Development and Status of a 100-kW Class Laboratory Nested channel Hall Thruster

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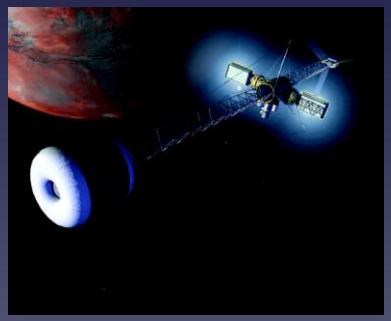
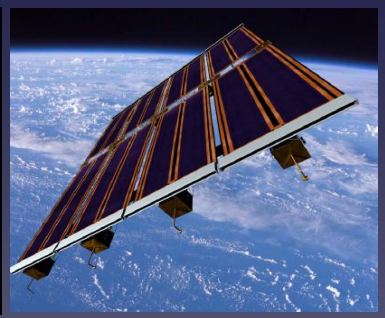
Overview

- Why high-power EP?
- Why Hall thrusters?
- Why NHTs?
- A 100-kW Class NHT
- Next Steps/Test Plan

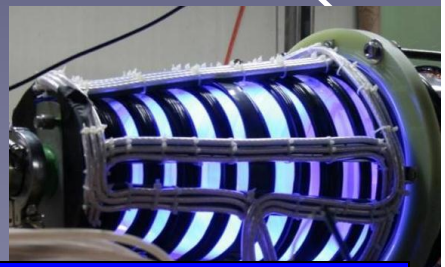
Why High-Power EP? (I)

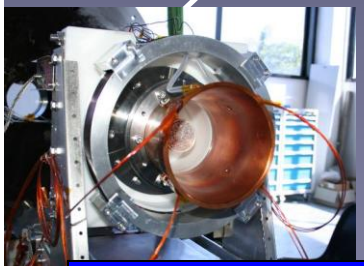




NASA Spacecraft

USAF-High T/P, expanded throttling





The ELF Thruster [1]

100 kW Class AFMPDT [2]

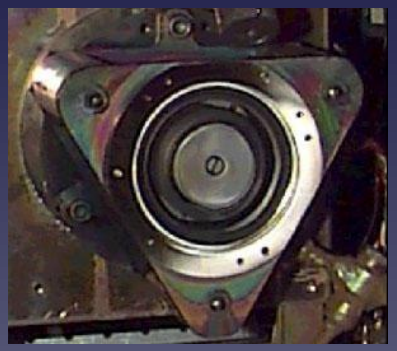
250-kW Class NHT

Multiple Missions

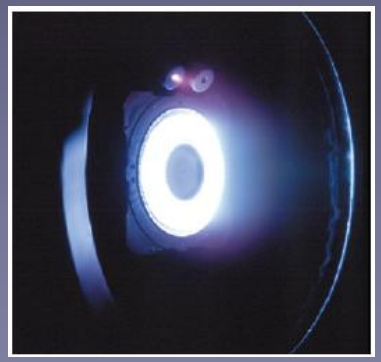
Distribution A: Approved for public release; distribution unlimited. PA Clearance Number 12610.

Why Hall Thrusters?

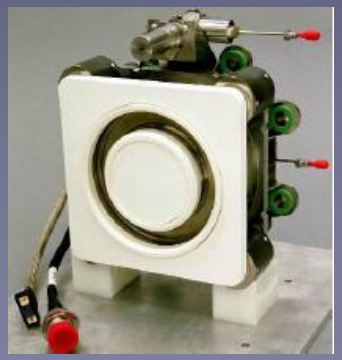
FAKEL SPT, 1972



TSNiiMASH D-55, 1998 [1]



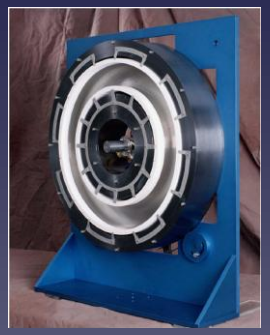
SNECMA PPs1350 2003 [2]



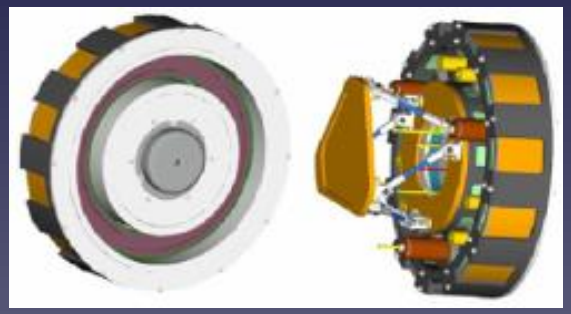
Aerojet BPT4000, 2008 [3]

Flight Heritage

Why Hall Thrusters?



