The Orion Nuclear Rocket

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The (proposed) interstellar Orion nuclear rocket (not to be confused with an Orion crew exploration vehicle being considered for flights to the moon and beyond) would use nuclear detonations to propel it through Interstellar space. Small nuclear devices would be released from the back of the vehicle and explode at a “safe distance.” The hot expanding gas of the explosion would push against a large plate at the rear of the vehicle to drive it forward. (Damon, 2011)

The race to the Moon dominated manned space flight during the 1960s and culminated in Project Apollo which put 12 men on the Moon. Unbeknownst to the public at that time, several U.S. government agencies sponsored a project that could have conceivably placed 100 people on the Moon and eventually sent crewed expeditions to Mars and the outer planets. These feats could have possibly been accomplished during the same period of time as Apollo and for approximately the same cost. Project Orion featured an unorthodox propulsion method known as Nuclear Pulse Propulsion. The concept is probably as radical today as it was then. Its development appeared to be so promising that it was only by political, and not technical, considerations that it was not used to extend humanity's reach throughout the solar system and even further, to the stars. (NASA, 2000)

Orion was conceived to deliver a propulsion system that could deliver far greater exhaust momentum per unit mass (i.e., specific impulse or Isp) than modern-day solid and/or chemical rockets, and that can operate at significantly larger power densities than current high-performance electric propulsion systems. The idea of using a series of explosive pulses to propel a rocket vehicle can be traced back to Hermann Ganswindt, who published his ideas in the 1890s, and R.B. Gostkowski who issued the first scientific study of the concept of using dynamite charges in 1900. (NASA, 2000)

Two basic types of nuclear pulse concepts have been researched over the years. These concepts share many common features and differ primarily in how momentum from the nuclear blast is converted to thrust. In all cases an individual explosive device

(i.e., pulse unit) is ejected from the rear of the vehicle and detonated at a predetermined standoff distance from the rear, behind a large plate. The resulting explosion vaporizes the entire pulse unit and causes this "propellant" to expand as a hi-energy plasma. with some fraction interacting with the vehicle and providing thrust. A large number of pulses take place, probably at equal intervals. (NASA, 2000)

Figure 1

NASA, 2000

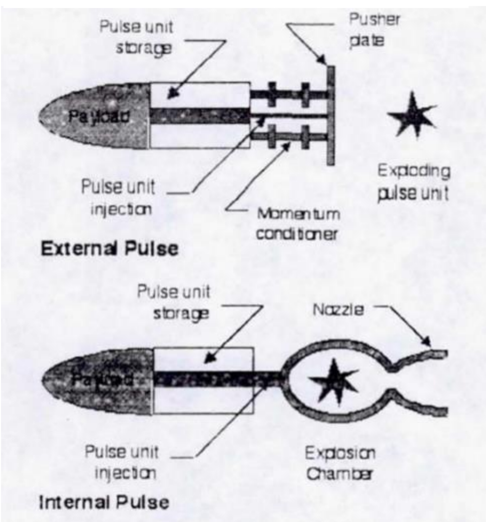


Figure 1: NPP Concepts

There are basic types of nuclear power plants (NPPs) that were researched during Orion's time: the External NPP and the Internal NPP. The External NPP was, historically, the first to be conceived. The pulse takes place at some distance from a pusher plate. which intercepts and absorbs the shock of the detonation. (Phillips, 2006) The momentum conditioning unit smoothes out the momentum transfer between pulses to provide a nearly constant acceleration and returns the plate to its proper location for the next pulse. The advantage of the External NPP is that no attempt is made to confine the explosion, so it circumvents the material temperature limits associated with confined concepts, such as solid and gas core nuclear thermal rockets. (NASA, 2000)

With the Internal NPP, the explosion takes place inside a pressure vessel (Explosion Chamber) from which heated propellant is expanded through a conventional nozzle. When this method was conceived, it was projected that the use of an enclosed "reaction chamber" and nozzle would eliminate the energy losses associated with isotropic external expansion, and lead to greater performance.

