REPORT TO
THE CONGRESS OF THE UNITED STATES

REVIEW OF
MANNED AIRCRAFT NUCLEAR PROPULSION PROGRAM
ATOMIC ENERGY COMMISSION
AND
DEPARTMENT OF DEFENSE

B-146759

BY
THE COMPTROLLER GENERAL OF THE UNITED STATES

FEBRUARY 1963

GAO Wash., D. C.

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON 25

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To the President of the Senate and the
Speaker of the House of Representatives

Herewith is our report on the review of the Manned Aircraft Nuclear Propulsion Program of the Atomic Energy Commission and the Department of Defense. The Aircraft Nuclear Propulsion Program was a joint project of the Atomic Energy Commission and the Air Force to develop a nuclear-powered airplane for military purposes; the Navy was a minor participant in the program.

Work relating to the nuclear propulsion of aircraft was initiated in 1946 and continued until the entire program was terminated in 1961. The total cost of the program was about $1 billion.

At the time of termination, the Aircraft Nuclear Propulsion Program was still in the research and development stage, with primary emphasis on high performance reactors. Although a number of research and development achievements can be credited to this program, at the time of termination an airplane had never been flown on nuclear power nor had a prototype airplane been built. The benefits accruing to the Government from the Aircraft Nuclear Propulsion Program are dependent upon the present and subsequent use of facilities constructed and the technology gained. The Atomic Energy Commission stated that these facilities and the technology became the basis of much of the research and development now being conducted as a part of the space reactor development programs.

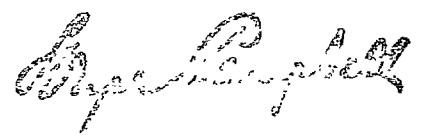
Although the Aircraft Nuclear Propulsion Program has been terminated, we have found deficiencies in administration of this program and have certain observations which we are reporting for the information of the Congress and for consideration by executive agencies so that appropriate steps can be taken to minimize the possibility of similar situations in future research and development programs.

The Aircraft Nuclear Propulsion Program was a technically complex and difficult research and development program carried out in competition with other programs for national defense. As a result, the importance attached to the program varied greatly throughout its history, and frequent changes in emphasis and direction of the program occurred.

Although it was outside our scope to examine into the reasonableness of or justification for the frequent changes in program objectives, we do not believe that a research and development effort of the complexity and magnitude of the Aircraft Nuclear Propulsion Program can reach its goal in an effective and efficient manner unless a certain degree of stability in objectives is accorded to the program. During our review we noted various indications that the Department of Defense did not furnish sufficient and timely guidance for the Aircraft Nuclear Propulsion Program and that program reorientations were not formalized on a timely basis. A summary of our observations and findings is presented in the forepart of the report.

The Department of Defense, in commenting on this report, has stated that it agrees that the program suffered considerably from lack of prompt decisions and from frequent changes in emphasis and goals and that it is for the purpose of minimizing the impact of such conditions in the future that it has instituted many new management procedures in the Department. The detailed staff comments from the Army and Air Force, with respect to the specific items concerning their respective roles in the program, are included at appropriate sections throughout the report. The Atomic Energy Commission has stated that the report provides a history of the major problems which influenced the execution of this difficult and complex research and development effort. The comments of the Atomic Energy Commission pertinent to particular observations within the report are included in the appropriate sections throughout the report. Comments were solicited from the major contractors engaged in the Aircraft Nuclear Propulsion Program, and the replies received indicated basic agreement with the facts presented in this report.

Copies of this report are being sent to the President of the United States; the Secretaries of Defense, the Army, the Navy, and the Air Force; and the Commissioners of the Atomic Energy Commission.



Comptroller General
of the United States

Contents

REPORT ON REVIEW

OF

MANNED AIRCRAFT NUCLEAR PROPULSION PROGRAM

ATOMIC ENERGY COMMISSION

AND

DEPARTMENT OF DEFENSE

INTRODUCTION

The General Accounting Office has made a review of the Manned Aircraft Nuclear Propulsion (ANP) Program of the Atomic Energy Commission (AEC) and the Department of Defense (DOD). This review was made pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), the Accounting and Auditing Act of 1950 (31 U.S.C. 67), the Atomic Energy Act of 1954 (42 U.S.C. 2206), and the authority of the Comptroller General to examine contractors' records, as set forth in 10 U.S.C. 2313(b).

The ANP program was based upon requirements established by DOD and was a joint project of AEC and the Air Force for developing a nuclear-powered airplane for military purposes. The Navy was a minor participant in the program. The AEC was responsible for the reactor and the related shielding, while the Air Force was responsible for the remaining parts of the airplane, mainly the turbomachinery, airframe, and auxiliary components.

The major contractors engaged in the ANP program were the Aircraft Nuclear Propulsion Department of the General Electric Company (GE), the Pratt & Whitney Aircraft Division of the United Aircraft

Corporation (P&W), the Convair Division of the General Dynamics Corporation (Convair), the Georgia Division of the Lockheed Aircraft Corporation (Lockheed), and the Oak Ridge National Laboratory (ORNL).

After 15 years of feasibility studies and research and development effort, the ANP program was terminated in March 1961. The total cost of the ANP program as of June 30, 1961, was about $1,040 million--$839 million for operating costs and $201 million for facilities and equipment. The Air Force furnished about $518 million, the AEC about $508 million, and the Navy about $14 million. For a detailed breakdown of the costs of the ANP program, see pages 110 to 113.

At the time of its termination, the ANP program had been redirected to the research and development stage with primary emphasis on high-performance reactors. A number of airborne reactor shielding studies had been carried out and turbojet aircraft engines had been ground tested with nuclear energy as the heat source; however, an airplane had never been flown on nuclear power nor had a prototype airplane been built. The benefits accruing to the Government from the ANP program are dependent upon the present and subsequent use of the facilities constructed and the technology gained. In summarizing accomplishments, AEC has stated that the ANP program started at the upper limits of nuclear technology which required many so-called "break-throughs" in materials, reactor concepts, instrumentation, shielding, and controls and that these circumstances automatically provided a tremendous acceleration in the advancement

of nuclear reactor technology. AEC has enumerated various accomplishments of the ANP program (see appendix V) and has concluded that it is not possible now to inventory, realistically, the total benefits derived from the ANP program. AEC has stated further that the high-temperature materials and radiation shielding information was undoubtedly of great value to the national space effort and that the extent to which this information saved time and money and expedited program efforts in the space and other important programs would be impossible to calculate.

The ANP program was a technically complex and difficult research and development program carried out in competition with other programs for national defense. As a result, the importance attached to the ANP program varied greatly throughout its history, and frequent changes in emphasis and direction of the program occurred. Because the ANP program was carried out over a period of 15 years and involved expenditures in excess of a billion dollars, our review was generally limited, of necessity, to selected administrative phases of the program. The scope of our review appears on page 107.

Although the ANP program has been terminated, we have found deficiencies in administration and have certain observations which we are reporting for the information of the Congress and for consideration by executive agencies so that appropriate steps can be taken to minimize the possibility of similar situations arising in future research and development programs.

The policy-making and other interested principal officials in the Atomic Energy Commission and the Department of Defense are listed in appendix VI.

SUMMARY OF OBSERVATIONS AND FINDINGS

Our major comments are summarized below. A page reference is given for a more complete discussion of the subjects, together with agencies' comments, in subsequent sections of this report.

CHANGES IN EMPHASIS AND DIRECTION OF THE ANP PROGRAM

The ANP program was characterized by frequent changes in emphasis and objectives, varying from a research and development program to an accelerated program to develop a weapon system for the Air Force.

The ANP program was carried out in competition with other programs for national defense. As a result, the importance attached to the ANP program varied greatly throughout its history. Although it was outside our scope to examine into the reasonableness of or justification for the frequent changes in program objectives, we do not believe that a research and development effort of the complexity and magnitude of the ANP program can reach its goal in an effective and efficient manner unless a certain degree of stability in objectives is accorded to the program. (See pp. 31 to 35.)

LITTLE OR NO USE MADE OF CERTAIN FACILITIES BECAUSE OF PROGRAM REORIENTATIONS

During our review we noted that various major facilities had been constructed at a total cost of about $17,147,000 but were never used, or used very little, for their intended purposes because of program reorientations. The two largest facilities were the Flight Engine Test facility that was constructed at the AEC National Reactor Testing Station, Idaho, at a cost of $8,061,000 to

AEC, and the Radiator Laboratory that was constructed at the Connecticut Aircraft Engine Laboratory, Middletown, Connecticut, at a cost of $6,306,000 to the Air Force. (See pp. 36 to 39.)

FACILITIES DESIGN WORK NOT USED

Our review of the designs of certain major ANP facilities disclosed that costs totaling about $2,953,000 were incurred for design and related work that were never used. It appears that most of the costs totaling about $997,000 were unnecessary and could have been avoided if (1) timely action had been taken to cancel or to suspend certain projects at the time when the need for them appeared questionable and (2) certain designs for a project had been initiated only after appropriate studies and tests had been made. Also, costs of about $780,000 were incurred for designs, relating to a flight test base, that were not used because AEC reconsidered a previous decision and would not permit a flight test base to be built at the National Reactor Testing Station in Idaho. Most of the other designs costing about $1,176,000 were unused as a result of program reorientations. (See pp. 39 to 53.)

REORIENTATION OF ANP PROGRAM NOT FORMALIZED ON A TIMELY BASIS

We made a review of the documents supporting the implementation of the reorientation of the ANP program to an experimental development program at GE after cancellation of the Weapon System 125-A program in 1956. The reorientation was not fully formalized on a timely basis, in our opinion, since months of negotiations were required between the contractor, and the Air Force and AEC

before an agreement on the current work program could be reduced to writing. We believe that communication between the contractor and the Government should have been improved to expedite the formalization of the current work program after the reorientation. (See pp. 54 to 57.)

VARIOUS INDICATIONS THAT THE DEPARTMENT OF DEFENSE DID NOT FURNISH SUFFICIENT AND TIMELY GUIDANCE FOR ANP PROGRAM

Our review disclosed various instances where it appeared that the Department of Defense (DOD) did not furnish sufficient and timely guidance to those responsible for carrying out the ANP program. In one instance, AEC requested DOD for a decision vitally affecting AEC's participation in the national defense effort, but over 2 years elapsed before DOD reached a decision. In another instance, DOD did not provide guidance that AEC considered adequate until almost 8 months after AEC was first requested to reorient the ANP program. At the time of that reorientation, AEC stated that it would indeed be deplorable if, when AEC developed the next advanced reactor which could provide sustained nuclear flight, it would evolve that there was no requirement for this reactor. AEC stated also that it seemed only reasonable that, if AEC was to continue to support the DOD in the ANP program, specific DOD requirements must be provided in order that AEC could establish proper nuclear criteria and parameters. Also, a DOD review group stated in 1957 that there was a lack of firm decision and direction in the program and the Joint Committee on Atomic Energy stated in 1959 that the ANP program still had no firm set of objectives. (See pp. 58 to 65.)

BENEFITS OF UNIFIED ORGANIZATIONAL ARRANGEMENT NOT FULLY REALIZED

The benefits of the organizational arrangement for the ANP program were not fully realized, in our opinion, because the Air Force and AEC each awarded separate contracts to GE and P&W for work on the development of the propulsion system. To simplify the accounting, budgetary, and administrative aspects of the project; to eliminate the lack of uniformity in contractual provisions; and to expedite negotiations with the contractors, we believe that, in future projects of this nature, the feasibility of awarding a single contract to each contractor should be considered early in the program. Furthermore, we believe that, to strengthen congressional control, each agency should explore, with the congressional committee for both agencies, the desirability of having one of the agencies justify and subsequently fund the entire cost of joint-agency projects. We reached similar conclusions from our review of the Large Surface Ship Reactor, ALW land-based prototype project on which we reported to the Congress on January 10, 1962. (See pp. 66 to 74.)

FREQUENT PROGRAM REVIEWS BY TEMPORARY GROUPS AND DELAY IN ESTABLISHING PERMANENT GROUP

Our review disclosed that (1) frequent reviews of the ANP program were made by temporary groups, (2) the reviews by these groups were based on brief visits to the contractors' plants and briefings and discussions in Washington, and (3) little continuity in membership could be found among the review groups. Since these reviews were intended, generally, to evaluate results accomplished and to provide advice to top management on direction of effort, it appears that a permanent review group comprised of appropriate DOD and AEC representatives with some continuity in membership would have been more efficient and effective and would have been more in keeping with the joint project concept under which the ANP program was carried out. (See pp. 75 to 79.)

UNNECESSARY COSTS INCURRED BY AEC FOR CONTINUED PROCESSING OF YTTRIUM OXIDE

Our review disclosed that AEC incurred unnecessary costs of about $517,000 by extending for a 7-month period a contract for the processing of high-purity yttrium oxide in order to keep the production capability alive. Placing the production facility in a standby condition would have accomplished the same purpose, and the contractor was willing to negotiate to keep the plant in standby condition. (See pp. 80 to 83.)

DELAY IN AGREEING ON INDEMNITY PROVISION OF THE AEC CONTRACT WITH GE RESULTED IN A DELAY IN REACTOR DEVELOPMENT WORK

Our review disclosed that a delay in AEC's and GE's agreeing on an indemnity provision in the contract may have resulted in

delays in certain significant areas of reactor development and in the inefficient use of certain contractor personnel. There was a delay of about 18 months in initiating work on critical experiments because, although GE employees had been trained and were prepared to proceed on critical experiments in December 1952, the experiments were not started until about July 1954. We understand that such experiments were necessary and should have been carried out concurrently with the development of the reactor. (See pp. 83 to 86.)

UNECONOMICAL PROCUREMENT AND CONTRACTING PRACTICES IN THE CONSTRUCTION OF THE CONNECTICUT AIRCRAFT NUCLEAR ENGINE LABORATORY

Certain uneconomical procurement and contracting practices were employed by the Corps of Engineers, United States Army, to accelerate the construction of the Connecticut Aircraft Nuclear Engine Laboratory because the facilities were expected to be needed by the Air Force to meet the demands of a weapon system. The Corps of Engineers provided for large segments of the work by negotiating substantial contract modifications--without competition--with firms already under contract. We believe that the use of negotiated modifications or change orders to fixed-price construction contracts is a customary and economical method for providing for minor changes to existing plans and specifications. However, we do not believe that change orders are an appropriate or economical method for providing for major portions of construction work when the scope and cost of the modifications far exceed the scope and cost of the basic contract.

In one instance, work covered by large negotiated contract modifications was almost entirely subcontracted and in turn sub-subcontracted, resulting in a pyramiding of overhead and profit allowances totaling over $237,000 to the prime contractor and the subcontractor for work done principally by the sub-subcontractor. We believe that a substantial portion of such overhead and profit allowances were unnecessary and could have been avoided had the Corps of Engineers (1) obtained competitive proposals from firms able to provide the required construction services or (2) taken steps to eliminate use of the tiers involved in the successive subcontracting. (See pp. 87 to 95.)

AIR FORCE AND AEC DID NOT REQUIRE MEANINGFUL COST DATA FROM GE DURING 3-YEAR PERIOD

The formal monthly reports that the Air Force and AEC obtained from GE during fiscal years 1956, 1957, and 1958 did not contain meaningful detailed cost data because the costs could not be related to the various experimental projects being carried out by GE. As a result, an effective monthly evaluation could not be made from the formal reports of the costs incurred by GE for major projects. Furthermore, during this period AEC's actual costs could not be related to the estimated costs because they were not reported on a comparable basis. Although the projects were reviewed in detail every 6 months under AEC's normal procedures, we believe that more meaningful detail cost data should have been required from GE in the formal monthly reports during fiscal years 1956, 1957, and 1958. During fiscal years 1959 and 1960, action was taken to correct these deficiencies. (See pp. 96 to 98.)

OTHER DEFICIENCIES NOTED DURING OUR REVIEW OF GE AND P&W

Our review of the activities of GE disclosed certain inefficiencies in property management and a need for improvement in the internal audits performed by the Air Force and AEC. Our review showed also that unallowable costs were charged to the AEC and Air Force contracts. (See pp. 98 to 102.)

Our review of the activities of P&W disclosed that the financial and quantity controls over materials and supplies inventories were generally weak. Our review showed also a lack of formal accounting records to support the financial reports prepared by P&W. (See pp. 103 to 106.)

Similar deficiencies had been found and commented on in AEC internal audit reports; however, corrective action had not been taken at the time of our review. During our review we discussed the deficiencies with appropriate AEC, Air Force, and contractor officials. They generally agreed with our findings. After our discussions with these officials, we noted that many of the deficiencies were being corrected or plans had been made to take corrective action.

BACKGROUND INFORMATION

GENERAL

The basic reason for pursuing the ANP program was to provide a new approach to the propulsion of manned aircraft by the use of nuclear fission as the power source, thereby overcoming the range and endurance limitations of chemically powered aircraft. The ultimate objective of the ANP program appeared to be the development of a militarily useful aircraft that could be used for reconnaissance and strategic purposes.

The manned nuclear-powered airplane program and the Air Force ballistic missile program started about the same time (1946), and both programs proceeded during a time when great advancements were being made in the improvement of chemically powered aircraft. As a consequence, the importance attached to the ANP program for future national defense varied greatly, with the result that frequent changes in emphasis and direction of the program occurred.

The major components of a nuclear-powered airplane are the propulsion system[1] and the airframe. Five major contractors worked in the ANP program. The major contractors for the propulsion system were the Aircraft Nuclear Propulsion Department of the General Electric Company (GE), Evendale, Ohio, and the Pratt & Whitney

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[1]A propulsion system is referred to as a power plant before the unit is geared to a specific airplane. A power plant is an unrefined propulsion system containing the same major components but may not contain certain auxiliary parts, such as controls and instrumentation. A power plant is assembled for test purposes only.

Aircraft Division of the United Aircraft Corporation (P&W), Middletown, Connecticut. The major contractors for the airframe were the Convair Division of General Dynamics Corporation, Fort Worth, Texas, and the Georgia Division of Lockheed Aircraft Corporation, Dawsonville, Georgia. The Union Carbide Nuclear Company, operator of the Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, was the major contractor in the general support area for the ANP program.

AEC financed the nuclear portion of the propulsion system, consisting of the reactor and the related shielding; the Air Force financed the nonnuclear portion of the propulsion system, consisting of the turbomachinery and other components. The Air Force financed also the work relating to the airframe. The Navy was a minor participant in the ANP program, financing various studies with GE, P&W, and other airframe contractors. Following is a summary of the total costs incurred on the ANP program to June 30, 1961.

	Total	Air Force	AEC	Navy
		(in millions)		
Operating costs:				
Propulsion system:				
Direct cycle	$ 468.0	$219.7	$246.7	$ 1.6
Indirect cycle	209.1	35.9	171.4	1.8
Total	677.1	255.6	418.1	3.4
Airframe	102.1	96.4	-	5.7
General support	60.4	29.8	25.7	4.9
Total	839.6	381.8	443.8	14.0
Facilities and equipment:				
Propulsion system:				
Direct cycle	94.8	42.4	52.4	-
Indirect cycle	71.3	62.6	8.7	-
Total	166.1	105.0	61.1	-
Airframe	20.9	20.9	-	-
General support	13.2	11.0	2.2	-
Total	200.2	136.9	63.8	-
Total costs	$1,040.1	$518.7	$507.6	$14.0
Summary:				
Propulsion system	$ 843.2	$360.6	$479.2	$ 3.4
Airframe	123.0	117.3	-	5.7
General support	74.1	40.8	28.4	4.9
Total costs	$1,040.1	$518.7	$507.6	$14.0

FEASIBILITY STUDIES

Work relating to a manned nuclear-propelled airplane was initiated in May 1946, when the Air Force awarded letter contract W-33-038ac-14801 (16250) to the Fairchild Engine and Airplane Corporation (Fairchild). The letter contract was converted into a definitive contract in May 1948. The contract provided for a feasibility investigation and research leading toward the adoption of nuclear energy as a means of propelling aircraft of tactical utility. The work under this contract was known as the Nuclear Energy for the Propulsion of Aircraft (NEPA) project.

The Air Force did not make the actual selection of Fairchild to conduct the NEPA project. During the months immediately following the end of World War II, the Air Force decided to sponsor a single unified project in the aircraft nuclear propulsion field, under the management of one industrial company with which all the companies in the recognized aircraft engine industry would be invited to participate in the project. At the request of the Air Force, a group of interested aircraft engine companies selected Fairchild to be the manager of the project and the recipient of an Air Force contract. Ten other companies participated as member companies in the NEPA project by assigning personnel and by participating as subcontractors.

In November 1950, AEC awarded to Fairchild a letter contract providing for work relating to the nuclear aspects of the NEPA project. Soon thereafter AEC and the Air Force decided to terminate the NEPA project. For several months work had been done under

the AEC letter contract; however, arrangements were made whereby the Air Force reimbursed Fairchild for AEC costs. The Air Force contract with Fairchild was terminated in April 1951.

AEC had initiated work at the Oak Ridge National Laboratory, Oak Ridge, Tennessee, in the fall of 1949 in support of the Air Force work under the NEPA project. The ANP work at the laboratory was done under AEC contract W-7405-ENG-26 with the Union Carbide Nuclear Company for the operation of the Laboratory.

Aircraft Division of the United Aircraft Corporation (P&W), Middletown, Connecticut. The major contractors for the airframe were the Convair Division of General Dynamics Corporation, Fort Worth, Texas, and the Georgia Division of Lockheed Aircraft Corporation, Dawsonville, Georgia. The Union Carbide Nuclear Company, operator of the Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, was the major contractor in the general support area for the ANP program.

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	Total	Air Force	AEC	Navy
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Total	839.6	381.8	443.8	14.0
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Propulsion system:				
Direct cycle	94.8	42.4	52.4	-
Indirect cycle	71.3	62.6	8.7	-
Total	166.1	105.0	61.1	-
Airframe	20.9	20.9	-	-
General support	13.7	11.0	2.7	-
Total	200.7	136.9	63.8	-
Total costs	$1,040.3	$518.7	$507.6	$14.0
Summary:				
Propulsion system	$ 943.2	$360.6	$479.2	$ 3.4
Airframe	123.0	117.3	-	5.7
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Total costs	$1,040.3	$518.7	$507.6	$14.0

PROPULSION SYSTEM

There were two major approaches for developing an aircraft nuclear propulsion system, the direct cycle of GE and the indirect cycle of P&W. In the direct cycle, air enters through the compressor, is forced into the reactor, and is heated by the fuel elements. After passing through the turbine, where energy is extracted to drive the compressor, the heated air is expelled at high velocity through the exhaust nozzle. In the indirect cycle, the heat generated in the reactor is absorbed by a liquid-metal coolant flowing through the reactor core. The liquid-metal coolant then flows through an intermediate heat exchanger where the heat is transferred to a secondary loop. The hot liquid-metal is then pumped to the jet engine. The jet engine contains radiators, where the heat is given up by the liquid-metal and imparted to the airstream flowing through the engine. Thus, the air is heated directly by the reactor in the direct cycle as contrasted with being heated indirectly by the reactor in the indirect cycle. (See appendixes III and IV.)

Direct cycle propulsion system

The research and development activities for the direct cycle propulsion system were carried out by the Aircraft Nuclear Propulsion Department (ANPD) of GE in Evendale, Ohio. Work on the engines was done under an intercompany arrangement with the GE owned and operated Flight Propulsion Division, also at Evendale. The research and development effort at Evendale was supported by testing

activities at the Idaho Test Station, an AEC facility operated by GE-ANPD within the AEC National Reactor Testing Station (NRTS) in Idaho.

The Air Force awarded CPFF letter contract AF 33(038)-21102 to GE in March 1951, for certain work relating to a nuclear propulsion system which was not specifically a part of the nuclear reactor. The letter contract was superseded by a definitive contract in May 1954. The definitive contract remained in effect until October 1958 when the Air Force awarded GE another definitive contract, AF 33(600)-38062, which remained in effect until the termination of the ANP program.

Negotiations between AEC and GE leading toward a definitive contract for the reactor portion of the propulsion system began in March 1951. However, as the negotiations continued it became apparent to AEC that, if development work on the propulsion system was not to be seriously delayed, AEC would have to finance the reactor portion of the propulsion system by a letter contract until agreement could be reached on a definitive contract. In June 1951, AEC awarded CPFF letter contract AT(11-1)-171 to GE, and the contract was converted into a definitive contract in July 1954. The definitive contract was extended at various times until the termination of the ANP program in March 1961.

During a conference concerning the NEPA project in February 1951, AEC and the Air Force agreed that GE would take over the NEPA project. Although available documents did not contain the Air Force's justification for the selection of GE, we noted that the

AEC based its decision to select GE on the recommendations of an Ad Hoc Committee on the ANP program, which consisted of representatives of the Air Force, AEC, Navy, and the National Advisory Committee for Aeronautics. The committee considered four strong aircraft engine development companies. The committee stated that it believed that, to obtain a successful and useful nuclear propulsion system, the development and construction of both reactor and engine had to be undertaken by an aircraft engine company familiar with the propulsion requirements of aircraft. The committee stated further that GE had experience in both types of work as a result of other Air Force contracts for engines and other AEC contracts for reactors, and GE's J-53 engine development program sponsored by the Air Force was considered by the committee as providing the engine most readily adaptable to a nuclear propulsion system.

Indirect cycle propulsion system

Between 1951 and 1957, the research and development activities for the indirect cycle propulsion system were carried out by P&W at several locations in Connecticut. In 1957, P&W moved the ANP activities to the newly constructed Connecticut Aircraft Nuclear Engine Laboratory (CANEL) near Middletown, Connecticut. Between 1954 and 1957, P&W assigned personnel to work directly with the Oak Ridge National Laboratory on an indirect cycle propulsion system.

In May 1951, the Air Force initiated work on an indirect cycle propulsion system by awarding CPFF contract AF 33(038)-27341 to P&W. The letter contract was converted into a definitive contract in December 1951 and continued in effect until it was terminated in

October 1957. P&W did no further research and development work on the ANP program for the Air Force until it was awarded CPFF definitive contract AF 33(600)-40548 in December 1959, and this contract was in effect at the termination of the ANP program.

At the time that the Air Force initiated work at P&W, the Air Force and P&W recognized that AEC support would be necessary and agreed that at the proper time P&W would request a collateral contract from AEC. P&W requested AEC's support in February 1952, but AEC and P&W did not agree on a contract until May 1953 when definitive CPFF contract AT(11-1)-229 was awarded.

P&W was selected as the contractor for the indirect cycle propulsion system because the Air Force wanted to evaluate a propulsion system based on a supercritical water reactor, and P&W had done studies on this type of system as a subcontractor under the NEPA project. When P&W requested AEC to support the indirect cycle work, AEC recognized that efficient and economical prosecution of the difficult type of nuclear propulsion program contemplated could be best achieved by assigning responsibility for all portions of the power plant to one contractor. In addition, AEC considered P&W's previous experience in the NEPA project and regarded P&W as one of the outstanding aircraft engine manufacturers in the business. In December 1959, when awarding P&W the final contract for the ANP program, the Air Force considered only P&W because it was the only contractor which had the capability and the proper facilities for performing the necessary research and development work.

AIRFRAMES

In conjunction with the development of the propulsion system, a parallel effort was developed within the ANP program for design and construction of the related airframe. The two major airframe contractors in the ANP program were Convair and Lockheed. Convair's airframe design activities were carried out at the Fort Worth, Texas, plant. Radiation effects were investigated at the Nuclear Aircraft Research Facility (NARF), one portion of the Texas plant. Lockheed's activities on airframe design were carried out at the Lockheed-Georgia Company facility located at Marietta, Georgia. Radiation effects work was planned for the Georgia Nuclear Laboratory (GNL) near Dawsonville, Georgia. The work of these contractors consisted primarily of (1) airframe design studies and support and guidance to the propulsion system contractors and (2) construction and operation of a radiation effects laboratory at each contractor's plant for the test of aircraft systems and subsystems. At the termination of the ANP program in March 1961, however, Lockheed was on a standby basis, while Convair's activities were being carried out to the extent necessary to support both the direct and indirect cycle propulsion systems.

Studies leading toward the development of an airframe were carried out by several aircraft manufacturers doing work on the NEPA project; however, since the primary purpose of the NEPA project was to work on power plant problems, no attempts were made on detailed airframe designs.

The Air Force awarded Convair (then Consolidated Vultee Aircraft Corporation) CPFF letter contract AF 33(038)-21117 in February 1951. The letter contract was converted into a definitive contract in September 1952. The definitive contract provided for work in connection with the GE program covering the construction of three B-36 type of test airplanes. It provided also for construction, operation, and testing of low-power reactors with suitable shields; analysis of flight base requirements; and propulsion and research studies. Convair, as a subcontractor under the NEPA project, had previously made preliminary studies on the B-36 airplane.

The Air Force awarded Lockheed CPFF letter contract AF 33(038)-21118 in February 1951. The letter contract was converted into a definitive contract in August 1951. The contract provided for an investigation of the tactical feasibility of high-speed, low-altitude, bombardment type of aircraft; an investigation of the problem of navigation, pay load delivery, and flight techniques of low altitude; and design of a series of airframes, utilizing a nuclear propulsion system. Lockheed had previously done studies on nuclear aircraft designs under the NEPA project.

In April 1955 the Air Force awarded fixed-price redeterminable contracts for studies and investigations for a nuclear-powered strategic bombardment weapon system--AF 33(600)-30292 to Convair, Af 33-(600)-30293 to Lockheed, and AF 33-(600)-30291 to Boeing Airplane Company. These studies and investigations were to be considered as part of a design competition leading to the award of development

contracts for the Weapon System 125-A program. An Aircraft Nuclear Propulsion Office official stated that, prior to the award of these contracts, the Air Force solicited proposals from six aircraft companies for such studies but that three of the six companies did not wish to participate. Boeing was subsequently eliminated from participation in the ANP program because it was chosen as the contractor for the Weapon System 110-A (chemical bomber) program.

The Air Force awarded CPFF letter contracts in December 1955--AF 33(600)-32054 to Convair and AF 33(600)-32055 to Lockheed. These contracts were essentially a continuation of the contracts AF 33(038)-21117 and AF 33(038)-21118 and provided for a pairing of the airframe contractors with the propulsion system contractors--Convair and GE were paired, and Lockheed and P&W were paired. The letter contracts were converted into definitive contracts, Convair's in April 1956 and Lockheed's in May 1957, and provided for work on weapon system consisting of aircraft designed for nuclear cruise, with chemical fuel augmentation permitted for penetration zone performance. Convair was to continue to utilize the GE nuclear propulsion system, while Lockheed was to continue to utilize the P&W nuclear propulsion system. Convair was also to review the application of the P&W nuclear propulsion system at a reduced level of effort sufficient only to maintain cognizance of that program. Lockheed was to make similar reviews on the GE nuclear propulsion system.

In August 1958 the Air Force awarded contract AF 33(600)-38003 to Convair and contract AF 33(600)-38004 to Lockheed for proposals for a development program for two aircraft utilizing the direct

cycle propulsion system. The development aircraft were to be prototype vehicles of the proposed Continuously Airborne Missile-Launcher and Low-Level Weapon System (CAMAL) requirement. (See p. 155.) These proposals, constituting a design competition, were to be considered in the selection of one contractor to undertake the development of the two aircraft. Both contracts were converted into fixed-price definitive contracts in September 1958.

In March 1959 Convair was selected as winner of the design competition and was awarded CPFF contract AF 33(600)-38946 effective March 30, 1959, the contract in effect at the termination of the ANP program. The Air Force did not approve the two airplane development programs; however, Convair was authorized under contract AF 33(600)-38946 to work with GE on an initial design of a nuclear-powered bomber prototype. Subsequently, in October 1959, Convair was authorized to prepare a preliminary design of two subsonic development aircraft capable of flight testing various nuclear power plants of either the direct or indirect cycle. The aircraft planned was to have the general characteristics of Convair Model 54 which was associated with the proposed CAMAL program. In October 1960 Convair was authorized to work on the NX-2, an airplane similar to the Convair Model 54. The objective of the NX-2 program was to design an airplane which would be able to demonstrate the capabilities of a nuclear-propelled system which could be applicable to mission employment. The NX-2 airplane design was to be compatible with either the direct or indirect cycle nuclear power plant.

The Air Force awarded Lockheed CPFF contract AF 33(600)-38947 in March 1959, as a follow-on contract to contract AF 33(600)-32055 awarded in 1955. Lockheed was to continue limited design work and to continue to operate the Georgia Nuclear Laboratory for radiation effects experiments in support of the over-all ANP program. In April 1960 the Air Force initiated action to place the laboratory on a standby basis. The Air Force awarded contract AF 33(600)-42486 to Lockheed in December 1960, essentially placing the contractor on a standby basis. This contract was in effect at the termination of the ANP program in March 1961.

GENERAL SUPPORT WORK

Numerous contractors and subcontractors were engaged in general support work for the ANP program.

The major organization doing work in the general support area was the Oak Ridge National Laboratory (ORNL) operated for AEC by the Union Carbide Nuclear Company. The major fields of effort at ORNL were in shielding, materials research and development, and investigations of components of reactors and of other parts of systems designed for the nuclear propulsion of aircraft.

