Countries race to develop Solar Electric Propulsion to power small Satellites for Spy missions to Deep Space Exploration

A new power revolution is going on in orbit – that of electrical propulsion for satellites. An ion thruster is a form of electric propulsion used for spacecraft propulsion. It creates thrust by accelerating ions with electricity. As the ionised particles escape from the aircraft, they generate a force moving in the other direction. Power supplies for ion thrusters are usually electric solar panels, but at sufficiently large distances from the sun, nuclear power is used.

Michael Patterson, senior technologist for NASA’s In-Space Propulsion Technologies Program compared ion and chemical propulsion with “Tortoise and the Hare”. “The hare is a chemical propulsion system and a mission where you might fire the main engine for 30 minutes or an hour and then for most of the mission you coast.” “With electric propulsion, it’s like the tortoise, in that you go very slow in the initial spacecraft velocity but you continuously thrust over a very long duration – many thousands of hours – and then the spacecraft ends up picking up a very large delta to velocity.”

Electric propulsion for satellites, is of course, not new and ion engines, plasma thrusters have been used for long-duration space exploration probes, as well as station keeping and
altitude control. (Indeed, ESA’s BepiColombo Mercury probe, which launched in October, uses Solar Electric Propulsion System (SEPS) ion engines from UK’s QinetiQ.) However, in recent years, it has begun to transform the commercial satellite market – thanks to its ultra-high efficiency in raising geo-telecommunication satellites into geostationary orbits of 36,000km.

“To do the same amount of velocity increase on the satellite, we use a fraction of the propellant because it’s five to ten times more efficient.” But this efficiency, translates into big savings, says Ben Olivier, CEO Thales Belfast: “What difference does it make commercially? It probably takes 20% out of the cost of the programme because you can use a smaller launch vehicle to put you into your injection orbit, and then do more of the work with your own propulsion sub-system.”

In early November 2018, the first UK-built electric satellite propulsion module was completed by Thales Alenia Space from its new facility in Belfast. With this, the UK joins Airbus in Germany, and Boeing in the US as a new manufacturer of all-electric propulsion technology for commercial satellites. This engine module, the Spacebus NEO Xenon Propulsion (XPS) is set to be delivered to Thales Alenia Space’s satellite factory in Cannes, France, where it will be integrated into the Spacebus NEO bus for Eutelsat’s KONNECT communications satellite ready for launch at the end of 2019.

SSL demonstrated its solar electric propulsion system on two communications satellites that were launched into geostationary orbit in 2018. The Maxar Technologies subsidiary said SPT-140 is an updated version of the SPT-100 electric thruster that has supported 34 missions and logged more than
100K firing hours. SPT-140 is designed to use the Power Processing Unit 140 and multiple gimbaled Hall effect thrusters to generate electric power of up to 8 kilowatts. NASA awarded SSL in August a contract to further develop a 6kW dual-mode electric propulsion engine as part of the space agency’s Tipping Point program. The company will also provide a solar electric chassis to help NASA send a probe to the metal-based asteroid Psyche and noted it will use SPT-140 to power four commercial satellites.

Israel Aerospace Industries (IAI) is working to upgrade the optical and radar payloads of the spy satellites serving the nation’s intelligence community. The company is developing a new generation of satellites for even more complex missions, using nanosatellite production and electric propulsion concepts.

**Electric propulsion to send smallsats from LEO to GEO orbit, moon**

Nanosatellite and microsatellite refer to miniaturized satellites in terms of size and weight, in the range of 1-10 Kg and 10-100 kg, respectively. These are the fastest growing segments in the satellite industry. ‘CubeSat’ is one of the most popular types of miniaturized satellites. CubeSats are miniaturized satellites built in increments of 10×10×10 cm cubes: one 10-cm³ cube is called 1U (one unit), two cubes together are called 2U, etc. Nanosatellites and microsatellites find application in scientific research, communication, navigation and mapping, power, reconnaissance, and others including Earth observation, biological experiments, and remote sensing.
Blue Canyon Technologies, a small satellite supplier based in Boulder, Colorado, is bidding on two missions to transport spacecraft from low Earth to geostationary orbit with electric propulsion in addition to a mission to send a satellite from low Earth orbit to the moon. The missions are scheduled to fly within the next couple of years, said George Stafford, Blue Canyon chief executive and president. With electric propulsion, it will take a satellite about four months to move from low Earth to geostationary orbit and six months to reach the moon, said Daniel Hegel, Blue Canyon advanced development director.

