Development Status and Performance Metrics of the Advanced NEXT Ion Propulsion System

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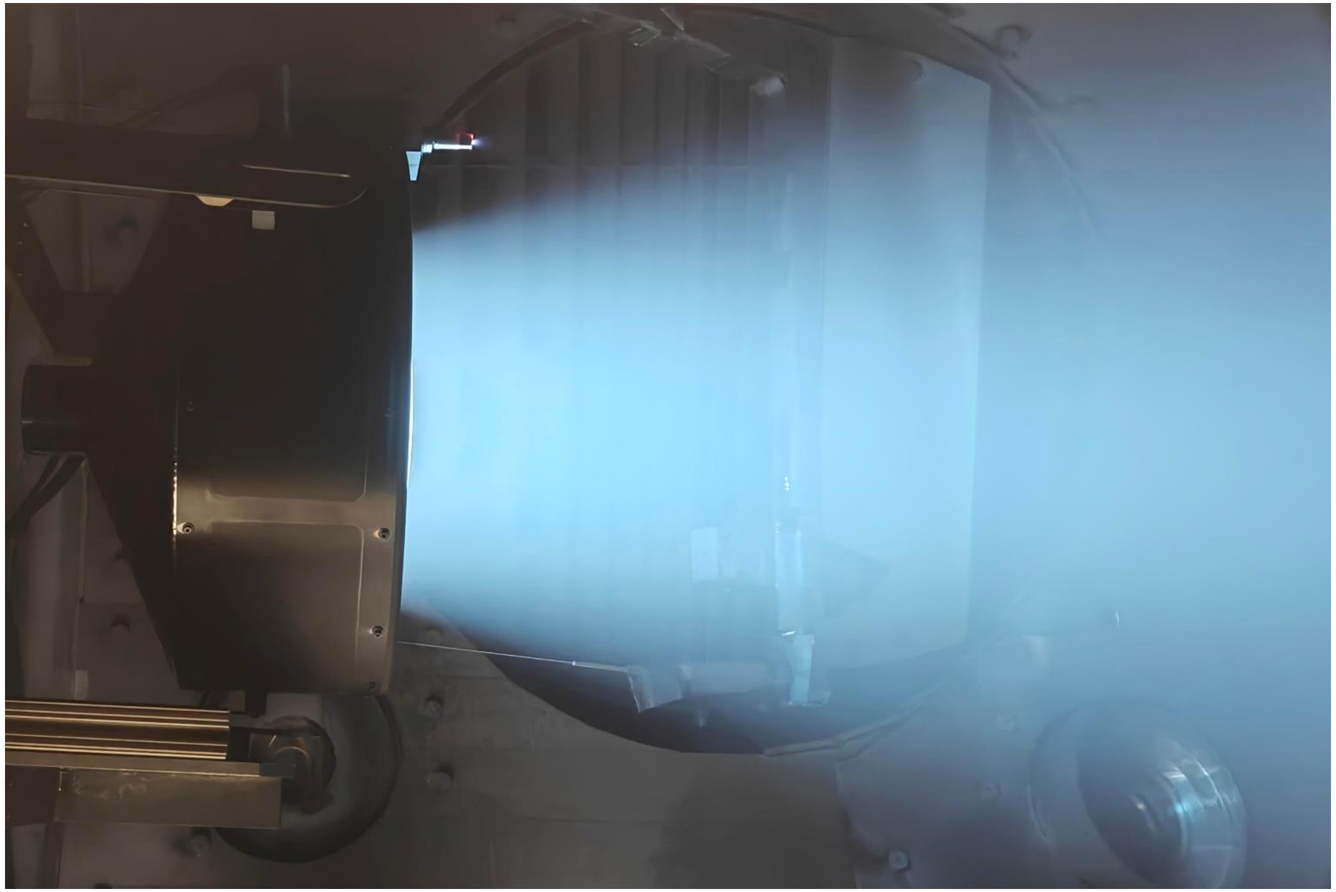


Background: NEXT

- NASA's Evolutionary Xenon Thruster (NEXT) was developed by NASA's In-Space Propulsion Technology Program and was led by NASA GRC

- The thruster, power processing unit, and xenon feed system were matured during the development program
  - system integration test
  - multi-thruster array test
  - environmental qualification testing
  - 51,184 hr thruster wear test

- The NEXT-Commercial (NEXT-C) project was initiated by NASA in 2015 to facilitate commercial adoption and address the risk of limited utilization following initial mission deployments
  - Aerojet Rocketdyne (now L3Harris) built flight thruster, ZIN Technologies (now Voyager Technologies) built flight PPU