ORGANIZATION AND MANAGEMENT

The organization and management structure of the ANP program evolved through various phases after the program started. An Ad Hoc Steering Committee for NEPA was established early in 1949 to provide program guidance to the work being done in the aircraft nuclear propulsion field. The committee was made up of representatives from the Air Force, Navy, AEC, and the National Advisory Committee for Aeronautics. In March 1950, AEC reorganized the Division of Reactor Development to include the Aircraft Reactors Branch to formulate and administer programs and policies for AEC's activities in the aircraft nuclear propulsion field. The Chief of the Branch also served as Executive Secretary to the Ad Hoc Steering Committee.

During mid-1952, AEC and the Air Force agreed to center the management of their respective activities in the ANP program under a single individual. This agreement culminated during the latter part of 1952 in the assignment of an Air Force officer as Chief of

AEC's Aircraft Reactors Branch and the establishment of an Office of Aircraft Nuclear Propulsion within the Air Force. The officer was assigned to head both organizations and was also designated within the Air Force as the Assistant for Aircraft Nuclear Propulsion to: (a) the Commanding General, Air Research and Development Command (ARDC) and (b) the Director of Research and Development, Deputy Chief of Staff, Development, Headquarters, United States Air Force. With the establishment of the Office of Aircraft Nuclear Propulsion, the Ad Hoc Steering Committee was phased out.

The separate AEC and Air Force organizations, with the same person in charge of both, continued until early in 1957 when action was initiated to realign the management structure of the ANP program to provide for a unified project office. In March 1957, a new position, Assistant Deputy Chief of Staff, Development for Nuclear Systems, was established. The individual who was assigned to this position continued as Chief of AEC's Aircraft Reactors Branch (later designated Assistant Director for Aircraft Reactors) and in November 1957 the joint project office, known as the Aircraft Nuclear Propulsion Office (ANPO), was established.

From November 1957 until the termination of the ANP program, the executive management of the ANP program was centered in the Aircraft Nuclear Propulsion Office at AEC Headquarters in Germantown, Maryland. ANPO was an integrated Air Force-AEC office, and the person in charge of this office had dual positions. For the AEC, he served in the capacity of the Assistant Director for Aircraft Reactors, Division of Reactor Development. His Air Force

position was the Assistant Deputy Chief of Staff for Nuclear Systems. (See appendix II.) The organizational structure of ANPO was established as an integrated office in order that, once policy and program direction were decided at DOD and AEC levels, executive management could be conducted from one office under the control and supervision of one person.

ANPO not only was responsible for the manned ANP program (the subject of this report), but also had responsibilities within the unmanned ANP programs, comprising the nuclear propulsion of rockets (Project Rover[1]) and ramjets (Project Pluto) and the development of systems for nuclear auxiliary power (Project Snap). ANPO Headquarters was organized into five branches, three of which furnished general support to both the manned and unmanned ANP programs. The Aircraft Projects Branch was responsible for formulating current programs; proposing projected programs; and providing technical and executive supervision, assessment, and direction of approved programs of the integrated AEC-DOD manned ANP program. The Missiles Project Branch carried out similar responsibilities for the unmanned ANP program.

Technical management of the propulsion systems flowed from ANPO to AEC's Lockland Aircraft Reactors Operations (LAROO), located near GE, Evendale, Ohio. LAROO was a field extension of ANPO and was assigned both AEC and Air Force responsibilities. LAROO

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[1]Removed from the cognizance of ANPO in August 1960 when a joint AEC-NASA (National Aeronautics and Space Administration) Nuclear Propulsion Office was established to carry on the Rover project.

established an office at P&W (Hartford Aircraft Reactors Area Office) and a division (Idaho Test Division) at the AEC National Reactor Testing Station (NRTS) where GE's testing activities were carried out.

Technical management for the airframe flowed from the Air Force Air Research and Development Command, Andrews Air Force Base, Washington, D.C., to the Wright Air Development Division (WADD) of ARDC at Wright-Patterson Air Force Base, Dayton, Ohio, to the WADD representatives at Lockheed and Convair. ANPO, however, provided ARDC with top-level guidance and policy on the ANP program.

Contracting for the ANP program followed separate agency routes. The AEC contracting was done by LAROO, and the Air Force contracting was done by the Air Materiel Command (AMC) of the Air Force. ANPO was responsible for the executive management and technical direction of AMC's contracting relating to the propulsion system, while ARDC had similar responsibilities for AMC's contracting relating to the airframe.

The following table shows, as of December 31, 1960, the total number of Air Force, AEC, and Navy employees of ANPO, excluding 60 secretaries, clerks, and other employees in similar positions.

	Head of Unit	Total	Number of employees					
			Air Force		AEC		Navy	
			Technical	Administrative	Technical	Administrative	Technical	Administrative
AEC Headquarters:								
Manned and unmanned ANP programs:								
Office of the Chief	Air Force	4	3	-	-	-	1	-
Plans and Requirements Branch	Air Force	6	6	-	-	-	-	-
Research and Analysis Branch	Air Force	2	2	-	-	-	-	-
Program Services Branch	AEC	8	-	6	-	2	-	-
Manned ANP program:								
Aircraft Projects Branch	Air Force	15	14	-	-	-	1	-
Unmanned ANP programs:								
Missiles Project Branch	Air Force	11	6	-	1	-	4	-
Total, Headquarters		46	31	6	1	2	6	-
Field:								
Manned ANP program:								
Lockland Aircraft Reactors Operations Office	AEC	4	-	-	1	3	-	-
Assistant Manager for Technical Programs	Air Force	3	2	-	1	-	-	-
Health and Safety Division	Navy	4	-	-	3	-	1	-
Engineering Division	AEC	11	6	-	5	-	-	-
Assistant Manager for Test Operations (Idaho Test Division)	Air Force	4	1	-	1	2	-	-
Test Division	Air Force	5	5	-	-	-	-	-
ANP Facilities Division	AEC	2	-	-	1	-	1	-
Hartford Aircraft Reactors Area Office	AEC	2	-	-	1	1	-	-
Technical Branch	Air Force	7	3	-	3	-	1	-
Administrative Branch	AEC	3	-	-	-	3	-	-
Assistant Manager for Administration	AEC	27	-	-	-	27	-	-
Total, Field		72	17	-	16	36	3	-
Total, Headquarters and Field		118	48	6	17	38	9	-

OBSERVATIONS AND FINDINGS

CHANGES IN EMPHASIS AND DIRECTION OF THE ANP PROGRAM

The ANP program was characterized by frequent changes in emphasis and objectives, varying from a research and development program to an accelerated program to develop a weapon system for the Air Force.

The ANP program was carried out in competition with other programs for national defense. As a result, the importance attached to the ANP program varied greatly throughout its history. Although it was outside our scope to examine into the reasonableness of or justification for the frequent changes in program objectives, we do not believe that a research and development effort of the complexity and magnitude of the ANP program can reach its goal in an effective and efficient manner unless a certain degree of stability in objectives is accorded to the program.

Following is a summary of the major changes in program emphasis and direction.

Program emphasis	Period		Length of time (months)
	From	To	
Flight demonstration program	April 1952	May 1953	13
Applied research and development	May 1953	November 1954	18
Weapon System 125-A program	November 1954	December 1956	25
Experimental development program--no flight objectives	January 1957	March 1957	2
Experimental development program--flight objectives	April 1957	February 1958	10
Development program--flight objective in militarily useful aircraft	March 1958	October 1958	7
Development program for CAMAL mission	October 1958	July 1959	9
Research and development program leading to major reactor experiments	July 1959	ANP termination--March 1961	20

The significant events that occurred during the various periods listed above are discussed in the history of the Manned Aircraft Nuclear Propulsion System. (See appendix I.)

The dates used to identify the various periods listed in the table were the approximate dates when decisions were reached to reorient the program. We noted, however, that program reorientations were not accomplished on a specific date and that many months of consideration and planning were required between the time of initial consideration of a program change and the date that the reoriented program became fully operative at the contractor level. (See pp. 54 to 57.) Furthermore, it appears that the changeover of the contractor's operations was not an immediate transition but rather a gradual phasing out of the old and phasing in of the new operation. Therefore, the length of time actually attributable to a specific program objective could vary from that shown in the table above.

Pertinent comments by responsible AEC and DOD officials evaluating the frequent changes in emphasis and direction of the ANP program throughout its history are quoted below.

In a July 1959 letter to the Secretary of Defense, the Chairman of AEC stated, in part, that:

> "The history of the ANP Program over the past decade has been marked by program reorientations and changes in program objectives which have consistently extended the date when a prototype power plant could be first flown or otherwise demonstrated. In spite of the cyclic nature of these program reorientations, consistent progress has been made on the nuclear elements of the power plant. In

this regard, we had planned a development program which, in our best judgment, provided a logical, sequential development effort oriented to take maximum advantage of technological advancements as they appeared.

"During this entire period, the Commission has utilized its General Advisory Committee to assess technological progress and provide their best judgement as to the timeliness and nuclear capabilities of proceeding toward nuclear flight. In the GAC's most recent review, as reported on 5 May 1959, it was their considered judgement that we had reached a state of reactor technology where a direct cycle nuclear propulsion system (XMA-1A) could be built to fly an experimental aircraft. They further concluded that reactor materials technology in both fuel elements and moderators had reached a state of development where they could subsequently be intergrated in the basic propulsion system and provide for increased aircraft performance and growth potential."

In July 1959, the Director, Defense Research and Engineering (DDR&E) stated, in part, that:

"It is our view that during most of the past 13 years and the expenditure of most of the $900 million, the ANP program has been characterized by attempts to find short cuts to early flight and by brute force and expensive approaches to the problem. Thus we find that only a relatively very small fraction of the funds and energies applied to this program has gone into trying to develop a reactor with a potentially high performance. Most of the resources have been applied to attempts to develop materials which could 'fly soonest'; to develop turbine machinery; to build facilities, many of which would only be needed in support of a flight program; to conduct experiments on the radiation resistance of tires, oils, insulation, electronic components, etc; and to develop new components for use in the unique environment which would be encountered only in the divided-shield situation as found in CAMAL and the old WS-125A. As a result of this approach to the problem we are still at least four years away from achieving flight with a reactor-engine combination *** which can just barely fly."

The competitive position of ANP for priority within the national defense program was aptly summarized in a report[1] of the Joint Committee on Atomic Energy, as follows:

> "It is to be noted that the period since 1946 has been one of major transition in the Nation's military requirements. The period also has been one of swift technological change, characterized by the emergence of ballistic missile systems capable of both strategic and tactical employment. These considerations have imposed upon military planners the difficult and fluctuating burden of allocating available funds between costly commitments for wide range military power in being able to meet the crises of the day and research and development programs to meet the crises of the future. Accordingly, the ANP program has, from time to time, shifted position in the competition for priority."

We do not believe that the effects that frequent changes in program emphasis had on the ANP program are subject to a precise determination. We noted, however, that because of program reorientations little or no use was made of certain facilities (see pp. 36 to 39) and certain facilities design work (see pp. 39 to 53).

By memorandum dated September 12, 1962, the Deputy for Development, Research and Development, Air Force, in commenting on this observation, stated:

> "The observations that a large complex program cannot achieve its goal in an effective and efficient manner unless a certain degree of stability in objectives is maintained is unassailable. The problem with ANP was that the ultimate goal shifted in response to a balancing of periodic estimates of achievable technology against evaluations of Air Force operational requirements. As a consequence, the timing of ground test and flight test

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[1]Report of the Joint Committee on Atomic Energy, entitled "Aircraft Nuclear Propulsion Program," 86th Congress, 1st session, Joint Committee Print, dated September 1959.

objectives also shifted. Obviously, such changes in emphasis and direction of the ANP program were considered appropriate and mandatory by the program management."

By letter dated October 3, 1962, the Deputy Secretary of Defense, in commenting on this observation, stated:

"We agree that the program suffered considerably from lack of prompt decisions and from frequent changes in emphasis and goals. It is for the purpose of minimizing the impact of such conditions in the future that we have instituted many new management procedures in the Department of Defense."

LITTLE OR NO USE MADE OF CERTAIN FACILITIES BECAUSE OF PROGRAM REORIENTATIONS

During our review we noted that various major facilities had been constructed but were never used, or used very little, for their intended purposes because of program reorientations. These facilities, costing about $17,147,000, are listed below.

Location and facility	Cost
National Reactor Testing Station, Idaho:	
Flight Engine Test Facility	$ 8,061,000
Connecticut Aircraft Nuclear Engine Laboratory, Middletown, Connecticut:	
Radiator Laboratory	6,306,000
Air Laboratory	1,428,000
Georgia Nuclear Laboratory, Dawsonville, Georgia:	
Shield Development Reactor	952,000
Roads and bridges	400,000
Total cost	$17,147,000

The Flight Engine Test (FET) facility was constructed at the AEC National Reactor Testing Station, Idaho, at a cost of about $8,061,000 to AEC. The FET facility was to be used for testing a nuclear power plant, both on the ground and in a prototype or flight test-bed aircraft, and was to provide auxiliary and emergency flight operations facilities. Construction started in September 1957 and was essentially completed by July 1959. The facility includes a hangar-type building, a control and equipment building, and supporting utilities. As of October 1962, the FET facility had not been used, except incidentally for storage. AEC officials advised us that the FET facility had been assigned for use in the SNAP-50 program to house the Lithium-Cooled Reactor Experiment

and supporting equipment and facilities and that work to modify the FET facility would start about December 1962.

The Radiator Laboratory was constructed at the Connecticut Aircraft Nuclear Laboratory (CANEL), Middletown, Connecticut, at a cost of about $6,306,000 to the Air Force. Construction was initiated about January 1957. This facility was completed as a shell only and was not finished because of the Air Force termination of its research and development work in August 1957. The Radiator Laboratory was designed to test full-scale liquid-metal-to-air radiators under a large range of simulated flight conditions. A small part of the laboratory was used for extraneous testing under the ANP program. As of October 1962, the Radiator Laboratory was not being used. AEC advised us that a liquid metal loop corrosion test was completed in August 1962 in the Laboratory and that since then no further use had been made of the facility. No definite plans had been made for the future use of the Laboratory.

An Air Laboratory was constructed at CANEL at a cost of about $1,428,000 to the Air Force. Construction started in July 1956 and was completed in October 1958. The facility was used on a limited basis in December 1960. The first extended use of the facility began in March 1961, the same month the ANP program was terminated. As of October 1962, the Air Laboratory was not being used. P&W advised us that it intended to use this facility for running vacuum tests under the SNAP-50 program and that certain modifications would be necessary.

Lockheed issued a purchase order in November 1956 for a Shie Development Reactor (SDR) for use at the Georgia Nuclear Laborato (GNL), Dawsonville, Georgia. When the activities at GNL were cut back in January 1957, work on the SDR continued, except for work c external components that was canceled in March 1957. Work on the remaining SDR parts was essentially completed. The total cost of the reactor to the Air Force was about $952,000. As of October 1962, the SDR had not been used as a unit. Although it had been used as a source of spare parts for another reactor, such use appeared to be inconsequential.

Prior to the cutback of activities at GNL in January 1957, a shield development facility was planned for construction at a location isolated from the other facilities. When the cutback occurred, construction of the shield development facility had not started and was canceled, but two bridges and a road (5.9 miles) leading to the facility were under construction. When the facility was canceled, the bridges and roads were abandoned, except for forest fire protection and ground inspection. The unfinished road and bridges cost the Air Force about $400,000. As of October 1962, no further use had been made of the road and bridges.

Because of program reorientations and ultimate program termination, costs of about $17,147,000 were incurred for the construction of various facilities for which no productive return has been realized to date.

By memorandum dated September 12, 1962, the Deputy for Development, Reasearch & Development Air Force, in commenting on this observation, stated:

"The GAO report discusses in great detail the construction of various facilities which, due to program reorientations and ultimately to program termination, remain largely unused today. We concur in the conclusion that the construction of these facilities represents an expenditure of Government funds from which no productive return has been realized to date. It should be noted, however, that these facilities were deemed essential to the success of the ANP program at a time when the success of the ANP program was deemed essential to the national defense. In spite of numerous program reorientations, the facilities remained an essential part of the ANP program. They became temporarily useless only when the program itself was terminated. The report contains no criticism of Air Force action with respect to their construction, and we therefore, assume that the GAO discussion intends no such criticism."

FACILITIES DESIGN WORK NOT USED

Our review of the designs of certain major ANP facilities disclosed that costs totaling about $2,953,000 were incurred for design and related work that were never used. A summary of the unused work follows:

Location and facility		Cost
National Reactor Testing Station, Idaho:		
Ground test facilities:		
Indirect cycle propulsion system	$885,000	
Initial Engine Test filter system	40,000	
Flight Engine Test exhaust system	72,000	$ 997,000
Others		889,000
Flight test facilities:		
Flight test base		780,000
Georgia Nuclear Laboratory, Dawsonville, Georgia		287,000
Total costs for unused designs		$2,953,000

It appears that most of those costs totaling about $997,000 were unnecessary and could have been avoided if (1) timely action had been taken by AEC to cancel or to suspend certain projects at the time when the need for them appeared questionable and

(2) certain designs for a project had been initiated after appropriate studies and tests had been made.

Most of the designs relating to the ground test facilities--others ($889,000), and the designs on the Georgia Nuclear Laboratory ($287,000) were unused as a result, primarily, of program reorientations. Costs of about $780,000 were incurred also for flight test base designs that were not used because AEC reconsidered a previous decision and would not permit a flight test base to be built at the National Reactor Testing Station.

Timely action not taken to cancel or suspend certain projects at the time when the need for them appeared questionable

AEC did not take timely action to cancel or to suspend certain design and related work at a time when a need for the facilities appeared questionable. The unused designs related to the ground test facilities for the indirect cycle propulsion system ($885,000) and the Initial Engine Test facility filter system ($40,000).

Ground test facilities for indirect cycle propulsion system

The design and related work for the ground test facilities for the indirect cycle propulsion system were continued during a time when the need for the facilities appeared questionable because significant changes were being made in the work on the indirect cycle propulsion system, technical progress did not appear encouraging, and the future course of the ANP program had not been defined. We believe that prompt termination or suspension of work at the time the Weapon System 125-A program (see p. 140) was canceled could have avoided most of the $885,000 costs incurred for unused designs and related work.

The Weapon System 125-A program was canceled in December 1956. During the time that design and related work continued (January to July 1957) the future course of the entire ANP program had not been defined. Long-term objectives for the program were lacking. (The importance of long-term objectives was recognized by a subcommittee of the Joint Committee on Atomic Energy in February 1957.) (See p. 143.)

Three DOD ad hoc groups reviewed the program early in 1957, and by June 1957 all had concluded that significant changes should be made in the program direction. One of the groups stated that its investigation had shown lack of firm decision and direction in the program and that the technical problems involved were of such magnitude that it appeared most unwise to plan on the availability of a supersonic strategic system by any specific date.

The ground test facilities for the indirect cycle propulsion system were to include reactor power test, power plant test, technical, and administrative and service facilities. During October 1956, P&W awarded a purchase order for the development of specifications and procedures for equipment to be used in the facilities. In November 1956, AEC awarded a contract for the architect-engineering services and P&W awarded a contract for engineering studies on the reactor power test and power plant test facilities. Preliminary design work on the reactor power test, technical, and administrative and service facilities was started in November 1956. Although AEC in January 1957 canceled the part of the architect-engineering contract covering the definitive design work and the supervision and inspection of construction, the preliminary design work underway at that time was continued and completed by July 1957. Also, preliminary design of the power plant test facility was started in May 1957 and terminated in July 1957. The purchase order relating to equipment was not terminated until July 1957, and the engineering studies were completed in April 1957. The cost of the design and related work for the ground test facilities for the indirect cycle propulsion system was about $885,000.

In addition, the future course of the entire ANP program had not been defined, significant changes were made in the work at P&W, and technical progress did not appear encouraging. P&W experienced serious technical difficulties with the single reactor concept, and in mid-1956 terminated the work and shifted to the twin reactor concept. During the latter part of 1956, the twin reactor concept proved unsatisfactory and work on that concept was terminated in the beginning of 1957, and P&W reverted to the single reactor concept. In addition, consideration was being given to whether the work at P&W on both the circulating-fuel reactor and the solid-fuel reactor should be continued. In June 1957, P&W recommended that, if funding limitations dictated that one of the programs be eliminated, no further support be given to the circulating-fuel reactor. In October 1957, AEC canceled work on the circulating-fuel reactor. Between August and October 1957 the Air Force withdrew from ANP activities at P&W. (See pp. 146 to 147.)

By letter dated November 9, 1962, the AEC General Manager, in commenting on this matter, stated:

> "*** Concerning the Ground Test Facility, the report concludes that the design work for this facility should have been cancelled because Weapon System 125a was cancelled. Actually, this cancellation did not change the requirement for the Ground Testing of the reactor-engine propulsion system. In fact, with the cancellation of Weapon System 125a, the Ground Testing of the reactor-engine propulsion system became the prime effort of the program. This is borne out on page 145 [now p. 140] of your report where you quote the Assistant Secretary of Defense, Research and Development, as stating: 'the principal effort of the program for the next several years should be directed to develop and prove the reactor-engine propulsion system.'"

Upon reexamining the comments of the Assistant Secretary of Defense referred to above and documents relating to the post Weapon System 125-A period, we still believe that the design work on the ground test facilities for the indirect cycle propulsion system should have been canceled or suspended at the time when the Weapon System 125-A program was canceled.

Early in 1957 the work on the indirect cycle was reoriented toward developing, on a delayed time schedule, an aircraft reactor of higher performance than could be achieved by "across-the-board" application of Aircraft Reactor Test technology. (See p. 142.) The uncertainty concerning the timing of the work on the facilities under discussion can be illustrated by further quoting the Assistant Secretary of Defense.

> "*** It is presently felt that the Pratt & Whitney program is at least one year behind General Electric. It may be unreasonable, therefore, to push this program with the intention of making it achieve a capability in the same time period as the General Electric.
>
> "I am asking a group of civilian technical consultants to examine for me the Pratt & Whitney development to determine the optimum rate at which this development should be pursued. This group of consultants will provide data as to the relative chances of success between the liquid-fuel reactor and the direct air cycle. Consideration will also be given to placing more emphasis on the solid-fuel reactor. If the latter is found desirable, it should be pursued at the proper rate by Pratt & Whitney rather than by the introduction of another company into the program. The Pratt & Whitney effort should be based on the CANEL facilities with only those facilities at NRTS, Arco, necessary for health and safety. This group will be expected to continuously examine the progress of the program over the next several years."

Furthermore, when the objectives of the ANP program were more clearly enunciated in April 1957 (see p. 144), the Air Force stated

that the ground test of a prototype indirect cycle propulsion was tentatively estimated for 1963 or 1964.

Because the time schedules for the testing of the indirect cycle propulsion system were uncertain and because the design of research and development facilities should have been scheduled to dovetail as closely as possible into their construction and use so as to take advantage of the latest research and development requirements, we believe that the design of the facilities could have been canceled or suspended at the time that the high-priority Weapon System 125-A program was canceled.

Initial Engine Test facility filter system

The definitive design work on the filter system for the Initial Engine Test (IET) facility, costing about $40,000, could have been canceled or suspended shortly after initiation.

The IET facility was used for testing reactors and engines at various power levels, and its major components included a test building, a control and equipment building, and associated facilities and appurtenances.

Definitive design of the filter system was started on June 11, 1956, and 1 week later GE advised AEC that there was a high degree of uncertainty that the filter chosen would be satisfactory and recommended that all filter work on the IET facility be stopped and that a research program be initiated to determine through actual test the most effective type of filter system. On August 8, 1956, AEC decided to terminate work on the filter system. However, definitive design work had already been completed on August 3, 1956,

at a cost of about $40,000. It appears, therefore, that most of the definitive design cost could have been avoided if the work ha been canceled or suspended promptly when the using contractor (GE made its recommendation.

Changes and redesign of Flight Engine Test exhaust system resulted because appropriate studies and tests were not made

AEC incurred costs of about $72,000 for design work on the Flight Engine Test exhaust system that was not used, primarily because design work was initiated before appropriate studies and tests had been made.

The FET facility was to be used for testing a nuclear power plant, both on the ground and in a prototype or flight test-bed aircraft, and for testing means of mating power plants with aircraft and was to provide auxiliary and emergency flight operations facilities. The facility includes a hangarlike building, an adjacent underground control room, and an exhaust duct and stack system.

The first preliminary design for the exhaust system, costing about $27,000, was included as part of the basic FET facility preliminary design and provided for a filter design for the exhaust system based on the filter designed for the Initial Engine Test facility. Shortly before the architect-engineer completed the preliminary design of the FET facility, GE recommended to AEC, on June 18, 1956, that all filter work on the Initial Engine Test facility be stopped. (See p. 45.)

Using criteria prepared by GE in February 1957, the architect-engineer completed the second preliminary design and the first definitive design in mid-1957 at a cost of about $45,000. Between July 1957 and August 1958, actual test and study revealed that some of the calculations on engine data were incorrect and that part of

the exhaust system could be constructed of less expensive materials. As a result, a study costing about $12,000 was made by the architect-engineer during the period August through October 1958. The study showed that a complete redesign of the exhaust system was necessary. The redesign was completed in February 1959 at an additional cost of about $45,000.

AEC therefore incurred total costs of about $72,000 for design work initiated before sufficient studies and tests had been performed.

Other ground test facilities designs

Most of the designs relating to the other ground test facilities at NRTS ($889,000) were unused as a result, primarily, of program reorientations. These unused designs were for the facilities listed below.

Propulsion System Test facility	$315,000
Shield Test facility	166,000
Flight Engine Test facility	164,000
Initial Engine Test facility	157,000
Radioactive Core Service Area	53,000
Low Power Test facility	34,000
	$889,000

AEC reconsidered the use of NRTS as flight test base after the Air Force expended substantial funds for plans, studies, and designs

After the Air Force spent about $780,000 for plans, studies, and designs relating to the flight test facilities, AEC reconsidered its previous decision and stated that NRTS could not be used for a flight test base. As a result, the work done by the Air Force was not used.

AEC approved the use of a part of NRTS by the Air Force as a flight test base in May 1952 and the following month informed the Air Force that plans for the construction of the ground test facilities at NRTS were proceeding under the assumption that they would later be integrated with the flight test facilities. AEC stated that with regard to the possibility of integrating the ground and flight test facilities there appeared to be many advantages and potential economies that would accrue to the ANP program by this move. AEC agreed in 1953 to act as construction agency for the Air Force's ANP facilities at NRTS.

The Air Force devoted a considerable amount of effort to planning the flight test facilities at NRTS. Under an Air Force contract, dated November 26, 1951, a contractor prepared a site study, a preliminary cost study, and four master plans for a flight test base. The total cost of the work under the contract was about $318,000. The site study consisted of an analysis comparing the suitability of the Edwards Air Force Base in California with that of NRTS. The site survey, completed in January 1952, recommended that NRTS be selected for the location of the flight test base. The four master plans were completed, one each in June 1952, December 1952, February 1953, and June 1953.

Convair, under a research and development contract with the Air Force, completed flight facility studies applicable to NRTS in July 1952 and in March 1953. In addition to the four master plans mentioned previously, a fifth master plan was initiated under an Air Force contract in October 1955. The plan was not completed,

and the contract was terminated shortly after the Weapon System 125-A program was canceled.

The initial project planned by the Air Force at NRTS was the flight test runway. AEC entered into a contract in February 1956 for the design of the flight test runway and related facilities. The design work, essentially completed by August 1956, cost about $462,000.

Construction contracts were not awarded. The flight objectives for the ANP program were canceled in December 1956, and the ANP program was reoriented without flight objectives. Subsequent reorientations of the ANP program in April 1957 and March 1958 provided for flight objectives, but contruction of the facilities was not started.

In April 1957 a DOD Ad Hoc Study Group recommended to the Assistant Secretary of Defense, Research and Engineering, that the ANP test runway should not be constructed at NRTS. (See pp. 144 to 146.) The Military Liaison Committee (MLC) stated in a letter to AEC in July 1957 that, although the Air Force was unable to fully assess the extent of the radiation hazards mentioned in the review group report, the Air Force believed that limited flight testing under rigid controls could be accomplished at NRTS without unwarranted risk to the public. The MLC stated also that a decision to locate these facilities at a site other than NRTS would necessitate further studies, would entail appreciable additional expenditures of funds, and would probably delay the date when initial nuclear flight testing could be contemplated. A request was made

by MLC as to AEC's position concerning the location of a runway at NRTS for testing of ANP aircraft. In September 1957, AEC informed MLC that a study was underway to assess the degree of radiological risk likely to be involved in the program and that, when the results of the study became available and were reviewed, AEC would advise the MLC of its position in the matter. The Ad Hoc Committee on ANP Hazards, appointed by the Deputy Secretary of Defense, reported in December 1957 that a coastal or island base was considered necessary for flight testing. (See p. 148.) DOD and AEC agreed in February 1958 to await the results of more complete studies of possible base locations, costs, etc., before arriving at a definite decision about experimental ANP flights.

In December 1958 the AEC Commissioners reached a unanimous decision that neither the AEC National Reactor Testing Station nor any other AEC installation was to be used for an ANP flight test site. In accordance with the request of the AEC Chairman in January 1959, an analysis was completed in April 1959 of Air Force accident rate experience for flight-testing experimental aircraft. An accident-probability scale for the proposed ANP aircraft was prepared on the basis of this analysis. The Director of Defense Research and Engineering, DOD, was advised of the December 1958 decision in September 1959, about 26 months after the initial request for a decision was made by MLC. It appears that the delay was due primarily, if not entirely, to the question of radiological hazards associated with flight testing.

By letter dated November 9, 1962, the AEC General Manager in commenting on this matter stated:

> "Regarding the use of NRTS as a flight test base, this was initially considered to be desirable because its remote location minimized the radiation hazards in the event of a crash, and because of the potential economies of combining ground and flight test facilities at one location. As additional knowledge was acquired regarding the potential hazards that might result from the crash of a nuclear propelled aircraft, both the AEC and DOD considered it necessary to reassess the situation. Special studies were therefore conducted which considered the radiological risks involved and the economics and feasibility of locating a flight test base elsewhere. The decision not to use NRTS for the flight test base gave due regard to prior Government expenditures, but it was determined that these were more than outweighed by the potential risks involved."

Unused designs for the Georgia Nuclear Laboratory

The Air Force awarded a contract in December 1955 to Lockheed, providing for the design and engineering of facilities to support the development of the Weapon System 125-A program. Construction of the facilities, known as the Georgia Nuclear Laboratory, Air Force Plant No. 67, started in August 1956. The Weapon System 125-A program was canceled in December 1956, and the Air Force advised Lockheed in January 1957 that its participation in the ANP program was to be immediately reduced. In February 1957 available construction funds were reduced from about $28.7 million to about $13.6 million.

The architect-engineering firm had completed certain design work on the facilities, but the facilities were not constructed due to a reduction in construction funds. The architect-engineering firm received about $287,000 for design work which was

not used because of the cancellation of the Weapon System 125-A program.

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In summary, we believe that the unused designs for the ANP facilities at NRTS illustrate the uncertainty surrounding the ANP program and the desirability of taking timely action to cancel or to suspend certain projects at the time when the need for them appears questionable. We believe, also, that appropriate studies and tests should have been made before designs for the FET facility were initiated.

REORIENTATION OF ANP PROGRAM NOT FORMALIZED ON A TIMELY BASIS

We made a review of the documents supporting the implementation of the reorientation of the ANP program to an experimental development program at GE after cancellation of the Weapon System 125-A program in 1956. GE was the major contractor involved in that weapon system. The reorientation was not fully formalized on a timely basis, in our opinion, since months of negotiations were required between the contractor, and the Air Force and AEC before an agreement on the current work program could be reduced to writing. We believe that communication between the contractor and the Government should have been improved to expedite the formalization of the current work program after the reorientation.

The Weapon System 125-A program was canceled in December 1956. During conferences in January 1957, AEC and the Air Force discussed the reorientation of the ANP program with GE. AEC and the Air Force, in a joint letter to GE dated February 13, 1957, confirmed the January discussion with GE and furnished program guidance. GE was advised that the Air Force forecast performance of the direct cycle nuclear propulsion system did not provide sufficient promise to justify a continuation of a weapon system program and that the Air Force was not prepared at that time to sponsor a weapon system permitting reduced propulsion system performance objectives. The letter stated that the objective of the revised program remained the flight-type propulsion system but that, however, the previously planned ground test of the prototype propulsion system was to be

reexamined with the objective of incorporating design improvements leading to significantly increased performance. The letter requested GE to submit to the Air Force and AEC, not later than March 12, 1957, a written outline of its revised program with a detailed analysis of expenditures for the remainder of contract year 1957 (ending September 30).[1]

On March 27, 1957, GE submitted the revised Air Force statement of work for the remainder of contract year 1957. By letter dated April 30, 1957, the Air Force advised GE that the revised statement of work for 1957 was not fully acceptable to the Air Force. With the April 30 letter, the Air Force forwarded to GE a proposed statement of work "that reflects the total Air Force requirement."

GE was advised in writing on May 10, 1957, to proceed on a reoriented program as it related to the AEC portion of the work. The Air Force and GE agreed on July 13, 1957, on a revised statement of work for contract year 1957.

By memorandum dated September 12, 1962, the Deputy for Development, Research and Development, Air Force, in commenting on this matter stated that the Air Force statement of work was on contract in less than 4 months of submission of the contract proposal and that this time interval was considered timely.

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[1]Subsequently, the 1957 contract period for the Air Force was extended to November 30, 1957.

