The Decay of the

Atomic Powered Aircraft Program

A Sufficiency by

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Course Number	Course Title	Term
HI1321	Intro To European Econ & Soc History	89A
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002333	Modern Science, History Of	90B
HI2334	European Technological Development	90C
HI3331	Topics In Science, Technology, & Society	91D

Presented to:
Professor Parkinson
Department of Humanities
Term C92
EMP-5202

Submitted in Partial Fulfillment
of the Requirements of
the Humanities Sufficiency Program
Worcester Polytechnic Institute
Worcester, Massachusetts

Introduction

Interest in atomic energy hit full force following World War II. The scientists who had raced to produce a bomb had also developed theories for a number of possible uses for the atom. Martin Mann lists a number of them in his book, Peacetime Uses of Atomic Energy. Ideas ranged from power generation, to nuclear excavation, to nuclear propulsion for vehicles on land, sea, and in the air. There were proposals for nuclear ships, nuclear locomotives, nuclear automobiles, and nuclear aircraft. It is this last proposal that is the topic for this paper, which will examine the technical and socio-political aspects of the United States Air Force's Aircraft Nuclear Propulsion (ANP) program and associated programs, including the reasons the ANP program was undertaken, and the reasons it was canceled after a decade of work.

Technology

The principles behind using atomic energy for the propulsion of aircraft were developed early in the atomic age. As early as 1942 Enrico Fermi and his associates involved with the Manhattan District Project discussed the use of atomic power to propel aircraft.[1] It was in 1946 that a study by John Hopkins University's Applied Physics Laboratory delineated the potentials and problems of using atomic power for aircraft propulsion. Chief amongst the problems at the time was the lack of data on the effects of radiation on materials which would be used in a design.[2] Some of the other basic problems were the possible release of radioactive fission products or isotopes during normal operation or due to any accident, shielding the crew and persons on the ground from radiation, and the selection of test sites and ranges. There was the potential for the release of radioactive materials to the atmosphere and the problems of direct radiation during operational use.[3] The requirements for an operational nuclear aircraft were that, even under the most adverse conditions, the aircraft did not add materially to the general background atmospheric radioactivity and that while in use the aircraft restricted all harmful radiation to within the craft or a predesignated exclusion area.[4]

In 1946 the interest in atomic aircraft developed into a long-lived project known as NEPA, for Nuclear energy for the Propulsion of Aircraft.[5] The NEPA project, which started in May, was controlled by the United States Air Force (USAF) and was therefore oriented towards developing both an atomic- powered long-range strategic bomber and high-performance aircraft. Nuclear power showed promise in both fields because of its dual nature of long-lasting fuel supply and the high temperatures theoretically possible using a reactor. However, in a paper in 1957 Kelly Johnson and F. A. Cleveland, both of Lockheed Aircraft Corporation, wrote, "It appears that the strategic bomber, by requiring both high speed and great endurance and because of the inherent low-altitude potential advantages over similar chemical airplanes, will be the first candidate for a nuclear power plant."[6]

The NEPA contract was with the Fairchild Engine & Airframe Co., and the work was conducted at Oak Ridge. By the end of 1948 the USAF had invested approximately ten million dollars in the program.[7] Extensive studies were conducted under NEPA from 1946 until 1951, at which time it was replaced by the joint Atomic Energy Commission (AEC) / USAF ANP program. The ANP program set forth the ambitious goal of full-scale development of aircraft reactor and engine systems. One of the factors that led to the creation of the ANP program was a study done at MIT by a group convened by the AEC in 1948 to look at the potential uses of atomic powered flight. "This study group, known as the Lexington Project, came to the conclusion that nuclear aircraft (manned) were likely less difficult than nuclear ramjets, which, in turn, would be less difficult than nuclear rockets to develop."[8] Ironically, this turned out to be the reverse of the proper order of difficulty, as later research and development would prove. Although nuclear ramjets, under Project Pluto, and nuclear rockets, under Project Rover, were successfully tested at the levels needed for operational use, an operational level atomic aircraft power plant was never developed. In 1954, B.C. Briant, who was then the director of the ANP Project stated that "manned nuclear aircraft pose the most difficult engineering development job yet attempted within this century."[9]

Unfortunately the ANP program wasn't very well organized. Instead of trying to develop one aspect of the technology to a working stage the effort was spread out over a number of areas. Part of the problem was that, under the conventional guidelines, the AEC was responsible for reactor development while the Air Force was responsible for development of the remainder of the system. Therefore the project was divided into two parts which needed to work closely together, but these two parts were managed by totally separate entities.

