowadays when you ask for payloads over a thousand and two thousand pounds. That means you have to fight for payload. And when you look only at getting the best out the engine, this is a more economic solution than the gas generator.

The gas generator, for things like the Saturn, for the particular Saturn booster, is probably a very good solution. But here, where we had to look for getting the best out of the missile, this bootstrapping as you call it, is the most ideal approach, and up to the present time I think, as I say, is the least of our headaches.

Mr. KARTH. It doesn't lend itself to growth, though, does it?

Dr. VON BRAUN. No.

Dr. HUETER. You are right when you say there is a limitation, very probably, because the volume of propellant to be heated for driving the pump increases faster than the surface of the engine which you need for heat transfer. So when you think of a 1-million pound engine, it is very doubtful that you could apply this principle. There might be other people who might believe in it, but that is essentially the point. But for this engine it is very ideal solution.

Mr. RANDALL. Mr. Chairman.

Mr. KARTH. Mr. Randall.

Mr. RANDALL. I recall the testimony of Dr. von Braun, this question of whether it was a weld or not—I think you used the expression "insulation", whatever that may mean. But now I don't think the question has ever been asked about this ground testing by the contractor. Is it provided that as to future—in this 8 or 10 we are talking about—is it going to be ground tested, or are we going through the same thing again?

Dr. VON BRAUN. Could I make a remark about the bulkhead here?

Mr. RANDALL. Yes.

Dr. VON BRAUN. What is quality control and what is welding and the design concept? Fundamentally, the idea behind this double bulkhead is that when you fill the vehicle with liquid hydrogen it freezes out the air in the interspace and draws a perfect vacuum, which will then heat insulate and cut down the heat transfer between the oxygen and hydrogen tanks. The problem is, of course, when you have a tiny little leak from either side into this interspace then you destroy this insulation completely.

And hydrogen has a way of getting into anything; any tiny little hair crack suffices to really wreck the vacuum very effectively.

Mr. RANDALL. Explain what you mean by cryogenic propellants. Is that low pressure?

Dr. VON BRAUN. That means boiling liquid, liquefied gases, like liquefied hydrogen or liquid oxygen.

Mr. RANDALL. Low temperature?

Dr. VON BRAUN. Low temperature propellants; yes. The problem now is you can have a perfect tank and it may still be that you go through three heating or cooling cycles; that is, you empty the thing, allow it to warm up, fill up with hydrogen three or four times, and suddenly you have a tiny little hair crack. This seems to be the difficulty with the unit.

This is accessible to design improvements. There are some stresses getting into that bulkhead that could be avoided with minor design modifications, and that is being attempted now. Whether it will ever be a very perfect solution remains to be seen. Some people are optimistic and say hair cracks can be avoided absolutely, others are less optimistic. Our present approach, however, with a two-burn Centaur, would enable us to live with the Centaur even if that problem is not absolutely licked, because it is really critical only during the 5-hour coast out to the 24-hour synchronous orbit when you have to turn the engine on again out at the apogee of this transfer elipse to inject it into the 24-hour synchronous orbit, and you have to fly out over a period of 5 hours with a tank only 10 percent full.

Mr. KARTH. You eliminate part of that problem by going to the Surveyor bus?

Dr. VON BRAUN. Surveyor bus; yes. So if we accept the Surveyor bus and eliminate the third burn, I think we can live with a less than perfect double bulkhead. For that reason I think the difficulty will be overcome one way or another.

Mr. KARTH. Are you trying to create a perfect bulkhead via the explosion route so that you form one piece with no welds, no fitted parts?

Dr. VON BRAUN. This is being done with some new projects, but I think there are no plans to introduce it——

Dr. HUETER. We use it as a sideline, the explosive forming of the bulkhead and electric forming of the bulkhead, but we have to study this further and make tests before we really can decide whether this is feasible.

Commander SCHUBERT. We have a number of methods, sir, in mind to solve the problem. One way is to improve the quality of our welds, which are not bad welds—they were perfectly good welds with other cryogenics than liquid hydrogen, but they become leaky welds when you put in hydrogen, which tends to leak.

Mr. KARTH. Is it the liquid oxygen that leaks?

Commander SCHUBERT. No, sir; it is the hydrogen. It is the tendency of hydrogen to leak through the tiniest holes, it is a characteristic not true of other cryogenic liquids. We can also make weld-free bulkheads, and have a program of this type to attempt this. One is called electroformed nickel, wherein you use electrical methods to deposit nickel on a substrata, and thereby obtain a complete 10-foot diameter bulkhead with no welds whatsoever. We have already begun work on that type.

Explosive forming is another possibility. The difficulty we face there, however, is in obtaining stainless steel of the type we use in wide enough widths to allow us to make a 10-foot diameter bulkhead in one piece without any welds whatsoever.

Mr. KARTH. The electrical mating has caused a problem, too; has it not?

Commander SCHUBERT. Mating of what, sir?

Mr. KARTH. Mating of the Centaur to the Atlas.

Dr. VON BRAUN. We had a few problems in ground equipment versus Centaur flight equipment.

Mr. KARTH. I see.

Dr. VON BRAUN. For example, the plug dropping off inadvertently.

Mr. KARTH. Has this problem been licked?

Dr. VON BRAUN. Sir, I would consider this a routine shakedown operation. I mean you usually have difficulties in that area with any project when it first gets to Canaveral, but this disappears after a while.

Mr. KARTH. Mr. Hammill?

Mr. HAMMILL. On page 9, of Dr. Newell's statement he says that in June 1960 complete responsibility for Centaur development was assigned to Marshall. Yet this small group under Colonel Seaburg was permitted to go along with its eight technical people out in Los Angeles until January 1962.

I wonder if there is an explanation for that?

Dr. VON BRAUN. I think this was corrected. He started out with 8 and we were supporting him with an ever-growing figure out of Marshall, about 15 assigned to his staff and many others doing a lot of traveling.

Mr. HAMMILL. But only 8 were technical out of the 15?

Dr. VON BRAUN. He had his original staff and that staff was expanded up to 15.

Dr. HUETER. May I explain it again?

Mr. HAMMILL. Yes.

Dr. HUETER. Colonel Seaberg had eight technical people including himself on his technical side. Colonel Murphy, who was a contracting officer, had approximately 15. I cannot swear whether it was exactly in July 1960, but later in the year he had about 15 contracting people helping Colonel Murphy.

As soon as we came in, we slowly built up both his office in Los Angeles and established a plant representative, after about 3 or 4 months, with a group of three or four people. Simultaneously we built up an advisory staff at Huntsville which Colonel Seaberg could call upon when certain technical problems developed, like, for instance, in the engine area.

But this until July 1961, was certainly not enough to go into all details of the Atlas-Centaur system. Only, let's say, we took care of the difficulties.

Dr. VON BRAUN. We put out first, you might say, whatever was burning, but we didn't have enough depth of penetration to anticipate the fire hazards.

Mr. HAMMILL. If, in fact, Marshall did have responsibility for the Centaur program starting in June of 1960, it is a little hard to understand why something wasn't done to correct the program's deficiencies in terms of personnel and so forth, all during that period, you see.

Dr. VON BRAUN. Well, there was a continuous buildup of more and more people. As I say now we have 140 which wasn't a very abrupt switch on our part, either. We built this up gradually. But most of these people were on call in Marshall to make themselves available if some fire arose.

The reason why we wanted Colonel Seaberg really in Huntsville was we felt there really wasn't enough communication. In other words, the men heard about difficulties only after there was something on fire. And I think it is really very necessary in a project like this to have a mechanism that enables you to anticipate problems before they strike.

Mr. HAMMILL. I would like to explore with Dr. Newell the control of the program that has been exercised from NASA Headquarters. Now, about a month ago during the course of our authorization hearings, we heard from Colonel Heaton, who at that time, we understood, was project manager of the Centaur program here in headquarters. Now we understand that Colonel Heaton is no longer with NASA, but is back with the Air Force.

Who is his successor in that job, sir?

Dr. NEWELL. I would like to point out that Colonel Heaton was head of the office in which the headquarters assignment in the Office of Space Sciences was made. He was not the project manager, per se. Commander Schubert has been entitled the "Centaur Program Chief."

The launch vehicle office, of which Colonel Heaton until recently was director, had responsibility for a number of vehicles; Scout, Delta, the Agena's, and Centaur, as well as sounding rockets. So that his attention, you see, or his responsibility, covered this whole area and in his office, on his staff, he had people for the different vehicles.

Mr. HAMMILL. I see.

Dr. NEWELL. Now, Vince Johnson has taken on Colonel Heaton's duties as head of this total office for the time being. We have recently hired Professor Morrison, from the University of Michigan, to take over this position which he will assume when he is able to wind up this year's work at the University of Michigan. He should be with us sometime this June.

Mr. HAMMILL. What I am really trying to determine, Doctor, is who has been responsible for the Centaur project in NASA Headquarters, and specifically, what are his responsibilities and what is his authority to supervise the project?

Dr. NEWELL. Well, prior to the 1st of November of 1960, this came under General Ostrander's office and, as I recall, was under Milton Rosen. Is this correct?

Dr. VON BRAUN. Yes.

Commander SCHUBERT. Yes.

Dr. VON BRAUN. Seaberg brought it direct to Rosen until Marshall became part of the NASA family and when the job was assigned by General Ostrander to Marshall, Seaberg was simply told to report to Marshall instead of to Rosen, but Rosen, of course, being the headquarters launch vehicle director, was still in charge in the Washington level.

Commander SCHUBERT. May I help, sir?

Dr. NEWELL. Yes.

Commander SCHUBERT. You asked about project management as such. It is the policy of NASA, and it is common throughout its programs, that project management is delegated by headquarters to a field center. In the case of Centaur, the delegation of project management was made to Marshall in June 1960. There is no, what you might call, project management at NASA Headquarters.

Mr. HAMMILL. There is not?

Commander SCHUBERT. Well, it would be a duplication obviously if there were.

Dr. VON BRAUN. There is funding control; that is a very essential element.

Commander SCHUBERT. At headquarters, we perform a rather different function, namely to convey only the broadest type headquarters policies to the field center charged with the immediate project management, and to perform the budgetary function which supplies funds to the program, and so on. There is a difference between the function provided at headquarters and at Marshall Space Flight Center.

Mr. HAMMILL. Well, what I was leading up to, and I don't seem to be able to get to it very well, is this: I think the committee has the impression that a project such as Centaur, or any launch vehicle development program, for that matter, has to have a strong man at the top who can direct the project. I think that the feeling here is that perhaps we haven't had that kind of supervision in this case. Moreover, certain military officers, undoubtedly very competent, have been assigned for brief periods and have acted as project officers, if you will, for these short periods, and then have been transferred back to their mother services, to be replaced by other military men. We wonder if this perhaps isn't the wrong way to approach these things. Maybe NASA should have someone in each case who can get on the project, and stay on it, and see to it that it is done properly, start to finish.

Dr. NEWELL. I see what you are leading to.

I might point out that in the period since this has been in the Office of Space Sciences a number of steps have been taken and are being taken. One of them has been to support Dr. Hueter's request that the organization be projectized. Another one has been an attempt to strengthen the demand on the headquarters team for a very close, shall I say, scrutiny and support of the field activities in this area, recognizing that we don't want to get in their way because this is the job of the Marshall Space Flight Center to get on with this work.

In addition, when we learned that we were going to lose the services of Colonel Heaton, we scoured the country for a competent individual to replace him and carry on the work of the overall project office and we are very fortunate in having Professor Morrison accept this position. I think that the overall vehicle program will be in good hands in his management. And, secondly, since we are also going to lose the services of Commander Schubert, we have undertaken to move up one of our strongest permanent members of headquarters, Mr. Johnson here, to take over when Commander Schubert leaves. Fortunately we have an overlap in time here during which the two can work together for a good period of time so as to maintain continuity before Commander Schubert is lost to us.

I think that with these steps and with the results of a very thorough review of the program and program requirements, technical, financial, managementwise, which the Marshall Space Flight Center has been conducting since last August, we will be able to get on top of this management problem. I think we have gone a long way toward doing that now.

Dr. von Braun. Mr. Hammill, may I add something to what Dr. Newell just said?

Mr. Hammill. Yes. Please do.

Dr. von Braun. You asked your question in a very general way, like this was the standard way NASA was handling all its launch vehicles. I think I should point out at this point that the Centaur is actually a very unusual way, even for NASA, to handle its launch vehicle developments. We inherited a program here that was actually initiated by ARPA, assigned to the Air Force, assigned to NASA halfway down the street and then, as we heard here, there had been several changes also inside NASA, a gradual transfer of the responsibility to us. Most other launch vehicles that we handle, particularly the Saturn family, both the C-1 and C-5, originated within NASA and all these problems that you heard here today just don't exist there. And I think none of the problems that came here to light today applied to the other projects at all.

Mr. Karth. So all of these things that we have been talking about today has added up to a series of delays.

Dr. von Braun. Yes, sir; but they involve Centaur only and I think one should be very careful in drawing the significance for NASA's launch vehicle management out of this. This is a very special case.

Mr. Karth. I am sure there is no misunderstanding on the committee's part, and if there is why let it be corrected in the record. I certainly agree with you, Mr. Randall.

Mr. Randall. Any apparent criticism by the committee, at least by this member of the committee, is not directed in any way to the Office of the Director of Space Sciences. I want to join with our chairman in stating my personal belief that he is one of the most able and sincere men in the entire space program. I am a little concerned about the remark that was made a moment ago about that there is no project management at NASA headquarters but only a funding control.

Dr. Newell. Yes, that should be clarified: The intent there was to point out that we have delegated the engineering responsibility for this to the Marshall Space Flight Center. It is their responsibility to bring into being a working, flying vehicle. The headquarters' function here is to keep on top of what is going on, to be aware of the needs, to work with the Marshall Space Flight Center, to be alert to problems as they are developing before they become real problems, and to attempt to develop a support for the Marshall Space Flight Center, fundingwise and otherwise, so that they can do their job right. In this sense there is a program management responsibility in headquarters as opposed to a project management responsibility which is at Marshall. I think there is a semantics problem here.

Dr. von Braun. Could I clarify this a little further from my point of view?

Headquarters tells us: This is the program we want you to implement, this is the money you get to do it. And we are also expected, of course, to tell headquarters whenever some difficulties arise where we need their help. But the implementation of a clearly defined program and the expenditure of the resources made available to this program is then delegated to the field center.

Mr. RANDALL. Mr. Chairman, only one thing further. I don't know that it is the proper forum, maybe this committee is not—you may feel that this subcommittee does not have the proper jurisdiction, but all afternoon we have been talking about officers of the various military services being with NASA awhile. And I assume that they would disrupt their military careers, they must be assured they will not remain over 3 years, or a period of time, and then they go back. There seems to be a constant turnover. I think that that is certainly one worthy of some study, maybe by the full committee. I don't know—the executive branch certainly—but if we have any oversight at all, I think some delay, somewhere along the line has been due to this sort of a situation.

Commander SCHUBERT. May I attempt to clarify that matter?

Mr. KARTH. Yes.

Commander SCHUBERT. When NASA began it was difficult to find people with experience applicable to the space program.

Mr. KARTH. Yes, sir.

Commander SCHUBERT. As I understand it, the only reason why any military people have ever come to NASA was to help NASA with their accumulated experience, primarily in the guided missile field, to get itself on the road as early as possible. It is the long-range plan, I am sure, that military people will gradually phrase out of this new family, and that permanent, civilian people as they can be recruited or trained in our universities, and so on, will take the places of these military people.

What you see is an early stage of development of a large organization that had to get going quickly and it had to get people where the qualifications were, regardless of their relationship.

Mr. KARTH. This is my understanding, Commander. Just two further questions and then we will adjourn for the day.

Dr. von Braun, Centaur has a long way to go yet, doesn't it?

Dr. VON BRAUN. We are not out of the woods yet, sir.

Mr. KARTH. There is no thought on the part of the NASA people at Marshall Space Flight Center that this program should conceivably be scrapped and be replaced with some other program, is there?

Dr. VON BRAUN. No. I am convinced that we will be successful. You asked me the question before: Are there any disagreements with the approach the contractor has taken? Dr. Hueter made his reply in rather general terms. I would say there is probably a little difference in the philosophical approach, in the design philosophy between the contractor and the way we are used to doing some of these things.

By and large, General Dynamics/Astronautics has taken a very imaginative but on occasions somewhat bold approach. In order to save a few pounds, they have elected to use some rather, shall we say, marginal solutions where you are bound to buy a few headaches before you get it over with. Ultimately when you are successful you have a real advanced solution, no question about that either.

Mr. KARTH. You like the gas operating pump system, don't you?

Dr. VON BRAUN. No, I am not referring to that. I like the bootstrap cycle very much.

Mr. KARTH. Would you state for the record your views?

Dr. VON BRAUN. Yes, sir, I would use it again. But for example the pressure-stabilized tanks; this is certainly a very great advance in the art, but looking backward now I would say we certainly have bought a lot of trouble by switching to that method.

It is a great weightsaver but it is also a continuous pain in the neck. And some other contractors, for example the Martin Co., for this very reason have elected not to use it.

Now there are many things of this nature. I wouldn't say that we are right and the contractor is wrong. I would say there are differences in the design philosophy in some of these areas.

Mr. KARTH. Anything else, Doctor?

Dr. VON BRAUN. If I could make a rather general remark here. I think we have all learned something from the way these things have gone. I think the general lesson we have learned from Centaur management is probably that one should never underestimate the magnitude of a program where so many new and unproven ideas are tried out and I think we will always get in difficulties, as a Government agency, unless we build up a competence in the Government that we can really stay on top of the problems right from the outset and learn how to identify potential problem areas before we have explosions and fires and setbacks.

And this is the one lesson I most certainly learned from this Centaur thing: That to get into a program of this magnitude with a few people belatedly and then try to penetrate this program and identify problem areas once you are right in the midst of it is a very tough thing to do.

It is for this reason that in the Saturn program we are really making an all-out effort to stick together with the contractor before major design decisions are even made and have our men argue with his men as to whether this is really the way to go.

Now they may still make some mistakes here and there, but I think it gives us far more protection against this kind of setback and, in my opinion, this is the only way in which a Government agency can really be held responsible for schedules and money expenditures—if this is done right from the outset, not belatedly.

I think the coverage on the part of the Government for a program of the magnitude of the Centaur was just plainly inadequate from the outset and should have been much greater. The only excuse one can have for it is that it started out as a little exploratory program and grew and grew and grew into a major program, and it wasn't intended that way from the outset.

And if we have made any mistakes at all, it was probably that our own management structure didn't grow as fast as the difficulties we were confronted with. But this won't happen again.

Mr. KARTH. Just like that prehistoric animal named brontosaurus who grew faster than his brain and somebody nibbled off his tail and his defenses were down and despite his size he was gentle as a mouse.

Dr. VON BRAUN. It wasn't quite that bad with the Centaur.

Mr. KARTH. I understand.

Dr. Newell?

Dr. NEWELL. I would like to concur in the general philosophy Dr. von Braun has just described. I would also like to be sure the record doesn't imply any reflection on the very competent officers who worked with us.

We would have been in the soup without people like Colonel Heaton and Commander Schubert and they have done a fine job.

We have, however, taken steps to eliminate this embarrassment of 3-year termination of duty by bringing on permanent people for these positions. At the same time we are very grateful and appreciative of the fine work that they have done.

Mr. KARTH. Fine. Any further questions?

If not, the meeting is adjourned. Thank you very much, all of you gentlemen. We appreciate your coming before the committee.

(Whereupon, at 5:03 p.m., the subcommittee adjourned, to reconvene at 10 a.m., Wednesday, May 16, 1962.)

CENTAUR LAUNCH VEHICLE DEVELOPMENT PROGRAM

FRIDAY, MAY 18, 1962

House of Representatives,
Subcommittee No. 3 of the
Committee on Science and Astronautics,
Washington, D.C.

The subcommittee met, pursuant to adjournment, at 10:15 a.m., in room 214–B, New House Office Building, Hon. Joseph E. Karth (chairman of the subcommittee) presiding.

Mr. Karth. The subcommittee will come to order. Today we will hear from Mr. Grant L. Hansen, who is vice president and Centaur program director for General Dynamics/Astronautics at San Diego, Calif. Mr. Hansen appears before the subcommittee today as the first witness representing the major industrial contractors involved in the Centaur program.

If there are other people from your firm who also intend to participate in the hearings, I wonder if you would identify them for the record at this point, Mr. Hansen.

Mr. Hansen. Only Krafft Ehricke and myself will speak.

Mr. Karth. Mr. Krafft Ehricke. Would you state his position with the company for the record?

Mr. Hansen. Krafft Ehricke is currently the director of advanced systems for General Dynamics/Astronautics.

Mr. Karth. Mr. Hansen, you have a prepared statement. Would you care to proceed with your statement at this time?

STATEMENT OF GRANT L. HANSEN, VICE PRESIDENT AND CENTAUR PROGRAM DIRECTOR, GENERAL DYNAMICS/ASTRONAUTICS, SAN DIEGO, CALIF.

Mr. Hansen. Yes, sir.

I have a brief introductory statement which expresses my point of view in this matter, after which Krafft Ehricke has a much more detailed statement and some film clips which he would like to show if the subcommittee is interested.

Mr. Karth. Fine. Then why don't you proceed in that order?

Mr. Hansen. Thank you.

Mr. Chairman and subcommittee members, as General Dynamics/Astronautics program director for Centaur since February 1, 1962, I will present current program information. With me is Mr. Krafft Ehricke, who was program director for Centaur at GD/A from program inception until February 1, 1962; he will present program background information.

We welcome this opportunity to discuss the Centaur program and its management with you.

The Cenatur program at GD/A includes design, development, and manufacturing of the Centaur upper stage itself and the system engineering to combine it with its engines, booster, payload, support equipment, and facilities for checkout and launching. We also handle flight testing at Cape Canaveral under the direction of NASA's Launch Operations Directorate.

During February 1962, those persons who were working on Centaur at GD/A were organized into a line department, responsible only to the Centaur program director and concentrated in one building of the GD/A Kearny Mesa plant at San Diego, Calif. Centaur operating personnel at the Edwards Rocket Base, Sycamore Canyon Test Site, and at the Atlantic Missile Range have also been made line units of the Centaur project organization and responsible to the Centaur program director for proper conduct of their portions of the program effort. There are approximately 1,100 people in the Centaur project at General Dynamics/Astronautics.

These organizational changes were made at the time when NASA and GD/A were in agreement that the new form of organization would result in improved teamwork and communication. The requirement for this was recognized by our management as a means to implement the design and development philosophies of the Marshall Space Flight Center.

In Dr. von Braun's previous testimony to this subcommittee, he mentioned the difference in design philosophy between GD/A and Marshall Space Flight Center. Used properly, as I believe it is being used, I consider this to be a program asset which gives me confidence and optimism for the success of the program.