By letter dated November 9, 1962, the General Manager, AEC, in commenting on this matter stated that during this time of negotiation the contractor was insisting upon a broader program than the Government considered necessary or desirable and that AEC could not enter into a firm arrangement until this matter was satisfactorily resolved. The General Manager stated further that an earlier formalization of the agreement could have been achieved only by acquiescing to the contractor's wishes, an action which would not have been in the Government's best interests.

Since the negotiations involved the formalization of an agreement for research and development work underway during the time of negotiations, we believe that the Government could expect to gain no particular advantage in prolonging negotiations until later in the contract year. Moreover, we do not believe that an early settlement could have been achieved only by acquiescing to the contractor's wishes, since the Government should be in a better position when negotiating for future work than in negotiating for work already completed.

We believe, therefore, that the reorientation of the ANP program after the cancellation of the weapon system objectives was not agreed to in writing on a timely basis. It was not until May 1957 --about 5 months after the reorientation was initiated--that GE was advised in writing to proceed on a reoriented program as it related to the AEC work. Agreement between the Air Force and GE was not reached in writing until July 1957--about 7 months after the reorientation was initiated. The reorientation of the ANP program was

not completely reduced to writing, therefore, until about 7 months after the preceding program objectives and about 8 months before the next reorientation was initiated. It appears that more timely and practical communication should have been established between the Government and the contractor to formalize current work programs.

VARIOUS INDICATIONS THAT THE DEPARTMENT OF DEFENSE DID NOT FURNISH SUFFICIENT AND TIMELY GUIDANCE FOR ANP PROGRAM

Our review disclosed various instances where it appeared that the Department of Defense (DOD)[1] did not furnish sufficient and timely guidance to those responsible for carrying out the ANP program. In one instance, AEC requested DOD for a decision vitally affecting AEC's participation in the national defense effort, but over 2 years elapsed before DOD reached a decision. In another instance, DOD did not provide guidance that AEC considered adequate until almost 8 months after AEC was first requested to reorient the ANP program. At the time of that reorientation, AEC stated that it would indeed be deplorable if, when AEC developed the next advance reactor which could provide sustained nuclear flight, it would evolve that there was no requirement for this reactor. AEC stated also that it seemed only reasonable that, if AEC was to continue to support the DOD in the ANP program, specific DOD requirements must be provided in order that AEC could establish proper nuclear criteria and parameters. Also, we noted that a DOD review group stated in 1957 that there was a lack of firm decision and direction in the program and that the Joint Committee on Atomic Energy stated in 1959 that the ANP program still had no firm set of objectives.

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[1] For convenience, the National Military Establishment (NME) is referred to in this report as DOD. NME, predecessor to DOD, was created by the National Security Act of 1947. DOD was established by the National Security Act Amendments of 1949.

Department of Defense delayed major decision for over 2 years

AEC requested a major decision from DOD in December 1948 but did not receive the decision until March 1951. The request concerned DOD's views on the military worth of nuclear-powered aircraft and on the urgency with which DOD regarded the proposed development program. In December 1950, AEC indicated to DOD that the need for a decision was critical from the standpoint of national defense and that a severe shortage of personnel in the atomic energy field was developing. In March 1951, AEC advised DOD that the need for a decision was particularly acute and shortly thereafter was informed by DOD of the priority to be given the aircraft nuclear power plant.

A review group engaged by AEC recommended in its Lexington Report that, if it was decided as a national policy that the high cost could be justified, a strong development program on nuclear-powered flight should be undertaken. (See p. 123.) In view of the Lexington Report, AEC in a letter to the Military Liaison Committee[1] in December 1948 stated:

> "The Commission would appreciate learning the views of the National Military Establishment with respect to the basic conclusions reached by the Lexington Project. The Commission desires to obtain a policy decision at

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[1]Established by The Atomic Energy Act of 1946 (42 U.S.C. 2037). The Committee consists of representatives of the Army, Navy, and Air Force. AEC advises and consults with the Department of Defense through this Committee on matters relating to military application of atomic weapons or atomic energy.

> the highest level which is based on a thorough evaluation of the respective merits of expending heavily of national wealth for the development of nuclear-powered aircraft as compared with similar expenditures for development of other means of national defense. Inasmuch as a decision will aid materially in getting a program underway, the Commission requests the views of the NME with respect to the manner in which such a decision can best be obtained at an early date. We would suggest that after your views have been formulated, this matter be made the subject of discussion between the AEC and the MLC."

The Military Liaison Committee (MLC) advised AEC in January 1949 that the views of DOD could not be given prior to action by the Joint Chiefs of Staff[1] and the Research and Development Board, AEC was advised also that a study had been introduced in the Joint Chiefs of Staff for the purpose of obtaining a policy decision. The MLC advised AEC in August 1949 that the Joint Chiefs of Staff had deferred a decision, pending an evaluation by the Weapons System Evaluation Group.

In December 1950, AEC again requested a decision from the Department of Defense. AEC stated, in part, that:

> "The present demand on qualified personnel in the atomic energy field is becoming severe and it is of utmost importance that those qualified personnel that are available, apply themselves to those items considered to be of greatest importance to our national defense.
>
> "The present status of the program *** suggest that the policy decision referred to should be made as early as it is practical to do so.

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[1] Included as a statutory agency within the Department of Defense under the National Security Act of 1947 (5 U.S.C. 171) and the members are the principal military advisers to the President, the National Security Council, and the Secretary of Defense. The Joint Chiefs of Staff consist of the Chairman of the Joint Chiefs of Staff; the Chief of Staff, United States Army; the Chief of Naval Operations; and the Chief of Staff, United States Air Force.

> "In view of the above it is requested that the AEC be informed of the views of the Department of Defense on the military worth of the nuclear-powered aircraft as well as the urgency with which the DOD regards the proposed development program leading to the 'flying laboratory' in 1956."

The MLC replied in January 1951 that the Joint Chiefs of Staff were currently considering the establishment of a requirement for the construction of an aircraft nuclear power plant suitable for the propulsion of aircraft.

The MLC requested AEC's views on certain matters, including the impact of the proposed requirement on AEC's other project priorities and production objectives. AEC replied on March 1, 1951, that, except for a "crash program" which could be extremely disrupting to AEC's essential production program, men and facilities could be found to make reasonable progress on this project, if the need could really be justified. AEC stated that the need for a decision by DOD was particularly acute.

On March 13, 1951--over 2 years after AEC initially requested a decision by DOD--the MLC informed AEC that the Joint Chiefs of Staff had determined that "a military requirement exists for the construction of a nuclear power plant suitable for aircraft propulsion, with priority for accomplishment to be after any reactor projects primarily concerned with the production of fissionable materials."

Department of Defense did not furnish AEC with sufficient guidance until 8 months after major reorientation was initiated

DOD initiated a major reorientation of the ANP program in July 1959 but did not provide AEC with what AEC considered to be clear guidance until February 1960.

During July 1959 the ANP program was reoriented from a development program for a weapon system for the Air Force to a research and development program leading toward major reactor experiments. The Director of Defense Research and Engineering (DDR&E), DOD, advised AEC on July 7, 1959, to emphasize the development of only such reactors as would be suitable for useful military performance, to continue the development of only such turbomachinery as might be necessary to establish the feasibility of nuclear-propelled aircraft, and to defer flight plans.

On July 30, 1959, the Chairman of AEC advised the Secretary of Defense that:

> "As a result of the recent review by the Director of Defense Research and Engineering, it is understood that the first nuclear developmental reactor, the so-called nichrome-zirconium hydride reactor, does not meet Department of Defense requirements and that some more advanced reactor must be developed. I am deeply concerned that the Commission has expended such extensive time and effort only to find that after we have achieved a capability of providing a nuclear system for flight, there is no DOD requirement for this system. Since ANP is an extremely costly development, it seems only reasonable that if the Commission is to continue to support the DOD in this joint effort, specific DOD requirements must be provided in order that the Commission can establish proper nuclear criteria and parameters. It would, indeed, be deplorable if when we develop the next advanced reactor which could provide sustained nuclear flight it would evolve that there was no requirement for this reactor.

> "In view of the above, the Commission requests that the DOD provide at the earliest practicable date firm ANP program requirements and/or objectives in sufficient detail to permit the Commission to properly and adequately cooperate in a joint program toward a common useful goal."

On September 9, 1959, DDR&E advised AEC that the Air Force and Navy had been furnished with interim guidance and that it would be appreciated if AEC would accept this guidance as the initial objectives of the program. The interim guidance stated that the objectives of both the direct and indirect cycle programs were to develop a power plant which could be used to fly a plane similar to the Convair model 54 design at a speed of between Mach 0.8 and 0.9 at an altitude of about 35,000 feet and which would have a potential life of about 1,000 hours.

With reference to DDR&E's interim guidance, AEC requested clarification on October 5, 1959, as to whether it was intended that each of the direct and indirect cycle programs develop separate power plants to satisfy the above objectives or whether it was intended that only one program be extended through the power plant development phase. DDR&E did not reply until February 27, 1960, because DDR&E was awaiting a report from an Ad Hoc Group that had been formed to make a more complete study of ANP and to recommend future courses of action. DDR&E concurred, in general, with the findings of the Ad Hoc Group and advised AEC that the aim of the ANP program should be to carry only one of the two power plant developments to the flight stage in the mid-1960's but to continue with both approaches toward achieving a relatively high performance

plant until technical progress or lack of progress enabled DDR&E to make a selection.

Thus it appears that, when the ANP program reorientation was initiated in July 1959, DDR&E did not furnish AEC with firm requirements and objectives in the detail that AEC considered necessary to properly and adequately carry out the program. AEC required further clarification after DOD furnished AEC with interim guidance in September 1959, but this clarification was delayed until February 1960 because DDR&E waited on the matter until a review group had issued its report.

Examples of other indications that there was a lack of sufficient guidance for the ANP program follow.

During January 1957, the Assistant Secretary of Defense (R&D) appointed an Ad Hoc Study Group to review the entire ANP program. The group's report, issued in April 1957, stated that there was a lack of firm decision and direction in the program and that it was apparent that there must be strong coordinated supervision and continuous examination of efforts undertaken and results achieved.

After a series of hearings on the status and future aspects of the ANP program, the Joint Committee on Atomic Energy in February 1959 commented that (1) the program still had no firm set of objectives, (2) no decision had been made regarding actual nuclear flight and no target dates had been set, (3) administrative indecision at high levels had plagued the program from the start, (4) the contractors had no clear guidance as to where they stand or where the program was going, and (5) the annual expenditure was a holding

operation to avoid difficult decisions which must be made to lend clear-cut direction to the program.

There are indications, therefore, that DOD did not furnish sufficient and timely guidance to those responsible for carrying out the ANP program.

By letter dated October 3, 1962, the Deputy Secretary of Defense, in commenting on this matter, stated that the program suffered considerably from lack of prompt decisions but that new management procedures had been instituted in DOD to minimize the impact of such a condition. (See p. 35.)

BENEFITS OF UNIFIED ORGANIZATIONAL ARRANGEMENT NOT FULLY REALIZED

The benefits of the organizational arrangement for the ANP program were not fully realized, in our opinion, because the Air Force and AEC each awarded separate contracts to GE and P&W for work on the development of the propulsion system. We believe that a single contract with each contractor would have simplified the accounting budgetary, and administrative aspects of the project; eliminated the lack of uniformity in contractual provisions; and expedited the Government's negotiations with the contractor. We believe further that, to strengthen congressional control where two agencies each have an interest in the project and the project is to be under the direction of an organizational unit consisting of personnel of both agencies, each agency should explore with the cognizant congressional committees for both agencies the desirability of having one of the agencies justify and subsequently fund the entire cost of the project. We reached similar conclusions from our review of the Large Surface Ship Reactor, AlW land-based prototype project.[1]

The research and development on the propulsion systems was carried out by the Air Force and AEC as a single integrated project under parallel cost-plus-a-fixed-fee contracts with GE and P&W. From November 1957 until the termination of the ANP program, the

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[1]Report to the Congress on review of Atomic Energy Commission and Department of the Navy Large Surface Ship Reactor, AlW land-based prototype project constructed under contracts with Westinghouse Electric Corporation (B-114878)--issued January 10, 1962.

organizational structure of the Aircraft Nuclear Propulsion Office (ANPO) provided for the carrying out of the technical direction of the propulsion system as a joint project effort of the Air Force and AEC.

We believe that in this instance the organization arrangement after November 1957 would have lent itself particularly well to having a single Government contract with each contractor. Accomplishment of this objective would have required an agreement between AEC and the Air Force covering such matters as (1) the mechanics of funding and payment--one possibility being for AEC to contract and make payments and for the Air Force to fund the cost of its work by advances or reimbursements to AEC--and (2) the cost reimbursement principles to be used in the contracts. We believe that extension of the single-job concept to the use of single contracts would have resulted in a reduction of the dual-control aspects inherent in the separate AEC and Air Force contractual arrangements, and in the elimination of certain inconsistencies in the provisions of the contracts.

An even more desirable alternative, in our opinion, would be for one agency to budget, to obtain congressional authorization, and to fund the entire cost of future projects of this nature. The advantages of this type of arrangement would be many. It would be economical and desirable from an administrative point of view since it would eliminate entirely the dual-control aspects inherent in separate funding arrangements by two Government agencies, particularly the burdensome task of accumulating costs separately for

billing and budgeting purposes, and it would eliminate certain inconsistencies in contractual provisions resulting from two different Government agencies' being involved. It would facilitate congressional review and strengthen congressional control. Under single-agency funding, the congressional review and determination regarding the budgetary request--both authorization and appropriation--would be based on a consideration at one time of the entire cost of the project. Supplemental funds, if necessary, would be considered by the same congressional committees and subcommittees that considered the initial request. This arrangement would result in a better accounting determination of costs for management purposes since the costs of the project would be determined on a consistent basis.

More liberal terms in Air Force contract placed AEC in unfavorable bargaining position and contributed to delay in AEC's initial support of indirect cycle propulsion system

AEC was in an unfavorable bargaining position in negotiating a contract with P&W because the Air Force had previously awarded to P&W a contract containing certain provisions that were more favorable to the contractor than AEC would agree to. P&W's attempts to get such terms incorporated in the AEC contract contributed to about a 14-month delay in AEC's initial support of the indirect cycle propulsion system.

The Air Force awarded a contract to P&W in May 1951 for certain work required to provide a thorough technical evaluation of a nuclear energy propulsion system. At that time both the Air Force and P&W recognized that some AEC support would be necessary to

accomplish this work and therefore agreed that at the proper time P&W would request a collateral contract from AEC. In February 1952 P&W requested AEC for a contract that would include fuel element fabrication and development, and design of a facility required for critical experiments. P&W stated that, in considering this request to AEC, it gave primary consideration to those problems in the reactor program, the solution of which, in its judgment, was most urgent if a logical sequence in the work was to be pursued. P&W pointed out that the work relating to fuel elements should be undertaken with no further delay in order to preserve an orderly sequence in the work. P&W pointed out further that the design of the facility should parallel fuel element fabrication and development because critical experiments would be mandatory if certain neutron physics problems peculiar to the ANP activities at P&W were to be solved.

In March 1952, AEC Headquarters requested its Chicago Operations Office to negotiate a contract with P&W to cover work necessary to establish the feasibility of undertaking a development effort on an aircraft type of reactor utilizing supercritical water as a moderator coolant fluid. Between May 1952 and January 1953, AEC forwarded at least three contract draft proposals to P&W and P&W forwarded at least two draft proposals to AEC. The principal problems involved in the negotiations related to fees, patents, personnel provisions, and termination of the work by P&W in event of lack of funds. In May 1953, 14 months after negotiations began, AEC executed a contract with P&W.

The need for AEC to actively participate in the ANP program at P&W was established in March 1952 when AEC Headquarters requested its Chicago Operations Office to negotiate a contract with P&W. The lack of agreement on certain major provisions in the proposed contract between March 1952 and May 1953 apparently delayed certain reactor development work on the indirect cycle propulsion system for about 14 months. Further, we believe that a major deterrent in reaching an agreement was the effort by AEC to negotiate terms more favorable to the Government than those that had already been incorporated in the Air Force contract. In our opinion, AEC was in an unfavorable bargaining position in negotiating with the contractor because (1) the contractor had already received an Air Force contract containing certain provisions that were unacceptable to AEC in its contract and (2) P&W was aware that it would likely receive an AEC contract because of the close relationship between the work to be done for the two agencies.

Fixed-fee rates allowed under the Air Force contracts were about double those allowed under AEC contracts with the same contractors

The fixed-fee rates allowed under the Air Force contracts with GE and P&W were nearly double the rates allowed under the AEC contracts with the same contractors. We believe that AEC was placed in an unfavorable bargaining position because the Air Force had previously agreed to pay the contractors fixed-fee rates for the Air Force work on the interagency project that were much higher than the rates that were acceptable to AEC.

The Air Force and AEC have separately negotiated their contracts and contract continuations with GE and P&W, usually on an annual basis. The fee bases (adjusted estimated costs) and the fixed fees under the Air Force and the AEC contracts since inception are summarized as follows:

Contract	Contract period From	Contract period To	Fee base	Fixed fee negotiated	Average percent
General Electric Co.:					
Air Force:					
AF 33(038)-21102	3-19-51	9-30-58	$122,723,000	$ 8,765,000	7.14
AF 33(600)-38062	10- 1-58	9-30-60	78,773,000	5,649,000	7.17
			201,496,000	14,414,000	7.15
AEC:					
AT(11-1)-171	6-29-51	6-30-60	181,234,000	6,067,000	3.35
Pratt & Whitney:					
Air Force:					
AF 33(038)-27341	5-31-51	10-15-57[a]	27,667,000	1,750,000	6.33
AF 33(600)-40548	12- 1-59	12-15-60	4,900,000	309,000	6.30
			32,567,000	2,059,000	6.32
AEC:					
AT(11-1)-229	5-21-53	6-30-60	65,795,000	2,921,000	4.55
Total Air Force			234,063,000	16,473,000	7.04
Total AEC			247,029,000	9,058,000	3.67
Total			$481,092,000	$25,531,000	5.31

[a]Between 10-15-57, and 12-1-59, the Air Force did not have an operating contract with P&W.

Although the fee bases of the Air Force and AEC contracts were about the same, the average rate of fixed fee negotiated by the Air Force (7.04 percent) was about double the average rate negotiated by AEC (3.67 percent). The negotiation records show that one of the principal problems involved in the negotiation of the AEC contracts with GE and P&W related to the amount of fixed fee. P&W wanted a fee for the AEC work that was comparable to the fee previously agreed to by the Air Force.

By memorandum dated September 12, 1962, the Deputy for Development, Research & Development, Air Force, in commenting on this matter, stated:

> "Relative to the fee difference between the Air Force and the AEC, the ANP contracts were negotiated by both agencies in conformance with established contractual policies and criteria. Air Force fees were within the boundaries allowed by the Armed Services Procurement Regulations. They compared favorably to those allowed other contractors for research and development programs of comparable complexity."

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Since a single contract to each contractor should simplify the accounting, budgetary, and administrative aspects of the project; eliminate the lack of uniformity in contractual provisions; and expedite negotiations with the contractors, we believe that, in future projects of this nature, the feasibility of awarding a single contract to each contractor should be considered early in the program. Furthermore, we believe that, to strengthen congressional control, each agency should explore, with the cognizant congressional committee for both agencies, the desirability of having one

of the agencies justify and subsequently fund the entire cost of joint-agency projects.

By memorandum dated September 12, 1962, the Deputy for Development, Research & Development, Air Force, concurred in our observation on the advantages of a single contract for an integrated dual agency research and development program. The Air Force emphasized, however, that this be done early in the program. The memorandum stated:

> "*** The exploration of advantages to be gained by a single contract in an existing environment of a 'going program,' well established and based upon dual contracts, involves many more considerations of balancing pros and cons than those which exist in the early stages of a program.
>
> "When the ANPO was operational as a joint AF/AEC management office in 1958, the single contract approach was considered. At that time, the administrative and technical disadvantages forecast as accruing from a changeover were evaluated as outweighing the administrative advantages.
>
> "Some of the forecast disadvantages were:
>
> 1. The necessity of renegotiating contracts in an area where the contracting agency management was not familiar with the technical content of the work to be done.
>
> 2. A disruption of the technical effort resulting from program redocumentation by the technical project managers.
>
> 3. A time-consuming recast of financial reports, controls and accounts into the contracting agency format. This involved the AEC program being on a fiscal year cost basis and the Air Force program being on a contract year obligation authority basis.
>
> 4. Some buildup of the administrative manpower of the agency managing the contract would be required.

5. In the development phase existing in the ANP program, it appeared that the AEC would necessarily be the single contracting agency by law. Then at a point in a flight test program, after prototype test, the Air Force would become the contracting agency on subsequent propulsion systems. This change of contractual coverage was one of the single contract concerns."

By letter dated November 9, 1962, the General Manager, AEC, in commenting on this matter stated:

"I agree with the views expressed in the report that where two government agencies are involved in the same project, a single contract with the same contractor helps to simplify the budgetary, accounting, and administrative aspects of the project. As I stated in my reply to your report on the AlW project, wherever feasible and economical, AEC will make every effort (as it did with NASA on the NERVA portion of the Rover Program) to arrange for single contracting in future jointly funded projects where a firm will be performing similar work for each of the agencies. I do not believe that it is desirable, as the report proposes, for one agency to justify and subsequently fund the entire cost of joint agency projects since it places that agency in the position of justifying to Congress a segment of a program for which another agency is responsible. In my view, adequate Congressional review and control is assured if Congress is advised fully by each agency, at the time funds are being requested, of the nature and anticipated extent of participation by the other agency. This is the present practice of AEC."

A report of the Joint Committee on Atomic Energy on hearings held on the ANP program in July 1959 stated that, since the ANP program was a research and development effort, the Congress might wish to consider the desirability of placing primary authority and responsibility for the conduct of the ANP program in AEC which was well equipped to carry the program forward as a development effort through the flight feasibility and demonstration stage. (See p. 166.)

FREQUENT PROGRAM REVIEWS BY TEMPORARY GROUPS AND DELAY IN ESTABLISHING PERMANENT GROUP

Our review disclosed that (1) frequent reviews of the ANP program were made by temporary groups, (2) the reviews were based on brief visits to the contractors' plants and briefings and discussions in Washington, and (3) little continuity in membership could be found among the review groups. Since these reviews were intended, generally, to evaluate results accomplished and to provide advice to top management on direction of effort, it appears that a permanent review group comprised of appropriate DOD and AEC representatives with some continuity in membership would have been more efficient and effective and would have been more in keeping with the joint project concept under which the ANP program was carried out.

During the course of our review, we noted that at least 14 reviews had been made by various groups since 1955. Except for one review group established to evaluate hazards, the groups were established to review broad aspects of the ANP program, and in most instances, it appeared that the mission of the groups was to review the entire ANP program with respect to past accomplishments and future objectives.

The following table shows the identity of the 14 review groups, the approximate dates the reviews were completed or the reports issued, and the time intervals between reports on the reviews.

Review group	Approximate date review completed or report issued	Time interval between reports (months)
Review group, consisting of the R&D Technical Advisory Panel on Atomic Energy and members of the steering group of the R&D Technical Advisory Panel on Aeronautics	Apr. 1955	2
Ad Hoc Committee on Aircraft Nuclear Propulsion of the Air Force Scientific Advisory Board to the Chief of Staff, Air Force	June 1955	5
Ad Hoc Group, appointed by a steering group, represented by the Technical Advisory Panel on Aeronautics, the Technical Advisory Panel on Atomic Energy, and the Aeronautical R&D Facilities Coordinating Committee	Nov. 1955	11
Air Force Scientific Advisory Board Nuclear Panel on Aircraft Nuclear Propulsion Program	Oct. 1956	3
Air Force Scientific Advisory Board	Jan. 1957	3
Ad Hoc Group, appointed by the Assistant Secretary of Defense, Research and Engineering	Apr. 1957	1
Review group, appointed by the Commander, Air Research and Development Command	May 1957	1
Ad Hoc Panel of General Officers, appointed by the Assistant Deputy Chief of Staff, Development, Air Force	June 1957	6
Ad Hoc Committee on ANP Hazards, appointed by Deputy Secretary of Defense	Dec. 1957	2
Department of Defense Ad Hoc Panel on Manned Nuclear Aircraft, appointed by Deputy Secretary of Defense	Feb. 1958	15
Review group, Mr. E. V. Murphree of the AEC General Advisory Committee, Chairman	May 1959	2
ANP Ad Hoc Committee of the Air Force Scientific Advisory Board to the Chief of Staff, Air Force	July 1959	6
Department of Defense AD Hoc Group on the ANP program	Jan. 1960	6
Ad Hoc Committee of the Air Force Scientific Advisory Board to the Chief of Staff, Air Force	July 1960	

Of the 14 review groups discussed above, 7 were Air Force, 6 DOD, and 1 AEC. Of the 7 Air Force, 5 were Panels of the Scientific Advisory Board which is the permanent program review and advisory body of the Air Force.

The reviews made by the various groups were based on brief visits to the contractors' plants and on briefings and discussions in Washington. The review group that issued its report in April 1955 on current and future prospects of the program based its findings on information received during an inspection trip for 1 day each to GE and the Oak Ridge National Laboratory and at a 1-day meeting with the Technical Advisory Panel on Atomic Energy. The review group that issued its report in June 1955 based its review on information obtained in Washington and did not visit the contractors' locations. The group that completed a review in April 1957 spent one day each at GE, P&W, Convair, and Lockheed and met for a total of 5 days in Washington with various contractors and Government agencies. The objective of this review was to examine into the entire ANP program, as to its objectives and the soundness of the technical approaches to the problem, and to advise as to the future ANP program. The group that issued a report in June 1957 spent a total of about 3 days at GE and the National Reactor Testing Station, about 2 days at P&W and the Oak Ridge National Laboratory, and about 11 days in briefings with various contractors and Government agencies. This group was to review the entire ANP program. The group that issued a report in February 1958 based its findings

on studies of previous study group reports and on information received at a 1-day meeting with representatives of the Navy, Air Force, and AEC and a 1-day visit each to GE and P&W. The objective of this review was to submit views concerning the status and plans of the ANP program. The group that issued its report in July 1959 spent about a week in receiving briefings and visiting and inspecting all important contractors and Government sites and laboratories engaged in ANP matters.

The July 1959 group recommended the establishment of a permanent technical advisory board with responsibility for periodic review and advice to the Air Force on the conduct of the program and stated that the contractors should be shielded from the harassment of continuous reviews by new temporary committees and investigating bodies because the field was too complicated for benefit to be derived from the inevitable superficiality of such brief contacts.

Seven of the nine review group reports available for our review showed the membership of the groups. We noted that in five groups only 1 of the 28 members of the groups served on more than one group. With respect to the other two groups--the July 1959 and the July 1960 ANP Ad Hoc Committee of the Air Force Scientific Advisory Board to the Chief of Staff, Air Force--about half the members of the July 1960 group had previously served on the July 1959 group.

We do not believe that effective reviews can be made of a complex research and development program, such as the ANP program, by

temporary groups, appointed at frequent intervals, and composed almost exclusively of members who have not served with a previous group. It appears that a single review group for the ANP program, comprised of appropriate DOD and AEC representatives with some continuity in membership, would have been more efficient and effective and would have been more in keeping with the joint project concept under which the ANP program was carried out.

By letter dated October 3, 1962, the Deputy Secretary of Defense, in commenting on this matter, stated:

> "*** The suggestion that a permanent review group would have been better than many temporary groups had been anticipated at least a year prior to termination of the project, when the Director of Defense Research and Engineering appointed such a group under the chairmanship of the Assistant Secretary of the Air Force for Research and Development, with membership from the joint Aircraft Nuclear Propulsion Office, the Navy and his own staff, all of whom had been closely connected with the program for many years. Reports from this group played an important part in the final decision to cancel the project in March, 1961."

UNNECESSARY COSTS INCURRED BY AEC FOR CONTINUED PROCESSING OF YTTRIUM OXIDE

Our review disclosed that AEC incurred unnecessary costs of about $517,000 by extending for a 7-month period a contract for the processing of high-purity yttrium oxide in order to maintain the production capability. Placing the production facility in a standby condition would have accomplished the same purpose, and the contractor was willing to negotiate to keep the plant in standby condition.

Early in 1956 when the ANP program was geared to the Weapon System 125-A objective, AEC initiated a crash program for procurement of yttrium metal required for the GE-ANP program. Yttrium oxide (oxide) is one of the intermediate products in the production of the metal. The two grades of oxide are high-purity and metallurgical grade (met grade) oxide, with the quality requirements for met grade oxide less severe than those for high-purity oxide.

In May 1956, AEC entered into two contracts for the large-scale procurement of oxide. By October 1958 one contract had expired, and the remaining contract with the Michigan Chemical Corporation (MCC) had been partially terminated. A modification to the MCC contract, in October 1958, provided that the contractor would reprocess the Government-owned met grade oxide into high-purity oxide during the period from October 10, 1958, through May 9, 1959, at a firm fixed price of $51.81 a pound. AEC paid for 15,146 pounds of reprocessed oxide under this modification for a total of about $785,000, including $232,000 for the amortization of MCC's

production equipment. Production under the MCC contract actually ended and the contract was terminated in May 1959.

From our review of the records it was not feasible to determine the reason for upgrading the met grade oxide to high-purity oxide, and we requested the Manager, Lockland Aircraft Reactors Operations Office, by letter dated April 5, 1960, to furnish this information. By letter dated June 7, 1960, the Manager replied that:

> "During the fall of 1958, the GE-ANPD program was not definitized insofar as the fuel elements and moderator materials were concerned. Moreover, GE was still attempting to use the Yttrium metal which had been delivered, whereas the Yttrium producers, particularly in the metal production phase, were still attempting to produce a purer material. In view of these circumstances, it was felt that since the projected requirements for this material positively did not discontinue the use of Yttrium, it was better to have the Michigan Chemical Corporation up-grade the metallurgical grade oxide to reactor grade oxide rather than terminate them in October 1958 and destroy the Yttrium production capabilities. Thus, it was considered in the best interest of the Government to keep the capability alive for approximately an additional six to eight months until it could positively be ascertained that we no longer required production of Yttrium in any form. In summary, therefore, the up-grading of the oxide which deferred the termination of the Michigan contract was our best judgment at that time."

After MCC delivered the remaining oxide and after the contract had expired in October 1958, sufficient quantities of high-purity oxide apparently were available to meet GE's requirements for about the next 25 months, assuming no significant increase in the improvement of the purity of the metal. MCC informed us that when the production facility was in st by condition the first finished product could be obtained in about months and that full production of the finished product could be obtained in about 6 months after production was initiated.

It appears therefore that costs of about $553,000 ($785,000 less $232,000 for amortization that AEC would otherwise have had to pay at termination of the contract) were incurred by AEC in order to keep MCC's oxide production capability intact for a period of about 7 months while a firm decision was to be reached on the need for yttrium. We noted, however, that on October 18, 1957, during the negotiation of the partial termination of MCC's contract, MCC had informed AEC that MCC would negotiate to keep the plant in standby condition, at an estimated cost of $10,000 to $12,000 to put the plant in standby and $41,300 annually to maintain the plant in standby. On the basis of this estimate, AEC could have contracted to maintain the MCC plant capability intact for 7 months at a total cost of about $36,000, or $517,000 less than the cost of the method chosen by AEC to achieve the same purpose.

Effective June 30, 1959, AEC and MCC entered into a 1-year contract under which MCC received $35,800 to place and maintain the plant on a standby basis, ready to resume production on 60 days' written notice from AEC. On September 26, 1960, the production facilities were sold to MCC as the highest bidder.

The high-purity oxide, upgraded by MCC from met grade, was not used. In July 1961, AEC advised the Office of Civil and Defense Mobilization (OCDM) that AEC had determined that yttrium would not be required for planned future programs and that the General Services Administration (GSA) had determined it to be surplus to the Government and approved the sale thereof. OCDM advised AEC in September 1961 that, in light of the statutory authorities under

which OCDM operated, there did not appear to be any justification for the retention of yttrium. In March 1962 the Department of Commerce advised AEC that the present time was not suitable for sales of yttrium to private purchasers. In April 1962, AEC advised the Department of Commerce that it would withhold any sales of yttrium for the present but that it would appreciate Commerce's reviewing the situation again in about a year, or sooner if the market appeared to warrant it.

It appears that the reason that the met grade oxide was processed into high-purity oxide was to keep the production capability of MCC intact. (See p. 81 for AEC's position.) Placing the facility in a standby condition would have achieved the same objective and would have avoided the unnecessary expenditures of about $517,000.

DELAY IN AGREEING ON INDEMNITY PROVISION OF THE AEC CONTRACT WITH GE MAY HAVE RESULTED IN A DELAY IN REACTOR DEVELOPMENT WORK

Our review disclosed that a delay in AEC's and GE's agreeing on an indemnity provision in the contract may have resulted in delays in certain significant areas of reactor development and in the inefficient use of certain contractor personnel. Until agreement could be reached on the indemnity issue, critical experiments were delayed about 18 months.

AEC executed a letter contract with GE in June 1951, before agreement had been reached on certain issues, including an indemnity provision. Agreement on the provision was not reached until about July 1954 when a definitive contract was executed. During

the negotiations, GE insisted that the contract contain an unlimited indemnity provision that GE would be indemnified against any loss or expense or for any liability of GE to third parties in connection with the work under the contract. GE wanted to be protected from all liability should an airborne nuclear propulsion unit fall in some inhabited area. AEC negotiators pointed out, among other things, that (1) the scope of the work did not include flight testing of an airborne reactor and that such testing when it did occur would be carried on by other than GE personnel, (2) the hazards and liabilities of ground testing were no different from those in any other AEC development contracts, and (3) the possibility of accidents involving inhabited areas would be extremely remote.