Under the ANP program the General Electric Co., at Evendale, Cincinnati was issued a contract to develop a direct-cycle turbojet, and Pratt & Whitney Aircraft Division of United Aircraft Corp. was authorized to study an indirect cycle and work was started at the Connecticut Aircraft Nuclear Engine Laboratory (CANEL).[10] In the direct air cycle air enters through the compressor stage of one or more turbojets. From there the air passes through a plenum an is directed through the reactor core. The air, acting as the reactor coolant, is rapidly heated as it travels through the core. After passing through the reactor the air passes through another plenum and is directed to the turbine section of the turbojet(s) and from there out through the tailpipe.[11] An indirect system is very similar, except that the air does not pass through the reactor itself. After passing through the compressor the air passes through a heat exchanger. The heat generated by the reactor is carried by a working fluid to this heat exchanger. The air then passes through the turbine and out the tailpipe as above. The working fluid in the indirect cycle is usually a dense fluid, such as a liquid metal, or highly pressurized water. This allows more heat energy to be transfer, thereby increasing the efficiency of the system.[12]

In an article in the SAE Journal, L.W. Credit wrote, "Of three alternatives for achieving flight reliability in nuclear aircraft through component or system redundancy, the single-reactor, all-nuclear aircraft seems to be the optimum design."[13] The other two alternatives were a dual-reactor system and a combination nuclear-chemical (combustion) system. Originally the ANP program was to develop an indirect cycle, single reactor propulsion system. However, a petition by General Electric to the government allowed them to develop the direct cycle system. GE claimed that the direct cycle was simpler and therefore would have a shorter development time. For the indirect cycle system, Pratt & Whitney developed the super-critical water reactor, in which the working fluid is water heated to 1,500 degrees Fahrenheit, but kept in a liquid state by pressurizing to 5,000 psi. This avoided the problems of using a liquid metal working fluid. The United States has never favored the operational use of liquid metal reactors. To date all military reactors in active service, with the exception of the one liquid sodium reactor on the attack submarine USS Seawolf, have been of the Pressurized Water Reactor (PWR) type. Even the USS Seawolf experienced enough problems that the liquid sodium reactor was replaced with one of a PWR design after a few years in service.

Part of the ANP program was the X-6 program. Beginning in 1952, the designated goal of the X-6 program was to produce two flying test beds powered by atomic energy. The test program started by testing shielding problems. A B-36 was converted for this purpose. This aircraft was referred to as the Nuclear Test Aircraft (NTA). The NTA began its life as a Convair B-36H bomber, but after conversion it was redesignated as an NB-36H. It was modified to carry a small air cooled reactor in the aft bomb bay and to provide shielding for the crew. The NTA incorporated shielding around the reactor itself and a totally new nose section which housed a twelve ton lead and rubber shielded compartment for the crew. There were also water jackets in the fuselage and behind the crew compartment to absorb radiation. The reactor was made critical in flight on several occasions and the aircraft was used for many radiation and shielding experiments.

Convair's successful flight program with the B-36 carrying a flight test reactor (July 1955 - March 1957)" showed that the "aircraft normally would pose no threat, even if flying low. The principal concerns would be: (a) accidents which cause the release of fission products from the reactors, and (b) the dosage from exposure to leakage radioactivity (in the direct cycle concept).[14]

It was decided that the risks caused by radiation were no greater than the risks that had been incurred during the development of steam and electric power, the airplane, the automobile, or the rocket.[15]

The B-36 was also to provide the basis for the actual X-6 aircraft. At the time the B-36 was the only existing, time tested, airframe large and powerful enough to carry the expected engine and shield weight. The engine chosen was the J-53 turbojet.[16] At the time the J-53 was a conventional turbojet in the planning stage at General Electric. The J-53 was a high- performance design and it was felt that conversion to nuclear power would present no more difficulty than any other design then in use. In the early stages of the program, before GE's petition, it was planned to connect the J-53 to a liquid-metal reactor for use on the X-6. The original propulsion system was to have weighed 165,000 pounds. This was composed of a 10,000 pound reactor, 60,000 pounds of reactor shielding, 37,000 pounds of crew shielding, and a total engine weight of 18,000 pounds plus an additional 40,000 pounds for ducts and accessories.[17] After experiencing development problems with the J-53, GE resorted to the J-47 as the power plant. J-47s converted for nuclear testing were referred to as X-39s.

