Twin Ion Engine Demonstration for Small Spacecraft Applications

SSC22-X-04

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36th Small Satellite Conference
Utah State University, Logan, UT, USA
August 6-11, 2022

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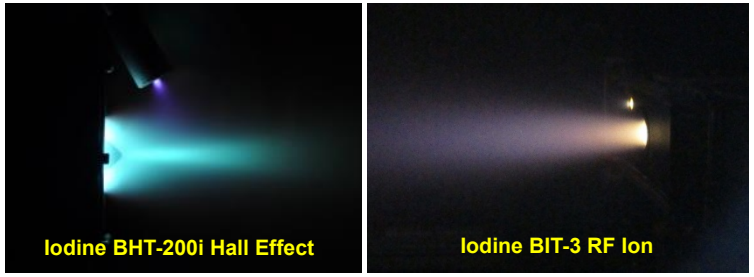
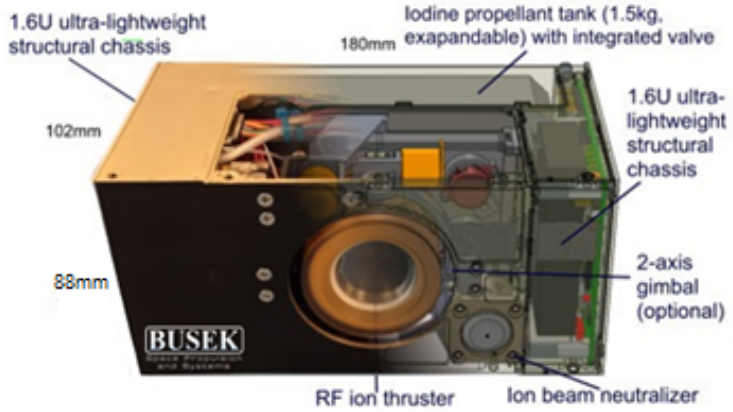
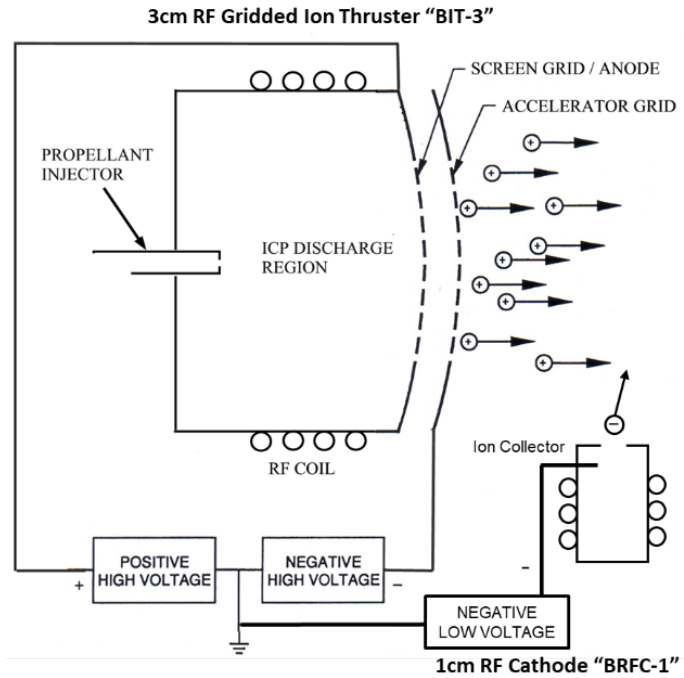
BIT-3 Overview and Gen-1 Upcoming Flights

