Nuclear Aircraft?? An Idea Whose Time Never Came

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Genesis

- Think late 1940's (Cold War):
  Air Force considered dominant branch of DoD
  --reliance on nuclear weapons
  --drawdown of conventional weapons
  --reduction in conventional forces
- Fascination with novel Nuclear Power
- Nuclear bombers:
  --could stay aloft "for years" or "for weeks at a time"
  (...what would crew think of this?)
  --ICBM's not yet developed; needed bombers for nuclear deterrence
- First discussed by Fermi 1942

NEPA (ANP)

- 1946: study by Johns Hopkins Applied Physics Laboratory on potential and problems of using atomic power for aircraft
  --led to authorization of USAF-AEC project NEPA (Nuclear Energy for Propulsion of Aircraft)
- 1948 study by MIT concluded nuclear aircraft could be developed in 15 years for $1B
- Renamed ANP (Aircraft Nuclear Propulsion) project in 1951

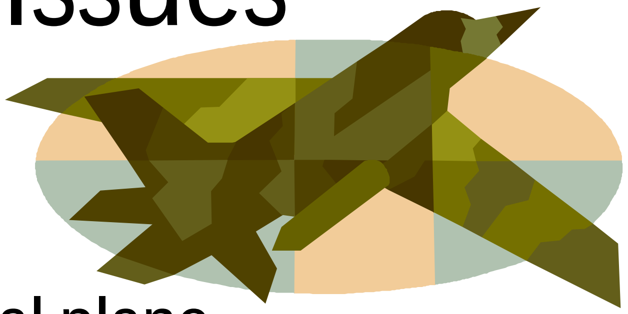
Nuclear Design Issues

- Shielding (weight)
- Materials (high temperature & radiation)
- Compact design (to fit on airplane):
  high power density
- Radiation levels/release for normal operations
- Plane crashes?
- Continuity of power?
- Approval to fly through foreign airspace?
- Did we mention Shielding??
- More complex than Nuclear submarine
- Shorter required core design life (100 hrs?)

Nuclear Design Requirements

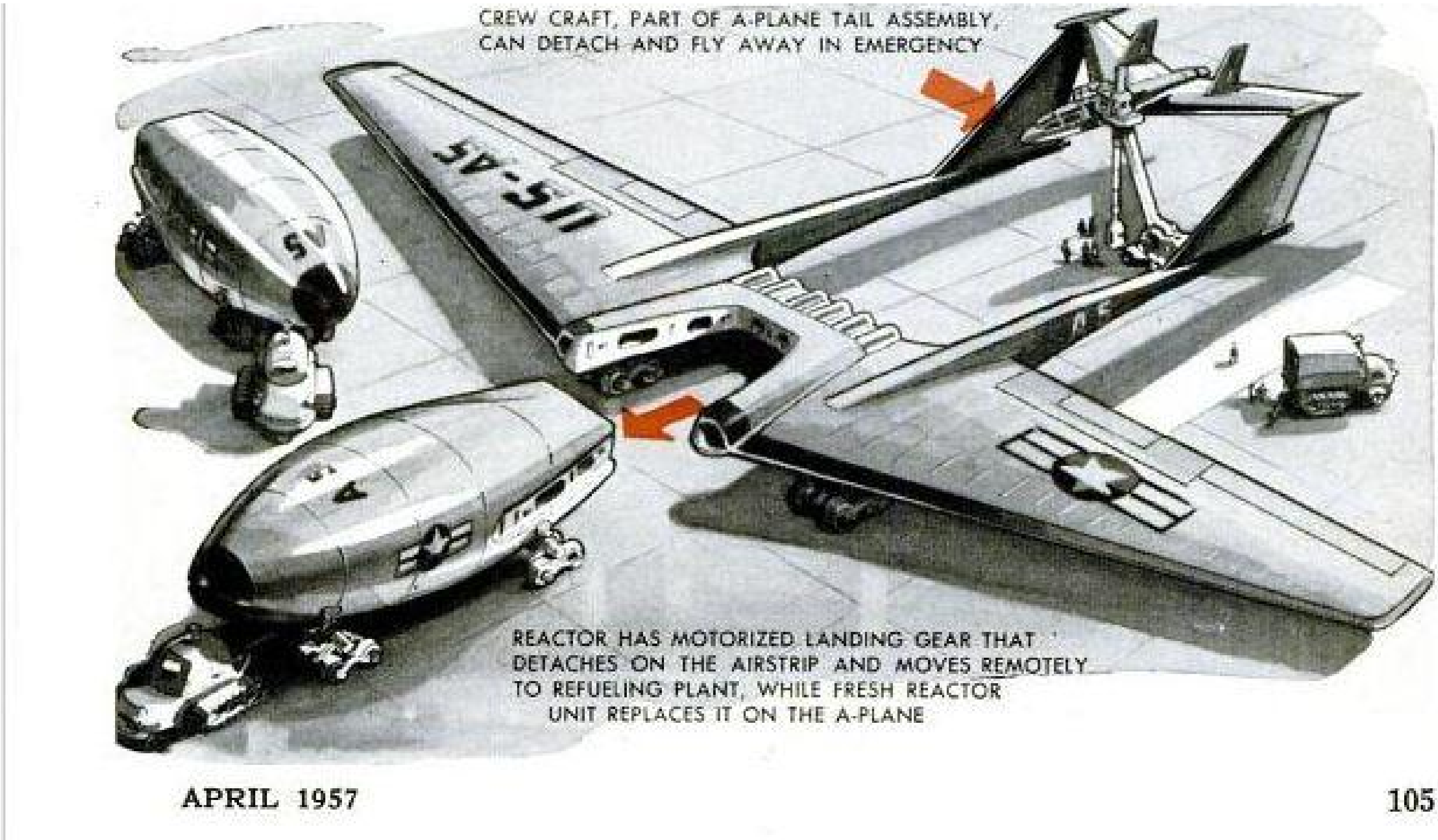
- High U-235 enrichment
- Thermal neutrons: higher power density
  --require moderation (slowing neutrons) and reflectors
- Very high temperature