It should be noted that the United States was not the only country working on atomic aircraft in the early years. The Soviet Union had a few projects of their own. One aircraft, a flying boat, proposed in 1950 would have had a flying weight of 1,000 tons. It was planned to equip the giant airplane with four atomic turbo-prop engines. The wing span was more than 130 meters, and the total power of the engines exceeded one-half million horsepower. This airplane was supposed to carry 1,000 passengers and 100 tons of load at a speed of 1,000 kilometers per hour.[18]

It was planned to surround the reactor with five layers of shielding. The layers were supposed to be as follows: first layer - beryllium oxide reflector; second layer - liquid sodium for removing heat from the walls; third layer - cadmium, for absorbing slow neutrons; forth layer - paraffin wax, for slowing down fast neutrons; fifth layer - a steel shell, for absorbing slow neutrons and gamma-rays. Such multilayer 'armor' permits decreasing the weight and size of the necessary shielding. The coolant was liquid lead.[19]

The Soviets studied many of the same options the United States considered; both direct and indirect cycles, turbo-props, shadow shielding, and the special ground handling needed. One fact that is striking is that in the Soviet design the total weight of the atomic power plant was to be 80 tons.[20] 80 tons is equal to 160,000 pounds, which compared to the original figures for the X-6 propulsion system, which was 165,000 pounds, was practically identical.

The reference to 'shadow shielding' above is to the practice of dividing the shields between the reactor and the crew, the crew being in the 'shadow' created by the shields. This is also referred to as the divided shield concept.

If it were possible to put as much shielding on the reactor as is done on ground reactors, we could reduce the radiation therefrom to a negligible amount. But the total weight of shielding required to do this would be prohibitive; in fact, we are forced to the so-called 'divided shield' concept in order to reduce total shield weight to an acceptable amount. Divided shielding is, of course, simply a division of the shielding between the reactor and the crew compartment in such a fashion as to result in near- minimum total shielding weight.[21]

Distributing the shields lessens the total shield weight, but it also means that the majority of the aircraft would have been exposed to higher levels of radiation. And once on the ground more radiation would penetrate the surrounding area. These problems were to be overcome by newer materials and by designing the aircraft's servicing equipment with the higher radiation levels in mind. Divided the shields also had some other benefits;

The directional nature of the radiation leads also to the fact that aircraft structure and components are useful as shielding material, and judicious use of such things as the wing box, landing gear, pay load, and fuel for landing go-arounds can reduce the thickness of shielding required on the crew compartment rear face.[22]

The problem with shield weight was one of two major problems which surfaced during the program. The other was increasing reactor performance. The ANP program focused a great deal of effort on developing the divided shield concept, decreasing the required shield size by decreasing reactor size via increasing reactor power density, increasing the operating temperature of the reactor to boost efficiency and therefore aircraft performance, and utilizing the reduced shield mass in aircraft design.[23] Although work on an actual airframe never got very far, a great deal of work was accomplished on the power plants.

General Electric ran a series of very successful experiments using the direct cycle concept. These were referred to as the Heat Transfer Reactor Experiment (HTRE) series. The series involved three reactors, HTRE-1 through HTRE-3. HTRE-1 became HTRE-2 at the conclusion of its test program. HTRE-1 (and therefore HTRE-2) successfully ran one X-39 (modified J-47) solely under nuclear power. HTRE-3 was the closest to a flight article the program came. It was solid moderated, as opposed to the earlier reactors which were water moderated, and it powered two X-39s at higher power levels. HTRE-3 was limited by the two turbojets, but it could have powered larger jets at even higher power levels. HTRE-1 was principally a proof of concept reactor. "HTRE-1 achieved a number of full-power runs that demonstrated conclusively the feasibility of operating a jet engine on nuclear power."[24] HTRE-2 was simply HTRE-1 modified to test advanced reactor sections in a central hexagonal chamber. In this way new reactor designs could be tested without the need to build a totally new reactor from scratch. The experience gained from HTRE-1 and HTRE-2 was used in the construction of HTRE-3. HTRE-3 was the final test item designed to prove the feasibility of producing an actual aircraft power plant. "The design and testing of HTRE-3 has advanced the direct-cycle program beyond the question of feasibility to the problems of engineering optimization."[25]

