Laboratory Model 50 kW Hall Thruster

David Manzella
The University of Toledo
Toledo, OH 43606
d.manzella@grc.nasa.gov

Robert Jankovsky
NASA Glenn Research Center
Cleveland, OH 44135

Richard Hofer
QSS Group, Inc.
Cleveland, OH 44135

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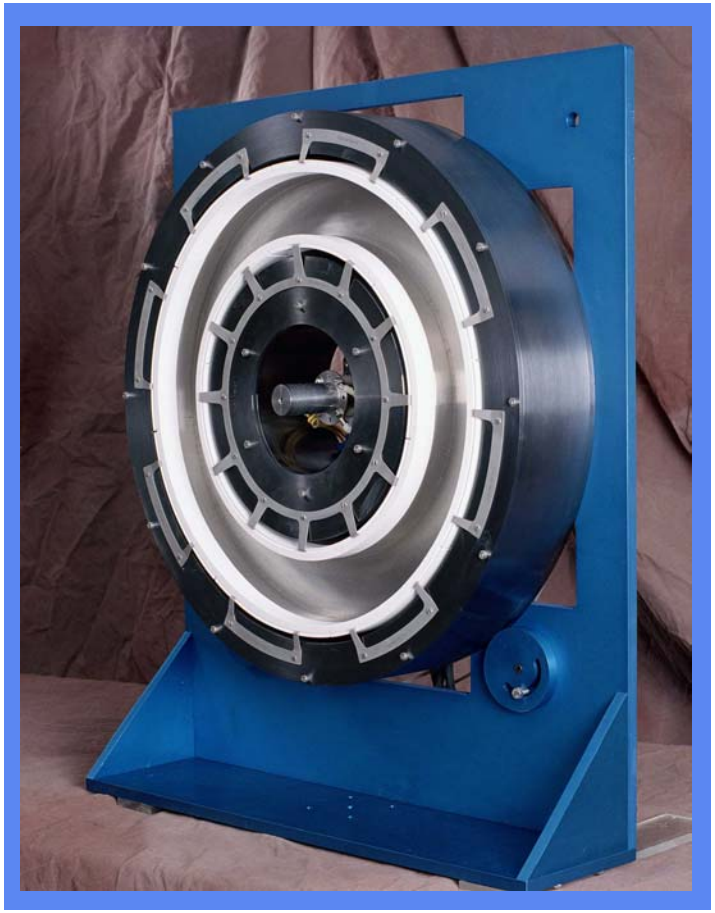
Thruster

Objective
Design and build a Hall thruster which is enabling for a new class of missions in order to rapidly identify critical issues

Approach
Design and build laboratory model thruster utilizing a scaling approach, extrapolating existing technology

Design Point
50kw (500V & 100A)

Design
Two coaxial electromagnets, centrally located hollow cathode, rear portion of channel is metallic. Gas injected through series of small radial holes



Result
Largest Hall thruster ever built utilizing a 457 mm diameter discharge chamber. Designed to operate at discharge currents up to 100 Amperes at pressures less than $5x10^{-5}$ Torr

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Magnetic Circuit

Design

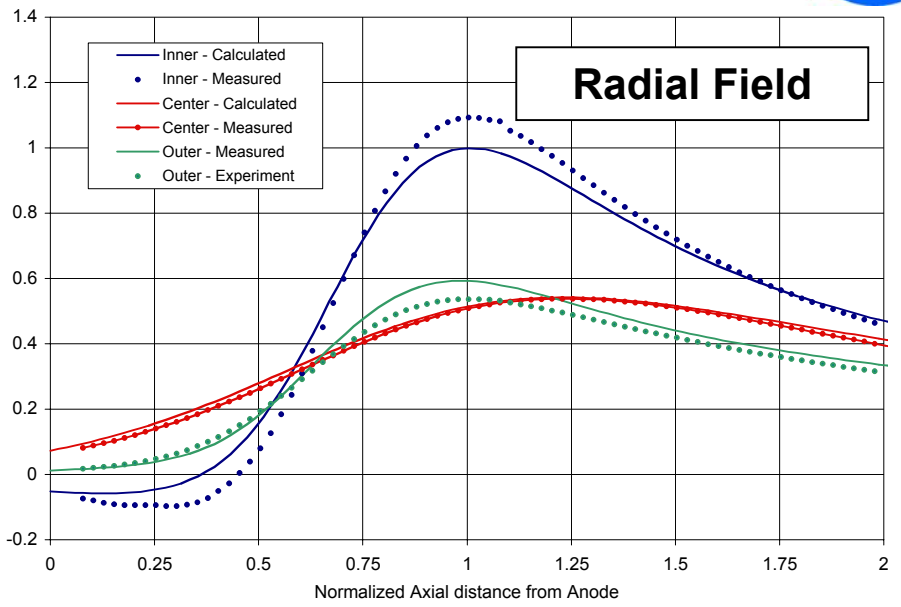
Configuration optimized through use of 3-D magneto-static computer code.
Magnetic circuit employs poles and screens along with independent magnet control

