Nuclear Energy and Space Exploration

Nuclear energy and technology have come a long way since their discovery in the 1930s by physicist Enrico Fermi when he first showed that neutrons could split atoms. Eventually, Fermi and other scientists were able to contain and control nuclear reactions which brought the scientific theory of nuclear reaction into a technological reality. Nuclear power reactors use a chain reaction to control nuclear fission. The rate of reaction is controlled by neutron absorbers; therefore, the power is dependent on demand. Harnessing this nuclear energy, scientists can use nuclear power in space exploration and spacecrafts. The main way the first space crafts were powered was by Radioisotope Thermoelectric Generators that create electricity. Modern spacecrafts also use this reliable source of power, and the future of space exploration will most likely use these nuclear power sources as well.

Radioisotopes, an unstable form of a chemical element that releases radiation as it breaks down and becomes more stable, have been an important source of energy in space since 1961. Radioisotope power systems, often known as "space batteries" or "plutonium batteries," are nuclear batteries that reliably transform heat generated by plutonium-238 disintegration into electric power. There are two types of radioisotope power systems, Radioisotope Heater Units (RHU) are small devices that supply heat to keep a spacecraft's electronic instruments and mechanical components operating in the harsh and frigid environment in space. Radioisotope Thermoelectric Generators (RTGs) are a type of alternative energy source that does not rely on a chain reaction. Most used plutonium-238 as a power source. The power is generated by converting the heat generated by radioactive decay of the radioisotope into electricity using thermocouples, and it is dependent on the initial amount of radioisotope used as fuel.

RTGs are designed to endure a long time. RTGs of the first generation contained modest amounts of radioactive materials and were designed to burn up at high altitudes if they re-entered the atmosphere. Later designs contain plutonium in case of reentry; however, this has changed. RTGs have a proven track record of reliability and have never caused a spacecraft mishap. Because of its durable and small construction, it's an excellent energy source for distant operations. They are incredibly reliable, enduring the severe surroundings and frigid temperatures of deep space flight for decades. RTGs have no moving parts and require no maintenance.

The U.S Navy's Transit 4A navigation satellite was the first spacecraft to be powered by nuclear energy or a Radioisotope Thermoelectric Generators (RTGs) in 1961. Its goal was to conduct navigation trials and demonstrations, enhance understanding of the effects of ionospheric refraction on radio signals, and learn more about the shape and gravitational field of the planet. In 1977, Voyager 1 and Voyager 2 were both powered by RTGs, and they both yielded some of the most important discoveries in U.S. space exploration history. These RTGs have allowed us to travel further away from the sun and power missions to explore other planets. RTG power sources were used by the Viking and Rover landers on Mars in 1975, as well as the Mars Science Laboratory Rover Curiosity, which was launched in 2011. Three RTGs, each producing 35 watts, were employed as heat sources aboard the Pathfinder Mars robot lander, which was launched in 1996.

The rover Curiosity landed on Mars in 2012 and is the first NASA mission to use the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG). They're made to work on both planetary worlds with atmospheres, like Mars, and in the vacuum of space. Furthermore, because it provides electrical power in smaller increments, slightly above 100 watts, the

MMRTG is a more adaptable modular design capable of addressing the needs of a wider range of missions. The MMRTG's design aims include guaranteeing a high level of safety, optimizing power levels over a 14-year minimum lifespan, and decreasing weight. Curiosity is gathering soil samples and rock cores from Mars and analyzing them for organic chemicals and environmental conditions that could have supported microbial life in the past or present. Curiosity is the United States' fourth rover to Mars, and it is also the largest and most capable rover ever deployed to study a planet other than Earth. Over 45 RTGs have been used to power over 25 US spacecraft, including the Apollo, Pioneer, Viking, Voyager, Galileo, Ulysses, Cassini, and New Horizons missions, as well as several civil and military satellites.

NASA, the Department of Defense, and the Department of Energy have investigated several types of nuclear power in space, such as space nuclear reactors, and have been interested in Nuclear Thermal Propulsion (NTP) for decades. In NTP, A nuclear fission reactor heats a liquid propellant, such as hydrogen. The heat turns the liquid into a gas, which expands via a nozzle to create thrust and move the spacecraft forward. NTP engines would decrease trip times to Mars by up to 25% compared to typical chemical rockets, and space planes would need to lift less fuel into space. An engine fueled by nuclear thermal propulsion could save flight time, making it easier to maintain crews alive while in flight and reducing cosmic radiation exposure. These reactor designs enable us to fly further into space, away from the sun, where we are unable to harness solar energy's power. Small, light fission reactors could offer up to 10 kilowatts of electrical power for at least 10 years on the moon and Mars, and small, light fission reactors could provide up to 10 kilowatts of electrical power for at least 10 years. This amount of electricity is sufficient to power multiple dwellings. By the late 2020s, NASA, in partnership with the DOE, plans to construct and test one of these systems on the moon, utilizing lowenriched uranium fuels which is now a top priority of the agency's Space Technology Mission Directorate. Additionally, in July 2021, Congress appropriated $110 million for NASA to advance the development of a new nuclear rocket capable of transporting goods and crew on interplanetary missions.

Nuclear technology and space exploration has come a long way since the discovery of nuclear reactions and the beginning of space exploration. With the creation of Radioisotope Thermoelectric Generators (RTGs), the path for space exploration changed as we can travel further in our solar system while keeping the spaceship powered. The far future with nuclear technology and space exploration is unknown but looks bright. It will most likely be the use of Nuclear Thermal Propulsion (NTP) paired with the reliable Radioisotope Thermoelectric Generators (RTGs) for heat and energy.

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