All three of the HTRE reactors were of the standard direct cycle configuration, with the addition of a chemical combustor just upstream from the turbines. This combustor allowed the jets to be started on chemical power and then be switched over to atomic heat as the reactor was brought up to operating temperatures. The operational system may have also utilized a chemical combustor for use during takeoff and landing, and possibly target penetration, when the reactors relatively slow response time could be a disadvantage.[26]

The HTRE either met or exceeded their goals, but although all had reactor cores of roughly the size needed to fit into an aircraft, none of the HTREs were designed to be a prototype of a flight system[27]; the series showed that it then appeared "possible and practical with the technology in hand to build a flyable reactor of the same materials as HTRE-3 and similar in physical size."[28] Despite the fact that HTRE-3 didn't produce the power that would have been needed for flight, that was mainly because it was not an optimized design; it was designed simply as a research reactor, to prove the concepts needed for a flight article.

At the end of the HTRE run the probability of flying a reactor seemed high. The test runs showed that a reactor using the same materials as HTRE-3, and which could power a gas-turbine power plant, could have been built at that time. Such a reactor would meet all of the requirements needed for a flight ready unit.[29] In their paper Kelly Johnson and F. A. Cleveland also stated that "when improved materials are available, we would expect the nuclear power plant to advance rapidly in its overall efficiency, with a consequent improvement in ability to install such power plants in airplanes of smaller size than those currently contemplated."[30]

While GE was working on the direct cycle, Pratt & Whitney (P&W) was working on the indirect cycle. However, progress went much slower that it did with the HTREs. P&W never ran a practical test system. In fact their work was limited to component testing. In addition to work on the super-critical water reactor P&W worked with liquid metal coolant designs. It was the latter that received the most attention. The two major designs were a solid core reactor, in which the liquid metal circulated through a solid reactor core, and a circulating-fuel design, in which fuel was mixed with the coolant and critical mass was achieved as the coolant circulated through a central core. After the circulating-fuel design showed promise, work on the super-critical reactor was halted. P&W did accomplish a great deal on the design of liquid metal cooling loops, corrosion prevention, and heat exchanger design. However, P&W work at CANEL never led to a test reactor, much less one which was flight ready. In the long run the indirect cycle showed more promise, but it also required a great deal more developmental work.

While these test programs were successful, there were other programs which weren't. A number of programs were begun at a great cost of time and money, only to be dropped when the program went through one of its many reorientations. The official U.S. government report on the ANP project lists such programs. A Flight Engine Test facility was built in Idaho for use to test the flight engine both on the ground and in the test aircraft. This facility cost over eight million dollars, yet it was never used during the ANP program, other than as a storage building, because the flight program was cancelled. A radiator laboratory was constructed at CANEL for use in studying liquid metal to air heat transfer. After spending over six million dollars the construction was halted with only a shell completed because the Air Force changed its mind. Another laboratory was built at CANEL to study vacuum conditions. This laboratory cost over a million dollars, and it entered use in March 1961, the same month that the ANP program was cancelled. These were only the largest of the wastes. There were numerous instances of wasted time and money, none of which can really be blamed on the technicians, since the leaders changed their minds and the equipment went unused.

Overall the technology seems to have been there, yet the ANP program died. GE's HTRE series proved that the direct cycle concept would work. P&W was making progress, slowly but surely, on the indirect cycle. The NTA reactor tests demonstrated that aircraft shielding could be done effectively. A myriad of smaller developments, new metals, synthetic lubricants, all worked out and were available to produce an aircraft. In 1960 Kenneth Gantz wrote, "The taming of the atom, coupled with the technological advances in aerodynamic and structural efficiencies achieved over the past several decades, now brings atomic-powered aircraft and missiles within our grasp."[31] But if it wasn't killed by technology, what were the reasons for the program's demise? The answer to that question follows in the next section.