- NEXT-C system briefly operated on Double Asteroid Redirection Test (DART) mission in late 2021

Motivation: Adv. NEXT

- Commercial applications dominated by operations that emphasize high thrust and power densities (to reduce volume), high thrust-to-power (to reduce transit times), with very modest power throttling and total impulse requirements
  - necessitates changes to heritage NEXT configuration, which was optimized for large total impulse planetary missions

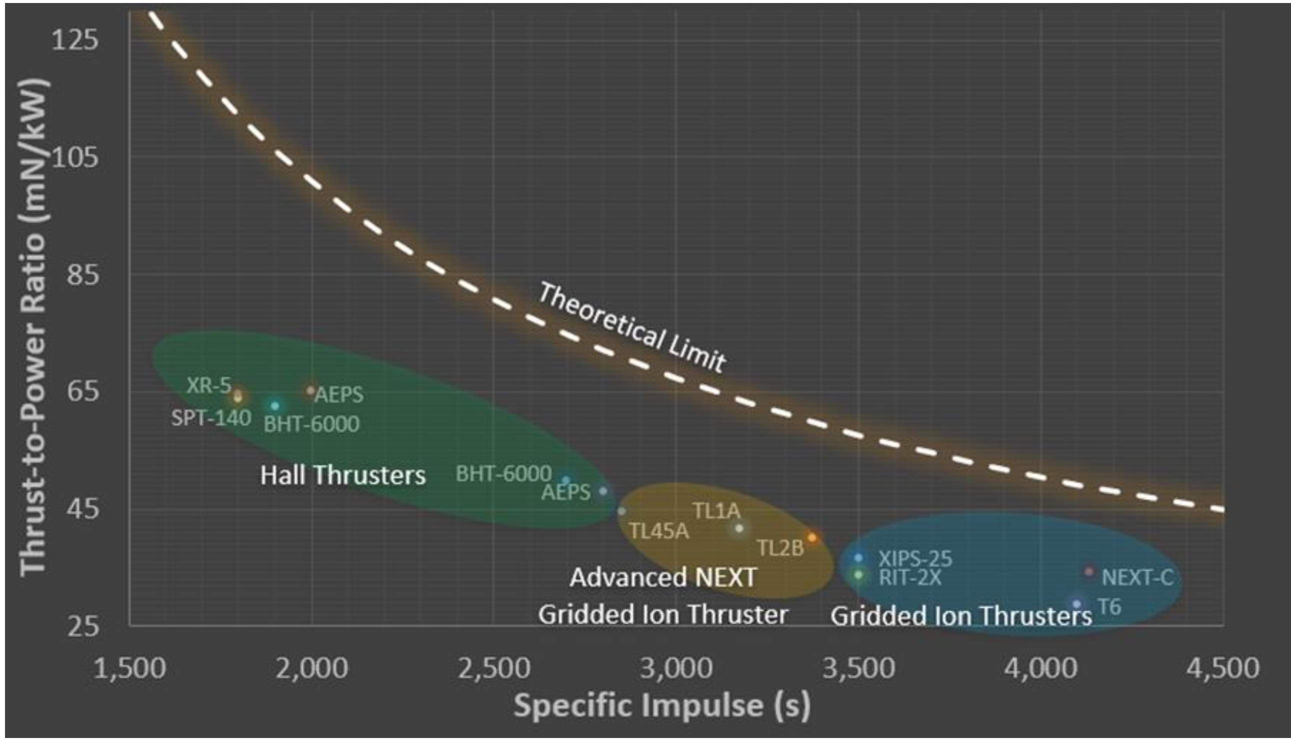
- The Advanced NEXT Project is an effort between NASA, commercial industry, and the U.S. Space Force to optimize the NEXT ion propulsion system for operation at increased thrust-to-power levels

'AF 2B'	
Defined Inputs:	6.0 A Beam Current; 1200 V Beam PS Voltage
Characteristics (Est's):	8.2 kW; ~3,400 sec Isp; ~330 mN, F/P = 40 mN/kW

Advanced NEXT Throttle Table

- Throttle levels defined by a unique combination of beam current (J_b) and beam supply voltage (V_{bps})
- Throttle levels chosen to deliver performance metrics consistent with near-earth applications

J_b, A	V_{bps}, V			
	1200	1100	1000	900
6.00	**2B**			
5.80		**1A**		
5.50			AN45C	**AN45A**
3.50	**AN37**		AN3.5A	AN3.5C
1.50	**AN14**		AN13	**AN1.5B**