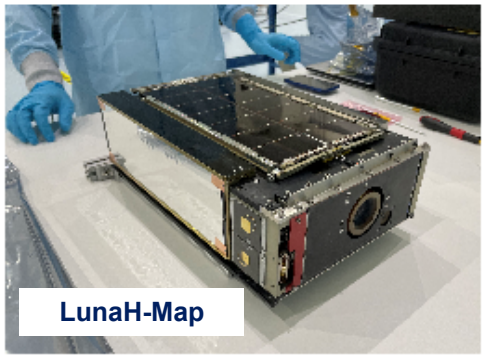
- BIT-3 is an RF gridded ion thruster with an RF cathode neutralizer, both fueled by iodine
- Iodine has many advantages over xenon while equal in performance
  - ➢ Solid storable; simpler tank requirement
  - ➢ 4.9 g/cc I2 storage density vs. 1.8-2.0 g/cc Xe
  - ➢ <$100/kg I2 cost vs. >$27,000/kg Xe (at least 300X difference)
- Busek one of pioneers on iodine EP
  - ➢ I2 HET
  - ➢ I2 RF gridded ion
  - ➢ I2 RF cathode

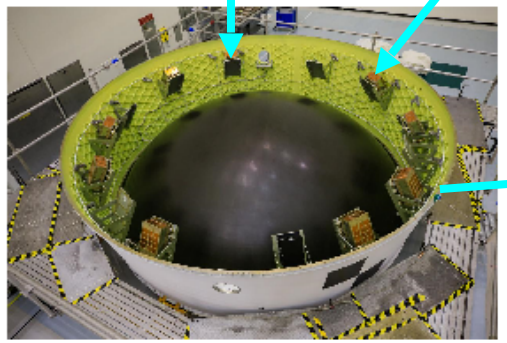




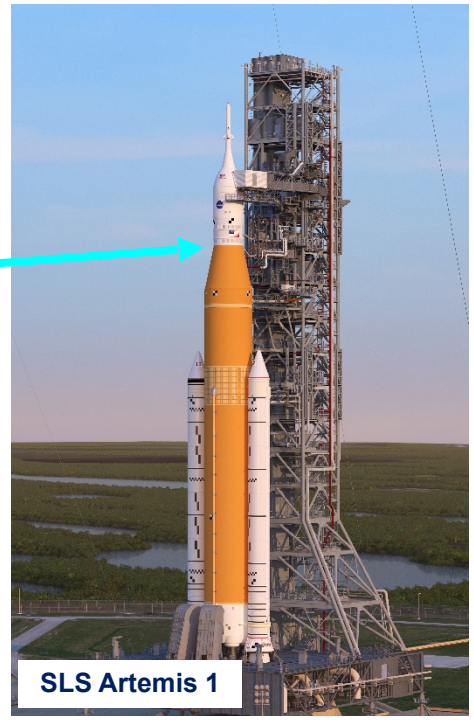


Two Gen-1 BIT-3 on SLS Artemis 1

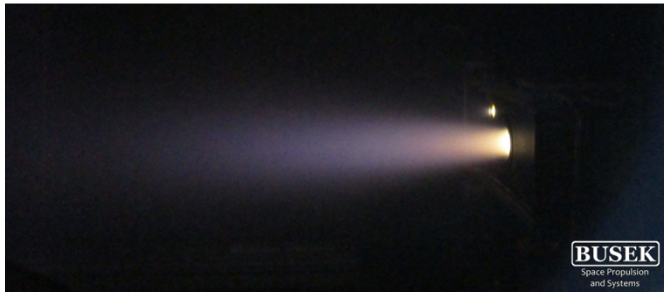




SLS Artemis 1's Ten 6U CubeSat Secondary Payloads Installed in the Orion Stage Adapter (OSA)



BIT-3 Development Timeline



01/2016

- Iodine gridded RF ion thruster proof of concept
- Gen-1 flight development began

01/2020

- 3x Gen-1 FM delivered
- Gen-1 3,500hr wear test began
- Gen-2 development began

01/2021

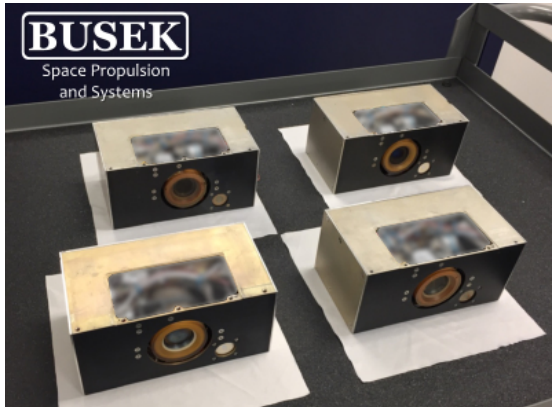
- Gen-1 3,500hr wear test completed
- Gen-2 fight production began