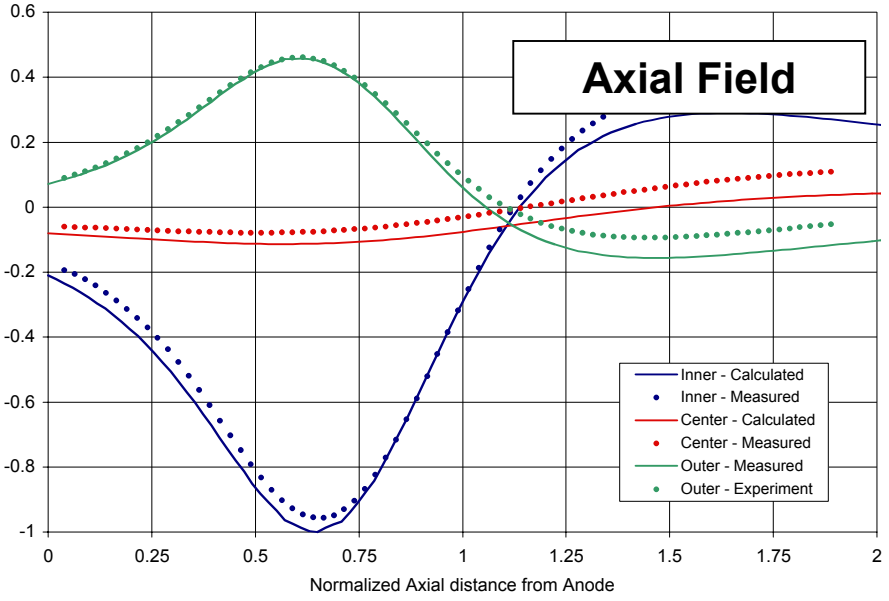
Validation

B field measurements within 10% of predictions.
Differences attributed to uncertainty in magnetic properties.

Result

Plasma lens topology similar to NASA 173M





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Facility

Vacuum Chamber

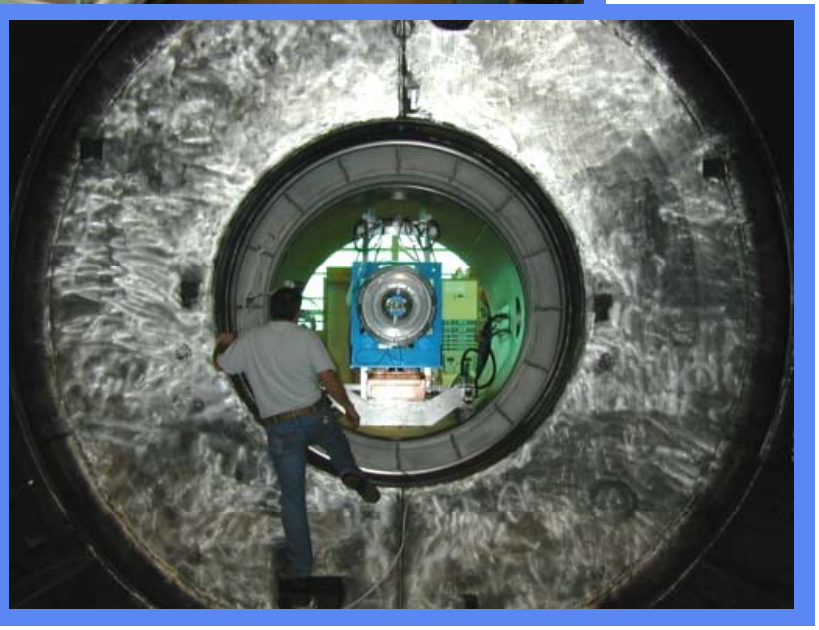
1M l/s 5m x 20m cylindrical tank modified with 2m x 2.5 m cylindrical test port w/isolation valve. Thruster fires along major axis of tank.