The bold, imaginative approach at General Dynamics/Astronautics, when coupled with the experienced, thorough competence of Marshall Space Flight Center and the capabilities of our associate and subcontractors, produces a team much stronger and more competent than any of us alone could be. We welcome the technical "penetration" which Dr. von Braun spoke of, because we believe that this attention will enable accomplishments which will reflect credit on all members of the Centaur team.

I have examined the management plans of NASA for Centaur in detail, and I can support them enthusiastically because I believe they are sound. I believe that our organization and management attitude at GD/A are entirely compatible with NASA requirements.

Our Centaur program is not without normal technical and management problems for this type of program. These are matters of mutual and concurrent concern between ourselves and the Centaur project office at Marshall Space Flight Center. I believe that we have the technical and management capability in the currently existing management structure of NASA, General Dynamics/Astronautics, Pratt & Whitney, Minneapolis Honeywell, Pesco, General Electric, Bell Aircraft, and our many other Government and industrial partners to complete the Centaur development successfully.

Krafft Ehricke contributes generously to me his advice and consultation on Centaur program matters. I am very pleased that he can appear with me today to tell you about it in detail from its inception.

Mr. KARTH. Mr. Ehricke, why don't you proceed and complete your statement and then the subcommittee would request both you and Mr. Hansen to answer some questions.

STATEMENT OF KRAFFT A. EHRICKE, DIRECTOR, ADVANCED STUDIES, GENERAL DYNAMICS/ASTRONAUTICS

Mr. EHRICKE. Thank you, sir.

Mr. Chairman, members of the subcommittee, in my prepared statement I will review areas of systems concept, mission objectives, engineering research and development, management, schedule and cost of the Centaur program during the period of November 1958 through January 1962 during which I served as program director.

I will also briefly cover the preceding period from early 1956 on, the period of conception of Centaur. The Centaur concept was perhaps the result of the most thorough systems and mission analysis of any space project at that time.

Our early advanced work led to what I refer to as the proto-Centaur, the four-engine, pressure-fed, oxygen-hydrogen stage which was the subject of our first proposal in December 1957. I was responsible for both the direction of the conceptual work, and for the GD/A program direction during the first 3 years of the Centaur development.

The work began with a study of suitable and important early space mission objectives and with the realization that vehicle systems to undertake these missions should have high thrust and high propulsive energy.

Briefly, the purpose of our vehicle studies was:

(1) To utilize the then unexcelled thrust power of Atlas to lift a large second stage.

(2) To provide the upper stage with a maximum energy level for its weight.

(3) To give the upper stage multimission capability in space.

(4) And to keep the payload variation with a change in mission energy at a minimum.

Requirements (2), (3), and (4) are now generally recognized as fundamental for launch vehicles and space missions. They call, above all, for high specific impulse; that is, a high-energy propellant.

The multimission capability I spoke of was studied with the objective to define and provide a first-generation capability for three of the most important mission classes at the beginning of an astronautic technology.

These are the:

(5) High-altitude satellites in the 8-hour, 12-hour and 24-hour orbits for the purpose of global surveillance, early warning, and global communication.

(6) Launching of instrumented space probes to the lunar surface and into the inner solar system, primarily to Venus and Mars; but solar probes inside the orbit of Mercury were also considered by us using a solid third stage, the same as we postulated for the lunar landing mission, since the energy requirement for both missions is the same.

(7) Establishment of a small manned orbital laboratory for a crew of three to inaugurate systematic preparations for deep space missions of manned spaceships.

A large number of high-energy propellants were investigated for the upper stage, including such combinations as fluorine-hydrogen, fluorine-hydrazine, ozone-methane, fluorine-ammonia, and oxygen-hydrogen. Oxygen-hydrogen was selected on the following grounds:

(8) The specific impulse is near the upper limit attainable with chemical propellants due to the use of hydrogen as fuel.

(9) No change in oxidizer was required. This allowed us to utilize the already well-developed liquid-oxygen technology.

(10) The final reason was on the basis of the long-range viewpoint that not only larger O_2-H_2 vehicles would be needed for chemical spacecraft, but that we had also to recognize the fact that at least the first generation of nuclear engines would have to use hydrogen, since the specific impulse advantage of these nuclear engines is based on the use of a gas which is lighter than the combustion gases of chemical propellants.

Among the variety of stage weights, an upper stage of 30,000 pounds weight was selected because—

(11) This weight was close to the upper limit which Atlas would carry under the then existing design and operational conditions and furthermore an upper stage diameter of 10 feet could be adopted, giving it the same diameter as Atlas. At this diameter, a 30,000-pound oxygen-hydrogen vehicle would be kept at a reasonable length, yielding an aerodynamically clear and dynamically stable configuration for Atlas-Centaur.

In October 1957 the studies of the first proto-Centaur and its mission objectives were essentially completed. The first proto-Centaur had many of the features of today's Centaur, such as jettisonable aerodynamic insulation and nose fairing, integral tank design in which oxygen and hydrogen are separated by a single intermediate bulkhead, the application of cryogenic vacuum formation in the intermediate bulkhead space and forward location of the hydrogen.

The intermediate bulkhead, however, was somewhat differently designed. Two major differences between the original and the present vehicle are in the area of tank design and propulsion system. Proto-Centaur had a second hydrogen tank inside the main hydrogen tank and also had an inner oxygen tank, inside the main oxygen tank. The propellant stored in these inner tanks was to be used for firings in orbit after a coast period.

The vehicle was to be powered by four engines at 7,000 to 7,500 pounds thrust each. The main tanks were to be emptied during the ascent into the parking orbit, serving thereafter as radiation heat shield and meteor protection device for the fluid stored in the inner tanks during the subsequent coast periods.

Propellants were pressure fed into the thrust chambers. The reason why we selected this engine system in teamwork with the Rocketdyne Division of N.A.A. was simply that we wanted to avoid the delay by what we thought would have to be a brand new pump development. We were, for security reasons, not aware of Pratt & Whitney's pioneer work in this field.

I recommended at that time that we proceed with pressure-fed engines to get the vehicle systems development underway and leave the introduction of a pump-fed system to a second-generation engine. We used a gas generator on the proto-Centaur; but its purpose was to serve as heat exchanger for the pressurizing of gas and to burn gaseous oxygen and hydrogen to drive the ullage and attitude control engines for maximum utilization of the boiloff gases contained in the vehicle. This proto-Centaur was the basis for the proposal submitted in December 1957 by General Dynamics/Astronautics to the Air Force, entitled: "A Satellite and Space Development Program."

After ARPA was established we made contact to discuss the proposed vehicle and missions. Our line of thought found interest. The fact of the Pratt & Whitney hydrogen pump development was made known to us and we were encouraged to submit a proposal using two pump-fed engines of the type which has been suggested by Pratt & Whitney, at 15,000-pound thrust each.

On the basis of a so modified second proto-Centaur we submitted a second proposal for the development of an O_2/H_2 vehicle to ARPA in August 1958. It was entitled "Proposal for a Mars Probe," because we were also quite mission conscious and attempted to emphasize the importance of gaining an early capability to send probes to Venus and Mars in view of the infrequent intervals at which these missions can be flown.

On August 28, 1958, ARPA order 19–59 was issued to ARDC for development of an O_2/H_2 upper stage for Atlas, weighing about 30,000 pounds, having a diameter of 10 feet, powered by two engines at 15,000-pound thrust. Seaberg (USAF/ARDC/Special Project Office) was assigned as USAF project manager at H2/ARDC. Murphy (USAF/HQARDC) was assigned as contract administrator. Overall technical and managerial guidance was to be furnished by ARPA (Director—at that time it was Roy Johnson and Chief Scientist, George Sutton).

The program was initially visualized as a state of the art development (make an oxygen-hydrogen stage work) leading to a space truck consisting of Atlas and Centaur and bridging the gap between Atlas-Agena on the one hand and much larger future booster vehicles on the other. A primary mission was not defined.

Development time to first flight was 25 months.

First flight was to occur in January 1961 on the initial schedule.

Astronautics was given systems management responsibility; that is, to design, develop, build, test, and launch the Atlas-Centaur vehicle.

The total contract cost for GD/A was close to $36 million and involved the following tasks:

(*a*) design and develop 6 Centaur flight articles;

(*b*) design and develop ground support equipment;

(*c*) design modifications for series D Atlas, including the interstage adapter;

(*d*) fabricate one battleship tank, for cold flow tests;

(*e*) conduct a flight test program at the Atlantic Missile Range; and

(*g*) provide miscellaneous reports.

You will notice that the tasks did not specify a new guidance system development (this was to be added later), or any test article which could be fired on a static test stand, nor does the list include any test facilities or launch complexes. All this, and other necessities were to be added later as more funds became available.

This is somewhat characteristic of a state of the art program approach, similar to the way in which Saturn was started. The purpose here is simply to "trigger" new lines of growth, so to say, get babies born who would later on develop into full-fledged personalities. In such cases, it is difficult to predict precisely what problems one will find, what delay they might cause and what additional funds they will require.

In view of the relatively small amount of money available (of which $6,750,000 was provided for fiscal year 1959), General Dynamics/Astronautics made it clear that this program would have to be one of utter austerity, minimizing ground testing in general and requiring the use of flight articles for captive firing tests.

The battleship tank was required for hydrogen tanking and flow tests at Astronautics' Point Loma test facility. These stipulations were approved by ARPA, due to the lack of more adequate funding. In addition, ARPA directed that the Atlas design and the current state of the art were to be applied wherever possible.

Program management rested with ARPA/ARDC, November 1958 through June 30, 1959; Headquarters, NASA, from July 1, 1959, until June 30, 1960; NASA/MSFC, July 1, 1960, until now.

Lieutenant Colonel Seaberg was program manager from 1958 through 30 June 1960 and thereafter was attached to Hans Hueter, Marshall Space Flight Center, Director of Light and Medium Vehicles. After return to the Air Force in January 1962, he was replaced by F. Evans, Marshall Space Flight Center.

As time went on, scope and importance of the Centaur program grew with the growing national interest in space. The difinition of the 24-hour orbit mission by ARPA as a primary mission followed in December 1958. The use of Centaur for NASA deep space missions began to be firmed up by December 1960.

With the management passing to MSFC, emphasis on ground testing increased. This trend was supported by General Dynamics/Astronautics; but increasing funding and more time is required to carry out these additional tasks.

During the calendar year 1959, the total GD/A program cost rose to $42 million due to the addition of the Centaur guidance system, the need for a flow test facility, and I might add other test facilities at Point Loma, design of a static test facility at Sycamore and other requirements. At the end of 1959 the flight test program was rescheduled to begin in June 1961 (previously January 1961) and to extend through June 1962 (previously June 1961).

In 1960, the total GD/A program cost rose to approximately $63 million due to a great extension of the program, such as the addition of a Centaur test program in the Tullahoma Vacuum Test Facility (Arnold Engineering Development Center), additional nose fairing development, zero-g flight test program with Aerobee rockets, a second reprograming adding four flight test Centaurs and providing for static ground testing of all Centaurs, rather than the first two flight articles only; a third reprograming, postponing the 1st flight to November 1961, and the 10th flight to January 1964 and other added requirements.

In 1961 the total GD/A program cost climbed to $100 million due to a large number of additions which included the propulsion test vehicle, wind tunnel tests of our insulation panels at the NASA Langley Facility, providing propulsion equipment to the NASA Lewis Research Laboratory, extending the zero-g test program, addition of a comprehensive reliability program, the construction of a coast phase test stand for studying and testing the Centaur attitude control systems, flight testing the Centaur guidance system on the Atlas and other items.

As you can see from the foregoing, the growing importance of the Centaur program led to added tasks and an expanding ground test program. The reprograming of the flight test program and the associated extension in time, in turn, were partly the result of delays due to normal development problems, and partly caused by the delays which unavoidably arose in the process of attempting to incorporate continuous additions and extensions of tasks in a going program.

We welcomed these additions because they put the program on a technically sounder basis on which we would have liked to have seen it from the start, and I might add when I say "we" I mean not only at General Dynamics/Astronautics, but many of our other contractors and our program manager, Colonel Seaberg; but these additions nevertheless meant delays compared to the original dates.

The first Centaur design in its present configuration, which was essentially frozen in the second half of 1959, is the result of an evolutionary process over which were superimposed certain initial constraints, such as the direction to use existing hardware and designs wherever feasible—or acceptable—even if not ideally so.

With the availability of pump-fed thrust chambers, it became possible to use a completely pressure-stabilized tank design. This design has been shown by the Atlas development to be quite practical and reliable, so much, indeed, that we entrust to it the lives of our astronauts.

Using this design, we achieved a very high mass ratio for a vehicle of this size with low-density propellants. The membrane bulkhead design uses cryogenic vacuum formation as the logical utilization of an existing extreme temperature environment; just like Pratt & Whitney's bootstrap method of engine start was an ingenious and logical utilization of the special physical characteristics of liquid hydrogen.

The present bulkhead problems have several solutions and we are positive, therefore, that our current difficulties in this respect are of transient nature.

We will encounter other problems, such as operation of all vehicle systems after extended coast in high vacuum, and possibly the need for more extensive meteorite protection. But these problems will be common to all space vehicles. They must be solved and the successful operation of the Centaur oxygen-hydrogen vehicle, whose design is basically sound, must be demonstrated. How else can we gain the confidence that we will be able to handle the far bigger oxygen-hydrogen stages and the nuclear-hydrogen stages to come.

Without such vehicles and without solving the problems of restart after long coast periods and other problems of an orbital technology into which Centaur will run, we will not be able to gain a significant space capability. We must face these problems and see them through.

The Centaur program is the bridge through which we can make the transition from missile to space technology. Therefore, Centaur has become a trail blazer in more than one respect. It is not only pioneering a hydrogen technology to be used more safely by followon vehicle develpments, but it has also sharpened our awareness of many other space flight problems. It has even been a guinea pig to develop better managerial concepts as they will be needed for the complicated vehicle developments and space operations ahead.

Let me summarize some of the salient points of the Centaur program so far:

In 1958 we had our program go-ahead in November, state-of-the-art development, minimum initial funding. Centaur, like any other space program such as Mercury, Saturn, launched in the early years of the space age, started on a shoestring budget, with governmental managerial capabilities in its infancy, its concepts and objectives doubted by man or met with lack of interest by others.

Like the other space programs, Centaur was to grow as it went along. Yet, unlike Mercury and Saturn, Centaur could never attain DX-priority although its contributions are as much a cornerstone of our future space capability as those of a manned space capsule and a high-thrust booster.

In December we received our primary mission assignment. It required, however, considerably longer time to define the operational mission constraints, the weight, size, and shape of the payload. Thus, as far as we engineers were concerned we had in one sense, a mission assignment; in the other sense we did not have one. Developmentwise this caused some difficulties.

1959: As systems integrator, we made the necessary engine operational specifications to give Pratt & Whitney their needed frames of reference; we specified the all-inertial guidance system requirements, evaluated bids and selected the subcontractors; we finalized the vehicle configuration and all essential components and selected the various subcontractors.

We started immediately to worry about zero-g propellant behavior and began to conduct a series of zero-g flights in the Air Force's C–131D at Wright Field. Special materials investigations were immediately undertaken in anticipation of problems which liquid hydrogen might cause. We acquired a vacuum test chamber facility for component and gas expansion tests. We built two heavy Centaur tanks, one for Pratt & Whitney, and the other for our flow tests. The Point Loma Test Facility was prepared and the very important tanking and flow tests with liquid hydrogen commenced. We designed our static test facility (S–4) in Sycamore Canyon and proceeded with the design of a Centaur launch complex—complex 36—at AMR.

1960: In January we received the contract for complex 36. In May we started building our first flight article, the one which was launched in May 1962. In August we started building the second flight article, received our first guidance system and received the first pair of ground test engines from Pratt & Whitney.

We expanded our zero g. test program and received authorization to build a special propulsion test vehicle (PTV) for static test firings. We modified stand 1–1 at the Edwards Air Force Base as PTV stand. Meanwhile, S–4 was completed, the PTV erected and cold ground tests started. We were preparing for hot firing tests when the first explosion occurred at Pratt & Whitney's vertical stand E–5. We temporarily halted our preparations and were directed by NASA not to resume them until present difficulties were overcome.

1961: Pratt & Whitney's temporary problems delayed the delivery of flight engines. In February we sent the first Atlas D booster (104D) to complex 36. The first flight article, the Centaur 2, that we ever delivered to AMR, followed on March 1, 1961. Together these two stages served to mate facility and vehicle, to correct deficiencies in the facility operation, and to train our launch crew.

Our zero g. program and component test program at Point Loma were continued. We continued cold flow tests at S–4 which gave us valuable information particularly because the bootstrap system permitted us to get initial engine start transients without igniting.

In late summer and fall, we encountered our first major difficulties when, during tanking tests at AMR we discovered the extensive heat transfer across the bulkhead, of which you have heard. Upon checking our first flight article at S–4 and finding again excessive heat transfer, we immediately launched a most intensive investigation of the causes and methods for future improvements.

Because of the lack of PFRT'd flight engines for C–1 we had changed its mission into a suborbital profile. For this flight the high heat transfer rate across the bulkhead could be tolerated. We attempted, with the approval of NASA Headquarters and Marshall Space Flight Center to launch C–1 before the end of the year. When this became inconsistent with sound engineering practice—due to a variety of small problems during preflight operations and due to occasional parts shortage, Marshall Space Flight Center, launch operations director, and we agreed to postpone the flight and continued to do so until we had reasonable assurance of a successful takeoff and flight.

The past 3½ years of Centaur work have laid the foundations of a hydrogen-oxygen vehicle technology from which Centaur's large successors already are deriving benefits.

Among the achievements of the program so far are:

Density measurements of liquid hydrogen in large quantities, rather than in laboratory quantities;

Development of liquid-gas sensors to measure the distribution of liquid hydrogen in the tank under zero g. conditions;

Development and successful application of a television system inside the hydrogen tank to permit transmission of pictures of the hydrogen behavior on the ground as well as in flight;

Development of a special valve to vent the hydrogen tank under zero g. conditions without losing liquid hydrogen, that is, heat transfer measurements with liquid hydrogen at 1 g. and at near zero g. conditions;

Development of theoretical and experimental methods to predict the liquid hydrogen distribution in the tank at prolonged zero g. periods;

Development of a propellent utilization system which operates at the extereme temperatures of liquid hydrogen; and

Operational tanking and detanking of liquid hydrogen as part of test and launch operations with large rocket vehicles.

Hydrogen itself has turned out to be less of a culprit than many thought initially. Hydrogen, like all chemical fluids, behaves fine if you know its little "idiosyncrasies" and treat it correctly. But you have to go through a development program such as ours first.

The present GD/A Centaur organization is the finest you can have for a project of this kind. Together with our associate contractor and our subcontractors, you have a powerful industrial team. NASA's management and development support has proved extremely valuable to the program.

In particular, I am, through my personal association, very much aware of the unexcelled capabilities of those among my former colleagues at Marshall Space Flight Center who are associated with the Centaur program under the direction of Dr. Hueter and Mr. Evans. On the launch site, we have established close team relations with NASA/LOD.

In view of the cordial and determined cooperation between the NASA teams at MSFC and LOD and the industrial team I believe, gentlemen, that fullest confidence in the success of the crucial Centaur program is justified.

If you have any questions, I will attempt to answer them to the best of my ability. In case you are interested in taking a 10-minute look, approximately, at some phases of our development work that I spoke of before, we have prepared a set of film clips which I am ready to show you.

This is the end of my prepared statement, Mr. Chairman.

Mr. Karth. Will you turn the light on, please.

I think what we will do is let the film clips go until after a while.

Mr. Ehricke. Yes, sir.

Mr. Karth. And if we have time to see them, why we would be very happy to take a look.

Mr. Ehricke. Yes, sir.

Mr. Karth. Mr. Hansen, on page 1 of your testimony, beginning of the third paragraph, you begin by saying during February 1962 those persons who were working on Centaur at GD/A were organized into a line department.

Would you explain that and explain why it was done in February of 1962 rather than sooner?

Mr. Hansen. Yes, By a line department I mean one in which all persons in that department report directly to the program director as opposed to the previous organizational arrangement in which the various specialists reported to a function head for that specialty and had their efforts coordinated by a program director who was in the organization in a staff capacity.

I think that it should be noted that the project organization or line organization which we formed was not, and is not, a complete project organization. It could only be if we had a separate division for Centaur. We took what we felt was the proper compromise between a direct line control of program elements and the economy of providing separate, for Centaur, such costly things as computing facilities, laboratories, that sort of thing.

So there are supporting activities within the astronautics division which are not part of the project organization. And it was for the purpose of giving me adequate authority over those functions to insure that we would properly support the program that I was made, in addition to Centaur program director, a vice president of the division.

Now, concerning why that was not done earlier, this has to be sort of impressions and opinions on my part, since I was made program director at a time when the decision had already been made to rearrange the Centaur organization.

As I stated in my prepared statement, at the time when NASA and our own management agreed that it was the proper time, this was done; NASA testimony on Tuesday indicated that from strictly a Centaur point of view they would have liked to have seen this move made earlier.

It should be pointed out that the forming of a project organization is not all advantages. Like anything else, there are advantages and disadvantages.

Mr. KARTH. But you agree it is better don't you; otherwise you wouldn't have gone to it at all?

Mr. HANSEN. Yes, sir. That is correct.

Mr. KARTH. Although there are disadvantages it is, in fact, better.

Mr. HANSEN. Although there are disadvantages, it is in fact better.

Mr. KARTH. Than the matrix system.

Mr. HANSEN. For today's circumstances.

Mr. KARTH. Maybe we ought to ask Mr. Ehricke then why this wasn't done a little sooner than it was done.

Mr. EHRICKE. Sir, the management of the program at General Dynamics went through two phases prior to the reorganization into the line type. During the initial phase the direction was by a program director in a staff position, main emphasis was in the engineering department, and a project office under a project engineer was established in the engineering department. The project engineer worked closely with the program director.

As the program broadened in late 1960, additional department representatives were added. That is, each department, not only engineering, but all the departments, had their representatives exclusively concerned with the program, and a staff was added to the program director's office.

Now, between this type of a matrix organization and the type of organization that Mr. Hansen is heading now are, of course, many in-between forms, primarily all in the direction of further adding to the program director's office and accumulating under him a growing amount of people to direct a growing program.

It was, however, in December 1961 and January 1962, anticipated that it would be in the best interests of the program to not continue accumulating people under a staff program director but rather to convert the entire program into a line organization as far as practical.

Mr. KARTH. Who first made the suggestion that you go to a project-type organization system, NASA or GD/A?

Mr. HANSEN. I would like to answer that.

To my knowledge, NASA never specifically requested a project organization of the type that we set up. They merely requested that a more effective management structure be built. They specified areas of their concern.

Mr. KARTH. But they were the ones who suggested to you that your management organization was not properly set up and that you should make some kind of a change, isn't that correct?

Mr. HANSEN. Yes, sir; that is correct.