01/2022

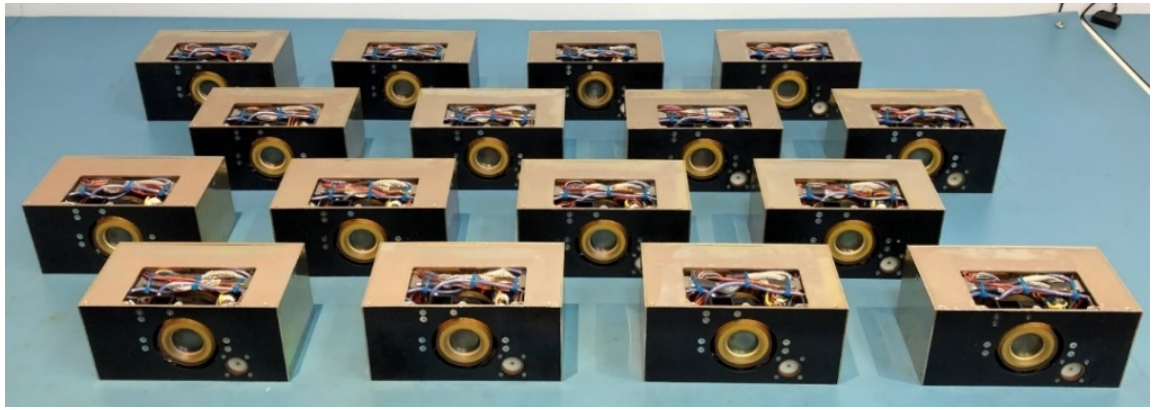
- Gen-2 10k hot-fire cycling test completed

06/2022

- Dual-engine demonstration
- 24x Gen-2 FM delivered (25x built)



