Low-Power Electric Propulsion System Enabling High-ΔV Smallsats

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Program: Strategic Initiative

Program Objectives

Deliver a low-power long-life electric propulsion (EP) system (i.e. an integrated thruster, power processing unit [PPU], and propellant feed system) that has achieved the following:

1. Demonstrated in relevant dynamic & thermal environments and has undergone experimental/analytical lifetime validation (i.e. achieve TRL 6)
2. Throttling range of 150 – 900 W with a peak total efficiency of >40% and a peak I_{sp} of >1,500 s
3. Capability of ≥100 kg Xe throughput (~10 kh operational lifetime)
4. Total system dry mass of ≤10 kg (not including the Xe tank)
5. Can be credibly proposed on Discovery and New Frontiers mission proposals within 3 years.

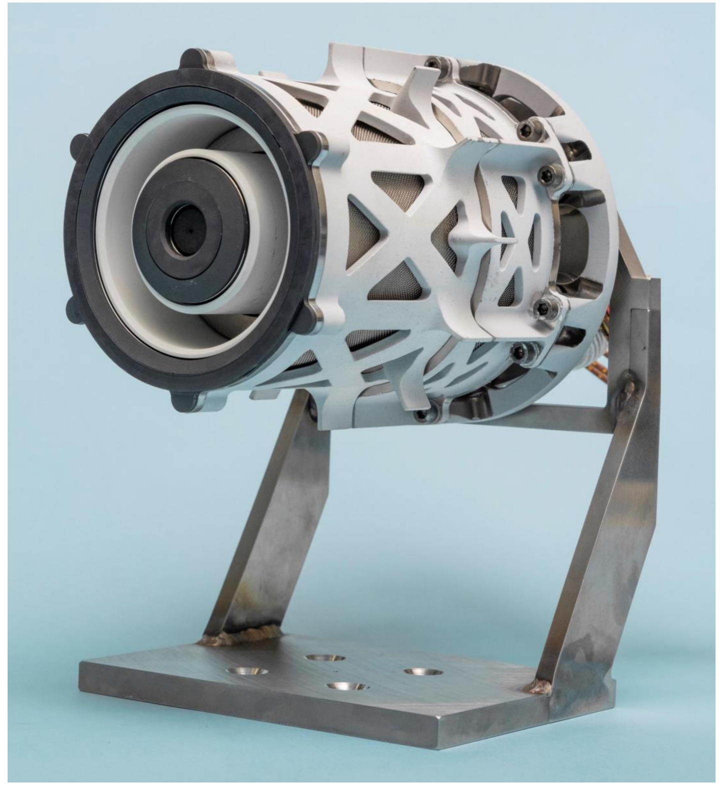
This initiative will enable >5 km/s ΔV sub-300 kg spacecraft science missions that improve science-per-$ return by a factor of ~2 compared to the current state-of-the-art through the development of low-power, long-life, high-performance, and low-mass electric propulsion system that is not available commercially.

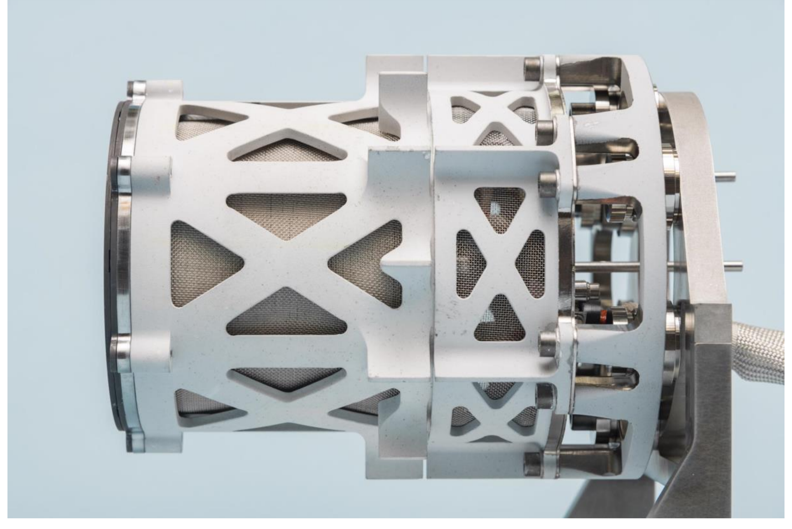
Benefits to NASA and JPL

The successful completion of the proposed initiative will ensure JPL's continued competitive advantage in long-life EP capabilities while expanding JPL's capabilities to ambitious low-cost, high-ΔV, multiple-target, high-science value interplanetary missions. ASTRAEUS (Ascendant Sub-kW Transcelestial Electric Propulsion System) meets or exceeds the applicable NASA/JPL Technology Roadmap desires for performance and ΔV (see Roadmaps 2.2.1.7 and 2.2.1.2).

