Return to Menu

Electronegative Gas Thruster

Project Manager(s)/Lead(s)

John Dankanich/ZP30
(256) 544–3441

Kurt Polzin/ER24
(256) 544–5513

Mitchell Walker/Georgia Institute of Technology
(404) 894–2760

Sponsoring Program(s)

Space Technology Mission Directorate
Center Innovation Fund

Project Description

The project is an international collaboration and academic partnership to mature an innovative electric propulsion thruster concept to Technology Research Level-3 (TRL-3) through direct thrust measurement. The project includes application assessment of the technology ranging from small spacecraft to high power. The Plasma propulsion with Electronegative GASES (PEGASES) basic proof of concept has been matured to TRL-2 by Ane Aanesland of Laboratoire de Physique des Plasma at Ecole Polytechnique. The concept has advantages through eliminating the neutralizer requirement and should yield longer life and lower cost over conventional gridded ion engines. The objective of this research is to validate the proof of concept through the first direct thrust measurements and mature the concept to TRL-3.

Traditional electric propulsion thrusters such as conventional gridded-ion thrusters (GITs) or Hall thrusters use a heavy gas that is ionized to produce a heavy positive ion. For a typical GIT, a screen grid biased below the anode potential is used to align charged particles, leaving the thruster in order to maximize thrust and limit the erosion of the downstream, negatively biased acceleration grid. A plasma sheath forms between the two grids extracting positive ions from the plasma and accelerates them to generate thrust. Electrons are collected by an anode in the discharge region and expelled at the thruster exit through a neutralizer cathode to maintain quasineutrality of the far-field plume. This thruster is unique through the use of an electronegative gas combined with a magnetic filter. The electronegative thruster then uses a temporally varying approach for ion extraction where a single grid assembly used an alternating voltage bias that changed from positive to negative over the course of a periodic waveform (e.g., sinusoidal, square, etc.) allowing for an alternating acceleration of positively and negatively charged species. The thruster concept and magnetic filter model are illustrated in figures 1 and 2, respectively.

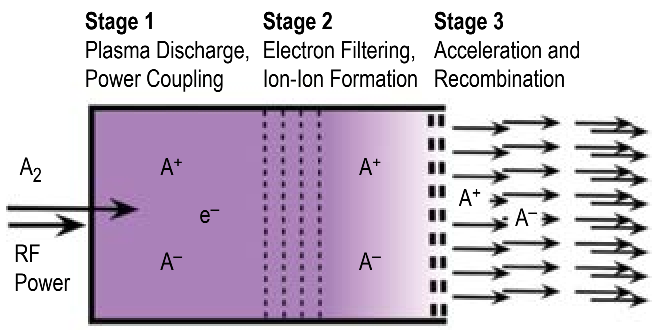


Figure 1: Concept of the electronegative gas thruster.[1]