In about December 1952 GE employees had been trained and were prepared to manufacture fuel elements needed to carry out critical experiments. However, because of the indemnity problems, GE would not accept fissionable material and the fuel elements could not be made. In September 1953, local AEC officials stated that the lack of agreement on indemnity had resulted in a problem that was then one of the major deterrents to the progress on the ANP project. They stated also that, in addition to the delays on critical experiments pending a solution of the indemnity problem, delays in the testing of fuel experiments in existing reactors, such as the Materials Testing Reactor at the National Reactor Testing Station, were occurring because of the remote possibility of liability under GE's ANP project. They stated further that these delays also resulted

in situations which adversely affected the economical utilization of funds in that people who were hired to perform this work could not be utilized effectively. In September 1953, an indemnity clause was added to the letter contract. This clause, in effect, provided for indemnity against atomic hazards, but payment would be subject to the availability of funds and AEC would use its best efforts to obtain such funds. Local AEC officials stated that the only effect that the inclusion of the indemnity provision had on GE's activities was that the long-delayed experiments utilizing the Materials Testing Reactor at NRTS were started by GE. GE, however, would not accept sufficient quantities of fissionable material to work on critical experiments because the contract did not contain an unlimited indemnity provision. Local AEC officials stated in October 1953 that the GE program had been and was being affected significantly by reason of the fact that GE would not handle, use, or process the quantities of fissionable material necessary for many of its program activities without an unlimited indemnity.

Presidential approval was required before AEC could agree to an unlimited indemnity provision in a contract. In February 1954, AEC requested the President to approve an unlimited indemnity provision for the proposed definitive contract under consideration at that time. The Attorney General recommended that the unlimited indemnity provision should, at the very least, contain a bad faith or willful misconduct clause which would be an exception to the Government's assuming unlimited liability. AEC revised the request in July 1954 to incorporate the recommendation of the Attorney General.

The President approved the revised request. The definitive contract containing the unlimited indemnity provision, as approved by the President, was executed in July 1954, and GE proceeded with critical experiments.

There was indication that delays in resolving the indemnity issue in a timely manner may have resulted in delays in certain significant areas of reactor development. There was about an 18-month delay in initiating work on critical experiments because, although GE employees had been trained and were prepared to proceed on critical experiments in December 1952, the experiments were not started until about July 1954. We understand that such experiments were necessary and should have been carried out concurrently with the development of the reactor.

By letter dated November 9, 1962, the General Manager, AEC, in commenting on this matter, stated:

> "*** As the report indicates, GE initially requested an unlimited indemnity covering all risks, both nuclear and non-nuclear. The AEC considered such a request to be unreasonable and could not recommend that the President approve such an arrangement. The indemnity provision, as finally negotiated, contained broad coverage in the area of nuclear risks only. While the protracted negotiations resulted in a delay in the conduct of certain experiments, it is our view that, under the circumstances, the delay was unavoidable."

We do not consider that taking 3 years (June 1951 to July 1954) to resolve a matter that culminated in delays in the conduct of important experiments constituted timely action.

UNECONOMICAL PROCUREMENT AND CONTRACTING PRACTICES IN THE CONSTRUCTION OF THE CONNECTICUT AIRCRAFT NUCLEAR ENGINE LABORATORY

Certain uneconomical procurement and contracting practices were employed by the Corps of Engineers, United States Army, to accelerate construction of the Connecticut Aircraft Nuclear Engine Laboratory (CANEL) because the facilities were expected to be needed to meet the demands of the Weapon System 125-A program. The Corps of Engineers provided for large segments of the work by negotiating substantial contract modifications--without competition--with firms already under contract. We noted in one instance that the work covered by substantial negotiated contract modifications was almost entirely subcontracted and in turn sub-subcontracted, resulting in a pyramiding of overhead and profit allowances totaling over $237,000 to the prime contractor and the subcontractor for work done principally by the sub-subcontractor. We believe that a substantial portion of such overhead and profit allowances could have been avoided had the Corps of Engineers (1) obtained competitive proposals from firms able to provide the required construction services or (2) taken steps to eliminate one of the tiers involved in the successive subcontracting.

At the request of the Air Force, the CANEL facilities were designed and built, under contracts administered by the Corps of Engineers, for P&W's use in developing an aircraft nuclear propulsion system under research and development contracts with the Air Force and AEC. The Corps of Engineers incurred costs of about $42 million in connection with the construction of CANEL, including

charges of $1.8 million by the Corps of Engineers for its administration, supervision, and inspection of the design and construction work.

An accelerated construction program for CANEL was considered necessary to meet the occupancy dates established by the Air Force because of the high priority given to the ANP program between March 1955 and December 1956 for developing the Weapon System 125-A for the Air Force. (See p. 133.) After the completion of the design criteria late in 1954, the Corps of Engineers in April 1955 entered into an architect-engineer contract providing for the design of CANEL. Initial construction contracts were awarded in August and October 1955. Until the Air Force ordered the deferment of certain proposed construction in May and August 1957, CANEL had been constructed on a "crash" basis.

Corps of Engineers provided for entire portions of the construction work without obtaining competitive proposals

The Corps of Engineers did not use formal competitive bidding in awarding construction contracts. Instead, to meet the Air Force occupancy dates, ranging from December 1956 to September 1957 for the various facilities, the Corps of Engineers solicited competitive proposals from a selected group of contractors and negotiated fixed-price contracts with the firms submitting the lowest proposals. In a number of instances, however, the plans and specifications for a particular facility or general area of work had not been completed at the time the proposals were solicited. As a result, the Corps of Engineers entered into fixed-price construction contracts providing for only portions of the planned facilities.

Subsequently, the remaining portions of the construction work were provided for under substantial modifications to existing contracts, after negotiations solely with the firms awarded the basic contracts and with only occasional limited competition for the subcontract work. This matter also was disclosed by the United States Army Audit Agency in an audit report, dated October 10, 1958. Negotiations with the firms already under contract were undertaken because the Corps of Engineers (1) determined that there was insufficient time to obtain competitive proposals and/or (2) considered it desirable to make a single contractor responsible for an entire facility or general area of work in order that the Government would not become involved in coordination problems between prime contractors or in disputes between contractors.

The following tabulation shows the extent to which certain contracts were increased by negotiated modifications.

Contract number	Date of contract	Facility or area of work	Amount of original contract	Net contract modifications
DA-19-016-4206	10-26-55	Central power plant	$ 218,000	$ 927,025
DA-19-016-4523	4-13-56	Shop laboratory	667,000	1,947,721
DA-19-016-4536	4-23-56	Roads and outside utilities	4,153,400	2,875,472
DA-19-016-4719	8-17-56	Heat exchanger laboratory	257,447	478,289

The above contract modifications included six large change orders, totaling over $4 million, ranging in amounts from $166,000 to $1,381,000. These modifications considerably expanded the scope of the original contracts and covered major portions of the construction specifications, such as the installation of heating, ventilating, and electrical systems and the construction of the outside electrical distribution system.

We believe that the use of negotiated modifications or change orders to fixed-price construction contracts is a customary and economical method for providing for minor changes to existing plans and specifications. However, we do not believe that change orders are an appropriate or economical method for providing for major portions of construction work when the scope and cost of the modification far exceed the scope and cost of the basic contract.

Pyramiding of overhead and profit allowances under negotiated contract modifications

The Corps of Engineers provided for the CANEL outside electrical distribution systems--costing about $1.8 million--by negotiating substantial modifications to an existing prime contract. The work, however, was almost entirely subcontracted and in turn sub-subcontracted, resulting in a pyramiding of overhead and profit allowances totaling over $237,000 to the prime contractor and the subcontractor for work done principally by the sub-subcontractor.

The original contract (No. 4536) with the Lane Construction Company provided for the construction of roads and certain outside utilities at a negotiated fixed price of $4,153,400. Lane subcontracted work costing about $2.7 million to other firms. Included in the subcontracted work was work under a subcontract with the Davison Construction Company which provided for the construction of a fuel oil pier, a river pump house, and certain miscellaneous buildings at a cost of about $645,000. Davison in turn sub-subcontracted the necessary electrical work to John J. Reilly, Inc., for $365,548. Subsequently, upon completion of the plans and specifications for the outside electrical distribution system,

the Corps of Engineers provided for this work by negotiating substantial contract modifications solely with Lane although the Corps was aware that the work was to be almost entirely undertaken by a sub-subcontractor and was considerably beyond the scope of the electrical work included in Lane's original contract. Further, at the time of the initial negotiations for the construction of the outside electrical distribution system, the Corps of Engineers already had prime contracts totaling about $5.5 million with Davison for other construction projects at CANEL.

There were about 50 modifications to Lane's original contract, involving in whole or in part the Lane-Davison-Reilly relationship, for construction of the outside electrical distribution system, which cost the Government about $1.8 million. The two largest modifications totaled about $1.6 million. Lane's job costs[1] for the two modifications were about $1.4 million, of which all except $2,300 represented costs under subcontracts to other firms, almost all of which was subcontracted to Davison. Davison's costs (exclusive of overhead) for the work covered by the two modifications were about $1.3 million, of which about $1.2 million represented costs under a subcontract with Reilly, the electrical contractor. On these modifications Lane received overhead and profit allowances

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[1]Job costs represent all costs except (1) indirect construction costs (i.e., supervision and engineering), (2) operating costs (i.e., bonuses and project office salaries), and (3) general administrative costs which cannot be assigned directly to a specific modification.

of about $154,200 applicable to work performed by Davison and Reilly, and Davison received overhead and profit allowances of about $59,100 applicable to work performed by Reilly.

Thus, overhead and profit allowances applicable to the work subcontracted and sub-subcontracted under the two largest modifications to the Lane contract totaled about $213,300--or about 15 percent of the amount of the subcontracted and sub-subcontracted work. We noted that, on other contracts where the Corps of Engineers negotiated substantial modifications, totaling about $2.5 million, with prime contractors for work almost entirely subcontracted, the overhead and profit allowance paid to the prime contractors on the subcontracted work where one tier of subcontracting was involved averaged about 9 percent of the estimated cost of the work. In contrast, the equivalent of about 15-percent overhead and profit markup was received by Lane and Davison under the Lane contract where two tiers of subcontracting were involved. We do not believe that any benefits derived from maintaining, in effect, two prime contractors for providing for electrical work primarily performed by an electrical sub-subcontractor were necessarily commensurate with the increased costs involved on such a contractual arrangement.

The overhead and profit allowances applicable to all modifications under the Lane contract relating to construction of the outside electrical distribution system totaled about $237,000, of which about $163,000 represented Lane's overhead and profit allowance applicable to work subcontracted and sub-subcontracted to Davison and Reilly and about $74,000 represented Davison's overhead

and profit allowances applicable to the work sub-subcontracted to Reilly.

Although Lane had received the basic contract for certain other portions of the outside utility work, we do not believe that Lane would have had to be the prime contractor for construction of the outside electrical distribution system. The outside electrical distribution system, costing about $1.8 million, was a large undertaking, and we believe that the contractor should have been selected on the basis of competitive proposals. Furthermore, Lane did not appear to specialize in this type of work and the Corps of Engineers was apparently aware of Lane's prior arrangements for providing for electrical work by successive subcontracting. We believe, therefore, that a substantial portion of the $237,000 in overhead and profit allowances accruing to the prime contractor and subcontractor for work principally done by the sub-subcontractor could have been avoided had the Corps of Engineers (1) obtained competitive proposals from firms able to provide the required construction services or (2) at least taken steps to eliminate one of the tiers involved in the successive subcontracting, particularly since the Corps had concurrent prime contracts with both Lane and Davison.

By memorandum dated September 6, 1962, the Deputy Assistant Secretary of the Army (Logistics) in commenting on this matter stated that the methods of contracting employed at CANEL were justified by the urgency of the project and that, had the follow-on work been awarded as the result of competition, the completion

dates essential to the program would not have been met. With respect to the pyramiding of overhead and profit on the construction of the electrical distribution system under the contract for outside utilities with Lane, he stated that the pyramiding of overhead and profit was recognized in the award of the first supplemental agreement to the Lane contract but that in negotiating the second supplement with Lane no markup was allowed to Davison for work performed by Reilly and that the pyramiding of overhead and profit was eliminated.

Our review of the contractor's records showed that the pyramiding of overhead and profit was not eliminated on the second supplemental agreement (modification). Under the first modification ($698,000) to Lane's original contract, the Corps of Engineers specifically allowed (1) a 5-percent overhead and profit allowance to the subcontractor (Davison) for the work to be performed by the sub-subcontractor (Reilly) and (2) a 10-percent overhead and profit allowance to the prime contractor (Lane) on the total amount negotiated for Davison, or the equivalent of about a 15-percent markup to the prime contractor and subcontractor for the work performed by Reilly. Under this modification the amounts subsequently distributed to the various contractors were almost identical to the amounts negotiated. Under the second modification ($895,000) the Corps did not allow a specific markup to Davison on work performed by Reilly but allowed the equivalent of about a 13-percent overhead and profit allowance to the prime contractor on the total amount negotiated for work to be done by Davison. In the subsequent

distribution to the various contractors under the second modification, Reilly, the sub-subcontractor received about $3,000 less than the amount shown as negotiated by the Corps and the subcontractor (Davison) received about $26,700 more than the amount shown as negotiated by the Corps. As a result, the prime contractor and subcontractor actually received under the second modification essentially the same markups that had been specifically allowed under the first modification (i.e., a 5-percent overhead and profit allowance to the subcontractor (Davison) for the work to be performed by the sub-subcontractor (Reilly) and a 10-percent overhead and profit allowance to the prime contractor (Lane) on the total amount paid the subcontractor.

It appears, therefore, to make little difference whether, as in the first modification, a specific markup is explicitly provided for the subcontractor or whether, as in the second modification, a higher-than-normal markup is provided to the prime contractor who subsequently passes a portion of the markup to the subcontractor.

AIR FORCE AND AEC DID NOT REQUIRE
MEANINGFUL COST DATA FROM GE
DURING 3-YEAR PERIOD

The formal monthly reports that the Air Force and AEC obtained from GE during fiscal years 1956, 1957, and 1958 did not contain meaningful detailed cost data because the costs could not be related to the various experimental projects being carried out by GE. As a result, an effective monthly evaluation could not be made from the formal reports of the costs incurred by GE for major projects. Furthermore, during this period AEC's actual costs could not be related to the estimated costs because they were not reported on a comparable basis. During fiscal years 1959 and 1960 action was taken to correct these deficiencies.

The Air Force and AEC furnished GE with program guidance setting forth the funding level and program objectives for the coming year. On the basis of this guidance, GE submitted annual program proposals to the Air Force and AEC containing the planned activities and estimated costs for work to be done during the coming year. GE submitted monthly administrative reports showing actual Air Force and AEC costs, and a monthly cost budget report showing the budgeted and actual AEC costs.

The program proposals, monthly administrative reports, and the AEC monthly cost budget reports did not provide sufficient detail to permit a meaningful detailed evaluation of costs. GE's annual program proposals showed estimated costs by broad AEC and Air Force work classes; for example, shield development and turbomachinery. GE's monthly administrative reports and AEC's monthly cost budget

reports showed AEC's actual costs in four main categories--research and development, fuel fabrication, test operations, and reactor fabrication--none of which could specifically be related to the work classes. The Air Force actual costs were reported in categories which generally followed the work class breakdown in the proposals. The cost categories shown in the annual proposals and monthly reports, therefore, did not provide the degree of detail information needed for an adequately detailed evaluation of costs applicable to specific projects; for example, Heat Transfer Reactor Experiments and XMA propulsion system. Such specific projects, and major subdivisions thereof, are referred to by GE as a "product." We noted that GE prepared cost reports that compared actual and estimated costs on a product basis. The product classification and the work classes were not reported on a comparable basis. Generally, work under one work class was applicable to several products and, conversely, work under one product was spread over several work classes.

In June 1959, AEC issued a revision to its formal budget and reporting classifications which became effective July 1, 1959. This revision provided for budgeting and reporting on a product basis each month. Changes were made also in the procedure for estimating the Air Force and AEC costs in the GE work program proposal for fiscal years 1960 and 1961. In general, this system provided for a more detailed cost breakdown by products or objectives rather than by work classes. The costs of the products were also broken down to show estimated costs of specific segments of each product.

Although the projects were reviewed in detail every 6 months under AEC's normal procedures, we believe that more meaningful detail cost data should have been required from GE in the formal monthly reports during fiscal years 1956, 1957, and 1958.

OTHER DEFICIENCIES IN OPERATIONS UNDER CONTRACT WITH THE GENERAL ELECTRIC COMPANY

Our review of the activities of GE disclosed certain inefficiencies in property management and a need for improvement in the internal audits performed by the Air Force and AEC. Our review disclosed also that unallowable costs were charged to the AEC and Air Force contracts. Certain deficiencies had been commented on in previous AEC internal audit reports; however, corrective action had not been taken at the time of our review. A summary of the deficiencies noted during our review follows.

1. Ineffective equipment accountability--GE did not maintain effective accountability for Government-owned equipment at the Evendale plant, as evidenced by the fact that (a) most of the equipment was not at the locations designated on the equipment accountability records, (b) GE was unable to determine the number and value of unlocated items until many months after the physical inventory counts had been completed, and (c) GE did not try to locate items after it had finally been determined that they were missing or misplaced. Prior to our review the GE internal auditors had noted certain deficiencies that contributed to ineffective property accountability--(a) property was sometimes furnished to vendors and subcontractors without adequate controls, (b) procedures for the

movement of property were inadequate and those in existence were not adhered to, and (c) Government property was loaned to employees for personal use and was loaned also to other companies and other GE departments without provision for return. As of May 31, 1960, GE's records showed that it was accountable for about $22 million worth of Government-owned equipment for use in the ANP program at Evendale.

2. Physical inventories not taken regularly--GE had taken only one complete physical inventory of general stores at the Evendale plant from the inception of GE's participation in the ANP program (from 1951 to January 1960). The physical inventory was taken in September 1957. GE's records showed that the general stores inventory on hand at the end of May 1960 totaled about $563,000.

3. Accumulation of stores outside storerooms--the various operating units at the Evendale plant had accumulated general stores items within their units in excess of needs.

4. Uneconomical purchases--GE purchased materials and supplies from commercial sources for use at its Idaho Test Station, even though these items were available at equal or less cost from the AEC-financed stock located in the central stores warehouse near the Idaho Test Station.

5. Deficiencies in accountability for certain inventories--GE did not maintain records showing the cost of spare parts and special stores inventories at the Idaho Test Station, and the procedures for issuing, receiving, and inventorying of these items were deficient.

6. Divided internal audit responsibility--the internal audit responsibility for GE's Aircraft Nuclear Propulsion Department was divided between the Air Force and AEC, and the combined scope of the internal audits did not provide for effective and comprehensive coverage of GE's ANP activities at Evendale.

7. Prompt corrective action not taken on internal audit findings--for several years, and in some instances as long as 4 years, AEC internal auditors had commented on (a) the lack of financial controls for stores-type material stored at various locations at the Evendale plant, (b) the need for following AEC instructions in computing depreciation on property at Evendale and at the Idaho Test Station, (c) GE's excessive automotive liability insurance coverage, and (d) GE's practice of issuing an excessive number of individual purchase orders having a low dollar value, both at Evendale and the Idaho Test Station. GE did not take prompt action to correct these deficiencies.

8. Accounting records did not segregate allowable and unallowable costs--between 1951 and 1960, GE's Aircraft Nuclear Propulsion Department charged all costs to the AEC and Air Force contracts, including costs that were specifically unallowable by the terms of the contracts. As a result, the burden of finding and disallowing such costs fell on the Air Force and AEC. For several years the Air Force and AEC internal auditors had pointed out this deficiency.

9. Government audit services not utilized--certain commercial bills for the transportation of Government-owned property were

audited by a commercial audit service even though the same audit service was available from the General Accounting Office. After we brought this matter to the attention of AEC and Air Force officials, they directed GE to discontinue the use of the commercial audit service and to forward the transportation bills to the General Accounting Office for audit.

10. Delay in suspending project--GE did not take timely action to suspend certain work relating to the nuclear operation of an unclad ceramic reactor. The Aircraft Nuclear Propulsion Office (ANPO) advised GE in July 1958 to cancel the work, but it was not until after ANPO expressed deep concern in November 1958 over the amount of effort spent on ceramics that GE terminated the work in December 1958. In January 1959, ANPO initiated procedures that were intended to prevent the recurrence of similar situations.

11. Improper method for computing fixed fee--the Air Force paid GE a fixed fee for certain contract periods that was based partly on estimated outstanding commitments at the end of such periods. For example, GE was paid about $640,000 in fixed fees during contract year 1959 applicable to $9 million of outstanding commitments for work that was not planned to be done until contract year 1960. We do not believe that such a procedure should have been followed because the fixed fee was not earned until the contractor had completed the work.

During our review we discussed the deficiencies with appropriate AEC, Air Force, and contractor officials. They generally

agreed with our findings. After our discussions with these officials, we noted that a number of the deficiencies were being corrected or plans had been made to take corrective action.

OTHER DEFICIENCIES IN OPERATIONS
UNDER CONTRACT WITH PRATT & WHITNEY AIRCRAFT

Our review of the activities of P&W disclosed weakness in the financial and quantity controls over materials and supplies inventories, and a lack of formal accounting records to support the financial reports prepared by P&W. Certain deficiencies had been commented on in previous AEC internal audit reports; however, corrective action had not been taken at the time of our review. A summary of the deficiencies follows.

1. Physical inventories not taken regularly--P&W did not take physical inventory of materials and supplies until about July 1957, even though it had operated under an Air Force contract since 1951 and under an AEC contract since 1953. The estimated value of the materials and supplies inventory at July 31, 1958, was about $4.5 million. We noted numerous and substantial errors in the July 1957 inventory. After we brought these errors to the attention of local AEC officials, AEC made a review of certain inventory balances as of December 1958. AEC found that the errors continued to exist; however, the incidence and extent of the errors had been substantially reduced.

2. Inadequate accountability for inventories--the value of materials and supplies inventories was not shown in the formal accounting records.

3. Stock records accessible to warehouse employees--stock records cards were located in the central stores warehouse and were readily accessible to all warehouse employees.

4. Improper handling of requisitions--requisitions for materials and supplies, although prenumbered, could not be accounted for. Moreover, many requisitions were not signed by the employees receiving the stock.

5. Absence of written procedures for inventories--P&W did not have written procedures or instructions relating to the taking of inventories, nor for the warehousing functions relating to the receipt, storage, issuance, or recordkeeping of materials and supplies.

6. Accumulation of excessive and obsolete inventories--the materials and supplies inventory at July 31, 1958, included many items that were obsolete or in excess of foreseeable needs. AEC stated that the accumulation of excessive and obsolete items was partially attributable to the lack of financial control but that accumulation of the bulk of the excess material resulted from a change in the program from research and development for a specific type of reactor to a basic research program.

7. Inadequate accounting records--P&W did not maintain a currently posted general ledger, subsidiary ledgers, or other formal records to support the financial reports, but instead used many informal work sheets and memorandum-type records.

8. Prompt corrective action not taken on internal audit findings--for several years the AEC internal audit reports had commented on (a) the need for certain formal accounting records, (b)

the lack of written procedures relating to the inventory function, and (c) the absence of financial controls over inventories. Prompt action, however, had not been taken to correct these deficiencies.

During our review we discussed the deficiencies with appropriate contractor officials and with officials of the AEC Hartford Aircraft Reactors Area Office, who generally agreed with our findings. After our discussions with these officials, we noted that a number of the deficiencies were being corrected or plans had been made to take corrective action.

We advised the Manager, Lockland Aircraft Reactors Operations Office (LAROO), of our findings in a letter dated July 22, 1960. LAROO replied on September 6, 1960, that further corrective action had been taken on certain deficiencies but stated that AEC did not have complete responsibility for the administration of P&W activities under the ANP program. LAROO stated further, in part:

> "The Pratt & Whitney organization, as you know, is now and has been primarily devoted to production of aircraft engines and accordingly does the majority of its total business with the Department of Defense. Thus, the contractor should be and is, in fact, thoroughly versed in the matter of operating under DOD administrative procedures.
>
> "Therefore, when P&WA [P&W] was requested to perform research work on the ANP Program for the U.S. Air Force in May of 1951, the applicable procedures required by the DOD had already been made known to P&WA, and this DOD influence was carried over to the USAF operating contract which became effective in May 1951. In early years, P&WA's work on the ANP Program was confined solely to the USAF cost-type operating contract, and in contract years 1951, 1952 and 1953 the following amounts were expended respectively: $0.3, $1.0 and $1.9 million - or accumulatively through contract year 1953, $3.2 million. It was

not until May 1953 that the AEC contract became effective and the AEC, in Fiscal Year 1953 expended only $13,000. This influence on the part of the DOD remained until October 1957 when the original USAF operating contract was terminated.

"I would also like to point out that P&WA is not an integrated contractor since they use their own funds to finance operations. Accordingly, they are not necessarily required in all cases to follow the procedures which the Commission has prescribed for its integrated contractors. We do, however, consider them as an integrated contractor for many purposes on an administrative basis and have made significant accomplishments in this respect."

SCOPE OF REVIEW

We examined into the organization, policies, and procedures relating to the ANP program and into selected activities of the major contractors engaged in the program. Our review included an examination of correspondence, reports, contracts, negotiation files, and other pertinent documents which were made available to us by the Department of Defense, the Air Force, the Navy, AEC, ANPO, and the major contractors.

Certain ANPO files were made available to us after being reviewed by ANPO personnel. We were informed that the purpose of this review was to remove data that did not pertain to the manned ANP program under our examination as well as data that represented incomplete staff work. Without knowledge of the specific data thus removed from the files, we could not establish whether it had relevance to the subject matter of our audit. Subsequently, AEC officials advised us that the aforementioned data had been restored to the files and that such files were available for our review. However, because the program had been canceled, and in the absence of any compelling reason for doing so, we did not consider our reexamination of the files necessary or practicable.[1]

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[1]Since April 1962, it has been AEC's written policy that, where documents are removed from official files prior to review by GAO, a listing shall be prepared and an appropriate explanation of the reasons for withdrawing each document shall be incorporated therein. At the same time, AEC noted that the President of the United States has reserved to himself the authority to invoke executive privilege and that no GAO request will be declined on the basis of executive privilege unless a determination to assert privilege has been made by the President.

We discussed matters pertinent to our review with Air Force, AEC, Navy, and contractor officials. We also examined, on a test basis, the data relating to the costs of the ANP program. In performing our review and determining the nature and extent of our tests, consideration was given to the work performed by the Air Force and AEC internal auditors.

Our review was conducted at ANPO Headquarters, Germantown, Maryland, and at the sites of the major contractors engaged in the ANP program--the Aircraft Nuclear Propulsion Department of the General Electric Company, Evendale, Ohio; the Pratt & Whitney Aircraft Division of the United Aircraft Corporation, Middletown, Connecticut; Convair Division of the General Dynamics Corporation, Fort Worth, Texas; the Georgia Division of the Lockheed Aircraft Corporation, Marietta, Georgia; the Oak Ridge National Laboratory, Oak Ridge, Tennessee; the AEC National Reactor Testing Station, Idaho Falls, Idaho; and the Wright Air Development Division, Air Research and Development Command, Dayton, Ohio.

SCHEDULES

TOTAL COSTS INCURRED BY THE ATOMIC ENERGY COMMISSION
AND THE DEPARTMENT OF DEFENSE
FOR FISCAL YEARS 1946 THROUGH 1961

	Funding agency	Total	Fiscal year 1946-51	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
							(000 omitted)						
DEVELOPMENT OF THE DIRECT CYCLE NUCLEAR PROPULSION SYSTEM:													
Operating expenses:													
Reactor development and related shielding studies	AEC	$ 246,728	$ -	$ 3,514	$ 9,665	$ 5,847	$ 8,113	$18,266	$ 32,800	$ 40,994	$ 46,980	$ 38,[illegible]	$ 42,410
Engine development	Air Force and Navy	221,225	356	2,866	4,570	2,835	6,612	8,602	29,027	40,[illegible]	44,[illegible]	40,[illegible]	31,[illegible]
Total operating expenses		467,953	356	6,380	14,235	8,682	14,725	28,128	61,827	80,[illegible]	91,[illegible]	78,[illegible]	74,[illegible]
Facilities and equipment:													
Provided by AEC	AEC	52,424	-	182	3,163	7,530	4,008	2,906	8,586	10,146	8,756	6,[illegible]	1,[illegible]
Provided by Air Force	Air Force	42,387	-	3,458	10,338	1,697	602	1,[illegible]	3,[illegible]	[illegible]	9,[illegible]	2,[illegible]	965
Total facilities and equipment		94,211	-	3,640	13,502	9,227	4,610	4,[illegible]	12,[illegible]	17,[illegible]	18,[illegible]	8,[illegible]	2,[illegible]
Total		562,764	356	10,020	27,737	17,879	19,335	32,[illegible]	74,[illegible]	97,[illegible]	109,[illegible]	87,[illegible]	76,[illegible]
DEVELOPMENT OF THE INDIRECT CYCLE NUCLEAR PROPULSION SYSTEM:													
Operating expenses:													
Reactor development and related shielding studies	AEC	171,373	6,884	7,109	7,618	8,725	14,444	26,201	27,372	19,[illegible]	15,[illegible]	20,[illegible]	20,[illegible]
Engine development	Air Force and Navy	37,731	-	833	2,243	1,981	3,297	[illegible]	[illegible]	[illegible]	654	[illegible]	[illegible]
Total operating expenses		209,104	6,884	7,942	9,861	10,707	17,741	28,[illegible]	37,[illegible]	19,[illegible]	16,[illegible]	23,[illegible]	23,[illegible]
Facilities and equipment:													
Provided by AEC	AEC	8,656	77	424	1	222	917	1,522	1,689	752	756	701	[illegible]
Provided by Air Force	Air Force	62,588	-	34	87	77	125	4,[illegible]	27,[illegible]	14,[illegible]	[illegible]	[illegible]	[illegible]
Total facilities and equipment		71,244	77	458	88	299	1,045	5,[illegible]	29,[illegible]	15,[illegible]	[illegible]	[illegible]	[illegible]
Total		280,348	6,961	8,400	9,949	11,006	18,786	33,[illegible]	66,[illegible]	35,[illegible]	32,[illegible]	30,[illegible]	32,[illegible]
AIRFRAME, SUBSYSTEM AND COMPONENT DESIGN, AND NUCLEAR SHIELDING AND RADIATION EFFECTS STUDIES:													
Operating expenses	Air Force and Navy	102,162	125	958	4,241	4,309	6,151	17,294	21,903	16,844	12,589	10,[illegible]	7,[illegible]
Facilities and equipment	Air Force	26,922	-	-	1,431	369	110	3[illegible]	[illegible]	[illegible]	[illegible]	87[illegible]	[illegible]
Total		129,084	125	958	5,672	4,681	6,261	17,670	27,253	21,[illegible]	16,[illegible]	10,[illegible]	8,[illegible]
STUDIES RELATING TO FEASIBILITY OF AIRCRAFT NUCLEAR PROPULSION AND GENERAL SUPPORT:													
Operating expenses	AEC, Air Force, and Navy	60,412	20,971	70	220	291	412	2,748	10,351	8,407	6,[illegible]	5,330	5,004
Facilities and equipment	AEC and Air Force	13,747	484	37	484	1,[illegible]	2	64	1,[illegible]	[illegible]	2,[illegible]	2,[illegible]	1,[illegible]
Total		[illegible]	21,455	87	704	1,834	414	2,813	11,832	[illegible]	[illegible]	7,[illegible]	6,[illegible]
TOTAL COSTS OF THE MANNED ANP PROGRAM		$1,040,[illegible]	$28,397	$18,625	$44,[illegible]	$35,[illegible]	$44,796	$91,[illegible]	$179,[illegible]	$179,[illegible]	$167,[illegible]	$135,[illegible]	$123,816

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TOTAL COSTS INCURRED BY THE ATOMIC ENERGY COMMISSION
AND THE DEPARTMENT OF DEFENSE (continued)
FOR FISCAL YEARS 1946 THROUGH 1961

	Total	Fiscal year 1946-51	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961
							(000 omitted)					
RECAPITULATION OF COSTS BY AGENCY:												
Atomic Energy Commission:												
Direct cycle nuclear propulsion system	$ 299,152	$ -	$ 3,696	$12,828	$13,377	$12,121	$21,174	$ 41,385	$ 51,032	$ 55,676	$ 44,046	$ [illegible]
Indirect cycle nuclear propulsion system	180,029	6,961	7,533	7,619	3,948	15,361	27,723	29,061	17,255	[illegible]	[illegible]	[illegible]
Feasibility studies and general support	28,413	484	17	484	1,603	2	516	8,703	[illegible]	[illegible]	[illegible]	[illegible]
Total, AEC	507,594	7,445	11,246	20,931	23,928	27,484	49,413	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Department of the Air Force:												
Direct cycle nuclear propulsion system	262,057	356	5,834	14,909	4,502	7,214	11,228	32,320	[illegible]	[illegible]	[illegible]	[illegible]
Indirect cycle nuclear propulsion system	98,478	-	917	2,330	2,058	3,425	10,355	37,632	[illegible]	[illegible]	7,450	[illegible]
Airframe, subsystem and component design, and related shielding and radiation effects studies	117,360	125	958	5,574	5,117	5,861	15,736	25,813	23,071	[illegible]	10,379	[illegible]
Feasibility studies and general support	40,831	19,471	70	145	257	325	734	3,113	[illegible]	[illegible]	[illegible]	[illegible]
Total, Air Force	518,726	19,952	7,779	22,958	11,944	16,825	38,063	99,378	[illegible]	[illegible]	[illegible]	[illegible]
Department of the Navy:												
Direct cycle nuclear propulsion program	1,555	-	500	-	-	-	223	-	[illegible]	-	-	-
Indirect cycle nuclear propulsion system	1,841	-	-	-	-	-	-	-	105	262	1,474	-
Airframe, subsystem and component design and related shielding and radiation effects studies	5,724	-	-	98	74	400	1,934	1,440	913	565	300	-
Feasibility studies and general support	4,915	1,500	-	77	24	87	1,563	16	[illegible]	[illegible]	-	-
Total, Navy	14,035	1,500	500	175	98	487	3,720	1,456	2,556	[illegible]	[illegible]	-
TOTAL COSTS OF THE MANNED ANP PROGRAM	$1,040,355	$28,897	$19,525	$44,064	$35,970	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]	$[illegible]

Note: The costs shown on this schedule do not include (1) the costs of special nuclear materials expended and the value of special nuclear materials and special reactor materials at June 30, 1961, and (2) the administrative expenses of the Atomic Energy Commission and the Department of Defense incurred in connection with the overall management and administration of the manned ANP program.