Gen-1 Units



Gen-2 Fleet

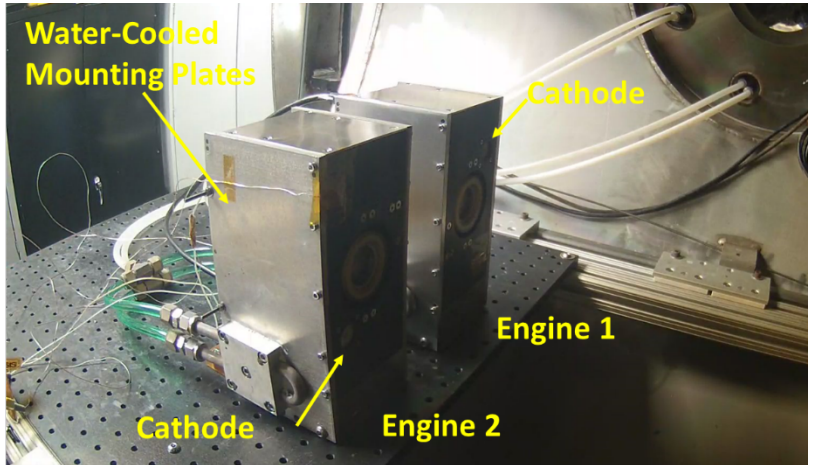
Dual Engine Test Objectives and Setup

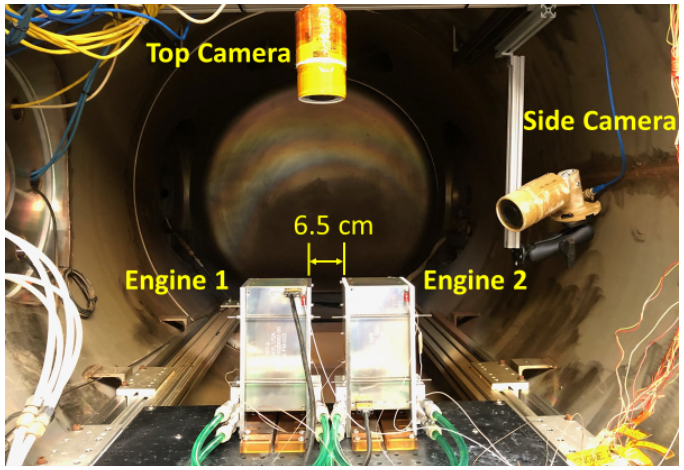
Objectives

- Demonstrate two BIT-3s can fire in close proximity (<10cm separation), simulating micro-sat volume constraints
  - ➢ Operating gridded ion clusters is not new (e.g. JAXA's Hayabusa mission), but never so close
- Demonstrate there is no electrical or plasma interferences during thruster startup and throttling (3 scenarios tested)
- Demonstrate ion beam neutralization
  - ➢ Total neutralizer electron emission current equal or higher than ion beam current

Setup

- Water-cooled mounting plates, simulating spacecraft mounting interface
- Two sets of bench power supplies and LabView/RS-485 controls
- Busek T-4 vacuum chamber, dedicated to BIT-3 iodine hot fire tests