Mr. KARTH. Although they didn't specify precisely what kind of an organizational team you should go to, what kind of a management team effort you should go to, they did suggest that some changes should be made?

Mr. HANSEN. Yes, sir; that is correct.

I believe that outside of the formal channels of correspondence there probably were discussions that were somewhat more specific with respect to suggested ways of organizing and discussion concerning what the advantages and disadvantages of that might be at that particular time. But I can't say that on the basis of positive knowledge, because I wasn't in those discussions.

Perhaps Mr. Ehricke wants to say something——

Mr. EHRICKE. I would like to say I believe it is fair to state that Mr. Dempsey's decision to go to a projectized organization as it exists now was more than the minimum type of improvement for the program. That is what I was referring to in my statement at the end, that now we have the finest organization you can get.

In other words, the improvements and the evolution of the Centaur management at GD/A was not continued gradually being just barely ahead of the requirements, but a rather large leap forward was made in this particular case to fit the Centaur program with a suit into which it could grow, which it wouldn't outgrow in maybe half a year or three-quarters of a year later again.

Mr. KARTH. After NASA first suggested that you change your management structure, how long did it take you to do so?

Mr. EHRICKE. Historically there has been a crucial meeting between Marshall officials and top officials of our company on this subject in early September 1960, and a month later I had——

Mr. KARTH. How long later, sir?

Mr. EHRICKE. A month or maybe even a little bit less than 1 month later, I had department representatives for the program in all departments, and I accumulated a staff of people to help me supervise the program.

Mr. HANSEN. This was the matrix organization.

Mr. EHRICKE. This was the matrix organization; yes, sir.

Then other suggestions about the management structure were made by NASA thereafter, of course, and the latest one—as the program continued—the latest one was in January 1962, and this was followed by the reorganization which Mr. Hansen has now.

Mr. KARTH. How long did it take after NASA first suggested that you change your management structure for you to go from the matrix to the project-type management system? What was the lapse of time in between those two periods?

Mr. EHRICKE. I would like to answer this as follows: Inasmuch as NASA never directly said "Please go to a projectized organization"——

Mr. KARTH. No.

Well, let's first establish that it is probably not their responsibility to tell you how to run your business. They give you a contract and say, "We would like to have you do this." Obviously you have some responsibility in managing the project. I suppose the only way NASA could have complete responsibility for it is to have an inhouse capability and just go ahead and do it themselves. Let's first establish this.

Now, I would like, if I could, for the record, to get from you when you went to a more efficient management structure after NASA first suggested it, and give me those two dates, if you can.

Mr. EHRICKE. Yes, sir. In early September NASA first suggested it officially, and in October we made the management structure more efficient in the direction of NASA desires.

Mr. KARTH. What year was that, Mr. Ehricke?

Mr. EHRICKE. This was in 1959——

Mr. HANSEN. Sixty.

Mr. EHRICKE. I am sorry, in 1960.

Mr. KARTH. September 1960.

Mr. EHRICKE. In September 1960; yes, sir.

At that point, as I said, department representatives were established and a staff began to be assembled under the program director. This staff was gradually enlarged during 1961.

Mr. KARTH. But did you change your management system? I understand you increased your staff as you went along but you increased your staff under the old matrix organizational system.

Mr. EHRICKE. Yes, NASA was not in disagreement with the matrix system.

Mr. KARTH. They were in disagreement with something, because they strongly urged that you change it.

Mr. EHRICKE. Yes. They were in disagreement with the pace of change within the matrix system, in other words, the number of personnel accumulated under the program director.

Mr. KARTH. All right.

How long did it take you to change this system to the satisfaction of NASA?

Mr. EHRICKE. Well, we kept on adding personnel during 1961. NASA was not completely satisfied, they looked at how it worked, felt more people should be added. This went on during 1961. By the end of 1961, NASA felt that a more decisive improvement had to be made in the management structure and the response to this occurred within approximately 2 months.

Mr. KARTH. I assume there was exchange of correspondence and telephone calls, perhaps?

Mr. EHRICKE. Yes, sir.

Mr. KARTH. Personal conversations?

Mr. EHRICKE. Yes, there have been at various times.

Mr. KARTH. Would you submit for the record all exchanges of correspondence wherein NASA was suggesting to you that you improve your management structure and those pieces of correspondence that you had in reply to those requests?

Mr. EHRICKE. Yes, sir; I would be glad to do this—to research this back into our files and send it in.

Mr. KARTH. If you could give me the dates and the situations—that is, was it correspondence, was it telephone, or was it telegram or something else.

Mr. EHRICKE. Yes, there were many oral discussions.

Mr. KARTH. And the precise instructions or requests or suggestions, whatever it might happen to be—give us that for the record.

Mr. EHRICKE. Yes, sir.

There are some letters at least which are classified, so we have to——

Mr. HANSEN. Can we abstract the applicable portions of those letters, or would you like them submitted on a classified basis?

Mr. KARTH. I am not sure that I heard you, sir.

Mr. HANSEN. The principal exhibit in this matter is a letter, from Mr. Hans Hueter to Jim Dempsey, president of General Dynamics/Astronautics, dated January 4, 1962. He has classified that letter "confidential."

Mr. KARTH. Can you tell me why it was classified? This had nothing to do with the national security, did it?

Mr. EHRICKE. There was other material in this that pertained to technical and schedule aspects, which are classified matters. It was classified for that reason. So would we have your permission to abstract those parts that pertain to the organizational discussion?

Mr. KARTH. Yes.

Mr. EHRICKE. Thank you, sir.

Mr. KARTH. That is really all we care about for the record, Mr. Ehricke, if you would do that.

Mr. EHRICKE. Yes, sir.

GENERAL DYNAMICS/ASTRONAUTICS,
May 31, 1962.

Hon. JOSEPH E. KARTH,
Chairman, Subcommittee No. 3, Space Sciences, Committee on Science and Astronautics, House of Representatives, Washington, D.C.

DEAR SIR: During the Centaur program hearings before your subcommittee on May 18, 1962, you requested that General Dynamics/Astronautics provide a record of all exchanges of correspondence between the National Aeronautics and Space Administration and General Dynamics Corp., relative to the need for any change in management structure at General Dynamics/Astronautics for the Centaur program. Attachment A to this letter is a summary of Centaur program management discussions and changes. A thorough search of our files reveals that the only written correspondence or records on the Centaur management subject are the January 4, 1962, personal letter from Mr. Hans Hueter, Director of Light and Medium Vehicles, George C. Marshall Space Flight Center, to Mr. J. R. Dempsey, president of General Dynamics/Astronautics, and the February 12, 1962, reply to that letter. Excerpts from the Hueter letter which are relevant to the Centaur management subject are attachment B to this letter. Attachment C is the relevant portion of the reply from General Dynamics/Astronautics to the Hueter letter.

As we stated before the subcommittee, the change to a line project type organization has disadvantages as well as advantages. The advantages were frequently alluded to in subcommittee testimony. The principal disadvantages are:

1. More difficulty in cross-communicating experience between various projects.
2. Somewhat greater current overhead and indirect expenses.
3. Decreased flexibility and reaction time for changes in project personnel manning levels.

General Dynamics/Astronautics adopted the line project scheme of organization for Centaur just as early as the centralized project control and authority urged by NASA, and other line project advantages, were judged to outweigh the disadvantages. Factors associated with the judgment that the change should be made in early 1962 were: (*a*) The beginning of launch operations at AMR emphasized the need for more direct communication channels among project designers and flight test system engineers: (*b*) the increasing development expenditures associated with the increasing scope of the program effort indicated a new phase of development; and (*c*) the expansion of Centaur program effort to a point where the size of organization required was significant enough, in comparison with the Atlas program effort, to justify the assignment of independent Centaur supervision and management. When the president of General Dynamics/Astronautics made the decision, it was implemented in record time. Although this change required a major rearrangement of organization, personnel, and facilities, the line Centaur project was put into full operation in a concentrated location within 30 days after the decision to change had been made.

You also asked that we provide additional information concerning cases where delays between technical direction and implementing contractual authority have caused delays to elements of Centaur program effort. Attachment D provides this information. It should be noted that there is no direct correspondence between overall development schedule delay and delay to schedules of specific elements of program effort. Through analysis and planning, utilizing PERT management techniques, program replanning is continually being done to minimize or eliminate the overall program impact of changes and delays in elements of the program. It must be acknowledged, however, that frequent reprograming does lead to some delay and added cost.

A question was raised during the hearing concerning cost and delay associated with additional development of the intermediate bulkhead because the original design did not completely fulfill its design specification. A discussion of the Centaur intermediate bulkhead design is attachment E to this letter, and includes estimates of schedule impact and costs.

It should be noted that the cost effect is principally one of expenditure now, rather than during the initial design phase of the program. The current research, development and test programs for bulkhead design are what would have been done earlier had program development philosophy and funding allowed.

We appreciate having this opportunity to supplement the record and clarify our testimony. We feel that the close attention of Congress will be very beneficial to the Centaur portion of the national space program.

Respectfully,

G. L. HANSEN,
Vice President and Program Director, Centaur.
K. A. EHRICKE,
Director, Advanced Studies.

ATTACHMENT A

SUMMARY OF CENTAUR PROGRAM MANAGEMENT CHANGES AT GENERAL DYNAMICS/ ASTRONAUTICS

PHASE I (NOVEMBER 1958–SEPTEMBER 1960)

A program director was appointed in a staff position to act as representative of the division manager and assure divisionwide program coordination. Engineering responsibilities rested with the engineering department. For coordination among the sections inside the engineering department with outside test facilities and with the subcontractors a project engineer was appointed. Program schedules, budgets, contractual arrangements, procurement, and manufacturing was handled in the respective departments.

During 1959, as the scope of the Centaur program broadened, an assistant project engineer was added to the project engineer in the engineering project office. This was in response to desire for broadening of Centaur management by General Dynamics/Astronautics expressed by the program manager, Colonel Seaberg, as well as General Dynamics/Astronautics recognition of this need. There were only oral discussions between Colonel Seaberg and Mr. Dempsey (astronautics division manager) or Mr. Ehricke (Centaur Program Director). Therefore, no documentation of this can be submitted.

PHASE II (OCTOBER 1960–JANUARY 1962)

On October 7–8, 1960, Dr. von Braun, H. Hueter, Colonel Seaberg, and O. Lange (MSFC Saturn Program Director) visited San Diego for a general meeting at the invitation of Mr. Naish, then president of the Convair Division of General Dynamics Corp., and Mr. Dempsey. The agenda included a frank discussion of the future management of the Centaur program at Astronautics. It was agreed that the office of the program director should be enlarged, providing him with assistance to manage the growing program. Within a month following the meeting, three assistants were attached to the program director and department representatives for Centaur were appointed in every department. This was followed by the appointment of a deputy program director.

The individual responsibilities remained with the departments, with the department representatives to act as internal department coordinators on behalf of the Centaur program. This was the matrix organization. No written record has been made of the October 7–8, 1960, meeting.

During the remainder of 1960 and during 1961, General Dynamics/Astronautics Centaur management was the subject of several oral discussions between General Dynamics/Astronautics management, Colonel Heaton and Mr. Hueter.

The rapid expansion of the program during this period led to further augmentation of the personnel in the engineering project office and the program director's office.

In January of this year, Mr. Hueter, in a letter to Mr. Dempsey, dated January 4, 1962, urged a strengthening of Centaur program management.

Shortly thereafter, Mr. Dempsey decided to replace the matrix system with a Centaur program projectized to the maximum extent consistent with proper utilization of the division's facilities. This decision was reported in his answer, dated February 12, 1962, to Mr. Hueter's letter.

PHASE III (FEBRUARY 1962–PRESENT)

The new Centaur organzation went into effect during February 1962 in San Diego. At AMR it was put into effect following the first Centaur launching.

ATTACHMENT B

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION,
GEORGE C. MARSHALL SPACE FLIGHT CENTER,
Huntsville, Ala., January 4, 1962.

Mr. J. R. DEMPSEY,
President, General Dynamics/Astronautics,
San Diego, Calif.

DEAR JIM: The year, 1962, as you certainly will agree with me, will be most significant to the Centaur program in that events during this year will not only prove the adequate design of the Centaur vehicle but also that we have set up a suitable organization to tackle the various technical problems in a timely manner in order to adhere to a program which doesn't give us much freedom for recovering mistakes.

In view of the foregoing and because of an intense feeling on my part that we have not yet established either an adequate General Dynamics/Astronautics organization or proper mutual working relationships, I should like to use this personal letter to convey my concern. Some of the more apparent major problems I discussed with yourself and Mr. Ehricke in late October at General Dynamics/Astronautics. In general, we were in agreement as to the need for certain changes and you expressed an intention to work out suitable solutions. The apparent implementation of some of these solutions has already produced noticeable progress.

As you are aware, the development difficulties experienced with the Pratt & Whitney engine and the resultant schedule delay together with the tremendous drop in Centaur payload capability, especially for Advent missions, has brought our program under close scrutiny as to whether or not the Centaur program should be continued. It now appears that we have cleared that hurdle, but not unmarked and inasmuch as the Centaur represents a sizable technological advance, further R. & D. setbacks and failures are most probable and should be anticipated. I am convinced, however, there is much we can do to avert and/or reduce the number of such occurrences; consequently I would like to point out and emphasize again certain areas where improvements should be made. I shall endeavor here to be brief and general.

A major portion of our past and present difficulties, I feel, have their origin with the organizational setup of your Centaur program office and its relation to the line divisions. We discussed this subject several times and I realize that there is no easy way out. Last time we discussed it, you rightfully referred to the similarity between General Dynamics/Astronautics and MSFC in the relation of project manager and line divisions. There is nothing basically wrong with the original idea. However, when I observe Krafft Ehricke's tremendous effort to keep abreast of what is going on, I can only conclude that, first, his own staff is not sufficient in number and quality, and second, the divisions do not truly support him.

It is interesting to note that in the Agena project, I had similar problems and LMSC finally found it necessary to set up in the engineering department a virtually independent NASA engineering group.

Your experience and success with the Atlas missile are clear proof that all the basic knowledge and experience are available within your organization but this capability has not yet been properly applied to Centaur. The NASA Centaur flight program, beginning with 1963, is highly ambitious and only with a very thorough and sober planning and control will we be able to fulfill it considering the known and yet unknown changes we have to go through with the ensuing documentation cleanup and firmup of reliable checkout and launch preparation procedures.

I would now like to touch briefly on NASA management of the Centaur development. The past uncertainties associated with such things as, where in NASA would Centaur project management be assigned, what would be the role of the NASA Project Manager, new philosophies, assignment of contracts, etc., have caused understandable confusion to General Dynamics/Astronautics. With the firm assignment of overall Centaur program responsibility to MSFC by Dr. Seamans in August 1961, we should now be able to define our mutual responsibilities and to establish proper working relationships. The MFSC management philosophy will differ from that employed before primarily in the degree and extent of Government participation. The MSFC Centaur Project Office with the support of the MSFC line divisions will establish requirements, flight test objectives, schedules, and will continually review and evaluate the contractor's efforts and furnish technical direction or redirection as appropriate or required to insure compliance with program requirements, objectives and NASA policies. As you are aware, the assignment of the Centaur project to MSFC was predicated upon the availability here of concentrated technical knowledge and experience in the guided missile field. It is my firm opinion that this talent should be used appropriately but extensively in support of the contractor's efforts. When the spirit of such an arrangement is sufficiently instilled in your organization, I'm sure the program will benefit tremendously. There is no doubt in my mind about yours and Krafft Ehricke's attitude. However, it will still require your firm hand for awhile to spread the gospel down the line and assure a responsive attitude toward NASA requirements and requests. I would like to emphasize that the planned MSFC participation will not compromise General Dynamics/Astronautics responsibilities but rather to expand the technical resources available to the Centaur development with the ultimate aim a coordinated cooperative first-class team.

A considerable advantage available to your company with this setup is the common justification of test programs which, under previous conditions, were often curtailed to a hardly defendable extent by monetary limitations. I refer to the intermediate bulkhead as an example. The difficult design and the environmental conditions call for an extensive test program on its own before integrating it into the structure. We could have saved a lot of money, delays and embarrassment that way.

In concluding, I want to repeat that I have used this personal letter to you to freely discuss our difficulties of the past once more in an endeavor to get the Centaur project off on the right foot in this probably most critical year, 1962. The notable successes General Dynamics/Astronautics has achieved in missile and space programs, such as the Atlas, have demonstrated to all the world that you have a highly competent first-class managerial-technical team. I think, in view of the vital importance of the missions planned for the Centaur vehicle, such as Advent, lunar, and planetary missions, this program should obtain the best resources and support you can muster. This is all the more important since the Centaur missile occupies payloadwise the large gap existing between the Atlas/Agena and the Saturn missile in the U.S. space program.

I would appreciate it very much if you would review and consider the problems and conditions discussed in this letter and advise me of your plans for resolving and correcting the apparent deficiencies not later than January 16, 1962, because I, myself, have a commitment to report to headquarters at about that time. Your planned action should include a General Dynamics/Astronautics organization, with names, to be applied to the Centaur project. I would also appreciate any suggestions you may have as to how our Marshall organization can be of more assistance in helping to fulfill your program responsibilities.

Sincerely,

HANS HUETER,
Director, Light and Medium Vehicles Office.

NOTE.—Classified and irrelevant material have been deleted from this attachment.

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ATTACHMENT C

GENERAL DYNAMICS/ASTRONAUTICS,
February 12, 1962.

Subject: Centaur problem areas.
Reference your letter M–L&M–DIR, January 4, 1962.

Mr. HANS HUETER,
Director, Light and Medium Vehicles Office,
National Aeronautics and Space Administration,
George C. Marshall Space Flight Center,
Huntsville, Ala.

DEAR HANS: We appreciate your frank and forthright letter concerning problems in the Centaur program. We do recognize the importance of Centaur to the NASA, the country, and to General Dynamics/Astronautics, and are cognizant of the fact that the program is now in a most crucial phase.

We believe that many of the problems of General Dynamics/Astronautics organization and management will be solved by the establishment of the Centaur project organization, to be in effect by February 19, 1962. Such an organization change cannot of itself automatically solve all the problems, but can serve as an effective tool for improving attention to the program, facilitating effective internal communications, clarifying responsibility and authority, speeding up program activity, and identifying team relationships and appropriate communication channels with the Marshall Space Flight Center and the General Dynamics-NASA office.

I have delegated the authority for direction of the Centaur program at General Dynamics/Astronautics to Grant Hansen; however, please be assured that both Mort Rosenbaum and I will continue to follow the program very closely and participate in it as may be required to assure success. In addition, Krafft Ehricke will remain available to the program for as much of his time and as long a period as may be required to assure a smooth transition of program direction and continuing consultation to help assure program success.

We believe that the geographic consolidation of Centaur personnel into our building 26 will help a great deal to improve internal communication, control, discipline, and reaction time. This consolidation is already taking place and should be essentially complete by mid-February.

Every possible effort is being made to achieve the required organizational realinement with minimum disruption to the program. No organization or personnel changes affecting assignments related to the F–1 launching will be made until after that launch date.

We agree with and will support the NASA/MSFC plan for management and technical direction of the Centaur program. We feel that the action we are taking strongly supports and compliments this plan. We are giving Centaur the very best resources and support which we can muster, and will continue to do this.

As we mutually work the plan which we have made, problems are bound to arise. Our plan provides for early recognition and prompt resolution of those problems. We appreciate your attitude of mutual, constructive communication and teamwork. I hold Grant Hansen personally responsible to conduct the program in such a manner that the results meet with your approval. We trust that you will not find it necessary to write a sequel to your January 4 letter.

Sincerely,

J. R. DEMPSEY, *President.*

NOTE.—Classified and irrelevant material have been deleted from this attachment.

Mr. KARTH. Mr. Hansen, on page 2 of your testimony at the bottom of the page, you say:

> Our Centaur program is not without technical and management problems.

Would you tell us what they are at the present time—the management problems, I mean? I am aware of some of the technical problems.

Mr. HANSEN. Yes, I would be glad to do that.

I would like to stress the fact, stated in the next sentence, that these matters are matters of mutual and concurrent concern between ourselves and our immediate program supervisors at the Marshall Space Flight Center.

Mr. KARTH. Yes, sir. Regardless of whom they are between, I wonder if you would, for the record, tell us what the management problems are that still remain.

Mr. HANSEN. Yes. I had prepared a list of these, but I think I would rather give you a little something than dig that out of my briefcase.

In the technical areas I think there has been exposure of these problems, such as the problem of heat leakage through the bulkhead.

We have encountered some problems in connection with the hydrogen peroxide and use of the hydrogen peroxide system.

We have had some technical problems in the guidance system, a number of those.

In the management areas, there has been a problem, in my opinion, associated with the transfer of contractual responsibility from Colonel Murphy's office to the Marshall Space Flight Center. I think these problems are now in better shape. I hope that they are solved.

The problem consists of a lag between technical directions from the technical project office at Marshall and the contractual coverage to implement action on our part, based on the technical direction which we had been given by Marshall.

Dr. Hueter has been well aware of this problem and, essentially, I feel that he was put somewhat in the position of being program technical director with inadequate authority to direct contractual action.

Mr. KARTH. Do you feel that is still the case?

Mr. HANSEN. I understand that this has now been corrected but this correction has been made quite recently and I can't honestly say that I have seen the effect of the correction.

Mr. KARTH. I wonder if you would just amplify on this problem that you talked about with respect to Dr. Hueter not having as much managerial oversight as you think he should, or whatever your point was in that instance. Tell us what authority he doesn't have that you think he should have.

Mr. HANSEN. The authority that he didn't have was to direct timely contractual action, in my opinion. We have very frequent technical management meetings at which program problems are discussed and in these meetings we are given directions to change a flight objective or some other matter which may involve a change to our specifications or our previous program planning which are contractual documents.

So, before we can take action on that technical direction except on a risk basis, we require that there be a change in the contractual direction.

There have been cases where, for example, the objectives of a flight are changed and the lag between the technical direction and the contractual direction, we feel, has held us up. We were hesitant to proceed on the basis of the previous contractual direction because we had confidence that the technical direction which we were given by Mr. Hueter would be backed up contractually, but at the same time, legally, we could not proceed on the basis of the new instruction because it had not been issued to us in a form which could support our effort in case the auditors started looking for whether we were legally authorized to do what we did when we did it.

I think this is an example.

Mr. KARTH. You are talking about making some changes in the original contract, then, which are slow in coming, which in turn cause some delay; is that what you are saying?

Mr. HANSEN. Yes, sir; with some clarification. These are changes in the contract which is comprised of the original contract and a substantial group of subsequent contract change-orders and supplemental agreements and contractual instructions.

Mr. KARTH. So in many cases you suggest contractual changes at the recommendation of your technical staff which are not immediately effected, and therefore this causes a delay; is that right?

Mr. HANSEN. Yes, sir.

Mr. KARTH. Effected.

