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# NUCLEAR PROPULSION FOR MANNED AIRCRAFT: [redacted]

# THE END OF THE PROGRAM

# 1959 - 1961

By

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April 1963
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# FOREWORD

This study is concerned primarily with the concluding phase of the program to develop a nuclear-propelled aircraft for manned flight. Covering the period from January 1959 to March 1961, it seeks to make clear the factors that brought about the termination of the program. The emphasis is on the policy-management level, and technological factors are dealt with only to the extent that they became involved at that level. A summary review is given of the earlier phase from 1946 through 1958. For this phase the study draws heavily, though by no means exclusively, from a historical study prepared by the Wright Air Development Center in 1959, The USAF Aircraft Nuclear Propulsion Program. Charts and tables are provided in an appendix to summarize the financial support of the program and to illustrate the organizational structure for its management.

Nuclear Propulsion for Manned Aircraft is part of the larger History of Headquarters USAF, Fiscal Year 1960. It is being published separately to make it more readily available throughout the Air Force.

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C O N T E N T S

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## I. REVIEW OF THE ANP PROGRAM, 1946-58

Air Force interest in nuclear propulsion for aircraft officially began in late 1945, when Brig. Gen. Alden R. Crawford, Acting AC/AS-4, Headquarters, U.S. Army Air Forces, directed the Air Technical Service Command to investigate all possible military applications of nuclear energy.* In early 1946 the AAF authorized North American Aviation, Douglas Aircraft, and a group of aircraft engine companies headed by Fairchild to pursue individual research projects that either primarily or secondarily involved nuclear propulsion for aircraft or guided missiles.† Concerned over possible security leaks and loss of trained personnel, Manhattan District finally required the AAF (later the U.S. Air Force) to concentrate all such work under the Fairchild group, known as Project NEPA (Nuclear Energy for Propulsion of Aircraft). From May 1946 through fiscal year 1950, NEPA functioned as a rather low-level feasibility study and research effort with funding of about $21 million. In addition, the Atomic Energy Commission (AEC) expended about $1.4 million for reactor research and the Air Force about $184,000 for general support.[1]

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*Col. Donald J. Keirn had made informal inquiries about a year before but had been discouraged from pursuing them. (WADC, The USAF Aircraft Nuclear Propulsion Program (1959), p 4.)

†The North American atomic propulsion work was integrated with its Project MX-770, which slightly antedated NEPA. The AAF reluctantly terminated the atomic propulsion phase of Project MX-770 in April 1947 after recruitment of an impressive array of scientific talent and production of a development proposal termed "interesting." Douglas planned its atomic propulsion research as a phase of Rand, which it then controlled. In early 1947, NEPA took over Rand's Battelle Institute contract and Rand agreed to stay out of design and construction while cooperating with NEPA in the evaluation of proposed propulsion systems. (See Lee Bowen & Robert D. Little, History of The Air Force Atomic Energy Program, II, 561-63.)

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Although firmly supported by the Air Force, NEPA came under heavy attack from certain members of the Committee on Atomic Energy of the Joint Research and Development Board (JRDB, later RDB) and in 1947-48 was close to cancellation. It was saved by the mildly favorable Lexington Report, prepared during mid-1948 by a group of MIT scientists at the request of the AEC. The Lexington scientists believed that manned nuclear-powered flight could be achieved within about 15 years if the United States provided about one billion dollars and a large quantity of its most vital scientific resources. Thus supported, the Air Force won lukewarm approval from the RDB and AEC and in July 1949 a tentative indorsement from the Joint Chiefs of Staff (JCS), who also requested the Weapons Systems Evaluation Group (WSEG) to study the matter further. At the same time, the interested agencies—the Air Force, AEC, National Advisory Committee for Aeronautics (NACA), and Navy—established a broader and more firmly coordinated program known as Aircraft Nuclear Propulsion (ANP).* Although this brought somewhat better cooperation from the AEC, together with some support from its Reactor Development Division, there was no significant increase in funding. The main activity remained centered in NEPA, which continued as a phase of ANP until 1951.[2]

By 1950, NEPA had identified two theoretically practicable approaches for a reactor-propulsion system. It had also established that the weight

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*The Air Force, Navy, AEC, and NACA representatives agreed in January 1949 that the AEC would accept responsibility for the reactor, the Air Force for the engine and airframe, and NACA for supporting aeronautical research. An ad hoc committee, including representatives from each, would provide policy direction. The NEPA project would continue as one phase of the enlarged program. An agreement provided for funding at $10 million per year over a three-year period, with the AEC, Air Force, Navy, and NACA furnishing 50, 30, 10, and 10 percent respectively; but this was not fully implemented. The larger program was approved by the Military Liaison Committee and the Committee on Atomic Energy. (See Hist, AF Atomic Energy Prog, II, 575.)

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of shielding might be held to about one-fourth of the predicted 500,000 pounds, permitting abandonment of the cumbersome tug-tow suggestion* and clearing the way for a possible experimental "flying test bed" aircraft. Accordingly, the Air Force proposed in November 1950 the modification of a B-36 to incorporate a liquid-cooled (indirect cycle) reactor to drive turbojet propulsion units. This meant accepting the AEC-favored indirect cycle (IDC) reactor in lieu of the NEPA-favored direct air cycle (DAC), rejecting Fairchild's proposal to build an entirely new experimental airplane, and terminating the NEPA contract.[3]

On 19 December 1950 the Air Force revived before the JCS the question of nuclear energy for aircraft propulsion, which had been quiescent in that body since July 1949. It cited the recent preliminary study, The Military Potential of Nuclear Powered Aircraft, prepared by the WSEG for the JCS, which had concluded: "Military requirements for the development of nuclear powered aircraft cannot be more sharply defined until aircraft nuclear power plant characteristics are more conclusively established on the basis of further research, development, and demonstration."[4] The Air Force contended that its B-36 modification plan was feasible for immediate implementation and that with further development a supersonic aircraft of unlimited range could be built. It explained that a test-stand nuclear power plant for the aircraft could be in operation by the end of 1954, a subsonic flying test-bed aircraft flown before the end of 1956, and a supersonic aircraft within two or three years thereafter. It recommended undertaking the first step immediately, with sufficient priority to assure completion before the end of 1954.[5]

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*Under this concept, originally proposed in the Lexington Report, the need for shielding would be drastically reduced by placing the reactor and engines in a remotely controlled unit that would tow by a steel cable a separate section containing the crew and payload.

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When queried on its views, the AEC replied: "It is the Commission's general conclusion that the aircraft project is technically feasible, and that, short of a 'crash program' basis, which could be extremely disrupting to our essential production program, men and facilities could be found to make progress on this project at a reasonable rate, if the need for it can really be justified."[6] The Military Liaison Committee (MLC) accordingly recommended that the JCS establish a requirement for the construction of a nuclear aircraft power plant with a priority after any reactor projects primarily concerned with production of fissionable material. On 12 March 1951 the JCS complied, also asking the MLC to request the AEC to undertake the development effort in cooperation with the Air Force. Since the Air Force had emphasized the need for a nuclear-powered aircraft to carry out its strategic mission, the reoriented program included a contract with Lockheed to study advanced aircraft designs and associated navigation, bomb delivery, and flight techniques as well as a contract with General Electric to develop a propulsion system. The Air Force also awarded study contracts to Boeing and Pratt & Whitney.[7]

Beginning work in March 1951, General Electric became convinced by August that the direct air cycle reactor was more practicable than the indirect cycle. It quickly won the support of the Air Force and, by April 1952, the reluctant assent of the AEC to a shift to the former. Both the AEC and Air Force continued, however, to support research on various forms of the indirect (closed) cycle, as a possibly more efficient alternative. This divided the principal development effort along two lines, with the result that $561 million would be expended on the direct air cycle and $288 million on the indirect cycle over the next 10 years.* Even in early 1961

*For a financial summary of the program, see below, App 1.

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the proponents of each approach, with no final choice made, still would be arguing the relative merits and disadvantages.[8]

On 8 April 1952, Acting Secretary of the Air Force Roswell L. Gilpatric informed the AEC of the three principal Air Force program objectives.[9]

1. To develop, in a cooperative program with the AEC, nuclear propulsion systems for aircraft, and to carry on research and development of importance in improving the performance of such systems beyond that which may be expected in the first phase.

2. To create a capability for studying, testing, and evaluating nuclear propulsion systems on the ground and in flight.

3. To flight test a nuclear propulsion system in a flying test bed in the period 1956-1957, with the condition that this target date is subject to change as technical progress and available funds may dictate.

The program made what appeared to be substantial progress during 1952. To emulate the rapidly advancing Navy-AEC effort on a nuclear-propelled submarine seemed obviously desirable, but the technical problems in aircraft propulsion were so different and so much more formidable that the only immediately practicable borrowing was the establishment of centralized control by one individual, Accordingly, in November 1952 the Air Force designated Maj. Gen. Donald J. Keirn overall coordinator* for its part of the program and the AEC simultaneously named him chief of its Aircraft Reactors Branch. In September 1952 the Air Force confirmed the choice of the B-36 and allocated two aircraft to Convair, the manufacturer, for modification as X-6 ground-test and flight-test vehicles. Completing the design of the propulsion system, General Electric estimated that the four X-40 engines, activated by an R-1 reactor, would develop a thrust of 26,000 pounds and propel the X-6 at 300 miles per hour, at an altitude of 15,000

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*More officially, within the Air Force, Keirn held the posts of Chief, WADC ANP Project Office; Assistant for ANP to the Deputy Chief of Staff/Development, Headquarters USAF; and Assistant for ANP to the Commander, Air Research and Development Command.

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feet. The power plant weight would be 140,000 pounds, including reactor shield. Athough it was obvious by the end of 1952 that the target date for nuclear flight had been entirely too optimistic and would have to be pushed back to 1958, the Air Force directed Boeing to proceed with design studies for a 1960-65 nuclear-powered bomber-reconnaissance aircraft.[10]

In early 1953, for the first time since 1948, the entire program came under fire and for a time was on the verge of cancellation, as a result of the defense reorganization by the new national administration. On 22 April the National Security Council (NSC) approved a recommendation from the Office of the Secretary of Defense (OSD) to terminate the entire program. Deputy Secretary of Defense Roger M. Kyes pointed out that this would "save" approximately $50 million during fiscal year 1954 and much larger sums during subsequent years. Despite the apparent finality of the action, the NSC accepted an Air Force reclama and on 6 May reversed itself and approved a program reduced to approximately $23.8 million for 1954, as compared to $59 million authorized for fiscal year 1953. The action in effect converted the time-oriented development program into one without definite schedules.[11]

In early 1954, Boeing presented to Headquarters USAF the concept* that a manned bomber using nuclear power for subsonic cruise to the general target area and added chemical fuel for a supersonic dash to the strike zone was the most suitable strategic weapon system for the 1960's. This idea gained rapid acceptance among Air Force nuclear propulsion proponents, who were further encouraged by several significant technical advances, partic-

*The concept had been considered within the program several times as a possible compromise shortcut to operational status for ANP. The germinal idea originated with Col. W. L. Krisberg of WADC. (Ltr, Maj Max E. Erwin, Dsgd Sys, DCS/S&L to AFCHO, 9 Aug 62, subj: AFCHO Historical Study, in AFCHO files; interview by Max Rosenberg with Col C. D. Gasser, Jul 62.)

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ularly in radiation effects and DAC development. Meanwhile, favorably impressed by Pratt & Whitney's efforts on an ingenious closed cycle system, the circulating-fuel ("fireball") reactor, the AEC pressed for increased support to develop a prototype propulsion system of this type.[12]

With support indicated from the AEC and congressional Joint Committee on Atomic Energy (JCAE), the Air Force Council in January 1955 took the first step toward accelerated development by approving a two-pronged program leading to selection of a cycle by 1958 and delivery of 30 operational aircraft in 1963. In March the Air Staff followed up by issuing General Operational Requirement (GOR) 81 for a piloted nuclear-powered intercontinental bombardment weapon system. After Secretary of Defense Charles E. Wilson approved the accelerated program in April the Air Research and Development Command (ARDC) issued System Requirement 18, which designated the project Weapon System 125A and assigned primary responsibility to the Wright Air Development Center (WADC). The minimum performance specified was a radius of 11,000 nautical miles, dash radius of 1,000 nautical miles, cruising altitude of 30,000 feet, dash altitude of 60,000 feet, cruising speed of Mach .9, "maximum possible supersonic" dash speed, and bomb load of 10,000 pounds. "Desired" figures were much higher. Noting that the program was fully as important to the Air Force as the Atlas project, Gen. Thomas D. White, Vice Chief of Staff, assigned to it a 1-A priority and the "highest supply precedence rating". The WADC project office, headed by Col. Ralph L. Wassell,* prepared a development plan calling for nuclear-powered flight in July 1961 and the first operational aircraft in July 1963. On the other

*Colonel Wassell reported directly to Lt. Gen. Thomas S. Power, Commander, ARDC, who was advised by General Keirn as overall coordinator of the program.

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hand, the Air Force Scientific Advisory Board (SAB), while agreeing with the plan objectives, found the schedule overoptimistic by three to five years.[13]

During the remainder of 1955 and early 1956 the program moved forward energetically, and obligated funds jumped to $157 million for fiscal year 1956 as against $54 million the previous year. Among other significant technical advances was the operation on 31 January 1956 of a turbojet engine, coupled to a direct air cycle reactor. An inherent hazard of the direct air cycle, leaks of radioactive material through cracks in the coating of the fuel elements, forced several shutdowns of this test system, however. It was also obvious that reactor operating temperatures would have to be raised much higher to secure a useful system. This in turn would increase the danger of leakage unless new, more heat-resistant materials were developed and/or the "hot-spot" problem alleviated by improved design and engineering. Meanwhile, exaggerated news accounts of the leakage hazard created public alarm that brought an end to the testing and threatened to force the building of more isolated facilities.[14]

During the course of 1956 more and more obstacles appeared in the WS-125A program. These at length made it obvious that the Air Force could not reach its operational goals under the schedule or any moderate extension of it. As early as April 1956, Lt. Gen. Donald M. Putt, Deputy Chief of Staff/Development, had stated that the WS-125A was beyond the current state of the art. Although Convair and Lockheed, the two principal airframe contractors, and General Electric and Pratt & Whitney, the two engine contractors, remained optimistic regarding their technical proposals, the frequent alteration of these was itself significant. The estimated cost of $3 billion for

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20 test and 30 operational aircraft also gave pause. In view of such uncertainties, the Air Force, although still convinced of the requirement, hesitated to advocate an all-out program, which would have required $330 million in Air Force funds for fiscal year 1957 alone.