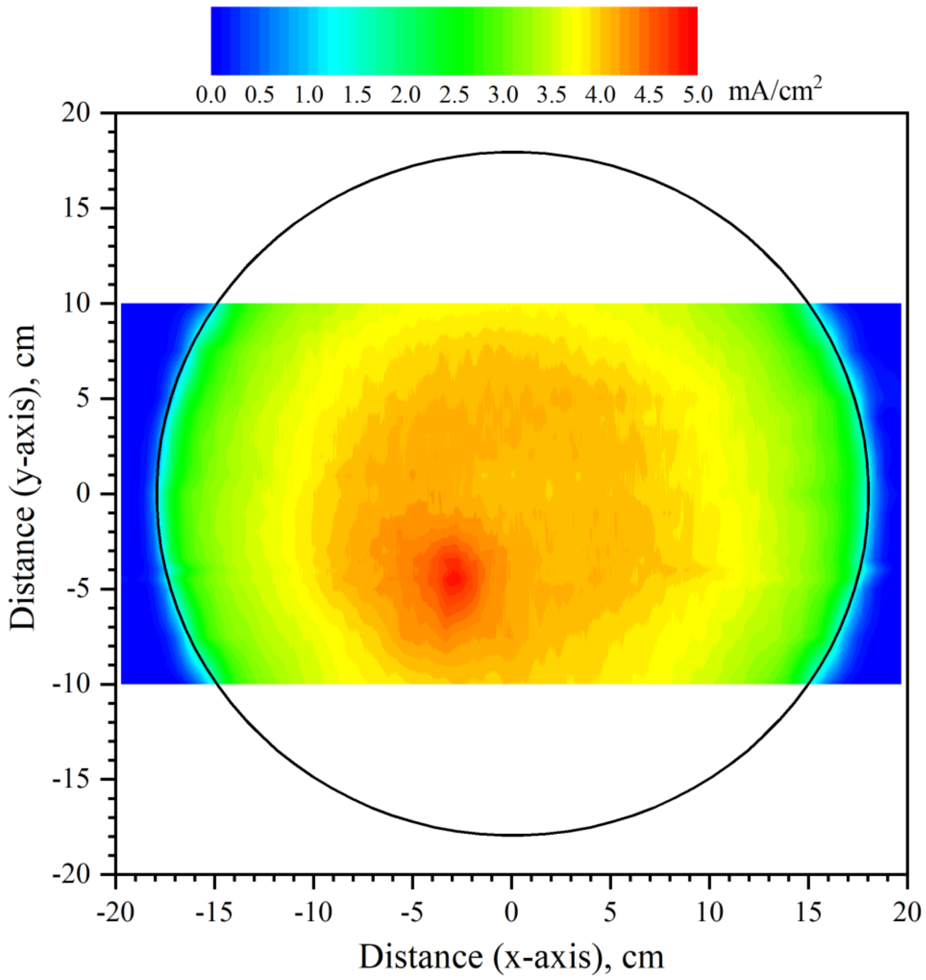
AdvNEXT Design Modifications

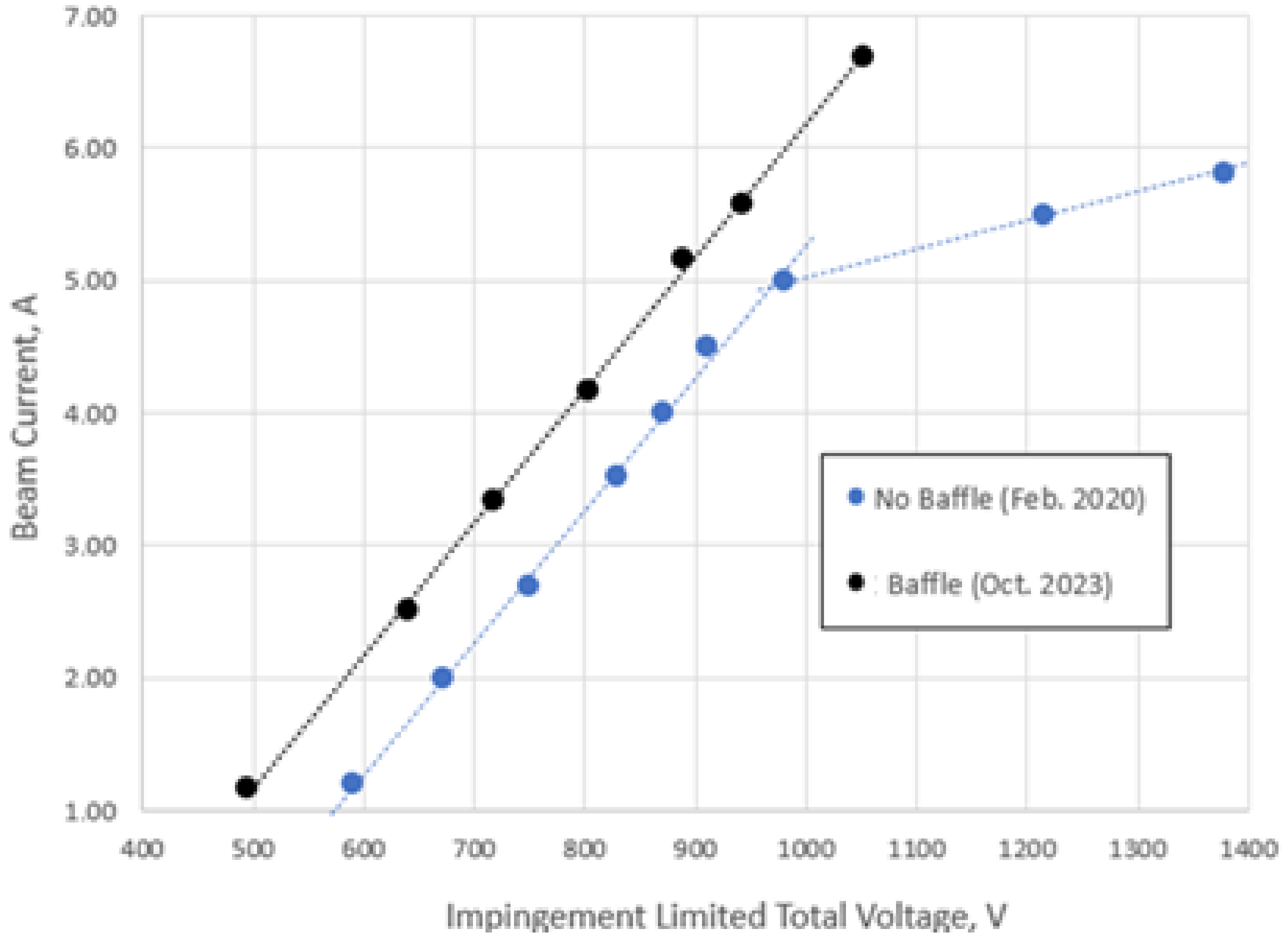
- Design philosophy is to utilize heritage components wherever practical, to reduce future hardware maturation and qualification costs
  - project goal is to keep system mass and volume approximately the same

- The major **thruster** changes are to the discharge cathode assembly and ion optics
  - cathode orifice adjusted to process up to 80% larger discharge currents
  - baffle assembly to create uniform current density across grids
  - carbon ion optics utilized to increase service life

- Several changes made to the **PPU**, incorporating lessons learned from NEXT-C
  - power supply architecture simplified to reduce cost
  - utilizing 100 V regulated input power bus
  - modest change to discharge magnetics to provide higher current levels