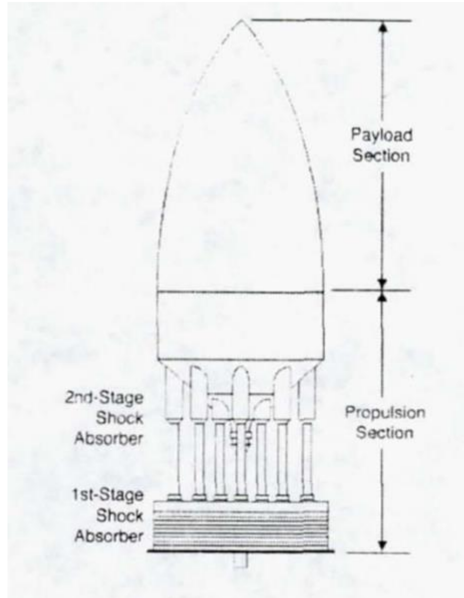


Figure 2: Early Orion Concept

Figure 2 - NASA, 2000

There are two main limitations to the performance of an internal system: One, radiation heating - most of the radiation emitted in the form of neutrons and y-rays (Gamma rays) is deposited into the chamber wall. Because of this, the vehicle requires cooling. This is the dominant performance limiting factor in the Internal NPP. The other limiting factor is the higher mass of the internal vehicles. Studies showed that the minimum mass of an external system will always be less than that of an internal system for the same payload and mission. Project Orion's plans called for the use of an External NPP. (NASA, 2000)

Project Orion was born during one of the most aggressive "weaponization of the atom" periods in the U.S. (and the world). In contrast, famed theoretical physicist Freeman Dyson saw that the potential energy of the atomic bomb could be harnessed for peaceful purposes, and he wasn't alone. Stanislaw Ulam and Cornelius Everett actually conducted the first serious investigation of atomic propulsion for space flight in 1944, while they were working on the Manhattan Project. While there were always going to be military applications for atomic energy, scientists like Dyson saw that the energy released from atomic fission wasn't any different from the energy released from chemical processes, at least in a practical sense. The amount of energy might be orders of magnitude larger than that produced in chemical combustion, but energy was energy.

In the 1950s, US President Eisenhower, the allied commander during World War II, introduced his "Atoms for Peace," plan which attempted to redirect atomic power towards peaceful applications that would benefit humanity, rather than threaten to destroy it. (Loeffler, 2021)

What really got the ball rolling for project Orion was Sputnik. While our scientists were searching for peaceful applications of this (nuclear) technology, the Soviet Union had successfully launched Sputnik, the first artificial satellite humanity ever put into orbit, to the shock and humiliation of the United States. The space race was unexpectedly on.

In response, the US Government consolidated the American space effort under the umbrella of the National Aeronautics and Space Administration (NASA), which worked hand in hand with the USAF and the Advanced Research Projects Agency (ARPA), later renamed the Defense Advanced Research Projects Agency (DARPA). The very first space project that ARPA researched was a plan by General Atomics to use nuclear power to put American astronauts into orbit. (Loeffler, 2021)

The idea behind Project Orion was conceptually simple: Use the enormous power from atomic bomb blasts to generate direct thrust that could lift a spaceship into space. This was the original challenge that General Atomics hoped to overcome. The project decided to develop a concept proposed in a 1955 paper by Stanislaw Ulam and Cornelius Everett. They suggested that bombs could be ejected backward from the vehicle, followed by solid-propellant disks. The explosions would vaporize the disks, and the resulting plasma would impinge upon a pusher plate, and act as thrust. It was calculated that the speed generated from all those atomic blasts would have generated enough propulsive energy to make the spaceship achieve orbit two to three times faster than what you could get out of conventional rockets. Once the ship reached the vacuum of space, that speed would be preserved as momentum, with any further propulsion adding to what it had already achieved once it had broken free of Earth's gravity. (Loeffler, 2021)