What kind of delays are we talking about, Mr. Hansen? Could you give us an estimate of the delays that this type of thing has caused, let's say in the last 2 years? Are you talking about a total of 6 weeks, 1 month—what are we talking about?

Mr. HANSEN. I don't believe that it is proper to speak of the last 2 years because this problem did not exist, to my knowledge——

Mr. KARTH. How far can I go back, then, to get an answer?

Mr. HANSEN. I think that you could go back to a period shortly before the transfer of contract responsibility from Colonel Murphy's office to the procurement and contracts office at Marshall Space Flight Center.

Mr. KARTH. All right, let's go back to that time.

Mr. HANSEN. At the time that Colonel Murphy's office was about to transfer the contract, they stopped definitization with us in contract negotiations, and it has taken a while, I think, to get the Marshall Space Flight Center office up to speed on this program.

Mr. KARTH. Was this the primary delay area, the transfer of the contractual responsibility from that group to NASA?

Mr. HANSEN. Yes, sir. I think that this problem occurred during the transient—of the period when this thing was being transferred and for the period of time that it has taken it——

Mr. KARTH. When it was being transferred from California to Marshall Space Flight Center, you mean?

Mr. HANSEN. Yes, sir.

Mr. KARTH. And how much delay are we talking about in this area?

Mr. HANSEN. I think that delay has to be stated against some sort of a measurement reference. I don't think we can attribute a total program development delay. The specific example which I could cite which cost us several weeks was a redirection of the objectives for, I believe it is, the fourth flight during a management meeting in January, and it was, oh, 2, 3 months—I would say it was a matter of several weeks', at least, delay in our getting the contractual direction to cover that.

I believe that one of the reasons for that was a reluctance on the part of the proceurements and contracts office at Marshall at that time to grant a go-ahead based on an area-type estimate. Although Marshall should speak for that, since that is their business.

Mr. KARTH. This 2-week delay seems to be uppermost in your mind. Do you have any other examples of delay caused by this problem?

Mr. BELL. Did you say 2 weeks, Mr. Chairman?

Mr. KARTH. Yes.

Mr. BELL. Was it 2 weeks——

Mr. HANSEN. I said a few weeks.

Mr. BELL. You said 2 months earlier. Is it 2 months? Is that the possible length of time we are talking about?

Mr. HANSEN. Yes, it might be.

Mr. BELL. Two months.

Mr. KARTH. From a few weeks to a couple of months?

Mr. HANSEN. Somewhere in that area.

Mr. KARTH. Would you more thoroughly for the record, at least, if you are not prepared to do so at this time, explain these delays in detail and what they were and precisely how long they took? Because there is quite a gap, you see, between a few weeks and 2 months. And I would like to know—the subcommittee would like to know—how much of the delay time, which has been considerable, in the Centaur program is attributable to this phase of it.

Mr. HANSEN. Well, if I could restate your request to make sure that I understand it. You are asking me to take the example which I have cited and to give you specific information as to when we received the technical direction and the date and form in which we received the contractual direction to allow us to implement the previous technical direction?

Mr. KARTH. I am asking you that in the best of your judgment you give us the delays that were caused as a result of this gap. Some of them might have caused no delays, as you previously mentioned.

Mr. HANSEN. Yes. Some of these—that is an excellent point.

Mr. KARTH. So I am only requesting those areas where delay did result between the time that you received your technical direction, if you will, and the time that you received your contractual authority, only those times and those instances that did in fact cause a delay as a result of the lag in time between two such events.

Mr. EHRICKE. Sir?

Mr. KARTH. All examples of this kind.

Mr. HANSEN. Yes, I understand that.

CASES OF TARDY CONTRACTUAL AUTHORIZATION FOR CENTAUR PROGRAM TECHNICAL DIRECTION

Presented here are cases where technical decisions, or a firm direction by the Government Program Manager to General Dynamics/Astronautics to accomplish new tasks or make changes in the program, were not promptly executed by the customer's contracting authorities. The decision to accomplish or redirect a task is usually made with the awareness that it must integrate into a currently existing matrix of hardware and schedule. In a dynamic R. & D. effort such as this program, the time tolerance is usually very narrow before other elements of the program are affected.

Such is the case in the instances cited here. As can be seen they cover several phases of the program, including our capability to obtain certain launch rates which has a national effect on planning of missions and the construction of spacecraft, confidence which we have to obtain certain things by a certain time in the program, risks we should take to maintain current schedules, and immediate effect on production line hardware.

In each case the delay could have been avoided if the customer had a system for giving timely go-ahead on the basis of planning or area estimates. In most cases, the technical customer is well aware of the scope of the work; he has explored this in order to make his decision to proceed. The negotiation of the firm estimate and detailed work statements of the task could be worked out while the work is progressing, as is done in certain cases in the Atlas program. These problems are well known to the NASA office at General Dynamics/Astronautics and to the Centaur Project Office at Marshall Space Flight Center. We have been assured that the mechanics for solution of problems relative to timely contractual approval are now in operation.

I. CHANGE OF F–4 MISSION [1]

Description

Centaur vehicles F–1, F–2, and F–3 were originally planned with basically propulsion test missions. Subsequent vehicles were to have primarily guidance test missions. Propulsion test vehicles are heavily loaded with additional instrumentation, such as television for zero g experiments.

History

In late 1961, NASA and General Dynamics/Astronautics discussed the advisability of converting F–4 from a guidance objective to a propulsion objective since F–1, because of late delivery of flight ready engines, was committed to a ballistic trajectory and would not experience the long "zero g" periods obtained in orbital flight. Because of this, and late guidance equipment deliveries, it was felt that an additional propulsion test flight was required.

Chronological history

January 18, 1962: Technical direction to convert F–4 from guidance to propulsion objectives (minutes of Centaur program review meeting, January 18, 19, 1962).

February 2, 1962: General Dynamic/Astronautics submitted a planning estimate to NASA (TWX SD 6418, Blakey to J. W. Locke, NASA/MSFC).

February 22, 1962: General Dynamics/Astronautics submitted an area estimate to NASA (General Dynamics/Astronautics letter 955–100, RFS:ms).

March 23, 1962: General Dynamics/Astronautics received contract change order 42; go-ahead authority.

March 23, 1962: General Dynamics/Astronautics issued sales order 12–1–184, and commenced task.

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[1] This is the case mentioned in committee testimony on May 18, 1962, by Mr. Grant L. Hansen.

Summary

Time from technical direction to contractual go-ahead, 2 months. Estimated delay to F–4 launch schedule, 7 weeks.

II. DYNAMIC TESTING OF CENTAUR AFT BULKHEAD

Description

A test program to determine the adequacy of the Centaur aft bulkhead under transient loadings which are higher than those which were anticipated and for which the bulkhead was designed.

History

In the fall of 1961, with the delivery of the initial flight rated engines to General Dynamics/Astronautics, it became apparent that the engine starting transient (or overshoot) was higher than the specification value to which the Centaur structure was designed. How much additional structural capability the bulkhead possessed could not be confidently calculated because of the redundancy of the structure. General Dynamics/Astronautics recommended that a test be conducted to insure confidence in the launch of F–2 and "fixes" to be incorporated in F–3 and on.

Chronological history

December 28, 1961: General Dynamics/Astronautics briefed NASA on requirement for tests. Technical concurrence by NASA was given.

January 15, 1962: Submittal of proposal by General Dynamics/Astronautics (letter 110–608, RFS :ms).

May 4, 1962: General Dynamics/Astronautics issued a risk sales order (12–1–195), to comemnce task.

May 7, 1962: Supplmental agreement No. 47 received at General Dynamics/Astronautics; contractual authority to commence the task.

Summary

Time from technical direction to go-ahead, 4 months.

Impact on program

F–2 cleared for flight initialy on basis of interim static tests and analysis. F–3 has since been fabricated; fix not yet known.

III. LOAD REDUCTION AUTOPILOT SYSTEM (ALPHA LOOP)

Description

In order for Centaur to carry payloads which require an extension to the present nose fairing (such as Advent, Mariner, etc.), certain changes must be made in the autopilots on those flights to preclude the necessity of strengthening the vehicle structurally, thus incurring a prohibitive weight penalty.

History

Studies of various configurations of Centaur during the last several years have demonstrated the requirement for the Alpha loop for Mariner and Advent configurations. Mariner is presently planned for vehicle F–8. Adequate test time, including prototype flight tests on the short R. & D. configuration, is required before committing to the longer Mariner configuration.

Chronological history

February 14, 1962: Technical direction to proceed received from NASA (NASA letter M–L&M–DIR, February 14, 1962).

February 28, 1962: Area estimate delivered to NASA (General Dynamics/Astronautics memo, Jeremiah to Hansen, February 28, 1962).

May 2, 1962: Change order No. 7 received at General Dynamics/Astronautics constituted go-ahead.

May 7, 1962: Sales order 126–1–23 issued. Task commenced.

Summary

Technical decision to contractual go-ahead, 3 months.

Impact on program

Delay in effectivity from vehicle F–4 to F–6.

IV. ACTIVATION OF LAUNCH COMPLEX 36B AT AMR

Description

Program to design and activate a second launch complex for Atlas/Centaur vehicles at AMR.

History

The earliest request for General Dynamics/Astronautics action concerning 36B which can be located is a TWX from BMC No. LBZ–BC–1163–E dated November 25, 1960, which reads as follows:

Subject: Construction of AMR Atlas stand 36B. This message for D. Davis.

The contractor is requested to provide, as soon as possible, minimum fund requirements through fiscal year 1961 for Centaur TGSE required on proposed AMR stand 36B. The following ground rules will apply:

(*a*) Stand 36B will have an Atlas B dual Agena and Centaur configuration.

(*b*) Facility construction will be through the Corps of Engineers and start January 1, 1961.

(*c*) Activation will be in accordance with the date mentioned to Mr. W. Jackson in this office on November 23, 1960. Request this office be furnished an area estimate of funds required and the date when firm funding information will be available. (The date referred to as "mentioned to Mr. W. Jackson" was activation to be accomplished July 1962.)

As a result of this TWX, General Dynamics/Astronautics generated a program study authorization dated December 15, 1960. This PSA culminated in a letter which was transmitted to BSD on January 13, 1961, which provided these cost data as well as a proposed program schedule. Therefore, chronologically the events which lead to the issuance of NAS 10–16 letter contract are as follows:

Chronological history

November 25, 1960: TWX BMC–LBZ–BC 1163–E requesting minimum funds required for complex 36B.

December 15, 1960: General Dynamics/Astronautics PSA, identified as PIN 60–2001.

January 13, 1961: General Dynamics/Astronautics letter 110–6249, statement of work and area cost estimates for activation of complex 36B.

March 13, 1961: SR No. 2968 entitled "Task Assignment Directive for Design Criteria of Centaur Launch Complex 36B."

March 16, 1961: Meeting held at NASA/LOD, Cape Canaveral for the purpose of reviewing SR No. 2968.

April 27, 1961: General Dynamics/Astronautics letter 110–2574, proposal for activation of AMR Complex 36B.

June 5, 1961: Received copy of letter from E. Mathews of LOD to the General Dynamics/Astronautics NASA plant representative, transmitting SR No. 2689 dated May 22, 1961, entitled "Task Assignment Directive for Preparation of Facilities Criteria for Centaur Complex 36B," which is a revision and updating of SR indicated above as SR No. 2968 dated March 16, 1961.

August 19, 1961: SSVC/JRR letter entitled "Request for Proposal, Facility Design Criteria for AMR Complex 36."

September 7, 1961: General Dynamics/Astronautics letter 110–662, area estimate to accomplish the design criteria for complex 36B.

September 20, 1961: SSVC/JRR letter entitled "Request for New Proposal for the Activation of Launch Complex 36B" at AMR.

September 27, 1961: SSVC/JRR letter transmitted three additional copies of "Task Assignment Directive, Preparation of Facility Criteria for Launch Complex 36B."

October 3, 1961: TWX from the Director, NASA LOD, entitled "Proposal for Complex 36 GSE," requesting the costs associated with the relocation of the blockhouse equipment for 36A, segregated as a separate item by General Dynamics/Astronautics.

October 5, 1961: General Dynamics/Astronautics letter 110–7775, which is a firm cost estimate to provide design criteria for complex 36B in response to SSVC/JRR letter dated August 19, 1961.

October 20, 1961: General Dynamics/Astronautics letter 110–7005 entitled "Relocation of Blockhouse Equipment, 36A." This relocation allows the 36B launch control gear to share the same blockhouse floor as 36A.

October 17, 1961: Change order No. 2 to contract AF04(695)–50 authorizes the design criteria to be developed as proposed in SSVC/JRR letter dated September 20, 1961.

November 21, 1961: General Dynamics/Astronautics letter 110–9114, subject "GD/A Area Proposal for Activation of Launch Complex 36 at AMR," in response to SSVC/JRR letter dated September 20, 1961.

December 20, 1961: NASA letter M–LOD–DF entitled "Task Directive for Centaur Launch Complex 36B," contains LOD's technical comments on the review meeting held on the design criteria on December 2, 1961.

December 29, 1961: NASA letter M–LOD–DF entitled "Transmittal to Astronautics of a Construction Schedule for Centaur Launch Complex 36B." This schedule transmitted by K. R. Debus, Director of Launch Operations, AMR, indicates facility construction will begin May 21, 1962, and be complete to a BOD date of April 21, 1963, and indicates a desire to have a missile on stand in August of 1963. This schedule is dated December 4, 1961.

January 16, 1962: General Dynamics/Astronautics letter 110–613 entitled "Firm Cost Prosposal for Activation of Launch Complex 36B at AMR." This proposal indicated a go-ahead of February 19, 1962, was needed in order to comply with a schedule which would permit a missile on stand in December of 1963, with a resultant launch in February of 1964. This proposal further states as follows:

It is apparent from the schedule statements above that the desired capability to launch from complex 36B in January 1964 cannot be met. It was expected that contractual authorization to proceed would be issued as a result of the reference (b) area estimate.

(This estimate was letter 110–9114 dated November 21, 1961, submitted as indicated above).

The schedule is further jeopardized by the BOD slippage to April 21, 1963, received in reference (d).

(Reference (d) is NASA letter M–LOD–DF dated December 29, 1961, indicated in item above.)

It is also apparent that the presently assumed go-ahead of February 19, 1962, cannot be met by going through the process essential to issuance of a definitive contract. It is therefore requested that serious consideration be given to the immediate issuance of contractual authorization for at least the design effort and procurement of long leadtime hardware.

March 3, 1962: NASA letter M–LOD–P&C–C transmitted a draft of their proposed letter contract NAS 10–16 which would authorize the activation of complex 36B.

March 28, 1962: NASA letter M–LOD–P&C–C was received as signed by C. W. Swanston, contract specialist, which was the formal instruction for submittal of a revised proposal for definitization of NAS 10–16 contract. This instruction indicates additional technical requirements which are to be included in the contract. The instruction further states that General Dynamics/Astronautic's revised proposal was to be submitted not later than 4 to 5 days after General Dynamics/Astronautics accepts letter contract NAS 10–16.

April 4, 1962: NAS 10–16 received and accepted by General Dynamics/Astronautics. During the period of February 19, 1952, to April 4, 1962, General Dynamics/Astronautics had no contractual funds under which to pursue the design of GSE required to activate complex 36B, nor did funds exist which would allow General Dynamics/Astronautics to participate in the design reviews being held by the architect and engineering contractor in Miami, concerning the facility design for complex 36B. In order to minimize schedule impact by lack of existing contract between NASA and General Dynamics/Astronautics, General Dynamics/Astronautics utilized its own funds to participate in design reviews, pending receipt of NAS 10–16. This delay in receiving contractual authorization for the activation of complex 36B has definitely had an impact on the activation date.

Impact on program

Based on the original TWX request from BSD on November 25, 1960, and General Dynamics/Astronautics proposal submitted to BSD on January 13, 1961, under letter 110–6249, it was proposed that a launch capability could be achieved by late 1962.

This launch capability was based on a go-ahead in January 1961; at the present time we will have complex 36B to a point of launch capability in early 1964, indicating a schedule delay of 15 months due to the many and varied directions given and proposals made.

Mr. Ehricke. May I make an additional explanation, sir?

I believe out of my own experience that the problem between a technical direction forthcoming and the contractual coverage of it is a standing one. We had this in the previous period, also, in many instances and the primary reason for this is this——

Mr. KARTH. This is rather normal in almost any kind of a vehicle that any contractor might be developing for NASA?

Mr. EHRICKE. That is right.

Mr. KARTH. For the Air Force or Army or anyone else, isn't that true?

Mr. EHRICKE. Yes.

Mr. KARTH. This is just the nature of the beast and everyone has the same problem, is that correct?

Mr. EHRICKE. Yes, that is correct.

Mr. KARTH. All right.

Mr. EHRICKE. The technical manager and the engineers get together and they decide certain changes ought to be made. Technical agreement is achieved; however, for contractual authorization it has to be put into the proper form. The procurement and contracts people, of course, have to safeguard the public interest as far as the bid, the cost, and so forth, is concerned, so contract negotiations, at least to some extent, do take place. So there is always a lag.

In many instances we have attempted to cover this by issuing risk sales orders, as we call it in the company, where we felt that the coverage was either assured by a preliminary statement, by the contracting agency, of principal agreement, or simply on the basis of the technical program manager's word.

However, in some instances, fairly large sums are involved and it is a little more difficult to get through our contracts department in turn.

Mr. HANSEN. Mr. Chairman, for the purpose of making sure that this record is straight on this point, I would like to request permission in my formal statement on page 2, the last paragraph on that page, to insert the word "normal" ahead of the word "technical" so that that sentence would read "Our Centaur program is not without normal technical and management problems."

In bringing up this particular example, I was attempting to respond to your request for an indication of what the nature of these problems are, rather than trying to indicate that this was an extremely large, unique, or insurmountable problem.

Mr. KARTH. Yes, sir, I understand. What we are attempting to find out, however, is what is abnormal about this Centaur situation which has caused a series of delays as opposed to the normalities of other situations under which we don't experience such extensive delays. This is the area.

Mr. Ehricke, on page 1 of your testimony, and on page 2 and page 3 you talk about the purpose of your vehicle studies.

Mr. EHRICKE. Yes, sir.

Mr. KARTH. And I notice quite generally the 9 or 10 purposes pretty much include all of that which is now included in the mission responsibilities for Centaur.

Maybe I should ask you this question: Were these the original purposes for the vehicle that you were given at the time that you were given this project?

Mr. EHRICKE. No, these were mission objectives which we studied and for which we investigated the potential suitability of a high energy upperstage.

Mr. KARTH. This was at the outset, is that correct?

Mr. EHRICKE. Yes, this was on our own, before we had any governmental encouragement.

Mr. KARTH. In No. 5 you talk about high altitude satellites in 8-hour, 12-hour and 24-hour orbits for the purpose of global surveillance.

Mr. EHRICKE. Yes.

Mr. KARTH. That is Advent, isn't it?

Mr. EHRICKE. It was not, of course, known by this name at that time, but in effect, yes.

Mr. KARTH. Not by name, but this was one of the purposes.

Mr. EHRICKE. This is one of the missions that we had looked at, yes, sir.

Mr. KARTH. So originally, at the beginning of your study of the concept, you did have a pretty good idea of what the mission responsibilities of Centaur were going to be, didn't you?

Mr. EHRICKE. Yes, although I might add at that time in looking at these various orbits we felt that the most desirable first satellite mission for Centaur would lie in the 8- to 12-hour orbit altitude rather than 24-hour orbit altitude because a 24-hour orbit is one that is particularly difficult to achieve and if you take a realistic look at a vehicle capability, even if you say at a certain point it is operational, it may have operational capabilities with certain limitations which only afterwards are being removed.

So consequently we always felt that the 24-hour orbit mission was about the toughest that a vehicle of this type could fly and this was before it was assigned to us. This was on the basis of our studies.

Mr. KARTH. This was even before we had an Advent, wasn't it?

Mr. EHRICKE. Yes, sir.

Mr. KARTH. We are not doing very well in that program, are we, sir? Centaur is not going to launch the first one or two or maybe any of them, is it?

Mr. EHRICKE. As far as Centaur, you mean as far as Centaur's capability is concerned?

Mr. KARTH. As far as the Centaur vehicle is concerned. I don't know what its capability is going to be at this point.

Mr. EHRICKE. Well, we have two parallel programs here, one is the Centaur program, the other is the Advent program. I believe that Centaur eventually will be developed to the point where it can carry the Advent satellite into orbit if it stays within certain weight limitations.

Mr. KARTH. Do you think it will be developed in time?

Mr. EHRICKE. As you have heard, we consider the use of the Surveyor bus. I believe that this will give us greater initial confidence.

Mr. KARTH. Yes, and this eliminates one of your problems with Centaur, doesn't it? It eliminates the third start, doesn't it?

Mr. EHRICKE. Yes, it eliminates the third start.

However, we still hope that we will be able to develop the third start eventually.

Mr. KARTH. So one of your critical problem areas in Centaur has been eliminated by the addition of the Surveyor bus?

Mr. EHRICKE. Yes, sir; at least temporarily, yes, this is correct.

Mr. KARTH. Let us go to page 4 of your testimony. In the middle of the page, you said "We were for security reasons"—I want to interrupt myself at this point. I would like, Mr. Hansen and Mr. Ehricke, for both of you to meet the chairman of the full committee who has joined us here today. This is Chairman Miller of California.

I wonder, Mr. Miller, if you would be so kind as to ask any questions you may have?

Mr. MILLER. No, I haven't any particular questions. I think you are covering it quite fully.

Mr. KARTH. Thank you very much, Mr. Chairman, for coming down. We appreciate it very much.

I notice in the middle of page 4 you said for security reasons you were not aware of Pratt & Whitney's pioneer work in this field. I wonder why your firm was not kept up to date or completely informed as to the technical progress that had been made in this field not only by Pratt & Whitney, but anyone else who might have had a capability? Could you amplify on this?

Mr. EHRICKE. Yes, sir.

Mr. KARTH. And tell us why you had to go on some tangent, perhaps in developing something that should have been made available to you which would have, I suppose, eliminated some time delays and probably even saved some money. The committee is interested in that.

Mr. EHRICKE. Yes, I would be glad to answer this. First of all let me state that these studies that we made in 1956 and 1957, in fact that we made up to November 1958, were all company funded, not government funded. They were done on company funds.

Mr. KARTH. I see.

Mr. EHRICKE. Now, as such they constituted a private effort. There were a number of projects, of course, in the Armed Forces which were considered so important that they were need-to-know projects.

Mr. KARTH. Let me just explore this. But as soon as you got your first contract on Centaur, was all of this information then made available to you?

Mr. EHRICKE. Oh, yes; in fact it was even made available to us before we got the contract, as soon as it looked as though our plan was interesting, we were given this information.

Mr. KARTH. I see

Would you explain as briefly as you can why it was so important to have the missions of Centaur laid before you, before you could do some of the things that had to be done, as long as you had the specification of the vehicle and knew prior to the development of some of the missions what this thing was supposed to do, in kind of a broad sense?