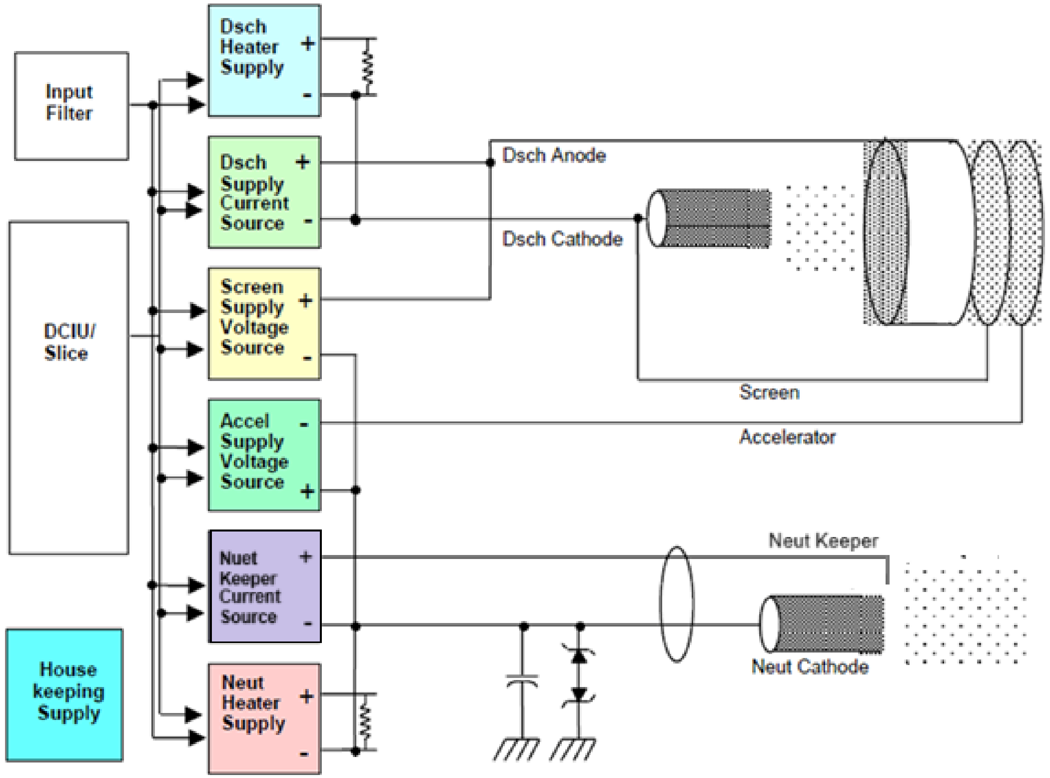
Current Extraction Capability





AdvNEXT PPU

- Six interconnected DC-DC converters used to power thruster
- Beam supply processes up to 88% of output power



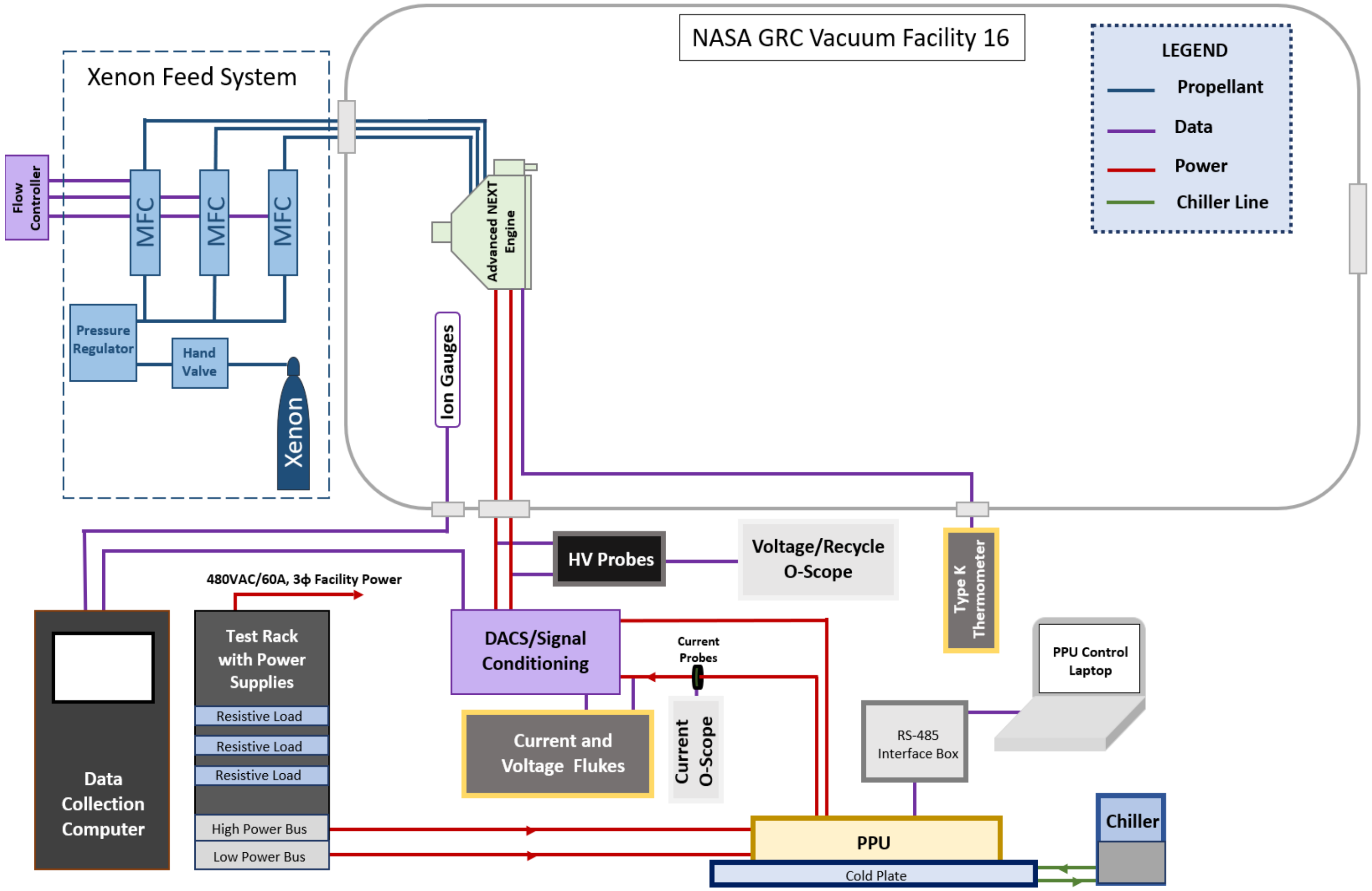
	Neutralizer Keeper		Neutralizer Heater		Discharge		Discharge Heater		Screen		Accel	
Input Voltage	95 to 105 Volt DC High Power Bus, 22 to 34 Volt DC Low Power Bus											
Output Voltage (VDC)	8	32	3	24	15	35	3	24	275	1200	115	525
Output Current (ADC)	1	3	3.5	8.5	4	40	3.5	8.5	1	6.0	0	0.04
Controlled Output	Current		Current		Current		Current		Voltage		Voltage	
Max Power Out (W)	96		204		1400		204		7200		21	
Min Efficiency (%) at Max Power Out @ TL2B (W)	> 93.5% @ 8200 W											