NASA 457Mv1 [4]



NASA 457Mv2 [5]

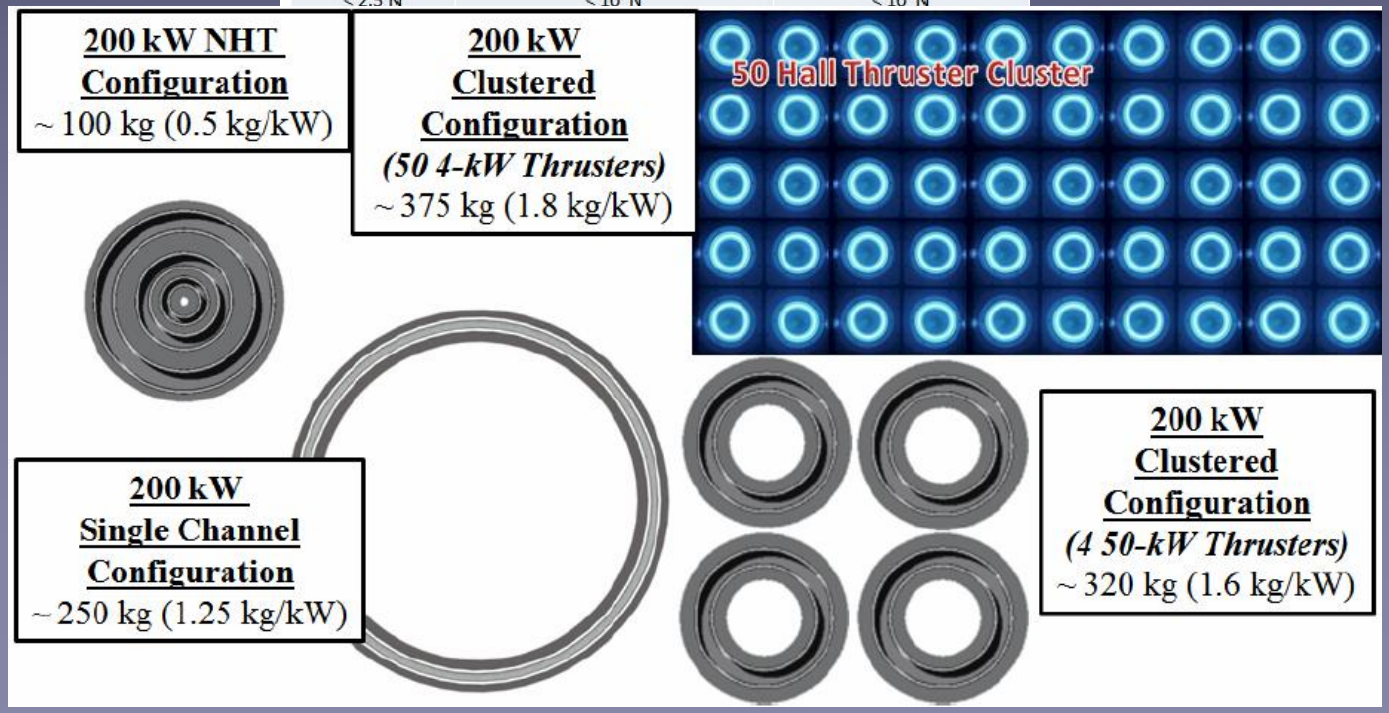
TSNiiMASH D-5 (D-160), 150 kW [4]

NASA 400M [5]