Aircraft Design Issues



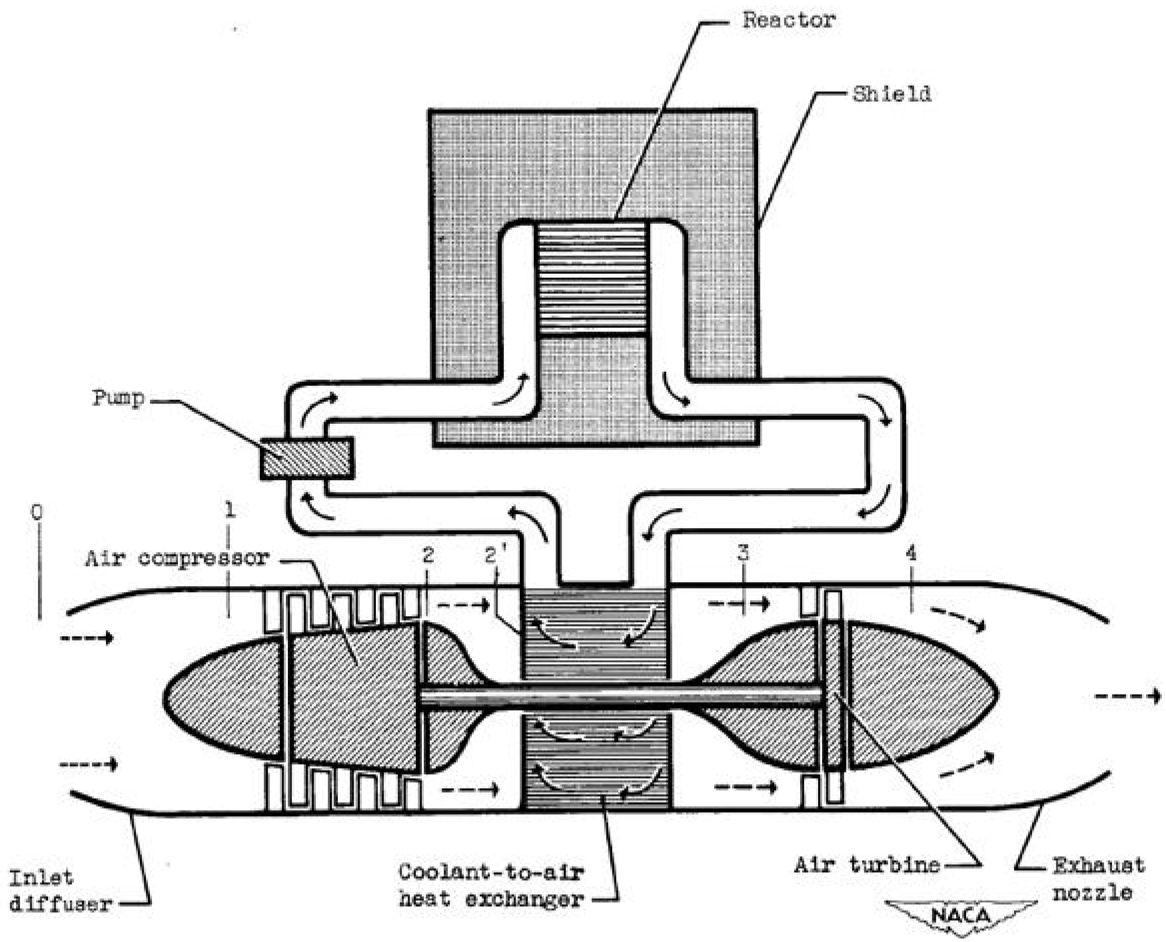
- Weight
- Landing gear & runways
  --plane would weigh the same to
  land as to take off, unlike conventional plane
  --needed extra large runways
  --would need exclusion areas on runways due to radiation levels
- Sufficient distance between crew and reactor
- Settled on “Shadow Shielding” – some shielding at reactor (equipment protection), some for cockpit/crew
- Required Shield Design (and weight!) highly dependent on reactor design.
- Specifications never really finalized for Aircraft platform. Up to 350 MW considered. Subsonic or supersonic?