Thrust Stand

Larger version of GRC inverted pendulum design. Used in displacement mode. In-situ calibration capability employed.

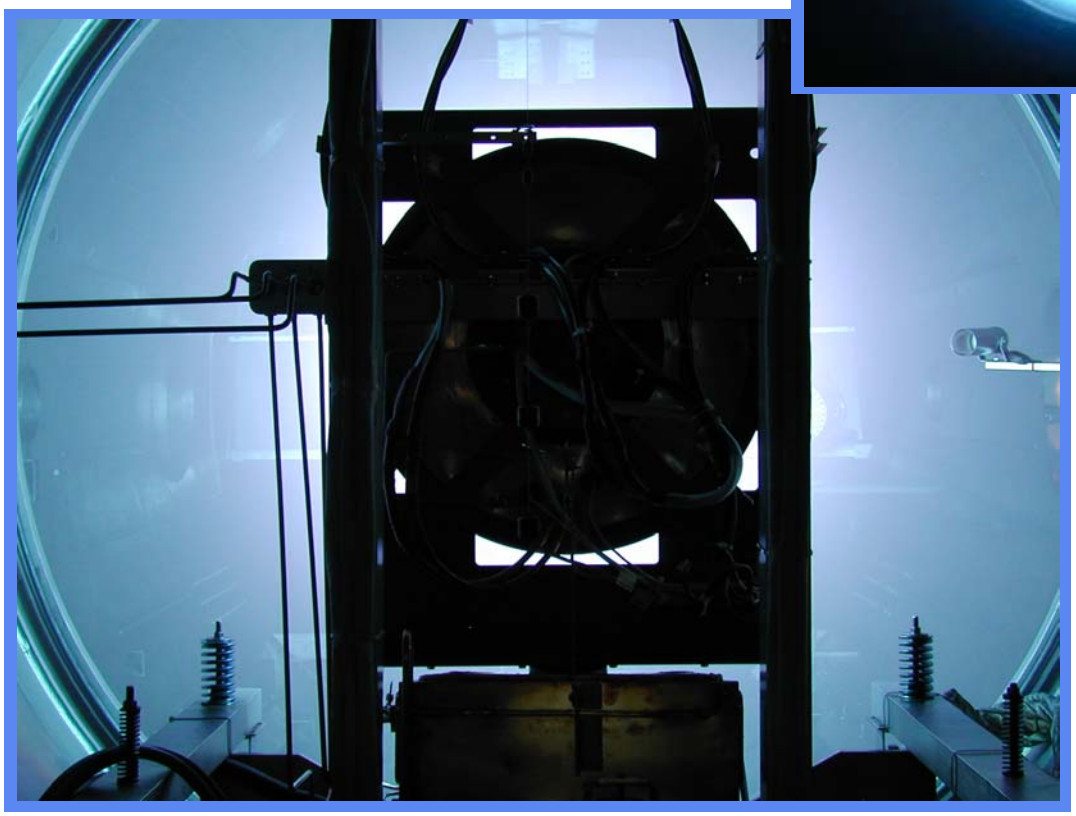
Power Source

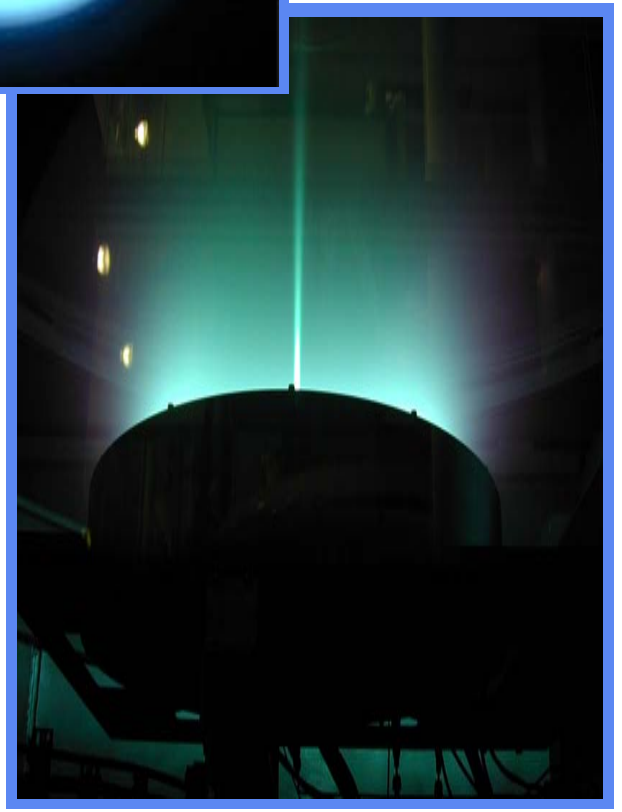
Commercial discharge power supply rated for 2000 Volts and 100 Amperes. 21 mF capacitor used as output filter.