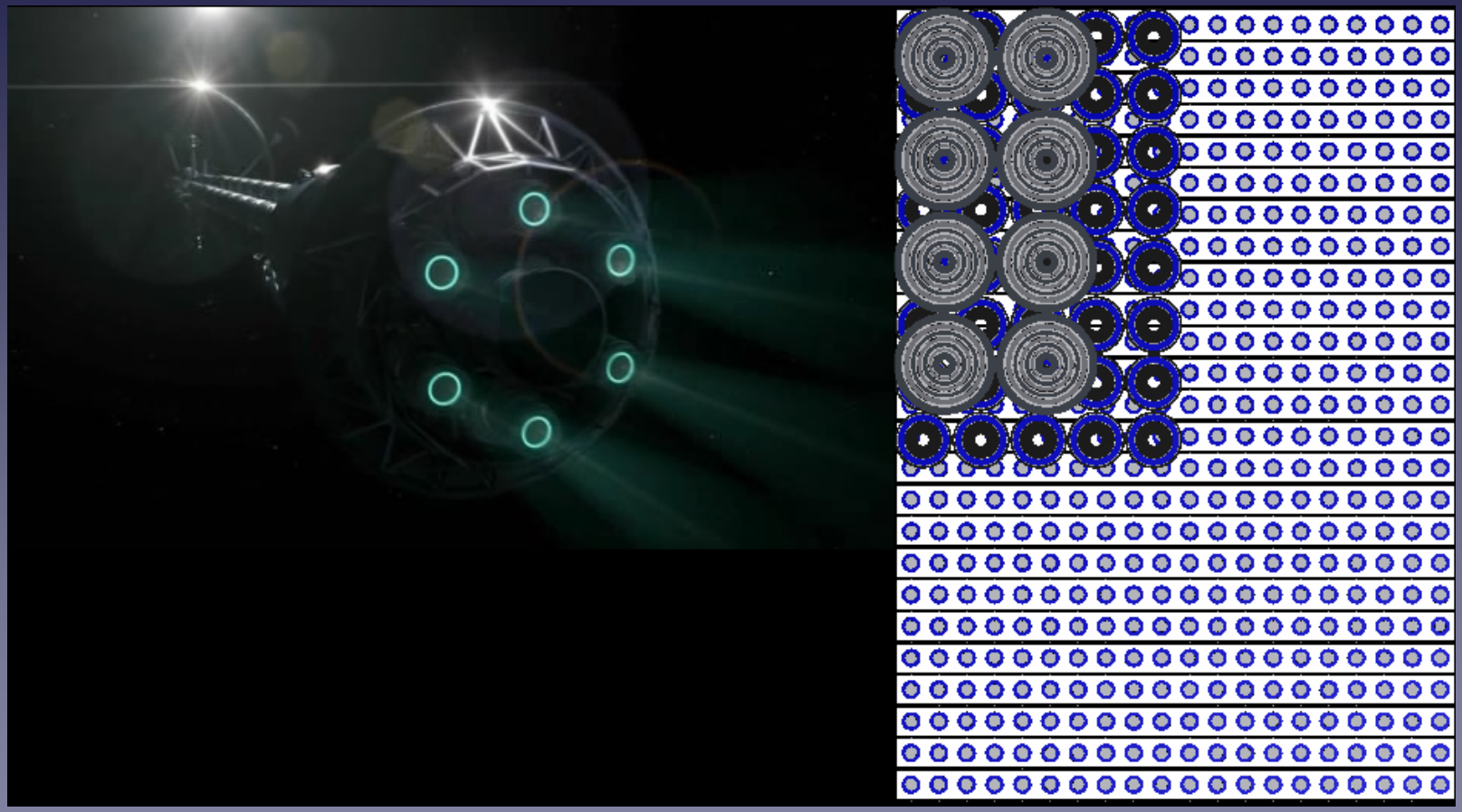
Demonstrated to high power (100 kW)

Advantages of NHTs (I)

50 kW Traditional Hall (1 Channel)	200 kW Traditional Hall (1-Channel)	200 kW Nested Hall (2-channels)
Isp ~ 1000 to 5000 sec. & Efficiencies up to 65%		
< 2.5 N	< 10 N	< 10 N



Advantages of NHTs (II)



Smaller Footprint

Distribution A: Approved for public release; distribution unlimited. PA Clearance Number 12610.