One Modular Plane Concept

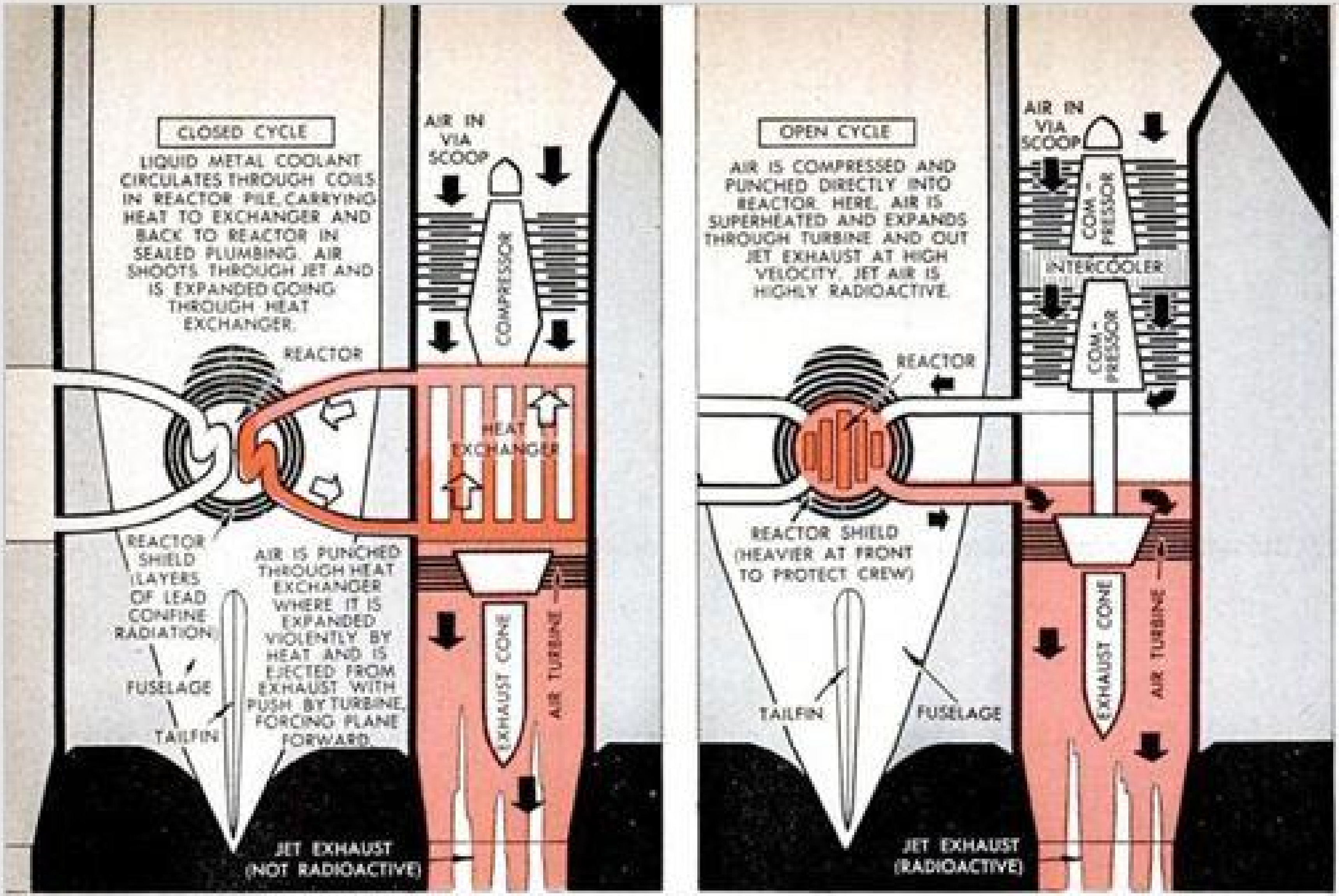


Reactor Design Concepts: Direct vs. Indirect Cycle

- Direct cycle: air that cools reactor also provides thrust from jet
  --simpler design
  --shorter development time
- Indirect cycle: allows intermediate cooling loop (e.g., Liquid Metal) for reactor, intermediate loop then cooled by air
  --better heat transfer, thus potentially smaller reactor even with secondary heat exchanger
  --less radioactive release
  --much more complex design



Indirect Cycle Aircraft Nuclear Engine Concept



Diagrams compare the closed-cycle and open-cycle reactor systems. Open-cycle system has radioactive exhaust

