National Aeronautics and Space Administration

A Deep-Throttling, High Specific Impulse Hall Thruster Enabling the Next Generation of Space Exploration

Principal Investigator: Richard Hofer (353); Co-Investigators: Jacob Simmonds, Dan Goebel, James Polk, Ioannis Mikellides (353)

Program: FY22 R&TD Topics
Strategic Focus Area: Electric propulsion

Objectives

A new Hall thruster capable of high specific impulse operation over large power throttling ratios is being developed for next generation deep-space mission concepts. The H10 is a high specific impulse, magnetically shielded, conducting wall, 10 kW Hall thruster with performance objectives that will radically increase capabilities relative to the state-of-the-art by:

1) operating at up to 3,000 s specific impulse over a 2:1 power ratio,
2) achieving efficiencies of 50-70% over a 10:1 power ratio, and
3) realizing a total power throttling ratio of 50:1.

The specific impulse itself represents a 50% increase relative to flight Hall thrusters. Maintaining the specific impulse over a wide range of power is the key challenge and will require operation at power densities two times higher than the state-of-the-art .

Background

Electric propulsion enabled NASA's Dawn mission with the use of the NSTAR Ion thruster. NSTAR operated at high specific impulse (3100 s), but was expensive to implement. Electric propulsion is also enabling NASA's Psyche mission, which will use SPT-140 Hall thrusters. The SPT-140 operates at lower specific impulse (1800 s) than NSTAR, but the system is significantly less expensive than equivalent Ion thruster systems. For the most-demanding future mission concepts across the solar system such as Comet Sample Return, Ceres sample return, and tours of the outer planets, what is needed is a system that can realize the cost efficiencies of Hall thrusters, but provide the high specific impulse of an Ion thruster. Currently, no such system exists.

Approach and Results

Pathfinding experiments on JPL's H9 thruster (Figure 1) have been performed that were aimed at demonstrating the high-power density required and the identification of design hurdles peculiar to these conditions. The testing has been critical to reducing risk in the subsequent build given the unique combination of high-voltage and high-power density that have never been demonstrated in a Hall thruster before.

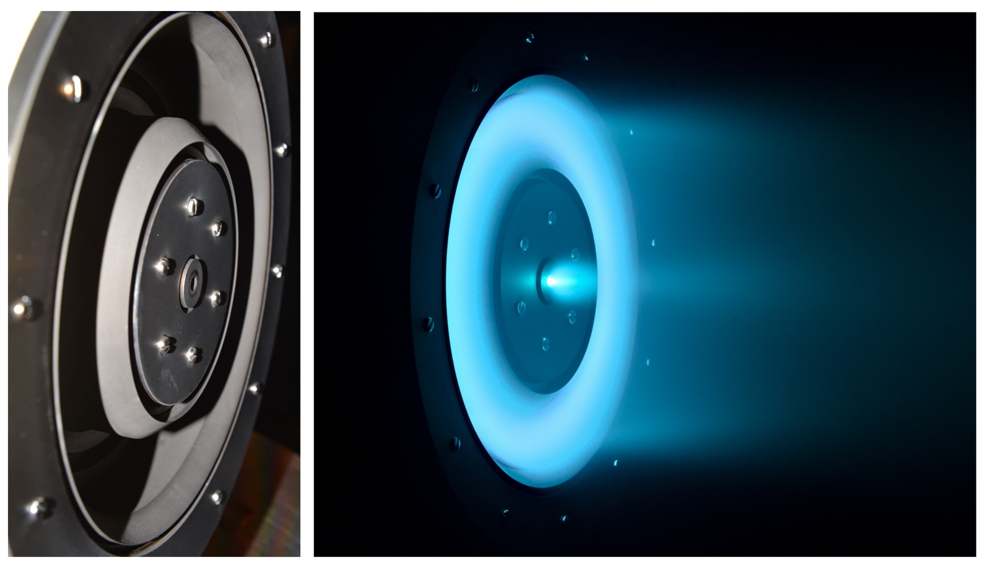

Figure 1. JPL's H9 thruster with graphite channel operating at 800 V, 9 kW. The thruster was operated up to 25 kW during high-power density testing.