Advantages of NHTs (II)

Maximum Exit Area (Low ISP—High T/P operation)	ISP Range (1400s-3200s)	Medium Exit Area (Mid ISP operation)	ISP Range (2000s-3600s)	Minimum Exit Area (High ISP Operation)	ISP Range (2000s-4600s)
	Power Range		Power Range		Power Range
	30 kW-240 kW		20 kW–170 kW		10 kW-140 kW
			15 kW–120 kW		5 kW-90 kW
			10 kW-80kW		1 kW-50 kW

Enhanced Throttling Range

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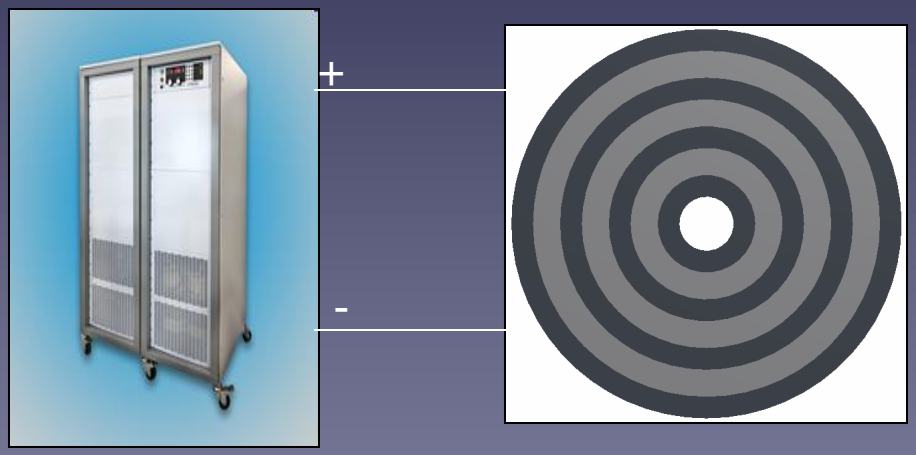
Advantages of NHTs (IV)

X2 NHT [7]



Simultaneous operation of all channels from single supply

Single PPU Operation

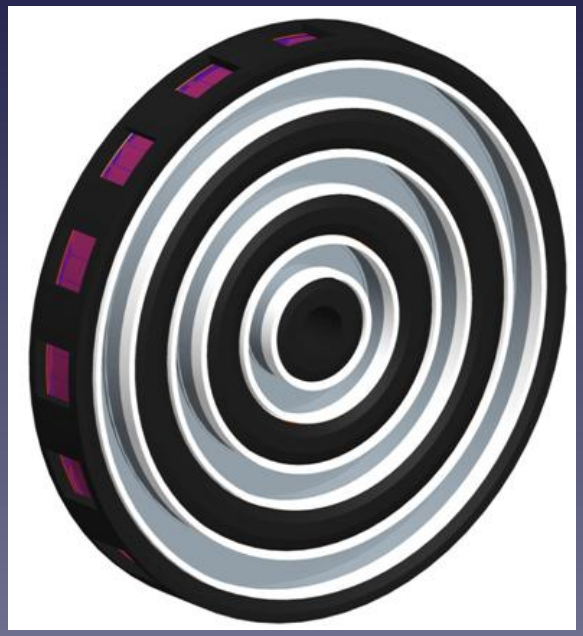
A 100-kW Class NHT-Introduction

100-kW NHT
Angled View (Front)

100-kW NHT
Angled View (Back)

Operating Range/Performance
Power Range: 1-200 kW
Thrust: 15 N(Xe)
ISP: 5,000 s (Kr)

X3 NHT Testing as a Benchmark (I)



Test	Facility	Power Range
Shakedown	PEPL LVTF	2-65 kW
Validation/High Power	GRC VF5	2-200 kW