In December 1956, after several months of near paralysis from lack of funds, the Secretary of Defense and the Director of the Bureau of the Budget, with Presidential concurrence, decided to reorient the existing program at a reduced level. On 1 February 1957 the Department of Defense (DOD) explained to the JCAE that the long-term requirement for a nuclear-powered bomber was valid but that the original program objectives would not be sought immediately. Five days later Maj. Gen. Jacob E. Smart, Assistant Vice Chief of Staff, USAF, reemphasized the continued official Air Force policy on the importance of the nuclear-powered aircraft. Grouping it with the intercontinental ballistic missile as examples of essential future weapon systems, he mentioned the necessity of developing power plants "for both high and low altitude applications and covering a broad spectrum of speeds." More realistically, the Air Force on 4 February advised the principal contractors to delay their schedules and in March lowered the precedence rating of the program from I-1C to II-3.[15]

Meanwhile, three ad hoc groups--the Littlewood Committee, the Mills Board, and the Canterbury Committee*--reporting to the OSD, the DCS/De-

*The Littlewood Committee, headed by William Littlewood, a member of the Technical Advisory Committee on Aeronautics, Assistant Secretary of Defense (Research & Development), included three other well-known civilian experts in the atomic, aeronautical, and electrical fields. The Mills Board, headed by Maj. Gen. John S. Mills, included four other major generals, one brigadier, and one civilian--most of whom had had extensive experience in the atomic energy program. The Canterbury Committee, headed by Maj. Gen. William M. Canterbury, otherwise consisted of five USAF colonels, all of ARDC.

velopment (Air Force), and ARDC respectively, restudied the entire question. There was general agreement in the three reports which emerged in April, May, and June 1957 that GOR 81 was unrealistic from the standpoint of performance and schedules. The boards also doubted the validity of the existing weapon system approach, advocated a return to more basic research and development, and recommended development of an experimental subsonic low-altitude aircraft as the first goal. Shortly thereafter, in mid-June, the four principal contractors testified before JCAE's Subcommittee on Research & Development that they were confident of success provided they received firm support, although disagreeing on the proper course of development. None would promise a flyable experimental aircraft before 1963, and Lockheed advocated switching to a subsonic, low-altitude bomber.[16]

An extensive revamping of the ANP program followed during the summer of 1957. In response to the demand of the JCAE for a greater degree of centralized control and responsibility, the Air Force on 3 June 1957 moved General Keirn from ARDC to Headquarters USAF, as Assistant DCS/Development for Nuclear Systems with full authority over all Air Force participating elements. In November the Air Force and AEC established a jointly staffed and jointly controlled project office, located in AEC headquarters, known as the Aircraft Nuclear Propulsion Office (ANPO). Keirn was also named to head this, while retaining his post as chief of the AEC Aircraft Reactors Branch as well.

Meanwhile, on 6 June 1957, General Smart had defined the ANP program as encompassing "the development and developmental testing of nuclear power plants for aircraft systems and the provision and use of suitable plants in flight" as well as "similar activities pertaining to nuclear propulsion

for missiles, nuclear auxiliary power plants for use in aircraft or missiles, and such other nuclear devices that may be subsequently assigned to the Program." In October 1957 he had also made clear that, although the general Air Force objective remained a strategic weapon system, the program for the next several years was to be basically limited to propulsion system development, with the entire effort concentrated under ANPO. Although GOR 81 remained in effect, these changes made it apparent that weapon system development was at least temporarily at an end.[17]

On 20 August 1957, Keirn had furnished other program specifics. The major objective was introduction of "a limited number of nuclear-powered turbojet strategic bombers in the 1966-69 time period," with both high- and low-altitude and subsonic and supersonic speed capabilities. Early experimental flights of a DAC system would begin in 1963 or 1964. Convair and Lockheed airframe design work would be cut back sharply. Development of an IDC propulsion system by Pratt & Whitney would continue, but under almost complete AEC control.* The Air Force and AEC would supply strong funding support for General Electric's DAC development in order to obtain a ground-test prototype and a first flight-test system as soon as possible. The Air Force would provide $60 million and AEC $90 million in each of fiscal years 1958 and 1959.[18]

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*Pratt & Whitney had abandoned work on the circulating-fuel reactor and was working on a solid-fuel liquid-cooled type. The "fireball" reactor had shown considerable promise for a time. An experimental version "went critical" with higher than expected output of 2.5 megawatts at Oak Ridge on 3 November 1954, and work on the reactor continued. The Oak Ridge National Laboratory in mid-1957 proposed a continued development effort leading to a prototype aircraft reactor in 1960, but severe engineering and fabrication problems were still unsolved and the necessary funds were not forthcoming. (WADC, The USAF ANP Program, pp 117, 126, 182, 203, 209, 213.) The AEC continued work on it for other purposes, and its early development became a byproduct of the program.

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Following the Russian launching of the first earth satellite on 4 October 1957, Chairman Melvin Price of JCAE's R&D subcommittee urged that the program be accelerated to provide a successful nuclear flight demonstration in order to recapture scientific prestige. The AEC stated a similar position, and the Air Force offered to demonstrate nuclear flight in 1962. In response, President Eisenhower's scientific adviser, James D. Killian, appointed an ad hoc committee, headed by Robert F. Bacher, to examine the prospects of early flight. After the Bacher Committee recommended continued concentration on a high-temperature reactor* the President on 25 February 1958 disapproved the accelerated flight proposal, stating that it would detract from the objective of creating a militarily useful aircraft.[19]

OSD took the occasion to establish more definite guidance for the ANP program, in accord with the President's decision. Deputy Secretary of Defense Donald A. Quarles advised the JCAE on 6 March and the Secretary of the Air Force on 13 March that the program would concentrate on reactor development, following two principal lines of attack. The direct air cycle reactor and associated turbojet propulsion unit would be the primary objective, with particular emphasis on the development of improved materials to achieve maximum performance, while the indirect cycle project would continue at the current level of effort, as justified by its long-range higher-performance potential. Although the Air Force took advantage of an invitation to request additional funds, no significant increase resulted.[20]

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*Many ANP enthusiasts questioned the findings of the Bacher Committee, despite its distinguished leadership, on what were to become familiar grounds--that there had been no searching for new facts or direct examination of the work in the field but only a rehashing of inaccurate information from secondary sources. (Ltr, Erwin to AFCHO, 9 Aug 62.)

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Meanwhile, the Strategic Air Command had devised a new concept for a nuclear-powered manned weapon system known as CAMAL (continuously airborne missile launcher). While taking full advantage of the endurance and range characteristics provided by nuclear power, the concept would not require the high speed and high altitude that for some years had been considered essential to a strategic bomber and were creating major development problems. CAMAL, its proponents argued, would be invulnerable to the Russian long-range ballistic missiles now regarded as operationally imminent.[21]

The USAF Aircraft and Weapons Board indorsed the CAMAL concept in May 1958, and in July the ARDC undertook a design competition to permit selection of an airframe contractor by January 1959. The designs would be based on the General Electric XMA-1 reactor, which was far along in development. On 28 October 1958 the Air Staff issued GOR 172, calling for the following relatively modest performance: flight endurance of 50 to 120 hours, payload of 2 air-launched ballistic missiles and a 10,000-pound bomb, speed of mach .83 to .9 at low altitude, and an initial operational date of 1966. Required by its mission to be able to maintain a continuously airborne alert and nomadic patrol, the desired aircraft would be capable of rapid reaction by air-launching ballistic-type missiles followed by low-level delivery of a "lay-down" weapon. The GOR also listed secondary capabilities for intelligence, armed reconnaissance, airborne command post, early warning, ZI-based global support of limited war operations, and active air defense.[22]

In late 1958 the Air Force proposed to OSD the start of a CAMAL development program leading to nuclear flight tests in 1962 and an initial operational capability in 1965-66, but it was unsuccessful in getting support.

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Nevertheless, the Air Force continued its airframe competition, and after evaluation by a 70-man USAF technical team, on 20 March 1959, selected Convair as the winner. The winning design, Model 54, was sufficiently flexible to accommodate first- , second- , and third-generation engines.[23]

Meanwhile, the Navy late in 1958 had proposed to install a nuclear power plant in a British-built turboprop seaplane, the Princess,* and then to follow this with a specially designed nuclear aircraft for antisubmarine and early warning missions. In December 1958, Aviation Week in a widely publicized article claimed that the Russians had already flown a nuclear-powered aircraft, exciting repercussions both from the public and from the JCAE. The ferment resulting from the injection of these new factors helped to induce program reexamination and, ultimately, another reorientation.[24]

On 2 January 1959, Deputy Secretary Quarles and AEC Chairman John A. McCone joined in asking Presidential approval of their proposed general course of action for ANP. They rejected both that CAMAL and Princess proposals in favor of the existing limited program. Conceding the CAMAL could be built by the mid-1960's, they stated that it would be of marginal military value and would not supplant other strategic weapons. They considered the Navy proposal technologically premature. McCone and Quarles deemed the political and psychological significance of first nuclear flight insufficient to justify an accelerated effort. Having rejected change in the major program objectives on these grounds, they also found no technical developments warranting significant change in emphasis or direction. They recommended

*Air Force nuclear propulsion officials regarded the proposed combination as virtually unusable, as well as requiring a complete redesign of the IDC propulsion system to be employed. (Ltr, Erwin to AFCHO, 9 Aug 62.)

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an obligational authority of $150 to $160 million for fiscal year 1960, about equally divided between the AEC and Air Force. This was about $90 million less than proposed by the Air Force and would actually constitute the Air Force and would actually constitute a small cutback from 1959. Policy guidance would remain as directed by the President in February 1958: primary effort on a DAC unit for the strategic mission and secondary effort on the IDC reactor, with limited associated investigations on shielding, radiation, the airframe, and operational hazards. With little delay, President Eisenhower approved the Quarles-McCone recommendations on 8 January 1959.[25]

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## II. THE 1959 REEVALUATION

The Presidential decision of 8 January 1959 by no means ended the matter, since the JCAE, which considered itself the watchdog of the ANP program, remained dissatisfied with the scope and schedules. Called before the JCAE's R&D subcommittee on 26 January to explain the viewpoint of the Air Force, Secretary James H. Douglas, Jr., conceded that the original goals had been set too high and the Air Force would now settle for a subsonic aircraft. While admitting also that the Air Force was giving less priority to the program than a few years back, he emphasized that the Air Force still had a firm operational requirement for nuclear-powered aircraft and a firm set of development objectives.* Although the Presidentially approved DOD-AEC program had set back both the development goal of nuclear flight in 1962-63 and the operational goal of a CAMAL system, the Air Force would still press at least for an experimental nuclear aircraft. All subcommittee members except one expressed opposition to the administration's decision to postpone a time-phased aircraft development.[1]

During the succeeding months the JCAE continued to bring pressure on the DOD to establish a definite aircraft program. In testimony before the committee on 5 February 1959, Deputy Secretary Quarles committed himself to continuous review of propulsion system development to insure a timely flight test program. In April, JCAE's R&D subcommittee visited General Electric's DAC reactor development facility at Evendale, Ohio, and was

*Although GOR's 81 and 172 had not been withdrawn, they were perforce held in abeyance. (See below, pp 30,39.)

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greatly impressed. Chairman Price then informed Quarles that GE's propulsion progress warranted a DOD "go-ahead" beginning in fiscal 1960 on detail design and construction of the prototype CAMAL. He contended that this would permit nuclear-powered flight in early 1963 with the best reactor then available, since the airframe would be adaptable to both types of reactors. If ground tests in 1961 were unsuccessful, airframe work could be stretched. Price asked Quarles for a technical and funding decision, stating that his subcommittee planned public hearings beginning 14 May.[2]

During the first week in May, possibly moved by this request, Quarles visited the Evendale facility. Immediately thereafter, on 7 May, he and McCone reviewed the ANP program with USAF and AEC representatives. According to USAF officers attending, Quarles announced that he would ask for Presidential approval of a plan presented by General Keirn to initiate work on a flight-test program using the direct air cycle engine. It would be a modest beginning, with the Air Force and AEC reprogramming $20 million and $5 million, respectively, in fiscal year 1960. At this point fate intervened--Quarles died of a heart attack during the night,* and his successor, Thomas S. Gates, Jr., passed the problem to Dr. Herbert F. York, Director of Defense Research and Engineering (D/DR&E).[3] York approached the matter cautiously despite the congressional pressures.

Meanwhile, three agencies--the WSEG, the SAB, and the JCS--were also studying the program. The first of these, WSEG, reported on 25 May that development of nuclear-powered aircraft weapon systems for the 1960-75

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*On the day following, the office of The Assistant DCS/D for Nuclear Systems and the MLC staff attempted to get out an MLC letter to the President along the lines directed by Quarles, but the D/DR&E blocked this. (Ltr, Erwin to AFCHO, 9 Aug 62.)