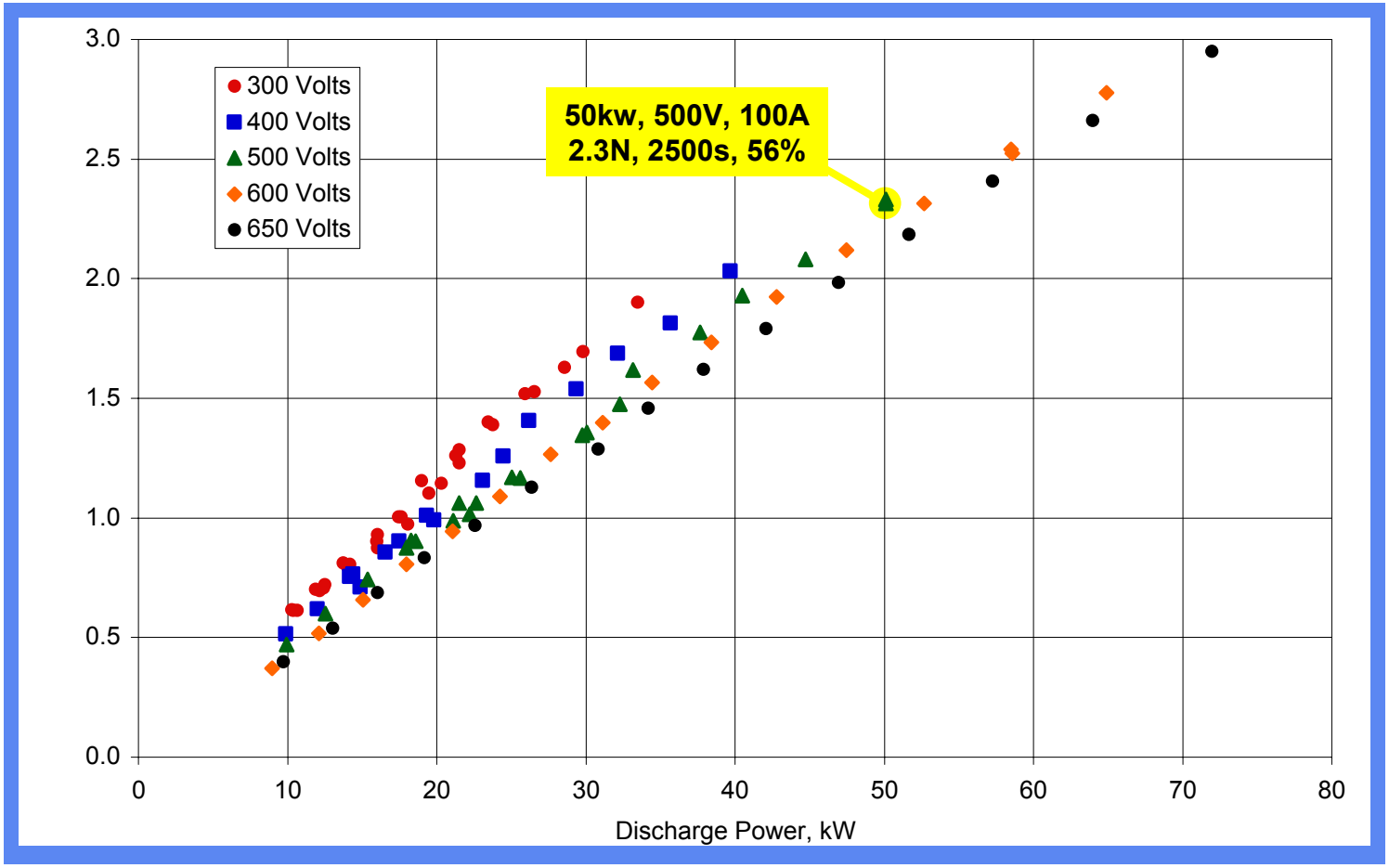
Thruster Operation

Tested Operating Range
15-93 mg/s anode mass flow rate
15-111 A discharge currents
300-650 V discharge Voltages
Discharge powers 9 to 72 kW