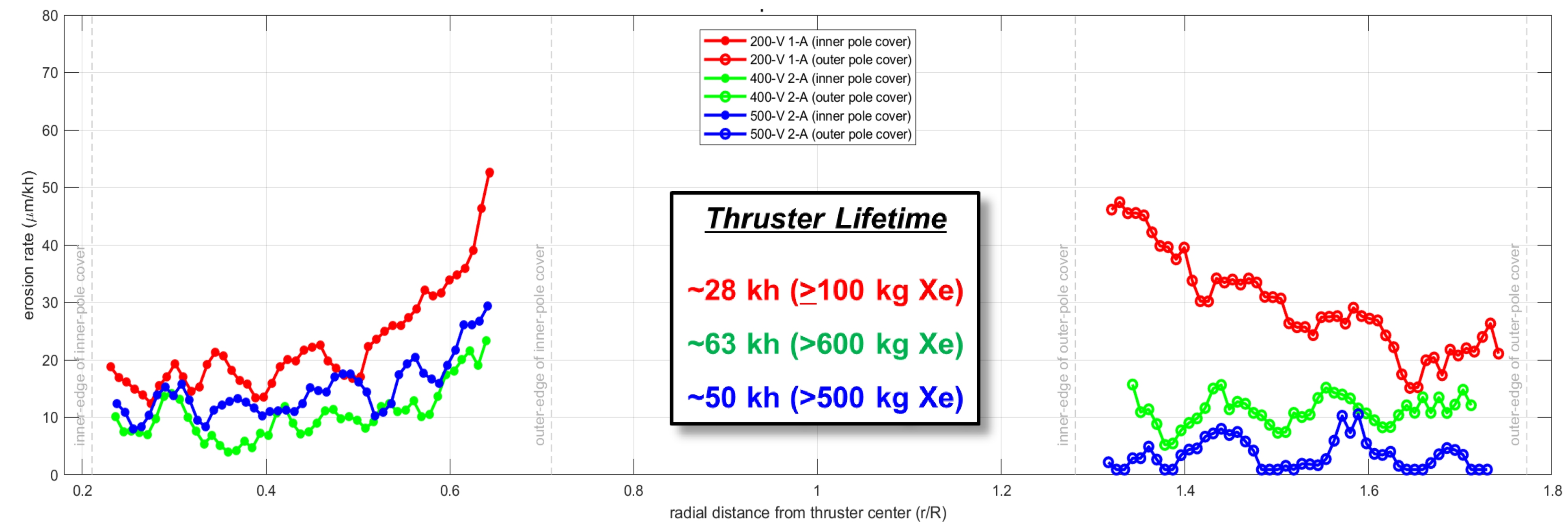
By using smallsats instead of conventional spacecraft, JPL & NASA will see a dramatic increase in science "return on investment" (ROI) while the number of proposal opportunities may significantly increase through the proposal and selection of "Half-Discovery" missions. Furthermore, conventionally sized (~1,000 kg) spacecraft using REP and the proposed system will be capable of rendezvous and orbit-capture at outer solar system planets and celestial objects, enabling previously infeasible/prohibitively expensive missions.