Result – Simultaneous Startup

Video Shown at 4x Speed

Result – Sequential Startup

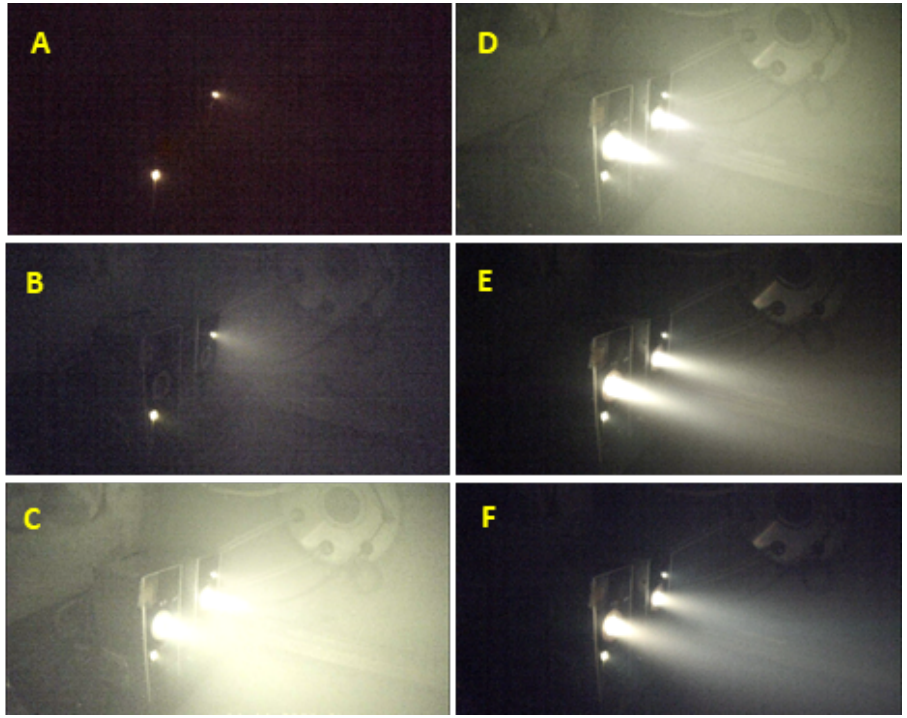
Video Shown at 4x Speed

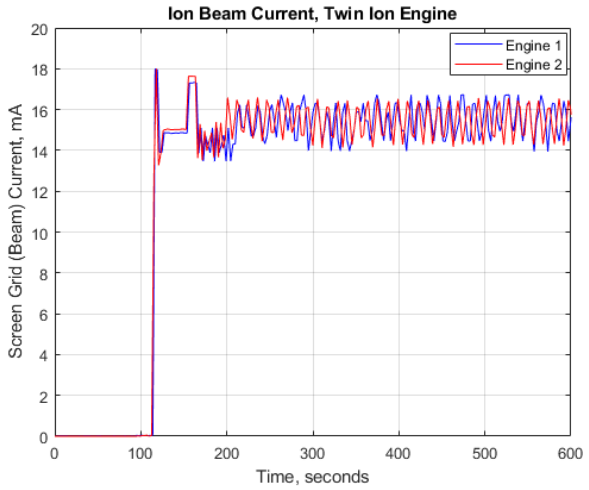
Result – Throttling

Video Shown at 2x Speed

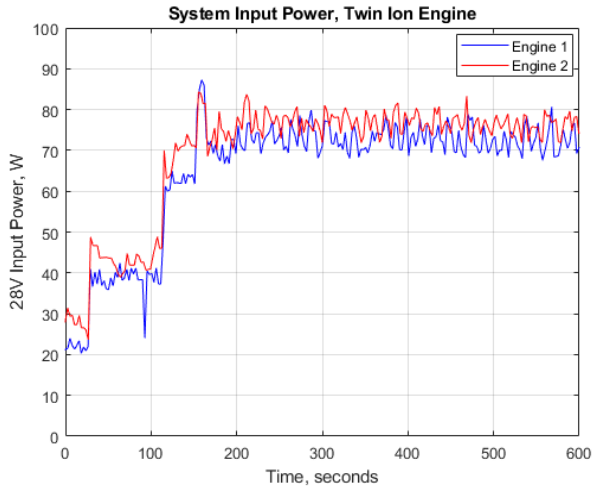
Result – Simultaneous Startup

- Both thruster started up near simultaneously (<1sec offset due to command timing)
- No startup plasma interference issue
- Achieved overall neutralization (total cathode current > or = total ion beam current)

