Manned Nuclear Aircraft Program

By: Jack Waid

The NB-36H with a B-50 in 1955, the only aircraft to carry a nuclear reactor.

A nuclear powered aircraft! Today it sounds like a crazy concept, but was it really? Within the last several months there was a joke in the office about this very thing. One of the historians in the office was writing a paper about the XB-70. The paper mistakenly mentions the engines of the XB-70 were nuclear powered (should have read it was a physics package delivery platform). As things often do the joke evolved and all in the office continue to laugh about. As it turns out the joke was much more a reality than most would believe. The XB-70, initially designed as a Mach 3 bomber, never went into production and the two XB-70 aircraft built saw use as experimental aircraft.

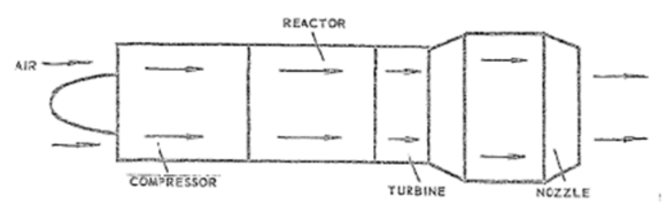
HISTORY IN TWO

The U.S. Nuclear Propulsion Program (or Manned Nuclear Aircraft Program) began in May 1946. This after Fairchild Engine and Aircraft Corporation, received the first formal study contract. The objective, to determine the feasibility of nuclear energy for the propulsion of aircraft. The Fairchild project known as the Nuclear Energy for Propulsion of Aircraft (NEPA) began at the Oak Ridge National Laboratory, TN.

Work at Oak Ridge proved building a nuclear aircraft was feasible and defined the major approaches to the program. As a result, the Air Force and Atomic Energy Commission (AEC) joined forces in the Aircraft Nuclear Propulsion (ANP) Program. In 1951, they contracted with the General Electric (GE) Company at Evendale, Ohio to, "…develop a nuclear aircraft propulsion system through an exacting research, development, design and component-test program on reactors, materials, shielding and an over-all nuclear power plant." [1]

At the time, there appeared to be two design concepts for a "nuclear" aircraft: the Direct-Air-Cycle and the Indirect. General Electric elected the Direct-Air-Cycle[2] due to the perceived simplicity, flexibility, adaptability and ease of handling. General Electric quickly developed high-temperature, compact, lightweight reactors and shields required for aircraft flight. The GE Company also believed their new technology had applicability to aerospace and ground power systems. In the 1950s, nuclear reactors were approximately the size of two railroad cabooses stacked on one another and the performance requirements for aircraft nuclear power plants were much more stringent than those for electrical power generation or surface transportation nuclear systems.

SCHEMATIC OF DIRECT AIR-CYCLE NUCLEAR PROPULSION SYSTEM



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

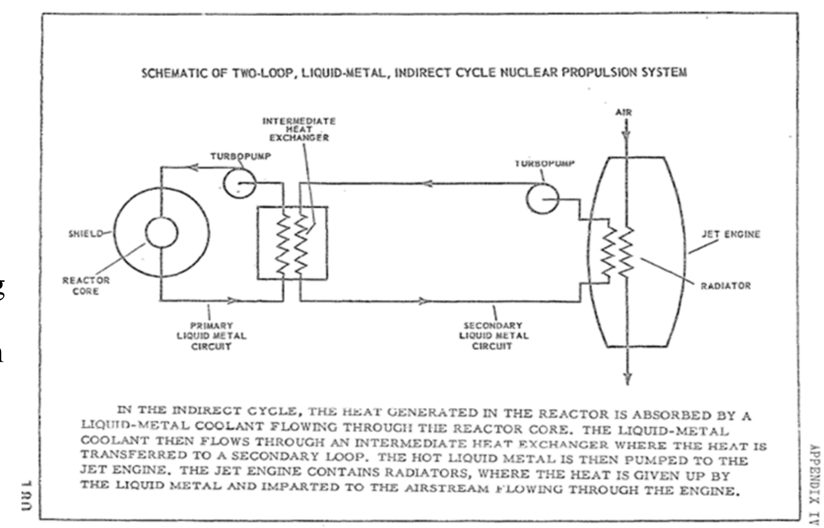
[1] (U) Study (U), Author Unknown, *Aircraft Nuclear Propulsion Department, Capability*, General Electric, circa 1961.

[2] After General Electric (GE) elected Direct-Air-Cycle Pratt and Whitney's (P&W) Middletown, CT facility received a USAF/AEC (Atomic Energy Commission) contract for an Indirect-Cycle nuclear turbojet.