The notes on pages 114 to 117 are an integral part of this schedule.

THE MANNED AIRCRAFT NUCLEAR PROPULSION PROGRAM

TOTAL COSTS INCURRED BY PARTICIPATING PRIME CONTRACTORS

FOR FISCAL YEARS 1946 THROUGH 1961

	Total	Operating expenses				Facilities and equipment		
		Total	AEC	Air Force	Navy	Total	AEC	Air Force
				(000 omitted)				
DEVELOPMENT OF THE DIRECT CYCLE NUCLEAR PROPULSION SYSTEM:								
General Electric Company (GE)	$ 527,384	$462,867	$241,642	$219,670	$ 1,555	$ 64,517	$22,913	$ 41,604
Wright-Chaney-Birch	6,168	-	-	-	-	6,168	6,168	-
Utah Construction Company	5,316	-	-	-	-	5,316	5,316	-
Ralph M. Parsons Company	4,146	52	52	-	-	4,094	3,776	318
Phillips Petroleum Company	3,689	3,621	3,621	-	-	68	68	-
Arrington Construction Company	3,245	-	-	-	-	3,245	3,245	-
J. H. Wise & Sons, Incorporated	3,157	-	-	-	-	3,157	3,157	-
W. R. Cahoon Construction Company	1,045	-	-	-	-	1,045	1,045	-
Others	8,614	1,413	1,413	-	-	7,201	6,736	465
Total, other than GE	35,380	5,086	5,086	-	-	30,294	29,511	783
Total	562,764	467,953	246,728	219,670	1,555	94,811	52,424	42,387
DEVELOPMENT OF THE INDIRECT CYCLE NUCLEAR PROPULSION SYSTEM:								
Pratt & Whitney Aircraft (P&W), Division of United Aircraft Corporation	164,468	138,200	100,468	35,891	1,841	26,268	5,657	20,611
Bureau of Public Roads--access roads for Connecticut Aircraft Nuclear Engine Laboratory (CANEL)	464	-	-	-	-	464	-	464
Union Carbide Nuclear Company--(Oak Ridge National Laboratory)	68,306	67,716	67,716	-	-	590	590	-
Others	5,597	3,188	3,188	-	-	2,409	2,409	-
Corps of Engineers--(CANEL) facilities:								
Davison Construction Company, Inc.	7,616	-	-	-	-	7,616	-	7,616
Lane Construction Corporation	7,102	-	-	-	-	7,102	-	7,102
Benjamin P. Shaw Company	4,935	-	-	-	-	4,935	-	4,935
John A. Volpe Construction Company, Inc.	3,715	-	-	-	-	3,715	-	3,715
Perini Corporation	2,209	-	-	-	-	2,209	-	2,209
Charles T. Main, Inc.	1,787	-	-	-	-	1,787	-	1,787
McConathy, Hoffman & Associates	1,141	-	-	-	-	1,141	-	1,141
Corps of Engineers charges	1,776	-	-	-	-	1,776	-	1,776
Others	11,232	-	-	-	-	11,232	-	11,232
Total, Corps of Engineers	41,513	-	-	-	-	41,513	-	41,513
Total	280,348	209,104	171,372	35,891	1,841	71,244	8,656	62,588
AIRFRAME, SUBSYSTEM AND COMPONENT DESIGN, AND RELATED SHIELDING AND RADIATION EFFECTS STUDIES:								
Convair Division of General Dynamics Corporation	70,312	63,860	-	60,922	2,938	6,452	-	6,452
Lockheed Aircraft Corporation	33,694	19,224	-	19,224	-	14,470	-	14,470
The Glenn L. Martin Company	2,399	2,399	-	-	2,399	-	-	-
Massachusetts Institute of Technology	2,390	2,390	-	2,390	-	-	-	-
International Business Machines Corporation	1,958	1,958	-	1,958	-	-	-	-
Bendix Aviation Corporation	1,650	1,650	-	1,650	-	-	-	-
Boeing Aircraft Corporation	1,600	1,600	-	1,600	-	-	-	-
Republic Aviation Corporation	1,562	1,562	-	1,562	-	-	-	-
General Electric Company	1,475	1,475	-	1,475	-	-	-	-
Western Electric Co., Inc.	1,188	1,188	-	1,188	-	-	-	-
Others	4,856	4,856	-	4,469	387	-	-	-
Total	123,084	102,162	-	96,438	5,724	20,922	-	20,922
STUDIES RELATING TO THE FEASIBILITY OF AIRCRAFT NUCLEAR PROPULSION AND GENERAL SUPPORT:								
Fairchild (NEPA Project)	20,971	20,971	-	19,471	1,500	-	-	-
Union Carbide Nuclear Company--(Oak Ridge National Laboratory)	24,907	23,489	22,859	630	-	1,418	1,418	-
Maxon Engineering Company	9,300	-	-	-	-	9,300	-	9,300
Ralph M. Parsons Company	1,455	413	-	413	-	1,042	-	1,042
Sylvania-Corning Nuclear Corporation	1,187	1,187	1,187	-	-	-	-	-
Corps of Engineers charges	552	-	-	-	-	552	-	552
Others	15,787	14,352	1,662	2,225	3,415	1,435	1,287	148
Total	74,159	60,412	25,708	29,789	4,915	13,747	2,705	11,042
TOTAL COSTS OF THE MANNED ANP PROGRAM	$1,040,355	$839,631	$443,808	$381,788	$14,035	$200,724	$63,785	$136,939

Notes:

1. The costs shown on this schedule do not include (1) the costs of special nuclear materials expended and the value of special nuclear materials and special reactor materials at June 30, 1961, and (2) the administrative expenses of the Atomic Energy Commission and the Department of Defense incurred in connection with the over-all management and administration of the manned ANP program.

2. The costs assigned to contractors include the c[illegible] of certain Government-furnished services, materials, facilities, and equipment assigned to the participating contractors, including the book value of equipment and machinery furnished at no cost from the Industrial Reserve.

The notes on pages 114 to 117 are an integral part of this schedule.

COSTS OF FACILITIES AND EQUIPMENT BY MAJOR INSTALLATION

FOR FISCAL YEARS 1946 THROUGH 1961

	Costs to June 30, 1961		
	Total	AEC	Air Force
	(000 omitted)		
DEVELOPMENT OF THE DIRECT CYCLE NUCLEAR PROPULSION SYSTEM:			
Evendale, Ohio:			
Air Force Plant No. 36 (operated by the General Electric Company, Aircraft Nuclear Propulsion Department)	$ 45,716	$11,890	$ 33,826
General Electric Company Plant (operated by the General Electric Company, Flight Propulsion Division)	7,778	-	7,778
Total--Evendale, Ohio	53,494	11,890	41,604
Idaho Falls, Idaho:			
National Reactor Testing Station (operated by the General Electric Company, Aircraft Nuclear Propulsion Department)	41,317	40,534	783
Total	94,811	52,424	42,387
DEVELOPMENT OF THE INDIRECT CYCLE NUCLEAR PROPULSION SYSTEM:			
Middletown, Connecticut:			
Air Force Plant No. 62, Connecticut Aircraft Nuclear Engine Laboratory (CANEL)--(operated by Pratt & Whitney Aircraft)	67,825	5,237	62,588
Oak Ridge, Tennessee:			
Oak Ridge National Laboratory (operated by Union Carbide Nuclear Company)	1,636	1,636	-
Idaho Falls, Idaho:			
National Reactor Testing Station (design costs for facility to be operated by Pratt & Whitney Aircraft)	1,783	1,783	-
Total	71,244	8,656	62,588
AIRFRAME, SUBSYSTEM AND COMPONENT DESIGN STUDIES, AND RELATED SHIELDING AND RADIATION EFFECTS STUDIES:			
Fort Worth, Texas:			
Air Force Plant No. 4, Nuclear Aircraft Research Facility (NARF) (operated by Convair Division of General Dynamics)	6,452	-	6,452
Dawsonville, Georgia:			
Air Force Plant No. 67, Georgia Nuclear Laboratory (GNL) (operated by Lockheed Aircraft Corporation)	14,470	-	14,470
Total	20,922	-	20,922
STUDIES RELATING TO THE FEASIBILITY OF AIRCRAFT NUCLEAR PROPULSION AND GENERAL SUPPORT:			
Wright-Patterson Air Force Base, Dayton, Ohio:			
Nuclear Engineering Test Facility (operated by the Air Force, Wright Air Development Division)	11,042	-	11,042
Oak Ridge, Tennessee:			
Oak Ridge National Laboratory (operated by Union Carbide Nuclear Company)	2,705	2,705	-
Total	13,747	2,705	11,042
TOTAL FACILITIES AND EQUIPMENT COSTS OF THE MANNED ANP PROGRAM	$200,724	$63,785	$136,939

The notes on pages 114 to 117 are an integral part of this schedule.

NOTES TO COST SCHEDULES

The amounts shown on the schedules were accumulated by the General Accounting Office from the records of the major operating contractors, the Department of Defense, and the Atomic Energy Commission with the cooperation and assistance of these organizations.

ANPO Headquarters prepared a "Financial Summary of Manned Aircraft Program," dated June 30, 1961. This summary, which includes fiscal year 1961 estimates, differs from the schedules prepared by the General Accounting Office because different sources and bases were used for accumulating the information. The information in ANPO's schedules is based on obligations, except for the information on AEC operating expenses which is based on costs. The statements prepared by GAO are on a cost basis or as close to a cost basis as it was practicable to obtain. The details of the various sources and bases used for the amounts shown on the statements prepared by GAO follow.

Atomic Energy Commission

The amounts for operating costs are shown on a cost basis and were developed from AEC's annual June 30 Re-Cast Cost Budget Reports.

The amounts for facilities and equipment are shown on a cost basis and include (1) the costs of equipment not included in construction projects, financed under research and development contracts with the General Electric Company and Pratt & Whitney Aircraft as shown in AEC's annual Re-Cast Cost Budget Reports and (2) the plant and equipment costs developed from the Cost Reports on Changes in Plant and Equipment in Progress.

Department of the Air Force

a. General Electric Company (GE)

The amounts shown for Air Force operating costs are based on costs developed from GE's monthly administrative reports.

The amounts shown for Air Force facility costs include (1) the costs of the special tools and equipment financed under Air Force research and development contracts with the Aircraft Nuclear Propulsion Department as developed from GE's monthly administrative reports, (2) the costs of the Air Force-financed facilities of the Flight Propulsion Division as developed from various GE records and reports based on GE's costs charged against the pertinent supplements to the Air Force facilities contract, (3) the costs of the facilities financed under the Air Force facility contract with the Aircraft Nuclear Propulsion Department based on GE's billings and end-of-year adjustments for unbilled costs, and (4) the book value of equipment and machinery furnished at no cost from the Industrial Reserve.

b. Pratt & Whitney Aircraft,
Division of United Aircraft Corporation (P&W)

The amounts shown for Air Force operating costs were developed from P&W's billings under the Air Force research and development contract.

The amounts shown for Air Force facility costs include (1) the costs of equipment financed under the Air Force research and development contract prorated by fiscal year on the basis of P&W's billings, (2) the costs of the equipment and facilities

financed under the Air Force facility contract, based on P&W's billings, and (3) the book value of equipment and machinery furnished at no cost from the Industrial Reserve.

We have segregated and shown separately the Connecticut Aircraft Nuclear Engine Laboratory cost of facilities constructed and of the equipment purchased by the Corps of Engineers, the charges by the Corps of Engineers for administration and supervision of the construction, and certain amounts authorized for road construction by the Bureau of Public Roads.

c. Convair Division of General Dynamics

The amounts shown for Air Force operating costs were developed from Convair's cost ledgers for the various Air Force research and development contracts.

The amounts shown for Air Force facilities include (1) Convair's disbursements reimbursed under the Air Force facility contract and (2) the book value of Government-furnished items transferred to Convair at no cost.

d. Lockheed Aircraft Corporation

The amounts shown for Air Force operating costs were developed on the basis of either (1) Lockheed's reimbursed and submitted costs or (2) Air Force disbursements under the various Air Force research and development contracts.

The amounts shown for facilities are based on Lockheed's submitted costs under the Air Force facility contract.

e. Other Contracts

The amounts shown for Air Force operating costs were developed primarily from the Air Force disbursement records applicable to about 170 contracts and orders. In a few instances the amounts were based on Air Force contract or delivery order obligations. The cost of the NEPA project was developed from contractor and Air Force reports. Due to (1) the length of time since the inception of the program, (2) the decentralization of the Air Force accounting records prior to 1959, and (3) the lack of detail supporting the Air Force obligation control records, there is no assurance that all the miscellaneous Air Force contracts applicable to the manned ANP program have been included in the cost schedules or that the costs shown in the schedules were incurred solely for the benefit of the program.

The amounts shown for other Air Force facilities represent the cost of the Nuclear Engineering Test Facility at Wright Patterson AFB, Ohio, based on (1) contractor payment estimates for the construction work and architect-engineer services, (2) Air Force disbursements for minor supporting contracts, and (3) charges by the Corps of Engineers for administration and supervision of the construction.

Department of the Navy

The amounts shown for Navy operating costs are based generally on contract obligations and were developed from reports prepared by the Bureau of Aeronautics or the Bureau of Naval Weapons, Department of the Navy.

APPENDIXES

HISTORY OF THE MANNED AIRCRAFT NUCLEAR PROPULSION PROGRAM

Contents

HISTORY OF

MANNED AIRCRAFT NUCLEAR PROPULSION PROGRAM

INTRODUCTION

This history is organized mainly in a chronological order and shows the various periods during which the ANP program was on a particular objective. Because the program reorientations generally had the most immediate impact on GE, the largest contractor under the program, we primarily considered the activities of GE in our organization of the history.

A major reorientation required many months of consideration and planning, both by the Government and by the contractors, from the time that initial consideration was given to a program change until the reoriented program was in full operation at the contractor level. Moreover, the changeover of the contractors' actual operations was not an overnight transition, but rather a phasing out of the old program and a phasing in of the new program. Generally, the dates identified with the various periods were the approximate dates when a decision was reached to reorient the program.

We included in the history only those events that we considered to be the most important on the basis of the material available, together with other pertinent information considered necessary for an understanding of the history.

FEASIBILITY STUDIES--1946-51

During this period (1946-51) the Air Force, with AEC support, carried out studies on the feasibility of using nuclear energy for the propulsion of aircraft.

Initiation of feasibility studies

The use of nuclear fuels for the propulsion of aircraft was visualized during World War II, but the matter was not pursued because of the urgent need for development of the atomic bomb.

After World War II, several industrial firms selected the Fairchild Engine and Airplane Corporation (Fairchild) to act as manager of the industrial firms' efforts in the aircraft nuclear propulsion field. In May 1946, the Army Air Force awarded Fairchild a contract thereby starting the Nuclear Energy for the Propulsion of Aircraft (NEPA) project. The purpose of the project was to explore the feasibility of using nuclear energy as a means of propelling aircraft of combat operational usage. During September 1946 the project moved from New York City to Oak Ridge, Tennessee, where it remained until termination in 1951.

Lexington review group

The Research and Development Board[1] requested AEC in December 1947 to review all work in the field of nuclear power for aircraft propulsion and to establish and carry out a single unified program with direct participation by the interested Armed Forces and selected contractors. AEC engaged the Massachusetts Institute of Technology to make the review. The resultant Lexington Report, issued in September 1948, concluded that, although success could not be guaranteed, there was a strong probability that some version of nuclear-powered flight could be achieved if adequate resources and competent manpower were put into the development. The report recommended that, if it was decided as a national policy that the high cost in technical manpower, fissionable material, and money could be justified, a strong development program on nuclear-powered flight should be undertaken.

AEC requested decision from DOD

In view of the Lexington Report, AEC in a letter to the Military Liaison Committee in December 1948 requested a decision. The request concerned DOD's views on the military worth of nuclear-powered aircraft and the urgency with which DOD regarded the proposed development program.

In December 1950, AEC again requested a decision from the Department of Defense. AEC stated that such a decision should be made as early as it was practicable to do so.

Joint Chiefs of Staff established military requirement

On March 13, 1951, AEC received a reply to its December 1948 and December 1950 inquiries concerning the level of effort that could be justified on the ANP program. AEC was advised that the Joint Chiefs of Staff had determined that a military requirement existed for the construction of an aircraft nuclear power plant, with priority for its accomplishment to be after any reactor projects primarily concerned with the production of fissionable materials.

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[1]The Board was established within the DOD by the National Security Act of 1947 (5 U.S.C. 171) to prepare a complete and integrated program of research and development for military purposes. The Board was abolished and its functions were vested in the Secretary of Defense by Reorganization Plan 6 of 1953 (50 U.S.C. 402).

Other activities between 1946 and 1951

In the fall of 1949, AEC initiated work at the Oak Ridge National Laboratory (ORNL) operated by the Union Carbide Nuclear Company to provide technical support to existing Air Force endeavors in the field of aircraft nuclear propulsion. In the summer of 1950, ORNL was given responsibility for the Aircraft Reactor Experiment (ARE) from which it was anticipated valuable experience and other information would be forthcoming to support development and construction of an acceptable aircraft reactor.

In December 1950 the Research and Development Board recommended that the first objective of the ANP program be the development of a nuclear propulsion system for installation in a subsonic aircraft by 1956 or 1957.

The feasibility studies ended at Oak Ridge with the termination of the Air Force contract with Fairchild in April 1951. The total cost of the NEPA project was about $21 million. The principal conclusion resulting from the project was that nuclear propulsion of aircraft was technically feasible.

INITIATION OF AIRCRAFT NUCLEAR PROPULSION PROGRAM--February 1951-March 1952

As feasibility studies at Oak Ridge were being phased out, the program known as the Aircraft Nuclear Propulsion program was started by the award of Air Force and AEC contracts.

Award of major contracts

The Air Force in February 1951 awarded Convair a contract for work relating to the modification of a Convair B-36 type of airplane, and the Air Force and AEC each awarded contracts to GE in March and June 1951, respectively, for work on a propulsion system. By November 1951, GE estimated that it could deliver the first power plant to Convair in about May 1956 at a cost of about $188 million.

In February 1951, the Air Force awarded Lockheed a contract that provided for design of a series of airframes and certain other work. The Air Force entered into a contract with P&W in May 1951 for work related to the supercritical water reactor.[1] P&W requested AEC's support in the ANP activities at P&W in February 1952, but AEC did not award a contract to P&W until May 1953 because agreement could not be reached on certain terms in the contract.

Evaluation of sites for test facilities

In February 1952 the Wright Air Development Center (WADC) advised the Air Research and Development Command (ARDC) that selection of a flight test base for the aircraft nuclear propulsion program had been under consideration for some time and that a survey had been made under the NEPA project. ARDC was advised also that, at a meeting in November 1951 between AEC and WADC representatives, it had been agreed that the AEC National Reactor Testing Station (NRTS) site and the Edwards Air Force base site would be evaluated in a detailed comparative site study to ascertain the suitability of each flight test base. ARDC was advised further that these sites were chosen on the basis of the NEPA study and because they provided an access to a flight corridor suitable for nuclear flight testing.

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[1] In this type of propulsion system, heat is carried from the reactor by steam at supercritical pressures and temperatures. Air coming into the engine is heated by the steam and expanded through a jet nozzle to produce thrust.

At the direction of the Air Force, GE and Convair selected a contractor to make a site study and master plan for a nuclear-powered aircraft test facility, including an evaluation of the two proposed sites--NRTS, Idaho, and the Edwards Air Force Base, California. The contractor received an Air Force contract to do this work and in January 1952 recommended that NRTS be selected as the location for the flight test base. GE engaged the same contractor to conduct a design basis study and to determine the most suitable plot arrangement at NRTS for the ground test facilities.

FLIGHT DEMONSTRATION (X-6) PROGRAM--
April 1952-May 1953

During this period (April 1952-May 1953) the major activity was the X-6 program of which the major objective was the flight testing in late 1956 of an airplane using nuclear power. The X-6 program included also the construction of a shield test airplane which was to be flown by conventional power sources. The conventionally powered aircraft was a B-36H aircraft modified to test an airborne test reactor and shield. The shield test airplane was known also as the nuclear research airplane and the nuclear test airplane. The X-6 program was carried out by GE and Convair.

Air Force submits first formal program proposal to AEC

In April 1952 the Air Force submitted its first formal program proposal to AEC for consideration. In summary, the principal objective of the proposal was to cooperate with AEC in carrying out a program leading to flight test of a nuclear propulsion system in a flying test bed in the 1956-57 time period, with the condition that this target date was subject to change as technical progress and available funds might dictate. The proposal was prepared with the help of AEC and certain contractors and was designed to be responsive to the recommendation made by the Research and Development Board in December 1950. (See p. 124.) The proposal sought to fulfill the military requirement established by the Joint Chiefs of Staff in March 1951. (See p. 123.) In June 1952, AEC accepted with reservations the immediate objectives of the ANP program. AEC stated that the initial steps of the recommended program and general principles of financing the program to meet these objectives could be carried out with the understanding that technical progress and availability of funds might justify changes from time to time.

Initiation of major test site at the AEC National Reactor Testing Station

During May 1952, AEC approved the use of a part of NRTS by the Air Force as a flight test base. During the following month AEC advised the Air Force of its decision and stated that it was then

proceeding with plans for construction of a ground test facility a NRTS under the assumption that it would later be integrated with the flight test facility under mutually agreeable conditions.[1]

The Air Force and AEC agreed that the Air Force would be responsible for financing and operating the flight test facilities and that AEC would be responsible for financing and operating the ground test facilities.

Major cutback in ANP program

During April and May 1953, a major cutback in the ANP program occurred. Major events leading up to the cutback included (1) the recommendation of the Ad Hoc Committee of the Air Force Scientific Advisory Board[2] in March 1953 that the ANP program be cut back by 50 percent on grounds that activities were unwarranted by state of the art and the rate of progress, (2) the request of the Executive Office of the President that the Secretary of Defense, cooperating with AEC, submit to the National Security Council not later than April 20, 1953, a definitive program for realizing additional reductions in DOD expenditures for fiscal years 1954 and 1955 in connection with selected areas of atomic energy operations, one of which was a stretch-out or postponement of the atomic energy propulsion program for airplanes, and (3) the decision of the National Security Council in April 1953 to eliminate, as not required from the viewpoint of national security, the existing program for aircraft nuclear propulsion.

With reference to the decision of the National Security Council, the Chairman of the Military Liaison Committee testified before the Subcommittee on Reactor Development of the Joint Committee on Atomic Energy in May 1953 that:

> "*** the military requirements have not been cancelled. The only action that occurred was the budget disapproval of specific projects in these areas, on the general premise that the program as presented did not

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[1] In December 1958, AEC decided that neither NRTS nor any other AEC installation could be used as a flight test base. (See p. 168.)

[2] The Scientific Advisory Board is a consultant body which advises the Chief of Staff, United States Air Force, on scientific matters pertaining to current research and technological developments and makes future plans in areas related to the fulfillment of the Air Force mission, with a special view toward future aircraft weapons.

> meet the standards which had been established by the Secretary [of Defense]. *** The March 1951 Joint Chiefs' requirement for a nuclear powered aircraft is still valid."

In May 1953 the Director of Research and Development, Deputy Chief of Staff, Development, USAF, advised the Air Research and Development Command that (1) after a recent DOD review of the ANP program, all fund requests for ANP in the fiscal year 1954 budget had been eliminated, (2) it would be necessary to reorient the ANP program immediately so that it could be continued through fiscal year 1954 with unexpended funds appropriated in previous years, and (3) the Air Force expenditures in fiscal year 1954 should be planned at approximately $9.6 million. GE was advised that, in planning the revised program, about $6 million of AEC funds and about $3 million of Air Force funds should be assumed to be available each year for fiscal years 1954 through 1956.

During April and May 1953, GE was advised of a minimum development program for the GE-ANP project. By this time, GE had fabricated most of the major components of a reactor intended for use in a ground test power plant. Further development of this reactor was canceled.

Between April and June 1953, the Air Force canceled all work on the nuclear-powered (X-6) airplane at Convair and work on the shield test airplane slowed down. Convair continued its efforts at solving shielding, radiation damage, airborne instrumentation, and ground handling problems. Most of the design, procurement, and fabrication of a Ground Test Reactor, in connection with the X-6 program, had been completed by Convair in 1952. A full-scale nose mock-up of the shield test airplane was built in 1952.

It appears that the cutback in the ANP program did not materially affect the work underway at P&W, ORNL, and Lockheed.

APPLIED RESEARCH AND COMPONENT DEVELOPMENT--May 1953-November 1954

The effect of the reorientation of the program in 1953 was the postponement to an undetermined time of ground and flight testing of an aircraft nuclear propulsion system. The ANP program at GE was redirected primarily toward applied research and component development of an advanced direct cycle reactor concept based upon a new configuration and a more promising type of fuel elements.

Initial active participation by the Navy

In May 1953 the Navy awarded study contracts to seaplane builders and to reactor consultants so that the significance of developments in nuclear power for naval aircraft design could be assessed. This was Navy's first active effort in the ANP program, although it had kept informed on the status of the program through liaison officers and conferences and had also transferred $1.5 million to the Air Force in connection with the NEPA project which had been carried out at Oak Ridge between 1946 and 1951.

In August 1953 the Navy advised AEC of its interest in low reactor power for a subsonic seaplane and stated that its current program was limited to securing sufficient data and analyses for determining further scope and objectives of a naval ANP program.

Air Force cited urgent need for nuclear-powered aircraft

The Air Force informed AEC in December 1953 that:

> "*** There is a highest priority requirement for an intercontinental bomber capable of delivering, with acceptable attrition rates, any of our nuclear weapons on any target from bases within our continental limits. Recent studies performed by the Office for Aircraft Nuclear Propulsion indicate that a nuclear propeller aircraft possibly can be built which may meet this requirement by as early as 1960, providing the Air Force and the Atomic Energy Commission place sufficient priority on the solution of the difficult R&D [research and development] problems involved."

The Air Force urged AEC to take such steps as it deemed appropriate to expedite the experimental work upon which the development of this means of aircraft propulsion might be based.

AEC replied in February 1954 that it would, within the limits of its resources and such funds as might be made available within over-all program priorities, continue to explore ways and means of

meeting requirements for the ANP program as these requirements became known in their joint and complimentary programs within DOD. The Air Force Council[1] in April 1954 unanimously agreed that the Air Force position on ANP must be that (1) there was an urgent military requirement for the achievement of an aircraft nuclear propulsion operational capability at the earliest possible date and (2) the Air Force would fully support development programs to achieve this capability.

Work at P&W redirected

Because of the promising aspects of the circulating-fuel reactor,[2] work on the supercritical water reactor[3] at P&W was terminated in June 1954. The decision for termination followed an analysis made by P&W, at the request of the Air Force in March 1953, comparing the supercritical water reactor with the circulating-fuel reactor under study at the Oak Ridge National Laboratory.

Shortly before termination of the work on the supercritical water reactor, P&W's primary effort had been devoted to the circulating-fuel reactor. In July 1954, P&W assigned employees to ORNL on a loan basis for work on the Aircraft Reactor Test (ART) program. The ART was a 60-megawatt circulating-fuel reactor. Sixty megawatts was about the power required for an investigation of the engineering problems which had to be solved and for disclosure of the operating characteristics to be expected of the higher powered reactors required for high-altitude supersonic strategic bombers.

Other activities during period
(May 1953-November 1954)

The Aircraft Reactor Experiment at ORNL was operated successfully in November 1954. The experiment was completed within 9 days and represented the first known extraction of power from a nuclear reactor at temperatures in the range required by turbojet engines; the results represented an important achievement in the development

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[1]Advisory body to the Air Force Chief of Staff.

[2]In the circulating-fuel reactor, heat from the reactor is carried to the engines by a liquid metal where the heat is transmitted to the air through radiators. The reactor fuel is in the form of a liquid-metal fluoride which circulates through the reactor. Additional thrust may be obtained by burning chemical fuel in the engine.

[3]For definition, see footnote, p. 125.

of nuclear propulsion systems for aircraft. The total cost of the Aircraft Reactor Experiment, including facilities and equipment, was about $4 million.

The Ground Test Reactor at Convair had been placed in operation and achieved criticality--first nuclear chain reaction. Convair had also designed and built another reactor known as the Aircraft Shield Test Reactor. This reactor was similar to the Ground Test Reactor except that it was designed to operate while airborne. The Aircraft Shield Test Reactor was first operated on the ground during November 1954.

GE operated two engines on a common heat source and performed its first critical experiment.

WEAPON SYSTEM[1] 125-A PROGRAM-- November 1954-December 1956

The major objective during this period was to fulfill an official requirement established by the Air Force for a nuclear-powered airplane with supersonic capability for use in a weapon system.

Reorientation

The Air Force and AEC wrote to GE in November 1954, stating that the objective and priority of the ANP program had been changed in that there was considered to be an urgent need for an aircraft nuclear propulsion system which would increase the capability of the Air Force Strategic Air Command to perform missions requiring extended range or extreme endurance. GE was requested to submit a program leading to early experience with reactors suitable for aircraft propulsion through the ground prototype stage.

Under the reoriented program, GE decided that development of the solid moderated reactor should be given a high priority, rather than to develop simultaneously both the solid and liquid moderated reactors. Work on the liquid moderated reactor was limited. GE stated that it recognized that the engine used in the tests at the AEC National Reactor Testing Station was not suitable for flight operations and that an extensive development effort would be needed to develop an engine needed for subsonic flight.

During this period of the Weapon System 125-A program, the Air Force awarded Convair and Lockheed contracts covering studies and investigations for a nuclear-powered strategic bombardment weapon system.

P&W continued work on the circulating-fuel reactor for the indirect cycle. In November 1955, P&W was authorized to investigate the feasibility of using a solid-fuel reactor as a back-up effort to the primary effort which was concerned with the circulating-fuel reactor concept.

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[1] A weapon system comprises the equipment, skills, and techniques, the composite of which forms an instrument of combat. The complete weapon system includes all related equipment, material, services, and personnel required solely for the operation of the air vehicle, or other major element of the system, so that the instrument of combat becomes a self-sufficient unit of striking power in its intended environment.

Air Force established requirement for nuclear-powered airplane

During March 1955 the Air Force issued General Operational Requirement[1] (GOR) No. 81 to provide a nuclear-powered, piloted bombardment weapon system (WS-125-A) capable of delivering nuclear munitions against any target in the world. The primary mission for this weapon system would be taking off from bases deep within the continental United States, proceeding by circuitous routes to a target located anywhere in the world, bombing the target, and returning to the base of departure, again using circuitous routes, if desirable. The GOR stated, with reference to speed, that (1) cruise speed should not be less than Mach 0.9 unless significant increases in performance in the combat zone were to be attained and (2) maximum possible supersonic dash speed in the combat zone was desired. The GOR, with reference to availability, stated that this weapon system would be required in operational units during 1963.

Review group

A review group[2] in DOD, on the basis of information received during a 2-day trip to GE and the Oak Ridge National Laboratory and during a meeting of the Technical Advisory Panel on Atomic Energy in March 1955, concluded that:

> "Since the review of this project about nine months ago, sufficient progress has been made that the objective of achieving practical and useful flight of a military plane powered by nuclear energy, probably augmented by chemical fuel during parts of the mission, seems more probable of attainment."

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[1]For the Air Force, a GOR is a statement of the operational characteristics required of a piece of equipment or a weapon system in order that such a piece of equipment or such a system may be worthy of application to one or more of the missions assigned to the Air Force. It is the basis for the expenditure of funds and effort on a development program.

[2]Consisted of the R&D Technical Advisory Panel on Atomic Energy and the steering group of the R&D Technical Advisory Panel on Aeronautics.