Politics

If the technology didn't kill the ANP, what is left? The other factors involved in any major project are the social and political forces behind it. It must be from these areas that the force which killed the ANP arose. However, it is also these areas from which the forces which began the ANP came.

The ANP began in an era when general attitudes towards atomic energy were quite favorable. In fact the type of attitude has been referred to as "Our friend the atom." The writers of the time made it seem as if the atom would be a welcome addition to everyone's life. The idea of an atomic airplane was made to seem quite attractive. At the time a number of books and articles aimed at the general public appeared, a few of which mentioned atomic aircraft.

An atomic airplane? This, too, can be built. --- The advantages of increased range and carrying capacity that make the A-ship so attractive apply as well to the A-plane - but more so. Ordinary airplanes can never really carry enough fuel, even though a big airliner loads more than fifty tons of gasoline into its tanks. Routes must be planned with carefully located alternate landing fields to guard against the disaster of running out of fuel in the air. Long flights over water are particularly worrisome. More than a few times an accumulation of small accidents - headwinds, engine failure, a fuel leak - has culminated in tragedy. Atomic fuel would solve these problems. A few ounces of uranium would keep an airplane aloft indefinitely.[32]

This may sound like a rosy review written by someone not involved directly with the field, but even aerospace professionals realized that atomic power gave aircraft something that no foreseeable chemical power source could, unlimited range.

Two of the pillars of the aviation community, Kelly Johnson and F. A. Cleveland, wrote in a 1957 paper; "After a half century of striving to make aircraft carry reasonable loads farther and farther, the advent of a type of power plant that will solve the range problem is of the utmost importance." [33] Later, when referring again to the unlimited range they wrote, "And this unique characteristic is one to be greeted enthusiastically."[34]

As I stated in the technology section, feasibility studies for atomic powered aircraft were begun in 1946. This was the year that NEPA was started up. NEPA ran until 1951 when it was dropped in favor of the ANP program. The ANP program was aimed at creating a strategic weapons system which eliminated the limitations of conventional power plants. The ANP program ran until 1961, when it was cancelled by President Kennedy. The total amount spent on the development of atomic aircraft was $1,040 million. Of this sum $839 million was for operating costs and $201 million was for facilities and equipment. Funding was provided by the Air Force, AEC, and US Navy, each supplying $518 million, $508 million, and $14 million respectively.[35]

Throughout its life the ANP program was plagued by a lack of direction. Neither the Air Force nor the Department of Defense (DOD) maintained a set of goals for the ANP project. "The ANP program was characterized by frequent changes in emphasis and objectives, varying from a research and development program to an accelerated program to develop a weapon system for the Air Force."[36] Without a set of goals the project managers had a hard time deciding what research to support. This caused a great deal of waste, both of time and money. Test facilities were erected, such as the radiator test facility in Connecticut, which were never utilized during the life of the program. These facilities were built to fill perceived requirements which never materialized due to a shift in project orientation. They either ended up as expensive storage buildings, or worse, as abandoned, half-finished hulks. This cannot be blamed on the AEC and the project managers as "Our review disclosed various instances where it appeared that the Department of Defense (DOD) did not furnish sufficient and timely guidance to those responsible for carrying out the ANP program."[37]

The ANP program floundered many times during its life and without its very vocal proponents it is likely that it would have died sooner. "William L. Borden, --- a man Herbert York describes as 'a fanatic on the subject of nuclear weapons', --- strongly favored --- a package he called 'the ultimate weapon system' --- the thermonuclear weapon carried by a nuclear powered airplane."[38] The Air Force favored the development of an atomic powered bomber because they wanted to keep manned aircraft an integral part of the deterrent force. At the time missiles didn't show a great deal of promise, and there was an aversion towards the pilots of the fifties becoming the "silo- sitters of the sixties." In fact, the Air Force set the priority for the ANP much higher than that for strategic missiles. Herbert York wrote that General Curtis E. LeMay, commander of the Strategic Air Command (SAC) at the time, placed the highest priority on the B-52H and B-70 programs. The ANP was slightly down his list of priorities, with long-range missiles at the bottom. [39] The politicians' ambitions were writing checks for the ANP program that the research couldn't cover. Despite the fact that at the time the research was nowhere near the point of producing flight hardware, in 1950 the Defense Department decided to fly a subsonic aircraft by 1957.[40] The JCAE called for the Air Force to either give the program sufficient support to insure success, or to cancel it.[41]