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period was feasible and that these systems could be used in at least four missions--antisubmarine warfare, airborne early warning, logistic transport, and long-range attack. However, WSEG also reported that nuclear-propelled aircraft would be more costly than conventional aircraft for the first three of these missions, even in a turboprop version. On the other hand, for airborne alert and long-range attack purposes, WSEG believed CAMAL had a pronounced advantage over both the B-52 and the proposed B-70 if the reactor had an operating life of 1,000 hours. The group warned that serious technical problems had to be solved and concluded that the most logical approach was to obtain operating experience from a small number of experimental aircraft before making large commitments to weapon system development.[4]

This middle-of-the-road report was not altogether displeasing to the Air Force, which was willing to accept an experimental rather than weapon system approach in order to get design work under way. In fact, the Air Force presented a similar viewpoint in the JCS, which had been asked by OSD for a military appraisal of the proper course of action. In reply on 19 June 1959, the JCS adopted this position--that there was considerable military potential in a nuclear-powered aircraft, that an early flight was in the national interest, and that precise military applications were not yet sufficiently clear to establish military requirements and define specific weapon system concepts. It approved the military desirability of a flight-test program as soon as technically feasible and recommended that the prototype aircraft be capable of testing all proposed engines.[5]

Five days later, JCAE's R&D subcommittee informally discussed the ANP program with McCone, Commissioner John F. Floberg, and General Manager

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A.R. Luedecke of the AEC; General Keirn, chief of the ANP program; Vice Adm. John T. Hayward, the Navy representative; Chairman Herbert B. Loper of MLC; and Gates and York. York quickly made clear that he would not follow the new course supposedly approved by Quarles before his death. He indicated that the primary problems concerned primarily the development of a reactor-engine combination capable of militarily useful flight and only secondarily flight-testing an experimental aircraft. Rejecting the Keirn proposal to begin development of a test aircraft, he would continue to emphasize reactor development until there was a definitely feasible and potentially useful item available. To do otherwise would interfere with reactor development, particularly of the indirect cycle. York argued that attempts to find shortcuts and apply "brute force" had characterized the program to date and that an insufficient proportion of the funds and energy had been expended to develop a high-performance reactor. Gates testified that Secretary of Defense Neil H. McElroy desired to put additional funds into the program, but only for Pratt & Whitney's experimental IDC reactor.[6]

The OSD stand was a severe disappointment to the Air Force, the AEC, and the JCAE. To some Air Force officials the decision meant essentially that the program would continue at low level until it "fell flat by being overtaken by time". Although sympathizing with DOD's financial difficulties, McCone emphasized his disappointment over York's conclusions and expressed his own belief that it would be worthwhile to build a nuclear aircraft even though it did not meet any specific military need. Successful flight in itself would provide both incentive and experience to complete development. Chairman Price, nearly all other members of the sub-

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committee, and Senator Clinton B. Anderson, chairman of the parent committee, strongly indorsed McCone's views. Only Senator Bourke B. Hickenlooper had reservations about a flight program that met no specific military need.[7]

On 7 July 1959, York formally rejected the Keirn proposal for early flight of the General Electric XMA-1A direct air cycle system but approved increased support to the indirect cycle system. York reiterated that the development program should concentrate on high-temperature reactors for militarily useful flight and on turbo machinery needed to verify the feasibility of nuclear flight. Nuclear flight itself should be deferred until the AEC had firmly established the feasibility and potential usefulness of an advanced power plant.[8]

In a simultaneous report to the Secretary of Defense, York gave some of the technical reasons for his conclusions. He conceded that the XMA-1A reactor using nichrome-V fuel elements could probably propel a Model 54 aircraft weighing 600,000 pounds at a speed of about Mach .6 and an altitude of 10,000 feet. However, there could be no payload other than supplementary chemical fuel for 750 miles, and the reactor would have an operating life of only 100 hours. Such performance, he said, had no military value. He contended that the Keirn proposals would cost at least $1.169 billion over the next five years, be no more than a repetition of the "brute force approach" of the past, and divert funds from the prime problem --development of a militarily useful reactor-engine combination. York argued that since no "reasonably possible" program could lead to militarily useful flight before 1970, it was impossible to describe in detail operational requirements for a nuclear-powered aircraft or prove its usefulness by cost-effectiveness studies.[9]

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With regard to reactors, York questioned the military worth of the more advanced DAC metal version using iron-chromium fuel elements, since the materials would have to operate too close to their theoretical thermal limits. He proposed an immediate jump to a third-step reactor using ceramic fuel elements of beryllium oxide. A similar situation prevailed with IDC reactors. The simplest form, using liquid sodium for heat transfer and stainless-steel jacketing for the fuel elements, could serve no useful military purpose. The second type, using lithium-7 and sodium potassium in a double-loop system with the fuel elements encased in columbium alloy, would also have to operate too close to theoretical thermal limits. Therefore, a jump to a third type, using lithium-7 in a single-loop system and columbium alloy for both heat exchanger and fuel element jackets, seemed in order. Only then could nuclear engines duplicate the speed and altitude performance of chemically fueled jet engines. The decision between the DAC and IDC reactors would necessarily have to be left to a later date, pending further advances and more performance data.[10]

The York decision meant at least another year's delay in embarking on a program leading to nuclear flight. Any disposition of the Air Force to object was quickly discouraged, however, by the appearance on 17 July 1959 of the report by the SAB's ANP ad hoc committee. The committee conclusions gave definite hope of ultimate nuclear flight but furnished little support to the Air Force for early flight tests. Among the most important points were the following: the earliest flight test could be made in five years using the XMA-1A metal core reactor, but with marginal performance; an improved ceramic core DAC might be available by 1965 and an IDC reactor by 1967; the IDC reactor appeared to have a clear advantage for supersonic

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flight and in ground handling; the general Model 54 configuration was suitable for testing both types of reactors; and no clearly supported military requirement for a manned nuclear aircraft had been presented.[11]

More important, the committee made four specific technical recommendations: (1) in the DAC reactor effort, development of metal cores should be dropped and emphasis placed on the ceramic (beryllium oxide) core; (2) development of the IDC single-loop system should be intensified; (3) Phase I study of a test-bed aircraft for flight-test purposes compatible with both cycles should be started at once; and (4) decision on construction of the aircraft could profit from a one-year postponement. The committee dealt at some length with the relative merits of the DAC and IDC reactors, finding the latter superior in several different ways although several years behind in development. It emphasized the great weight advantage deriving from the smaller amount of required shielding and the greater versatility in permitting the use of "off-the-shelf" turbojet and turboprop engines. The committee also urged that the program be more closely coordinated by a permanent technical advisory board composed of contractor and other qualified experts.[12]

The SAB report was received unhappily by General Keirn, who saw his stand for a metallic-core DAC reactor in the first aircraft (with the ceramic as an improved follow-on) contradicted by the recommendation for using a ceramic-core reactor initially. This would mean drastic modifications to the current ANP program and delay the first-flight development effort by at least two years. "Hardware will be put on the shelf, subcontracts terminated, personnel strength at GE reduced, and in all probability the Flight Engine Test Facility at /Arco/ Idaho will be placed in standby, and

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a new facility complex at the Nevada Test Station constructed," he stated.[13]

The JCAE was not disposed to take York's decision quietly. It reacted by holding on 23 July 1959 the first public hearings in the history of the ANP program. At that time, Representative Price observed that members of the committee had been "distressed to learn that plans for a flight program . . . are now being shelved in favor of continuing a policy of drift and indecision which has characterized the program from the start," despite the general agreement in both the DOD and AEC that a direct air cycle system was now in existence for initial flight tests.

McCone again supported the committee's contention that the greatest need was establishment of a flight-test phase as a definite program objective. While technical feasibility of nuclear flight had now been assured, he said, there was a critical need for operational data to be used with improved systems. Nevertheless, he conceded that the requirement for a nuclear-powered aircraft was less than in 1948 or 1950 because of the advent of rival weapon systems.

Under Secretary Fred A. Bantz and Admiral Hayward stated the Navy's need for an aircraft of extended range and endurance for a variety of missions, particularly antisubmarine warfare and airborne early warning. Hayward felt that failure to set "flight at any speed" as the first objective had been the basic mistake in the ANP program. Instead, advanced weapon systems were spelled out and then attempts made "to invent on schedule" to meet the requirements. He stated that York's decision to concentrate on the engine was basically sound and should have been made long before, but he expressed also disinterest in a supersonic capability for the first test engines.[14]

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General Keirn, who was soon to retire, appeared before the committee to make a final plea for an immediate flight-test development program based on a DAC engine using materials already developed and to propose construction of two Model 54 aircraft as CAMAL prototypes. While admitting that only strategic air operations could justify the cost of the program, he stated that other uses could well appear. His statement was sharply curtailed and weakened by D/DR&E censoring on security grounds. Support of Keirn's position from the other USAF witnesses--Assistant Secretary (Materiel) Philip B. Taylor and Chief of Staff Gen. Thomas D. White--was less than firm. Taylor recognized the importance of nuclear flight for military purposes but emphasized that it "must take its proper place in relation to other military projects of high priority." He characterized nuclear flight-testing as "a useful experiment which should be undertaken as soon as a powerplant with characteristics within the militarily useful flight spectrum is available." He explained that in its previous appearance before the joint committee, the Air Force had felt that the GE direct air cycle reactor would soon justify going ahead with flight tests, but it now seemed wiser to wait until better performance was demonstrated. Another examination of power plant progress would be made at the end of fiscal year 1960 and availability of funds for 1961 would also influence any change in the decision. General White supported Taylor, carefully distinguishing between his personal enthusiasm for early nuclear flight and his official position in which he had to heed scientific advice.[15]

Gates and York again presented the OSD view that the first flight propulsion unit had to have a growth capability for military utility, and Gates specifically denied that the decision had hinged primarily on finan-

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cial considerations. As further reason for delay, York stated that it was currently impossible to decide between the two reactors but ventured the opinion that the IDC was "intrinsically more useful."

Representatives of the two reactor-developing companies also had the opportunity to state their views. D. Roy Shoults, general manager of General Electric's ANP department, denied the implication that the DAC system lacked growth potential. Still supporting the program for early flight, which GE had presented to the JCAE on its 10 April visit, he asserted that the only major limiting factor to further DAC reactor development was lack of ground- and flight-testing data. Pratt & Whitney's B.A. Schmickrath reported that the IDC was in the advanced research and development phase and promised that the flight version would be a prototype system with the ultimate potential recommended by York.[16]

Despite the overwhelming view of JCAE (only Senator Hickenlooper and Representative Craig Hosmer seemed to support the York-Gates position) that the Air Force-AEC early flight position was sound, the committee took no official action to oppose the program outlined by the DOD.

On 14 August 1959, York described the ANP program objectives in greater detail. He informed the Air Force and Navy that the principal goal was development of a power plant with a potential life of 1,000 hours capable either singly or in combination of flying a Model 54-type airplane at a speed of Mach .8 or .9 at an altitude of 35,000 feet. Work on the Model 54 would, however, be limited to design studies. York also suggested that Assistant Secretary of the Air Force (R&D) Joseph V. Charyk establish an ad hoc advisory group to refine further the program guidance, particularly on the matters of the Navy's turboprop proposal and the safety problem arising from ejection of fission products.[17]

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The program was now reoriented along the described lines. GE successfully tested the experimental model of the XMA-1A DAC reactor in Heat Transfer Reactor Experiment 3 without follow-up and then shifted DAC development effort to the XMA-1C, incorporating higher-temperature fuel elements with ceramic (beryllium oxide) coating. The Air Force also revised its turbojet contract with General Electric, optimistically calling for a combination of the GE X-211 turbojet engine with the advanced DAC reactor by 1961-62. No significant increase took place in the planned fiscal year 1960 program for the IDC, on which there had been little disagreement, and the first development goal remained the construction of a 10-megawatt experimental reactor. However, in December 1959, York directed the Navy to cancel its IDC contract with Pratt & Whitney in order to avoid possible conflict with that company's work on the advanced IDC reactor.[18]

AEC General Manager Luedecke found the guidance insufficiently specific, and on 1 September 1959 and again on 5 October asked for more definite goals, but York delayed an answer pending receipt of a report from the Charyk advisory group. This group made its report on 25 January 1960, generally approving the York guidance as sound. Apart from high-performance requirements, the group found the most critical development areas to be fuel-element lifetime and shielding. It also expressed the opinion that there was "little doubt, given adequate time and money, that technological problems can be solved in both power plant developments to attain the initial performance criteria" and that "both reactor cycles have a potential for improved performance with advancing technology." However, the IDC had a definite superiority in potential performance and was suitable for a wide variety of missions. This was a viewpoint that was to be heard increas-

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ingly during the following year. The report recommended that both cycles be pursued through ground-testing, both scheduled for 1962.[19]

More broadly, the group concluded that "early nuclear flight in a manned experimental aircraft continues to be an important and valid goal" but that it was not yet possible to spell out the details of a military weapon system. The unique characteristics of nuclear flight and national prestige considerations both dictated a vigorous approach to development. Accordingly the group proposed that a $150 million airframe program be started in fiscal year 1962 to assure flight in early 1966.[20]

York was quite willing to accept the essentials of the report, which generally supported his own views, but not the recommendations on airframe development. Replying on 27 February 1960 to Luedecke's letters of September and October, he reaffirmed his earlier guidance. Expressing general concurrence with the conclusions of the Charyk report, he stated that after the reactor tests, possibly in late 1962, the AEC and DOD should reconsider the technical and cost factors. Test aircraft and supporting bases could then be dealt with. He estimated available funding as $130.7 million for fiscal year 1960 and $144.7 million for fiscal year 1961. Of this, the Air Force would provide $63.2 million in 1960 and $67 million in the following year, with the AEC providing the remainder.[21]

At the conclusion of the months-long detailed analyses and evaluation, the ANP program appeared stabilized for at least the next two years. But this was not the case. The JCAE was still unwilling to let the program rest at the level of effort determined by the DOD. The unique advantages of nuclear propulsion also offered an irresistible enticement to Air Force planning and operational officials, and they sought during late 1959 and

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1960 to correct the inconsistencies that had caused a softening in high-level support. On the other hand, OSD, alarmed at the threatened increase in allotment of development resources to the program, showed some disposition to question the worth of the entire effort. These and other factors made 1960 another year of controversy.