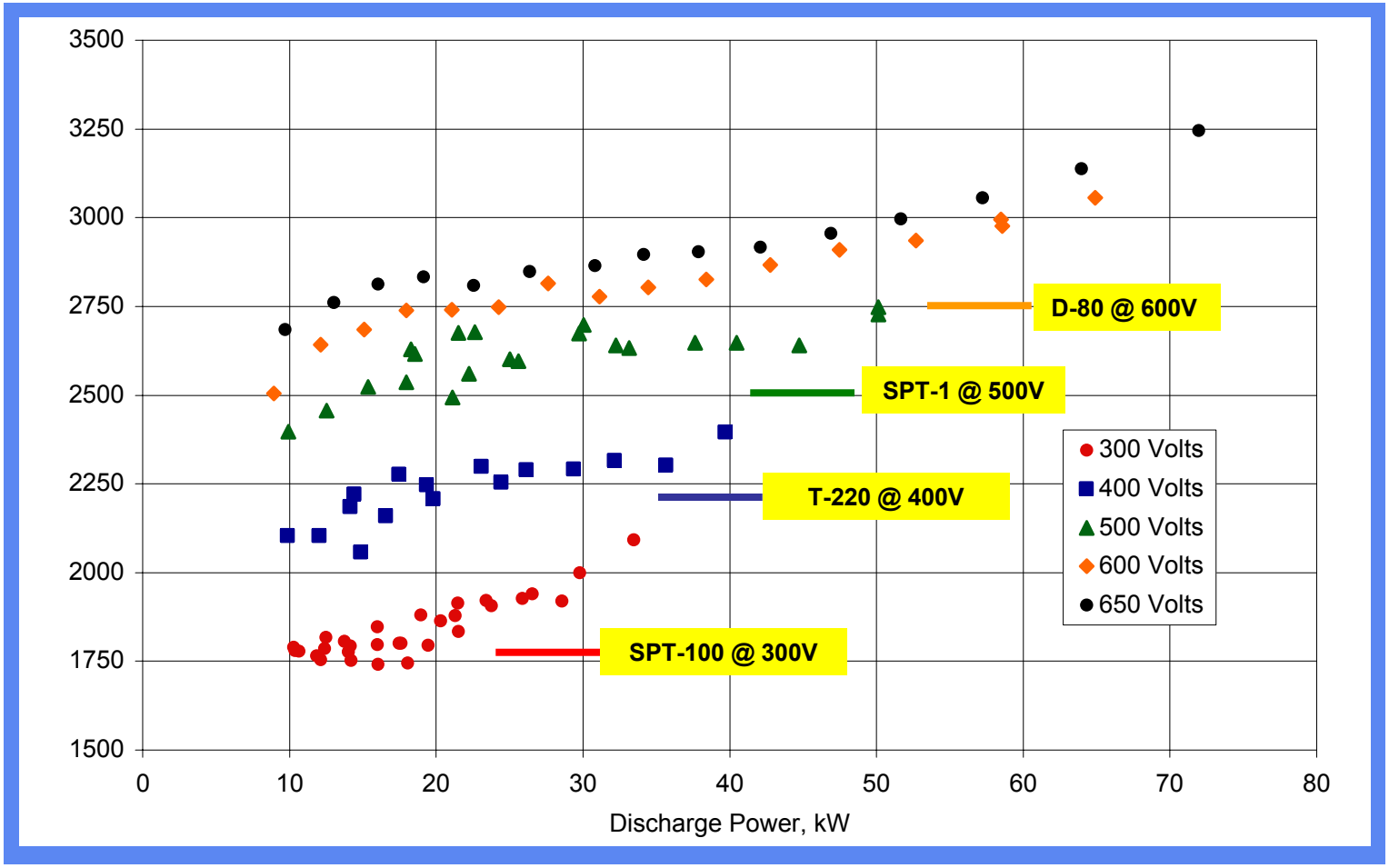


Thrust versus Power



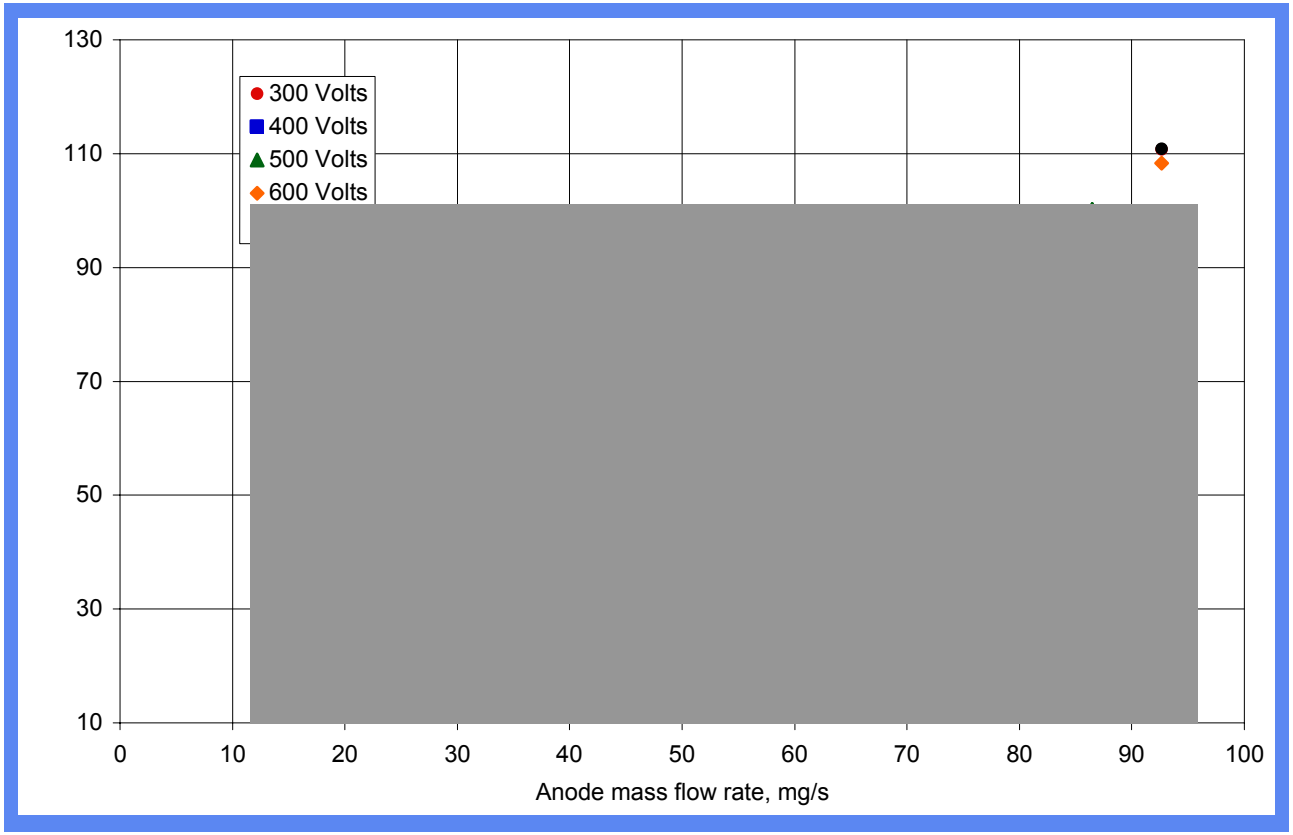
- **Maximum measured thrust: 2.9 N at 650 V & 111 A**
- **Voltage isolation problems at voltages > 650 V**
- **Higher powers possible (greater I and/or V)**

Anode Specific Impulse versus Power



- Specific Impulse compares favorably with other thrusters
- Performance benefit of increased current density