System Integration Test

- System integration test performed at NASA GRC using an engineering model thruster and a prototype model PPU

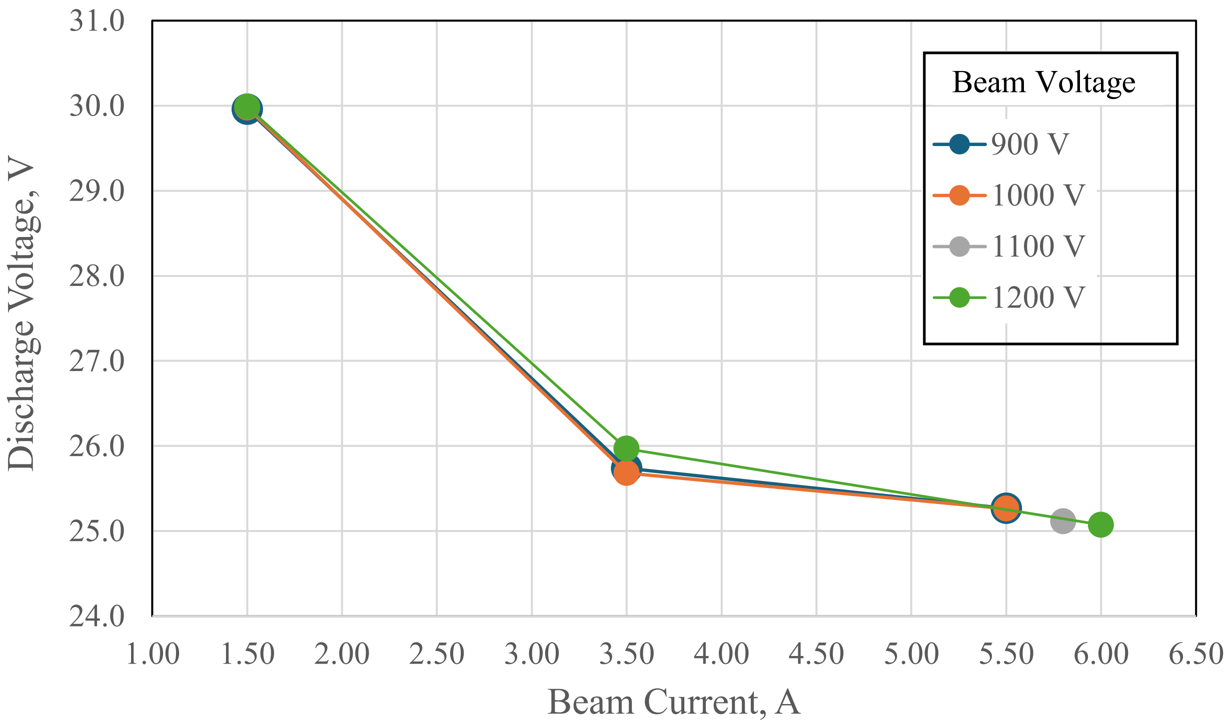
- The objectives of the test were to:
  - demonstrate system functionality across the full AdvNEXT operating envelope
  - evaluate steady-state efficiencies
  - identify potential PPU issues
  - verify fault management (arc recovery) capabilities
  - characterize transients during thruster startup
  - reduce risk for future integration tests