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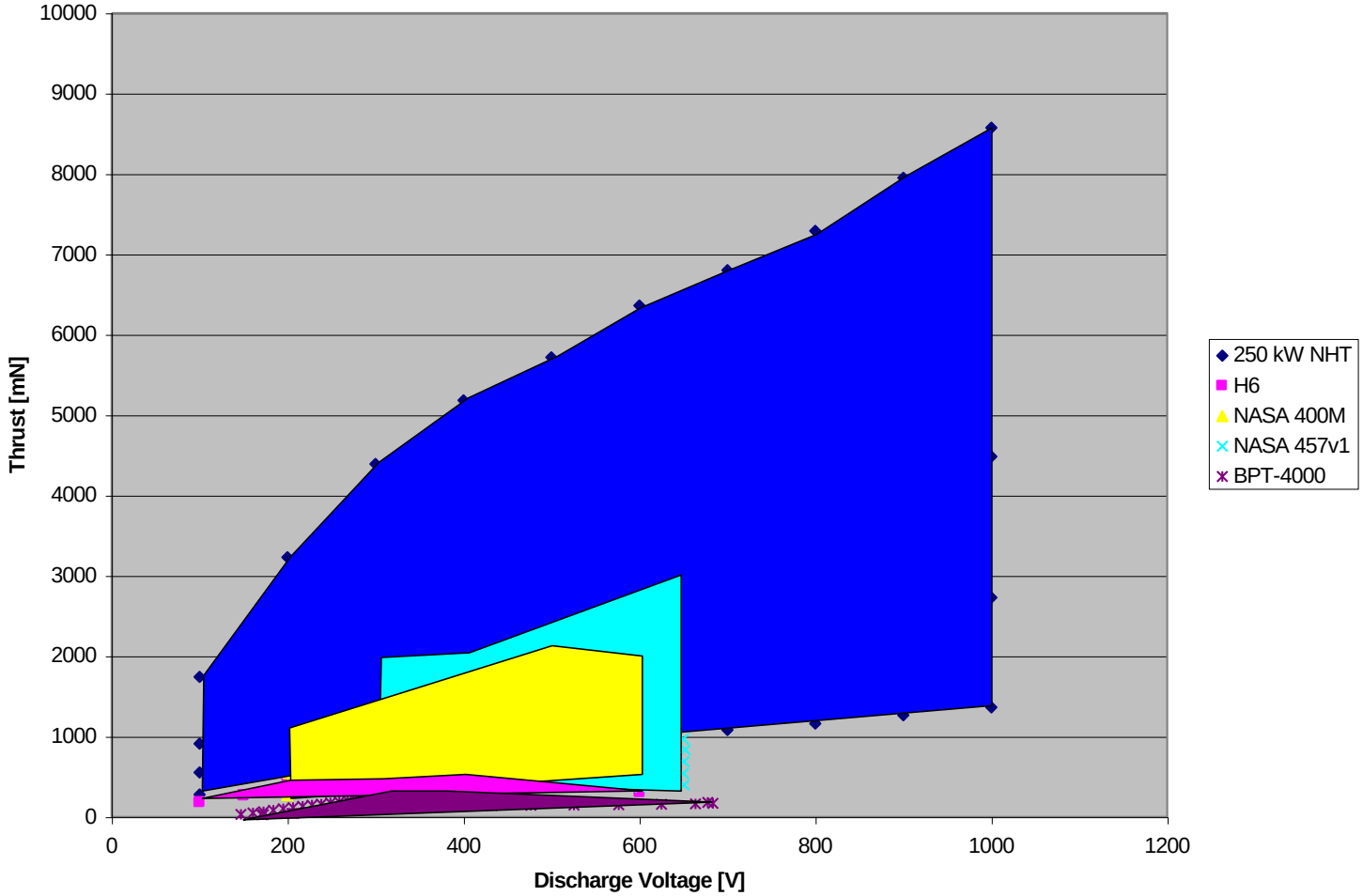
X3 NHT Testing as a Benchmark (II)



Projected Thrust of a 250-kW NHT based on and compared to existing Hall thrusters