Mr. EHRICKE. Yes, I can explain it briefly and in regard to main points. Point No. 1 is that in the 24-hour orbit you have to inject the vehicle at a particular point in the orbit. As long as the particular injection point or the number of injection points desired by the customer are not specified, we cannot finalize our entire set flight profiles, hence coast periods and other things.

Furthermore, as long as the size, weight, and shape of the payload is not specified we cannot define our nose fairing safely and we cannot define our dynamic load conditions in the upper portion of the vehicle.

These are two definitions that, as a vehicle development engineer, you would like to have as soon as possible.

In other words, just saying you go into 24-hour orbit or maybe even say inject it at this point, in itself is not enough unless you are given the whole story.

Mr. KARTH. I imagine one of the reasons why you got the contract was because you indicated some experience in this field; you had spent some of the company's funds, you had made investigations, you had done some research and development work. Isn't that correct?

Mr. EHRICKE. Yes, sir. This is correct. We did, as I pointed out before, in looking at the 24-hour orbit realize that this was one of the toughest assignments. We were aware of the fact that our flight performance, storage time requirement of the cryogenic fluids, and so forth, did depend on injection points.

So consequently we were very much aware of the limitations that were given due to the fact that the specification was fairly general at that point.

Mr. KARTH. What in your opinion was the reason for the latest explosion of the Centaur?

Mr. EHRICKE. Maybe Mr. Hansen—or do you wish me to answer? I would be glad to answer it.

Mr. KARTH. Either one or both.

Mr. EHRICKE. All right.

Mr. HANSEN. Since I talked on the telephone with the chief of our evaluation team late last night I would like to answer this question.

Mr. KARTH. Yes, sir. Proceed, Mr. Hansen.

Mr. HANSEN. Our investigation to date leads us strongly to the opinion that the specific cause of this difficulty was that the design of the weather shield in the area between the nose fairing and the Centaur stage, itself—the weather shield in this area, I am pointing to this junction between the conical section and cylindrical section here—the design in that area was based on assumptions concerning the aerodynamic loads which have since proven to be incorrect.

Mr. KARTH. This is an engineering mistake, isn't it?

Mr. HANSEN. Yes, sir.

Mr. KARTH. Haven't we had considerable experience in this field already?

Mr. HANSEN. Yes, sir; this is an engineering mistake.

Mr. KARTH. And we are aware of the fact at a certain point, as the vehicle proceeds out of the atmosphere, it encounters a great deal of disturbance and vibrations set in. I mean this is nothing new in the state of the art, is it? Isn't this something we have known for quite a long time?

Mr. HANSEN. This difficulty occurred in the transsonic flight regime, and it occurred—the specific loads which we felt, which we now believe were the cause of this difficulty, occurred during the period when the flow around this corner was supersonic but the ambient flow along the body was still subsonic.

The fine detail of the flow around particular areas, particular corners and so on is very difficult to calculate by analysis and it is difficult to pinpoint in fine detail even in a wind tunnel, except on a full-scale model at the specific mach number.

Scale models which have a scaling Reynolds number to make a correspondence between the size of the model and the size of the actual vehicle do not constitute an exact simulation of the fine detail.

Mr. KARTH. I understand that.

Mr. HANSEN. In other words, what I am saying is that I think that the engineering analysis which was done on this was reasonable analysis. I think that with hindsight we now know that we did not have adequately accurate detailed information, but it is finding out this sort of a thing that a development program is for.

Mr. KARTH. But we had known this, we had had this information long before Centaur blew up on May 12, isn't that correct?

I have been reading it in the newspapers for a good long time.

Mr. HANSEN. I am sorry, I don't understand that question. Could you——

Mr. KARTH. I say we knew that there would be a problem of this kind at certain stages of flight long before May 12 of 1962.

Mr. HANSEN. No, sir; I question that. We felt that the conditions which would exist during this flight regime had been adequately provided for in the design. Looking back at what happened, if our theory as to what happened is correct, our present knowledge says that our evaluation that we did understand in adequately fine detail what would happen was presumptive.

Mr. KARTH. What kind of delay are we talking about now, because apparently you are going to have to redesign this thing to some degree at least. So what kind of a delay are we talking about now, Mr. Hansen?

Mr. HANSEN. I would like to make it clear that we guard very much against jumping to a conclusion and locking it down too early, such that we might overlook something else. So I can't state positively that this is the answer. We are continuing our investigation, supported within our project group by our best technical specialists from General Dynamics and with the NASA people from Marshall Space Flight Center and a group from Headquarters NASA assisting on this.

Once we feel that we have locked down what the problem was, then normally fixing it is a much simpler problem than determining what needs to be fixed. Now if the hypothesis that I have indicated is decided to be the correct one, fixing this is a relatively simple problem.

We haven't actually programed a fix, but I have the feeling that this is a sort of a fix which could be accomplished in a matter of a couple of weeks at the most.

Mr. KARTH. Tell us about your quality control organization, will you, Mr. Hansen?

Mr. HANSEN. Yes, sir; I would be glad to do that.

Quality control and reliability are combined in one organization in our Centaur Project Department at Astronautics under a manager who reports directly to me. He has the total responsibility to me for assuring high reliability and good quality control for the Centaur program.

Mr. KARTH. So your quality control man has a voice right up to top management on the Centaur project?

Mr. HANSEN. Yes, sir; he reports directly to me.

Now in addition to that reporting in the Division there is a Director of Reliability and Quality Control for the Division who serves as my manager in this area and me with advice, consultation, and support, and is charged by Mr. Dempsey with the responsibility to approve any deviation which we might want to make from our Division policies for reliability control and quality control.

Mr. KARTH. Do you have a quality control engineering staff that enforces all specific designs?

Mr. HANSEN. Yes, sir; that is correct. That group reports to this same man, Mr. Bill Monroe, who is our manager of reliability and quality control.

Mr. KARTH. How about original designs?

Mr. HANSEN. Yes, sir. They participate in original designs with particular emphasis in the area of design reviews. This is an occasion in which field people, reliability people, other experts as required, gather around a proposed design and review it for its adequacy to meet its performance and reliability objectives, value analysis, all those things which go into making up a good design.

Mr. KARTH. Who participates in design review? Could you give us that for the record?

Mr. HANSEN. Yes. Each design review, each design to be reviewed is analyzed by the reliability engineers and the design engineers to determine what combination of people constitutes the best review board for that particular subject, so that the makeup of this group is not the same for every case.

Mr. KARTH. Do you have any people in from NASA, for example, or from Marshall Space Flight Center, or are these all in-house quality control engineers?

Mr. HANSEN. The Marshall Space Flight Center has an excellent technical staff located at General Dynamics/Astronautics, members of that staff participate in all design reviews.

In addition to that for a specific design they may, and frequently do, call in additional engineers, experts in particular fields, from Marshall Space Flight Center.

Mr. KARTH. They may or they do?

Mr. HANSEN. They do.

Mr. KARTH. I see.

Mr. HANSEN. In addition to that there are a number of technical working groups under the chairmanship of technical members of Mr. Hueter's staff who conduct periodic and rather frequent reviews in specific areas such as propulsion, structure, et cetera, which are, in effect, themselves higher level design reviews.

So we really have two levels of design review. There is the local level which is with our people and the local NASA office, with additional consultation as appropriate, and then there are the reviews normally on about a monthly basis for everything that is going on within a particular technical area by the technical working groups out of Mr. Hueter's office.

Mr. KARTH. How long has this system of quality control been in effect?

Mr. HANSEN. As far back as my memory of the program goes. Let me refer that question to my colleague.

Mr. KARTH. Yes, Mr. Ehricke?

Mr. EHRICKE. Yes. Quality control and reliability was handled in principle very similarly in the past except that before Marshall came in we did not have as strong a Government participation in the quality control and design and reliability aspects review of the designs.

However, as far as our company operations are concerned, we had special reliability boards which reviewed design changes.

Mr. KARTH. Before NASA's Marshall Space Flight Center became involved in the project, who did review your quality on the part of the government? And how often did that review take place? How often were they called in when you had these design review meetings?

Mr. EHRICKE. They were called in periodically to review our design. We had monthly meetings in which Colonel Seaberg and his staff participated. Then interspersed between monthly meetings were meetings for special problems, for example guidance systems review, which included reliability, any change in the tank system or booster system or any failure on any part of the boost propulsion system was then specifically reviewed and members of Colonel Seaberg's staff were invited into these reviews and they participated.

Mr. KARTH. When was this, a year or 2 years ago when you had three explosions in a row, or was it two explosions in a row and then you ran out of engines? When was that?

Mr. EHRICKE. Pratt & Whitney had the explosions in November 1960 and January 1961. I cannot speak for Pratt & Whitney's particular arrangement.

Mr. KARTH. All right, fine.

Did you have a quality control review board to evaluate hardware, for example?

Mr. EHRICKE. You mean at this time?

Mr. KARTH. Yes.

Mr. HANSEN. Yes, sir. When I spoke of design reviews the normal times at which design reviews take place are to review the design criteria and then after some work is done to review the design layout and then to review the final design and then to review the first hardware produced to that design and then to review the test results of the tests on the hardware to that design.

Mr. KARTH. This involves that hardware that might have been repaired or did not conform to specifications?

Mr. HANSEN. Yes, sir; that is correct. However, that review takes place on a little bit different basis. The design reviews of which I spoke are conducted among the group of the design engineers with the reliability engineers and the responsible Marshall Space Flight Center engineers.

Mr. KARTH. I am talking about quality controls here.

Mr. HANSEN. In the case of discrepancy in materials, quality control in the factory, the discrepant material is rejected on paperwork by the cognizant inspectors. The disposition of that discrepant material is then made by a material review board. The material review board is comprised of responsible design engineers in the particular area and the area is noted on the rejection paper, and the cognizant quality control personnel and the cognizant member of Mr. Hueter's local technical staff.

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So essentially there is a three-man material review board for disposition on discrepant items, where something does not conform with the design drawings. Basically the two groups that I have mentioned, operate in two areas. One is you might say the inherent reliability which is a function of the design itself. This is the design review group.

The second area is that of assuring that the manufacturing processes conform to the design intent which comes within the cognizance of the procedure for material review with this material review board which is the responsible quality control man, the responsible design engineering man, and the responsible member of Mr. Hueter's resident staff.

Mr. KARTH. How about in the case of failures in tests and flights, for example. Are your quality control people called in immediately to participate in the check, whatever it might be?

Mr. HANSEN. Yes, sir; they are.

Mr. KARTH. How big is your quality control staff on Project Centaur?

Mr. HANSEN. At the present time we have approximately 50 people in that organization and we hope that they don't have to be called in because they are already there, so that they can know what happened on a firsthand basis instead of a secondhand basis. It is our policy to have these quality personnel participating.

Mr. KARTH. How about your subcontractors, what kind of quality control measures do you impose on them?

Mr. HANSEN. To begin with, we feel that quality in the subcontractor's organization is his responsibility. It is our responsibility to see to it that he handles his responsibility.

To this end, before a subcontractor is selected there is an evaluation. In addition to his technical capability, the business aspects of his proposal and so on, he does receive a quality survey by responsible quality control people who determine whether he has the systems, procedures, staffing, that are necessary to do a good job. Records are kept as to their quality performance.

Mr. KARTH. But after the subcontract is let then you do not impose any quality control?

Mr. HANSEN. No, sir; that is not correct. Once the subcontract has been let, we have quality control surveillance. In the case of major subcontractors, we have resident quality control people who, by reviewing the systems and procedures, by sampling techniques, have the responsibility to determine on a continuing basis, that the quality promise which the proposal indicated is carried out.

Mr. KARTH. These are GD/A people?

Mr. HANSEN. Yes, sir.

Mr. RANDALL. Will the gentleman yield?

Mr. KARTH. Mr. Randall.

Mr. RANDALL. I want to apologize to the chairman. I have to leave soon. I want to get in one or two questions before going.

Would you say that Pratt & Whitney was a subcontractor or an associate contractor in this?

Mr. HANSEN. Pratt & Whitney is an associate contractor.

Mr. RANDALL. And not a subcontractor?

Mr. HANSEN. Yes, sir.

Mr. RANDALL. All right, thank you.

Mr. EHRICKE. Sir, I would like to add that we have a very rigid system of acceptance testing of all the products that are delivered to us by the subcontractors. This acceptance testing is carried out with our participation, at least under our supervision, either at the subcontractor's place or at our place.

Of course if it is done at our place it is done by us. This has been so throughout the program.

Mr. KARTH. I see. Is there a difference of opinion in design philosophy between General Dynamics/Astronautics and Dr. Wernher von Braun at the moment?

Mr. HANSEN. Yes, sir. This is the difference of philosophy which Dr. von Braun spoke of in the earlier hearing and I have referred to this in my formal statement.

The Marshall Space Flight Center design philosophy is a somewhat more conservative one. I might give you a specific example.

Structural design criteria for safety margins which we have normally used in our past design practice and which we used on the Atlas program and which was satisfactory to the Air Force was a 25-percent margin of safety.

Marshall Space Flight Center design criteria requires a minimum of 35-percent margin of safety. It is my opinion that the difference in philosophy which Dr. von Braun expressed was just that. We are inclined, I think, to be willing to take a little bit more of a design gamble to achieve a significant improvement, whereas I think they build somewhat more conservatively.

As I indicated, I think this makes a real good combination, because our point of view is that we will introduce our opinion, the ideas that we have; we will try to sell it to the Marshall Space Flight Center people on the basis of its merits as we see it; we will have a thorough airing of the thing.

Once we have been heard and understood, then we will carry out whatever direction we receive from the technical supervisors of the program.

Mr. KARTH. So if Marshall insists on 35 percent, it is going to be 35 percent, is that right?

Mr. HANSEN. Yes, sir. If we feel that isn't right, we will discuss the matter thoroughly, but there is no question that if they direct us to use a different criteria, we will do that enthusiastically, because we do recognize they have had a great deal of experience and some very good success in their previous programs.

Mr. RANDALL. Mr. Chairman, would it be of value to establish at this time the components or the items in this safety margin?

What exactly are you talking about?

Mr. HANSEN. I am talking, for instance, of the design criteria for strength of structure.

Mr. RANDALL. Materials and things?

Mr. HANSEN. Yes, sir.

Mr. RANDALL. And what else?

Mr. HANSEN. Well, the particular figure which I quoted relates to the safety margin of expected loads above the strength of the material in the structural design.

Mr. RANDALL. Fine. I think that is helpful to spell it out.

That is all.

Mr. KARTH. Did you receive about the same amount of supervision under Colonel Seaberg as you receive now under the Marshall Space Flight Center? And if there is a difference, what difference is there?

Mr. EHRICKE. Sir, as far as managerial and general technical supervision is concerned, the condition is similar. As far as penetration in depth is concerned, as Dr. von Braun expressed it during the last hearing, the situation is different and the penetration in depth, that is the direct checking and discussion and weighing of individual technical decisions which are being made today is more intense under the Marshall Space Flight Center supervision.

Mr. KARTH. This is a rather important area, isn't it?

Mr. EHRICKE. Yes, sir; it is.

Mr. KARTH. How much of that did you receive under Colonel Seaberg? Any?

Mr. EHRICKE. Yes, we very definitely did because Colonel Seaberg had officers with him who were trained in various aspects of development; he had personnel who were familiar with liquid hydrogen. And their advice and direction in this respect was quite valuable.

When we came under NASA headquarters management, we gained access to the NASA research laboratories, which was helpful to us, such as Lewis, Langley Field. This was even before Marshall was in the picture.

Mr. KARTH. Your explanation of technical penetration means then that under Marshall Space Flight Center they go through the whole program?

Mr. EHRICKE. Yes, sir.

Mr. KARTH. And this was not the case under Colonel Seaberg, is that correct?

Mr. EHRICKE. That is correct.

Mr. RANDALL. Mr. Chairman, may I have one question?

Mr. KARTH. Yes, sir, Mr. Randall.

Mr. RANDALL. This goes back to this margin of safety. Could it be said that any of that spread between 25 percent and 35 percent was in any way involved or does it fit in, in any particular, with this first flight failure?

Mr. HANSEN. No, sir. This particular thing—well, I answered that pretty positively for a person who does not really know for sure yet what happened.

Mr. RANDALL. Well, we all ask in the same spirit.

Mr. HANSEN. OK.

Mr. RANDALL. So your answer——

Mr. HANSEN. Based on our current opinion as to what caused that, then I could answer positively, "No."

Mr. RANDALL. All right.

Mr. HANSEN. It was our previous analysis in this case that no forces would be acting in the direction which we now believe forces acted. So this is not the difference between a margin of safety, it is a complete change in the concept of where the forces are acting.

Mr. RANDALL. That is all, Mr. Chairman.

Mr. KARTH. This trouble that has developed in the bulkhead between the tanks is primarily due, is it not, to the use of the Atlas fabrication techniques, and these techniques not meeting the stresses and strains imposed by Centaur?

Is this correct, Mr. Ehricke?

Mr. EHRICKE. Yes, sir. We were using Atlas manufacturing techniques for the intermediate bulkhead as well as for the forward and after bulkhead.

The Atlas manufacturing technique and quality control permits the detection of leaks in bulkheads down to the order of 1/10,000 of an inch. No such leaks were detected.

For oxygen this is completely satisfactory. We found—we had reason to believe that if you do check down to these magnitudes that your bulkhead is most likely tight. We found, also, that a bulkhead which is tight under normal temperature can open up very minute holes, less than 1/10,000 of an inch under extreme cryogenic temperatures.

It was this precise thing that happened. We got holes which were below 1/10,000 of an inch. And in view of the high diffusivity of the hydrogen gas and of the helium which pressurizes most tanks, you get enough influx into the bulkhead cavity to destroy your insulation quality.

Mr. KARTH. Is this the area in which you work for Atlas, 1/10,000 of an inch?

Mr. EHRICKE. Yes.

Mr. KARTH. Your tests didn't show there would be a difference between liquid oxygen and kerosene on the one hand and liquid hydrogen and liquid oxygen on the other?

Mr. EHRICKE. Our specimen tests did indicate and we made a large number of specimen tests where we welded a piece of bulkhead together with insulation in between and submerged it in liquid hydrogen. These tests indicated that you could weld the material, would not get a leakage and would indeed get the vacuum that was theoretically predicted.

What happened was that at the material thickness that we were using we were at the very edge of welding capability. We had to use what we call doublers; that is, local reinforcements to weld the thin walls of the intermediate bulkhead together.

Mr. KARTH. The extra 10-percent safety factor should help this, shouldn't it?

Mr. EHRICKE. Yes, sir. We have definitely in this particular case, if I might say so, gambled at a very low weight and found that we have to correct ourselves. We have now under fabrication bulkheads which have greater wall thickness at the points of welding so that we are confident we can overcome this problem.

Mr. KARTH. How much weight does this add to the vehicle?

Mr. EHRICKE. We believe that it may add as much as somewhere between 35 and 60 pounds to the bulkhead. You see we are not increasing the bulkhead thickness overall, we are actually only—the bulkhead originally is of the full thickness and is then chemically etched down to lower thickness except for those regions where we weld.

Mr. KARTH. Will it affect the capability of the vehicle to any appreciable degree?

Mr. EHRICKE. I can say "No," not that it destroys the payload capability of the vehicle as such, no.

Mr. KARTH. Now the additional 10 percent safety factor doesn't affect the vehicle's capability, but my question at this point would be: How much does that gamble you took cost the Government, the taxpayers of this country.

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Mr. EHRICKE. It is difficult to isolate this particular point, sir, because we haven't lost a vehicle or even had an explosion on account of this particular bulkhead design.

Mr. KARTH. But this problem has caused considerable delay, hasn't it?

Mr. EHRICKE. No, sir. I don't think that one can say this, because our missions were laid out in this manner: The first one was a suborbital mission. Actually the high heat transfer across the bulkhead did not hurt us.

Mr. KARTH. Yes, but as you get into the farout reaches of space this vacuum is not going to hold up and that is where it is important, isn't it?

Mr. EHRICKE. Yes; we hope very strongly that as we go on with the flight tests and explore in other problem areas of Centaur, such as the ascent, engine ignition, and so forth, on missions which do not yet require the ultimate in insulation that during this time we will concurrently improve the bulkhead to the point so that when the vehicle is to fly its ultimate missions it can carry them out.

Mr. KARTH. As I understand Centaur this has been one of the problem areas.

Mr. EHRICKE. Yes, sir.

Mr. KARTH. The invasion of the vacuum.

Mr. EHRICKE. Yes, sir.

Mr. KARTH. That is the insulation between the two tanks?

Mr. EHRICKE. That is correct.

Mr. KARTH. By leaking gas?

Mr. EHRICKE. Yes.

Mr. KARTH. Hydrogen.

Mr. EHRICKE. Yes.

Mr. KARTH. Now this must have caused some delay, caused additional research and development, and cost additional money.

Mr. EHRICKE. Yes.

Mr. KARTH. I would like your best estimate of each one of these things, how much money, how much delay, how much additional research and development?

Mr. EHRICKE. As far as——

Mr. KARTH. If you can't at the moment arrive at a proper conclusion on this, I would ask that you do so when you have some time to think about it and then you provide it for the record. Can you do this, sir?

Mr. EHRICKE. Yes; I will do that.

Mr. KARTH. If you would rather do it that way, it is perfectly all right. We do want to have it in the record, however.

Mr. EHRICKE. Right.

ATTACHMENT E

CENTAUR INTERMEDIATE BULKHEAD

The intermediate bulkhead design of the Centaur tank was based on the successful design of the Atlas intermediate bulkhead. The basic concept (cryofreezing of the bulkhead cavity) was theoretically correct and was subsequently verified experimentally by submerging welded sections of the bulkhead wall in liquid hydrogen.

The thin gage of both walls of the intermediate bulkhead was chosen in order to provide lightweight design. The risk taken was a calculated one, not taken lightly. Many difficult decisions had to be made at that time (1959), based on engineering judgment and experience. Most of these were subsequently proven to be correct. A few decisions have to be amended and modified in any development program. This was one of them.

The need for lightweight design across the board was based on payload commitments made for Centaur. Whenever the payload weights seemed to slide, GD/A was exposed to criticism by the various customers, although GD/A Centaur management repeatedly pleaded, in spring and summer 1961, for understanding that the lower payload figures would apply only to the series of the first six test vehicles whose purpose it was to demonstrate the feasibility of the system, rather than to carry payload. A difference of 50 to 60 pounds in intermediate bulkhead weight between the old and the corrected design may not appear to be a critical weight increase. If measured against the vehicle empty weight or even against the payload weight. It must be understood, however, that the bulkhead was only one in many areas where we had to be weight conscious. There was no reason to single this particular item out and disregard weight consideration. If weight considerations would have been disregarded across the board in a similar fashion as it now appears in the wisdom of hindsight that we should have disregarded it on the bulkhead, we would have experienced weight increases at least in the order of 250 to 300 pounds and this would have constituted a serious decrement in payload.