Discharge Current versus Anode Flow



Hofer 500V, 100 A predictions:*

Singly charged:
101 mg/s, 2.6N, 2622 s

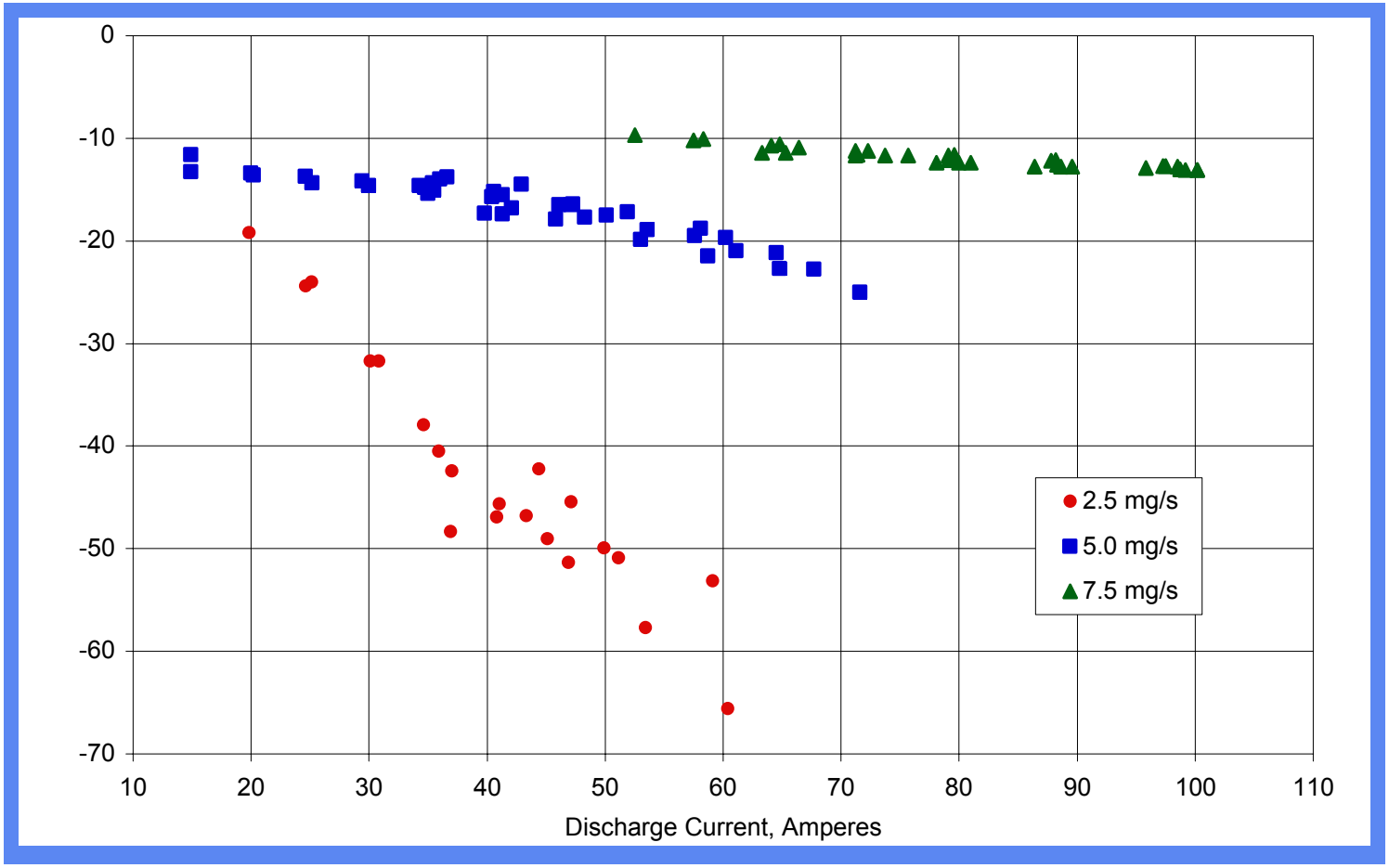
Multiple charged
89 mg/s, 2.4 N, 2768 s

Measured:
86 mg/s, 2.3 N. 2750

- **Linear dependence below 70 mg/s**
- **Increased current at higher flows primarily attributed to multiple charged ions**