FY19 Results

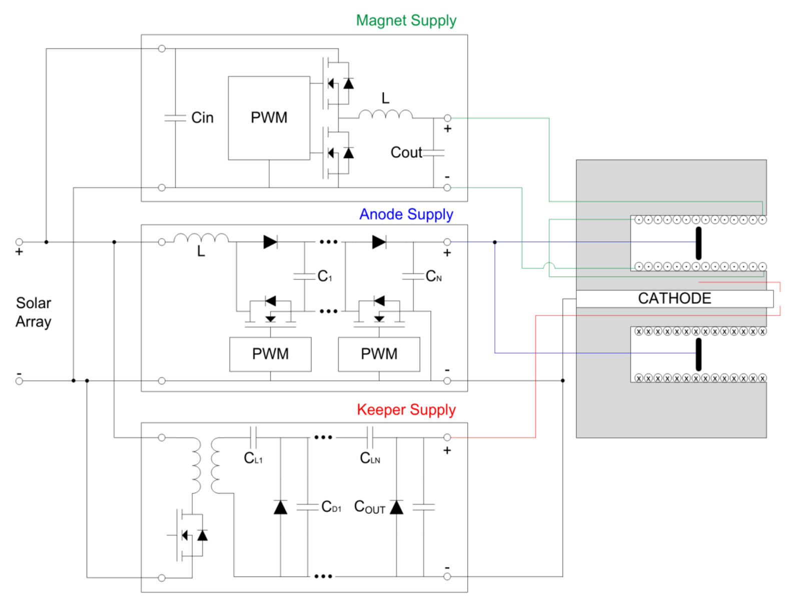


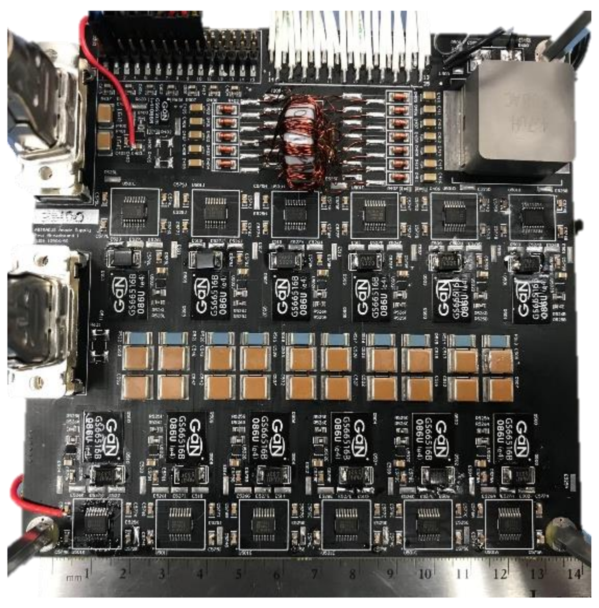


MaSMi-EM SN001, fabricated, assembled, and delivered by commercial partner Apollo Fusion, Inc. (Mountain View, CA).

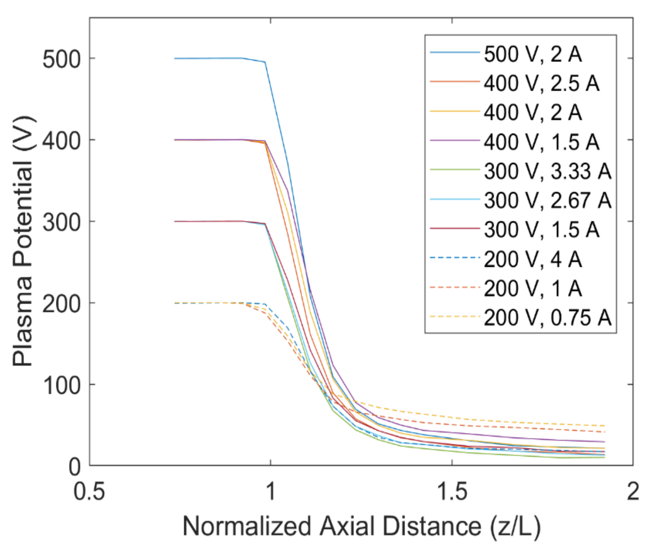


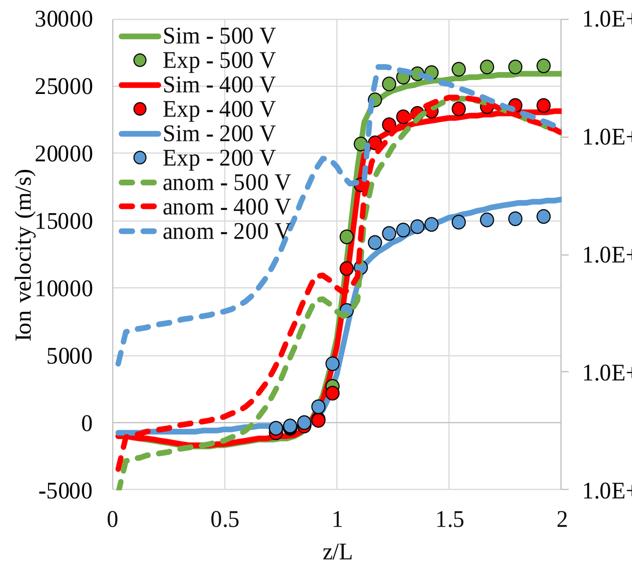
Measured graphite pole cover erosion rates on the MaSMi-DM Hall thruster at three operating conditions, indicating that the thruster useful lifetime meets or exceeds the 100 kg Xe throughput requirement.