The ANP program did actually die in March of 1953. At that time Secretary of Defense Charles Wilson cancelled the program. However, the JCAE restarted the ANP program as a crash effort in April of 1954.[42] The program labored on burdened by an inefficient and ineffective command structure. There were redundant offices in the Air Force and AEC. A major program was undertaken to correct this situation. This resulted in a more streamlined command structure which could have been quite effective if utilized properly, unfortunately it wasn't. The program, while making definite progress, continued to meander across a wide variety of research fields, wasting time and money on the way. The program was again stuck in its own mire when a new boost rocketed onto the scene, quite literally. The Soviets launched Sputnik.

The launch of Sputnik not only started the space race, but also a general technological race. Representative Melvin Price, Chairman of the JCAE subcommittee, holding the hearings on the ANP, wrote a letter to President Eisenhower urging him to speed up the ANP program to produce operational atomic powered aircraft in answer to the Soviet's launch of Sputnik.[43] Many people involved in the project came out in favor of an early flight date, including the director of the ANP project Major General Donald Keirn, "who believes many important problems of flight can be solved thereby without delaying the installation of improved reactor cores."[44] "Dr. York said, however, that changing a reactor core in an airship 'is not a minor thing'. Secretary Gates adds that the proper time to fly an airframe would be 'when we have a reactor that is possible of greater growth than the reactor we would now have to use."[45]

Despite these words of warning the hysteria and paranoia caused by Sputnik continued to spread, and was in fact encouraged by some to help continue the ANP program. In a speech, General Keirn said that there was an increased drive for technological development, and proposals to accelerate the ANP program were part of this drive.[46] Both the budget for the B-70 and the budget for the ANP program were temporarily increased, despite their nearly nonexistent links to space.

The paranoia also spread to the public via the press and television. The rumor was spread that the Soviets had beaten us to the punch and had already flown an atomic powered aircraft.

Senator Richard B. Russell of Georgia said in a television statement; 'The report the Russians have test-flown an atomic-powered aircraft is an ominous new threat to world peace, and yet another blow to the prestige and security of our nation and the free world. It follows in tragic sequence the Russian success of last fall in launching the first earth satellite.[47]

On December 1, 1958, Aviation Week magazine ran an editorial in which it was announced that the Soviets had flown an atomic powered bomber prototype.[48] This was accompanied by sketches, complete with large red stars, and supposed data on the aircraft. Time has shown all of this information to be false. It is likely that someone involved with the ANP program created these rumors to use the public to put pressure on Congress to continue funding the ANP program.

A short time after this scare, in 1959, the ANP program came under the control of then Director of Defense Research and Engineering, Herbert York. Dr. York, together with Arthur T. Biehl, set forth a new set of program objectives. They were as follows:

(a) continue the development of only such reactors and power plants as would be suitable for militarily useful nuclear flight; (b) increase the effort on the indirect-cycle program so as to determine its potentialities at an earlier date than previously contemplated, and (c) defer initiation of a specific flight program until one of the advanced power plants was established as feasible and potentially useful, and until a flight program could be instituted without seriously interfering with the development of militarily useful power plants.[49]

Unfortunately for the ANP program these new objectives came too late. The program had become so mired in bureaucracy that, despite the leaps in technology achieved, it wasn't productive enough to be sustained. The ANP program was clouded by political infighting and controversy.[50] The DOD and the AEC muddled about in each other's business. The JCAE continuously tried to take total control of the program. And through it all the contractors took advantage of the disarray. About the only thing that remained constant was that the Air Force continuously said that there was a definite need for nuclear aircraft and that important military applications would derive from atomic propulsion. The problem was that the Air Force never narrowed down what exactly their need was.

A couple of the decisions concerning the technical aspects of the program were made politically. Among the things examined were the danger to the public caused by a development program. Using accident experience gathered >From other experimental jet programs, risk assessments as if those aircraft had been nuclear powered. It was decided that proper selection of bases and flight planning would limit the hazard to the public to risk levels no greater than those associated with the normal operation of other military aircraft. [51] This meant operating away from populated areas and flying in isolated corridors. These tactics would seem to defeat some of the originally perceived advantages of atomic aircraft, in particular the advantage of being able to fly anywhere, without being confined to strict flight paths. Another decision involved the crew, for although the shield tests accomplished all of their goals, it was still felt that some mildly harmful radiation may reach the crew. This begot a plan which in hindsight look rather ridiculous, although at the time it was quite serious.