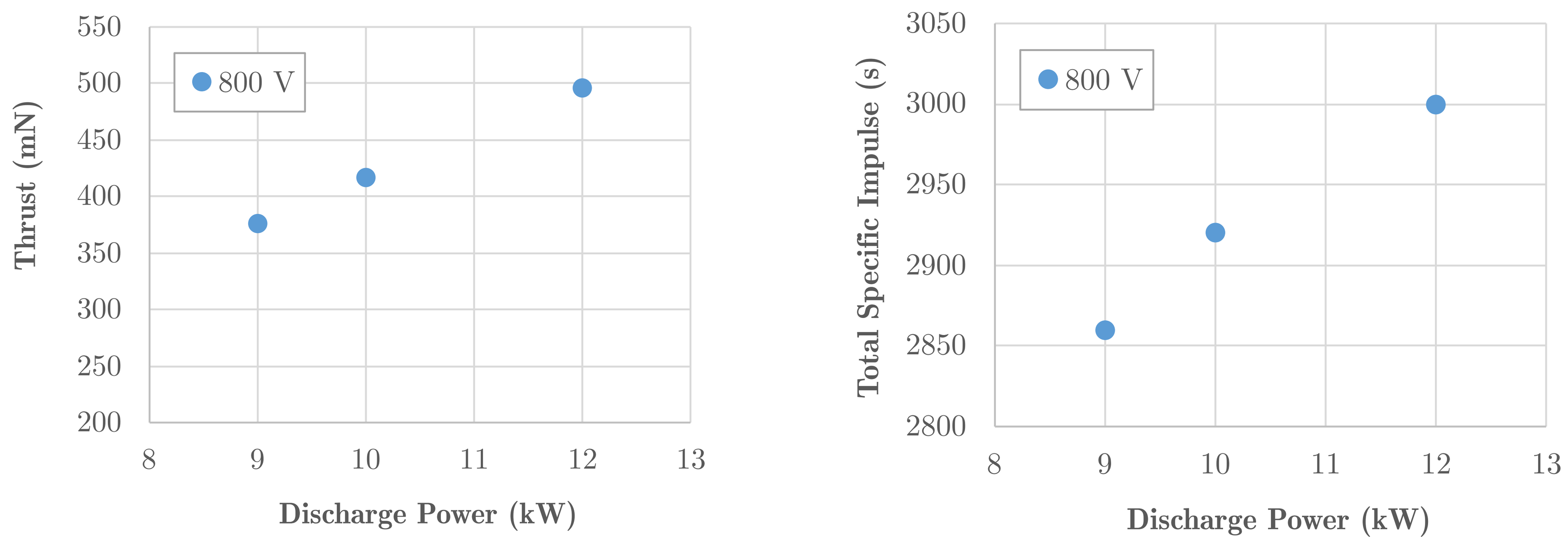

Figure 2. Thrust and specific impulse of the H9 versus discharge power at 800 V [A].

Figure 2 shows the thrust and specific impulse of H9 versus discharge power at 800 V. A specific impulse of 3000 s was reached at 12 kW. The H9 has a nominal power of 9 kW and we successfully the thruster up to 25 kW. This was 2.7X higher power density than the state-of-the-art, well past the 2X planned for this program. The testing did not reveal any significant plasma instabilities or performance deficits, significantly reducing risk in the new thruster design. Additionally, we completed assembly and testing of a heaterless, LaB_6 hollow cathode. This is the first heaterless, LaB_6 cathode ever demonstrated in the 5-35 A range of current.

Following the pathfinding experiments, the new thruster was "virtually prototyped" using JPL's proven plasma-magnetic-thermal designs tools. These tools have been previously applied to thrusters in this power class, such as the H6, H9, and HERMeS Hall thrusters, to achieve cutting-edge performance. The mechanical design and fabrication drawings are nearing completion and fabrication will begin in early FY23. Figure 3 shows a solid model of the H10 thruster.