As an aside, the individual in charge of the ANP Program held both USAF and AEC positions. Major General Donald L. Keirn, served from 1950 to 1959 as the AEC assistant director for its aircraft reactors branch and in the Air Force, as Deputy Chief of Staff/Development for Nuclear Systems. General Keirn was a fitting choice, tasked by General Hap Arnold in 1941, a major at the time, to lead the Air Force Project Office developing the first US turbojet engine developed by GE.[3] After his retirement in 1959, Brigadier General Irving L. Branch wore the dual hats until the program was halted in March of 1961.

The objective of the ANP Program expanded to include the demonstration of nuclear-powered flight. Still in 1952, the Air Force decided that direct nuclear cycle engine developments were progressing well and began construction of a power plant for the Convair B-36 flight testing and targeted for 1956 for the first flight. In 1953 the Secretary of Defense Charles E. Wilson abruptly cancelled the B-36 experimental flight program, Wilson, a skeptic, contended "that experimental "proof-of-principle" flights were worthless unless they were performed by a prototype for as an actual weapon systems."[4] The money slated for the project was for a weapons system so, the prototype requirements leaned this direction.

Though the B-36 experiment halted, Air Force leaders managed to keep GE's direct cycle developments moving forward and Pratt and Whitney continued their progress. Pratt and Whitney used a pressurized water, indirect cycle engine which failed to progress (see below schematic). Pratt and Whitney changed gears and began working with the Oak Ridge on a molten salt circulation fuel reactor, still using the indirect cycle nuclear turbojet concept. Throughout the testing and experimentation, Pratt and Whitney remained behind GE in developments.



Schematic of two-loop, liquid-metal, indirect cycle nuclear propulsion system.

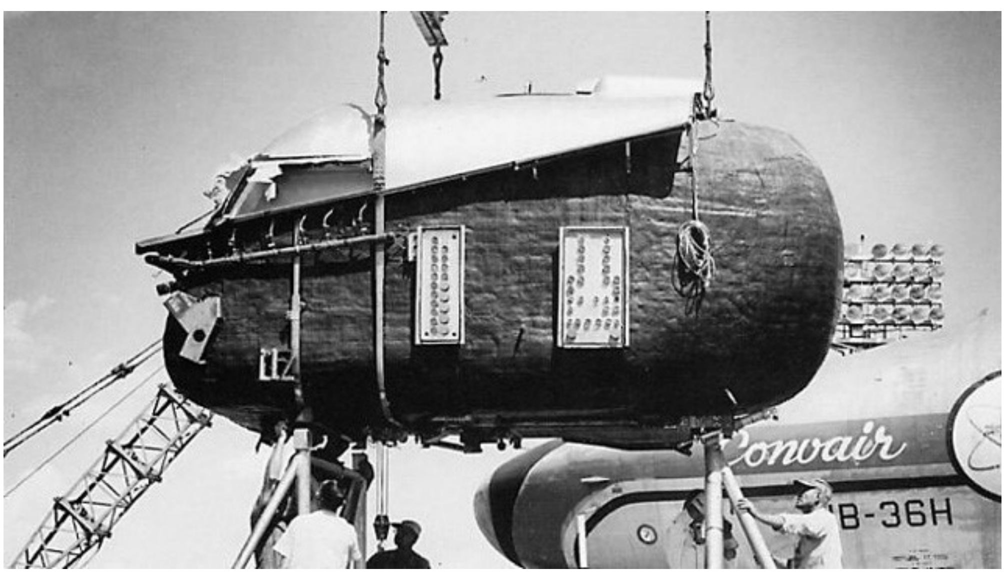
[3] See AFMC/HO, "*Bullet Background Paper on J-33/I-40 Turbo Supercharger Jet Engine*," 4 January 2019. After his retirement in 1959, Brigadier General Irving L. Branch wore the dual hats until the program halted in March of 1961.

[4] (U) Study (U), Author Unknown, "*The Nuclear Aircraft Engine*," circa 1962.

Though Air Force leaders cancelled developments for a B-36 nuclear powered aircraft, a Convair B-36, designated as the NB[5]-36H and specially refitted to contain a fully operational nuclear reactor however, the NB-36H did not use the reactor for propulsion.

NB-36H…Note the "radiation" symbol on the tail of the aircraft

In 1954, responding to Secretary Wilson's desire to have a weapon system prototype, the Air Force established a strategic weapon system requirement calling for a bomber that cruised to targets at subsonic speeds and then fly over the target supersonically; standard turbojets for the supersonic capability augmented nuclear engines. The weapons system was designated the WS-125A; GE and P&W remained the engine contractors, while Lockheed and Convair were designated the airframe builders.