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## III. THE ESTABLISHMENT OF NEW AIR FORCE REQUIREMENTS, 1959-60

The more convinced USAF proponents of nuclear propulsion considered York's decision of July 1959 a signal defeat, and they lost little time in seeking a basis for reversing it. On 6 August 1959, Maj. Gen. Hewitt T. Wheless, Director of Plans, proposed to the Director of Operational Requirements and the Assistant DCS/Development for Nuclear Systems that the Air Force try to establish a specific military operational requirement for nuclear aircraft weapon systems and obtain JCS indorsement. Otherwise, the program would continue to receive insufficient emphasis.[1]

On 13 August, Technical Director Joe C. Jones of ANPO expressed similar views to Brig. Gen. Irving L. Branch, General Keirn's successor. Jones believed that "the weak Air Force stand on CAMAL," together with the uncertain WSEG cost-effectiveness findings, had led to York's request for JCS views and to the subsequent failure of the JCS to state a specific military requirement. A clear and definite military operational requirement was needed as guidance for power plant development. Jones contended that in the past the Air Force had centered its interest on strategic applications of traditional type, placing an excessive strain on propulsion technology. If a supersonic power plant were the primary objective, then the GE X-211/XMA combination would be inadequate and the money for its development should be applied elsewhere. Unless the Air Force supported the CAMAL concept or other reasonable objectives for the initial power plant, Jones forecast that the Navy with its low-performance Princess approach might emerge with the first nuclear-powered aircraft. He suggested that DCS/Plans

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and Programs and DCS/Operations prepare a firm Air Force position and then approach the JCS for its indorsement.[2]

Lt. Gen. Roscoe C. Wilson, DCS/Development, acted along these lines a few days later, asking the two staff agencies to form a task group "to evaluate the most appropriate areas of usefulness of manned nuclear aircraft in the post-1970 period in order that current ANP efforts can be appropriately reoriented." Stating that recent reviews by the DOD necessitated a realignment of the ANP technical program more directly toward "militarily useful" propulsion systems, he urged that "we . . . sufficiently define military utility to allow the establishment of appropriate development objectives and requirements." He explained that the proposed technical program had become vulnerable when the Air Force failed to support CAMAL (the justification for the XMA propulsion system) as a military requirement. Accordingly, Wilson recommended that the Air Force drop both GOR 81 and GOR 172 unless it could fully support them.[3]

Air Force procedures for stating weapon system requirements were then in process of revision, with the General Operational Requirement (GOR) being replaced by two new types of requirement statements--the System Development Requirement (SDR) and the Specific Operational Requirement (SOR).* The SDR described in general terms a proposed weapon system designed to fulfill an anticipated long-range operational need beyond current technology or to exploit a significant technological advance having a potential military application. The SOR described in more specific terms a weapon

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*Still other documents--the Operational Support Requirement, Subsystem Development Requirement, Qualitative Operational Requirement, Research Document, and Command Operations Document--described more limited and specialized requirements.

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system within the current state of the art and for which a production program was considered desirable. (In his appearance before the JCAE on 23 July, General Keirn had explained that GOR 172 /CAMAL/ would be an SDR under the new system.) In addition, the revised procedural system included two new "guidance" documents: the Required Operational Capability (ROC), an overall statement of general operational capabilities for some specified time in the future (usually 10 years), and the Long Range Research and Development Objectives (RDO), a broad description of technological objectives offering potential for fulfilling an ROC.[4]

After concurrence from Lt. Gen. Dean C. Strother, DCS/Operations, and Lt. Gen. John K. Gerhart, DCS/Plans and Programs, Maj. Gen. Bruce K. Holloway, Director of Operational Requirements, established the Wilson-proposed ad hoc task group on 24 September 1959. He directed the group, headed by Col. George D. Hughes, to (1) investigate the present Air Force operational requirement for ANP and make recommendations for an ROC and SDR, (2) recommend goals and the future course of the development program, (3) investigate the advantages and disadvantages of early flight for ANP and recommend an Air Force course of action, (4) compare chemical and nuclear propulsion for extended range and endurance, and (5) investigate and make recommendations in other pertinent areas.[5]

At a meeting of the group on 29 September, Lt Col. William W. Elliott of ANPO reviewed the current program and requested that a specific weapon system goal not be stated at theis time. Explaining that the current goal was to reach the flight stage and then proceed toward a weapon system, he pointed out that the CAMAL concept was probably three to five years ahead of a nuclear-powered B-70. Nevertheless, the ad hoc group, obviously under

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some pressure to align the manned ANP effort with the proposed B-70, in a preliminary report requested General Strother to have North American and Pratt & Whitney carry out an immediate study on an ANP/B-70 merger, including compilation of cost estimates to permit comparison with Model 54 estimates.[6]

This integration had first been proposed in 1958, but the resulting analysis, presented to the Weapons Board and the Air Force Council in January 1959, had concluded that "the B-70 had no effective application to the current ANP program as a development test vehicle and that the current General Electric nuclear propulsion system technology would provide the B-70 with no effective operational capability." The Air Force Council had then recommended that ANP proceed with development of a subsonic weapon system (CAMAL). Nevertheless, support for the ANP/B-70 combination continued within the Air Staff and reemerged following York's rejection of the CAMAL proposal. Necessarily it was closely tied to the IDC, since only this cycle had the desired supersonic performance potential. Although General Strother immediately took action to secure the study desired by the ad hoc group, several delays followed, and its results did not become available until the following May.[7]

By December 1959 the ad hoc group had prepared conclusions and recommendations on which it sought Air Staff coordination. The most important conclusions may be summarized as follows: (1) the IDC offered greater potential advantage for a supersonic "long-endurance missile-carrying penetrator"; (2) funds were insufficient "to optimize the development" of both propulsion systems during the 1960-67 period; (3) since the Air Force required a high-supersonic capability, development of the DAC should be discontinued; (4)

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any reorientation should be held in abeyance pending the outcome of the ANP/B-70 study; (5) assuming the results of the study were favorable, ANP should be reoriented toward the earliest practicable flight test using the B-70 airframe; and (6) in the event add-on funds for the B-70 weapon system development were not forthcoming, the B-70 program should be reoriented toward a nuclear-powered version, with entry into the inventory during a later period (1967-70). The group formally recommended approval of a proposed ROC and SDR and cancellation of GOR's 81 and 172, and expedited development of the IDC. The failure to include a recommendation to cancel the DAC apparently stemmed from the view that the Air Force should withhold action until the OSD forced a cancellation.[8]

The proposed ROC described a concept of operations based on a continued need, during 1968-75, to capitalize on the basic qualities inherent in manned systems, including abilities to search out and attack targets of unknown or inexact location, to exercise judgment in unforeseen situations, to be recalled and recovered, and to collect intelligence. The desired system would rely on either airborne mobility or quick reaction for survival, enable the commander in chief to keep his force in the air and inaccessible to enemy attack while the decision to counterattack was made, and place air-to-surface missiles and bombs in position for immediate strike after the decision. The proposed ROC pointed out that manned strategic forces would be limited in their flexibility until they had unlimited range, endurance, and a large load-carrying capability and that technical advances in nuclear propulsion indicated a promise of meeting these requirements. The proposed SDR, more specific in nature, called for the development of "a nuclear powered strategic bomber, having an omnidirectional global range and long

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endurance, capable of delivering warheads to any earth target." The required bomber would have a speed of Mach 3 above 70,000 feet and .9 at 500 feet, endurance of five days, force readiness of one-third at all times, payload of six air-to-surface missiles and one 10,000-pound bomb in various combinations, and reliability of 90 percent in delivering payloads on targets.[9]

The Nuclear Systems office regarded the proposed SDR with some reserve, General Branch pointing out that the requirement for supersonic speed was not consistent with current DOD objectives and that the proposed SDR was "to a large extent a restatement of the CAMAL requirement of GOR 172 with the addition of a supersonic requirement." He believed it would provide desirable guidance but would require full and active Air Force support to achieve concrete results. Despite such reservations, it was on opposition from the Deputy Director of Plans that the findings of the ad hoc group eventually foundered. Maj. Gen. Glen W. Martin asserted in February 1960 that the Chief of Staff's policy statement of 20 January on the B-70 had suggested a merger with ANP and thus superseded major portions of the ad hoc group's report. To comply with the stated policy on the B-70, he recommended that Operational Requirements secure final Air Staff coordination on the proposed ROC and that it transmit the proposed SDR to Development Planning for necessary action and final Air Staff coordination. He also urged that action be taken to cancel the DAC effort, as without potential to meet the requirements of the supersonic penetrator, this to be carried out before 31 March in order to avoid commitment of fiscal year 1961 funds.[10]

Although the ad hoc group was quite willing to rewrite its recommendations along the line suggested by Plans, the Nuclear Systems office on

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7 March reversed itself on the cancellation of the DAC. It pointed out that the DOD ANP advisory group (Charyk)* had recently recommended, with indications that York would approve, the continuation of both the DAC and IDC until further test data accumulated. Nuclear Systems added that cancellation of the DAC would encourage placing the whole program under the AEC and that the funds released could not be applied to other parts of the program.[11]

Meanwhile, General Holloway had emphasized on 29 February 1960 that the Weapons Board wanted all resources concentrated on prospective operational systems and accordingly insisted that "all efforts on a nuclear powered aircraft should be directed toward a significant improvement to the B-70." Although Nuclear Systems indicated agreement with Plans on going ahead with coordinating the ROC and SDR, which would lay the foundation for the merger, the Air Staff concluded on 8 April that the ANP/B-70 combination was impracticable.[12]

Nevertheless, the concept of keeping ANP geared to the "higher and faster" philosophy died hard, and General Strother, among others, wanted to issue an ROC for a nuclear-propelled high-altitude supersonic weapon system of the B-70 type if only for internal consumption. He also insisted that an experimental ANP aircraft must have the capability for supersonic flight. General Branch finally delivered the death blow to lingering thoughts of the ANP/B-70 merger on 9 May, reporting that North American's interim report called for an essentially new aircraft. By 15 June, General Holloway accepted defeat on the B-70 proposal but expressed the belief that this also ended the chance of getting a militarily useful nuclear-

*(See above, pp 26-27.)

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propulsion weapon system during the required time period. Consequently, he recommended canceling the ANP program and reorienting the effort to space applications.[13]

No new requirement statement, either ROC or SDR, emerged from this series of conflicting and sometimes confusing events, and the USAF ad hoc ANP group had little to show for its efforts. The ROC was dropped completely, while the SDR passed to Development Planning. Although it was obvious that GOR's 81 and 172 should be rescinded, there was still no agreement on what should supplant them. General Branch presented a program for ANP to the Strategic Air Panel on 3 July 1960 which differed little from that recommended by ANPO a year earlier. This would lead to subsonic flight in an NX-2 airframe in 1965. Ultimate missions included air alert, missile launch, low-level penetration, logistic transport, reconnaissance, and patrol. The program would aim at low technical risk, wide applicability (both as to type of propulsion system and mission), and relatively low cost.[14]

In contrast, Development Planning presented on 26 July what was essentially the proposed SDR prepared by the Air Staff ad hoc ANP group, calling for a Mach 3 speed at 70,000 feet and Mach .9 at 1,000 feet. There was no immediate agreement on what form the SDR should take, and a mood of disillusionment took hold within the Air Staff as the realization spread that nuclear propulsion could not compete for at least the next decade with chemical propulsion on the traditional basis of higher and faster. In this situation the Nuclear Systems office continued to stress the one unarguable advantage of nuclear propulsion--extended endurance without inflight refueling--which offered obvious advantages even

at subsonic speed for such missions as airborne alert, antisubmarine warfare, strategic missile carrier, and long-range air transport.[15]

Meanwhile, in May 1960, Generals Wilson and Branch had requested the SAB to review the ANP program again, partly because of the disagreements within the Air Staff and partly because the program was again under fire from outside the Air Force. The SAB report, in July, was rather narrow in scope, dealing principally with the potentialities of the two cycles and the feasibility of developing an experimental airframe.* Nevertheless, USAF proponents of a supersonic ANP weapon system immediately employed the conclusions to argue for a reduced, longer-range program.[16]

On 24 August 1960, Colonel Hughes, who had headed the ad hoc task group, recommended to the Weapons Board that the ANP program be deemphasized. After reviewing the SAB findings, he pointed out that the speed and altitude requirements of strategic systems for the late 1960's and early 1970's, though not definitely determined, appeared to be beyond ANP and that its operational value therefore appeared questionable. He proposed that research and development be continued at a lower rate of expenditure on a program involving less technical risk, even if it meant a delay in nuclear flight. Concluding that it was too early to specify a military application, he recommended the following actions: (1) cancel both obsolete GOR's, (2) cancel the DAC effort, (3) continue the IDC with an ultimate goal of high-supersonic speed on nuclear power alone, (4) publish an SDR to provide development guidance in accord with SAB's Alternative III of the July 1960 report,† and (5) insure that all public state-

*For summary, see below, Chap IV.

†This was nuclear flight with a more advanced aircraft and an engine having growth potential beyond that specified in the York guidance.

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ments and documents emphasize the national character and importance of nuclear propulsion rather than its specific Air Force applications.[17]

At this juncture, with the outlook dark for Air Force advocates of a continued strong and shorter-range development effort, the Strategic Air Command's chief, Gen. Thomas S. Power, came forward with strong support for the concept of operations urged by General Branch. In a letter to General White, Power described ANP as "the only propulsion system capable of providing an atmospheric force which can not only operate from air alert posture prior to hostilities but also remain in 'airborne reserve' for days or weeks thereafter, completely independent of surface facilities," and suitable for a variety of missions, including initial air-launched ballistic missile strikes, armed reconnaissance, and airborne command and control. He added that actual test flight and maintenance were of course essential to provide data on cost effectiveness in order to compare ANP with other proposed systems.[18]

The requirement decision, which came on 21 September, was essentially a compromise. At that time General White informed Secretary Douglas that the ultimate objective should be "the development of nuclear power plants capable of powering very large payload aircraft, with essentially unlimited endurance, at supersonic speeds." Although it was too early to spell out precise weapon systems, their obvious potential justified flight-testing to provide military and cost-effectiveness estimates. He also predicted that "a well planned research and development program leading eventually to manned supersonic flight, under nuclear power only, will provide the technology required to produce nuclear powered subsonic systems of potential military use . . . ."[19]

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The Chief of Staff's statement cleared the way for unwinding the requirements tangle. On 9 November 1960, the Air Staff issued Advanced Development Objective (ADO)* 20 in place of GOR's 81 (WS-125A) and 172 (CAMAL). The document stated:

> The objective of this program is to develop a manned nuclear-powered test aircraft with essentially unlimited endurance, independent of inflight refueling, which will have the potential of adding a new dimension to the spectrum of manned flight. This 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.

