Solar Electric Propulsion: Near Future Applications

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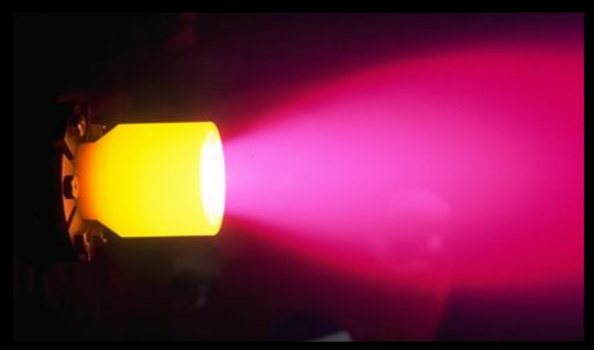
Introduction

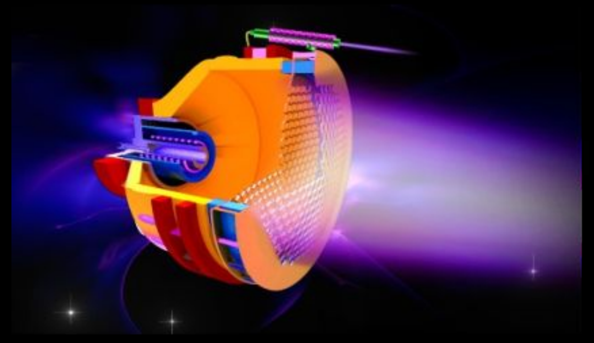
Maneuvering spacecraft in orbit have long been dependent on chemical propulsion systems, but as missions become more complex the weight of storing propellant and the finite amount of propellant has been a limiting factor for space exploration. A Solar Electric Propulsion system (SEP) is an electric system that derives its power from solar cells. By implementing solar electric propulsion the mass of the propulsion system is reduced with the absence of storing a chemical propellant. SEP systems allow for longer mission life spans, larger and heavier cargo, and cost-efficient launches.

A Brief History

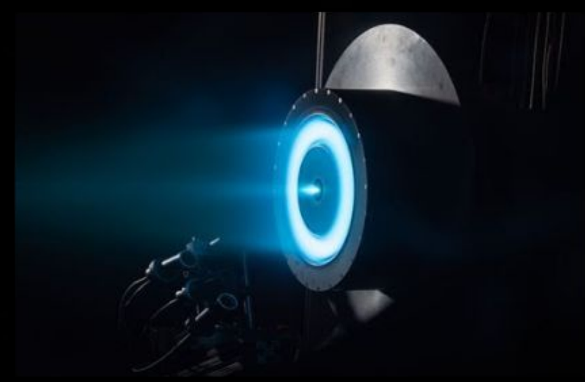
- SEP systems operate by combining solar arrays to power an electric thruster
- The most successful type of electric thruster based on Hall Effect Electrostatics: ions are created and accelerated in a electric field
- Before the application of solar arrays to electric propulsion systems, power was supplied from onboard battery or generated from thermal radiation.
- Xenon: gas used as primary propellant



Electrothermal
=>Heat the gas, expel through nozzle



Electromagnetic
=>Magnetic field accelerates plasma



Electrostatic
=>Electric field accelerates ions

What's going on right now?

- Since 2000, there has been over 35% growth in satellites with Electric Propulsion [3]
- SEP is wisley accepted among satellites for orbital purposes.[3]
- The use of SEP systems in satellites is expected to increase as solar panels get more efficient.[3]
  - Flexible solar arrays [Roll Out Solar Arrays (ROSA) and MegaFlex Solar Arrays]
  - Can provide around 50kW of electrical power
- Improvements in Hall Thruster tech
- NASA's Evolutionary Xenon Thruster-Commercial (NEXT-C) [5]
  - Very high fuel efficiency (Specific Impulse of 4,190 seconds)
  - Produces ~7kW (6.9kW) thruster power
  - Can throttle between ~25 to 235 mN of thrust