Dr. Stuhlinger visited GD/A on April 1, 1960, as a personal representative of Dr. von Braun and encouraged us to propose additional tests we deemed necessary. The Centaur program director sent a letter, dated April 20, 1960, to Colonel Seaberg, in which he enclosed a 5-page list of tests suggested by Astronautics for incorporation in the NASA program. A separate copy of this list was forwarded to Dr. Stuhlinger and Mr. Hueter. A total of 28 test programs was suggested, including test to determine the effect on heat transfer coefficient when leaks of various sizes occur through the Centaur insulation bulkhead into the vacuum compartment between propellant tanks during coast phases of flight.

On September 23, 1960, GD/A submitted a "Proposal for Tests to Support Centaur Space Research Vacuum Facility" to the Centaur program office in Los Angeles. A total of five test programs was proposed including heat transfer of Centaur intermediate bulkhead.

This test program will measure the heat transfer through the intermediate bulkhead. This will allow a more accurate determination of the payload capabilities of Centaur, and also the effect of the heat transfer through the intermediate bulkhead on the critical energy balance in the LO_2 tank.

Proposals for intermediate bulkhead testing were not accepted.

Even though this particular test program proposal did not mention bulkhead leaks specifically, in contrast to the before-mentioned letter of April 20, 1960, it is likely that such information would have been gained from these tests, since we were aware of the danger of leaks.

As a result, we did not find out about the sensitivity of the bulkhead design until in summer and fall 1961, when such leakage was found for the first time on Centaur C–2 during tanking tests at complex 36.

The need to correct the bulkhead design has not delayed, and is not expected to delay in the future, any of the flight dates of Centaur.

As far as its effect on the flight objectives is concerned, the currently planned F–2 mission will be affected inasmuch as the vehicle may not be capable of reaching the 24-hour orbit, as originally planned. It will, however, enter the parking orbit, coast briefly, and restart. As a result, most of the primary objectives of the F–2 flight are preserved. The F–1 flight objectives were limited by flight-rated engine availability such that bulkhead performance was satisfactory for F–1 flight objectives. The flights F–3 through F–6 will carry a bulkhead with intermediate corrections, at least to the extent required to reach 24-hour orbit altitude thereby avoiding delays in the flight test program or derating of flight objectives. In the meantime, the final design of the corrected bulkhead will be established and subjected to comprehensive testing. It is expected to be incorporated in the flight articles F–7 and on.

As stated above, correction of the present bulkhead requires bulkhead redesign. The cost of this redesign is estimated to be $130,000. Test articles using this redesigned bulkhead will be manufactured and tested under the new program philosophy prior to incorporation into the flight article. The expenses connected with their manufacture and testing are not true added costs since they would have, and should have, been incurred earlier in the program as part of a more comprehensive bulkhead development.

Mr. Karth. Mr. Randall.

Mr. Randall. I would like to fix back again—I don't want to labor this safety margin point, but you mentioned a moment ago the weight increase. You said it was only 60 pounds, is that right? Is that the figure?

Mr. Ehricke. This is the order, approximately.

Mr. Randall. What is the total overall weight of the vehicle, sir?

Mr. Ehricke. The vehicle weight, itself, without payload at burnout is approximately 3,600 pounds.

Mr. Randall. In other words, that was quite a gamble to take to not have that 60 pounds in the first instance, wasn't it?

Mr. Ehricke. Yes, sir; this is correct. However, in order to keep the structural weight down, we had, of course, to take similar measures in other areas where it did work out.

Mr. Karth. Mr. Hammill.

Mr. Hammill. During our authorization hearings it was brought out that the fuel and oxidizer tanks in the Centaur vehicle are not optimized with respect to their relative size. Colonel Heaton in his testimony indicated that he didn't regard this as a major problem. But it still seems fantastic that they would not have been designed so as to be perfectly compatible one with the other.

Can you explain why it is that the tanks are not of the proper relative size?

Mr. Ehricke. Yes; the reason for that was twofold. No. 1, as I mentioned before we were urged to use existing hardware wherever possible to design the Centaur. So consequently we did design the oxygen tank out of two bulkheads of Atlas.

Now this is designwise perfectly sound and correct. On the other hand, we wanted to keep the ignition weight of Centaur—limited to

32,000 pounds because we didn't want to go all out to the limits of the Atlas capability as they existed at that time. For this weight it turned out that if you put these two bulkheads together the volume is a little bit too large for the amount of oxygen that we required.

Now from the weight viewpoint this is a very minor penalty. All I can say here is that it did not maximize the performance of Centaur. It was a slight compromise that was taken; yes, sir.

Mr. HAMMILL. Well, the use of the Atlas components and fabrication techniques, as was said during our authorization hearings, has left the committee with the impression that Centaur is a sort of makeshift device, and for something that apparently has grown into an item that is of fundamental importance, to our space effort, what is your view of this matter at this point?

Mr. EHRICKE. Sir, my view at this point as well as earlier naturally was that I wished we didn't have these constraints. I was convinced that the program is important, would become important, and I wished it would have been put on a broader basis right from the start.

However, if I would be asked: Could you with a good conscience accept these constraints and still contribute significantly to the development of an oxygen-hydrogen vehicle and to developing a technology that goes with it? I would have to say "Yes, we can."

I believe that it will be necessary, eventually, or at least desirable, I should say, to adjust the lengths and the weight of Centaur so that full advantage can be taken of the oxygen tank. We have made such a proposal to Marshall and Marshall has it under consideration at this time.

Mr. HAMMILL. Does that mean a redesign of the vehicle?

Mr. EHRICKE. No; it would merely mean a lengthening of the hydrogen tank, because you see we have a fixed mixture ratio which provides that for every pound of hydrogen we are spending 5 pounds of oxygen. So the hydrogen tank which determines the overall length, in fact the entire cylindrical area is hydrogen tank only, the overall length did limit the amount of oxygen that we need. So what is necessary is that we increase the length of the hydrogen tank by something.

Mr. HAMMILL. Will that add to the weight of the second stage?

Mr. EHRICKE. Yes; that would add.

Mr. HAMMILL. Will the Atlas still be able to perform underneath it?

Mr. EHRICKE. Yes, today's Atlas will.

Mr. HAMMILL. It is structurally strong enough to support it?

Mr. EHRICKE. Yes; there were changes made in the structure of Atlas and also in the engine system of Atlas to allow operation of the sustainer engine at earlier jettisoning of the booster engines.

Mr. KARTH. Excuse me, Mr. Hammill.

Were these changes in Atlas made specifically for the Centaur?

Mr. EHRICKE. They were made as a part of the development of an Atlas space booster by the Air Force. The engine changes were not made specifically for Centaur, only the forward end changes were made specifically for Centaur.

Mr. KARTH. How much weight will that add to Centaur?

Mr. EHRICKE. The extension?

Mr. KARTH. Yes.

Mr. EHRICKE. The extension of the tank, itself, should add approximately 10 to 20 pounds weight as far as the structure is concerned. The payload weight gained by far would outweigh this increase. The payload gain, of course, depends on the mission.

Mr. HAMMILL. Dr. von Braun testified that in his opinion there was not sufficient technical penetration by the Government representatives, and I assume that he meant supervision, generally over the contractors.

How would you evaluate the technical supervision that you got from the Seaberg group during all the time that they were in charge of the program; and was there someone assigned to your facility during that period or in constant contact?

Mr. EHRICKE. No, sir; there was not a local representative at our facility, at our company at that time.

The contacts were less frequent as long as project management sat at Headquarters, ARDC, in Baltimore or in Washington, and this changed after Colonel Seaberg and his staff moved over to Inglewood. From that time on, I can say that we had almost daily contact by phone and four to five physical contacts, or three to four physical contacts per week with representatives of Colonel Seaberg's office.

Now Colonel Seaberg was supported by additional personnel from NASA-Lewis, and also could call on personnel at NASA's Lewis or Langley Field, and this was frequently done.

Headquarters also established review boards, which checked in depth into the Centaur program, however, not on such a continuous basis as it is being done right now by Marshall.

Mr. KARTH. A good deal of their time was being utilized in the changing of contracts, was it not, rather than as a supervisor of the project?

Mr. EHRICKE. Not of Colonel Seaberg's. This was Colonel Murphy's job.

Mr. KARTH. I see.

Mr. EHRICKE. Colonel Seaberg and the people, members of his staff. were entirely——

Mr. KARTH. And how many were there on that staff of Colonel Seaberg?

Mr. EHRICKE. Well, originally there were three people, Major Diehl, who was the liaison man to our operations; Major Gardner, the liaison man to Pratt-Whitney operations, and Major Brill, a hydrogen operation specialist at ARDC.

After Colonel Seaberg moved to Inglewood, he requested additional help. People were given to him from Lewis, there were at least two more people, which brought the total to five, and there were a number of temporary personnel who came in, stayed there shortly and went back again.

Colonel Seaberg did request additional personnel, this I know of my own experience, from NASA, especially when he was assigned by General Ostrander also the handling of the so-called common engine, that is, the Pratt & Whitney second generation engine which serves S–4 as well as the Centaur.

Exactly how this worked out for Colonel Seaberg in detail I cannot say, because Colonel Seaberg, as I said, had not only our program but he had also the engine program, and he also had to worry about the contract for the launch complex.

Mr. KARTH. Certaintly there weren't enough people for any penetration in depth, were there?

Mr. EHRICKE. No, sir; there were not enough people for penetration in depth.

Mr. KARTH. You were pretty much on your own?

Mr. EHRICKE. Yes, sir.

Mr. HAMMILL. Did Colonel Seaberg or any member of his group ever give you any specific direction?

Mr. EHRICKE. Yes, very definitely.

Mr. HAMMILL. Can you give us an example?

Mr. EHRICKE. Yes. For example, in the handling of hydrogen, in the storage of hydrogen, these things were reviewed by Colonel Seaberg and Major Brill and specific directions and improvements were made at that time, mainly based on practical experience of these people with liquid hydrogen.

Colonel Seaberg also called Arthur D. Little and other hydrogen experts in, for example, National Bureau of Standards at Boulder. They were drawn in and together with Colonel Seaberg's people reviewed our hydrogen system, storage system, the measuring of—temperature measurements of liquid hydrogen and associated things, very definitely.

As far, however, as our design philosophy was concerned, tank design, thrust structure, and so forth, we did this essentially, ourselves.

Mr. HAMMILL. I see.

Mr. EHRICKE. Every selection, I might add, of a guidance system contractor, evaluation of the type of guidance system or boost pump system or other subsystems that we did was—every one of these was evaluated by Colonel Seaberg and his people, plus additional people whom he called in as it was necessary.

Mr. HAMMILL. All right. I think we have established that the field supervision was really not adequate, but how about NASA headquarters? Whom did you understand to be the boss of this project, and did you ever see him, and did you ever get any direction from him at all?

Mr. EHRICKE. Yes. Our first boss in NASA headquarters was Mr. Rosen, and we had frequent meetings with Mr. Rosen. However, inasmuch as Colonel Seaberg was transferred to NASA, we were still getting our primary directions and were primarily to turn to Colonel Seaberg, just like now we have primarily to deal with Mr. Hueter, rather than with representatives of the program in headquarters.

Mr. HAMMILL. All right. Now who were the succession of bosses, let us say, in NASA headquarters?

Mr. EHRICKE. Mr. Rosen, General Ostrander, Colonel Schubert. I am sorry, Commander Schubert.

Mr. HAMMILL. And you say you did meet with Mr. Rosen on occasion. How about General Ostrander and Commander Schubert, have they ever visited your facilities?

Mr. EHRICKE. Yes.

Mr. HAMMILL. And to what extent have they given you any direction at all? Have they really taken control of the program in your opinion, or is it just a matter of paying the checks?

Mr. EHRICKE. Their direction was primarily given to Colonel Seaberg, sir. I have made several presentations on the program to General Ostrander. However, of course, General Ostrander himself did not participate in technical meetings in detail, as such. He gave his instructions to Colonel Seaberg. With Commander Schubert, the cooperation was considerably closer. Commander Schubert was very frequently down. He concerned himself to considerable detail with our technical problems, were they guidance or propulsion or whatever they were. He was very well informed and there was a rather close contact.

Mr. HAMMILL. Now to summarize, could you just give the committee your opinion of the supervision of this project by Government officials during the period when you were project officer?

Mr. EHRICKE. Yes, sir. The supervision during this period was broad and comprehensive but was not very penetrating in depth. As such, the supervision was, in toto, less than the supervision that was given to ballistic missiles developments, for example, or supervision that is given by NASA and Marshall at the present time to projects like Centaur and similar projects.

Mr. HAMMILL. You are still affiliated with the program Mr. Ehricke, though not as project officer, is that correct?

Mr. EHRICKE. I am not organizationally affiliated; as a consultant I am.

Mr. HAMMILL. Perhaps I should ask Mr. Hansen, then, what if any changes he would recommend with respect to the Government supervision of this program at the present time.

Are you completely satisfied?

Mr. HANSEN. I am thinking about it.

I know of no changes in the Government's management plan for Centaur that I would recommend at this time. The problems which I have seen or heard of in the past and which I have alluded to, I think, have been recognized in the Government management channels, and I think that corrective action has been taken, and I am completely satisfied with the management organization which we now have.

Mr. HAMMILL. The reason I ask the question is that at an earlier hearing it was suggested that perhaps Centaur, as important a program as it has turned out to be, requires a strong man at the top to really take hold and direct the program, and to see that it is carried out properly.

Mr. HANSEN. Well, from my point of view in the Centaur program, my boss is Francis Evans, who is the Centaur program manager at Marshall Space Flight Center, and his boss is Hans Hueter, Hans Hueter takes a very intense and detailed interest in the program, and both of these gentlemen are very strong men.

Mr. KARTH. From now on, then, I suppose we can say there is almost a dual responsibility for whatever advances might be made or for whatever mistakes might come about as opposed to prior to Marshall Space Flight Center's being assigned to this thing most of the mistakes that were made, or most of the advances that were made is pretty much the responsibility of General Dynamics/Astronautics, because you didn't have this penetrating supervision, is that correct?

Mr. EHRICKE. Yes, sir, I would say this.

Mr. KARTH. So, as a result of that, everything that has gone on before was pretty much your responsibility, the mistakes and advances?

Mr. EHRICKE. Speaking for that period, this is correct, yes, sir, because we didn't have this penetration.

Personally, I would like to add for the record that I also wished that Colonel Seaberg, who was always dedicated to the program, would have been in a stronger and more consistent position, but conditions as they were I think did not permit that.

Mr. HAMMILL. I think the subcommittee is glad to know that you regard the program as being in good hands now, because it seems to have taken a long time for Marshall to take hold of this program. It was assigned to them in June of 1960, if I am not mistaken, and, apparently, it is only recently that they have taken very much interest in it. Would you say that is correct?

Mr. EHRICKE. May I answer that?

Mr. HANSEN. I think you are the one that has to, Krafft.

Mr. EHRICKE. All right.

In answer to this, I think if I have to answer with a yes or no, the answer is: It is correct, yes.

Mr. HAMMILL. Oh, no. You should feel free to explain.

Mr. EHRICKE. But the explanation for this is that Marshall, when it was given the responsibility for Centaur, was also given the responsibility for Agena and the responsibility for a growing Saturn program, and they were therefore naturally—they had their own problems and it took them sometime to organize themselves to take hold of all the added responsibilities that were thrown at them, especially since this mode of operation previously was far more self-contained and with not as many outside contractor directions as they had to face from that point on.

I think the time, yes, there was a certain time where I think it is explainable, justifiable.

Mr. HAMMILL. That is all, Mr. Chairman.

Mr. KARTH. Mr. Beresford?

Mr. BERESFORD. Yes, Mr. Chairman.

Mr. Ehricke, in your opinion, could the technical difficulties that have caused delay and failures in the Centaur program have been avoided by either better concepts and designs or by better organization and management?

Mr. EHRICKE. I believe primarily they could have been avoided by more and earlier ground testing and, as far as management organization is concerned, and as far as I myself am concerned, I naturally would have liked to have a stronger organization than I had.

Mr. BERESFORD. Why wasn't the ground testing done?

Mr. EHRICKE. Initially, the program, the overall program funding, which I think was made probably out of existing funds at the time ARPA started it, just did not permit it.

Gradually, we increased the funding and increased the tasks, but the ground testing, you know, a certain amount of time had been lost and this is just irrevocably gone and we are paying a little bit for this now.

Mr. BERESFORD. Did your company request additional funds for that purpose?

Mr. EHRICKE. Yes, we did request—well, our request was in the form of technical requests which, if granted, would have brought us additional funds, yes sir. Especially in the area of cryogenic testing and zero-g testing.

Mr. BERESFORD. Mr. Hansen, do you think Centaur should be given a DX priority? Would that do any good at this stage?

Mr. HANSEN. I think the answer is "Yes" to both of those questions. I think it would do good. We have on record letters from eight of our principal subcontractors indicating that there are priority conflicts which interfere with them giving us the kind of service we like to have. Yes, I think the importance of this program to the national space effort is equally as great as other efforts which do have a higher priority.

Mr. BERESFORD. Mr. Ehricke, in the earlier stages of the program, did you experience difficulties because of the low priority as well as the lack of funds?

Mr. EHRICKE. Yes, sir. This became apparent in all cases where the subcontractors had to make a choice between deliveries to DX projects and non-DX projects.

It also played a role in the construction of Complex–36 in 1960 which, as you might remember, fell into the period where we had a rather long and bitter steel strike. This again resulted in what limited supply was available to be made available to DX priority projects first.

Also, of course, in any cases of choice between Atlas and Centaur, Atlas simply had to be given priority, be it in the factory, or be it on an electronic computer program, where we sometimes had to stand, not only sometimes but frequently, had to stand back and wait until certain important Atlas runs had been made.

But this is, of course, the rule, if one project has DX priority and the other doesn't.

Naturally, I myself always desired to have DX priority for the project and also for the stand, but perhaps I am prejudiced. I fully realize that you perhaps cannot give everybody DX priority, it doesn't mean anything anymore.

Mr. BERESFORD. You can't give it to every project.

Mr. EHRICKE. And the space age came on us so fast that some agonizing choice had to be made, and I personally regret that Centaur was among those that did not receive DX priority.

Mr. BERESFORD. I have one more question, Mr. Chairman.

I am trying to remember earlier testimony in which, as I recall, it was said that—not your testimony, testimony that we had from other witnesses—it was said that the Centaur flight, I believe, test shot, which I think would be the qualifying or final shot of the test series, will take place on schedule in spite—that is, the present schedule, in spite of the recent failure.

Do you really believe that?

Mr. EHRICKE. As Mr. Hansen had pointed out, if our present theory that we have on the failure is borne out, the second flight is unlikely to be delayed on account of a failure in the first flight. The other flights are not at all affected then by what happened in the first flight but could, of course, be affected by problems that we encounter afterward.

This you just can't say, we are just at the beginning of our flight test series, which is expressly designed to find out problems.

Mr. BERESFORD. Have you made any efforts to have some of the constraints removed, these constraints that you spoke of, such as the direction to use existing hardware and designs? and there must be others that you haven't mentioned.

Mr. EHRICKE. Yes, sir; only in those cases where it turned out to be absolutely necessary. In many other respects we tried to live up to our word that many of the constraints would be acceptable to us, even though we certainly didn't consider them ideal.

For example, in the question of whether we should feed the propellants to the Pratt & Whitney pump by means of gas pressure in the tanks or whether we should rather use boost pumps, such a consideration entered, and this was this: If we would have used pressure we would have had to go into a more comprehensive development program of new valves than we had if we were using boost pumps.

Now, the boost pumps, at least the hydrogen boost pump, had already been in an advanced state of development at Pasco at an earlier Air Force project. So we believed under those conditions we could with good conscience make a design decision which avoided going into a new valve program, and which was still of high quality. In fact, it also turned out that the vehicle's payload capability would even be increased by using the boost pumps.

But in many phases throughout the year 1959 these considerations did enter, but where we honestly believed here is some new development necessary, such as in the zero-g vent valve, for example, for the hydrogen tank, there we made our point very clear and were accepted.

Mr. BERESFORD. No further questions.

Mr. KARTH. Mr. Ehricke, on these technical suggestions that you made, which in turn would have caused increased appropriations for the Centaur project, what were we talking about in terms of dollars? How much would this have cost at the time?

Mr. EHRICKE. If we take special developments into account, such as the design of a new bulkhead and more testing, I would say it would have been at least of the order of another $10 to $15 million. In fact, I think this is a low estimate; $15 to $20 million is more likely.

Mr. KARTH. And at that time how much money was in the project, Mr. Ehricke?

Mr. EHRICKE. During 1959 ——

Mr. KARTH. Was that the time when you had what, $59 million in it?

Mr. EHRICKE. No, sir. The time I am talking about here was late 1958, early 1959. I have the program here. In the course of 1959 the additions which were absolutely necessary brought the program, already, to $42 million, but this was not all unforeseen additional expenditures. For example, when we got the original ARPA contract it was stipulated that test facility for static testing, guidance, and additional facilities such as vacuum facilities would be funded separately, also the launch complex.

A certain amount of the difference between the $36 million and the $42 million that the program rose to in 1959 are due to these foreseen additions to the program, not because we had all of a sudden very much more money available which we could use for more ground testing.

In other words, what I am saying is we should have had and it would have been desirable to have for the 1959 and early 1960 engineering activity something of the order of perhaps $57 to $62 million.

Mr. KARTH. Or an increase of about $15 million?

Mr. EHRICKE. Yes, sir.

Mr. KARTH. Now, at that point there was no doubt in your mind but what the Centaur project was going to go ahead, was there?

Mr. EHRICKE. Not in my mind, sir, no.

Mr. KARTH. You had no doubt in your mind that it was going to go ahead?

Mr. EHRICKE. Yes, sir.

Mr. KARTH. But you didn't feel that it was worth the risk for the company to go ahead and initiate these things on their own and then later be reimbursed for whatever the risk might have involved in terms of dollars and cents?

Mr. EHRICKE. Sir, this is, of course, a question that I am not quite able to answer since it was not my decision to make this for the company. The company had at that time ——

Mr. KARTH. Was the matter ever discussed by the company?

Mr. EHRICKE. Yes, sir, it was discussed.

Mr. KARTH. And the decision was that they should not do it, apparently.

Mr. EHRICKE. The decision was that the company was—let me put it this way: The indications that I received from Mr. Dempsey during discussions of this type were that this level of additional expenditure was very difficult for the company since over $20 million had been put into the astronautics facility by the company when Astronautics was established. And at that time, incidentally, another five, a little bit over $5 million was put in for new buildings in order to take up the increased personnel for the Atlas and the Centaur program.

Mr. KARTH. Now, we have had several estimates of the cost of this development. It started out, as you know, at a relatively low figure. We have already spent about $200 million on it. The estimate a month ago was that ultimately we would spend about $300 million on it. The latest estimate as of yesterday was $350 million for the total development program. What is your estimate? Let me ask you this: Do you think $350 million will finally make this program operational?