Navy established requirement for nuclear-powered seaplane

In February 1955 the Navy issued Operational Requirement[1] No. CA-01503 for the development of multipurpose land- and sea-based aircraft systems capable of attack, reconnaissance, and mining in all conditions of weather against heavily defended enemy sea and land areas. In April 1955 the Navy issued Development Characteristic No. CA-01503-3 which provided the avenues of approach toward the fulfillment of the Operational Requirement. Features, characteristics, and capabilities were established in the Development Characteristic as guides for the development of nuclear-powered seaplanes of high subsonic capability for long-range attack, minelaying, and reconnaissance. The system was to be considered a complete weapon system. The primary function of the system would be to attack on naval shore targets, warships, and shipping with conventional and special weapons. The secondary function would be for purposes of mining and of forward-area reconnaissance. The Development Characteristic stated that completion of a prototype for evaluation no later than 1961 was desired.

After an instruction from the Secretary of Navy in May 1955 that a vigorous program should be developed and pursued for the nuclear propulsion of naval aircraft, the Navy engaged several contractors to make studies in relation to the Development Characteristic of April 1955.

Prospects during mid-1955

In June 1955, AEC and DOD agreed to accelerate the ANP program, with the objective of testing a prototype propulsion plant in about 1959.

The Ad Hoc Committee on Aircraft Nuclear Propulsion of the Air Force Scientific Advisory Board,[2] in a report issued in June 1955, stated that it believed that the technical objectives were in the main attainable although some relaxation in the details of the Air Force General Operational Requirement No. 81 would almost certainly

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[1]For the Navy, an operational requirement constitutes the official statement by the Chief of Naval Operations addressed to a lead or action bureau which outlines in broad terms the operational performance which should be attained in a specific weapon or support system to solve, wholly or in part, an operational problem stated or implied in a system concept. An operational requirement is derived from approved system concepts in the long-range research and development plan or from the demonstrated needs of the fleet.

[2]For explanation, see footnote 2, p. 127.

be required. The Committee stated also that the proposed short development period was highly desirable and should be kept as an objective but that it would be unrealistic to rely on the actual availability of a nuclear-powered Strategic Air Command capability in 1964. The Committee stated further that, in view of the planned overlapping and dovetailing of the various phases of development, it seemed likely that the proposed time scale might not actually be met, perhaps by as much as 3 to 5 years. The Committee expressed doubt whether the planned schedules could be met for developing the reactor, engine, and airframe and pointed out that the time allowed for flight development probably was inadequate.

Construction initiated on the Connecticut Aircraft Nuclear Engine Laboratory

To accommodate the ANP activities at P&W in the accelerated program, construction of the Connecticut Aircraft Nuclear Engine Laboratory (CANEL), Air Force Plant No. 62, was started about September 1955. Over 1,000 acres near Middletown, Connecticut, were acquired for the CANEL site. The total cost of the facilities, including land, buildings, and equipment, at June 30, 1961, was about $68,000,000. About $42,000,000 of those costs were incurred by the United States Army, Corps of Engineers, acting as the construction agency for the Air Force. The remaining costs of about $26,000,000 were incurred by P&W under an Air Force contract for additional equipment and facilities and under the AEC operating contract.

Certain uneconomical procurement and contracting practices were adopted by the Corps of Engineers to accelerate the completion of the construction of CANEL. (See pp. 87 to 95.)

Work initiated on solid-fuel reactor

AEC authorized P&W in November 1955 to investigate the feasibility of using a solid-fuel reactor[1] as a back-up to the primary effort which was concerned with the circulating-fuel reactor[2] concept. The investigation was to be conducted in such a manner as to minimize interruption and/or delay in any work pertinent to the work on a circulating-fuel reactor.

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[1]The solid-fuel reactor, as in the circulating-fuel reactor, employs a liquid metal which circulates and transfers its heat to the air in the engine. However, in the solid-fuel reactor the nuclear fuel is contained in the reactor itself in the form of solid elements.

[2]For definition, see footnote 2 p. 130.

GE established target dates

In September 1955, GE established target dates for the completion of major program steps and advanced the engine development schedule. The target dates called for the start of ground prototype tests during the 6 months ended March 1959, the start of flight testing during the 6 months ended December 1960, and the production of militarily useful power plants in July 1963.

Prospects as of September 1955

In September 1955, AEC advised the Military Liaison Committee that:

> "We suggest that the GE and P&W projects with their variations provide no more than the minimum acceptable assurance of producing a satisfactory powerplant for the nuclear powered strategic bomber scheduled to become operational in 1964."

Teaming of propulsion system and airframe contractors

During October 1955, the two airframe contractors were teamed with the two propulsion system contractors. Convair was teamed with GE, and Lockheed was teamed with P&W.

Department of Defense disapproved proposal by the Navy

During late 1955 and early 1956, a proposal by the Navy for a power plant development by a third contractor was under consideration by DOD. This proposal for development was in addition to the Air Force development efforts at GE and P&W. In reply to a letter in November 1955 from DOD on the subject of a third approach, AEC advised DOD in March 1956 that AEC believed it appropriate to postpone discussions on a third approach until it could be determined whether the Navy's requirement for an aircraft reactor could be met from the existing program without adversely affecting strategic bomber power plant development.

At the request of the Assistant Secretary of Defense (R&D), a group[1] reviewed a proposal of a contractor to develop an aircraft nuclear power plant package. In March 1956, the review group

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[1]Steering Group of the Technical Advisory Panel on Aeronautics, with representation from the Technical Advisory Panel on Atomic Energy and the Aeronautical Research and Development Facilities Coordinating Committee.

recommended that the contractor's proposal not be approved since it was believed that separate development of a third engine-reactor system was not justified and that the Navy's attack seaplane requirement be assured of continued adequate support from the two existing nuclear propulsion projects.

The Assistant Secretary of Defense (R&D) advised the Navy in March 1956 that he was in agreement with the recommendations of the review group. The Chief of Naval Operations stated that, having eliminated the prospects of a power plant tailored for naval missions, the Navy found it necessary to continue aircraft design studies which would permit utilization of the Weapon System 125-A power source.

In July 1956, DOD impounded $7.4 million of Navy ANP funds until such time as review and reorientation of the ANP program could be accomplished.

Construction of Georgia Nuclear Laboratory initiated

In August 1956 Lockheed began construction of a nuclear research facility, known as the Georgia Nuclear Laboratory (GNL), Air Force Plant No. 67. The facility, however, was reduced from a $28 million to a $14 million facility after the WS-125-A program was canceled in December 1956. Lockheed purchased and donated at no cost to the Government about 10,000 acres near Dawsonville, Georgia, for the facility. The facility was used for irradiating and testing aircraft components and subsystems in the radiation environment anticipated for nuclear-powered aircraft under operational conditions.

Prospects during mid-1956

The Air Force Chief of Staff advised the Joint Committee on Atomic Energy that he believed that there was a strong requirement for nuclear-powered aircraft and expressed interest in achieving nuclear flight at the earliest practicable date. The Office of Aircraft Nuclear Propulsion advised the Joint Committee that the ground test of a propulsion system was possible in about 1959 and the first flight in about 1960. GE estimated that about $2.5 billion would be required for a program leading to and including delivery of 120 nuclear power plants for the first wing of 30 aircraft by 1964.

Department of Defense withdrew order for impoundage of Navy funds

In December 1956 DOD advised the Navy that it had withdrawn the impoundage order of July 1956 and that the funds could be

requested through normal channels.[1] DOD stated that a review had been made and that the present Navy studies were considered a valuable import to the over-all ANP program.

Expansion of facilities at the AEC National Reactor Testing Station

The testing facilities at the AEC National Reactor Testing Station (NRTS) were expanded during the time of the Weapon System 125-A program. Construction of a Flight Engine Test (FET) facility at NRTS was authorized in July 1955, and design of the FET facility was initiated in March 1956. Construction of the facility started in September 1957 and was essentially completed by July 1959 at a cost of about $8 million, but the facility was not used. Construction of ground test facilities at NRTS for the use of P&W was authorized in May 1956. Design work on the facility continued after cancellation of the weapon system program, but construction was never initiated. The total cost of the design work was about $885,000. Between February and August 1956, design work on a runway and related facilities at NRTS was completed at a cost of about $462,000, but the facilities were not constructed. Designs of other facilities at NRTS were also initiated during the time that the Weapon System 125-A program was in effect, but the designs were never used. (See pp. 39 to 53.)

Budgetary and technical considerations during late 1956

The Air Force Scientific Advisory Board Nuclear Panel on USAF Aircraft Nuclear Propulsion Program stated in October 1956 that:

> "*** While the present state of the reactor art is encouraging, it does not conclusively demonstrate that a useful vehicle can be built. ***
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> * * * * *
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> "We understand that serious consideration is being given to decreasing the size of the budget, primarily by eliminating some of the long lead-time items in the present plan. This action would, of course, postpone the time at which vehicles could be available. As we further understand it, no reduction in reactor effort or other efforts essential to determination of the feasibility of

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[1] Accordingly, the Navy requested funds at various times during 1957 but received nothing until after the Navy presented study plans for the Princess program in December 1957. (See pp. 148 and 149.) Early in 1958 DOD released $5.2 million of the $7.4 million for this purpose.

the project is contemplated. We are, therefore, in agreement with such a reduction. ***

"We feel that the present plan is too strongly oriented towards achieving operational aircraft at an early date, at the possible expense of insufficient emphasis on research and development aspects. This leads to tight scheduling, insufficient backup of vital items, such as the reactor development, and to rigidity in long-range planning. ***"

The Assistant Secretary of Defense, Engineering, recommended to the Secretary of Defense in October 1956 that:

1. The scope of the nuclear-powered supersonic aircraft system be changed to that of a research program, oriented to realize the radical improvement necessary to make a nuclear-propelled aircraft system which was a major advance over a chemically powered aircraft system.

2. All phases auxiliary to the demonstration of reactor feasibility be deferred, i.e., engines and unessential facilities.

3. As the success of the above research activities warranted, system studies and engineering feasibility determinations be made to establish whether a nuclear-powered aircraft would be a major advance over a chemically powered aircraft.

4. Further development of a nuclear-powered aircraft for service use be deferred until research, component development, feasibility, and system studies all indicated concurrence that nuclear propulsion should be employed.

In December 1956 the Assistant Secretary of Defense, Research and Development, advised the Secretary of Defense that:

"For some time there has been a growing concern from both technical and fiscal aspects that the ANP program must be substantially reoriented. *** It appears now that the probability of attaining the high performance desired in the 125A [Weapon System], in the originally established time period is almost nil. ***

"*** In view of both budget and manpower limitations for research and development, the program for accomplishing a nuclear powered aircraft should be examined critically. Accordingly, this Office has been conducting reviews of the ANP programs of both the Navy and Air Force.

"It is presently concluded that neither the Navy nor Air Force program is acceptable. In their stead I propose an alternate program having the immediate objective of providing the technical feasibility of nuclear propulsion. The ultimate nature of the Weapon System to which this type of propulsion is applied should be determined on the specific requirements and aircraft capabilities available at the time the propulsion system has been proven. This reoriented ANP program should therefore take the following general form:

"a. The principal effort of the program for the next several years should be directed to develop and prove the reactor-engine propulsion system.

"b. Efforts on airframes should be restricted to general feasibility studies until the above has been accomplished, at which time work on a prototype aircraft should be initiated.

"c. A vigorous program should be conducted to obtain basic information on shielding problems and the effects of radiation."

Cancellation of the Weapon System 125-A program

After a meeting of officials in DOD and the Bureau of the Budget with the President of the United States in December 1956, the Weapon System 125-A program was canceled. In referring to the cancellation, the Chief, ANPO, stated in July 1959 that:

"Turning now to those mission areas which appear economically justifiable, in 1955, general operational requirements No. 81 was promulgated by the Air Force. This requirement called for a nuclear-powered strategic system in which the vehicle would cruise at subsonic speeds on nuclear power alone, but would be capable of a high-altitude supersonic dash by augmenting the nuclear thrust with chemical fuel. A program to meet this requirement was initiated in weapon systems 125-A. When detailed design of reactors meeting these requirements were underway, certain limitations in the physical properties of available materials were encountered which resulted in an unacceptable reduction in predicted system performance. To be more specific, the predicted dash radius became less than desired and predicted aircraft weights became greater than desired. These limitations indicated the need for further basic materials development (structural, fuel element, and moderator materials) before reactors meeting the criteria of general operation requirement No. 81 could be

produced. It appeared, therefore, ill advised to continue a full weapon system development program to meet this requirement until further advances in the reactor art could be achieved."

GE was informed in a joint letter from the Air Force and AEC in February 1957 that the Air Force forecast performance of the GE nuclear propulsion system did not provide sufficient promise to justify a continued weapon system program leading toward its use in the cruise-dash-cruise mission. GE was informed also that the Air Force was not prepared at that time to sponsor a weapon system permitting reduced propulsion system performance objectives.

During the time that the Weapon System 125-A program was in force, GE set up and checked out a complete mock-up of the reactor control system. GE also started a series of Heat Transfer Reactor Experiments (HTRE)[1] at the AEC National Reactor Testing Station. Initial criticality--first nuclear chain reactor--in HTRE No. 1 had been achieved in November 1955, and during January 1956 the engine in HTRE No. 1 was operated on heat supplied exclusively from the reactor. GE also essentially completed the preliminary design study on an engine for the Weapon System 125-A program.

Studies by GE during this period on different reactor-engine configurations for the power plant for the weapon system airplane led to the conclusion that the one-reactor, two-engine package offered the best propulsion combination of good thrust-to-weight ratio and features which could be developed adequately with maximum certainty. The official designation XMA-1 was established for the initial power plant. The engines for the XMA-1 were designated the X-211. The propulsion system for one airplane was to consist of two XMA power plants. Toward the end of this period, XMA power plant development was continuing with analytical and experimental evaluation of the performance of various power plant components.

Convair essentially completed the nuclear test airplane (formerly called the shield test airplane, see p. 128). The first flight of the airplane when the Aircraft Shield Test Reactor (see p. 131) went critical was made in September 1955, and the first airborne experiments were made the following February.[2]

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[1]The HTRE test assembly consists of a reactor connected to turbojet engines, together with auxiliary systems.

[2]The nuclear test airplane flight test program was completed with flight No. 47 in March 1957.

EXPERIMENTAL DEVELOPMENT PROGRAM--NO FLIGHT OBJECTIVES--January 1957-March 1957

The period following the cancellation of the WS-125-A program appears to have been one of uncertainty. The ANP program was reoriented to an experimental development program, but long-term objectives were lacking.

Reorientation

No flight objectives were established for the reoriented program. Work on both the indirect and direct cycle propulsion systems continued, but emphasis was placed on the latter.

The direct cycle was reoriented toward developing a propulsion system on an extended time schedule with increased emphasis on higher performance and engineering refinements. The program, as in the past, consisted of the development of materials and components and a series of reactor experiments. The X-211 engine development was to be an experimental turbojet development capable of supporting requirements of the reactor development program, and no plans were made to carry the engine to production qualifications.

The work of P&W and the Oak Ridge National Laboratory on the indirect cycle was reoriented toward developing, on a delayed time schedule, an aircraft reactor of higher performance than could be achieved by "across-the-board" application of Aircraft Reactor Test technology. (See p. 130.)

At the request of the Air Force and AEC, P&W completed preliminary studies of indirect cycle power plant characteristics required to substantially improve performance of nuclear-powered weapon systems over that performance offered by the current power plant designs. P&W stated that it immediately became apparent in the course of these studies that any significant improvement would require a reduction in weight of the power plant, which dictated a single reactor system. To attain this reduction, P&W terminated work on the twin reactor concept in the beginning of 1957. Work had been initiated on this concept in mid-1956 when technical difficulties concerning reactor structural material were encountered with the single reactor concept.

AEC gave P&W freedom in determining the relative emphasis on research and component development as between the circulating-fuel and solid-fuel reactor concepts, with the immediate objective of selecting one of these concepts for initial reactor construction and operation. However, fabrication of a reactor was not authorized by AEC.

Early in 1957, P&W initiated investigations of high-performance single reactor turbojet power plants for use in a

cruise-dash bomber and in an all-nuclear supersonic bomber. These studies included both circulating-fuel and solid-fuel reactors.

General support work at the Oak Ridge National Laboratory continued.

The Air Force advised Convair and Lockheed to immediately reduce their efforts to weapon system design studies and general radiation effects research.

Review group

The Air Force Scientific Advisory Board reviewed the ANP program in January 1957 and recommended less emphasis on engine and airframe development and more emphasis on reactor research and development.

Program guidance

During February 1957 the Research and Development Subcommittee of the Joint Congressional Committee on Atomic Energy advised the Secretary of the Air Force that the Committee believed it important to give the program a definite objective to aim for, a sense of organized planning beyond fiscal year 1958, and a more effective administrative organization to lend impetus to the entire effort.

EXPERIMENTAL DEVELOPMENT PROGRAM--FLIGHT OBJECTIVES--April 1957-February 1958

The program was essentially an experimental development program but was not fully geared toward flight objectives until near the end of the period.

Establishment of flight objectives

Flight objectives were mentioned in April 1957 when the Air Force replied to the February 1957 letter from the Research and Development Subcommittee of the Joint Committee on Atomic Energy. In summary, the Air Force stated that:

1. The basic objective in the ANP program was the achievement of an initial operational capability with nuclear-powered strategic bombers during the period 1966 to 1969.

2. Ground test of a prototype direct cycle propulsion system would occur in 1962 and that first experimental nuclear-powered flight was then visualized as occurring late in 1963 or in 1964.

3. Ground test of a prototype indirect cycle propulsion system was tentatively estimated for 1963 or 1964.

In May 1957 a joint AEC-Air Force letter gave GE guidance pertaining to the objectives as outlined to the Subcommittee and stated that, until the program was formally approved, AEC activities should be guided by the comments in the letter but that, with regard to the Air Force activities, the comments were intended as guidance for preparation of the GE contract continuation proposal for the contract year commencing October 1, 1957. GE submitted various program proposals, but it was not until November 1957 that one was found to be acceptable at which time the Air Force portion of the program was reoriented toward flight objectives. (See pp. 54 to 57.)

Various review groups

The Littlewood Group[1] issued a report in April 1957 on its review of the ANP program. The report, in part, stated that:

> "The aircraft nuclear propulsion program has been and continues to be one of the most technically complex and expensive research and development efforts of the

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[1]Ad Hoc Study Group appointed by the Assistant Secretary of Defense (R&D) to review the ANP program.

> Department of Defense. The Group's investigation has shown instances of needless duplication and lack of firm decision and direction in the program. It is apparent that there must be strong coordinated supervision and continuous examination of efforts undertaken and results achieved. Therefore, the Group recommends the prompt establishment of over-all direction within the Office of the Secretary of Defense for the control and coordination of the entire ANP program. The direction should assure that full consideration is given to the ANP requirements of both the Navy and Air Force.
>
> "The potential advantages of inherently unlimited range and endurance of nuclear-powered aircraft justify a substantial ANP research and development program covering all related phases of nuclear-powered flight. However, the technical problems involved in the development of an ANP supersonic strategic aircraft delivery system are of such magnitude that it appears most unwise to plan on the availability of such a system for operational use by any specific date."

The report stated further that: (1) the development of a subsonic nuclear aircraft should be the immediate objective of the ANP program, (2) there was adequate justification for continuing both the direct- and indirect-cycle approaches to the ANP program but that at that time substantially greater emphasis should be placed on the direct-cycle approach, (3) in view of the known contamination hazards, ANP test runways should not be constructed at NRTS, Edwards Air Force Base, or similar active bases, (4) the facilities planned or sought for research on radiation effects and shielding appeared to be considerably in excess of the needs of the proposed ANP program, and (5) the Nuclear Aircraft Research Facility at Convair should be held to current capacity and capabilities and the Georgia Nuclear Laboratory at Lockheed should be discontinued unless considerations other than the ANP program dictated its continuation.

The Canterbury Board[1] concluded in May 1957, in part, that (1) within the present state of the art, a nuclear-powered aircraft could not be built to meet the Air Force General Operational Requirement (GOR) No. 81 (see p. 133) and (2) a low-level all-subsonic weapon system was more feasible than a weapon system with a high altitude supersonic dash capability. The Board recommended, among other things, that the ANP program be assigned a stable program status for the next 4 or 5 years with major emphasis on reactors.

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[1] A board of officers appointed by the Air Research and Development Command, Air Force, to evaluate the nuclear aircraft program.

In June 1957 the Mills Panel[1] reported that the General Operational Requirement for ANP (GOR No. 81) was not possible within the present state of the art and should be rewritten to reflect more realistic objectives. The Panel recommended, among other things, that GOR No. 81 be modified to provide for a nuclear-powered flight in a suitable test aircraft as the immediate objective and that the reactor program be so oriented as to permit the early fabrication and flight testing of a prototype propulsion plant by 1962 or 1963, with the direct cycle being considered for the first nuclear flight.

Cutback of indirect cycle work

During October 1957, the Air Force and AEC considered the disposition of the P&W program as part of the over-all ANP program. As a result, the AEC work at P&W and the Oak Ridge National Laboratory was reduced and the Air Force operating contract at P&W was terminated.

During the preceding several years, emphasis on the indirect cycle had been given to the circulating-fuel reactor, with the primary development effort centered on the Aircraft Reactor Test at the Oak Ridge National Laboratory. In June 1957, P&W recommended that, if funding limitations dictate that one of the reactor development programs be eliminated, no further support be given to a circulating-fuel reactor. P&W stated that, based on advances in materials and coolants technology, the results of design and performance studies indicated the potential performance of the solid-fuel reactor propulsion systems to be superior to potential performance of circulating-fuel reactor propulsion systems. After considering the relative merits of the two reactor concepts, AEC canceled work on the circulating-fuel reactor in October 1957 and the P&W-ORNL relationship was terminated.

AEC stated that the primary consideration in making a reactor selection in October 1957 was that the funding level would not support more than one development effort on the indirect cycle program. AEC stated further that it recognized that a calculated risk was involved regardless of which reactor concept was selected but that the solid-fuel reactor exhibited certain important advantages over the circulating-fuel reactor and therefore the solid-fuel reactor was the only one of the two reactors that offered a potential at that time for possible supersonic flight on nuclear power alone.

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[1]Ad Hoc Panel of General Officers appointed by the Assistant Deputy Chief of Staff, Development, Air Force, to review the entire ANP program.

All work on the Aircraft Reactor Test was canceled in October 1957. Design, shop drawings, and much of the component testing and fabrication of the ART had been completed at the time of cancellation. All outside contract work on the facility in which the ART was to operate had been completed. The ART was placed in standby condition pending a determination of its usability for other purposes. An Engineering Test Unit (ETU), the nonnuclear prototype of the ART, was being fabricated and assembled. This work was also terminated. About $48 million was spent on the circulating-fuel reactor by P&W and the Oak Ridge National Laboratory. This included operating costs of about $16.7 million for the ART and ETU and about $1.6 million for the ART facility.

Between August and October 1957, the Air Force withdrew its support of the work at P&W. The Air Force continued to provide for capital improvements and abnormal maintenance costs, and AEC provided for normal maintenance and operating costs of CANEL. ANPO advised us that the Air Force contract termination was due to engine availability in other non-ANP work at P&W and that the only Air Force work on the ANP program required at P&W at that time to keep pace with the AEC reactor work was on radiator development which by agreement between the two agencies was carried on by AEC. In October 1957, P&W moved the ANP activities to the newly constructed Connecticut Aircraft Nuclear Engine Laboratory facilities.

After work on the ART and ETU was terminated, the Oak Ridge National Laboratory generally directed its efforts in support of the ANP work at GE and P&W. The major fields of effort were sheilding, materials research and development, and investigation of reactor components and of systems designed for nuclear propulsion of aircraft.

The AEC contract with P&W that was to expire on September 30, 1957, was extended for 3 months--to December 31, 1957--and AEC authorized a limited amount of research and experimentation on the solid-fuel reactor. On December 13, 1957, the Director of the AEC Division of Reactor Development requested the AEC General Manager to approve an extension of the P&W contract, stating, in part, that:

> "Recognizing that the circumstances which have made it necessary to defer a positive decision on the Pratt & Whitney program and contract for the past several months have had a decidedly adverse effect on contractor progress and morale, your early action in approving this contract extension will be appreciated."

In December 1957, the AEC-P&W contract for the continuation of work on the solid-fuel reactor was extended through September 1960.

Congressional Subcommittee appeals to the President

In October 1957 the Research and Development Subcommittee, Joint Committee on Atomic Energy, made a direct appeal to the President of the United States to lend the necessary initiative and support to the ANP program.[1] The Subcommittee stated that:

> "Recent events including the launching of an earth satellite by the Soviet Union have lent urgency to the longstanding need for the United States to develop a flying capability in the field of nuclear-propelled aircraft. ***
>
> "Speaking frankly, Mr. President, the ANP program since its inception has suffered from a lack of incentive and initiative on the part of those who have been charged with the responsibility of conducting the program. It has also been characterized by the lack of any well-defined future objective, including target dates for completion, and has not had the kind of well-coordinated and centralized direction which is necessary for the successful achievement of such an extremely difficult research and development task."

Review group on ANP hazards

In November 1957, an Ad Hoc Committee on ANP hazards was appointed by the Deputy Secretary of Defense, in agreement with AEC, to provide "advice and guidance on the hazards to be anticipated in the operation of nuclear-powered aircraft and the measures to be taken in the public interest in relation thereto." The Committee's report, issued in December 1957, stated, in part, that during initial phases of development and testing in time of peace there should be no nuclear-powered flights over the continental United States with the reactor in a condition which would allow the escape of a significant amount of fission products in the event of a crash. The report stated further that nuclear-powered flights should be conducted over the ocean and, therefore, that a coastal or island base with appropriate exclusion area was considered necessary.

Navy proposed "Princess" program

In December 1957 the Navy proposed a program for developing a turboprop propulsion system for installation in a British "Princess" flying boat to meet the national objective of early nuclear

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[1]For the President's reply in March 1958, see p. 152 and 153.

flight. The Navy proposal was most unacceptable to the Air Force. The Air Force stated that it was not in a position to question the Navy's requirements for an aircraft of this type, nor would it be appropriate for the Air Force to do so; but the Secretary of the Air Force pointed out to the Deputy Secretary of Defense that:

> "The first point the Air Force desires to raise is one of timing. The turboprop propulsion system proposed by the Navy is at the present time a preliminary paper study only. While the Air Force would not propose to question the ability of the contractor, in due course, to produce such a propulsion system, the system has not reached a hardware state of development as has the turbojet system. While the Navy has referred to the lower reactor power as reflecting an easier and earlier development program, the reactor they propose merely requires a fewer number of fuel passages within the reactor. The problems of materials, heat transfer, power distribution, power density, mechanical integrity and controls are of the same order of magnitude as those confronting the turbojet system. The problem of controls in the turboprop system is considerably more difficult and complex than the turbojet system and has not yet been engineered even on a preliminary basis. Finally, no test stand or test facility exists for a nuclear turboprop propulsion system test."

The Secretary of the Air Force stated also that a portion of the technical problems cited could be reduced in magnitude by retaining large core size while operating at considerably reduced power but that there would be additional radiation problems involved in the Navy approach. The Secretary stated further that it was the Air Force's firm conclusion that the only way the turboprop propulsion system could possibly be brought into being in advance of the turbojet propulsion system was to curtail or stop the development on the turbojet propulsion system since the Navy contemplated utilizing the same contractor (GE).

The Air Force Secretary stated that the Air Force interposed no objection to the Navy proposal provided the Navy funded its own program and employed a separate propulsion system contractor, such as P&W, or utilized GE capability on a nonpriority basis without interference with the GE turbojet development.

To finance additional studies of the "Princess" programs, DOD released $3.2 million of the $7.4 million that had been withheld. (See pp. 137 and 138.)

Air Force recommended accelerated program leading to early flight

In December 1957 the Secretary of the Air Force advised the Deputy Secretary of Defense that:

> "The Air Force urges that the Department of Defense strongly recommend to the President that approval be given to accelerate the Air Force ANP Program leading to early nuclear flight in a KC-135 or similar type aircraft using the XMA turbojet propulsion system to: (a) Meet the Air Force requirements, (b) to achieve the national objective of early nuclear flight."

The Secretary also stated that the Air Force had not defined explicitly the military characteristics of the manned bombardment weapon system, as to whether it would be high altitude supersonic, subsonic low-level bombardment, or missile-launching aircraft, nor did the Air Force believe it expedient to do so until the performance, shield, and weight characteristics of a nuclear propulsion system could be more accurately defined. The Secretary stated that it was mandatory, however, that the Air Force nuclear propulsion system employ turbojet machinery for high subsonic speed and supersonic potential for maximum flexibility in the selection and operation of a manned strategic bombardment weapon system.

Accelerated program under consideration

In January 1958, DOD advised the Research and Development Subcommittee, Joint Committee on Atomic Energy, that consideration was being given to an accelerated program aimed at the early development of a nuclear aircraft. Shortly thereafter, the Subcommittee was advised that DOD was awaiting a review of an advisory committee appointed by Dr. James R. Killian, Jr., Special Assistant to the President,[1] before submitting recommendations to the President and that no action would be taken until completion of the review.

Air Force cites urgent need for ANP plane

Early in February 1958 the Air Force advised DOD that the Air Force had a firm requirement for a high-performance nuclear turbojet system and that such a system could also satisfy the Navy's long-range, high-speed, attack seaplane requirement. The Air Force strongly recommended that the nuclear turbojet system development proceed immediately on an accelerated basis to provide an early flight demonstration and that the Air Force develop a new, subsonic experimental nuclear-powered aircraft.

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[1] Dr. Killian appointed Dr. Robert F. Bacher as chairman of this committee in January 1958. The group was later reconstituted as the Department of Defense Ad Hoc Panel on Manned Nuclear Aircraft.

Review group disfavored accelerated program

Late in February 1958, the DOD Ad Hoc Panel on Manned Nuclear Aircraft submitted its views concerning the status and plans for the ANP program. The Panel agreed with the Canterbury Board (see p. 145) that within the present state of the art a nuclear-powered aircraft could not be built to meet the Air Force General Operational Requirement No. 81. They concluded, in part, that accomplishment of the proposed accelerated Air Force program schedule for first experimental flight in January 1962 using the direct cycle was very doubtful and recommended that major efforts be directed toward developing a reliable, high-temperature reactor suitable for flying. They recommended also that neither the Air Force nor the Navy accelerated program for early flight be implemented at that time.

Accelerated program disapproved

After a meeting with DOD and AEC officials, the President of the United States decided in February 1958 that an accelerated flight program would detract from the goal of achieving militarily useful aircraft and disapproved early flight proposals.

Other activities during period (April 1957-February 1958)

The major effort of GE during this period was on developing the XMA power plant and on conducting HTRE tests[1] at the AEC National Reactor Testing Station. Experimental and analytical evaluations of the design and performance of components for the first prototype of the power plant were made by GE.

Early in 1958, GE made an evaluation of a direct cycle nuclear-turbojet propulsion system proposed in a book published in the Soviet Union. The evaluation disclosed that the data appeared to be realistic and self-consistent but that there was no evidence indicating that the Soviet power plant was actually under development. Also early in 1958, the first chemical test operation of the engine (X-211) was performed.

During July and August 1957, HTRE No. 2 experiments were conducted. HTRE No. 2 further substantiated HTRE No. 1 experiment results and permitted the testing as inserts of full-size, advanced fuel elements, moderators, and structural components.

At the end of this period P&W was continuing its efforts on the solid-fuel reactor. The ultimate objective of the work was the engineering design and development of reactors suitable for use in an advanced aircraft propulsion system.

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[1]For definition, see footnote 1, p. 141.

DEVELOPMENT PROGRAM--FLIGHT OBJECTIVE IN MILITARILY USEFUL AIRCRAFT-- March 1958-October 1958

The major difference in the objective during this period and the objective during the preceding period appeared to be the designation of a subsonic aircraft.

Reorientation

The policy of the President of the United States, with respect to developing the nuclear plane, was summarized by ANPO in March 1958 as follows:

> "The objective of the ANP program is the early achievement of an operational military aircraft as opposed to an early nuclear flight demonstration having no military utility. Notwithstanding the importance of both of these objectives, they were believed to be conflicting in that the latter course would divert effort from attacking fundamental problems that must be solved in achieving a militarily important aircraft. Since the need for a high priority military aircraft was considered to override the significance of a nuclear flight demonstration, the program will continue to go forward as rapidly as it effectively can, placing major emphasis on basic problem areas such as materials and reactor development which must be resolved in achieving an operational capability. Developments in the program will be followed very closely in order to capitalize to the greatest possible extent on progress as it is achieved."

ANPO advised GE in March 1958 that the program objectives were defined as the earliest possible achievement of a prototype propulsion system for application to a low-level subsonic mission. The fundamental steps or milestones toward achieving this objective were further defined as the early nuclear ground testing of the first XMA propulsion system followed as closely as possible by the initiation of flight development testing of the XMA system. In July 1958, GE presented its revised program to ANPO and the reoriented program got underway.

The President replied to congressional subcommittee

In March 1958 the President replied to the appeal made in October 1957 by the Research and Development Subcommittee, Joint Committee on Atomic Energy. (See p. 148.) The President, in addition to expressing his current policy with respect to the development of the nuclear-powered aircraft, stated that:

"You also stressed the need for well-defined future objectives and completion target dates. The development of a nuclear propelled aircraft capable of military missions has always been the prime goal of this program. This objective is clearly understood by all engaged on the project. Because the program requires development of new materials and techniques beyond the present state of knowledge, the specifying of dates for completion of these endeavors must be somewhat arbitrary and therefore may be unrealistic."