P-1 Reactor Design

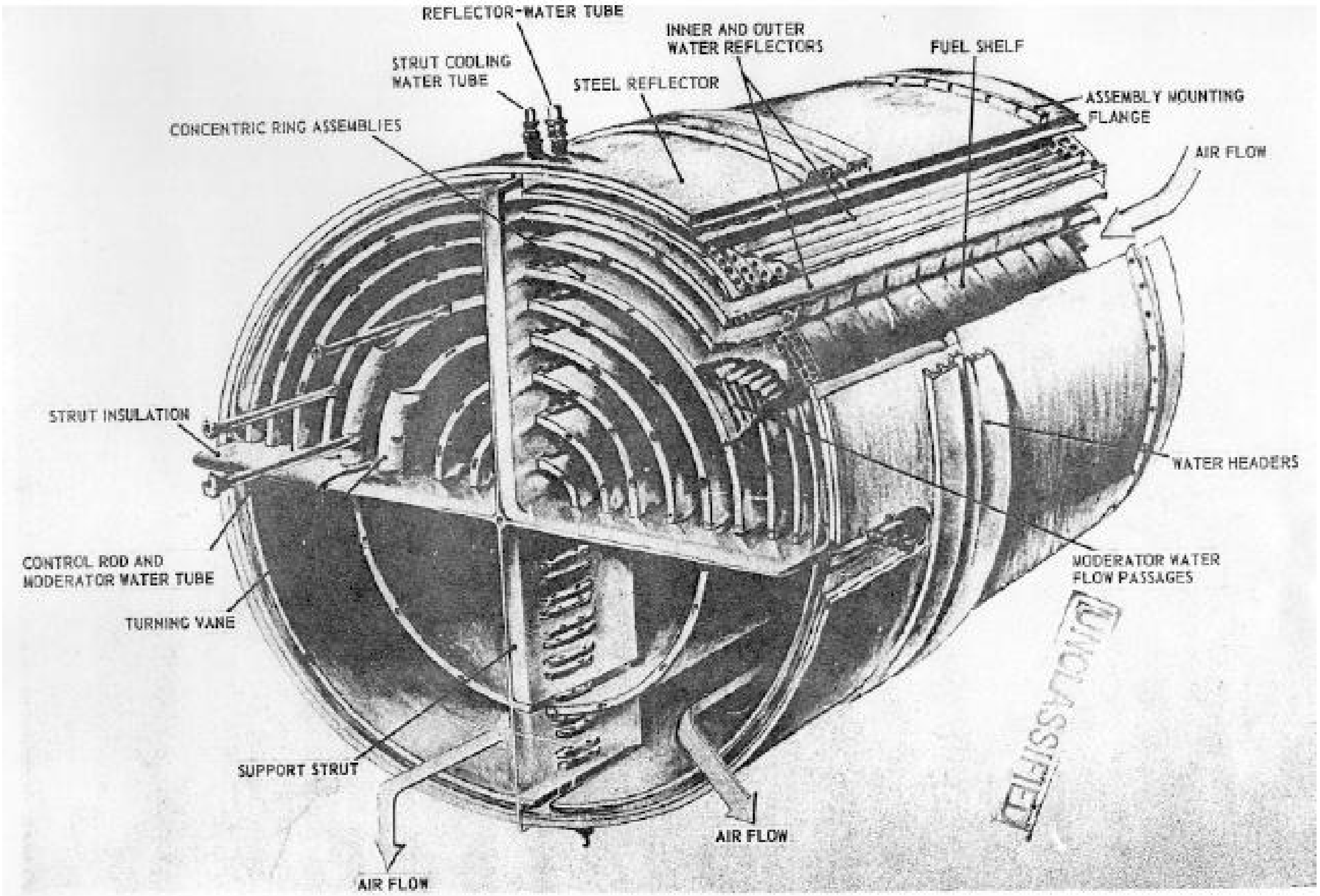


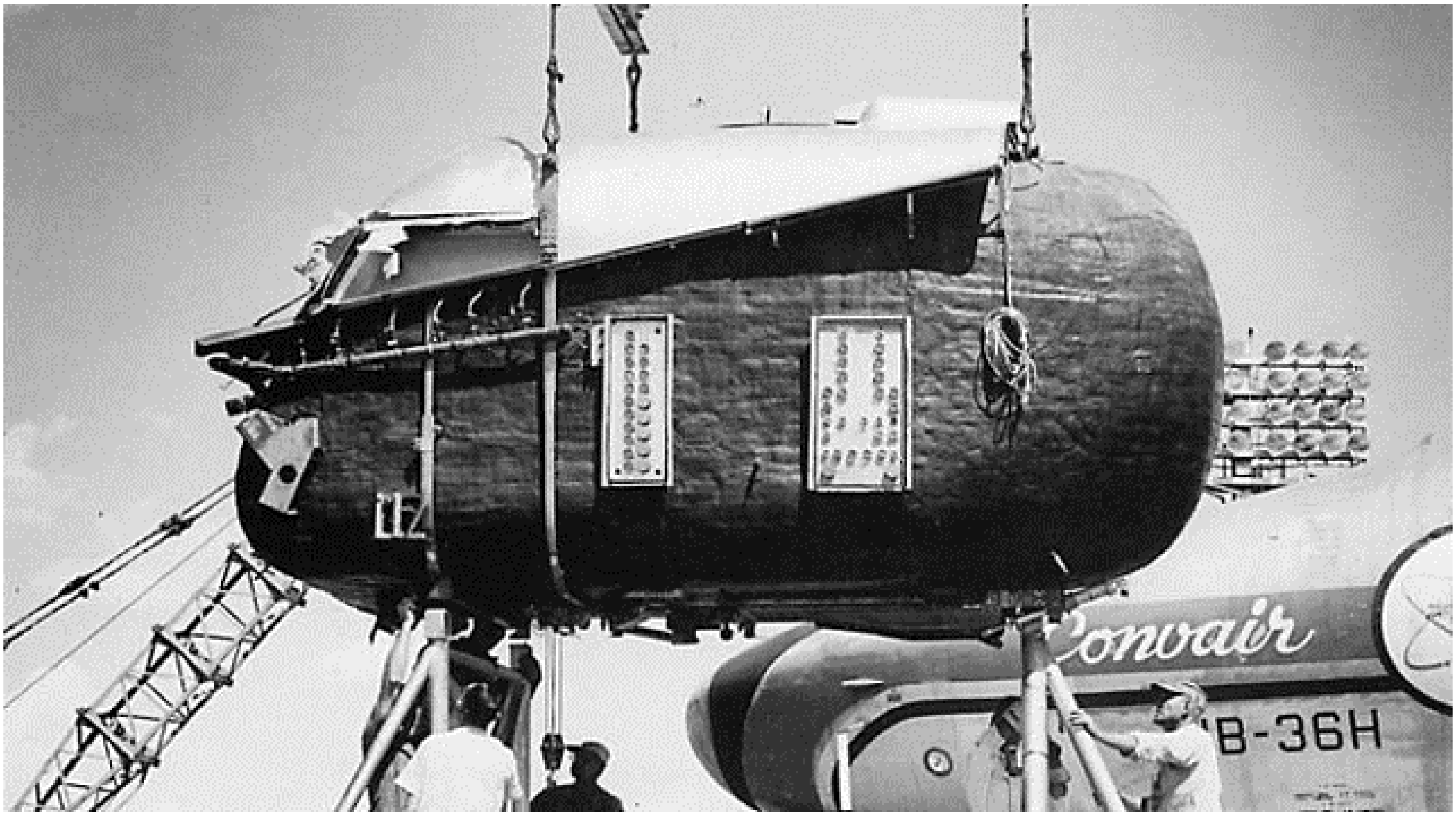
Fig. 2.2 – P-1 reactor structural arrangement