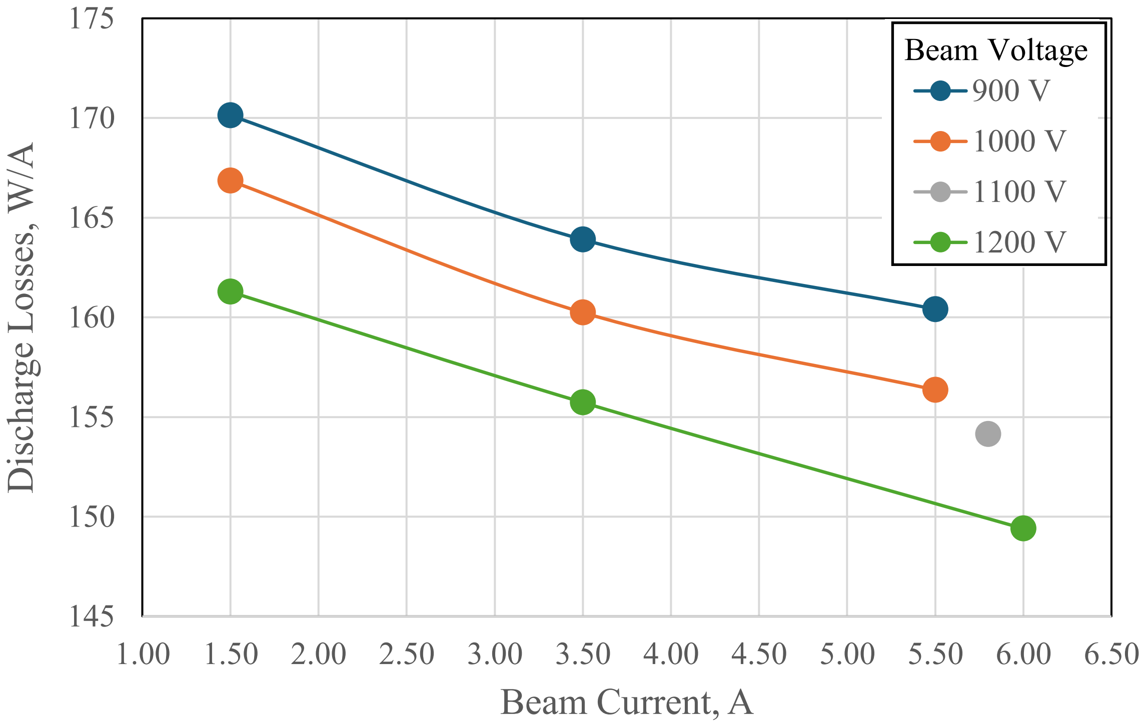
Test Setup


NASA GRC Vacuum Facility 16
LEGEND
Propellant
Data
Power
Chiller Line
Xenon Feed System
Flow Controller
MFC
MFC
MFC
Pressure Regulator
Hand Valve
Xenon
Advanced NEXT Engine
Ion Gauges
HV Probes
Voltage/Recycle O-Scope
Type K Thermometer
480VAC/60A, 3ϕ Facility Power
Data Collection Computer
Test Rack with Power Supplies
Resistive Load
Resistive Load
Resistive Load
High Power Bus
Low Power Bus
DACS/Signal Conditioning
Current Probes
Current and Voltage Flukes
Current O-Scope
RS-485 Interface Box
PPU Control Laptop
PPU
Cold Plate
Chiller

Thruster Test Results

- Propellant flows adjusted to moderate discharge voltage, observed numbers commensurate with desired service life
- Discharge losses ranged from 150-170 W/A, consistent with heritage NEXT-C performance
- Thruster operated with adequate electrostatic margins