Navy participation at P&W

The Navy awarded a study contract to P&W in April 1958 for the preparation of reports on preliminary power plant characteristics of several nuclear propulsion systems and on the suitability of specific aircraft nuclear propulsion systems for application to military missions. The contract authorized P&W to use the Connecticut Aircraft Nuclear Engine Laboratory for this work on a no-charge-for-use basis.

Strategic Air Command proposed CAMAL

In June 1958 the Strategic Air Command proposed an operational requirement for a Continuously Airborne Missile-Launcher and Low-Level Weapon System (CAMAL). (See p. 155.)

Competition for development of system to meet CAMAL requirements

During August 1958 the Air Force awarded contracts to both Convair and Lockheed. After performing the work outlined in the contracts, the contractors were expected to propose to the Air Force a development program for two aircraft together with the technical management approaches, known solutions, and procedures considered necessary to accomplish the ANP development objectives through 2 years of nuclear flight test. These development aircraft were to be prototype vehicles of an airborne alert, missile-launcher, and low altitude penetration weapon system (CAMAL) for the Strategic Air Command in the 1965-75 time period. After the Air Force evaluation of the proposals, one contractor was to be selected for developing a system to meet the CAMAL requirement. In October 1958, Headquarters, United States Air Force established a requirement for the CAMAL mission. (See p. 155.)

The contractors completed their work about October 1958 and the following month presented their briefings to the Air Force. The Air Force did not announce that Convair was the winner of the

competition until March 1959. (See p. 158.) Convair received a contract to work with GE on an initial design of a nuclear-powered bomber prototype; however, it did not receive approval for the airplane development program. The CAMAL program was phased out in July 1959 when the ANP program reverted to a research and development program.

Secretary of Defense did not support the "Princess" Program

The Navy conducted detailed studies of the "Princess" program, under contracts with GE, P&W, Convair, Saunders Roe, and the Martin Company, during the time the ANP program was directed toward the development of a subsonic airplane. In October 1958 the Navy reaffirmed its position on the "Princess" program (see pp. 148 and 149) and advised the Secretary of Defense that recent studies confirmed the feasibility and desirability of utilizing the "Princess" seaplane for the purpose of an initial development aircraft effort. The Navy considered an early flight aircraft development program essential in achieving long-range ANP objectives and proposed that a program of this type be initiated immediately. The Navy estimated that the program could be completed through nuclear flight test over a period of 5 years and that the total cost would be about $200 million, including AEC costs of about $75 million.

Since no formal reply was received by the Navy, the Secretary of Defense apparently did not support the Navy proposal for the "Princess" program.

Other activities during period (March 1958-October 1958)

During this period GE continued work on the XMA power plant and on the HTRE tests.[1] In support of GE's activities, Convair conducted shielding materials tests and developed more adequate techniques for integrated aircraft shield system design.

Low power testing of HTRE No. 3 started during this period. This HTRE, unlike the two previous HTREs, employed a horizontal configuration as would be required for flight purposes.

During this period, P&W continued studies of power plants for supersonic bombers. A critical experiment designed to define the nuclear characteristics of a 10-megawatt solid-fuel reactor (lithium cooled) was performed in October 1958. Investigation continued on design and testing of other components external to the reactor.

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[1]For definition, see footnote 1, p. 141.

limitations precluded parallel major testing and large-scale hardware developing of more than one type of advance core, and the metallic core could be ground tested earlier than the ceramic core.

During the period when the ANP program was geared to a development effort for CAMAL, P&W continued its studies of nuclear power plants for supersonic bombers and studies were made on power plants for a low-level missile. Power plant and missile studies were expanded to include the application of these power plants to a high subsonic speed, low-level bomber and missile launcher.

Air Force requested funds for expanded program

The Air Force submitted its fiscal year 1960 budget program to DOD in October 1958. A total of $146.7 million was requested to support an expanded ANP development program leading to nuclear flight testing, consisting of $101.5 million for expanding the propulsion effort to include flight qualification of the direct cycle XMA power plant and $45.2 million for initiating development and fabrication of two experimental flight test airplanes and initiating a reactor test facility at the Connecticut Aircraft Nuclear Engine Laboratory.

Department of Defense disapproved expanded program

After DOD reviewed the budget between October 1 and November 27, 1958, program expansion to include flight testing was disapproved and program objectives were restricted to reactor development with enough turbomachinery and other support work consistent with such objectives. The funding level for the Air Force was established at $75 million for fiscal year 1960.

Status of program early in 1959

In January 1959 representatives of DOD, Air Force, Navy, and AEC testified on the status of the ANP program before the Joint Committee on Atomic Energy. The Committee was informed that both the Air Force and the Navy had established requirements for nuclear-propelled aircraft. Representatives of both Air Force and AEC stated that their agencies recommended increases in their 1960 funds for a flight program but the recommendations were not approved. The Chief, ANPO, estimated that budget cutbacks would result in a delay of about 1 year in achieving a ground test prototype and confirmed that no decision had yet been taken on a flying program.

The Secretary of the Navy advised the Secretary of Defense in January 1959 that, in recognition of the long-range potential of the indirect cycle system and its relative development status in comparison with the direct cycle system, the Navy was willing and

ready to concentrate its current ANP efforts on a joint AEC-Navy nuclear propulsion system development program with P&W at the Connecticut Aircraft Nuclear Engine Laboratory. The Secretary of the Navy stated further that arrangements had been made with P&W to implement the initial phase of this program in 1959 and that the Navy was prepared to provide necessary fiscal support.

Joint Committee on Atomic Energy criticized program

After a series of hearings in executive session by the Research and Development Subcommittee of the Joint Committee on Atomic Energy,[1] the Joint Committee released certain information in February 1959 regarding holdups in the ANP program and the need for a greater level of support for the ANP program. The committee commented that:

> "The results of these hearings have left us gravely concerned, both from the point of view of our national security and from the standpoint of world confidence in America's scientific capabilities.
>
> "After twelve long years of effort, during which time substantial technical progress has been made by our hardworking scientists and engineers in the field, we find this almost incredible situation:
>
> > "1. The program still has no firm set of objectives looking toward the development of a nuclear propelled aircraft;
> >
> > "2. No decision has been made regarding actual nuclear flight and no target dates have been set for such flight;
> >
> > "3. Recommendations of the project director as to funding levels required to get the job done have been virtually ignored;
> >
> > "4. It is authoritatively estimated that cuts in proposed funding levels for the program in Fiscal 1960 will delay the achievement of a ground test prototype for an additional year and will thereby delay achievement of nuclear flight for at least that period of time;

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[1] Witnesses at the hearing included the Deputy Secretary of Defense, the Secretary of the Air Force, the Secretary of the Navy, members of the Atomic Energy Commission, and the Chief, ANPO.

"5. Administrative indecision at high levels and inter-service rivalries have plagued the program from the start and have rendered a great disservice to the nation;

"6. No less than seven advisory committees have been set up in the past decade to review the program, including the so-called Killian Committee, and yet the contractors in the field still have no clear guidance as to where they stand or where the program is going;

"7. The annual expenditure of $150 million for the ANP program as a holding operation to avoid difficult technical and administrative decisions which must be made to lend clearcut direction to the program is a completely indefensible use of the taxpayers' money;

"8. The Air Force and the Navy, after due consideration by their expert military advisers, have established firm requirements for nuclear propelled aircraft. The Air Force and AEC both recommended an increase in their own fiscal 1960 budgets for the program to back up these requirements, but have been turned down."

Convair won design competition

As a result of design competition between Convair and Lockheed, initiated under contracts awarded in August 1958 (see pp. 153 and 154), the Air Force in March 1959 announced the selection of Convair. Convair was to work with GE in the initial design of a nuclear-powered bomber prototype. The selection did not imply immediate implementation of an airframe fabrication program nor did it imply approval of the development airplane program.

Lockheed was to continue limited design work on a nuclear-powered airplane and to operate the Georgia Nuclear Laboratory for radiation effects experiments in support of the over-all nuclear propulsion program.

Navy initiated development work on indirect cycle propulsion system

In March 1959 the Navy informed the Air Force that the Navy was contemplating supporting an aircraft nuclear propulsion component development program with P&W, but that performance of the proposed program was subject to Air Force approval of the use of the Connecticut Aircraft Nuclear Engine Laboratory facility. Accordingly, the Navy requested approval for the use of the facility in

carrying out its proposed program. The Air Force replied in March 1959 that it would be impractical to comment either affirmatively or negatively to the request but that it would give the matter prompt constructive consideration. The Air Force pointed out that research accomplishments of P&W had progressed more rapidly than anticipated and stated that it was currently reviewing the impact of the accelerated progress. The Air Force pointed out also that the terms of its facilities contract with P&W restricted utilization of the CANEL site and facility to that for which the facility was established and that other usage was to be authorized only to the extent that there would be no interference with the basic objectives of the facility.

In March 1959, DOD advised AEC that it had approved Navy's direct participation in developing an indirect cycle system for turboprop application, subject to such arrangements as were necessary to insure resolution of any conflicting interests which might arise in the joint use of governmental and contractor facilities and to insure maximum efficiency in the utilization of funds and personnel. However, DOD advised the Air Force and the Navy during April 1959 that implementation of the initial phase of the Navy program through application of fiscal year 1959 funds had been held up pending determination of the feasibility of the joint use of the Connecticut Aircraft Nuclear Engine Laboratory facilities in the prosecution of Air Force and Navy programs, which appeared to have basically different objectives. ANPO stated that there was a difference between the Navy and Air Force indirect cycle requirements in that the Navy low performance reactor would use sodium, while the Air Force requirements called for higher performance based on a lithium heat transfer system. ANPO stated further that these two different subsystems would require different development programs and test facilities, necessitating program and facility capability review prior to agreement on the acceptability of conducting both programs at CANEL. DOD stated in April 1959 that it was infeasible to establish at that time a firm program extending through experimental reactor and prototype propulsion plant development because such a course of action would require a change in the basic ANP objective approved by the President of the United States. DOD stated further that a decision had not been reached, from the standpoint of public safety, as to the feasibility of constructing either an experimental or a prototype reactor at the Connecticut Aircraft Nuclear Engine Laboratory nor had formal AEC agreement to undertake the development of either reactor been obtained. Pending a resolution of the above matters, DOD requested that, in order for the first phase of the Navy program to be initiated without delay, the Air Force and Navy cooperate in developing plans and making suitable arrangements for the proposed use of the facility.

ANPO agreed in June 1959 to make the Connecticut Aircraft Nuclear Engine Laboratory available to P&W for development work of the Navy, provided that, among other things, priority would be

given to development work of interest to the Air Force. A lithium-cooled reactor experiment was considered by ANPO as the initial reactor development step leading toward the Air Force objectives. ANPO stated that, should DOD and AEC approve development of an intermediate power indirect cycle propulsion system of Naval application, this would be considered as contributory to the present high-performance objective of the Air Force, provided a lithium-cooled reactor was utilized.

In June 1959 the Navy amended the study contract that had been awarded to P&W in April 1958. The purpose of the Navy study contract as amended was to carry on generalized development of those propulsion components external to the reactor shield assembly in parallel with the AEC-supported development of the reactor.

Prospects for direct cycle propulsion system

In April 1959 GE stated that studies indicated that the basic XMA-1 power plant was suitable for the CAMAL mission. Studies by both Convair and Lockheed on the CAMAL airplane based on design objectives for the XMA-1C[1] power plant indicated the possibility of attaining such an airplane. GE proposed that, after the airplane had been checked out on chemical power plants, the XMA-1A[2] would first be tested, to be followed by testing of the XMA-1C power plant.

On June 19, 1959, the General Advisory Committee[3] reported that:

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[1]Expected to use an advance fuel element of iron-chrome-aluminum or a ceramic material. The turbine inlet temperature was expected to be 1700° F., producing about 42,000 pounds of thrust at static sea level conditions.

[2]Planned to operate with nichrome fuel elements at a turbine inlet temperature of about 1500° F, producing about 26,000 pounds of thrust at static sea level conditions. As a consequence of a program reorientation in July 1959, work on the XMA-1A powerplant was canceled in August 1959.

[3]Established by the Atomic Energy Act of 1946, as amended (42 U.S.C. 2036), composed of nine members appointed from civilian life by the President of the United States to advise the AEC on scientific and technical matters relating to materials, production, and research and development.

"The work by General Electric has now reached the point where it appears likely that fuel elements can be developed which will be capable of making the performance of the direct cycle reactor high enough to be useful for propulsion of military aircraft.

"If the Department of Defense is in favor of proceeding with this system, then the Reactor Subcommittee recommends that the necessary steps be taken to develop the XMA powerplants by General Electric and these steps include provision for flight testing and demonstration of these propulsion systems as proposed by General Electric and Convair."

Guidance from Joint Chiefs of Staff

DOD received guidance from the Joint Chiefs of Staff on June 19, 1959. The Deputy Secretary of Defense summarized the guidance as follows:

"Briefly stated, the Joint Chiefs of Staff expressed their conviction that there is considerable military potential in the nuclear-powered aircraft and that early achievement of the capability for nuclear flight would be in the national interest. They stated, however, that they were unable at this time to establish a military requirement for nuclear-powered aircraft or to define the specific weapons system for which it would be used. With respect to the future course of the development program the Joint Chiefs of Staff advised that the present program should be extended to include flight test as soon as technically feasible. The test vehicle selected should be capable of testing any of the engines that may be developed and the program should enable the application of advances of reactor technology as they occur."

R&D PROGRAM WITH PRIMARY EMPHASIS ON HIGH-PERFORMANCE REACTORS--July 1959-March 1961

During this final period, the ANP program was on an R&D effort, with primary emphasis on high-performance reactors. The work on the direct and indirect cycles was directed toward major reactor experiments in the 1962-63 time period. At the conclusion of these experiments, one of the cycles was expected to be selected for further development and to be continued through a flight-test phase.

Reorientation initiated

On July 7, 1959, the Director of Defense, Research and Engineering (DDR&E),[1] advised AEC that DDR&E had completed a review of ANPO's proposal for expanding the ANP program to include early flight of the direct cycle XMA-1 power plant and of the various proposals to augment the indirect cycle work. DDR&E's conclusions were as follows:

"1. In general;

(a) There should be no specific flight program preparation at this time, and

(b) The indirect cycle work should probably be expanded to a greater extent than heretofore proposed.

"2. In particular; we should

(1) Emphasize the development of only such reactors (including other critical components such as heat exchangers, shields, etc.) as would be suitable for heating air to high enough temperatures to give useful military performance. This should hold for both the DAC (direct air cycle) and IDC (indirect cycle) versions.

(2) Continue the development of only such turbo machinery as may be necessary to establish the feasibility of nuclear propelled aircraft.

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[1]The principal adviser and staff assistant to the Secretary of Defense in the functional fields of scientific and technical matters; basic and applied research; research, development, test, and evaluation of weapons, weapons systems, and defense material; and design and engineering for suitability, producibility, reliability, maintainability, and materials conservation. He supervises all research and engineering activities in the Department of Defense.

(3) Defer plans for flight until:

a. One of the advanced power plants is established as definitely feasible and potentially useful, and

b. Until a flight program can be instituted without seriously interfering with the development of one of the advanced reactors. We believe that an early flight program at this time will seriously impede progress in functional reactor problems and may delay the final accomplishment of a useful nuclear airplane."

The DDR&E also requested the Air Force, with Navy participation, to work out with AEC a plan to implement the program along the lines indicated above.

On July 7, 1959, DDR&E forwarded its conclusions to the Deputy Secretary of Defense, the Secretary of the Air Force, the Secretary of the Navy, and the Chairman of the Military Liaison Committee[1] and stated that:

"In our opinion, no possible (within reason) ANP development program can lead to an operational capability which the military could depend on for important and useful missions before approximately 1970. Since no one can foresee what the military situation will be at that time, it is not possible to describe in any detail what ANP will be used for, although a number of disparate possibilities, including CAMAL, logistics, and ASW or AEW/C surveillance, have been proposed. Similarly it is not possible to 'prove' as is sometimes attempted, by means of cost effectiveness studies based on present requirements, that ANP is not useful. A recent paper of the Joint Chiefs of Staff, dated 19 June 1959, solidly supports this view, and states that while no definite military requirement can be stated at this time, the continued development of ANP is considered as very important and potentially very useful.

* * * * *

"It is our view that during most of the last 13 years and the expenditure of most of the $900 million, the ANP program has been characterized by attempts to find short

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[1]For explanation, see footnote 1, p. 59.

> cuts to early flight and by brute force and expensive approaches to the problem. Thus we find that only a relatively very small fraction of the funds and energies applied to this program has gone into trying to develop a reactor with a potentially high performance. Most of the resources have been applied to attempts to develop materials which could 'fly soonest'; to develop turbine machinery; to build facilities, many of which would only be needed in support of a flight program; to conduct experiments on the radiation resistance of tires, oils, insulation, electronic components, etc; and to develop new components for use in the unique environment which would be encountered only in the divided-shield situation as found in CAMAL and the old WS-125A. As a result of this approach to the problem we are still at least four years away from achieving flight with a reactor-engine combination *** which can just barely fly. We regard the ANPO proposal as being nothing more than an extension of the past philosophy into the future. ***"

P&W initiated reactor development program

The program reorientation did not significantly change the direction of the effort on the indirect cycle program, but increased emphasis was to be placed on that program. AEC authorized P&W to initiate in October 1959 an experimental high-power, high-temperature reactor program utilizing a solid-fuel (lithium cooled) reactor to be operated at the Connecticut Aircraft Nuclear Engine Laboratory facilities.[1] Plans were to operate this reactor at full temperature but at lower power (10 mw) as a component test leading to a subsequent integrated fuel power test of a propulsion system. That reactor program was under consideration, however, prior to the program reorientation and was rejustified under the reoriented program. Construction of the reactor was intended to determine the feasibility of developing high-temperature reactors (lithium cooled) for application to a variety of possible nuclear propulsion systems. The reactor experiment was scheduled for the first part of 1963. This was the first reactor to be built and operated by P&W after it began work on the ANP program in 1951, although it had participated at the Oak Ridge National Laboratory in the Aircraft Reactor Test that was canceled in October 1957.

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[1] In November 1959, AEC decided to conduct this reactor experiment at the AEC National Reactor Testing Station instead of the Connecticut Aircraft Nuclear Engine Laboratory.

Review group recommended initiation of flight test program and permanent review group

The ANP Ad Hoc Committee, Air Force Scientific Advisory Board,[1] issued a report on July 17, 1959, based on a review of the ANP program during June 1959. The committee recommended the initiation of a study of a test-bed aircraft for flight test purposes compatible with the direct and indirect cycle systems. The committee pointed out that the earliest flight test could be made in about 1964 by using the direct cycle system, with marginal nuclear flight performance. The committee pointed out also that the ANP program management might benefit from the services of a permanent "Technical Advisory Board" with responsibility for periodic review and advice to the Air Force on the conduct of the program. The committee stated that the contractors should be shielded from the harassment of continual reviews by new temporary committees and investigating bodies and that the field was too complicated for benefit to be derived from the inevitable superficiality of such brief contacts.

Joint Committee on Atomic Energy held public hearings on ANP program

Public hearings on the ANP program were held for the first time by the Research and Development Subcommittee of the Joint Committee on Atomic Energy on July 23, 1959. These hearings culminated 11 years of consideration and discussion of the ANP program by the Joint Committee in closed hearings. During these years the Joint Committee lent its active support to this project in recognition of the vital potential of nuclear energy for aircraft propulsion. A major point of controversy during the hearings was the question of so-called early flight. Proponents of the early flight concept pointed out that historically aviation development has occurred on a step-by-step basis and that, to begin with, prototype aircraft are always limited-performance vehicles. Advocating this approach were the Chief, ANPO, the Chief of Staff of the Air Force, the Chairman of AEC, the General Advisory Committee,[2] and the General Electric Company. Those opposing the early flight concept were principally the Deputy Secretary of Defense and the Director of Defense Research and Engineering.[3] The Deputy Secretary of Defense, in referring to conclusions of a study by the DOD Weapons

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[1]For explanation, see footnote 2, p. 127.

[2]For explanation, see footnote 3, p. 160.

[3]For explanation, see footnote, p. 162.

Systems Evaluation Group, stated that nuclear-propelled aircraft did not offer a substantial margin of improvement over chemically fueled aircraft. He added that propulsion systems constructed of materials that were essentially at hand at that time would fall short of chemically fueled systems of competitors. DDR&E expressed the view that an aircraft with a propulsion system utilizing available materials could not be a militarily useful vehicle and the particular power plant involved would have little or no growth potential. The Assistant Secretary of the Air Force for Material stated that budgetary considerations had played a substantial role in the decision not to proceed with a flight program at this time and that consideration of the availability of funds from the 1961 budget also influenced this decision. The Joint Committee stated that it was in the national interest to achieve nuclear flight as early as possible, not only to meet stated military requirements, but also to provide a boost to world confidence in America's scientific capabilities. The Joint Committee stated also that it was clear from the hearings and the history of the ANP project since its inception that there had been a lack of concrete objectives and target dates either for a ground test prototype propulsion system or for early flight. The Joint Committee pointed out the need for concrete objectives and firm target dates and a need to strengthen program direction. With respect to a possible alternative, the Joint Committee stated:

> "In view of statements by Department of Defense representatives that there is at present no general operating requirement by the Defense Establishment for a nuclear-propelled aircraft, and that the program, as it is presently constituted, is basically a research and development effort, the Congress may wish to consider the desirability of placing primary authority and responsibility for the conduct of the ANP program in the Atomic Energy Commission, which is well equipped to carry the program forward as a development effort through the flight feasibility and demonstration stage. Present cooperation with the Defense Department would be continued, under such an arrangement, but the primary emphasis of the program would be upon the development of a ground test prototype propulsion system and the flight testing of such a propulsion system in an experimental aircraft. Such an approach in the committee's opinion should prove out the feasibility of nuclear flight and would provide the basis for a judgment by the Defense Department on firm military requirements for a nuclear-propelled aircraft."

Department of Defense provided interim guidance to Air Force and Navy and suggested establishment of review group

On August 13, 1959, DDR&E provided the Air Force and the Navy with interim guidance for the ANP program and proposed establishing, at the DOD level, an ANP Ad Hoc Advisory Group for the purpose of refining the interim guidance, establishing long-term objectives of the program, and advising DDR&E of the program status. DDR&E stated that, until further refinement of the objectives of the ANP program could be made, the objectives of both the direct cycle and the indirect cycle programs should be to develop a power plant which could be used (either singly or in combination) to fly a plane similar to the Convair model 54 design (later designated the NX-2 airplane) at a speed of between Mach 0.8 and 0.9 at an altitude of about 35,000 feet, which would have a potential life of about 1,000 hours under these conditions. The monies programed by both the Air Force and the Navy were to be used for accomplishing these objectives. Inasmuch as the Air Force's and the Navy's objectives had not as yet been reconciled, the proposed Ad Hoc group was to find some way to include the Navy's objective of achieving a nuclear turboprop or turbofan power plant within the indirect cycle program but without creating dual development efforts, at least during the next few years, in such matters as reactor power levels and basic heat exchangers.

On September 9, 1959, DDR&E advised AEC that the Air Force and the Navy had been furnished with interim guidance and that it would be appreciated if AEC would accept this as the initial objective of the program. No target dates were indicated.

Need for the Georgia Nuclear Laboratory questioned

ANPO advised the Air Research and Development Command (ARDC) on August 13, 1959, that, in view of current DOD guidance and the disapproval of a flight development program for the immediate future, the necessity and the desirability of continuing to operate the Georgia Nuclear Laboratory (GNL) with manned ANP funds had been reevaluated. ARDC was advised by ANPO that it had been determined that GNL could not be supported at previously planned levels and that, except for a complete check-out of the Radiation Effects Reactor at the 10-megawatt level, subsequent support which could be expected from the ANP program would be very minimal until such time as a full-scale flight development program was approved. ANPO stated that, if ARDC's internal program coupled with those of other Government agencies and/or industrial efforts was not sufficient to fund and to justify continuation of the GNL operation, appropriate action would be taken to terminate the contract and close the facility.

AEC cited plans for fiscal year 1960

In a September 1959 letter to DDR&E, AEC summarized the general status of actions toward resolution and finalization of the ANP program for fiscal year 1960. AEC stated that (1) primary efforts would be placed on reactors having higher performance than that indicated for the XMA-1A[1] power plant, (2) work on advanced fuel elements and moderators would be accelerated with primary emphasis on ceramics, and (3) the direct cycle program would be reoriented toward the XMA-1C.[1] AEC stated further that the currently planned program at P&W for fiscal year 1960, containing a 10-megawatt experimental reactor as an initial feasibility step to higher power production, probably should not be increased to any appreciable degree. AEC stated also that it had taken note of DDR&E's memorandum of August 13, 1959, to the Navy and the Air Force and that the Commission considered that at that time a statement of some definitive objective was of great importance.

Decision of AEC concerning the AEC National Reactor Testing Station as flight-test base made known

In September 1959, AEC informed the Joint Committee on Atomic Energy and DDR&E that the AEC Commissioners had unanimously decided that the AEC National Reactor Testing Station (NRTS) was not to be used for an ANP flight-test base. The AEC Commissioners had decided in December 1958 that neither NRTS nor any other AEC installation was to be used for an ANP flight-test site.

The September 1959 letter to DDR&E was in reply to a July 1957 request from the Military Liaison Committee (MLC) that a decision should be made at an early date concerning the selection of a location for a runway suitable for testing the initial nuclear-powered aircraft. In the July 1957 letter, MLC stated that the Air Force-AEC agreement of June 1952 provided that flight-test facilities for initial nuclear flight testing would be constructed at NRTS. The letter stated also that congressional authorization had been obtained for the flight-test runway and that architectural and engineering work for the runway had been completed. The letter pointed out that a decision to locate the facilities at a site other than NRTS would necessitate further studies, would entail an appreciable additional expenditure of funds, and would probably delay the date upon which initial nuclear flight testing could be contemplated.

A review group in April 1957 had stated that ANP test runways should not be constructed at NRTS (see pp. 144 and 145), and another

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[1]For explanation of XMA-1A and XMA-1C power plants, see footnotes 1 and 2, p. 160.

review group in December 1957 had stated that a costal or island base was considered necessary for a flight-test base. (See p. 148.)

Reorientation of activities at Convair and Lockheed

The Air Force interim guidance in September 1959 provided that, because the redirection of efforts on the propulsion systems eliminated the requirement for initiation of airframe construction for 1 or more years, (1) the current design effort at Convair should continue to review and refine the design of the Convair model 54 airplane to be applicable to both the direct and indirect cycle power plants, (2) the nuclear support activities at Convair should be continued, (3) Lockheed's design efforts should be terminated at the completion of the contract period (September 30, 1959), and (4) the nuclear support contract of Lockheed should be renewed for a period of only 6 months.

AEC requested clarification of program objectives

With reference to DDR&E's interim guidance of September 9, 1959 (see p. 167), AEC made the following request of DDR&E in October 1959:

> "To assist us in our program planning, clarification is requested as to whether it is intended that each of these programs develop separate power plants to satisfy the singular aircraft performance objective or whether it is intended that only one of these programs be extended through the power plant development phase."

Status of program in November 1959

During November 1959, AEC reviewed the ANP program to determine whether or not it was practicable at that time to select a single reactor approach in providing a nuclear propulsion system to meet established DOD requirements. AEC decided that neither the direct cycle nor the indirect cycle had reached a stage of development where it could be preferentially selected with any degree of technical confidence. AEC summarized the status of the two cycles as follows:

> "Direct Cycle: The direct cycle program is assessed as being ahead of the indirect cycle in the engineering of components and reactor know-how. Reactors have been operated and a broad component test program is in being. Cycle simplicity is of a prime consideration. However, the requirement to achieve a minimum power plant weight is countered by the requirement for a large heat transfer area resulting in comparatively large reactor dimensions and consequent large shield dimensions and weight.

"Indirect Cycle: The indirect cycle program is on a par with the direct cycle in the development of high temperature materials required for reactor operation. The efficiency of liquid metal heat transfer allows a smaller core, less shielding weight and a lower over-all power plant weight. However, the reactor coolant has never been used in a reactor, the structural alloy is new and still under development, the Contractor has never built or operated a reactor, and the neutron energy of the reactor is in a relatively unknown spectrum."

AEC stated that, in view of the technical uncertainties involved, both the direct cycle and the indirect cycle programs had been oriented toward the experimental verification of the critical areas of uncertainty and that, upon completion of these reactor experiments in 1962 and 1963 together with the successful accomplishment of concurrent component tests, a cycle selection could be made with a greater degree of confidence.

Department of Defense directed the Navy to terminate development program

In December 1959, DOD reversed its position of March 1959 (see p. 159) and advised the Navy that it would not be to the best interests of the country to continue at that time with two parallel development programs, one responsive to Navy requirements and one responsive to Air Force requirements. DOD, therefore, requested the Navy to terminate its development program at P&W as soon as practicable but advised the Navy to continue to study the ANP program, and the possible Naval applications, in order to be alert to any technical developments which might make it desirable to reopen the question of continued active development support by the Navy.[1]

Air Force work resumed at P&W

In December 1959 the Air Force awarded P&W a new operating contract for design and performance studies of power plants for application to missile launching aircraft with low-altitude attack capability. The radiator work funded by the AEC after the Air Force work was terminated in October 1957 was transferred back under the Air Force contract.

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[1]In March 1960, the work under the Navy contract with P&W, together with corresponding funds, was transferred to the Air Force contract with P&W. This action ended Navy's active participation in the ANP program.

Report of ANP Ad Hoc Advisory Group
of Department of Defense

The Ad Hoc Group, proposed by DDR&E in August 1959 (see p. 167), issued its report about January 1960. Although the report could not be located by DDR&E, a part of the report was quoted in a letter to AEC from DDR&E, dated February 27, 1960. That part of the letter relating to the review group follows:

"On the question of propulsion system selection, the group stated:

'As has been indicated, there does not exist, at the present time, a sound technical basis for selection of either the direct cycle or indirect cycle power plant if one desires to expect without risk a flight date in the mid-1960's. Critical problems can arise in either case which could have significant effect on the development of the power plant. On the other hand, there do not appear to be fundamental limitations in either case, which could eliminate the possibility of ultimate successful accomplishment of the desired goals. Therefore, assuming that the achievement of manned nuclear flight in a reasonably early time period in an aircraft possessing an interesting military potential is deemed important, the best assurance can be provided by continuing, for the present, the dual approach. Both programs have been laid out with important milestones flagged. Continuation of the developments on the schedules suggested must be conditioned on a successful attainment of those milestones. They can also provide a basis for judgment as to whether, at some point along the way, one or the other cycle should be eliminated. However, there appears to be little opportunity to reach a complete engineering basis for selection prior to the completion of the advanced core test in the case of the direct cycle, and the operation of the ten megawatt reactor in the indirect cycle case. The total funding allocated to this program and the importance of the achievement of the flight goals must obviously be conditioned by consideration of priorities in competition with other programs. Ideally, it is felt that both cycles should be pursued until after completion of the critical tests outlined above, which should be achieved sometime in 1962. This would insure that the flight date goal can be anticipated with high confidence. If priorities and budgetary considerations are such as to suggest that considerable technical risks might be acceptable, it is of course possible to make a system selection at any of the milestones along the way. At the present time, the Group is of the opinion that the greater promise and utility

rests with the indirect cycle power plant and believes that this program should be accelerated.'

* * * * *

"The Group also made the following recommendations:

'1. The performance objectives of the interim guidance should be established as the initial objective of the ANP program. For the present and until the results of appropriately defined mileposts dictate otherwise, the development of both the DC and IDC power plants towards the achievement of this objective should be continued.

'2. If all milestones have been passed successfully, a decision should be made no later than early 1962 to continue development of only one system through flight test. This decision must be based upon an evaluation of the technical potential demonstrated by each system at that time.

'3. As knowledge and experience in the techniques of Aircraft Nuclear Propulsion advance, continuing studies should be made leading to a definition of militarily and economically effective weapon systems.'"

AEC received clarification of program guidance

On February 27, 1960, DDR&E answered AEC's request of October 1959 concerning clarification of plans for power plant development. (See p. 169.) DDR&E stated that its reply to the October 1959 letter had been delayed pending a report from an Ad Hoc Group formed to make a more complete study of ANP and to recommend future courses of action. The DDR&E stated further that:

"*** our aim in the ANP program should be to carry one, and only one, of the two power plant developments to the flight stage in the mid-1960's; but to continue with both the direct and indirect cycle approaches toward a relatively high performance plant until technical progress--or lack of progress--enables us to make a selection.

* * * * *

"*** Continuation of this program past 1962 will involve construction of a suitable test aircraft and the provision of an acceptable base for test flights. The current studies on radioactive fission product release and other reactor hazards are expected to provide reasonable and timely guidance in selecting a site for the test base."

The basis of this decision was a report from the Ad Hoc Group. (See pp. 171 and 172.) ANPO advised us in April 1961 that it had received no further guidance from DDR&E during the remaining time of the ANP program.

Georgia Nuclear Laboratory placed in standby status

The Air Force advised Lockheed to phase down the contract from the $3 million annual level of April 1, 1960, to a standby annual level of about $500,000 by October 1, 1960. Lockheed was advised also that a total of $750,000 was available for the phase-down operation and a complete check-out of the reactor at 10 megawatts.

The Air Force authorized Lockheed, beginning October 1, 1960, to operate GNL at a reduced level of $650,000 for 1 year.