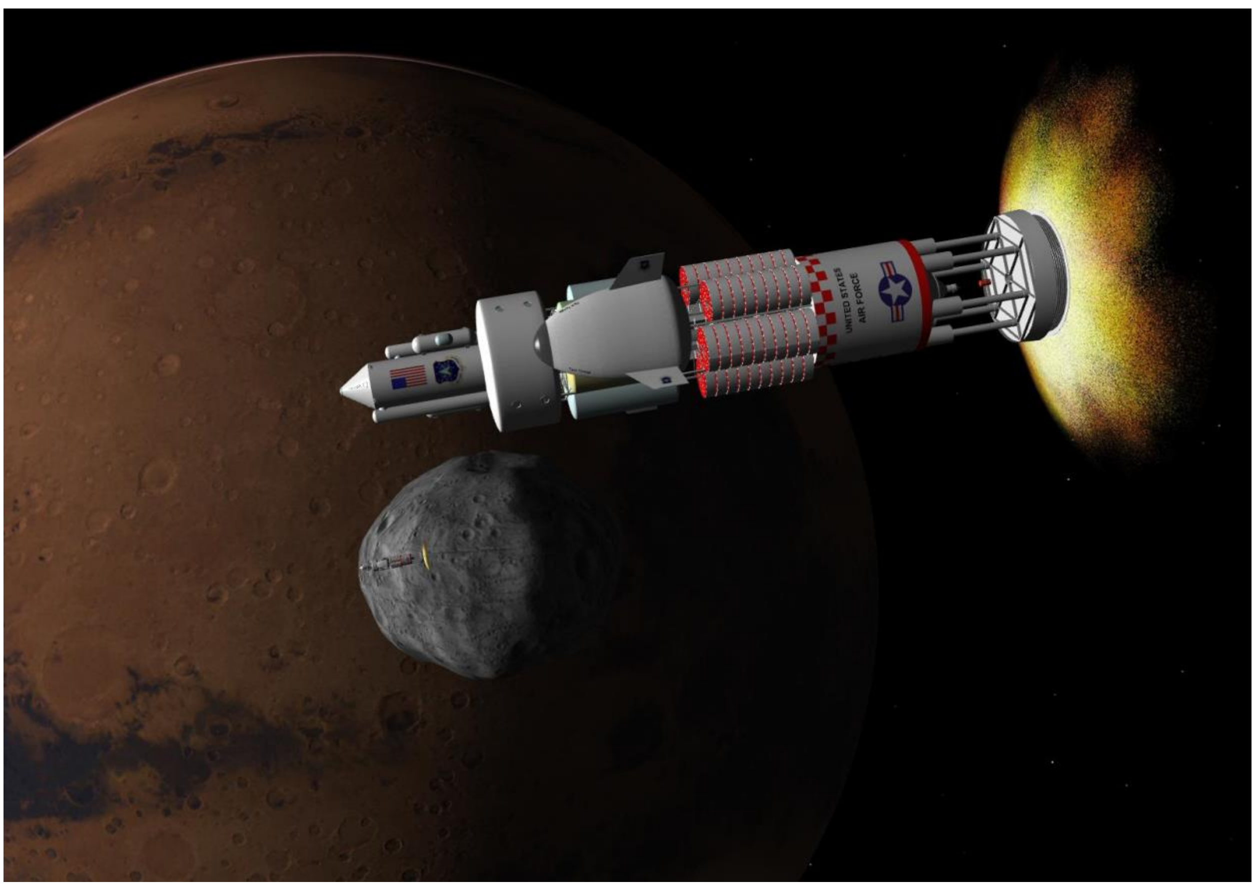
Unfortunately, there were obvious problems with Project Orion that proved insurmountable. Back in the inspired Cold War days of the 1960s, when no expense was spared to ensure America didn't fall behind the Soviets again (after Sputnik), there were certain things bottomless budgets just couldn't fix - namely, radiation.

Dealing with the radioactive fallout from one atomic bomb was a challenge that demanded big risks and big resources. Dealing with "hundreds of them detonating once a second in a towering column of atomic fire dozens of miles high" (Loeffler, 2021) would make the former look like child's play. There were other concerns: what if the ship blew up on launch? What if a bomb ruptured? What about the radiation exposure to the crew (some estimates indicated the crew could be exposed to 10 times the minimum dose needed to trigger acute radiation syndrome PER DETONATION)?

Project Orion's final nail in its coffin. The hammer struck that nail in August 1963 with signing of the nuclear test-ban treaty. Although the tests required for development of an Orion vehicle were now illegal under international law, it was still possible that an exemption could be granted for programs that were demonstrably peaceful. However, there is no doubt that the treaty greatly diminished (vacated) Orion's political support and that avenue was unrealistic. Wanting to put its resources into the Apollo Program, NASA made its decision in December 1964 and announced publicly that it would not continue to fund Orion. The Air Force then followed suite and announced the discontinuation of all Orion funding, thus terminating Project Orion.

Figure 3

Phobos orbital insertion, Cornell University



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