Lead encased cockpit

[5] 'N' designation used to denote a permanently modified airframe.

By early January 1956, GE successfully modified a J47 turbojet engine, solely to operating on nuclear power. "The engine tested a Direct-Air-Cycle, water moderated reactor utilizing nickel-chrome clad enriched uranium fuel elements. The reactor had an aluminum tube and shell arrangement with concentric ring fuel elements inserted into the tubes."[6] For the first time this modified engine combined the components of a Direct-Air-Cycle nuclear turbojet, though still not in an aircraft engine configuration. The first engine received the designation of Heat Transfer Reactor Experiment-One (HTRE-1) (See pictures below). After the HTRE-1 came the Heat Transfer Reactor Experiment-Two (HTRE-2) and this still in 1956. The HTRE-2 was a modified HTRE-1 designed to test alternative fuels and reactor designs under actual operating conditions. As 1956 drew to a close, the Pentagon decided the WS-125A was a drain on resources and terminated the program. Though terminated, GE and P&W, with permission, continued nuclear engine development.

On 4 Oct 1957, the Soviet Union launched Sputnik I. This caused concern throughout the nation and many within Congress wanted to accelerate the ANP Program in an effort to recapture national prestige. However, in February of 1958, President Eisenhower informed Congress there was no urgency placed on the ANP Program. He did authorize $150 million a year for ANP Program development; of which P&W received some funds to begin limited work on a solid fuel reactor for an Indirect-Cycle engine and General Electric received monies to continue their efforts with the Direct-Cycle engine.

The last major modification, introduced in 1958, came in the form of the Heat Transfer Reactor Experiment-Three (HTRE-3). The HTRE-3 affixed horizontally within an aircraft and designed for flight loads. Like the HTRE-2, the HTRE-3 utilized modified J47 engines and included basic flight control system. Specifically, this reactor generated up to 35 megawatts, enough power to operate two J47 engines for 64 continuous hours. This occurred during the HTRE-3's 120-hour operational test. This reactor, before its retirement in 1958, "made a series of all-nuclear starts, a sequence never before accomplished."[7] Previously an external starter set the turbomachinery in motion and the engine reached full speed with conventional chemical inter-burners.

[6] (U) Study (U), Author Unknown, "*The Nuclear Aircraft Engine*," circa 1962.
[7] *Ibid*.

HTRE-3, left, and HTRE-2, right, now on display at the Idaho National Laboratory near Arco, Idaho. HTRE-2 was the converted HTRE-1. HTRE-1 or "Heater One" demonstrated the principle of nuclear-powered turbojet engines.

In 1958, the Air Force, in an attempt to keep the ANP Program alive, introduced new mission requirement. Known as CAMAL (continuous airborne alert, missile launching and low level penetration), it was a rehashing of a nuclear weapons system aircraft.[8] During the summer of 1959, Dr. Herbert F. York, Director of Defense Research and Engineering in the Pentagon and other Department of Defense research officials pushed a reorientation of the ANP Program project. These officials called for the development of a useful nuclear turbojet capable for installation in and flown on a Convair Model 54 (the NX-2). Additionally, the aircraft needed to reach Mach 0.8 or 0.9 at an altitude of 35,000 feet and high subsonic performance at lower altitudes. Lastly, the nuclear engine must maintain 1000 operational hours before an overhaul. Leadership at the Pentagon eliminated the CAMAL project before the end 1959.

[8] Convair won the competition for the CAMAL airframe early in 1959 but Dr. Herbert F. York, the Pentagon's Director of Defense Research and Engineering, soon rejected the project.

There was no question the speed requirements could be met, as David F. Shaw, general manager of GE's ANP Program department, told two engineering groups in January of 1961 (in Cincinnati), "It is no longer a question of can we build a nuclear-powered aircraft system, but when can we place such a system in an aircraft. We have reached the point that we can say that when an airframe is ready, we can have the nuclear Direct-Air-Cycle power place ready for installation." Pratt and Whitney recognized they were in a similar position with the Direct-Air-Cycle engine, but were unfortunately still behind GE.

Everything changed in January 1961 as President John F. Kennedy entered his official duties and directed a review of all military projects. Not long after, GE, P&W and Convair all received official contract termination notices in March 1961. As the space race leapt full speed into the nation's purview, it was not long before the Atomic Energy Commission began working with companies to develop nuclear rocket engines (Project Rover) and nuclear ramjet (Project Pluto). These programs had potential here on earth and in space for both military and civilian applications.

[9] (U) Study (U), Author Unknown, "*The Nuclear Aircraft Engine*," circa 1962.