NB-36H

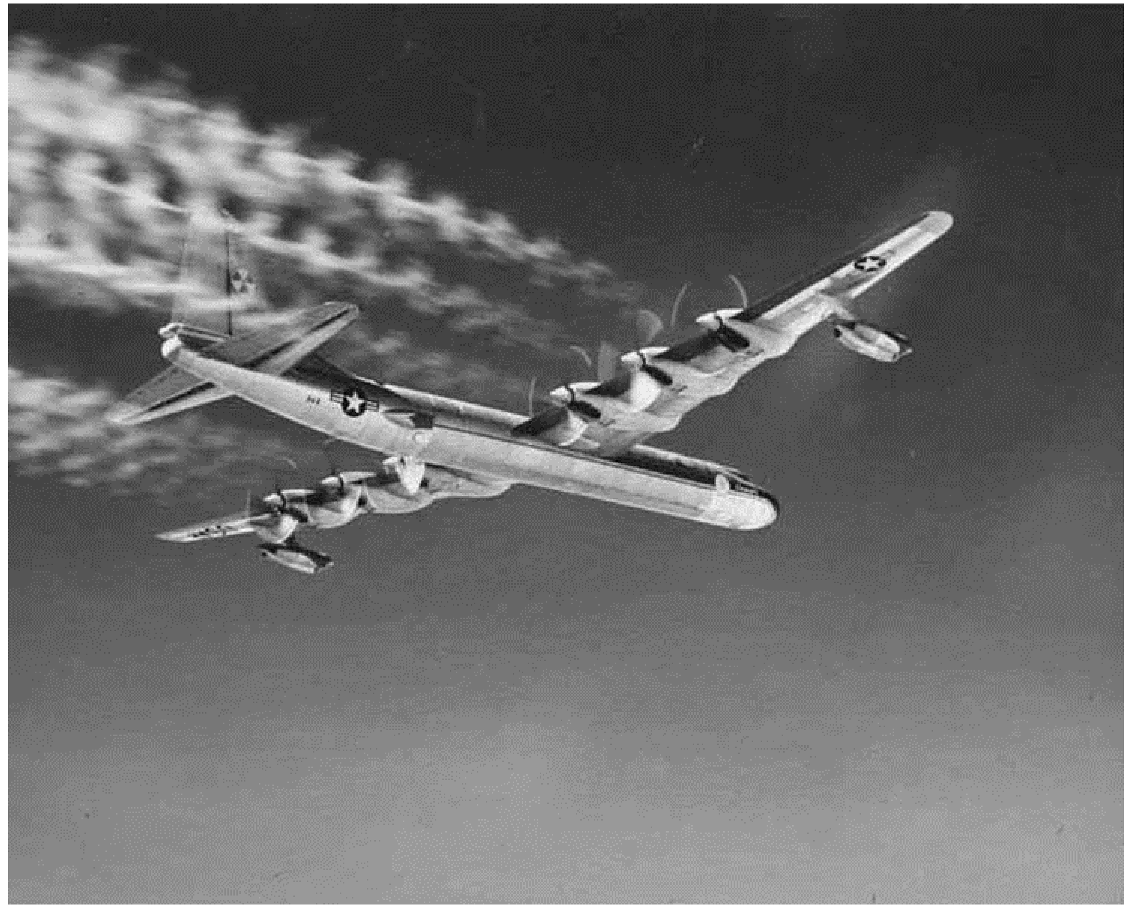
NB-36H

- Convair B-36 Peacekeeper bomber used for aircraft reactor shielding experiments
- Conventional power for engines
- Hung a 20 ton 3MW air-cooled indirect cycle reactor from a hook in bomb bay to study effects of different shielding configurations
  --water as primary coolant
  --had capability to drop reactor in case of emergency
- 47 flights, Sept.'55 – March '57
- 215 hours aloft (89 critical)
- Cockpit enclosed with 11 tons lead for shielding
- Adjusted reactor shielding configuration to try to optimize weight and effectiveness

NB-36H Shielded Cockpit



NB-36H



- Followed on flights by a C-97 transport with Marines
  --If NB-36H crashed, Marines would parachute and quarantine the crash site
- Also had direct hotline to President's Office in case of nuclear accident

Bomber comparisons

- Comparison of B-36, B-52, and hangar USAF built for a never-built or never-final-design nuclear aircraft:

	B-36	B-52	Hangar
Wingspan (ft)	230	185	205
Length (ft)	162	159	135
Weight (lb)			
(empty)	166,165	185,000	--
(max takeoff)	410,000	488,000	--