Initiation of work on new direct cycle power plant configuration

GE and Convair completed a propulsion system configuration study in February 1960. The purpose of the study was to establish guidelines for research and development work, and the study was aimed at a detailed reevaluation of the XMA-1 two-engine propulsion system as opposed to a single-engine, single-reactor system. As a result of the study, GE recommended a single-engine reactor system and submitted a program proposal for its development. GE designated the new single-engine, single-reactor power plant as the P140E.

On July 7, 1960, ANPO approved a program, essentially based on a GE proposal for developing the P140E power plant. The power plant, including an Advanced Core Test (ACT) (a reactor/engine test in the integral, in-line configuration) to operate in 1962, was the primary objective of the direct cycle program. The program included, for planning purposes, a ground test power plant scheduled to operate in mid-1964 and, pending selection of the direct cycle for flight test, a flight test power plant scheduled for aircraft installation and flight by mid-1965. The P140E power plant concept was under development at the time the ANP program was terminated in March 1961.

Advanced Development Objective established for the ANP program

In November 1960, the Air Force established Advanced Development Objective (ADO)[1] No. 20, superseding GOR 81 and GOR 172. The ADO stated that the objective was:

> "A To develop a manned nuclear powered test aircraft with essentially unlimited endurance independent of in-flight refueling which will have the potential of adding a new dimension to the spectrum of manned flight. Due to the present state-of-the-art, the initial system will be limited to subsonic performance, however, the ultimate attainment of supersonic speeds on nuclear heat only is an objective of the program. The aircraft will be used to explore the feasibility and suitability of nuclear power for manned aircraft by studying (a) the performance and handling characteristics of nuclear aircraft, (b) the problems of carrying personnel and equipment for long flight durations, and (c) the problems of operations and maintenance.
>
> "B To provide a manned nuclear powered aircraft which can be used to investigate the operational problems and the applications of manned nuclear powered aircraft to various military missions."

Other activities during the period (July 1959-March 1961)

Between November 1960 and January 1961, GE completed the last phase of testing of HTRE No. 3 at NRTS. In the tests two turbojet engines were started and brought up to normal operating range on nuclear power alone, in contrast to previous HTRE experiments where engines were started with chemical fuel and, once they had obtained the operating range, were transferred to nuclear power.

The major effort of Convair during the period was directed toward design of aircraft compatible with either the direct or indirect cycle nuclear power plant.

The budget of the United States for the fiscal year ended June 30, 1962, submitted to the Congress in January 1961, provided

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[1] An Advanced Development Objective describes the general characteristics of a new effort designed to (1) fulfill an anticipated long-term operational requirement beyond present technical capabilities and/or (2) exploit a significant technological advancement with a potential military application.

for about one half the funds that had been requested for the preceding fiscal year and stated that the ANP project could be carried at a lower funding level than had been programed in previous years, as work was to be continued on one propulsion system. The budget did not specify, however, whether the direct or indirect cycle propulsion system should continue.

TERMINATION OF THE ANP PROGRAM--March 1961

President recommended the termination of the ANP program

The message on national security, transmitted by the President of the United States to the Congress on March 28, 1961, recommended the termination of the entire ANP program. The President stated:

> "Nearly 15 years and about $1 billion have been devoted to the attempted development of a nuclear-powered aircraft; but the possibility of achieving a militarily useful aircraft in the foreseeable future is still very remote. The January budget already recommended a severe curtailment of this project, cutting the level of effort in half by limiting the scope to only one of the two different engines under development, although not indicating which one. We believe the time has come to reach a clean-cut decision in this matter. Transferring the entire subject matter to the Atomic Energy Commission budget where it belongs, as a nondefense research item, we propose to terminate development effort on both approaches on the nuclear powerplant, comprising reactor and engine, and on the airframe; but to carry forward scientific research and development in the fields of high temperature materials and high performance reactors, which is related to AEC's broad objectives in atomic reactor development including some work at the present plants, making use of their scientific teams. This will save an additional $35 million in the Defense budget for fiscal 1962 below the figure previously reduced in January, and will avoid a future expenditure of at least $1 billion, which would have been necessary to achieve first experimental flight."

Contractors notified to terminate activities

On March 30, 1961, AEC advised GE and P&W that the ANP program was being terminated. The contractors were notified that AEC would not continue any work, under the contracts directed toward developing a nuclear-powered aircraft, beyond the contract expiration date of April 30, 1961. GE was requested to stop all work except work related to basic high-temperature materials research. P&W was requested to stop all work except work related to high-temperature materials research and development work directly necessary to carry out a possible 10-megawatt reactor experiment on a relaxed time schedule with the prime objective of advancing nuclear reactor technology in a broad application.

On March 30, 1961, Headquarters, USAF, directed the Air Materiel Command to issue termination notices to GE, P&W, Convair, and

Lockheed. AEC also notified ORNL to terminate the radiation shielding work for the ANP program.

At termination of the ANP program, over 7,000 contractor employees were engaged in the ANP program. The manpower levels at the various major contractors were as follows:

General Electric Co.	4,044
Pratt & Whitney	2,524
Convair	206
Lockheed	213
Oak Ridge National Laboratory	157
Total employees	7,144

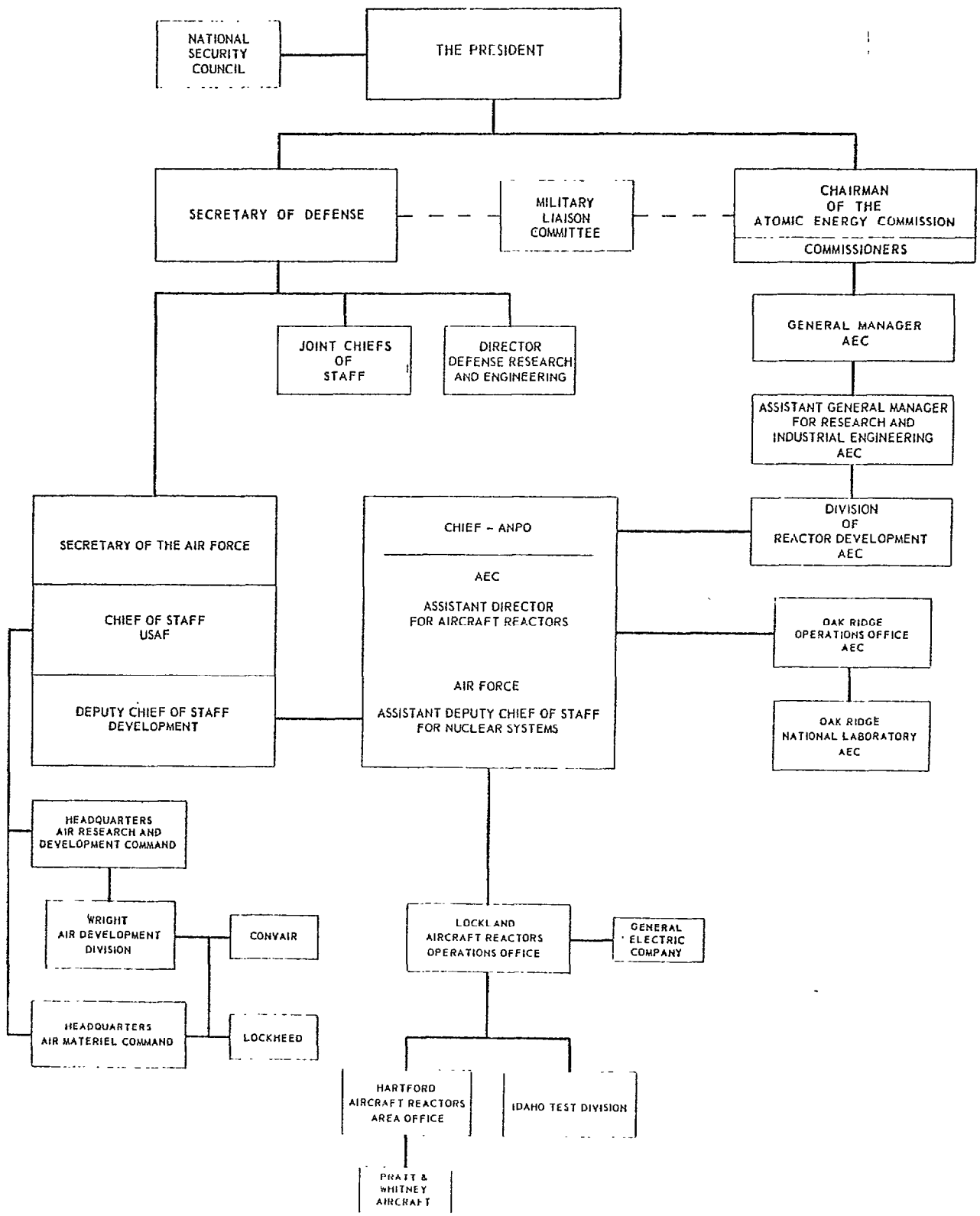
New research program initiated

After the termination of the ANP program, all work oriented toward actual aircraft application was canceled. In April 1962, AEC adopted a new research program for high-temperature materials and high-performance reactors. Some of the equipment and facilities previously used in the ANP program and the services of some of the employees were utilized in the new program.

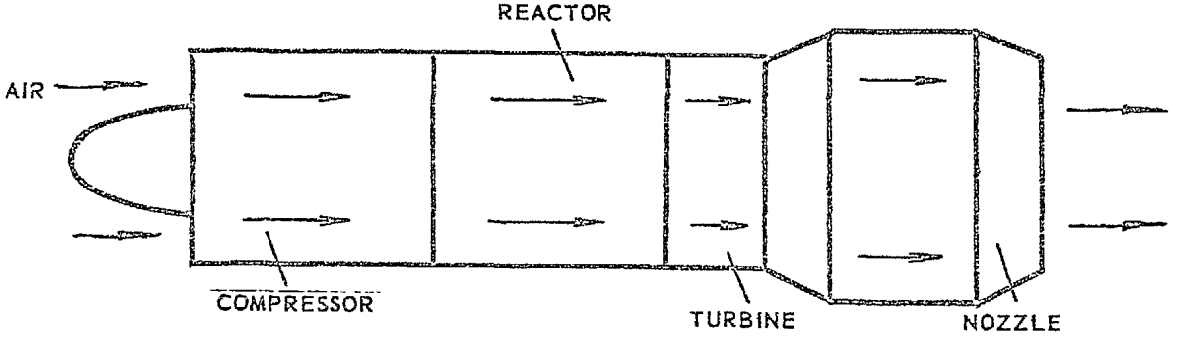
AEC's budget for fiscal year 1962 provided about $19,925,000 for the new research program, including about $6,625,000 for high-temperature materials research--$4,500,000 by GE, $950,000 by P&W, and $1,175,000 by ORNL--and about $13,300,000 for developing a high-performance reactor experiment by P&W.

MANAGEMENT STRUCTURE OF THE MANNED AIRCRAFT NUCLEAR PROPULSION PROGRAM

JANUARY 1, 1961

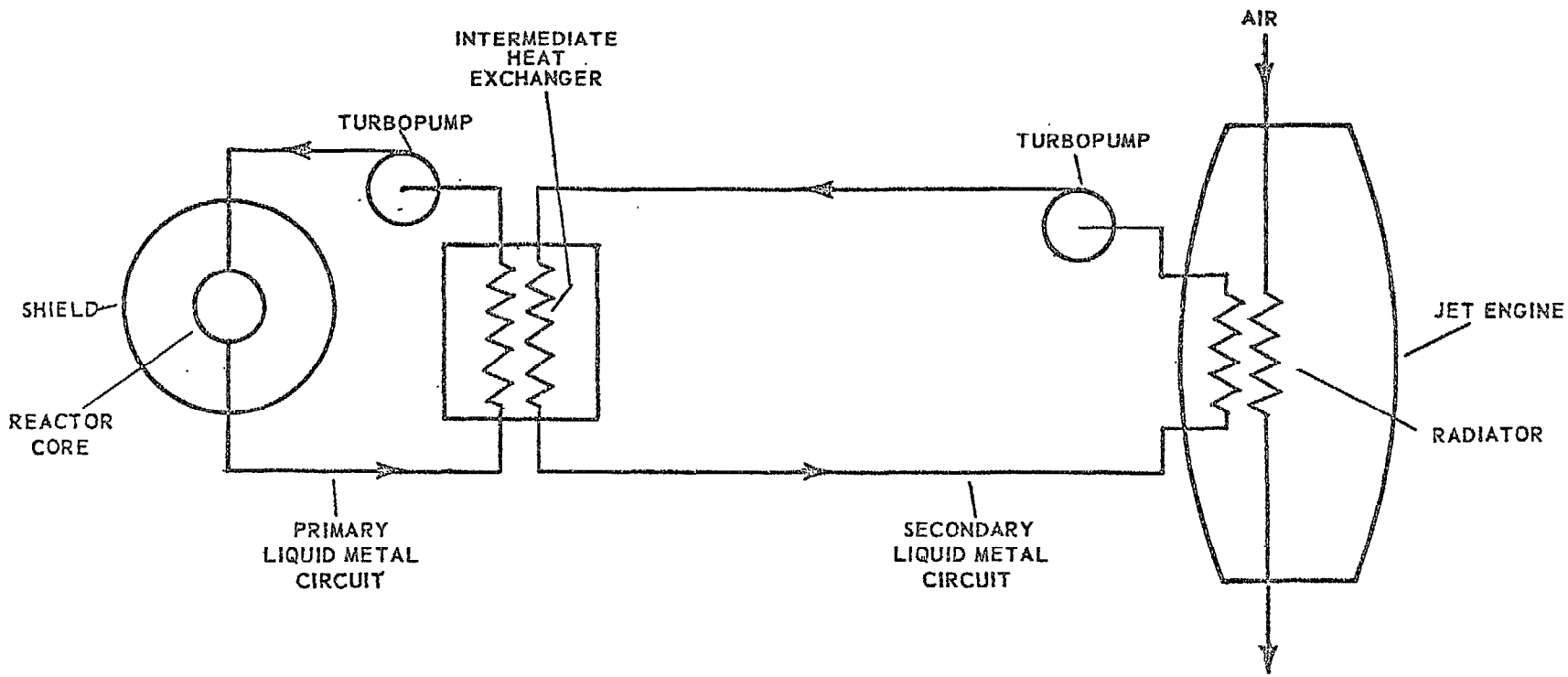


SCHEMATIC OF DIRECT AIR-CYCLE NUCLEAR PROPULSION SYSTEM



IN THE DIRECT AIR-CYCLE, AIR ENTERS THROUGH THE COMPRESSOR, IS FORCED INTO THE REACTOR, AND HEATED BY THE FUEL ELEMENTS. AFTER PASSING THROUGH THE TURBINE, WHERE ENERGY IS EXTRACTED TO DRIVE THE COMPRESSOR, THE HEATED AIR IS EXPELLED AT HIGH VELOCITY THROUGH THE EXHAUST NOZZLE.

SCHEMATIC OF TWO-LOOP, LIQUID-METAL, INDIRECT CYCLE NUCLEAR PROPULSION SYSTEM



IN THE INDIRECT CYCLE, THE HEAT GENERATED IN THE REACTOR IS ABSORBED BY A LIQUID-METAL COOLANT FLOWING THROUGH THE REACTOR CORE. THE LIQUID-METAL COOLANT THEN FLOWS THROUGH AN INTERMEDIATE HEAT EXCHANGER WHERE THE HEAT IS TRANSFERRED TO A SECONDARY LOOP. THE HOT LIQUID METAL IS THEN PUMPED TO THE JET ENGINE. THE JET ENGINE CONTAINS RADIATORS, WHERE THE HEAT IS GIVEN UP BY THE LIQUID METAL AND IMPARTED TO THE AIRSTREAM FLOWING THROUGH THE ENGINE.

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D. C.

IN REPLY REFER TO:
RD:AE:RCM

JAN 2 - 1962

Mr. Arthur L. Litke
Assistant Director
General Accounting Office
Washington 25, D. C.

Dear Mr. Litke:

In accordance with your request of December 18, 1961, there is attached a statement which reflects the major key technical accomplishments of the ANP Program. This statement I believe reflects a fair summation of the principal contributions of the ANP Program to reactor technology.

Sincerely yours,

Frank K. Pittman, Director
Division of Reactor Development

Attachment:
Accomplishments
of ANP Program

CONTRIBUTIONS OF THE ANP PROGRAM TO REACTOR TECHNOLOGY

A nuclear jet propulsion system for aircraft application requires the minimizing of size and weight and the maximizing of power (heat) output. This problem is further increased in difficulty by the necessity of providing adequate nuclear shielding. Power output is derived from the heat produced by the reactor, hence the requirement for a reactor which produces extremely high temperatures while at the same time minimizing size and weight. The ANP Program was, therefore, starting at the upper limits of nuclear technology which required many so-called "break throughs" in materials, reactor concepts, instrumentation, shielding and controls. These circumstances automatically provided a tremendous acceleration in the advancement of nuclear reactor technology.

Listed below are some of the major contributions made by the ANP Program:

A. The ANP Circulating Fuel Reactor Program at the Oak Ridge National Laboratory has led to the Molten Salt Reactor Program for civilian power presently underway at ORNL. In addition to establishing the feasibility of this type of reactor by the operation of the Aircraft Reactor Experiment in 1954, the following accomplishments and applications were provided:

(1) A new nickel-molybdenum alloy (HOR-8) was developed which increased the operating life of reactors using lithium-based fused salts.

(2) High temperature liquid metal pumps, valves, seals, heat exchangers and instrumentation technology have been used in the development of the Sodium Graphite Reactor, Liquid Metal Fuel Reactor and the Enrico Fermi Fast Breeder Reactor.

(3) Corrosion data on various alloys with lithium, sodium, sodium-potassium, lead, bismuth and various types of fused salts have been obtained and used in the above programs.

(4) New materials, reactor grade inconel and stainless steels, and new fabrication techniques for large beryllium components, were developed.

(5) The Bulk Shield Reactor (Swimming Pool Reactor) was designed and built at ORNL to obtain shielding data on large shield components for ANP. This, the first swimming pool reactor built, has served as a model for many of the research reactors that are in use at universities throughout the Free World today. The reactor that was demonstrated as a part of

the U. S. exhibit at the first Geneva Conference was based on this reactor design.

(6) A new 5 MW spherical geometry tower shielding reactor was design and fabricated by ORNL for use in ANP radiation shielding development. Due to the core geometry this unique reactor provides an isotopic radiation source for a variety of experiments. It has been used in radiation effects studies, radiobiology and is being used in connection with U. S. Army radiation studies.

B. The Indirect Cycle Program effort by Pratt and Whitney has resulted in the development of extensive liquid metal technology which has recently been directed to the development of an advanced high temperature lithium-cooled reactor system. This work has produced the following important contributions:

(1) A high strength refractory metal-columbium-zirconium alloy has been developed for high temperature engineering applications. Its demonstrated chemical compatibility with lithium allows the design of very high power density nuclear reactors capable of previously unattainable temperatures. The nuclear and structural ramifications of this development provides substantial advantages to any nuclear power conversion system requiring light weight, high temperature performance.

(2) This technology has many possible applications for space, mobile packaged power, central station and marine power plants.

(3) Development of a reliable, high power density, fuel element has been a very significant accomplishment of the indirect cycle program. This development will permit smaller cores, higher specific power, higher fuel burn-up and lighter weight systems.

C. The Direct Cycle Program has provided the following important contributions:

(1) The metallic dispersion fuel element was first developed under this program. It has been used in the Army Power Package Program, the Gas Cooled Reactor Experiment and in the nuclear superheat system for the Pathfinder Civilian Power Reactor Program.

(2) The zirconium hydride solid moderator technology has been used in the Space Nuclear Auxiliary Power Program and in the TRIGA research and training reactors.

(3) Separation, purification and fabrication of the rare earth yttrium was developed which is used as an alloying material to provide high strength and oxidation resistance to stainless steels. This material is now being produced commercially. Yttrium is also used as a stabilizer for zirconium crucibles in use by industry today.

(4) Rhenium-tungsten thermocouples which operate up to 3000°F in a nuclear environment were also developed.

(5) Extensive information on radiation effects on organic materials such as alkyl benzene, Dowtherm-A, etc. was determined which is used in organic moderated reactors.

(6) The Direct Cycle Program produced extensive ceramic fuel element technology which contributed to the Nuclear Ramjet Missile, Maritime and Civilian Gas Cooled Reactor Programs. Ceramic coated wires, resistant to high temperature and nuclear radiation were developed for thermocouple leads for reactor applications.

(7) The fission product release problems of the direct cycle program resulted in the establishment of extensive information on electrostatic precipitator systems to filter effluent air which is of interest to the civilian and gas cooled reactor programs.

(8) In the field of reactor theory much information has been developed on calculational methods which have been programed for computer use. For example, one of the procedures for heat transfer calculations is used in the Nuclear Ramjet Missile Program.

(9) Numerous instruments and devices, some miniaturized, for determining test results and reactor control have been pioneered under the Direct Cycle Program.

(10) The Heat Transfer Reactor Experiments resulted in the operation of turbojet aircraft engines on heat supplied by a nuclear reactor. These tests proved the feasibility of the direct cycle system by 65 continuous hours of operation at temperatures approaching 2000 F, using metallic fuel elements.

D. Many engineers and scientists received valuable training and experience in the ANP Program. The knowledge and experience gained was and is being used in other nuclear programs. Under the ANP Program new and unique test facilities were developed, designed and built which will continue to serve the advancement of nuclear technology.

While the above identifies the major known contributions of the ANP Program, it is not possible to inventory, realistically, the total benefits derived from the Program. The high temperature materials and radiation shielding information was undoubtedly of great value to the National space effort. The extent to which this information saved time and money and expedited program efforts in the space and other important programs would be impossible to calculate. It is clear that by the very nature of the program the technology produced was and is a very important asset.

LIST OF POLICY-MAKING
AND OTHER INTERESTED PRINCIPAL OFFICIALS
AIRCRAFT NUCLEAR PROPULSION PROGRAM

DEPARTMENT OF DEFENSE

	Tenure of office From	To
SECRETARY OF DEFENSE:		
James V. Forrestal	Sept. 1947	Mar. 1949
Louis Johnson	Mar. 1949	Sept. 1950
George Catlett Marshall	Sept. 1950	Sept. 1951
Robert A. Lovett	Sept. 1951	Jan. 1953
Charles E. Wilson	Jan. 1953	Oct. 1957
Neil H. McElroy	Oct. 1957	Dec. 1959
Thomas S. Gates, Jr.	Dec. 1959	Jan. 1961
Robert S. McNamara	Jan. 1961	Present
DEPUTY SECRETARY OF DEFENSE:		
Stephan T. Early*	Aug. 1949	Sept. 1950
Robert A. Lovett	Oct. 1950	Sept. 1951
William C. Foster	Sept. 1951	Jan. 1953
Roger M. Kyes	Feb. 1953	May 1954
Robert B. Anderson	May 1954	Aug. 1955
Reuben B. Robertson, Jr.	Aug. 1955	Apr. 1957
Donald A. Quarles	May 1957	May 1959
Thomas S. Gates, Jr.	June 1959	Dec. 1959
James H. Douglas	Dec. 1959	Jan. 1961
Roswell L. Gilpatric	Jan. 1961	Present

*Served as Under Secretary of Defense from May 2, 1949 until August 9, 1949, when that position was abolished, and that of Deputy Secretary of Defense was established.

DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING, formerly Assistant Secretary of Defense (Research and Engineering):		
Herbert F. York	Dec. 1958	Apr. 1961
Harold Brown	May 1961	Present

(Position created under terms of the Reorganization Act of 1958.)

LIST OF POLICY-MAKING

AND OTHER INTERESTED PRINCIPAL OFFICIALS

AIRCRAFT NUCLEAR PROPULSION PROGRAM (continued)

	Tenure of office From	To
DEPARTMENT OF DEFENSE (continued)		
ASSISTANT SECRETARY OF DEFENSE (RESEARCH AND ENGINEERING) formerly Assistant Secretary of Defense (Research and Development) and Assistant Secretary of Defense (Engineering):		
Frank D. Newbury	Mar. 1957	May 1957
Paul D. Foote	Sept. 1957	Oct. 1958
ASSISTANT SECRETARY OF DEFENSE (RESEARCH AND DEVELOPMENT) formerly Chairman of Research and Development Board:		
Donald A. Quarles	Sept. 1953	Aug. 1955
Dr. Clifford C. Furnas	Dec. 1955	Feb. 1957
ASSISTANT SECRETARY OF DEFENSE (ENGINEERING) formerly Chairman of Research and Development Board:		
Frank D. Newbury	Aug. 1953	Mar. 1957

Combined with Assistant Secretary of Defense (Research and Development) as Assistant Secretary of Defense (Research and Engineering). This position was originally designated Assistant Secretary of Defense (Applications Engineering).

CHAIRMAN OF RESEARCH AND DEVELOPMENT BOARD:		
V. Bush	Sept. 1947	Oct. 1948
Karl T. Compton	Oct. 1948	Mar. 1950
William Webster	Mar. 1950	July 1951
Walter G. Whitman	Aug. 1951	June 1953
ASSISTANT SECRETARY OF DEFENSE (DEPUTY DIRECTOR, DEFENSE RESEARCH AND ENGINEERING):		
John H. Rubel	May 1961	Present

(Position created in 1961)

LIST OF POLICY-MAKING

AND OTHER INTERESTED PRINCIPAL OFFICIALS

AIRCRAFT NUCLEAR PROPULSION PROGRAM (continued)

	Tenure of office	
	From	To
DEPARTMENT OF DEFENSE (continued)		
CHAIRMAN OF THE JOINT CHIEFS OF STAFF:		
General Omar N. Bradley, USA	Aug. 1949	Aug. 1953
Admiral Arthur W. Radford, USN	Aug. 1953	Aug. 1957
General Nathan F. Twining, USAF	Aug. 1957	Sept. 1960
General Lyman L. Lemnitzer, USA	Oct. 1960	Present
DEPARTMENT OF THE AIR FORCE		
SECRETARY OF THE AIR FORCE:		
W. Stuart Symington	Sept. 1947	Apr. 1950
Thomas K. Finletter	Apr. 1950	Jan. 1953
Harold E. Talbott	Feb. 1953	Aug. 1955
Donald A. Quarles	Aug. 1955	Apr. 1957
James H. Douglas	May 1957	Dec. 1959
Dudley C. Sharp	Dec. 1959	Jan. 1961
Eugene M. Zuckert	Jan. 1961	Present
CHIEF OF STAFF:		
General Carl Spaatz	Sept. 1947	Apr. 1948
General Hoyt S. Vandenberg	Apr. 1948	June 1953
General Nathan F. Twining	June 1953	June 1957
General Thomas D. White	July 1957	June 1961
General Curtis E. LeMay	June 1961	Present
DEPUTY CHIEF OF STAFF, RESEARCH AND TECHNOLOGY formerly, Deputy Chief of Staff, Development:		
Major General G. P. Saville	Jan. 1950	July 1951
Major General D. L. Putt (Acting)	July 1951	Nov. 1951
Lieutenant General L. S. Craigie	Nov. 1951	Apr. 1954
Lieutenant General D. L. Putt	Apr. 1954	June 1958
Lieutenant General Roscoe C. Wilson	July 1958	Nov. 1961
Lieutenant General James Ferguson	Dec. 1961	Present

LIST OF POLICY-MAKING

AND OTHER INTERESTED PRINCIPAL OFFICIALS

AIRCRAFT NUCLEAR PROPULSION PROGRAM (continued)

	Tenure of office From	To
DEPARTMENT OF THE AIR FORCE (continued)		
ASSISTANT DEPUTY CHIEF OF STAFF, R AND T FOR ATOMIC ENERGY formerly, Assistant DCS for Nuclear Systems; Aircraft Nuclear Propulsion Office (ANPO):		
Major General Donald J. Keirn	Nov. 1957	Aug. 1959
Brigadier General Irving L. Branch	Aug. 1959	July 1961
Colonel Ola P. Thorne	July 1961	Present
COMMANDERS, AIR FORCE LOGISTIC COMMAND created April 1, 1961, formerly Air Materiel Command:		
Lieutenant General Nathan F. Twining - Acting		Sept. 1947
Lieutenant General Nathan F. Twining		Oct. 1947
General Joseph T. McNarney	Oct. 1947	Sept. 1949
Lieutenant General Benjamin W. Chidlaw	Sept. 1949	Aug. 1951
General Edwin W. Rawlings	Aug. 1951	Feb. 1959
General Samuel E. Anderson	Mar. 1959	Aug. 1961
General William F. McKee	Aug. 1961	July 1962
General Mark E. Bradley, Jr.	July 1962	Present
COMMANDERS, AIR FORCE SYSTEMS COMMAND created April 1, 1961, formerly Air Research and Development Command:		
Major General David M. Schlatter	Jan. 1950	June 1951
Lieutenant General Earle E. Partridge	June 1951	June 1953
Lieutenant General Donald L. Putt	June 1953	Apr. 1954
Lieutenant General Thomas S. Power	Apr. 1954	June 1957
Major General J. W. Sessums, Jr.	July 1957	July 1957
Lieutenant General S. E. Anderson	Aug. 1957	Mar. 1959
Major General J. W. Sessums, Jr.	Mar. 1959	Apr. 1959
General Bernard A. Schriever	Apr. 1959	Present
DEPARTMENT OF THE NAVY		
SECRETARY OF THE NAVY:		
James V. Forrestal	May 1944	Sept. 1947
John L. Sullivan	Sept. 1947	May 1949
Francis P. Matthews	May 1949	July 1951

LIST OF POLICY-MAKING
AND OTHER INTERESTED PRINCIPAL OFFICIALS
AIRCRAFT NUCLEAR PROPULSION PROGRAM (continued)

	Tenure of office From	To
DEPARTMENT OF THE NAVY (continued)		
SECRETARY OF THE NAVY (continued):		
Dan A. Kimball	July 1951	Jan. 1953
Robert B. Anderson	Feb. 1953	May 1954
Charles S. Thomas	May 1954	Apr. 1957
Thomas S. Gates, Jr.	Apr. 1957	June 1959
William B. Franke	June 1959	Jan. 1961
John B. Connally	Jan. 1961	Dec. 1961
Fred Korth	Jan. 1962	Present
CHIEF, BUREAU OF AERONAUTICS Bureau dis-established December 1959, Bureau of Naval Weapons, activated January 1960, combined Bureau of Aeronautics and Bureau of Ordnance:		
Rear Admiral Harold O. Sallada	June 1945	May 1947
Rear Admiral Alfred M. Pride	May 1947	May 1951
Rear Admiral Thomas S. Combs	May 1951	June 1953
Rear Admiral Apollo Soucek	June 1953	Feb. 1955
Rear Admiral James S. Russell	Mar. 1955	July 1957
Rear Admiral Robert B. Dixon	July 1957	Dec. 1959
CHIEF, BUREAU OF NAVAL WEAPONS:		
Rear Admiral P. D. Stroop	Dec. 1959	Present
DEPARTMENT OF THE ARMY		
CHIEF OF ENGINEERS:		
Lieutenant General Samuel D. Sturgis	Jan. 1953	Oct. 1956
Lieutenant General Emerson C. Itschner	Oct. 1956	Mar. 1961
Lieutenant General W. K. Wilson, Jr.	May 1961	Present
ATOMIC ENERGY COMMISSION		
COMMISSION CHAIRMAN:		
David E. Lilienthal	Nov. 1946	Feb. 1950
Dean E. Gordon	July 1950	June 1953
Lewis L. Strauss	July 1953	June 1958
John A. McCone	July 1958	Jan. 1961
Glenn T. Seaborg	Mar. 1961	Present

LIST OF POLICY-MAKING
AND OTHER INTERESTED PRINCIPAL OFFICIALS
AIRCRAFT NUCLEAR PROPULSION PROGRAM (continued)

	Tenure of office From	To
ATOMIC ENERGY COMMISSION (continued)		
GENERAL MANAGER:		
Carroll L. Wilson	Dec. 1946	Aug. 1950
Marion W. Boyer	Nov. 1950	Nov. 1953
Kenneth D. Nichols	Nov. 1953	Apr. 1955
Kenneth E. Fields	May 1955	June 1958
Paul F. Foster	July 1958	Nov. 1958
A. R. Luedecke	Dec. 1958	Present
DIRECTOR, DIVISION OF REACTOR DEVELOPMENT:		
Lawrence R. Hafstad	Feb. 1949	Feb. 1955
W. Kenneth Davis	Feb. 1955	July 1958
Frank K. Pittman	Oct. 1958	Present
CHIEF, AIRCRAFT REACTORS BRANCH:		
Robert M. William	Mar. 1950	Mar. 1951
R. L. Wassell	Mar. 1951	Feb. 1953
Major General Donald J. Keirn	Feb. 1953	Nov. 1958
ASSISTANT DIRECTOR FOR AIRCRAFT REACTORS:		
Major General Donald J. Keirn	Nov. 1958	Sept. 1959
Brigadier General Irving L. Branch	Nov. 1959	Mar. 1961
MANAGER, LOCKLAND AIRCRAFT REACTORS OPERATIONS OFFICE:		
Harry Gorman	July 1958	June 1960
John L. Wilson	June 1960	July 1961
MANAGER, CHICAGO OPERATIONS OFFICE:		
John J. Flaherty	Apr. 1954	Nov. 1957
Kenneth A. Dunbar	Nov. 1957	Present