The initial test aircraft would only have subsonic performance; however, supersonic flight was the ultimate objective. The goal for the first flight was 1965, with performance characteristics corresponding to York's guidance of July-August 1959.† The propulsion cycle was to be selected in 1962, with ground test to follow in 1964.[20]

The issuance of the ADO, although bringing the Air Force shorter-range development objectives into harmony with those of the OSD, marked a definite retreat from any thought of intermediate-term operational capability. In effect, the Air Staff acknowledged that a specific operational requirement based on foreseeable nuclear-propulsion technology was impracticable and that its past efforts in that direction had been mistakes. Operational capability of any type receded to some uncertain time in the future. There was a large measure of realism in the new position, but its late appearance was bound to expose the program to new attacks.

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*This was the new terminology for the System Development Requirement.

†(See above, pp 20,25.)

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This was especially true since the Air Staff itself still seemed unable to decide between supersonic and subsonic ANP.

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## IV. RECONSIDERATION AND TERMINATION, 1960-61

While the Air Staff undertook its extensive reexamination of requirements for ANP, a reconsideration of the entire program was occurring at the JCAE-DOD-AEC level. This began in January 1960 and continued throughout the spring with hearings before numerous subcommittees of the House and Senate committees on appropriations and of the Joint Committee on Atomic Energy. These hearings were in great part the result of opposition by economy-minded Congressmen to the huge program obligations of the past, amounting to about $980 million through fiscal year 1960, and the large estimated cost of $850 million yet to be borne before the first nuclear flight. There was also dissatisfaction over the lack of concrete results and the long-term nature of the ANP program, which contrasted sharply with the Navy's successful nuclear submarine program.[1]

### Budget Considerations for 1961 and 1962

Proposed funding for fiscal year 1961 totaled $152.7 million, with the Air Force providing $75 million and AEC $77.7 million. After testimony by General White and Assistant Secretary Charyk in January 1960 the DOD Subcommittee of the House Committee on Appropriations approved the Air Force budget request for $75 million. In April, however, the Subcommittee on Public Works Appropriations balked on AEC's nuclear propulsion request, now reduced to $73 million, and suggested that the $75 million previously approved for the Air Force be divided between the Air Force and the AEC. Subcommittee Chairman Clarence Cannon then established a special subcommittee under George H. Mahon for the purpose of forcing ANP program supporters

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to rejustify the request on the basis of military necessity.[2]

On 5 May 1960, Representative Price supported AEC's budget request for ANP with a strong speech in the House, stating:

> Never have I seen a development program more fraught with outside interference, red tape, and vacillating support . . . . It is truly phenomenal that in spite of the difficulties injected by such outside interference steady technical progress has been made in this program by the working scientists and engineers in this field. It is truly gratifying that in spite of these difficulties we have progressed to the point where we can finally apply the technical knowledge we have obtained to a flyable aircraft engine.

He forecast enormous technical advantages and scientific prestige for the nation first making a nuclear flight and argued that actual nuclear flight rather than military usefulness must therefore be the immediate goal. He urged employment of the direct air cycle as the most practical means for gaining this objective. Representative Chet Holifield, who stressed the potential importance of nuclear propulsion in space travel, strongly seconded Price's speech.[3]

Shortly after, the House Committee on Appropriations, reversing its subcommittee, approved AEC's $73 million request but placed a spending limitation of $58 million. Although recommending approval of the $75 million for the Air Force phase of the program, the committee was also rather critical:

> This program is a classic example of the obstacles found in attempts to "invent on schedule" or to attempt to push development at a faster rate than the state of the art will permit. This program has been going on for better than ten years and has cost the taxpayers of the country approximately $1 billion. Each year the Committee has inquired into the status of the program and has been assured that progress has been made and that development of a nuclear-powered aircraft is technically feasible, and successful completion of the program will require more time. Accomplishments to date indicate that the achievements each year have been small for the amount of money spent.

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Noting that some committee members believed the program could be pursued more expeditiously and that several witnesses had questioned its worth in the light of the high cost, the committee insisted that the DOD again review the program to determine whether modification or even termination was indicated and suggested that the JCAE conduct a similar review. At the same time, the committee voiced the view that development of aircraft nuclear propulsion would be a significant achievement and should not be abandoned to another nation.[4]

Acting on the House bill, the Senate Committee on Appropriations approved the $75 million for the Air Force and reestablished the full amount authorized for the AEC at $73 million. This was sustained in the House-Senate committee conference.[5]

The numerous reservations stated by the House committee had made it clear that the ANP program was again under heavy pressure, and already at the beginning of fiscal year 1961, several reviews were under way. The SAB had begun a review in mid-June intended to satisfy the committee's request for a DOD reexamination. AEC Chairman McCone had also promised during Senate hearings that the AEC would conduct a review. The Mahon Special Subcommittee of the House Committee on Appropriations was conducting an investigation, to be completed in January 1961. A further element of uncertainty would appear with the election of a new national administration in November 1960.[6]

The SAB's ad hoc committee, under the chairmanship of Dr. Ernst H. Plesset, met on 13 June 1960 and reported about one month later after considering three possible courses of action: (1) nuclear flight at the earliest possible date, regardless of military value, and possibly with chemical

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assist; (2) nuclear flight meeting OSD's guidance of the preceding year; (3) nuclear flight with a more advanced aircraft and an engine having growth potential beyond that specified in OSD's guidance. If the first course of action were adopted, the committee recommended use of the direct air cycle in an existing airframe such as the B-52H. This could lead to flight in 1965-66 at a cost of about $1 billion. The value would lie in the demonstration of the practicability of nuclear flight and accumulation of handling experience, but the system would have limited growth possibilities and might represent a dead end. For the other two courses of action, the committee recommended the liquid-metal IDC and concluded that nuclear flight could be achieved by 1966-67 if design of a suitable airframe were begun at once. The resulting propulsion system would have a significant growth potential. Attainment of the OSD-stated objectives with the direct air cycle appeared doubtful, since the inevitable contingencies and degradations would consume the small performance margin. The third course of action offered definite advantages over the second, since there would be less technical risk and a lower annual rate of expenditure. Moreover, both the design of the airframe and of the final propulsion system could be deferred, with the result that the performance of the prototype combination would significantly better the OSD objectives.[7]

The report thus weakened the ground under the current program and in effect proposed a shift to a longer-term, more advanced program. At the same time it gave strong support to selection of the indirect cycle as more certain for achieving the stated objectives and future growth. Either supersonic flight or flexible subsonic applications were seen as possibilities. The committee recommended work on both the single-loop and double-

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loop heat-transfer IDC systems, with the latter as the interim and the former as the ultimate system. It proposed also increased research and development on advanced materials, which it found insufficiently emphasized. It suggested that the direct air cycle had its future in the Pluto program rather than in manned aircraft.[8]

The Air Staff disagreed with some of the major conclusions. For meeting the OSD guidance objectives, it found the conclusions pessimistic toward the direct air cycle and optimistic toward the indirect cycle. While agreeing that the indirect cycle had a greater performance potential, the Air Staff found it to carry a higher technical risk and reiterated the necessity for attaining greater certainty by continuing both cycles.[9]

On the other hand, the first response from Defense Research and Engineering was highly favorable to the report. John E. Jackson and Thomas C. Muse* of that office indicated their willingness to go all out for the indirect cycle. In a draft letter to the Secretary of Defense, prepared for Dr. York, they proposed reducing the direct air cycle to an AEC research program on ceramic reactor elements and proceeding with accelerated development of the indirect cycle to permit nuclear-powered flight in 1966-67. They pointed out that the termination of General Electric's DAC work would cover the cost of design for the recommended Phase I aircraft during the last half of fiscal year 1961 and all of the next year. Observing that progress of the ICBM had diminished the importance of the manned bomber, they contended that the degree of "urgency" for ANP set forth by the JCS was not sufficient to justify development of two separate nuclear propulsion systems or even a backup for the more promising.[10]

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*Jackson was Director of Atomic, Biological, & Chemical Warfare. Muse was Director of Aeronautics.

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Jackson and Muse went even further than the SAB ad hoc committee in supporting the indirect cycle, emphasizing its greater compactness, smaller shield, more positive reactor control, and greater power potential. They pointed out that during the last year General Electric had changed the DAC reactor to a "straight-through" design with added weight and other complications and that another switch to the "folded flow" or other radical design would be necessary for high performance. Even so, supersonic flight appeared unlikely with the direct air cycle, for the limiting temperature of the ceramic fuel elements had proved much lower than the predicted 3,000 degrees.[11]

Although the Jackson-Muse views were sent to Assistant Secretary of the Air Force (R&D) Courtland D. Perkins for coordination, they were withdrawn and never used, a note stating that OSD had decided on "another approach." Notwithstanding, it was clear that DAC was in serious trouble, if not doomed, although Representative Price of the JCAE, in answer to a GE complaint on the report, came to its defense in November. The Air Force also continued to cling to its stand for an additional period of experimentation and engineering effort before deciding between the two cycles "with an acceptable degree of technical confidence."[12]

Describing the somewhat confused situation, William Weitzen, Perkins' Deputy for Development, reported that the OSD was "eager to force a decision on one of the two cycles," the SAB report did "not precisely take a position," ANPO recommended no cycle selection, and the General Advisory Council to the AEC wanted to drop the Pratt & Whitney indirect cycle. Adding to the confusion, the Air Staff had apparently indicated a supersonic requirement only, but Dr. Charyk did not agree, and Col. Ola Thorne

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of the Nuclear Systems office was then preparing a new Air Staff position. Weitzen explained:

> This position obviously puts us in an untenable spot as far as the support of the direct cycle is concerned. Jackson indicates to me that he is preparing a DOD staff position which will recommend termination of the direct cycle, but he is concerned about the Air Force attitude toward such a paper. Apparently DOD has promised Mahon word on 1 October on a DOD position.

On this basis, Weitzen stated that he would meet with Charyk and attempt "to firm up a position " for OSD.[13]

Meanwhile, the Bureau of the Budget (BOB), with DOD's "general concurrence," had impounded approximately $50 million of the fiscal year 1961 funds. As of 14 September, only $22 million of the $72 million appropriated* had been released, and Maj. Gen. Victor R. Haugen, Assistant DCS/Development appealed to Perkins for aid in getting $20 million released for Pratt & Whitney, whose contract expired the following day. Haugen reported that John E. Jackson and Paul J. Kopp of the OSD had refused to act pending a choice of cycles. The financial situation remained critical throughout the winter, with only incremental funding being allowed. In December 1960 the Secretary of Defense prohibited expansion of facilities by General Electric or Pratt & Whitney until program objectives were resolved. In addition the AEC had withheld funding of General Electric's advanced core test.[14]

By the end of the first half of fiscal year 1961 the BOB had imposed a ceiling of $42.3 million for the Air Force as against the $72 million appropriated and had placed AEC's $73 million under controlled release.

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*The $75 million appropriated by Congress had been lowered to $72 million by R2 Application, Serial 2, approved 9 September 1960.

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Even more indicative of the uncertain program status was the handling of the budget for fiscal year 1962, the last to be submitted by the outgoing administration. At the direction of the OSD, the Air Force presented three budget programs, at levels of $75 million, $54.5 million, and $35 million. The first covered continuance of the currently approved program, with selection of the cycle to follow advanced core testing; the second assumed selection of one cycle, with the other continuing in research, and a start on airframe design; the third also assumed selection of one cycle, but with design of the airframe postponed and research on the cycle at a still lower level. The Bureau of the Budget immediately selected the third and lowest budget of $35 million and also reduced AEC's request from $92.6 million to $42.9 million. USAF Project Recovery sought to substitute the second-level budget of $54.5 million, but even if successful, this would still have meant immediate selection of one cycle. The principal difference was that work on the airframe could get under way. The $35 million proposal remained in the budget, however, as the incoming Kennedy administration took over.[15]

## Last-Minute Efforts for Continuance

At this critical juncture, the Air Force was still quite reluctant to make a cycle selection, and the AEC avoided any definite stand. On 4 January 1961, Assistant Secretary Perkins restated to Representative Price the official Air Force position:[16]

> Insofar as concerns the board /Scientific Advisory Board/ recommendations on the selection at this time of one of the two cycles for development, it is the position of the Air Force that an additional period of experimentation and engineering effort will yet be required before such a decision can be made with an acceptable degree of technical confidence. The Air Force hopes that budgetary problems will not force an early and therefore risky cycle selection.

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General Branch explained the Air Force's reluctance in a technical status briefing to incoming Air Force Secretary Eugene M. Zuckert. Both cycles had made excellent progress during the preceding year. For the direct air cycle General Electric had dropped the XMA design and was developing the greatly altered P-1CE power plant, consisting of a small beryllium oxide reactor located directly behind the compressor of an X-211 jet engine, with the shaft passing through the reactor. The reactor would produce 135 megawatts, and three P-1CE power plants would produce 73,000 pounds of thrust, enough to fly the NX-2, Convair's latest proposed aircraft, with a 50,000-pound payload at Mach .8 or .9 at an altitude of 35,000 feet. Pratt & Whitney was developing the NJ-18A indirect cycle power plant, consisting of two 200-megawatt liquid-metal-cooled reactors coupled through a double-loop heat-exchanger system to four modified J-58 engines.* Generating 60,400 pounds of thrust, the power plant would fly the NX-2 to currently stated objectives. Convair's NX-2 design, a modification of the previous Model 54, was adaptable as a test bed for either cycle. It was planned as a subsonic aircraft of about 500,000 pounds gross weight, 164-foot wingspan, 160-foot length, 51-foot tail height, and 50,000- to 100,000-pound payload. As pointed out earlier in this paper, the program called for DAC advanced core test and IDC low-power (10-megawatt) reactor tests in late 1962 or early 1963, with only one cycle continuing thereafter. Contractors reported propulsion development on schedule except for AEC test facilities at Arco, Idaho, but airframe construction would have to begin by October 1961 to meet the 1965 first-flight date.[17]

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*The previously mentioned 10-megawatt test reactor would be the pilot model for this. (See above, p 26.)