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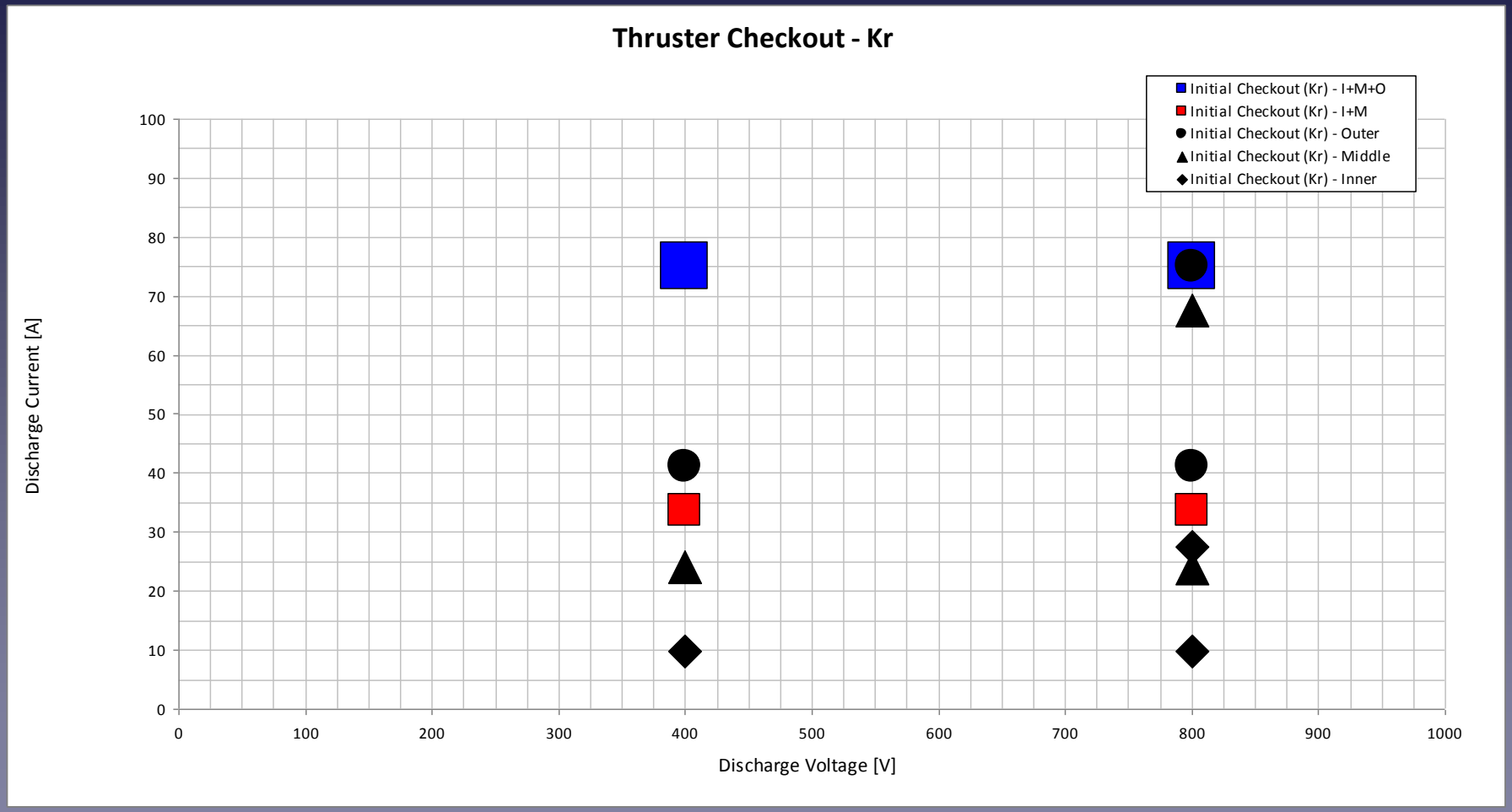
X3 NHT Testing as a Benchmark (III)



- Prior to main low-power test, Kr points to test assembly/connections
- Points NOT optimized, rough thruster settings only

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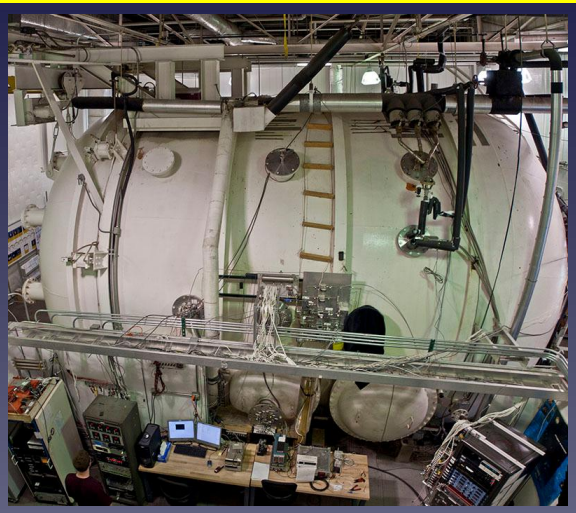
A 100-kW Class NHT-Preparation (I)