While most of the intellectual effort devoted to solving these problems was of the usual serious and straight forward kind, occasionally some bizarre proposals arose. One which was discussed quite seriously was that older men (i.e., men beyond the usual age for begetting children) should be used as pilots so that genetic damage from radiation would be held to a minimum and because older people are generally more resistant to radiation than younger ones.[52]

In the end the program had simply been around for too long while producing too few results. Just prior to President Kennedy taking office in 1961, Herbert York and his staff again reviewed the ANP program. They decided to halt all further work on the direct cycle and continue the work on the indirect cycle at a reduced pace.[53] He discussed this recommendation with the incoming staff of the Kennedy administration. "If there was any difference between [President Kennedy's Special Assistant for Science and Technology, Jerome Wiesner's] views and mine, he felt more negatively about the program, and, as a result, ANP was cancelled in the first months of the Kennedy administration."[54] Low level work did continue for a time on the indirect system at P&W.

On March 28, 1961 President Kennedy issued a statement cancelling the ANP program. In it he wrote, "Nearly 15 years and about $1 billion have been devoted to the attempted development of a nuclear-powered aircraft; but the possibility of achieving a militarily useful aircraft in the foreseeable future is still very remote."[55]

Conclusion

The ANP program is an example of the leaders failing to lead. In this case it wasn't a matter of removing the snake's head. This time there were too many heads all trying to control something. The official government report of 1963 reviewed the program: "we do not believe that a research and development effort of the complexity and magnitude of the Aircraft Nuclear Propulsion Program can reach its goal in an effective and efficient manner unless a certain degree of stability in objectives is accorded to the program."[56] The politicians wanted to be in on everything, and they tried to control things better left to the experts, much like what they did with the Vietnam war, which took place only slightly later. Herbert York wrote:

The politicians persisted in concerning themselves with how to go about developing the power plant for a nuclear aircraft, In particular, they tried to insist on a particular sequence of developmental steps (all of which would be, to be sure, ultimately necessary). The result was a mess, and the nuclear airplane was never built.[57]

The technicians and scientists did their best to succeed with the ANP program, and they did make a great deal of technological progress. However, without guidance their efforts were too spread out. The blame for the failure of the ANP program cannot rest with the technology, it belongs to the politicians and the military. "While technical objectives have been generally met by the contractors, there are apparently no firm military requirements set by the Joint Chiefs of Staff."[58]

The ANP program resembles in many ways the World War II German atomic bomb effort. There wasn't enough leadership, and what was there was indecisive. There were too many different development efforts competing for the available resources. Both projects made significant advances in their field, but both were too broad and shallow. If either project had been given better direction early in their lives then the odds are they would have succeeded. As it happened both projects came close, but failed in the end. Perhaps it is a recurring symptom which must be guarded against. We have to make sure that the politicians and leaders set sound goals for new programs while leaving the actual development work to the experts. If we don't, then we may repeat these events yet again. Remember the ANP project cost a good deal of money, but the German bomb effort may have cost them the war.

Near the end of the ANP program Herbert York stepped in and tried to reorganize the project. But it was too little and too late to save the program. The damage had already been done. All the years of cost overruns and disorganization had made the program seem to be a waste of time and money, at least in the eyes of President Kennedy and his staff, and those were the people who really mattered.

It has been said that the cancellation was partially due to the development of accurate missiles, or due to ecological protests which at the time were also plaguing the B-70 and SST programs. Surely these played a part, but the majority of the blame lies with the mismanagement of the program.

Endnotes

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Appendix

When I started writing this paper I didn't expect it to be as complicated as it turned out to be, source wise that is. Since a good deal of the ANP program was classified at the time there were a number of contradictory articles which appear to be either an attempt by the author to fill in the blanks, or perhaps deliberate disinformation by the government.

The idea of powering aircraft with atomic power is still a topic which causes very strong opinions, one way or the other. During the time I have been researching and writing this paper I have discussed this topic with a good number of my friends. And a common reaction is simply, "Why?" Why would anyone want to fly an atomic aircraft. After explaining the goals of the ANP program many people still don't see what the point was, most consider atomic aircraft to be simply too big a risk to be worthwhile.