Mr. EHRICKE. Yes, yes. Again, here depending upon the amount of risk you want to take it could be less than $350 million.

Mr. KARTH. I asked Dr. von Braun yesterday whether or not he felt Centaur was out of the woods. What would be your answer to that question, Mr. Ehricke?

Mr. EHRICKE. My answer would be "We do not know." I doubt that Centaur is out of the woods, because no program really is—already can be called that after the first test flight.

Mr. KARTH. Are there any further questions?

Mr. BERESFORD. No, sir.

Mr. KARTH. Unless there is something that you would like to add for the record, Mr. Hansen or Mr. Ehricke, we will adjourn until 2 o'clock, at which time we will hear the representatives of Pratt & Whitney.

Mr. HANSEN. I would like to make a statement if I might.

Mr. KARTH. Yes, sir; if you wish go right ahead.

Mr. EHRICKE. I would like also to make a brief one. I would like for the record to express my full confidence in the program. We have not met principal insurmountable difficulties. I believe that under the broader auspices in which this program is now being handled, more ground testing, the possibility of at least temporarily working on dual or backup solutions, I think assures the success of the program.

There is one thing that I personally could wish to be added to the program. It is, Give it DX priority. It is important enough for it.

Mr. KARTH. While Mr. Hansen is thinking, another thought just occurred to me, Mr. Ehricke. Do you think Titan III can replace the Centaur project?

Mr. EHRICKE. I think Titan III could greatly benefit from the use of Centaur as a final stage, especially for 24-hour orbit missions. The payload increase would be tremendous over the present Titan III vehicle.

Mr. KARTH. What do you think about Titan III as a replacement vehicle?

Mr. EHRICKE. I think Titan III as a replacement vehicle as it is designed right now is very good for low-altitude payloads. For high-altitude payloads and into 24-hour orbit Titan III would not be a good replacement for Centaur.

Mr. KARTH. Thank you very much, sir.

Mr Hansen?

Mr. HANSEN. Actually, it would be my preference, if this procedure is an acceptable one, that I might make a few brief closing remarks after the recess for lunch.

Mr. KARTH. Well, I would like very much to conclude our hearing now for General Dynamics/Astronautics so that we could immediately get into Pratt & Whitney testimony this afternoon. I have a feeling that some of those people probably made plane reservations, too, and I would hesitate to ask them to stay over until tomorrow.

Mr. HANSEN. Very well.

The point that I would like to make here is that I think the Centaur program has been the subject of a considerable amount of unwarranted criticism.

I have been experienced, as my biography will indicate, in a number of development programs of similar nature, and I have followed the progress of a number of other programs. And earlier, Mr. Karth, you made the statement that you would like to have explained for you the abnormal delays.

Any development program has a certain amount of risk in it. I think if one looks at the accomplishments of this program, at the design that was made, I think that it can be recognized that some programs have done better. I think it should be recognized that some programs have done better.

Mr. KARTH. Many people feel that way about it, sir, yes.

Mr. HANSEN. I think that it should also be recognized that some programs have done worse, and I feel that there is a great deal of credit due to the accomplishments that have been made in the Centaur program so far for the amount of time spent and the amount of money spent.

I think it is entirely proper that this type of hearing and investigation of this thing take place, and I think that it is very beneficial to us, not only for the things that we have had the opportunity to say here, but for the background work which we have felt necessary to be properly prepared to come here.

But I do feel that the accomplishments are noteworthy and I feel that the progress of this program has been significant. I think that the design competence in this thing is reasonable, I think it is state-of-the-art type of thing and I feel that there should be an equal recognition of these accomplishments with the recognition of the fact that the program has not come along as rapidly as the early optimistic estimates were that it might.

Mr. Karth. Mr. Hansen, I can say that we appreciate greatly your coming down here, and we hope that the interest of Congress in the Centaur development program, to some degree, helps you. We appreciate the fact that General Dynamics/Astronautics has done many fine jobs for the Government, and I would be remiss if I didn't say that.

We are concerned about this because this is very vital to a substantial portion of our space effort. We do feel that there are a few areas in Project Centaur that have not come up to the expectations that we had for it or that we hold out for it at this time, and we hope that our very sincere interest in it has helped you people as much as we feel you have helped us.

Again, I want to thank you very much. The meeting will be adjourned until 2 o'clock this afternoon, when we will hear the people from Pratt & Whitney.

(Whereupon, at 12:42 p.m., the subcommittee adjourned, to reconvene at 2 p.m., the same day.)

AFTERNOON SESSION

Mr. Karth. The committee will come to order.

Mr. Bruce Torell is the program manager of the RL-10 engine program at Pratt & Whitney Aircraft Division of United Aircraft Corp.

Mr. Torell, I assume that you have several well-informed people along with you on this subject matter. Would you like to introduce them for the record at this time, and then proceed with your prepared statement?

STATEMENT OF BRUCE N. TORELL, PROGRAM MANAGER, RL-10 ENGINE PROGRAM, PRATT & WHITNEY AIRCRAFT DIVISION OF UNITED AIRCRAFT CORP.; ACCOMPANIED BY W. L. GORTON, GENERAL MANAGER OF FLORIDA RESEARCH & DEVELOPMENT CENTER; R. J. COAR, CHIEF ENGINEER; AND R. C. MULREADY, DEVELOPMENT ENGINEER, IN THE RL-10 ENGINE PROGRAM

Mr. Torell. Thank you very much.

I would like to introduce Mr. W. L. Gorton, general manager of our Florida Research & Development Center; Mr. R. J. Coar, chief engineer, and Mr. R. C. Mulready, development engineer in the RL-10, seated behind me.

Mr. Gorton is to my immediate right.

Mr. Karth. Yes, sir.

You may proceed.

Mr. Torell. Thank you.

Mr. Chairman and members of the Subcommittee on Space Sciences, I want to express our appreciation for this opportunity to come before your committee to discuss our efforts in the development of the free world's first liquid hydrogen rocket engine.

Mr. W. L. Gorton, Mr. R. J. Coar, and Mr. R. C. Mulready, all from our Florida Research & Development Center, are with me today, and we will all be pleased to answer questions you may have following this presentation.

In this presentation, I will try to explain very briefly the steps which led to our proposal for such an engine, the philosophy underlying its design, our major problems and successes in its development, and our expectations for its future.

To provide the proper background for our discussions of the RL–10 engine development, we must go back to the latter half of 1955. At that time, Pratt & Whitney Aircraft initiated studies to explore the potential advantages of liquid hydrogen as a fuel for aircraft propulsion. This work was followed by an Air Force contract for a novel hydrogen-burning turbojet engine. Under this program, we successfully converted one of our J–57 jet engines to use liquid hydrogen. This engine operated satisfactorily for the first time in September of 1956.

The novel hydrogen-fueled engine, designated the 304, which evolved from this program was first tested in September of 1957. Four full-scale experimental engines were run, and significant component development and testing experience was gained. In the course of this program, we used more than a million gallons of liquid hydrogen.

Thus, when we proposed the development of a 15,000-pound thrust liquid oxygen-liquid hydrogen rocket engine in 1958, we were not operating in an area of technology completely new to us. The engine we proposed to develop is the RL–10, now scheduled for use in the Centaur and Saturn S–IV vehicles.

This engine, shown in figure 1, is our part of these two most important spacecraft. The particular engine shown in this photograph and also shown in this larger photograph behind me, is the engine which successfully completed its official flight rating test in November 1961. The photograph was taken upon conclusion of that test.

The combination of hydrogen and oxygen as propellants can produce a given thrust for approximately 40 percent longer than can the same weight of conventional propellants. As a result of this and other design features, the RL–10 has higher performance, or specific impulse, than any engine developed to date.

Although the superiority of hydrogen as a rocket propellant had long been recognized, its feasibility as a safe and practical fuel remained to be proved. The experience gained in the practical day-to-day handling of liquid hydrogen at NASA's Lewis Laboratories, at the U.S. Air Force's liquid hydrogen production facilities, and at Pratt & Whitney Aircraft have demonstrated its relative safety. Liquid hydrogen is now being transported by pipeline up to a distance of 3,500 feet, over the road by truck, and across the country by rail tank car on a weekly schedule. We have used more than 20 million gallons of it during the course of development of the RL–10 engine.

The RL–10 engine, as well as the 304 engine before it, employs a regenerative or "bootstrap" cycle, as shown in figure 2. If I may I would like to divert a little and go through the cycle.

Mr. Karth. Please do.

Mr. Torell. This is a grossly simplified schematic of the engine showing the propellant flow. This is the engine which we are developing, the RL-10.

Going briefly through this schematic, hydrogen enters the hydrogen pump here, goes through a two-stage pump, is delivered in liquid form to the thrust chamber cooling jacket.

I might say that the thrust chamber consists of a series of tubes which are hollow and which are cooled by virtue of the propellant flowing through them. This is common to many other rocket engines.

This hydrogen passing through the tubes gains energy and cools the tubes. In other words, it picks up heat as well as cooling the tubes. This heat then provides the energy which drives the turbine. This turbine, as you will note, is geared to drive the oxidant pump, so that it is an extremely simple cycle.

The energy for driving the turbine which drives the fuel pumps is taken out before the hydrogen finally flows into the injector where it is mixed with the oxygen to produce combustion.

Now, there has been a considerable amount of discussion about the bootstrap cycle, and I thought perhaps it would be of interest to compare this cycle with a cycle which would employ a gas generator.

We have prepared an overlay which essentially shows the additional equipment that would be necessary to provide a gas generator on this engine. You will notice now that rather than having the propellant which has cooled the tubes, pass through the turbine, it passes directly into the combustion chamber.

To provide energy to drive the turbine we must have a separate supply of hydrogen and of oxygen flowing through control valves and burning in the separate combustion chamber, which must be separately cooled to provide the energy to drive the turbine.

Now, you will notice the duplication that exists here. There is an additional combustion chamber which must be cooled, there is an additional ignition system which must operate, there are additional control valves which must operate, and there is a control system that must operate. This is duplicated on the main chamber.

There are similar valves which must work on the main chamber as well. In essence, therefore, we have a duplication of two systems by virtue of using the gas generator.

So we feel that in this particular instance and for this particular size engine the bootstrap cycle permits a gross simplification whereby we utilize energy that is already existent in the propellant to drive the turbopumps.

Mr. Karth. Why, then, does this engine have limitations, Mr. Torell, which allows it to grow not beyond the 25,000-pound thrust capacity?

Mr. Torell. I think the best way to answer that, Mr. Karth, is to say that the performance gains that are available with this cycle are not—do not outweigh the increase in weight that is required if you get beyond a certain point in thrust size.

This cycle—the advantages of the cycle can be enjoyed up to a certain thrust class and beyond that the additional weight that you must add, because of a surface-to-volume ratio problem, more than offsets the gain in performance.

Mr. KARTH. How much more does this engine weigh using the bootstrap cycle system rather than it would weigh if it used the gas operating system?

Mr. TORELL. It so happens in this particular engine size the engine would weigh considerably less, in my opinion.

Mr. KARTH. Using the bootstrap system?

Mr. TORELL. Yes. I think it is clear, if you compare these two directly.

We have no additional valves or additional combustion chamber to deal with here. So you have to actually add the weight of this equipment here if you want to make a direct comparison.

As you get to a large, very large engine size, the changes that you have to make to produce the desired heat transfer in the chamber offset the performance gains that I am speaking of.

Mr. KARTH. Dr. Wehrner von Braun yesterday, I believe, said that this type of an engine does not allow itself to grow beyond 25,000 pounds of thrust. Would you agree with that statement?

Mr. TORELL. I think that generally I would agree. I think, also, however, that before you could draw that conclusion you would have to examine the specific requirements of that engine.

Generally speaking, I think that somewhere beyond 25,000 pounds thrust you reach the crossover point where the gas generator system would tend to be a better choice from a performance standpoint.

Mr. KARTH. How much less does this engine weigh than the gas generating system would have weighed if you had used that in the Centaur engine? I mean what are we talking about in pounds?

Mr. TORELL. I don't think we can answer that other than to say that it would—the gas generator system would weigh more.

Mr. KARTH. Do you have any idea how much more?

Mr. TORELL. We don't have any numbers with us, Mr. Karth, but we'd be glad to have a look at it and supply these numbers.

Mr. KARTH. Well, you appeared to be so certain that it would weigh more.

Mr. TORELL. Yes.

Mr. KARTH. I was quite sure that you had tried both systems or at least evaluated both of them and probably picked this one.

Mr. TORELL. Yes.

Mr. KARTH. Because the Centaur vehicle is to be kept at a minimum weight due to the job or the mission or the missions that have been set up for it.

Mr. TORELL. Yes.

Mr. KARTH. But you have no estimate as to what the difference in weight would be?

Mr. TORELL. No.

Mr. KARTH. If you could give us that later for the record then.

Mr. TORELL. Yes.

WEIGHT OF RL10 ENGINE AS DESIGNED (WITH BOOTSTRAP CYCLE) COMPARED TO WEIGHT OF RL10 ENGINE WITH GAS GENERATOR CYCLE

With the technology available in 1958, the selection of the bootstrap cycle offered a weight saving of approximately 20 pounds per engine over the gas generator cycle. The gas generator cycle engine would thus have weighed approximately 7 percent more than the bootstrap cycle engine, a direct result of

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the additional components required in the gas generator engine. Since there are two RL10 engines used in the Centaur vehicle, the weight saving in the vehicle is 40 pounds.

In addition to the weight reduction in the engine, the increase in specific impulse which the bootstrap cycle offers also makes possible a reduction in fuel weight. This performance increase is a minimum of 4 seconds, and we are told that this gives significant payload improvement particularly for missions such as Advent.

Using the technology available today, it would be possible to design a gas generator engine to meet the RL10's current performance at less weight than the current RL10 weight. With today's technology, however, it would also be possible to design a bootstrap cycle engine to better both the gas generator engine's weight and its performance. Of course, great care must be taken to avoid comparison of paper designs with actual weight of existing hardware and with actual demonstrated performance.

Mr. Torell. Actually, I should clear up one point, and that is the basic choice was based on impulse rather than purely weight considerations; that is, the performance advantage also inherent in this cycle. This will come out a little later in my prepared statement.

Mr. Karth. I see.

We had considerably more experience with the development of a gas operating system than we did with the bootstrap cycle system at the time that you got into this, did we not?

Mr. Torell. Yes, I think that is correct.

Mr. Karth. How much money did it cost to develop this kind of a system?

Mr. Torell. I think that for the particular application whereby we were dealing in a new technology with hydrogen as a fuel, that one cannot say that the use of the bootstrap cycle for this specific engine, and most of these engines are tailored, so to speak, would cost any more, if as much as the cost of using a gas generator system.

Mr. Karth. Did you check out the costs of the two systems, one as opposed to the other?

Mr. Torell. I am afraid I am not prepared to answer that.

Do you know, Dick, whether that was ever checked?

No. I don't think we can answer that at the moment.

Mr. Karth. This is a matter of opinion, then, rather than a matter of having checked these things out from a technological standpoint and an engineering standpoint and having arrived at a specific figure, is that correct?

Mr. Torell. I think you can only tell this by having done it. But I think that if you will permit me once again to point out the difference in the hardware, it is reasonable to assume, with this additional hardware that you have to develop, that the costs should be in favor of the bootstrap system.

We have not developed a gas generator system, so that we are not qualified to make a valid comparison in costs.

Mr. Karth. But those people who have, you see, are ready, willing, and able, they tell me, to argue the point with you. That is why I was wondering whether or not we had any facts as to your position.

Mr. Torell. The only facts I can point to are the hardware, Mr. Karth.

Mr. Karth. I see.

Go ahead. Proceed.

Mr. Torell. And I might add, not very many people have developed a hydrogen engine. Perhaps I should return to my statement now.

Mr. KARTH. Yes, go ahead.

Mr. TORELL. The bootstrap cycle is possible only because of the unique physical properties of hydrogen. Hydrogen is passed through the thrust chamber cooling jacket, absorbing heat, and in this cycle this heat provides the energy to the turbine driving the propellent pumps. Satisfactory engine starts have been demonstrated with the thrust chamber cooled to a temperature of 313° Fahrenheit below zero.

In the gas generator system, on the other hand, figure 3, since the heat of combustion in the engine is not used for driving the turbine, there must be a separate combustion chamber. This second combustion chamber must itself have control, cooling, and ignition systems, and the engine will not operate unless these systems, and the duplicate systems, in the main thrust chamber, function simultaneously.

The simplicity of the bootstrap system leads to an inherently higher engine reliability, because there are fewer components to malfunction.

Not only does this cycle result in a simpler and more reliable engine, but a performance advantage is also gained, since the propellants are burned in the main thrust chamber where they produce full thrust. The propellants, burned in a gas generator, do not produce full thrust.

In the RL–10 engine, advantage has been taken of the unsurpassed cooling attainable with hydrogen. By cooling the bearings and gears with hydrogen, it has been possible to eliminate completely an oil lubrication system, another major source of unreliability. Thus, during a long period of coasting in space, no heating is required to keep lubricants from freezing. Elimination of warm oil from the gearbox avoids high temperature differences which would otherwise occur between the bearings and the pump impellers and thus simplifies the design.

The contract to develop the RL–10 engine was received from the Air Force in mid-October 1958. The first flight-type thrust chamber was fired in 7 months, and the first complete engine firing was accomplished 2 months later.

Rated thrust and specific impulse were demonstrated in the 11th month after contract go-ahead. Eighteen months after contract go-ahead, an endurance test of a development engine equivalent to six Centaur missions was completed. The first pair of ground test engines was delivered to the Government in mid-August of 1960, 22 months after contract go-ahead.

On the 6th of November 1960, the first dual engine firing with the Centaur propellent system was successfully completed on the vertical test stand. At this point in time, 230 firings had been successfully accomplished on horizontal stands.

Mr. KARTH. You mean now, or then?

Mr. TORELL. At that time.

Mr. KARTH. I see.

Mr. TORELL. On the second firing attempt on the vertical stand, only one engine lit, and the propellent charge which accumulated in the test stand exhaust duct from the unlit engine exploded and damaged both engines, the propellent supply system, and the test stand.

It was determined from the tape recording of the countdown that inadvertent misoperation of the test stand sequencer had occurred, causing a marginal propellent condition for ignition. It was therefore believed that the engine was not involved in the failure to light, and the next firing was scheduled to be accomplished as soon as repairs were completed. The actual deficiency in the ignition system remained hidden.

The third dual engine firing was attempted on January 12. Again, only one engine fired, and an explosion resulted. In this test, all conditions appeared normal and within specification limits.

The investigation of this failure of the system to light reliably in the vertical stand was underway when on January 30 an engine failed to light in a horizontal stand. The nature of this ignition problem was determined in rig tests on February 22, 1961. By the end of the next week, a modified torch ignition system which insured the existence of both propellants in the vicinity of the spark at the time of ignition was being tested. This configuration with minor modification is in use today and has had over 900 successful tests in both horizontal and vertical positions. The total elapsed time from the recognition of the problem to a satisfactory solution was about 6 weeks.

Mr. KARTH. How much time in total?

Mr. TORELL. I don't understand your question, Mr. Karth.

Mr. KARTH. You didn't recognize the problem. You used the word "recognition" of the problem. You recognized the problem after the third misfire?

Mr. TORELL. Actually, the problem was diagnosed after the second misfire which occurred on January 12.

Mr. KARTH. I see.

But including the time delay after the third misfiring plus the time loss caused by the misfiring of the first two, one of which destroyed the test stand, et cetera——

Mr. TORELL. Yes.

Mr. KARTH. How much total time is involved in the delay?

Mr. TORELL. The first failure to light which resulted in an explosion was in November 1960, and the successful correction took place 6 weeks after——

Mr. KARTH. Six weeks after February 22, right?

Mr. TORELL. If you will excuse me for just a moment, I think our numbers are—I think the correct answer is 16 weeks.

Mr. KARTH. Sixteen weeks.

Mr. TORELL. Yes.

Mr. KARTH. All right, sir. Proceed.

Mr. TORELL. Since correction of the ignition problem, some 27 successful dual vertical engine firings have been completed. In addition to these tests, five dual engine firings, with durations as long as 280 seconds, have been accomplished with the propulsion test vehicle at Edwards Air Force Base.

The official flight rating test required by the Government was successfully completed on November 4, 1961. This test involves 20 firings and the equivalent of 6 Centaur missions duration. This test was accomplished in just under 5 days' total time.

The development of the RL-10A-1 engine through its official test was therefore accomplished in a 3-year period.

To the best of our knowledge, no other rocket engine has been brought from inception to successful completion of its official flight rating rest in as short a period of time.

A total of 29 RL-10 engines have been delivered. The development of an improved version has progressed to the point of an official flight rating test. This version has been developed for increased performance and longer firing time, and can be installed interchangeably in the Centaur of the Saturn vehicle. Deliveries of this engine are scheduled to begin in July of this year.

That completes my formal statement, Mr. Karth. I would be glad to answer any questions you may have.