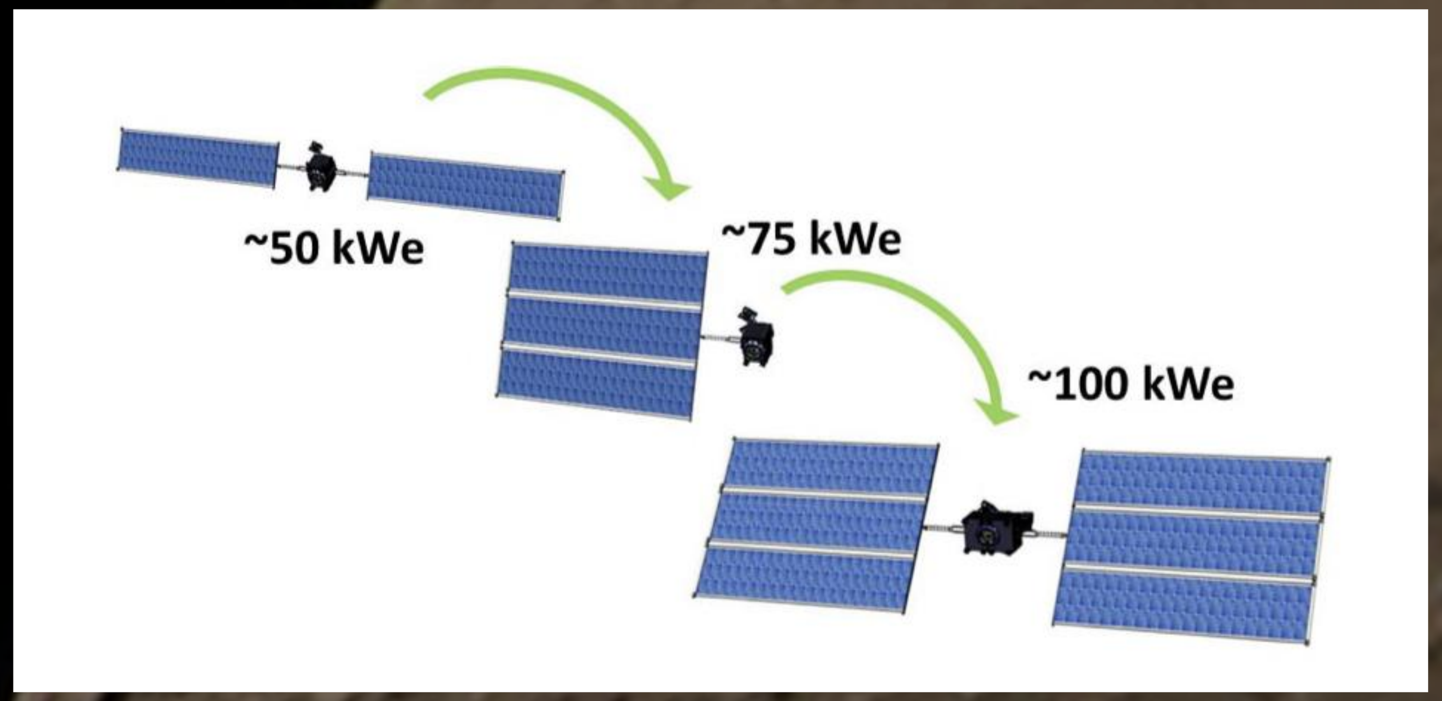


Fig. 2 Modular Assembly of Solar Arrays

Comparison of propulsion technologies

	Chemical		Electric
	Small monopropellant thruster	Fregat Main Engine (S5.92M)	SMART-1 Hall Effect Thruster (PPS-1350)
Propellant	Hydrazine	Nitrogen tetroxide / Unsymmetrical dimethyl hydrazine	Xenon
Specific Impulse (s)	200	320	1640
Thrust (N)	1	1.96×10^4	6.80×10^{-2}
Thrust time (s)	1.66×10^5	877	1.80×10^7
Thrust time (h)	46	0.24	5000
Propellant consumed (kg)	52	5350	80
Total Impulse (Ns)	1.1×10^5	1.72×10^7	1.2×10^6

Fig.3 Chemical vs. Electrical Propulsion

Gains & Losses

Pros

- Spacecraft is able to carry much larger masses, allowing for more mass dedicated for useful payload [3]
- Spacecraft is able to travel much larger distances, allowing for deeper exploration of the solar system.
- 6-10x more efficient than chemical propulsion
- Total Thrust time is 10000x greater than chemical propulsion
- Lower reliance on caring propellant
- Enables sustainable exploration of the Moon and Mars

Cons

- Thrust is 100,000x less (in Newtons) than chemical propulsion
- Will accelerate at a slower rate
- Can only be used in the vacuum of space

Near Future Applications

- Artemis Mission Gateway
  - A 50kW class SEP called Power and Propulsion Element (PPE) will be used on the Lunar Gateway, the future space station that will orbit the moon. [3]
  - The PPE will allow it to provide power, transportation, altitude control, and communication [6]
- International Space Station (ISS)
- Commercial Satellites

References

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[2] R. Cassady et al. "The Importance of Electric Propulsion to Future Exploration of the Solar System" 36th Intl Electric Propulsion Conference, researchgate.net, [Article] Available: https://www.researchgate.net/publication/336042067_The_Importance_of_Electric_Propulsion_to_Future_Exploration_of_the_Solar_System [Accessed: September 8, 2020]

[3]

[4] D Irimes. *Solar Electric Propulsion. Nasa.gov/space/sep*. Glenn Research Center. 4 September 2020

Acknowledgements

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