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The new Secretary of Defense, Robert S. McNamara, and his deputy, Roswell L. Gilpatric, were also quickly approached by proponents of nuclear propulsion from within and outside the Government, particularly advocates of the direct air cycle, most seriously menaced by the low budget request and the proposed program revision. Representative Price on 1 February wrote to Secretary McNamara to explain the importance of ANP and protest the contemplated program changes as announced in the outgoing administration's 9 January 1961 budget message. Asserting that "basic elements of mismanagement" had severely handicapped the program, he mentioned "many changes in objectives, the lack of a firm set of nuclear engine requirements, the lack of clear-cut lines of responsibility for the work, ups and downs in program guidance and financial support." He stated that five days after receiving the Air Force's 4 January statement on the two-cycle approach, the outgoing administration had announced that development would continue on only one cycle, although failing to identify it. Price cited this as another example of interference by the Director of Defense Research and Engineering in AEC's area of development responsibility and in the Air Force's responsibility for specifying required performance characteristics. Meanwhile, the AEC informed McNamara that neither cycle presented insurmountable problems and both could meet the OSD guidance. The AEC indicated that the direct air cycle was more advantageous from the standpoint of early flight and the indirect cycle from the standpoint of greater performance potential.[18]

Individuals in private business, particularly from General Electric, also undertook to provide helpful orientation. Cramer W. LaPierre of General Electric wrote to Deputy Secretary Gilpatric personally, explaining

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that the frequent program shifts had prevented GE from making good on its 1951 estimate of building a nuclear power plant within five years. Nevertheless, basic technology had advanced surprisingly well, and it was now possible to build, test, and fly within three years a DAC nuclear turbojet far superior to that considered possible in 1951. Pointing to the differences of scientific opinion over the two cycles as the basic cause of the frequent shifts, LaPierre assured Gilpatrick that the current DAC program was the more feasible of the two.[19]

General Electric also took the offensive into the Air Force, giving Under Secretary Charyk a presentation on recent DAC progress and plans. The company claimed that the principal problem in the new compact, "shaft-through" DAC reactor (P-140E) was radiation rather than heat, but a minimum operating life of 1,000 hours could be obtained easily. Charyk expressed disinterest in supersonic speed and high altitude as immediate objectives but desired increased reactor life, smaller reactors, and long-endurance aircraft employing turboprop and turbofan as well as turbojet engines. He felt that the potential payoff to the Air Force was in large subsonic aircraft with essentially unlimited endurance and greater payloads.[20]

The first definite reaction of the new Secretary of Defense and his advisers appeared in a 28 February 1961 proposal to the AEC. Gilpatric suggested that the AEC take over complete responsibility for power plant development, that it select one cycle immediately, and that the Air Force transfer most of its fiscal year 1962 funds ($25 million). The Air Force would retain only $10 million to work on radiation problems and aircraft designs. Gilpatric also modified the DOD performance guidance, last stated

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by York on 27 February 1960, drawing a distinction between short-term characteristics (for the experimental model) and long-term characteristics (for a militarily useful aircraft). He set the following short-term performance characteristics: a speed of Mach .8, altitude of 35,000 feet, and reactor life of 100 hours. Long-term characteristics included a reactor life of 1,000 hours, reliability comparable to current aircraft engines, fission-product releases sufficiently low to permit operations from military airfields in peacetime without creating a public hazard (as defined by the AEC), and unitary reactor shielding. Supersonic flight was desirable, but not required. Gilpatric believed the indirect cycle to be the more promising of the cycles but ostensibly left the choice to the AEC. Actually the shielding requirement would have virtually compelled selection of the indirect cycle.[21]

The AEC reacted to the proposal cautiously. Chairman Glenn T. Seaborg stated that the Commission had considered the proposal and found it to have merit; however, its implications should be fully recognized by the President and the Bureau of the Budget. Any decision on cycle selection should also include adequate funding for early flight, and this would involve $700 to $800 million in addition to what had already been obligated. Emphasizing that operational aircraft could not be available before 1970, Seaborg declined to accept responsibility for the proposed program without assurances that the President approved.[22]

The OSD proposal aroused immediate opposition from among JCAE direct air cycle proponents. Representative Price protested to Gilpatric, questioning the soundness of the proposed nuclear engine specifications and claiming that AEC and OSD witnesses before his subcommittee did not know

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who had developed the criteria or on what basis. Emphasizing that the AEC had not participated in formulating the criteria and had not approved them, Price wondered whether the purpose was to rig a decision in favor of the "cycle preferred by the DOD." He cited the "disorganized criteria preparations" as typical of the poor management in the ANP program.[23]

Appearing before the JCAE on 15 March, Gilpatric testified that after considering the reasons behind the low budgetary request of the outgoing administration, he and Secretary McNamara had concurred. However, within the next few weeks, the President would affirm the decision, expand the program, or reduce it. The committee's questioning of AEC Commissioner Robert E. Wilson on the same day produced an equally unpalatable answer on the DOD criteria for reactor selection. Conceding that the requirement for unitary shielding would in effect rule out the direct air cycle, Wilson nevertheless believed it proper that the DOD establish such criteria.[24]

Meanwhile, the Air Force had begun to give ground on its position that cycle selection at this time was premature. The first sign of softening came on 22 December 1960 when Perkins indicated to York that if it were not possible to carry on through 1961, when a solid technical decision could be made, the proper course of action would be to select one cycle and reduce the other to the research level. Although the DAC had shown considerable progress since being redirected toward the ceramic reactor, revealing some growth capability, and the DAC advocates had generated increased political pressure, he favored the IDC on the ground that the DAC could solve no mission requirements better than chemical engines while the IDC had much greater potential, particularly if the single loop proved practicable.[25]

As previously noted, Perkins on 4 January 1961 had again restated

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USAF support for the two-cycle approach, but on 2 February the Office of the Assistant DCS/Development for Nuclear Systems expressed the widespread Air Staff belief that immediate selection, despite the technical risk, was essential to stay within either financial plan having a chance of acceptance.[26] At the request of Secretary Zuckert, the Air Staff drafted a new Air Force position for use in answering congressional inquiries and for possible forwarding to the Secretary of Defense. It stated in part:[27]

> The Air Force believes we have now reached the point in the development of nuclear propulsion for aircraft where it may no longer be advisable to continue funding the development of the two separate cycle systems to achieve the same end result. It now appears appropriate to take a certain calculated risk in the program and select the one cycle which shows the greater promise of meeting the present and future military interests. The Air Force interests lie in the areas of improved power density, lighter shielding, and longer fuel element life which will lead to higher payload-to-gross-weight ratio and to the ultimate achievement of unit shielding and improved aircraft performance, including supersonic flight. It is our understanding that the Liquid Metal Indirect Cycle shows the greater promise of achieving these advanced performance objectives in the most reasonable future. This cycle can be readily adapted to a variety of military power applications such as turbojet, turboprop, and turbofan propulsion systems and promises greater facility in the conversion of its excess reactor heat to auxiliary power.
>
> The Air Force, therefore, believes that continuing to pursue the goals established in 1959, by concentrating on the Liquid Metal Indirect Cycle system, is probably the best approach that we can follow with the funds which may be available. The Air Force also believes that we should provide sufficient funds in FY 62 for initiation of airframe and other supporting activities required to permit nuclear flight on a reasonable technical and funding time scale. This is in accordance with the desires expressed by the Joint Chiefs of Staff for nuclear flight as soon as technically feasible. It is estimated now that such flight, of military interest, can be attained in the mid-1960's.

General Electric, doubtless aware that events had turned strongly against it, played its last card on 14 March 1961, proposing to use a B-52 airframe with a replica of the advanced core test system* to begin

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*This would have been essentially a less sophisticated version of the P-1AOE design. (Telcon, author with L/Col Bruce D. Witwer, Asst/NE, 11 Mar 63.)

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nuclear flight test by late 1963. This would be in addition to the current NX-2 plan. Apparently notified in advance, Representative Price on 9 March had requested a copy of the proposal, and a General Electric representative appeared before the JCAE on 15 March 1961 to testify on it. The proposal involved $236.7 million but also assumed expenditure of an equivalent amount on other research and development and component improvement. On the basis of the limited facts submitted, the Nuclear Systems office thought that the costs were considerably underestimated and gave the proposal a cool reception, terming it a dead-end program technically. At any rate, it was much too late to halt the sequence of events now under way.[28]

## Decision and Rejoinder

Shortly after assuming office, McNamara had directed the preparation of approximately one hundred staff studies on major DOD problem areas, among them the aircraft nuclear propulsion program. The D/DR&E, still headed by York pending appointment of his successor, issued the ANP study with a date of 20 March 1961. This ANP "white paper" was generally believed within the Air Staff to be the work of John E. Jackson.*[29]

The white paper consisted of five sections dealing with the problem, its history and current status, principal alternative courses of action, pros and cons of each, and major points needing decisions. The first two sections reviewed in an objective tone the history of the program and the principal technical factors relating to the two cycles under development and the proposed experimental aircraft. The study conceded that some type of flight would already have been possible if military usefulness had been

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*(See above, pp 45-46.)

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disregarded. The third section proposed three alternative actions: cancel the program, drop one cycle and continue the other through flight test (beginning about 1967) at a cost of about $750 million, or continue research on both cycles at a low level with minimum hardware fabrication at an annual cost of about $30 million. The pro-and-con section conceded that nuclear aircraft had possible military uses as long-range transports, as missile platforms in a continuously airborne strategic force, and as low-level strategic bombers. Against these possibilities were ranged the high cost of the research and development program, the high cost of producing weapon systems, and the possibility that cheaper systems would do these jobs as well. The last section pointed out that a decision had to be made immediately on the future of the program. If it were not dropped entirely or reduced to research status, a second decision would be necessary within a year on whether to proceed with development of the test plane and construction of flight facilities at an additional cost of several hundred million dollars. A decision on producing weapon systems would have to await flight tests and, if favorable, would cost many billions. Although the paper made no specific recommendations, it was not optimistic in tone, particularly on the technical and financial factors.[30]

The Air Force received the D/DR&E white paper, along with 21 similar studies, on 22 March 1961, with a request for comments within four days. General Branch and his staff immediately recognized the significance of the paper but judged it unsound. They first attempted to correct inaccuracies and include important omissions by "line-out and write-in," but this proved so complicated that Branch decided to submit a new substitute

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paper. He presented this to the Air Force Council early on 24 March, and after General LeMay had approved, the paper went to Under Secretary Charyk. Although Branch had prepared a cover letter from Zuckert to McNamara, Charyk sent the letter and its two attachments to the OSD later that day as an unsigned rejoinder to the white paper.[31]

Restating its belief in the important role of nuclear propulsion for future aircraft weapon systems, the Air Force stated: "The White Paper on the Aircraft Nuclear Propulsion Program contains many inaccuracies of fact and philosophy. The conclusions are not clear; they do not appear to be in accord with basic Air Force interests." It proposed substitution of its own study, Aircraft Nuclear Propulsion: Objectives and Facts Bearing on the Problem, as more representative of the philosophy behind "this most vexing problem." The second attachment, a detailed technical analysis of the current ANP status, was an ANPO evaluation prepared on 24 February 1961 mainly for AEC use.[32]

The Air Force paper gave a much more favorable but still temperate appraisal of the direct air and indirect cycles and their potential worth for an operational aircraft. Contending that DOD performance objectives, including a 50,000-pound payload and operation from existing B-52 bases, could be met by either propulsion approach, the Air Force stated: "Since mid-1959, the objectives and method of attainment have been clearly defined and have held firm. This has resulted in significant technical progress to the extent that present technologies, when assembled, will enable exploration of the military potential and application of nuclear powered airplanes." The paper contained four possible choices: (1) continue both cycles through ground test in 1963 and then select one to be carried

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to flight test in 1965 at a cost of $900 million; (2) cancel one cycle and continue the other through flight test in 1965 at a cost of $700 million; (3) continue both on a research and development basis for the next two to three years, with flight-testing deferred, at a cost of $140 million; (4) cancel the ANP manned program. The Air Force recommended the first approach unless economic considerations dictated the second, in which case the concentration should be on the indirect cycle. It flatly opposed the last two possibilities. The Air Force did not argue for any specific military application but contended that cancellation would involve (1) "willingness to forego what appears to be an important military potential, as yet uninvestigated and untapped, at a point in the development of the technology when assessment is possible"; (2) "cessation of a program which is apparently being seriously pursued by the Soviets"; and (3) "serious economic impact in the Cincinnati, Idaho, and Hartford areas."[33]

Action at the OSD and Presidential level followed hard on the heels of the Air Force rejoinder. Secretary McNamara soon made his recommendations,* which presumably received the concurrence of the President's scientific adviser, Jerome D. Weisner. On 28 March 1961, President John F. Kennedy announced in his budget message to Congress that he had reduced the aircraft nuclear propulsion program to research in high-performance reactors and materials, to be conducted under the AEC, with a budget of $25 million for fiscal year 1962. He terminated all work leading to a manned aircraft, including airframe design, shielding studies, and turbojet adaptation, and eliminated all USAF funding in this field. Three offshoots of the program—Projects Pluto (nuclear ramjet for pilotless

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* What part Dr. York or the incoming D/DR&E, who assumed office on 3 May 1961, played in the decision is not clear.

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aircraft), Rover (nuclear-assisted rocket), and SNAP (systems for nuclear auxiliary power)* continued with little change.[34]

Apparently unwilling to rest on the unsuccessful USAF rejoinder, General Branch three weeks later transmitted to Secretary Zuckert a detailed critique on the OSD white paper and a summary of his own views. With no possibility of reversing the decision in the immediate future, this statement served as a temporary requiem. General Branch asserted in part:[35]

> In my opinion, the serious omissions and many inaccuracies of technical fact and philosophy in the DDR&E White Paper develop a biased case for cancellation of the ANP Program. The paper purports to be comprehensive and objective; however, it presents only selected information and subjective judgments to lead to the conclusion that the program should be cancelled. For the most part, technical truths, quantitative analysis, and experimental results will not warrant the subjective judgments of the White Paper; enlightened engineering evaluation would disagree with most of its significant judgments.
>
> The ANP Program is able actually to satisfy the criteria for new strategic weapons which the Secretary of Defense announced after the ANP Program had been cancelled. It seems obvious that the Secretary was not advised of these ANP capabilities. Instead, the White Paper dwells on the theme that the JCS had not documented a requirement for a specific, full-scale weapon system (although they had endorsed the need for the ANP Program's strategic potentialities).