Roccor, a small company based in Longmont, Colorado, that specializes in deployable space structures, has developed a new product it intends to market: a full solar wing that can be stowed compactly for launch and deployed in orbit, Doug Campbell, Roccor chief executive said. After a rocket drops the spacecraft off in low Earth orbit, Roccor solar arrays will generate “several kilowatts of power” to move it to geostationary orbit, said Campbell.

“It is expensive to launch satellites to geostationary orbit,” Campbell told SpaceNews during an interview at the Small Satellite Conference here. “We see this as a huge unmet need.”

Because the satellite industry is going through a period of rapid change, some geostationary satellite operators have been reluctant to invest in new spacecraft. The cost calculation would change if spacecraft could travel from low Earth to geostationary orbit, Stafford told SpaceNews during an interview at the Small Satellite Conference.
In the past, satellites booked rides to their desired orbit because most electric propulsion systems were not powerful enough to help them move from low Earth to geostationary and the systems that would have made that possible were prohibitively expensive, Hegel said.

**Nano satellites, equipped with ion thrusters**

Now, aerospace suppliers and governments across the globe see the tools as the future of deep space exploration, like Paulo Lozano, director of the Space Propulsion Lab at the Massachusetts Institute of Technology, said sending the tiny satellites to asteroids could help improve space research (or even save the planet from an asteroid attack, he said). However they have limitations of lacking self propulsion. “One of the big limitations in CubeSats is that they are launched as secondary payload. Once they are in space, they cannot move,” Lozano said.

Lozano’s team designed a set of mini thrusters that create an electric field that tugs on the charged particles in salt water until they peel off. The result is a spray made of charged molecules called ions. This ion spray doesn’t create a lot force. It’s always less than a millinewton, which is akin to the force produced when a mosquito lands on your arm. But the spray moves very fast, and even a small action creates a reaction in the frictionless vacuum of outer space. Use this to move ions in one direction, and a CubeSat will move uber fast in the other.
The thrusters, which look like computer microchips, are the size of quarters. The chips contain a grid of 500 needles — each a custom-built nozzle for spewing ions. His team tests them inside a large vacuum chamber at their lab in Boston.

Scientists are now researching mini boosters that shall enable CubeSats to stay in space. Lozano team has developed small electric thrusters using static electricity and tiny drops of salt water. “Dr. Lozano’s system is probably the frontrunner for the possibility for deep space missions,” Lemmer said. “In order to go interplanetary, you’re going to have to have an electric propulsion system because they are so much more efficient.”

**Electric thrusters promise space revolution**

This XPS propulsion module, manufactured in Belfast, for the Spacebus NEO is not some tiny thruster, but a 1.8tonne module fully fuelled, that stands 1.8m high and 3.6m wide and features Xenon propellant tanks with the gas compressed to 125bar. “it’s not a trivial piece of equipment” says Olivier, “You’re talking about fluidic titanium piping, pressure regulation and pressure management and systems, valves, etc. And two axis mechanisms to vector the thrust and all the flexible piping to transmit the xenon efficiently. All of that has got to work in the extreme environment of space, and survive launch.”

With the Eutelsat KONNECT being the first all-electric Spacebus NEO satellite from Thales Alenia Space, it also has three more follow-on orders in the pipeline, with the next one a XPS module for the French military Syracuse satellite, then
commercial operator SES and another satellite for Eutelsat. “We expect more to be sold” says Olivier.

**NASA Works to Improve Solar Electric Propulsion for Deep Space Exploration**

NEXT-C will be the ion thruster used on a 2021 mission, named DART (Double Asteroid Redirection Test), led by the Johns Hopkins University Applied Physics Laboratory for NASA. DART is a kinetic impact mission designed to collide with a moonlet around the Didymos asteroid and slightly alter its orbit. This mission will be a critical step in demonstrating NASA’s impact threat mitigation capabilities for redirection of a potentially hazardous object such as an asteroid.

Serving as the primary propulsion source for DART, NEXT-C will establish a precedent for future use of electric propulsion to enable ambitious future science missions,” said Eileen Drake, CEO and President of Aerojet Rocketdyne. “Electric propulsion reduces overall mission cost without sacrificing reliability or mission success.” Under a cost-sharing agreement with NASA’s Science Mission Directorate through the agency’s Glenn Research Center, Aerojet Rocketdyne is developing the NEXT-C electric propulsion engine and power processing unit. In addition to DART, additional NEXT-C units may be launched on future NASA planetary missions.