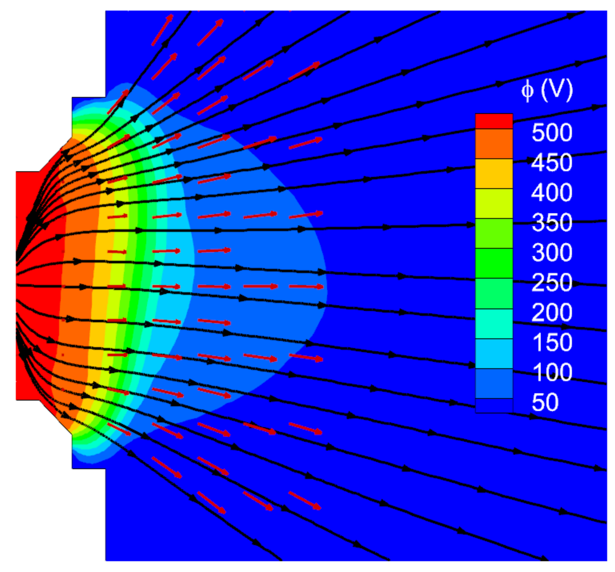




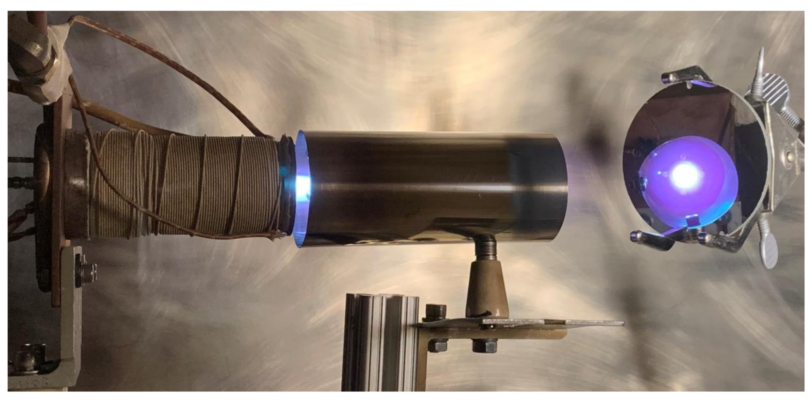
LEFT: ASTRAEUS breadboard PPU topology diagram.
RIGHT: Breadboard PPU discharge converter undergoing pre-test preparations.