General Branch emphasized the tremendous value that greatly extended range and endurance could have to Air Force operations and suggested ways

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* Pluto was a joint AEC-Air Force effort established in 1956. The AEC concentrated on the reactor and the Air Force assisted with the development of nonnuclear components. Rover was undertaken even earlier by the AEC on much the same basis, but the OSD transferred the Air Force responsibility to NASA in late 1958. Both the Air Force and NASA maintained a development interest in SNAP, which the AEC had undertaken in 1955. In early 1961, progress was particularly noteworthy in Pluto, presumed power source for the proposed SLAM weapon system. Testing of the Tory IIA reactor, the first development milestone, was scheduled for May 1961. (Address by B/Gen Irving L. Branch to Aircraft Luncheon Club of Washington, 14 Mar 61; Memo for Record by R. D. B., 8 Apr 61, w/atch questions and answers for Gen. White, both in Asst/NE files.)

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in which they could be put to use: airborne survival of striking forces, airborne early warning, extended restrike capability, reconnaissance, low-altitude penetration capability, flexibility in strategic employment, and independence of logistic support from oversea bases. Charging that the white paper had ignored completely the value of ANP in these Air Force missions, General Branch stated that this was the salient point making it unacceptable. He also objected to its repeated claim that the program's initial performance goals had no military value, since this was characteristic of most radically new developments.[36]

General Branch listed some 18 specific technical inconsistencies, inaccuracies, and omissions in the white paper:[37]

1. It implied that the Air Force objective in early flight was prestige rather than military purposes.

2. It did not completely summarize JCS views, since it omitted those on flight test.

3. It was ambiguous on the question of early flight, which it did not define.

4. It implied that a reactor with an operating life of 1,000 hours was beyond the current state of the art.

5. It discussed Quarles' unfavorable views on the mere achievement of nuclear flight without immediate military value but failed to mention his shift of viewpoint.

6. It incorrectly implied that the AEC had agreed to Gilpatric's proposal of 28 February 1961 that the AEC select one cycle at once.

7. Its criticism of the Air Force for handling ANP under the advanced development program rather than going all out for an early weapon system was unsound.

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8. It incorrectly indicated that the current DOD guidance related to a militarily useful airplane when it actually related to a militarily useful propulsion system.

9. It incorrectly indicated that the DOD had not supported early flight because it was based on the direct air cycle system.

10. The statement regarding the 1,000-hour operating requirement was pointless since both cycles were designed to exceed this.

11. It incorrectly stated that present landing fields could not accommodate an aircraft heavier than 500,000 pounds.

12. It incorrectly stated that the area between the crew compartment and the reactor was too radioactive for equipment and bombs.

13. It indicated that the DAC reactor might release fission fragments during takeoff and landing, although these operations would be performed on chemical fuel.

14. It overemphasized the danger of leaks in the indirect cycle. This was essentially a common design problem and would not necessarily mean loss of the aircraft.

15. Keeping liquid the lithium and sodium-potassium heat-transfer fluids was not the severe problem depicted.

16. Reactor materials for the power plant were past the laboratory stage.

17. The liquid-fuel (fireball) reactor had been terminated because of lack of funds, not impracticability.

18. The nuclear reactor was potentially no more dangerous in the event of accident than the fuel carried in other large aircraft. Unsafe operation was not inherent but was amenable to engineering and procedural solutions.

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To these might well have been added two other points. First, the statement on McCone's pessimistic views concerning indirect cycle "plumbing" was misleading since he had more recently testified before the JCAE on 18 January 1961 that neither cycle presented insurmountable problems. Second, the cost of development appeared to be overemphasized, particularly in comparison with programs of similar importance. Although the Government had spent approximately one billion dollars, this had been spread over a 15-year period. Allowing for price inflation, it still fell below the development cost estimated in the Lexington Report of 1948. Only $35 million was "saved" for fiscal year 1962 by the revamped program, since it replaced an already low-level program. This amount was small in comparison with both the total ANP obligations through fiscal year 1961 ($1.04 billion) and the President's DOD budget for fiscal year 1962 (about $42 billion). The implication that another $700 to $800 million was "saved" by removing the need to build an experimental aircraft also seemed of doubtful logic.[38]

Secretary of Defense McNamara provided the principal rationalization for program cancellation when he appeared before the Senate Committee on Armed Services on 4 April 1961. Drawing heavily on the D/DR&E white paper, he emphasized the past and possible future costs of the program, the technical uncertainties and hazards, and the lack of a specific military requirement. He conceded that a nuclear-powered aircraft could already have flown had a larger effort been made, but he depreciated its value. He did not admit, as had the white paper, the several possible military uses of a nuclear-powered aircraft and expressed doubt of the value for either science or national prestige of nuclear flight.[39]

The most emphatic public rejoinder came from Representative Price,

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who stated: "The Kennedy decision was in error because of incorrect advice provided by his scientific and defense advisers. The same people who have been assembling the information for decisions on ANP provided the input again." Citing as evidence the failure of the DOD to "consult the experts responsible for the direction of the program and for the development of the designs" when establishing the new program criteria (that of 28 February), he charged that "the members of the new Administration in the Defense Department relied solely on the advice and recommendations of the same people in the Defense Department who have been against the project for years." He further contended that these advisers "were not familiar with the technical developments in the program and had not even attempted to obtain first hand information regarding our nuclear propulsion program."[40]

"Wrapping up" Air Force participation in the ANP program began on 3 April 1961, when the DCS/Development directed his Assistant DCS for Nuclear Systems to terminate all contracts, reprogram outstanding funds, evaluate program elements with a view to conservation, and reassign personnel. The Nuclear Systems office would continue to function until reorganized. It would draft development plans; assemble records for documenting the technical, organizational, management, and financial history; and develop a schedule for the reassignment of personnel and the transfer of functions.* Secretary Zuckert emphasized that the ANP contracts should be terminated in as orderly a manner as possible, with an effort to continue those research elements of continuing interest to the Air Force for purposes other than ANP.[41]

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*Actually the office continued to function as a center for the monitoring and coordination of nuclear research and development matters.

[redacted]

By the end of April the Air Force had sent termination notices to General Electric, Pratt & Whitney, Lockheed, Convair, and several smaller companies. Since some of the work supported such USAF-generated nuclear propulsion projects as Pluto, it was also necessary to transfer contracts and reprogram funds through the current contract period.[42]

A principal termination problem involved disposition of USAF installations constructed for the program contractors at a cost of more than $100 million at Evendale, Ohio; Dawsonville, Ga.; and Middletown, Conn.* Utilization of employees at Evendale and Middletown, where General Electric and Pratt & Whitney propulsion activities were concentrated, was also a matter of concern. Although the AEC had received $25 million for research on high-temperature materials and reactors during fiscal year 1962, it appeared in April 1961 that only $19 million of this would be actually available for 1962 expenditure. The AEC consequently planned a program to include $4.5 million for high-temperature materials research by General Electric at Evendale and $14.25 million for similar research plus advanced reactor study and development by Pratt & Whitney at Middletown. This work would utilize only a small portion of the available facilities, and General Branch proposed that the Air Force maintain title pending possible use in other programs. The outlook was bleakest at the Georgia Nuclear Laboratories in Dawsonville, built for Lockheed's investigations on the effects of radiation on aircraft components.[43]

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*Two other installations--the Convair installation at Dallas, Tex., and the incomplete Nuclear Engineering Test Facility at Wright-Patterson AFB, Ohio--were found to be useful in continuing phases of the USAF atomic energy program.

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## A Final View

Several factors had made the ANP program vulnerable to the termination action. Despite the technical advances since 1946, there were still many in 1961 who doubted that industry could develop a nuclear combination even in the next decade to power weapon systems of the traditional "higher and faster" strategic type. Perhaps as important was the changed situation evolving in the area of strategic weapons since 1946. At that time the major argument for a large-scale program was the limited range of the chemically fueled strategic bomber and the resultant restrictions on its operations. By 1961, these had in large measure been corrected by improved air refueling techniques and better-performing jet engines. The intercontinental ballistic missile also appeared ready to take over a large share of the strategic role. Many confidently forecast satellite bomber operations in the not-too-distant future, and large resources were being allocated to support this and related concepts. The reasons for continuing the ANP program therefore had to be recast in terms of new missions--low-level strategic penetration, airborne alert missile carrier, logistic transportation--which the Air Force itself found far less appealing than the original one. The competition with other advancing technologies for financial and scientific resources also had adverse effects on the ANP program. Altogether, such factors were far more important in the death of the program than the seemingly proximate one--the desire of the new national administration to build up near-term military strength without drastic increases in the defense budget.

Congress severely and repeatedly criticized the program throughout

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its life--for its uncertain and vacillating management, its inability to produce concrete achievements, and its unfavorable progress when compared with the programs for the nuclear-propelled submarine and the intercontinental ballistic missile. Although the comparisons lack validity to the extent that the ANP technical problems were of a greater order of difficulty, it is probably true that a more highly integrated and heavily supported program could have achieved more. Unfortunately, this required a higher degree of official urgency than the program ever acquired. Financial support was always uncertain, and the program underwent repeated reevaluations that reflected the organizational pulls being exerted upon it and the varying interests of the participating agencies.

Perhaps the Air Force should have deemphasized the weapon system approach until a nuclear-propelled aircraft had flown--it subsequently came to accept this view, at least in part--but this would have been a contradiction to the general philosophy of the time on military development programs of this scope. One had only to recall Secretary Charles E. Wilson's disparaging remark of 1953 regarding the Air Force's "shitepoke" and the continued attacks on the ANP program following the nonspecific JCS statement of 1959 to realize that the chances of getting large sums for "only" an experimental aircraft were slim indeed. Under these circumstances, the nuclear aircraft proponents were under heavy pressure to tie their hopes to the weapon system approach. Contractors doubtless aggravated the situation with their excessive optimism on development schedules and performance objectives. Although this optimistic attitude was common to many programs, it appears that it complicated the handling of the ANP program unduly, especially in view of JCAE's constant attention and pressures.

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Despite the ultimate frustration, great advances were made in the technology of aircraft nuclear propulsion. It seems particularly ironical that the ANP program ended when answers to most of the questions raised in the Lexington Report were at hand and both reactor projects were apparently making excellent progress. Reactors had been reduced tremendously in size while power output underwent a corresponding increase. Airframe contractors had solved many difficult technical problems bearing on flight by nuclear power. There was also an impressive windfall of side benefits in the form of scientific advances applicable to many fields of knowledge. Although ANP was officially dead as an Air Force program, many still confidently looked forward to nuclear-powered aircraft flight at some indefinite future date.

[redacted]

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# G L O S S A R Y

| | |
|---|---|
| ADO | Advanced Development Objective |
| AEC | Atomic Energy Commission |
| AFCHO | USAF Historical Division Liaison Office |
| AHG | Ad Hoc Group |
| ANP | Aircraft Nuclear Propulsion |
| ANPO | Aircraft Nuclear Propulsion Office |
| ARDC | Air Research & Development Command |
| ASSS | Air Staff Summary Sheet |
| BOB | Bureau of the Budget |
| CAMAL | continuously airborne missile launcher |
| Cnsl | Counsel |
| DAC | direct air cycle |
| D/DR&E | Director of Defense Research & Engineering |
| DOD | Department of Defense |
| Fdg | Funding |
| FPD | Force Plans Div |
| GOR | General Operational Requirement |
| IDC | indirect air cycle |
| JCAE | Joint Committee on Atomic Energy |
| JCS | Joint Chiefs of Staff |
| JRDB | Joint Research & Development Board |
| LL | Legislative Liaison |
| MIT | Massachusetts Institute of Technology |
| MLC | Military Liaison Committee |
| NACA | National Advisory Committee for Aeronautics |
| nd | no date |
| NE | Nuclear Energy |
| NEPA | Nuclear Energy for Propulsion of Aircraft |
| NS | Nuclear Systems |
| NSC | National Security Council |
| O | Operations |
| OR | Operational Requirements |
| OSD | Office of the Secretary of Defense |

| | |
|---|---|
| Pdn | Production |
| Prog | Program |
| RDB | Research & Development Board |
| RDO | Research & Development Objectives |
| ROC | Required Operational Capability |
| SA | Secretary of the Army |
| SAB | Scientific Advisory Board |
| SAD | Strategic Air Division |
| SAP | Strategic Air Panel |
| SDR | System Development Requirement |
| SLAM | supersonic low-altitude missile launcher |
| SN | Secretary of the Navy |
| SOD | Secretary of Defense |
| SOR | Specific Operational Requirement |
| U/SAF | Under Secretary of the Air Force |
| w/ | with |
| WADC | Wright Air Development Center |
| WP | War Plans |
| WSEG | Weapons Systems Evaluation Group |

Appendix 1
Table 1

## ANP Manned Aircraft Funding by Agency[a]
(In Thousands)

| | AIR FORCE[b] | | | | AEC[c] | | | NAVY[b] | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FY | Direct Cycle | Indirect Cycle | Airframe & GS[d] | NEPA | Direct Cycle | Indirect Cycle | GS | Direct Cycle | Indirect Cycle | Airframe & GS[d] | NEPA | Total | FY |
| 46 | - | - | - | 1,300 | - | - | - | - | - | - | - | 1,300 | 46 |
| 47 | - | - | - | 2,000 | - | - | - | - | - | - | - | 2,000 | 47 |
| 48 | - | - | - | 6,150 | - | - | - | - | - | - | 1,000[f] | 6,150 | 48 |
| 49 | - | - | 084 | 6,782 | - | - | - | - | - | - | 500[f] | 6,866 | 49 |
| 50 | - | - | 100 | 5,200 | - | 1,383 | - | - | - | - | - | 6,683 | 50 |
| 51 | 750 | 1,500 | 529 | - | - | 5,974 | - | - | - | - | - | 8,753 | 51 |
| 52 | 13,007 | - | 3,039 | - | 3,865 | 7,109 | - | 500[f] | - | - | - | 27,020 | 52 |
| 53 | 16,197 | 2,000 | 10,736 | - | 20,485 | 7,618 | 2,000[e] | - | - | 200 | - | 59,236 | 53 |
| 54 | 771 | 3,712 | 1,879 | - | 9,402 | 8,922 | (2)[e] | - | - | 100 | - | 24,784 | 54 |
| 55 | 6,097 | 9,749 | 12,931 | - | 9,242 | 15,370 | - | - | - | 500 | - | 53,889 | 55 |
| 56 | 27,924 | 41,975 | 33,925 | - | 21,407 | 27,715 | 516 | 515 | - | 3,195 | - | 157,172 | 56 |
| 57 | 42,131 | 31,920 | 27,618 | - | 44,690 | 29,421 | 8,703 | - | - | 1,500 | - | 185,983 | 57 |
| 58 | 62,185 | (4,000)[e] | 4,778 | - | 54,143 | 16,520 | 4,834 | 832 | 375 | 1,687 | - | 141,354 | 58 |
| 59 | 39,369 | - | 12,692 | - | 52,263 | 16,581 | 4,138 | - | 1,932 | 1,507 | - | 128,482 | 59 |
| 60 | 43,768 | 5,656 | 11,036 | - | 40,209 | 21,248 | 3,887 | - | - | - | - | 125,804 | 60 |
| 61(Est) | 14,141 | 5,485 | 8,576 | - | 38,600 | 32,300 | 3,700 | - | - | - | - | 102,802 | 61 |
| TOTAL | 266,340 | 97,997 | 127,923 | 21,432 | 294,306 | 190,161 | 27,776 | 1,347 | 2,307 | 8,689 | | 1,038,278 | |

a. Figures in the text follow this table. b. Obligations. c. Obligations & costs. d. Airframe & general support. e. De-obligation of funds. f. Funds transferred to AF and not included in Navy totals.