NASA is leading the next steps into deep space near the moon, where astronauts will build and begin testing the systems needed for challenging missions to deep space destinations including Mars. Under a program dubbed Deep Space Gateway, agency officials said they still plan to use the lunar orbit as a staging platform to build and test the infrastructure and
the systems needed to send astronauts to Mars. But instead of breaking off a chunk of asteroid and dragging it to the moon, NASA’s new plan calls for building an orbiting spaceport that could have even more uses.

This spacecraft would be a reusable vehicle that uses electric and chemical propulsion and would be specifically designed for crewed missions to destinations such as Mars. The transport would take crew out to their destination, return them back to the gateway, where it can be serviced and sent out again. The transport would take full advantage of the large volumes and mass that can be launched by the SLS rocket, as well as advanced exploration technologies being developed now and demonstrated on the ground and aboard the International Space Station.

The NASA Glenn Research Center has been a leader in ion propulsion technology development since the late 1950s, the NASA Solar Technology Application Readiness (NSTAR) ion propulsion system enabled the Deep Space 1 mission, the first spacecraft propelled primarily by ion propulsion, to travel over 163 million miles and make flybys of the asteroid Braille and the comet Borelly.

NASA has selected Aerojet Rocketdyne, Inc. of Redmond, Washington, to design and develop an advanced electric propulsion system that will significantly advance the nation’s commercial space capabilities, and enable deep space exploration missions, including the robotic portion of NASA’s Asteroid Redirect Mission (ARM) and its Journey to Mars.
“Through this contract, NASA will be developing advanced electric propulsion elements for initial spaceflight applications, which will pave the way for an advanced solar electric propulsion demonstration mission by the end of the decade,” said Steve Jurczyk, associate administrator of NASA’s Space Technology Mission Directorate (STMD) in Washington. “Development of this technology will advance our future in-space transportation capability for a variety of NASA deep space human and robotic exploration missions, as well as private commercial space missions.”

Aerojet Rocketdyne will oversee the development and delivery of an integrated electric propulsion system consisting of a thruster, power processing unit (PPU), low-pressure xenon flow controller, and electrical harness. NASA has developed and tested a prototype thruster and PPU that the company can use as a reference design.

The company will construct, test and deliver an engineering development unit for testing and evaluation in preparation for producing the follow-on flight units. During the option period of the contract, if exercised, the company will develop, verify and deliver four integrated flight units – the electric propulsion units that will fly in space. The work being performed under this contract will be led by a team of NASA Glenn Research Center engineers, with additional technical support by Jet Propulsion Laboratory (JPL) engineers.

The first operational test of an electric propulsion system in space was Glenn’s Space Electric Rocket Test 1, which flew on July 20, 1964. Since then, NASA has increasingly relied on solar electric propulsion for long-duration, deep-space robotic science and exploration missions to multiple
destinations, the most recent being NASA’s Dawn mission. The Dawn mission, managed by JPL, surveyed the giant asteroid Vesta and the protoplanet, Ceres, between 2011 and 2015.

The advanced electric propulsion system is the next step in NASA’s Solar Electric Propulsion (SEP) project, which is developing critical technologies to extend the range and capabilities of ambitious new science and exploration missions. ARM, NASA’s mission to capture an asteroid boulder and place it in orbit around the moon in the mid-2020s, will test the largest and most advanced SEP system ever utilized for space missions.

This first exploration mission will allow NASA to use the lunar vicinity as a proving ground to test technologies farther from Earth, and demonstrate it can get to a stable orbit in the area of space near the moon in order to support sending humans to deep space, including for the Asteroid Redirect Mission. NASA and its partners will use this proving ground to practice deep-space operations with decreasing reliance on the Earth and gaining the experience and systems necessary to make the journey to Mars a reality.