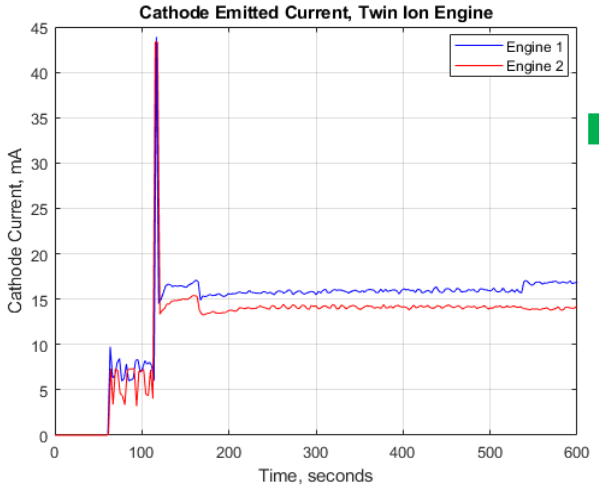




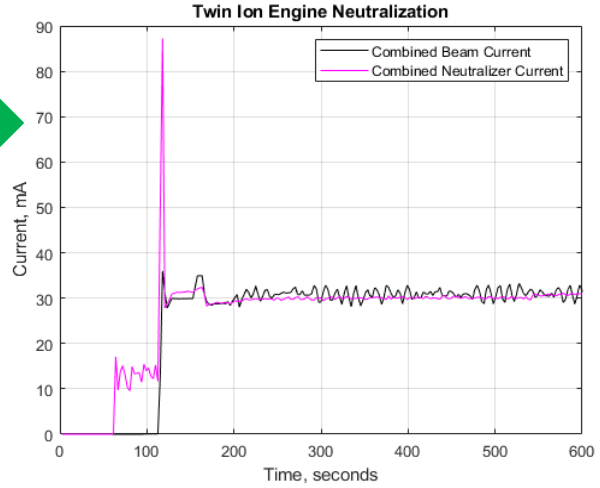
Thruster Ion Beam Current



System Input Power



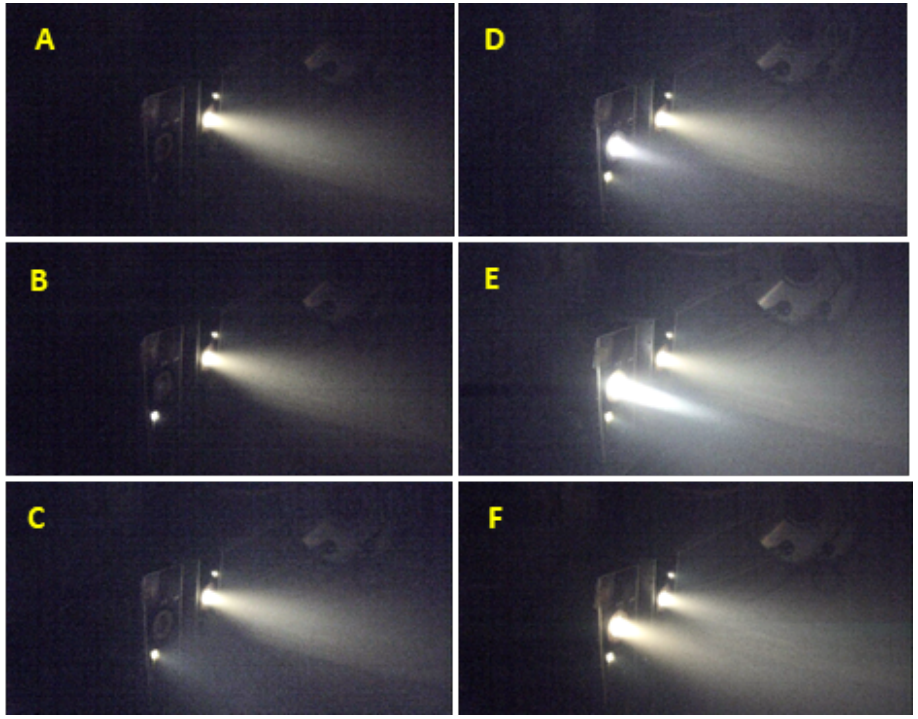
Cathode Electron Current



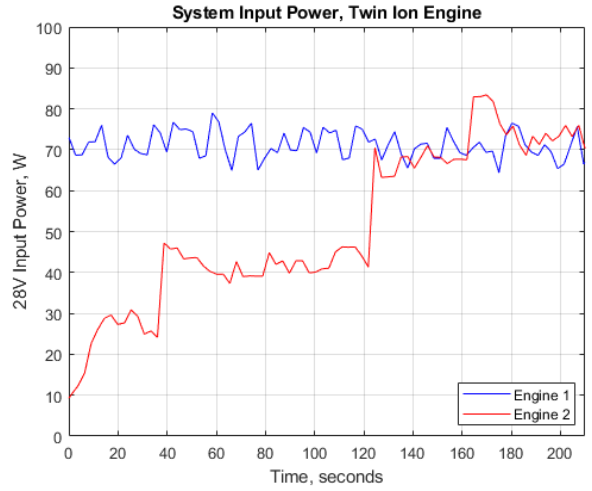
Combined Beam vs. Cathode Current

Result – Sequential Startup

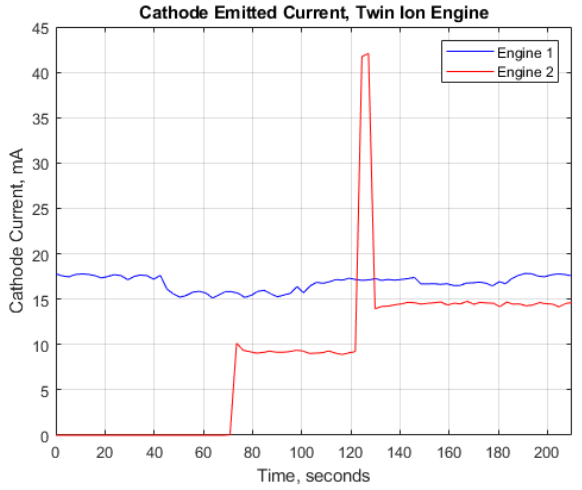
- Thrusters fired sequentially to simulate unsynchronized startups or single engine flame-out recovery
- No startup plasma interference issue
- Achieved overall neutralization (total cathode current > or = total ion beam current)