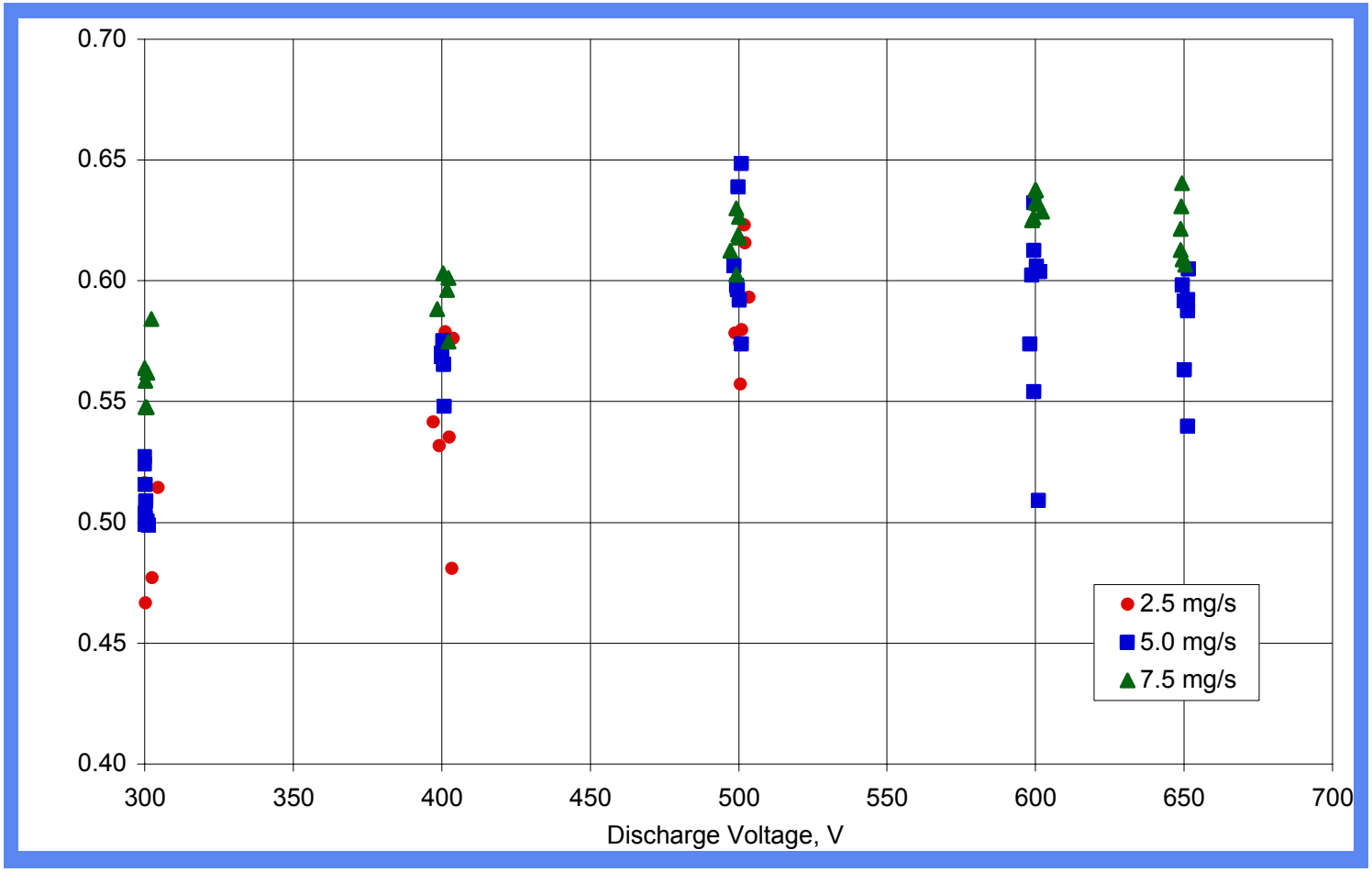
* Hofer, R. and Jankovsky, R., "A Hall Thruster Performance Model Incorporating the Effect of a Multiply-Charged Plasma," AIAA-2001-3322, July 2001.

Cathode-to-Ground versus Cathode Flow



- Cathode tests @ 2 mg/s with currents up to 100 A had voltages <15V
- Cathode-to-discharge coupling mechanism flow dependant
- Cathode flow rates 10% of anode provide desired voltages (> - 20 V)

Anode Efficiency versus Discharge Voltage



- Peak efficiencies at voltages of 500 - 600 Volts
- Increased cathode flow rate increased discharge efficiency
- Efficiency not optimized wrt cathode mass rate

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Summary

- A 50-kilowatt class laboratory model Hall thruster was designed, fabricated, and successfully tests at powers over 70 kW producing up to 2.9 N of thrust
- Thruster performance equal to or higher than smaller thrusters
- Performance at design point suggests multiple charged ions significant
- Efficient cathode coupling requires increased cathode flow