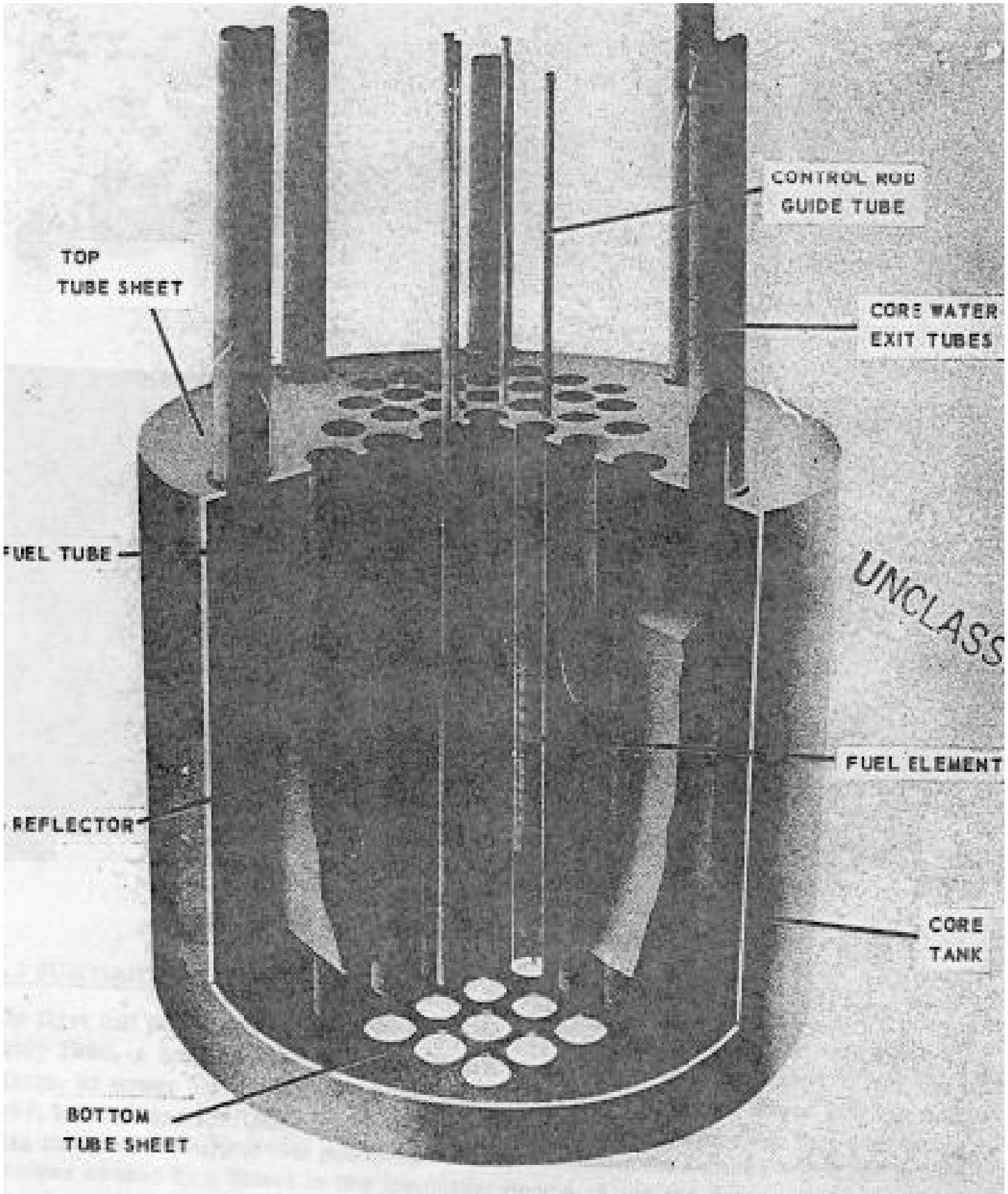
HTRE
(Heat Transfer Reactor Experiment)

- Test platform for Direct Cycle Aircraft Nuclear Propulsion (at Idaho Nuclear Reservation)