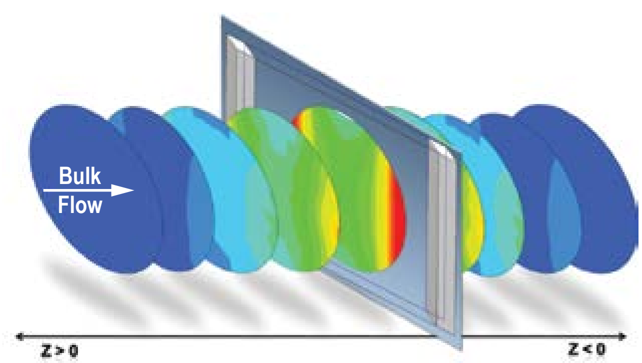
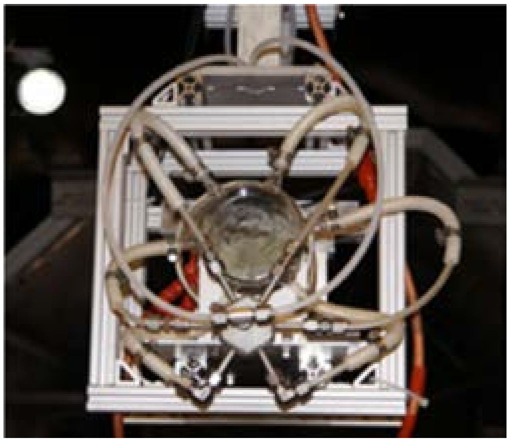
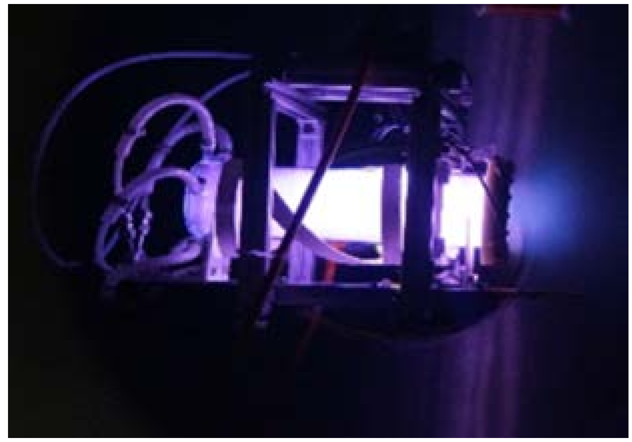


Figure 2: Modeling of the magnetic filter.

The project included system optimization studies, FLUENT simulators of the gas flow, magnetic field optimization, gas distributer optimization, thermal modeling for grids, two iterations of the thruster design, integrated power electronics, performance of preliminary testing, and presenting progress at a technical conference. The thruster alone demonstrated very simple ignition and operation relative to conventional gridded ion thrusters. No thruster (cathode) conditioning was required. Testing conditions included flow rates between 2 and 20 sccm on argon, SF6, and xenon, radio

(a) (b)

Figure 3: Electronegative thruster on the MSFC thrust stand: (a) Configuration and (b) operation.

CIF

frequency (RF) power levels from 100 to 600 W, and RF frequencies of 13.56 MHz and 4 MHz for two different antenna configurations.

Anticipated Benefits

While electric propulsion may be the only viable method for very high ΔV capability for small spacecraft, electric propulsion thrusters are often cost prohibitive. Though the electronegative thruster is not expected to achieve performance of conventional gridded ion and Hall thrusters, the thruster represents a potential for a lower cost electric propulsion thruster. A conventional gridded ion engine requires a main propellant flow, an ionization cathode, and a neutralizer cathode while the electronegative thruster only requires one. The elimination of the cathode reduces propellant cost by reducing propellant purity concerns and simplifies propellant loading and handling and reduces system conditioning requirements. The increased recombination speed of the plasma should reduce spacecraft plume interactions, and charge exchange erosion is reduced, increasing grid life.

Potential Applications

The applications pursued included low-cost electric propulsion missions. However, the performance estimates are significantly lower than state-of-the-art thrusters and the complexity of the thruster places additional burden on the power processing unit. Even with the concepts thruster advantages, the low performance combined with the additional power system complexity is likely to limit infusion opportunities. The thruster can serve as a test-bed for future plasma physics studies. The thruster may have increased mission potential through an advantage of a xenon/iodine propellant combination.

Notable Accomplishments

This project produced two new technology reports that could result in patents.

References

1. Aanesland, A.; et al.: "Directions for the Future: Successive Acceleration of Positive and Negative Ions Applied to Space Propulsion," Laboratoire de Physique Des Plasmas, CNRS Ecole Polytechnique, France, doi: 10.5170ICERN-2013-007.575, 2014.

2. Schloeder, N.R.; Lie, T.M.; Walker, M.L.; et al.: "Design and Preliminary Testing of Electronegative Ion Thruster," AIAA No. 2014-3425, 50th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, Cleveland, OH, July 28–30, 2014.