One of the Technology Area (TA) of NASA’s Mars roadmaps is In-Space Propulsion Technologies that addresses the development of higher-power electric propulsion, nuclear thermal propulsion, and cryogenic chemical propulsion. Improvements derived from technology candidates within this TA will decrease transit times, increase payload mass, provide safer spacecraft, and decrease costs.
Successful testing gives NASA’s Advanced Electric Propulsion System a boost

Working in coordination with NASA engineers from Glenn Research and the Jet Propulsion Laboratory, Aerojet Rocketdyne says it has completed its early systems integration test of the Advanced Electric Propulsion System (AEPS) 13-kW Hall thruster that is it building for NASA, clearing the way for further development. According to Rocketdyne, the recent tests were of the AEPS Hall thruster’s power elements, which include the discharge supply unit (DSU) and the power processing unit (PPU).

NASA Glenn had awarded a contract to Aerojet Rocketdyne to fabricate two NEXT flight systems (thrusters and power processors) for use on a future NASA science mission. In addition to flying the NEXT system on NASA science missions, NASA plans to take the NEXT technology to higher power and thrust-to-power so that it can be used for a broad range of commercial, NASA, and defense applications.

NASA’s Evolutionary Xenon Thruster-Commercial (NEXT-C) was developed by NASA and is being commercialized by Aerojet Rocketdyne. NEXT-C has 7kW of maximum power and greater than 4100s specific impulse (Isp). Its high Isp and flexible operational capabilities make NEXT ideal for scientific space missions.
Request for Information (RFI)

The agency published a Request For Information (RFI) July 17 to capture the U.S. industry’s current capabilities and plans for spacecraft concepts that potentially could be advanced to provide power and advanced solar electric propulsion (SEP) to NASA’s deep space gateway concept. Solar electric propulsion typically refers to the combination of solar cells and ion drive for propelling a spacecraft through outer space. This technology has been studied by NASA and is considered promising. The main concept is a nexus of Solar panels on spacecraft and ion thruster.

“Through the RFI, we hope to better understand industry’s current state-of-the-art and potential future capabilities for deep space power and propulsion,” said Michele Gates, director of the Power Propulsion Element at NASA Headquarters in Washington. “With the upcoming BAA, we will fund industry-led studies to identify the most urgent areas for focus over the next several years, for the benefit of human spaceflight, as well as commercial applications.”

The Power and Propulsion Element (PPE) is the first planned element in the Deep Space Gateway (DSG) concept and would launch as a co-manifested payload with the Orion crewed vehicle on the Space Launch System (SLS) on Exploration Mission-2.

This NextSTEP Appendix C, targeted for release in the August 2017 timeframe, will seek proposals for areas necessitating further study for this specific application of advanced solar electric propulsion (SEP). Studies are anticipated to be brief (3-4 month duration) with succinct products to assist in the
development of the PPE concept and approach.

Studies intend to address key drivers for PPE development such as but not limited to potential approaches to: meeting the intent of human rating requirements; concept and layout development; attitude control; propulsive maneuverability; power generation; power interface standards; power transfer to other Gateway Elements; hosting multiple International Docking System Standard (IDSS) compatible docking systems; batteries/eclipse duration; 15 year lifetime; communications; avionics, assembly integration and test approaches; extensibility; accommodations of potential (international or domestic partner provided) hardware such as robotic fixtures, science and technology utilization and other possible elements; and options for cost share/cost contributions.

NASA may also request assessment of impact of acquiring high power, high throughput SEP strings as part of the commercial bus, rather than through a Government Furnished Equipment route.

**PPE Reference Capability Descriptions**

- The PPE will have a minimum operational lifetime of 15 years in cis-lunar space.
- The PPE will be capable of transferring up to 24kW of electrical power to the external hardware.
- The PPE will be capable of providing orbit transfers for a stack of TBD mass with a center of gravity of TBD.
- The PPE will be capable of providing orbit maintenance for a stack of TBD mass with a center of gravity of TBD.
- The PPE will have 2,000 kg-class tank Xenon capacity
- The PPE will be compatible with the SLS vehicle co-
manifested launch loads on the Exploration Mission -2 (EM-2) flight.

Market growth

Market analysts forecast the global electric propulsion satellite market to grow at a CAGR of 13.95% during the period 2017-2021.

The Top Key players are: Airbus, Boeing, OHB, Orbital ATK, Thales, Ball Aerospace, Lockheed Martin, Mitsubishi Electric, and Safran.

References and resources also include:


https://www.nasa.gov/feature/nasa-power-propulsion-rfi

https://www.fbo.gov/index?tab=documents&tabmode=form&subtab=core&tabid=5b75177986f2eee65643cc9068919a35

