

## Better Propulsion System for Next Generation Space Travel

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### OPINION

Any method used to accelerate spacecraft and artificial satellites is referred to as spacecraft propulsion. In-space propulsion is the use of propulsion systems in the vacuum of space and should not be confused with space launch or atmospheric entry. Several methods of pragmatic spacecraft propulsion have been developed, each with its own set of benefits and drawbacks. For orbital station-keeping, most satellites use simple, reliable chemical thrusters (often monopropellant rockets) or resist jet rockets, and some use momentum wheels for attitude control. The term “hypothetical in-space propulsion technologies” refers to propulsion technologies that could be used to meet future space science and exploration requirements.

These propulsion technologies are intended to provide effective exploration of our Solar System, allowing mission planners to plan missions that “fly anytime, anywhere, and complete a host of science objectives at the destinations” and with greater reliability. In-space propulsion takes over where the launch vehicle’s upper stage leaves off, performing primary propulsion, reaction control, station keeping, precision pointing, and orbital maneuvering. The primary propellant force for orbit transfer, planetary trajectories, and extra planetary landing and ascent is provided by the main engines used in space. A propulsion system’s purpose in space is to change the velocity, or  $v$ , of a spacecraft. Because this is more difficult for larger spacecraft, designers typically discuss spacecraft performance in terms of the amount of momentum change per unit of propellant consumed, also known as specific impulse. Interstellar travel is the currently hypothetical concept of interstellar probes or crewed spacecraft moving between stars or planetary systems in a galaxy. Interstellar travel would be far more difficult than interplanetary travel. Whereas the distances between planets in the Solar System are typically less than 30 astronomical units (AU), the distances between stars are typically hundreds of times greater. The speeds required for interstellar travel in a human lifetime far outstrip what current space travel methods can provide.

Even with a hypothetically perfect efficient propulsion system, the kinetic energy associated with those speeds is enormous by today’s energy development standards. Furthermore, collisions between the spacecraft and cosmic dust and gas can be extremely hazardous to both passengers. Researchers at the University of Stuttgart’s Institute of Space Systems (IRS) have been investigating a possible propulsion system for space transport based on an approach known as inertial electrostatic confinement (IEC) of plasma sources. An electric field is used to heat plasma to fusion temperatures. Both

electric space propulsion systems and air breathing propulsion systems can reduce the amount of propellant required to launch rockets into space.

Electric propulsion systems, which are currently used in Russian satellites, expel propellant at a high rate, requiring less propellant than a chemical rocket. Air breathing systems use atmospheric oxygen to burn fuel onboard, resulting in a lighter, more efficient and cost-effective system. This type of system could be used in the Gravity Field and Steady State Ocean Circulation Explorer (GOCE) mission, which aims to map the Earth’s gravity field. Significant technological and economic challenges must be overcome for both crewed and uncrewed interstellar travel.

Even the most optimistic views on interstellar travel believe it will be decades away. Regardless of the challenges, if and when interstellar travel is realized, a wide range of scientific benefits are anticipated. Most interstellar travel concepts would necessitate a developed space logistics system capable of transporting millions of tonnes to a construction/operating location, and most would necessitate gigawatt-scale power for construction or power (such as Star Wisp or Light Sail type concepts). If space-based solar power became a significant component of the Earth’s energy mix, such a system could grow organically. According to the law of conservation of momentum, in order for a propulsion method to change the momentum of a spacecraft, it must also change the momentum of something else. A few designs use magnetic fields or light pressure to change the momentum of the spacecraft, but in free space, the rocket must bring along some mass to accelerate away in order to push itself forward. With less reaction mass, a rocket with a high exhaust velocity can achieve the same impulse as a rocket with a lower exhaust velocity.

The energy required for that impulse, however, is proportional to the exhaust velocity, so more mass-efficient engines require significantly more energy and are typically less energy efficient. In-space propulsion represents technologies that have the potential to significantly improve a number of mission-critical aspects. Space exploration is about getting somewhere safely (mission enablement), quickly (reduced transit times), with a lot of mass (increased payload mass), and cheaply (lower cost). Technical solutions that improve thrust levels, Isp, power, specific mass (or specific power), volume, system mass, system complexity, operational complexity, commonality with other spacecraft systems, manufacturability, durability, and cost will result from technology development. These types of advancements will result in shorter transit times, increased payload mass, safer spacecraft, and reduced costs.

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