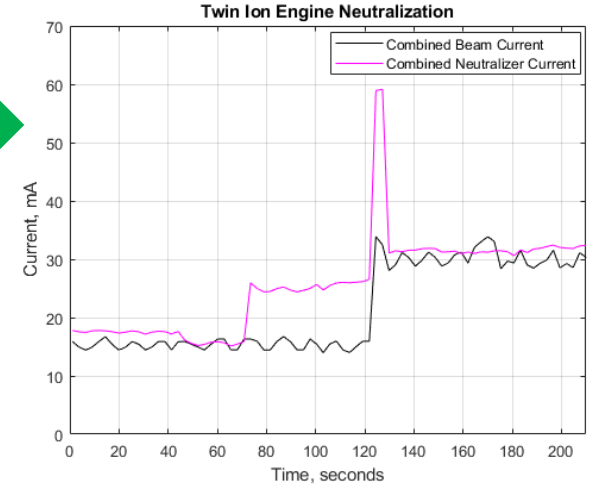
Thruster Ion Beam Current



System Input Power



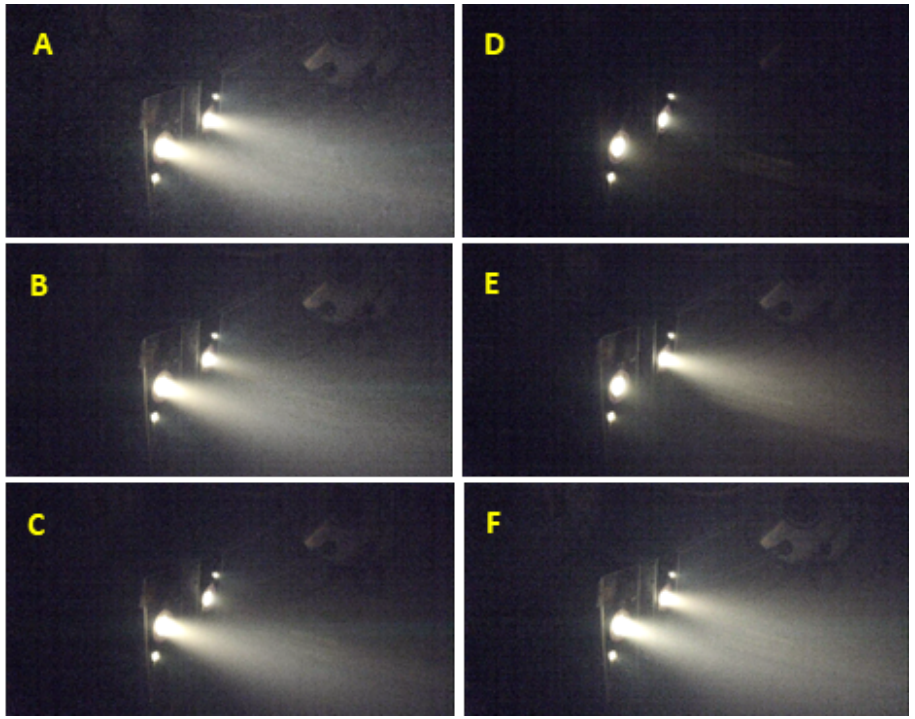
Cathode Electron Current

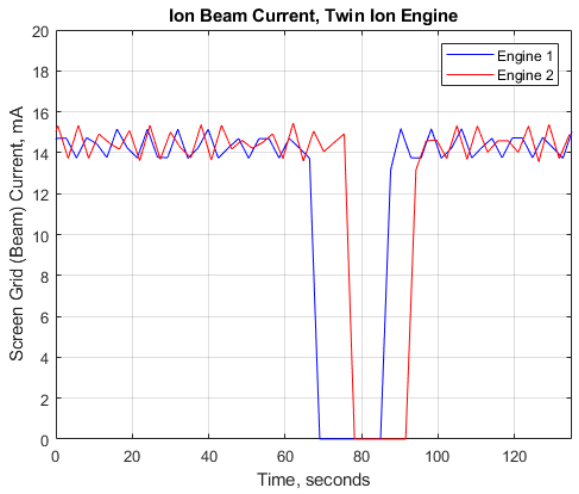


Combined Beam vs. Cathode Current

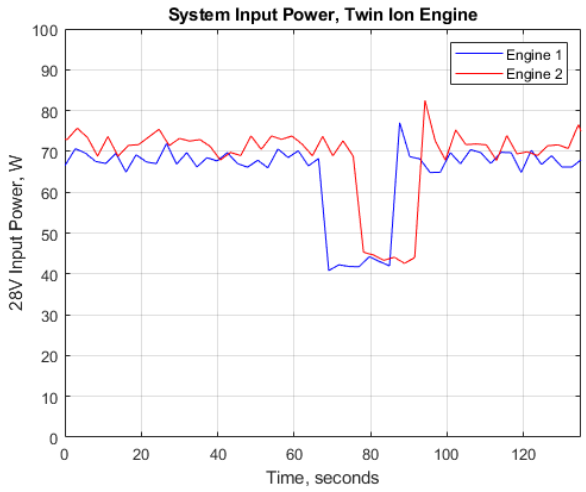
Result – Throttling

- Thrusters throttled sequentially from Lv4 (1.0mN) to Lv0 (no thrust) and back to Lv4
- No plasma interference issue / no flameouts
- Achieved overall neutralization (total cathode current > or = total ion beam current)

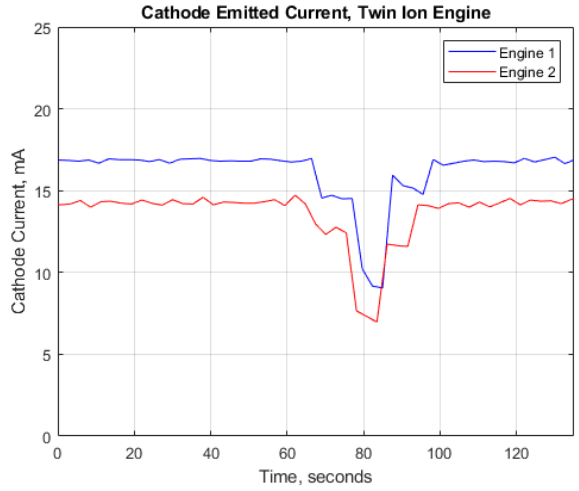




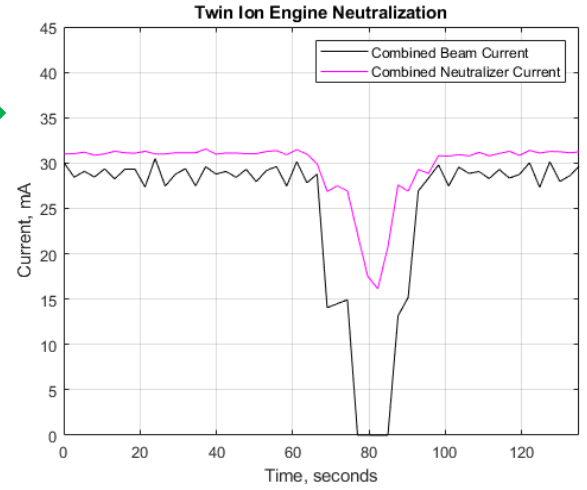
Thruster Ion Beam Current



System Input Power



Cathode Electron Current



Combined Beam vs. Cathode Current

Conclusion

- Two Gen-2 BIT-3 systems successfully demonstrated iodine hot firing side by side
  - Close proximity (6.5cm separation) had no observable electrical or plasma-interaction issues
  - Plasma plumes not entangled
  - Greatly reduces risk of clustering BIT-3 in confined s/c volume
- Three scenarios examined; thruster and cathode stable in all cases
  - Simultaneous ignition
  - Sequential startup
  - Independent throttling
- Iodine ion plumes were fully neutralized
  - The two cathode neutralizers were able to couple to the plumes via plasma bridge, and emit greater than or equal to the ion beam current