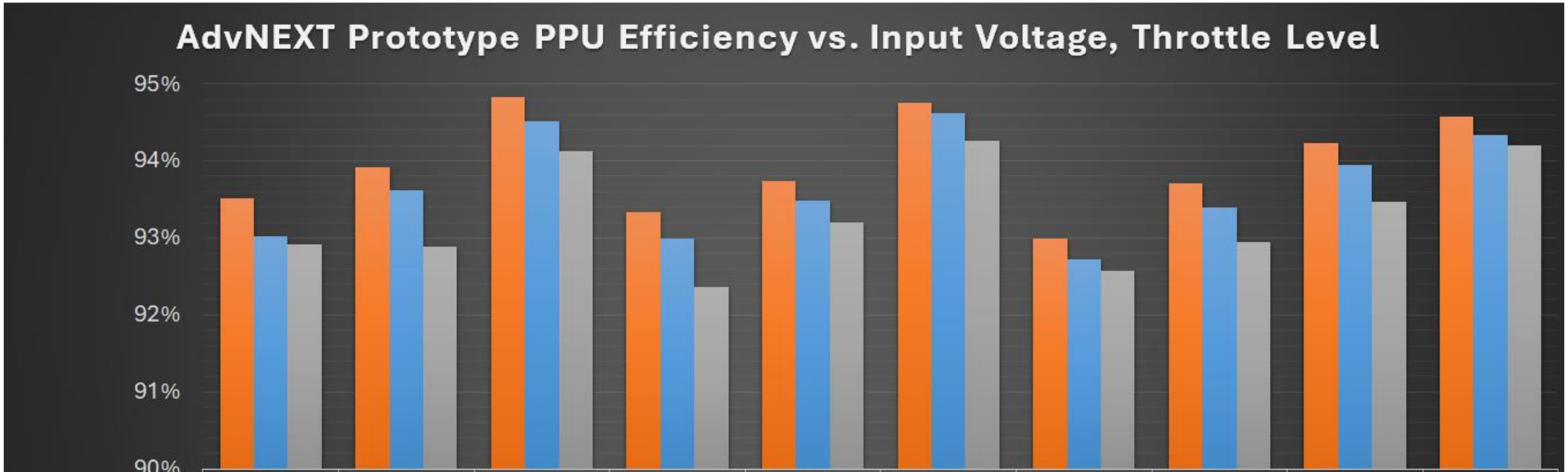
Thruster Performance

- Thruster demonstrated 40% increase in thrust relative to heritage NEXT-C design

Throttle Level	Beam Current, A	Beam Voltage, V	Thrust. mN	Specific Impulse, s	Thruster Efficiency	Thrust/Power, mN/kW
AN1.5B	1.50	900	71	2,530	54%	43
AN13	1.50	1000	75	2,668	55%	42
AN14	1.50	1200	82	2,930	57%	40
AN3.5C	3.50	900	166	2,964	64%	44
AN3.5A	3.50	1000	175	3,134	65%	42
AN37	3.50	1200	192	3,424	67%	40
AN45A	5.50	900	261	2,919	63%	44
AN45C	5.50	1000	276	3,085	64%	43
1A	5.80	1100	306	3,251	66%	42
2B	6.00	1200	330	3,401	67%	40

PPU Performance

- PPU operated at all ten AdvNEXT throttle levels
- Successfully executed arc recovery (“recycle”) mode and captured transient voltage/current data
- Demonstrated efficiencies ranging from 92% - 95%



	AN1.5B	AN13	AN14	AN3.5C	AN3.5A	AN37	AN45A	AN45C	TL1A	TL2B
Efficiency, 95Vin	93.5%	93.9%	94.8%	93.3%	93.7%	94.8%	93.0%	93.7%	94.2%	94.6%
Efficiency, 100Vin	93.0%	93.6%	94.5%	93.0%	93.5%	94.6%	92.7%	93.4%	94.0%	94.3%
Efficiency, 105Vin	92.9%	92.9%	94.1%	92.4%	93.2%	94.3%	92.6%	92.9%	93.5%	94.2%

Future Work

- Upcoming efforts will focus on advancing the maturity of the thruster and PPU

- Thruster work includes:
  - fabrication and testing of carbon ion optics
  - cathode/baffle wear test
  - fabrication of prototype model hardware in support of future qualification tests

- PPU work includes environmental tests
  - electromagnetic compatibility
  - pyrotechnic shock
  - random vibration
  - thermal vacuum

Summary

- The AdvNEXT system delivers improved performance capability while maintaining comparable mass and volume relative to the NEXT-C system
  - the thruster demonstrated a 40% increase in thrust (330 mN), with a thrust-to-power ratio of 40 mN/kW

- A system integration test was successfully completed with an engineering model thruster and prototype PPU
  - the thruster operated with efficiencies consistent with the NEXT-C system, with adequate current and electrostatic margins
  - the PPU operated at the ten AdvNEXT conditions, was tolerate of surge currents during transients, and properly executed recycle sequence
  - the PPU operated with efficiencies ranging from 92% - 95%

- Near-term tasks include testing the carbon ion optics, a subcomponent wear test, and environmental testing of the PPU