(Figs. 1, 2 and 3, are as follows:)

FIGURE 1

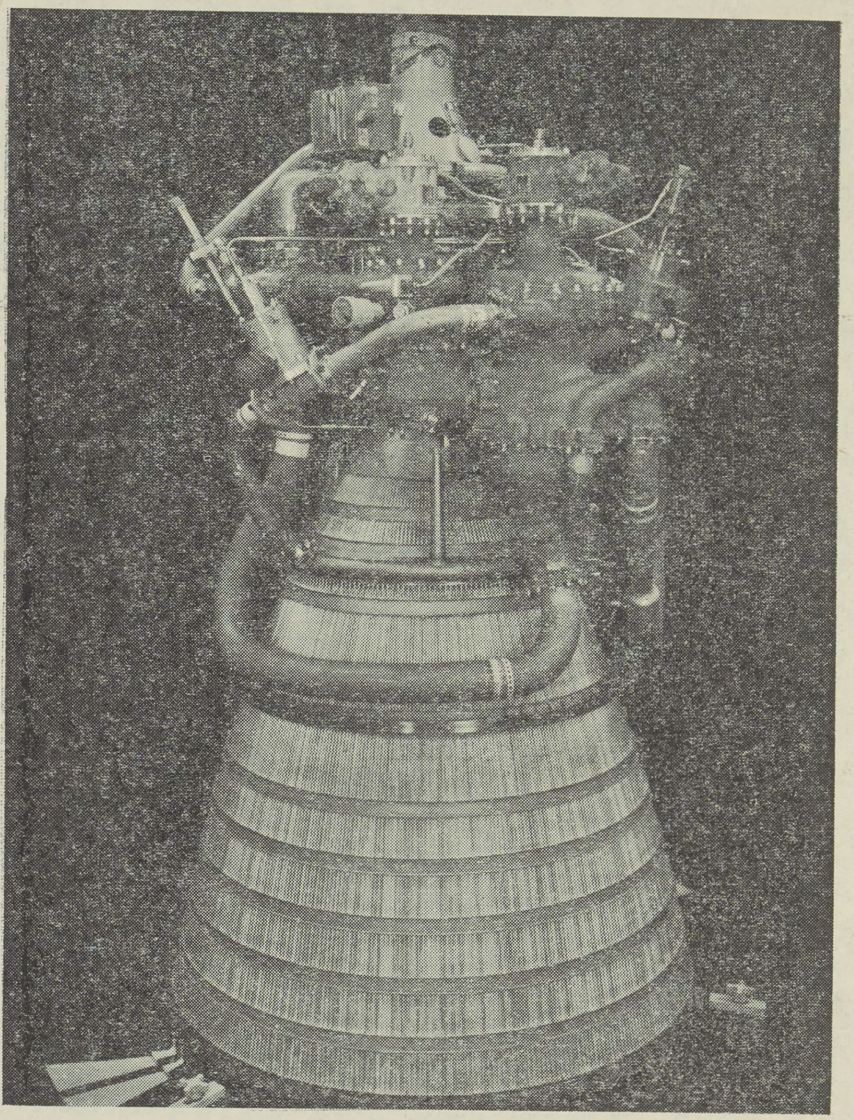


FIGURE 2

PROPELLANT FLOW SCHEMATIC

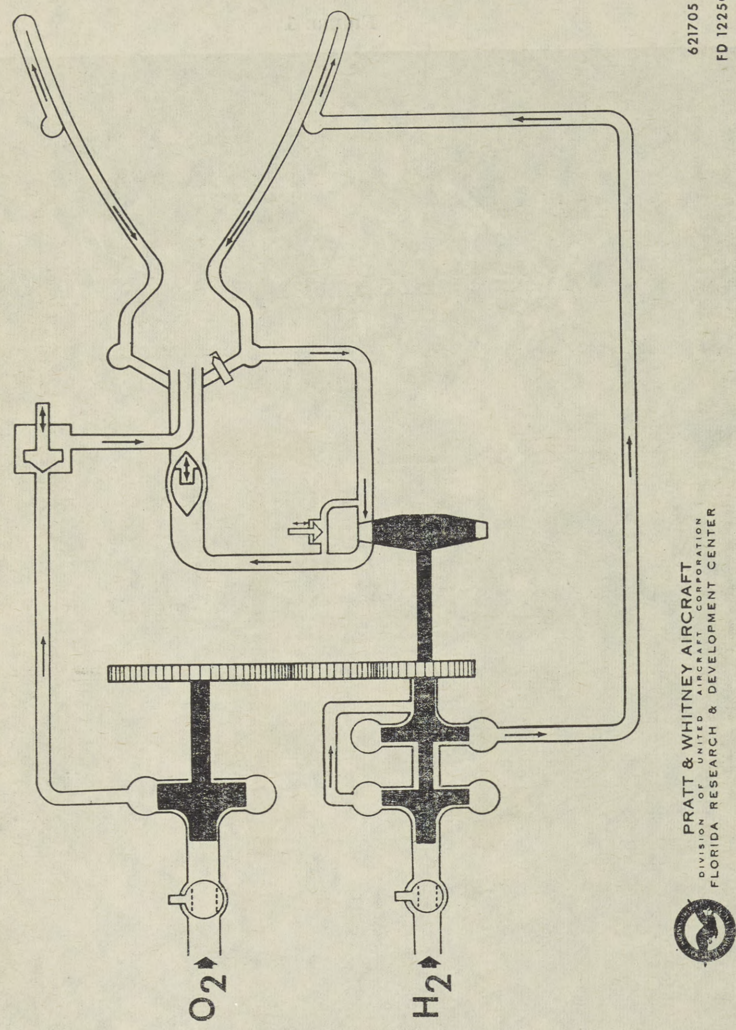
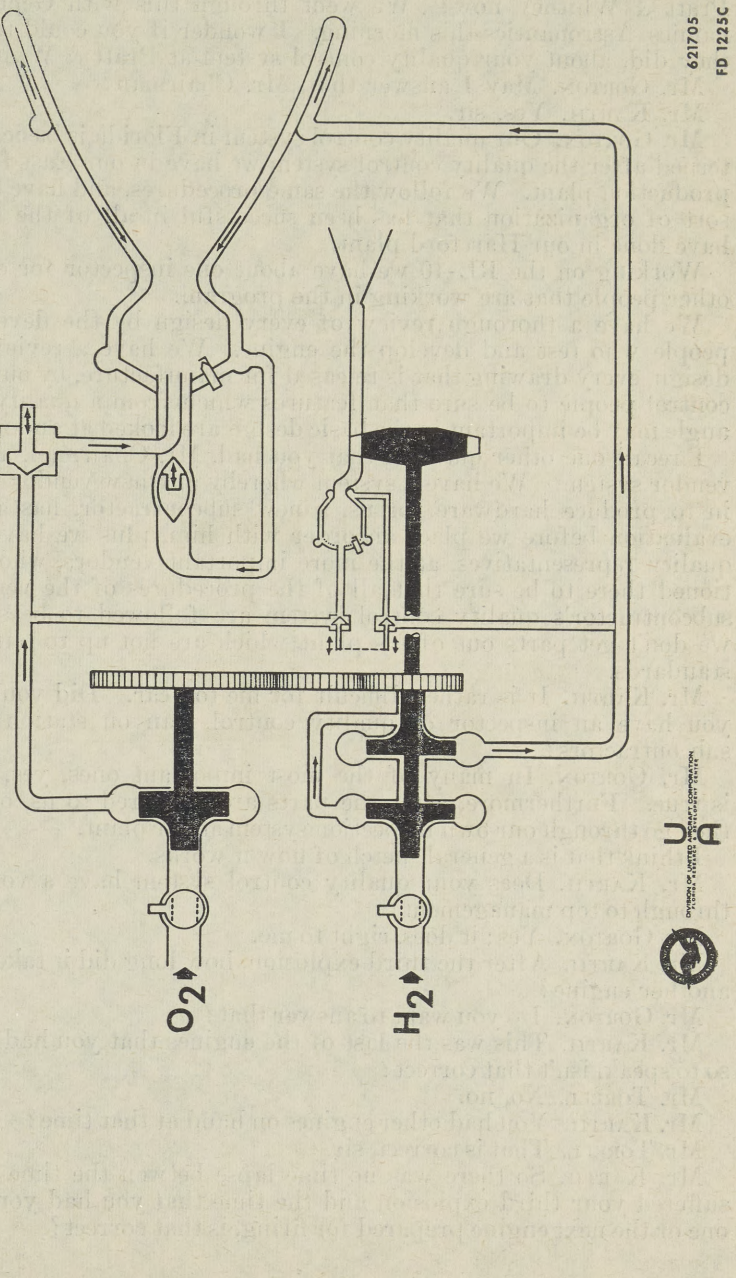


FIGURE 3

PROPELLANT FLOW SCHEMATIC



Mr. KARTH. Did you make an exhaustive test or checkout after the first and second explosions?

Mr. TORELL. Following the second explosion there was an exhaustive study of the stand system and the equipment and it is my understanding that there was additional equipment added to increase the safety for future firings.

Mr. KARTH. What kind of a quality control system do you have at Pratt & Whitney now? We went through this with General Dynamics/Astronautics this morning. I wonder if you could tell us, as they did, about your quality control system at Pratt & Whitney?

Mr. GORTON. May I answer that, Mr. Chairman?

Mr. KARTH. Yes, sir.

Mr. GORTON. Our quality control system in Florida is basically patterned after the quality control system we have in our East Hartford production plant. We follow the same procedures, and have the same sort of organization that has been successful in all of the work we have done in our Hartford plant.

Working on the RL–10 we have about one inspector for every six other people that are working in the program.

We have a thorough review of every design by the development people who test and develop the engine. We have a review of the design, every drawing that is released for manufacture, by our quality control people to be sure that features which from a quality control angle may be important in the basic design are looked at and reviewed.

I recall one other question that you had, Mr. Chairman, about the vendor system. We have a system whereby any new vendor we bring in to produce hardware for us, a new subcontractor, has a quality evaluation before we place an order with him, plus we have vendor quality representatives, at the more important vendors, who are stationed there to be sure that all of the procedures of the vendor's or subcontractor's quality control system are followed to be sure that we don't get parts out of his plant which are not up to our quality standards.

Mr. KARTH. It is rather difficult for me to hear. Did you say that you have an inspector or quality control man on station at your subcontractors?

Mr. GORTON. In many of the most important ones, yes, sir, this is true. Furthermore, after the parts are delivered to us, of course, they go through our own inspection system at our plant.

I think that is a general sketch of how it works.

Mr. KARTH. Does your quality control system have a voice right through to top management?

Mr. GORTON. Yes; it does, right to me.

Mr. KARTH. After the third explosion, how long did it take to build another engine?

Mr. GORTON. Do you want to answer that?

Mr. KARTH. This was the last of the engines that you had in stock, so to speak, isn't that correct?

Mr. TORELL. No, no.

Mr. KARTH. You had other engines on hand at that time?

Mr. TORELL. That is correct, sir.

Mr. KARTH. So there was no time lapse betwen the time that you suffered your third explosion and the time that you had your fourth one or the next engine prepared for firing, is that correct?

Mr. TORELL. That is essentially correct; yes. However, of course, until we had determined the cause and made changes to the engine, obviously we didn't want to proceed with the development testing.

Mr. KARTH. You people are aware of the weight of the Advent, are you not?

Mr. TORELL. I am not sure that we are aware of the latest figures, sir.

Mr. KARTH. I wasn't asking that you divulge any figures, I was just asking whether you are aware of it. Which leads me to another question. That is, is the Centaur as it is now developed, the engine, at a performance level so that it can do the job, one of the jobs it was originally designed to do and that is to orbit the Advent?

Are you aware of this, whether it can do the job or whether it can't at this point?

Mr. TORELL. I don't think, Mr. Karth, we are competent to comment on that question.

Mr. GORTON. Mr. Chairman, may I add a little something to what Mr. Torell said.

Mr. KARTH. Sure.

Mr. GORTON. I would like to point out that the engines have always met their specification requirements as far as thrust and specific impulse are concerned, so that insofar as the job we signed up to do in the beginning performancewise, it has been met from the start.

Mr. KARTH. The original spec started at 15,000 pounds thrust and you are meeting the 15,000 pounds thrust; is that correct?

Mr. GORTON. That is correct.

Mr. HAMMILL. You were present this morning when we were discussing the question of supervision with General Dynamics/Astronautics. I wonder if you could give us a rundown on the kind of technical supervision that you had prior to the Marshall Space Flight Center taking over complete control and tell us to what extent it has changed under the new system?

Mr. GORTON. Well, the first answer to your question, I believe, is that we have always had a project manager type system in the development of the RL-10. In fact, in all of the engines that we have developed, not rocket engines, but other engines, since 1939, we have always used the project type system at Pratt & Whitney Aircraft.

Fundamentally there have been no changes since NASA took over. The same system exists and I think, so far as I know, they find no fault with it.

Mr. HAMMILL. I wasn't referring to your internal organization. We are aware that that has not changed, as it has in General Dynamics/Astronautics; the extent of the supervision by the Government people who are responsible for this development program is the point of my question.

One of the things that Dr. von Braun pointed out was that there was not sufficient depth of supervision, and that there were not enough technical people assigned to the job. I am wondering if you had the same experience during the time when Colonel Seaberg's team had responsibility for the program. Did they have an officer there at your facility, or did they visit your facility from time to time? What was the extent of their supervision of your activities?

Mr. GORTON. Well, I think I can answer this question by saying that there isn't any major difference during the changeover. Now the changeover has been rather gradual. It started back in July of 1960.

NASA may have a few more people there at the present time than previously, but, on the contrary, or to explain this, there is a lot more going on now.

We are delivering engines and I don't believe that there is any significant difference so far as the development of the engine is concerned. Under both regimes—you must realize that Colonel Seaberg and his people were working for NASA so far as their supervision of our operation.

Under both regimes I think that the supervision on the technical side of the thing was not significantly different.

Mr. HAMMILL. Supervision was adequate; is that what you are saying?

Mr. GORTON. We believe it was adequate in both cases.

Mr. KARTH. As far as the engine development of Centaur is concerned, you are pretty well satisfied that you are out of the woods on that, aren't you?

Mr. GORTON. Yes, I believe we are.

Mr. KARTH. Do you see any major problem areas at this time in the engine?

Mr. GORTON. I should amplify what I said by saying that when you flight test any propulsion engine, and you get it off the ground, you always find that there is something that you weren't able to turn up in your ground testing and I am sure those problems are ahead of us yet.

What they will be we don't know, but we don't think they will be major, because this engine has been tested at space conditions since the beginning, you see; that is the particular difference between the way this engine has been developed and other engines.

So we anticipate no major problems when the engine is actually launched from the cape. However, speaking from long experience in the past, we hate to say that there isn't going to be something turn up. But there is no man smart enough to forecast what those things will be.

Mr. KARTH. Dr. von Braun yesterday and the General Dynamics/Astronautics people this morning indicated quite strongly, it seemed to me, that they were not out the woods yet with Centaur. Now perhaps they meant in areas other than in the engine. You don't feel quite as strongly about it as they do, is this a proper understanding on my part?

Mr. GORTON. I won't attempt to speak for the vehicle. As far as the engines are concerned ——

Mr. KARTH. I just want you to speak for the engine.

Mr. GORTON. That is right. As far as the engines are concerned, and as far as what it is humanly possible to find out by ground testing of all sorts we feel the engine is out of the woods.

Mr. KARTH. And it is going to meet its original requirement in terms of thrust?

Mr. GORTON. That is correct.

Mr. KARTH. How much more money do you think it is going to take for Pratt & Whitney to deliver what remains to be delivered for the Centaur program? That is the 10 vehicles that are involved?

Mr. GORTON. Can you answer that?

Mr. KARTH. Can you tell us how much money has up to this point been spent on the engine and how much yet needs to be budgeted for the engine?

Mr. GORTON. This answer is a little difficult for us because we don't control how many engines go to the Centaur program. That is established by NASA. We are delivering engines right along which, at the present time, are being used both in the Centaur and Saturn programs. So it is a little hard to come up with a forecast as to what the cost is going to be.

Mr. KARTH. I see.

I would like for the record, if you could, Mr. Torell, to give us a rather detailed breakdown of your quality control management. I am not sure that you have had sufficient time to think about it in its entirety—so if you would do this for the record we would be very happy.

Mr. GORTON. We would be very happy to.

QUALITY CONTROL AT PRATT & WHITNEY AIRCRAFT

The quality control system which is used in the RL10 program at Pratt & Whitney Aircraft is that which Pratt & Whitney Aircraft has developed in the course of developing and building aircraft engines over a period of more than 30 years and which has contributed significantly to the record of dependability established by Pratt & Whitney Aircraft engines. The quality control system in East Hartford, where all RL10 delivery engines scheduled for delivery after July will be manufactured, is managed by and staffed with the same people who have made this system so successful. The quality control system at the Florida research and development center is the same as the system in East Hartford with identical organization and procedures, and with key people all drawn from the East Hartford organization.

The purpose of the system is to insure that the highest quality is designed into every engine, and that the manufacturing department build into each engine that quality which is designed into it.

The engineering department has complete responsibility for product quality. The quality control department has always been a function of the engineering department, to insure that the quality designed into the product is built into it by the manufacturing department.

In East Hartford, the quality control manager reports through the chief of engineering operations to the engineering manager, who in turn reports to the general manager. At the Florida research and development center, the quality control manager reports to the chief of engineering operations, who reports to the general manager. The quality control manager, FRDC, has regular meetings with the chief of engineering operations and the general manager twice weekly and has direct access to the general manager at all times. In both cases, then, the quality manager is not under the control of, and is free to make quality decisions without consideration for, the manufacturing department.

At the Florida research and development center, 280 quality control department employees work on quality control of the RL10 engine, and in East Hartford, 293 quality control department employees work on quality control of this engine. The time of these people is preponderantly spent on the RL10 engine.

Our organization includes adequately equipped and staffed material control laboratories, both in East Hartford and in Florida. In Florida, the materials control laboratory has 106 people (not included in the quality control department count, above), all of whom spend part of their time in assuring basic material quality for the RL10 engine. In East Hartford, 12 people in the materials control laboratory devote their full time to the RL10, and 6 more devote part of their time to this engine. The materials control laboratories continuously check the physical properties of raw material used, and maintain control of processes such as plating, heat treating, welding, etc.

We thus have a total of 697 people working on RL10 quality.

The factory manager in East Hartford also has a quality group working for him. The factory manager's group is charged with the responsibility of changing manufacturing methods as required to assure the manufacture of parts of only the highest quality. Each employee who works in manufacturing is trained to report all deviations from drawings to quality control, and all manufacturing problems affecting quality to the factory manager's quality group. It is axiomatic that quality cannot be inspected into an article—it must be built in.

Every design must be approved by our development engineers before being released for development and manufacture. We thus take advantage of their background and experience in the operation and test of previous similar hardware to insure the basic soundness of new designs.

Every drawing released for manufacture is reviewed by our quality control department to insure that features in the basic design which are important from a quality control standpoint are carefully considered and, if necessary, the design revised.

All parts manufactured by us are inspected by the quality control department. No part rejected by the quality control department may be used in a delivery engine unless and until the material review board, which includes a Government representative, agrees that the variant part may be accepted.

The control of quality of material and manufactured parts purchased from vendors is of vital concern to us. In all cases, we have either resident or visiting quality control representatives in the plants of vendors to insure compliance with our rigid quality requirements. We thus have approximately 150 people, in addition to those counted above, stationed in vendors' plants to control quality for all our engines. Parts purchased from vendors are inspected in our plant even though we may have company and Government inspectors at the vendors' plants.

We conduct a careful review of vendor quality control methods, procedures, and organization, including, where appropriate, testing of samples.

Our material control laboratories participate in vendor selection and in the exercise of continuing surveillance over vendor material control. Our use of the material control laboratories includes, where appropriate, the placing of resident laboratory technicians and metallurgists in vendors' plants to insure maintenance of continuing quality, in process controls, laboratory procedures, and tests. We now have 23 material control laboratory personnel, in addition to those counted above, resident in vendors' plants for these purposes for all our engines.

In summary, our demonstrated history of high quality results from quality procedures, and a mature quality organization, developed over a period of more than 30 years, and adherence to the following principles:

(1) A fundamental policy which makes quality a prime objective of the designers and engineers charged with designing and developing the engine.

(2) Quality consciousness at all levels of the manufacturing process, so that the quality designed into an article is built into it.

(3) A quality control organization completely independent of the organization charged with manufacture, and a quality control manager with uninhibited access to top management.

Mr. KARTH. One other thing: Now Pratt & Whitney at the time that they received their first Centaur contract had been in the business of making jet engines rather than rocket engines.

How much time would you say was involved in this learning curve that had to come about as a result of going from jet engines to rocket engines? Just talking about the learning curve, not talking about the 3-year time which I know is already a part of the record as you previously stated; from the time of the original contract until you delivered the engine. I am just asking whether or not you could ascertain how much time was needed to develop this learning curve in the rocket engine field?

Mr. GORTON. Mr. Chairman, we have, because of the difficulties that we were in at one time, we have heard from various sources that some of this was caused by our not knowing anything about the rocket game. We do not agree with this.

Mr. KARTH. That is why I wanted to give you a chance to defend yourselves.

Mr. GORTON. Thank you.

This particular rocket engine has pumps which pump a gas, two gases. It has a turbine, it has seals of all kinds, it is made up of fabrication, a thrust chamber which is fabricated from stainless steel. It has aluminum castings in it. It also has a combustion chamber. All of these things are no different, technologywise, than what we have in jet engines. We have turbines, we have fluid pumps, we have combustion chambers.

The fundamentals are not different, and we do not believe that we lost any time for the Government in this development because we had to learn something. In fact, we believe that at the time this contract was awarded us that we probably could have done it better than anybody else for the simple reason we did have some experience with hydrogen.

Mr. KARTH. No one else at that time had had that same experience?

Mr. GORTON. Not to our knowledge, nobody had anywhere near that amount. Other people had worked with hydrogen on a research basis, but nobody had attempted anything like what we had done.

Mr. KARTH. You found no problem though with the handling of the hydrogen, did you? You found this to be a fairly unstable product to be sure, but you have worked out the technology so that it can properly be handled and you found no real particular problem areas here, did you?

Mr. GORTON. Once we learned its peculiarities we find it, I think, just about as tractable as gasoline. You have to be very careful of gasoline, and you have to handle it right.

Mr. TORELL. Relative to our capabilities in the rocket engine field, I might add one more thing or repeat one thing, and that is that although this was the first rocket engine that we had built, we did bring the engine to its official test in a 3-year period of time and again, to the best of our knowledge, no other engine manufacturers, regardless of their past experience, have bettered that time.

Mr. GORTON. That is on a completely new engine we are speaking of, such as this one was.

Mr. KARTH. Yes; I understand.

Mr. Beresford?

Mr. BERESFORD. Just one question, Mr. Chairman.

Do you feel confident now that the RL–10 engine will perform satisfactorily in flight with a high degree of reliability?

Mr. GORTON. Well, I will go back to what I said before. As near as it is humanly possible to determine this from the tests that the engine has been given on the ground—we have no way of actually flying the thing in the conditions it is going to be used at in the Centaur—yes, we have a very high degree of confidence.

Mr. KARTH. Elimination of the third burn in the Centaur has eliminated to a considerable degree, I suppose, some of your problems, has it not?

Mr. GORTON. No. It may have lessened the hazard that the engine is going to be subjected to; that is the number of chances it will get to strike out, but fundamentally it has been developed for the three missions—the three burns.

Mr. KARTH. And whatever problems may have existed as a result of the third burn probably were in areas, in components in the project other than in the engine, itself, is that right?

Mr. TORELL. The third burn had nothing to do with the engine, you are correct in that assumption.

Mr. KARTH. How about the ignition of the engine in space, do you feel this problem has been pretty well licked?

Mr. TORELL. Yes. In particular this is one area where we have a high level of confidence simply because every start we make is essentially made in space.

That is, we have some steam diffusers which evacuate the discharge of the engine and pull the pressure down to space conditions.

Mr. KARTH. Thank you very much, gentlemen.

There are no further questions on the part of the committee.

We want to thank you very much for coming down. And if you feel, after you leave, there is something that you might have forgotten to put in the record, and you would like to do so, please feel free to write us and we will make sure that it gets in the record.

Mr. GORTON. Mr. Chairman, we appreciate that opportunity and we appreciate the opportunity of appearing before you.

Mr. KARTH. Do you have any closing statement that either one of you would like to make at this time?

Mr. GORTON. None whatever.

Mr. KARTH. Fine; thank you very much.

The meeting is adjourned.

(Whereupon, at 3:04 p.m. the subcommittee adjourned.)

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