GE J-87

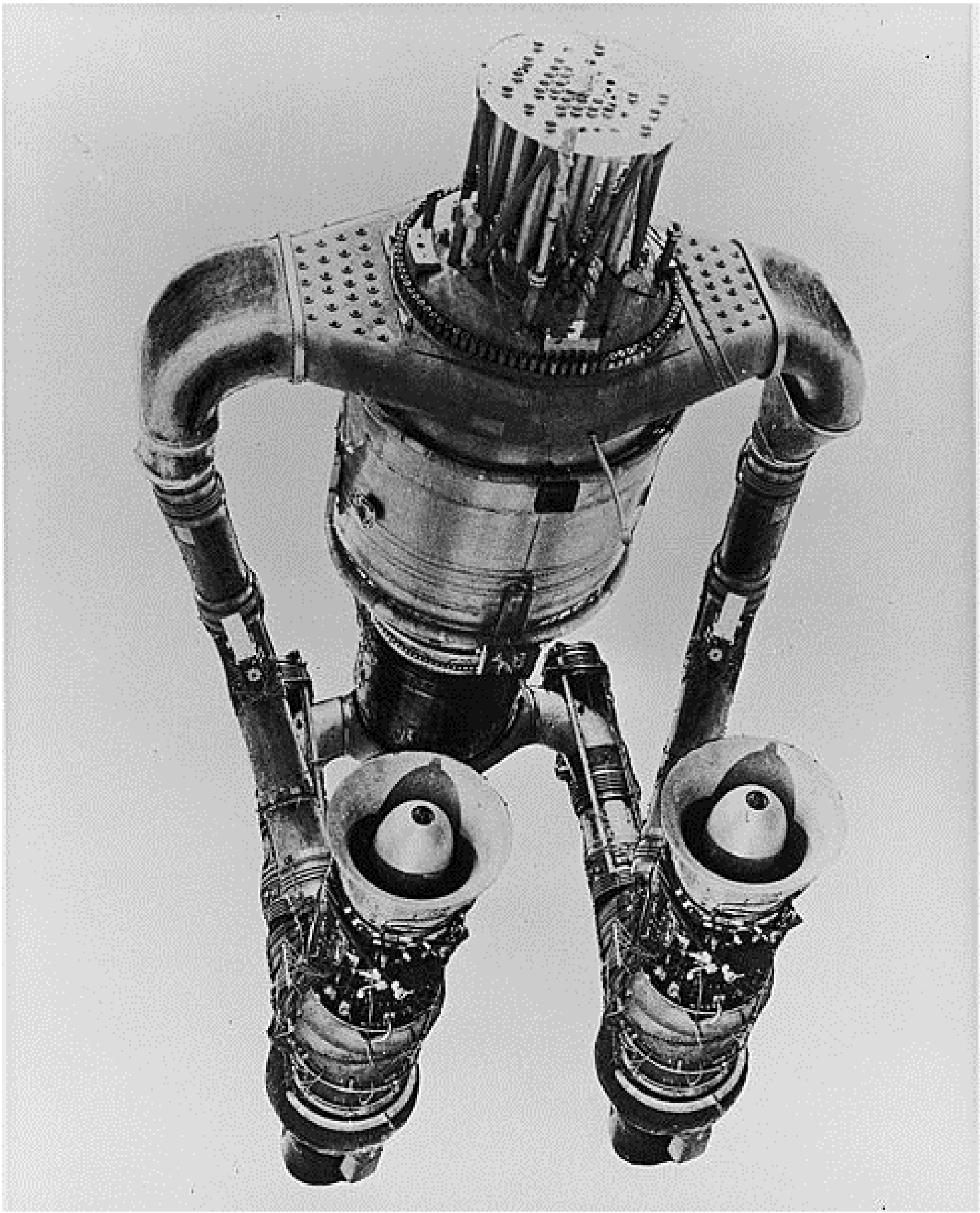
- nuclear powered turbojet for proposed WS-125 long-range nuclear bomber
- 2 J-87's per aircraft, powered by single reactor
- had bypass for conventional fuel (for startup, landing, decay heat removal)

HTRE-1 Reactor Core



HTRE-3

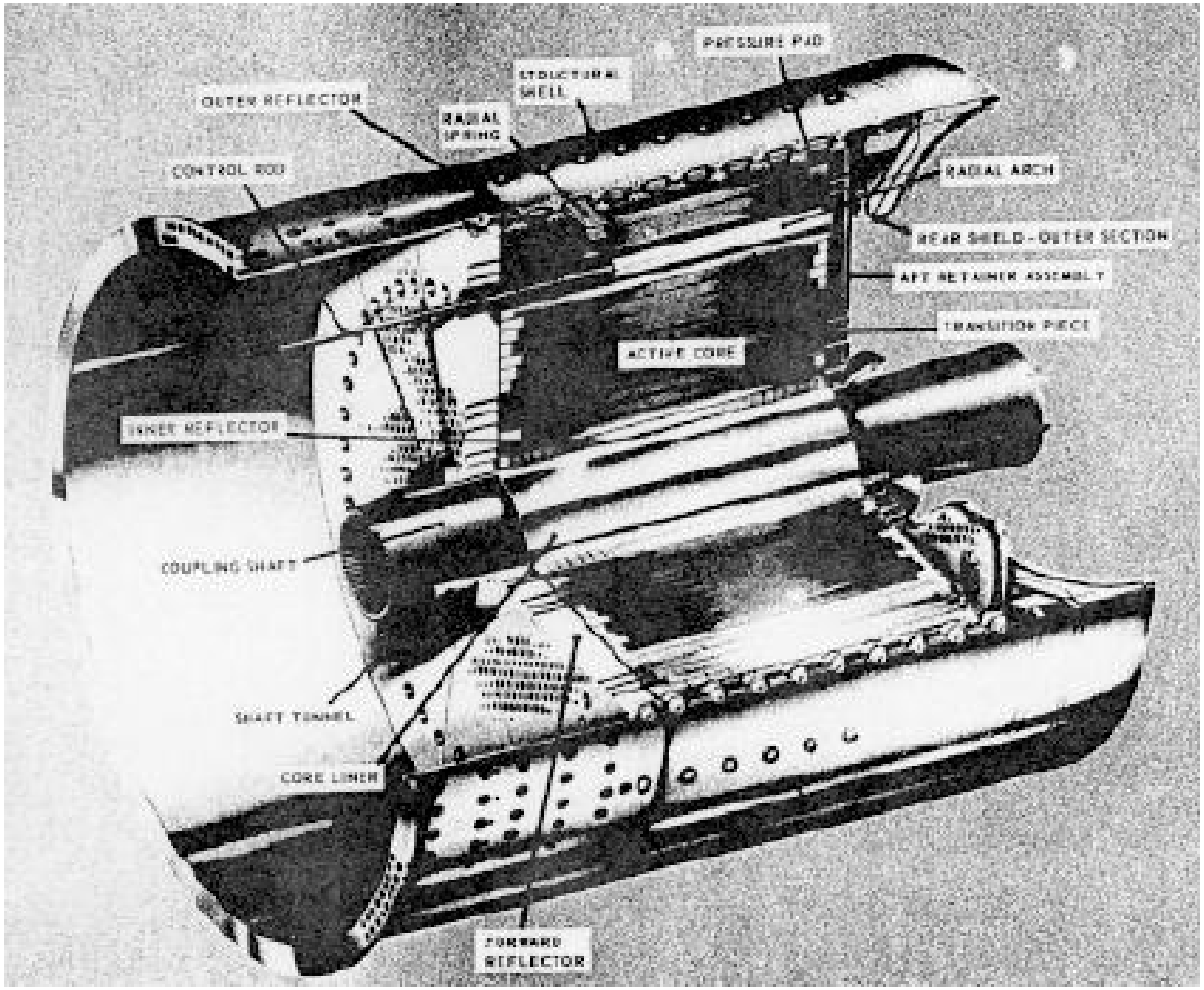
· Reactor design similar to earlier P-1
· Tubular air passages, Nb-Cr fuel matrix and clad.
· 1350F outlet air temperature