My initial conversations gave me the idea to go to the nets and solicit opinions there. I posted to wpi.students, rec.aviation, sci.military, and sci.aeronautics asking for opinions on nuclear powered aircraft. This should not be considered to be a good sampling of the general public as, in general, those people on the nets have a high level of education and are, for the most part, involved in some technical field. Plus the newsgroups I posted to have a high concentration of people interested in aviation simply because of what their subjects.

I received a fair number of replies and in general the reaction was again, why use atomic power. However, a few people did acknowledge that it was feasible, and perhaps desirable for the military. Here are a few selected quotes, no attribution as I stated I would not use names. "I think that the words 'nuclear' and 'aircraft' coming together in the same breath would freak out a lot of people, mostly those who don't know a lot about the idea. --- However, I personally think the idea would be feasible, providing that it is well-maintained and well-regulated." "This doesn't sound feasible! Nuclear engines on military aircraft? Wouldn't the nuclear product yield an identifiable signature?" "The major problem, I think, would be that crashes would make things rather messy." "How do you plan to eliminate the danger of radioactive contamination in the event of a crash or other catastrophic failure (and there *will* be catastrophic failures)?" "Planes crash. How can you make it safe? If you *could* make it safe, and convince me it was safe, I guess I'd have no objections." "Nuclear propulsion for aircraft was one of the stupidest ideas they ever came up with. --- The consequences of accidents, --- overwhelmingly outweigh any benefits." "Why would you want nuke engines, anyway?" "This is absolutely crazy! --- If I was a terrorist I don't see how I could resist the temptation to blow it over a city. --- Nah, not a good idea." "Much as I like the idea of nuclear use, I don't know how you could do nuclear propulsion in the vicinity of an inhabited/able planet." "The multiple problems of crashing, radioactive emissions and production hazards seem to be great." "As a semi-informed member of the public (Physics Ph.D., and a general interest/support of nuclear power), I really doubt that such a thing can be made to work safely at any reasonable cost." "I personally think that's just fine, but with the general populace, the idea will never fly." "Negative, think of the new dimension it would add to airplane crashes." "--- the idea of using nuclear reactors to power aircraft is insane." "Too much risk of radiation release against only a marginal benefit." 'As far as opinion goes, I'd ride in one, but I was told that the results of the experiment showed that a properly shielded nuclear reactor is much too heavy to use for aircraft."

As you can see from the above quotes, opinions vary widely. There are those who feel atomic aircraft are fine, and those who feel the idea is insane. A few new points were brought up by the replies too. When the ANP project took place there wasn't any real problem with terrorists, but now they are a very real risk. Bringing a nuclear aircraft down on a populated area could cause a great deal of trouble. The one point that was repeated the most was the simple fact that planes crash. The military could get around this by operating in their own airspace away from cities, but a nuclear civilian airliner would need to get close to cities to be effective. A large number of crashes occur during take-off and landing, this is when a nuclear airliner would be the most dangerous to the public.

Personally I don't have any problem with the use of atomic power for aircraft, and I would fly in one if I believed it was safe. I feel that as a passenger my odds of dying on an airliner are the same whether it is chemically powered or powered by a reactor. But why? Conventional jets have come a long way since the ANP program ran. Modern airliners have the range for nearly any flight one would want to make, and as a matter of business airlines don't fly a great deal of non-stop flights long distance. The nuclear airliner wouldn't fit the present system. And for the military, the nuclear bomber is a purely strategic weapon. With the thawing of the cold war there is no use for such an expensive and complicated system. The B-2 would have a better chance if ever used, and it is being cut back drastically.

In this day of curtailed military spending I don't think the ANP would have ever come about. It took the pressure of the early cold war years to give it life. The nation was almost constantly on a ready for war footing, and as time went on we relaxed and began to seriously look at our projects. The ANP seemed to be unneeded. If the program had had better guidance perhaps it would have made progress quicker and produced a flight article before the cold war cooled off. If it had we may have been introduced to a world of nuclear aircraft. But that isn't the way it happened, at least not in this universe.

Editor's note: The original publication of this paper was published in the Aeronautics Digest, 4.38, November 12,1992 under the title Nuclear Flight, The ANP & X-6.