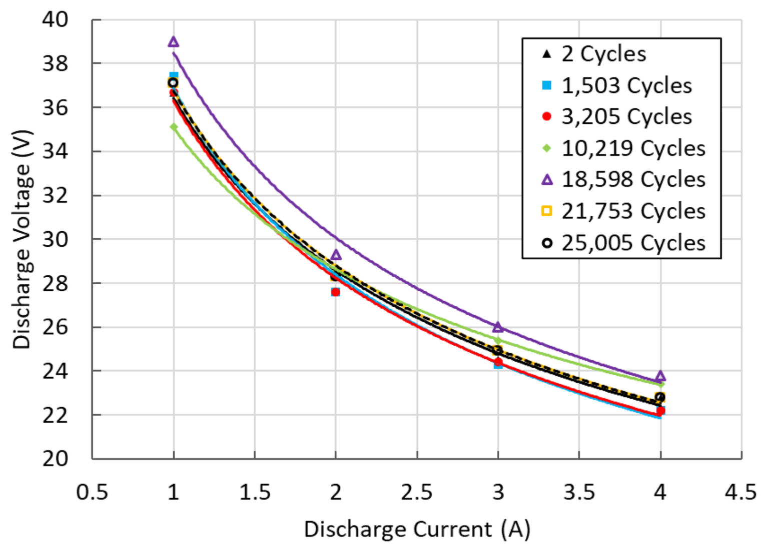




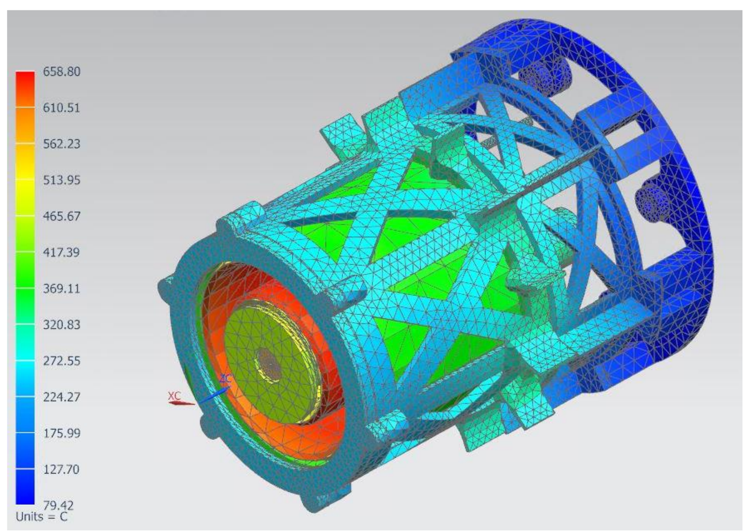


LEFT: Channel centerline laser-induced fluorescence results from the MaSMi-DM at 10 unique operating conditions.
MIDDLE: Comparison between numerical simulation and LIF measurements of the ion velocity along the channel centerline for three MaSMi operating conditions, normalized to the discharge channel length *L*.
RIGHT: 2-D comparison of the ion velocity field for the 500 V- 2 A operating condition.

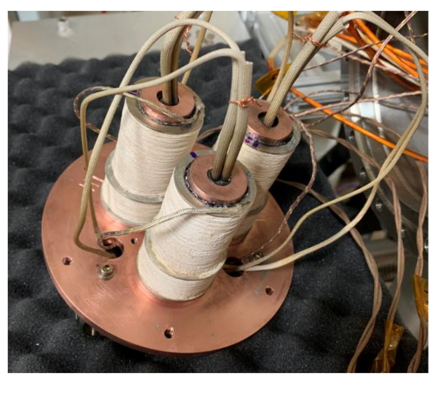


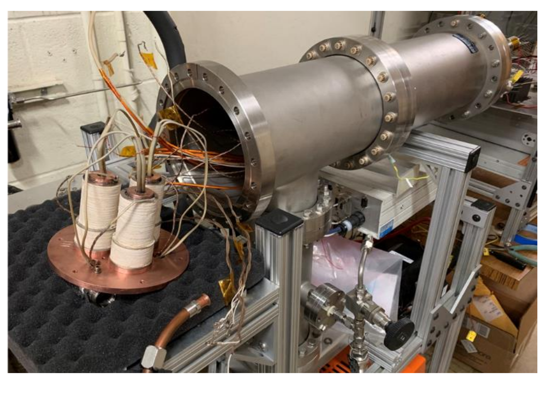


TOP: EM cathode undergoing a combined ignition cycle and long-duration wear test.
BOTTOM: EM cathode performance throughout a >25,000-ignition cycle test.



Case	Backpole	Inner Coil Max	Outer Coil Max	Outer Front Pole Max
$WCC_{non\text{-}ops}$	-103ºC	-103ºC	-107ºC	-107ºC
WCC_{ops}	341ºC	447ºC	390ºC	229ºC
WCH	347ºC	454ºC	395ºC	247ºC
Ground Test Facility	346ºC	452ºC	395ºC	237ºC





TOP: Validated thermal model of the MaSMi-EM (500 V, 1 kW).
MIDDLE: MaSMi-EM worst case temperature predictions
BOTTOM: MaSMi-EM magnet coil TVAC qualification.

Publications / Patents

Conversano, *et. al.*, "Low-Power Long-Life Hall Thruster, Ultra-Compact Hollow Cathode, & Anode Manifold with Ultra-High Propellant Flow Uniformity," U.S. Patent Application No. 16/205,048.

Conversano, R. W., *et al*, "Performance Characterization of a Low-Power Magnetically Shielded Hall Thruster with an Internally-Mounted Hollow Cathode," *Plasma Sources Science and Technology*, 2019.

Conversano, R. W., *et al*, "Overview of the Ascendant Sub-kW Transcelestial Electric Propulsion System (ASTRAEUS)," IEPC-2019-282, Vienna, Austria: 2019.

Conversano, R. W., *et al*, "Development of and Acceptance Test Preparations for the Thruster Component of the Ascendant Sub-kW Transcelestial Electric Propulsion System (ASTRAEUS)," IEPC-2019-283, Vienna, Austria: 2019.

Chaplin, V. H., *et al*, "Ion Velocity Measurements in the Magnetically Shielded Miniature Hall Thruster (MaSMi) Using Laser-Induced Fluorescence," IEPC-2019-531, Vienna, Austria: 2019.

Lopez Ortega, A., *et al*, "Plasma Simulations for the Assessment of Pole Erosion in the Magnetically Shielded Miniature (MaSMi) Hall Thruster," IEPC-2019-281, Vienna, Austria: 2019.

Lobbia, R., *et al*, "Pole Erosion Measurements for the Development Model of the Magnetically Shielded Miniature Hall Thruster (MaSMi-DM)," IEPC-2019-298, Vienna, Austria: 2019.

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