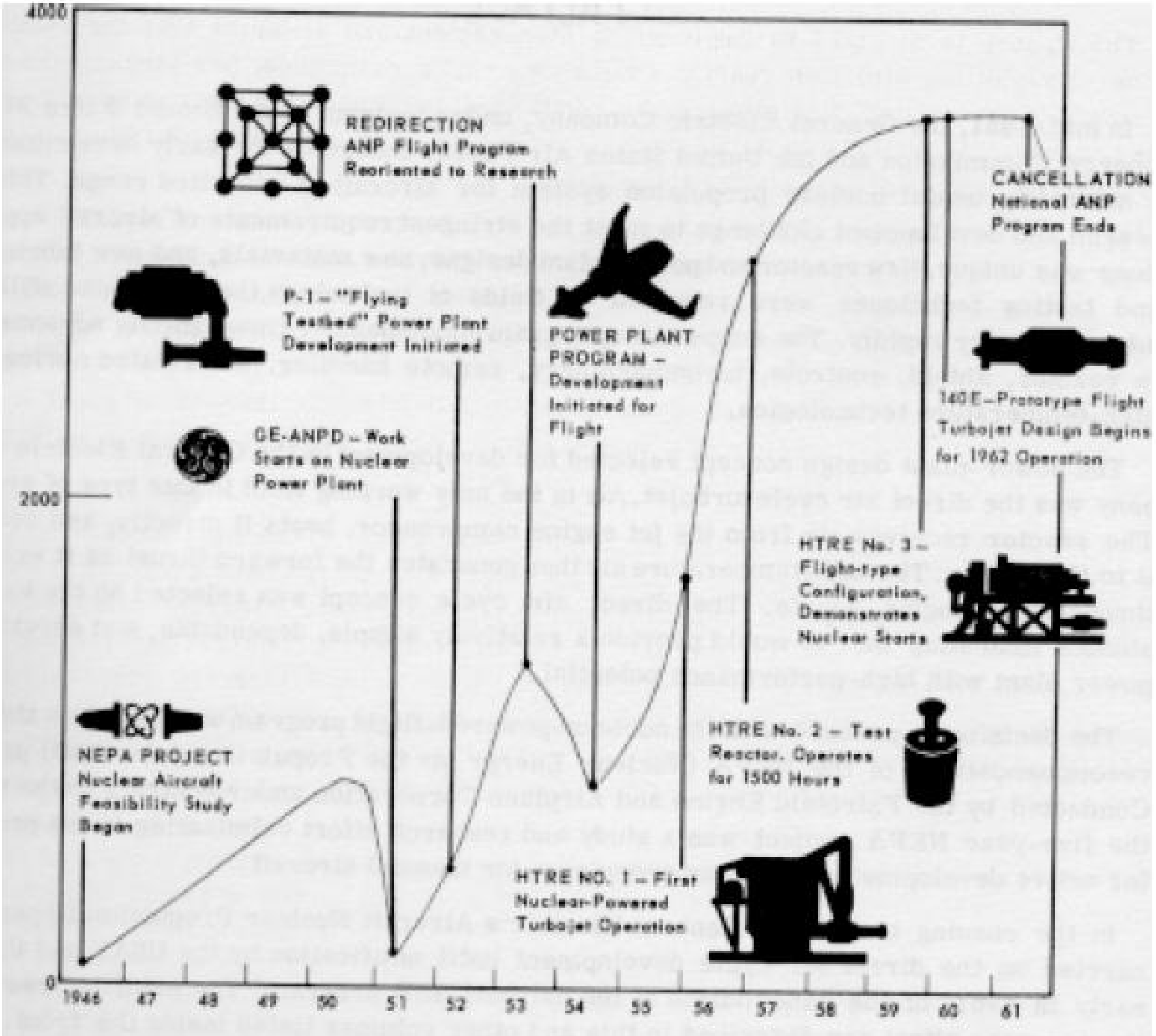
End of ANP

- USAF decided 1956 WS-125 bomber not feasible as a operating aircraft
- However, research on ANP continued until 1961; X-6 prototype of converted B-36 was planned --similar core to HTRE-3 with Be fuel matrix
- JFK killed program March 1961 (recommendation left by Eisenhower administration)
- Epilog: a mismanaged program: spent $1B, no results, inconsistent direction, while more modest Navy programs had 14 nuclear subs already commissioned,
  took only 7 years to launch Nautilus.

XNJ140E Reactor for X-6 Prototype



- “Nearly 15 years and about one billion dollars 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”



ANP Program Timeline and Resources