Source: Office of Asst DCS/D for Nuclear Systems.

## ANP MANNED AIRCRAFT PROGRAM (All Agencies)
Summary (In Millions)

| Fiscal Year | AEC | Air Force | Navy | Total |
|---|---|---|---|---|
| 1946 | $ - | $ 1.3 | $ - | $ 1.3 |
| 1947 | - | 2.0 | - | 2.0 |
| 1948 | - | 6.2 | (1.0)[a] | 6.2 |
| 1949 | - | 6.9 | (.5) | 6.9 |
| 1950 | 1.4 | 5.3 | - | 6.7 |
| 1951 | 6.2 | 2.8 | - | 9.0 |
| 1952 | 10.9 | 16.0 | (.5) | 26.9 |
| 1953 | 30.1 | 28.9 | .2 | 59.2 |
| 1954 | 18.3 | 6.4 | .1 | 24.8 |
| 1955 | 24.6 | 28.8 | .5 | 53.9 |
| 1956 | 49.7 | 103.9 | 3.7 | 157.3 |
| 1957 | 82.8 | 101.7 | 1.5 | 186.0 |
| 1958 | 75.5 | 63.0 | 2.9 | 141.4 |
| 1959 | 73.0 | 52.1 | 3.4 | 128.5 |
| 1960 | 65.4 | 60.5 | .3 | 126.2 |
| 1946-60 | 437.9 | 485.8 | 12.6 | 936.3 |
| 1961 (Estimated) | 74.3 | 73.1 | - | 147.4[b] |
| TOTAL | $512.2 | $558.9 | $12.6 | $1,083.7 |

a. Figures in parentheses mean Navy funds transferred to Air Force and included in the Air Force amounts.

b. Represents amounts in FY 1961 congressional budget. The Air Force amount is $72.0 NOA and $1.1 carryover. Does not reflect effect of contract termination.

Source: Office of Asst DCS/D for Nuclear Systems.

Appendix 1
Table 2B

## ANP MANNED AIRCRAFT PROGRAM (AEC)
Summary (In Millions)

| Fiscal Year | Operations (Costs) | Equipment (Costs) | Facilities (Obligations) | Total |
|---|---|---|---|---|
| 1946 | $ - | $- | $ - | $ - |
| 1947 | - | - | - | - |
| 1948 | - | - | - | - |
| 1949 | - | - | - | - |
| 1950 | 1.4 | - | - | 1.4 |
| 1951 | 5.5 | - | .7 | 6.2 |
| 1952 | 10.6 | .1 | .2 | 10.9 |
| 1953 | 17.3 | .5 | 12.3 | 30.1 |
| 1954 | 14.6 | .6 | 3.1 | 18.3 |
| 1955 | 22.6 | 1.3 | .7 | 24.6 |
| 1956 | 45.0 | 1.7 | 3.0 | 49.7 |
| 1957 | 68.9 | 4.5 | 9.4 | 82.8 |
| 1958 | 62.2 | 4.4 | 8.9 | 75.5 |
| 1959 | 66.8 | 4.3 | 1.9 | 73.0 |
| 1960 | 62.8 | 3.9 | -1.3 | 65.4 |
| 1946-60 | 377.7 | 21.3 | 38.9 | 437.9 |
| 1961 (Estimated) | 70.1 | 3.2 | 1.0 | 74.3 |
| TOTAL | $447.8 | $ 24.5 | $ 39.9 | $512.2 |

Source: Office of Asst DCS/D for Nuclear Systems.

Appendix 1
Table 2C

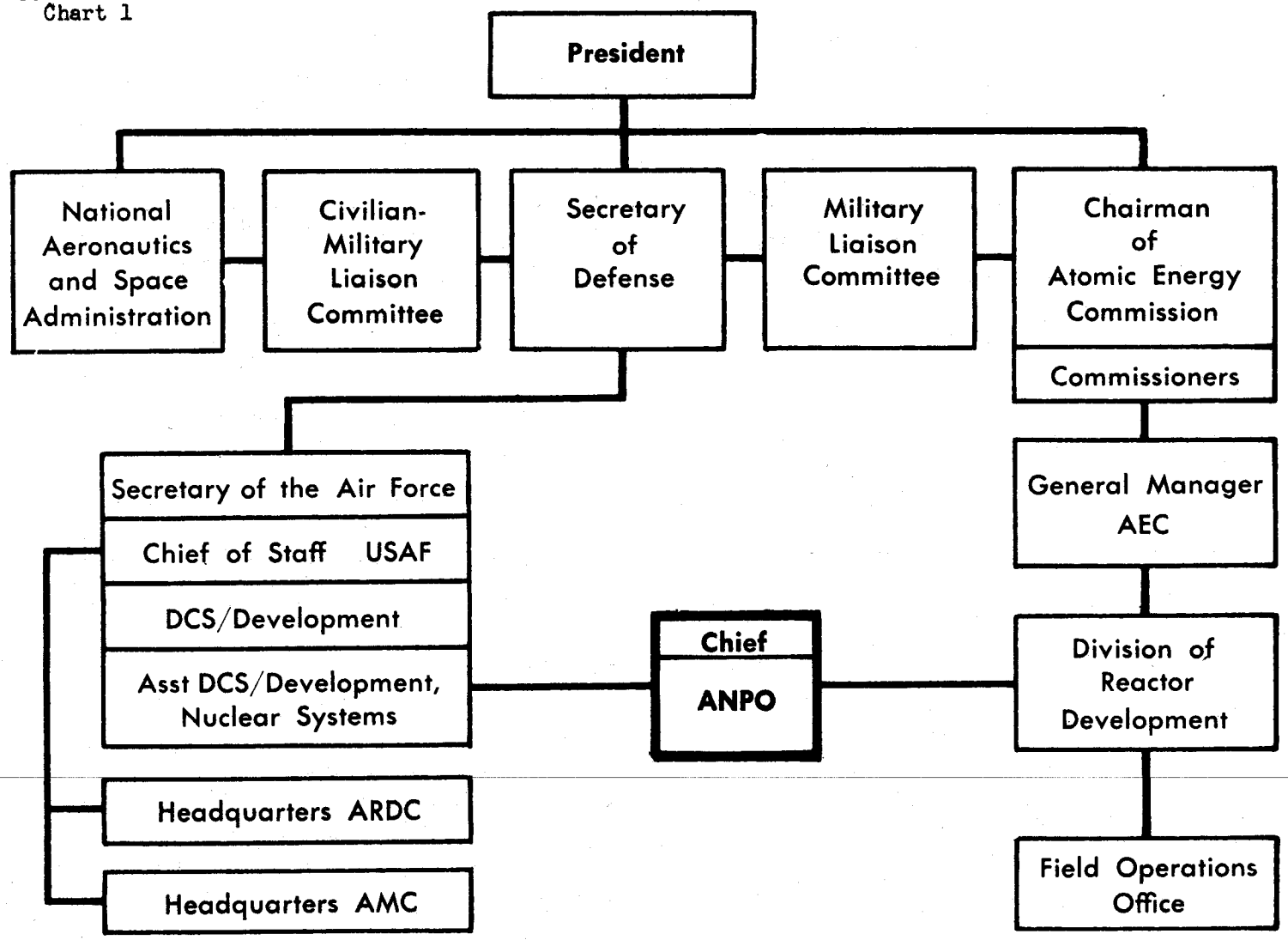
ANP MANNED AIRCRAFT PROGRAM (Air Force and Navy)
Summary (In Millions)

| Fiscal Year | Air Force Operations | Air Force Facilities | Air Force Total Oblig | Navy Operations (Oblig) |
|---|---|---|---|---|
| 1946 | $ 1.3 | $ - | $ 1.3 | $ - |
| 1947 | 2.0 | - | 2.0 | - |
| 1948 | 6.2 | - | 6.2 | (1.0)[a] |
| 1949 | 6.9 | - | 6.9 | (.5) |
| 1950 | 5.3 | - | 5.3 | - |
| 1951 | 2.8 | - | 2.8 | - |
| 1952 | 10.0 | 6.0 | 16.0 | (.5) |
| 1953 | 22.6 | 6.3 | 28.9 | .2 |
| 1954 | 6.2 | .2 | 6.4 | .1 |
| 1955 | 22.4 | 6.4 | 28.8 | .5 |
| 1956 | 46.4 | 57.5 | 103.9 | 3.7 |
| 1957 | 66.1 | 35.6 | 101.7 | 1.5 |
| 1958 | 60.5 | 2.5 | 63.0 | 2.9 |
| 1959 | 52.1 | - | 52.1 | 3.4 |
| 1960 | 59.2 | 1.3 | 60.5 | .3 |
| 1946-60 | 370.0 | 115.8 | 485.8 | 12.6 |
| 1961 (Estimated) | 72.0 | 1.1 | 73.1 | - |
| TOTAL | $442.0 | $116.9 | $558.9 | $12.6 |

a. Figures in parentheses mean Navy funds transferred to Air Force and included in the Air Force amounts.

Source: Office of Asst DCS/D for Nuclear Systems.

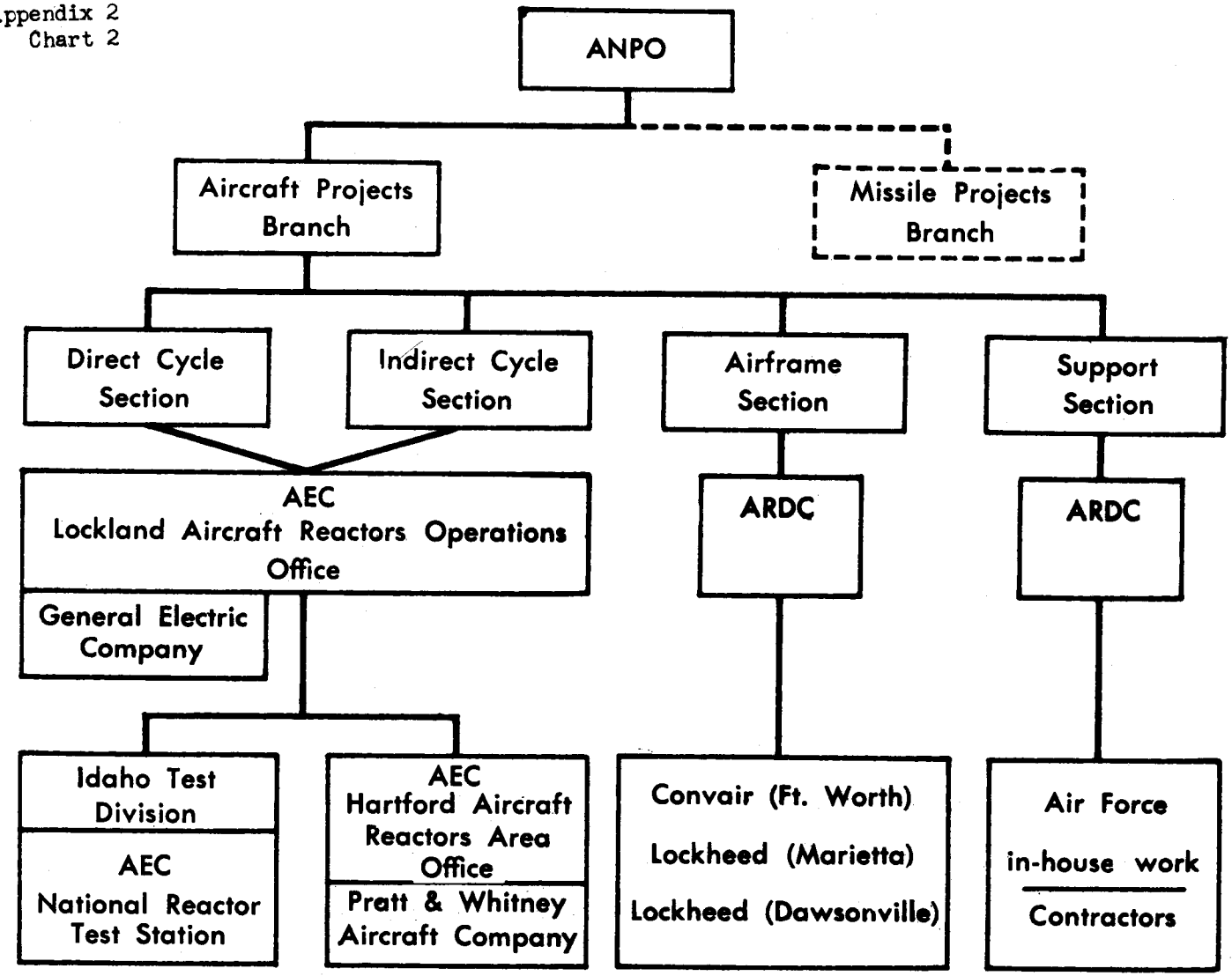
Appendix 2
Chart 1




Source: AU Quarterly Review, XI (# 3&4), p 15.

Appendix 2
Chart 2






Source: AU Quarterly Review, XI (# 3&4), p 21.

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