Significance/Benefits to JPL and NASA

A comparison of various state-of-the-art Hall and Ion thrusters is tabulated in Figure 4. Flight Hall thrusters, such as Maxar's 4.5 kW SPT-140 that will be flown on Psyche and Aerojet's 3 kW XR-5, operate at no more than 2,000-s specific impulse, which limits their use on high delta-V (>10 km/s) missions such as comet surface sample return, Ceres sample return, Mars orbiters, or tours of the outer planets. Gridded ion thrusters, such as NEXT-C that flew as a technology demonstration on DART, typically operate at the >3,000-s specific impulse necessary to efficiently perform these missions, but the high-cost of these NASA-developed systems significantly limit their use. By combining the specific impulse of Ion thrusters with the cost efficiencies of Hall thrusters, this task aims to provide a propulsive capability to science missions not available by any other EP technology.

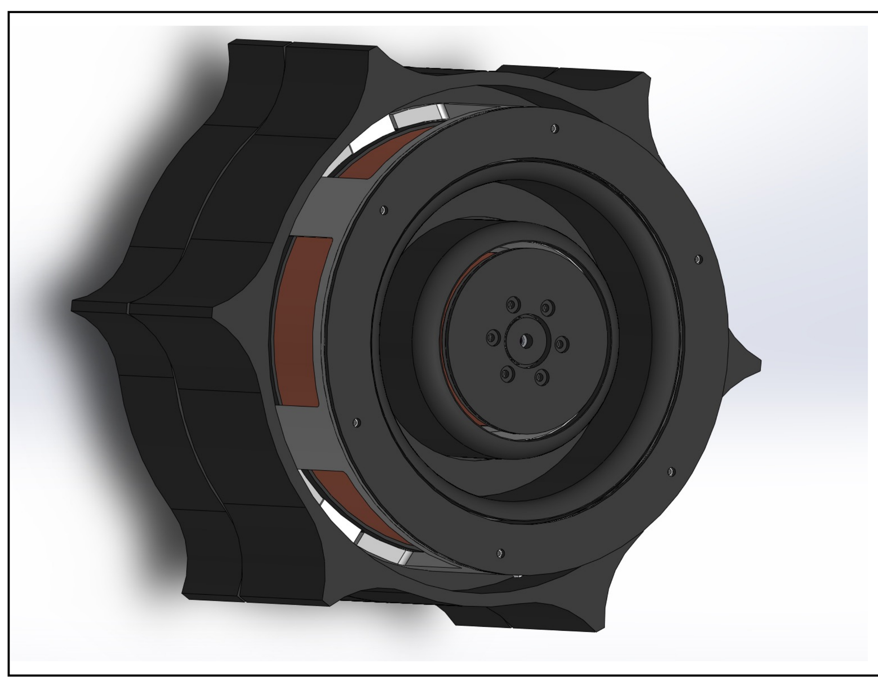

Figure 3. Solid model of the 10 kW, 3000 s Isp, H10 Hall thruster. Fabrication and testing will occur in FY23.

System	Max Power (kW)	Max Specific Impulse (s)	Deep-space Technology Readiness Level	Planned Deep-space flights
Ion Thrusters				
NEXT (NASA/Aerojet)	7	4100	7	DART - 2022
RIT-2X (Ariane Group)	7.5	3500	5	MSR - 2028
Hall Thrusters				
XR-5 (Aerojet)	3	2000	8	None
SPT-140 (Maxar/Fakel)	4.5	1800	8	Psyche - 2022
BHT-6000 (Maxar/Busek)	5	1900	6	PPE - 2025
PPE-AEPS (Maxar/Aerojet)	12.5	2800	6	PPE - 2025

Figure 4. Comparison of state-of-the-art Hall and Ion thruster systems. The 10-kW, 3000 s I_{sp} H10 thruster will realize the cost efficiencies of Hall thrusters, but provide the high-I_{sp} of an Ion thruster.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

Clearance Number: CL#22-5659
Poster Number: RPC#R22116

Publications:

[A] Hofer, R. R., Lobbia, R., and Arestie, S., "Performance of a Conducting Wall, Magnetically Shielded Hall Thruster at 3000-s Specific Impulse," Presented at the 37th International Electric Propulsion Conference, IEPC-2022-401, Cambridge, MA, June 19-23, 2022.

PI/Task Mgr. Contact Information:

Email: Richard.R.Hofer@jpl.nasa.gov