LVTF, PEPL

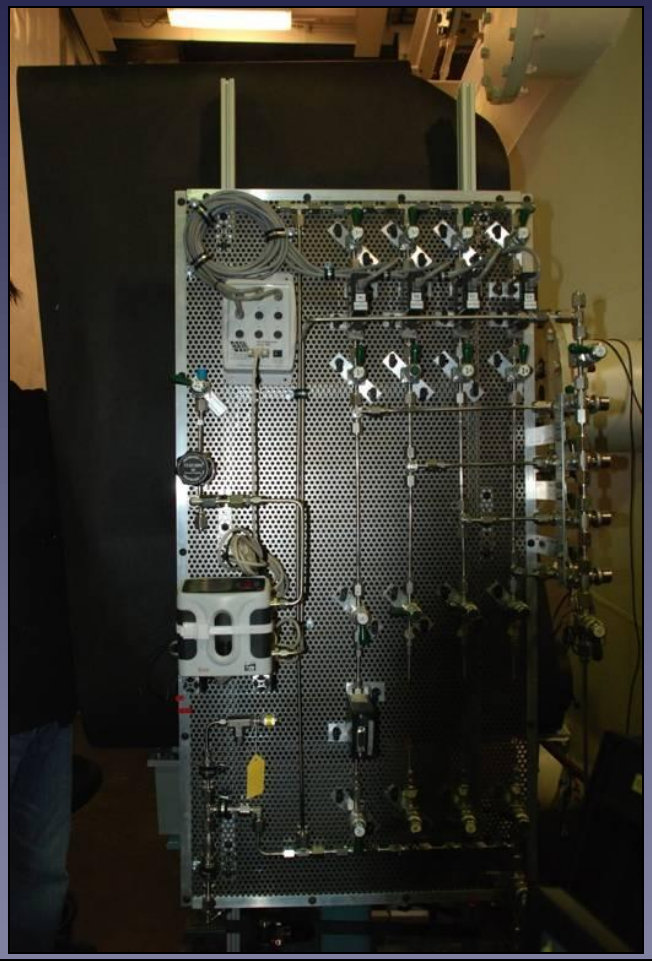
VF 5, NASA GRC

POWER SUPPLIES

Distribution A: Approved for public release; distribution unlimited. PA Clearance Number 12610.

A 100-kW Class NHT-Preparation (II)

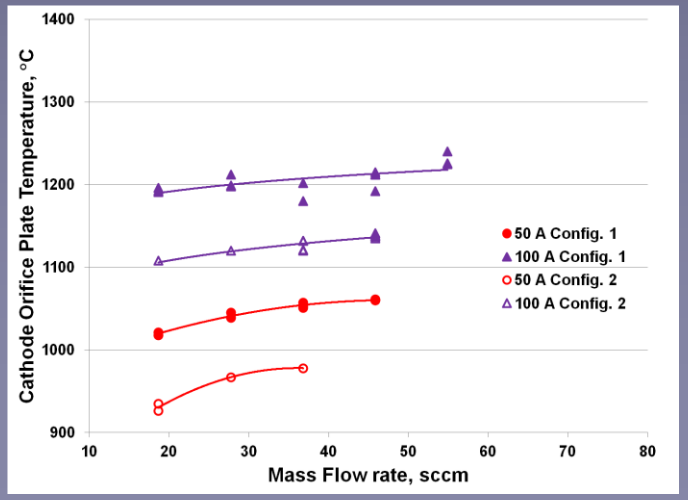
New Electrical Infrastructure (PEPL)



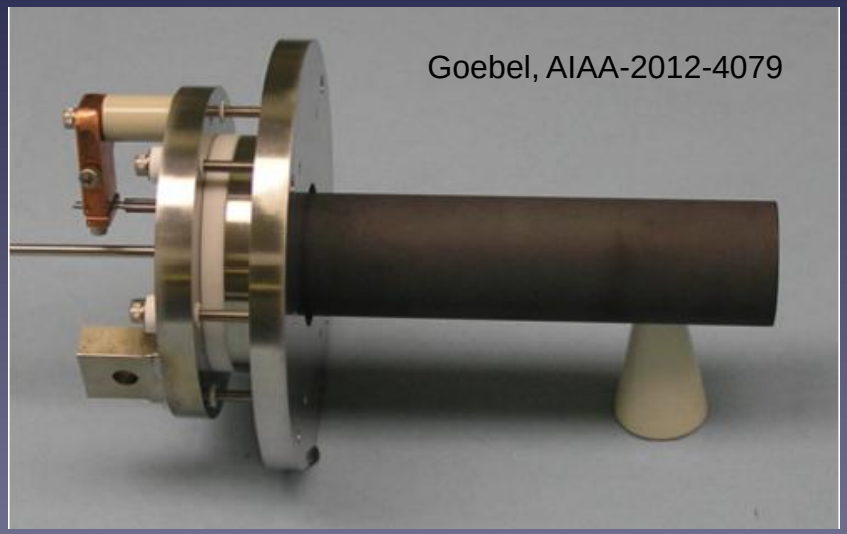
New Gas Feed Infrastructure (PEPL)

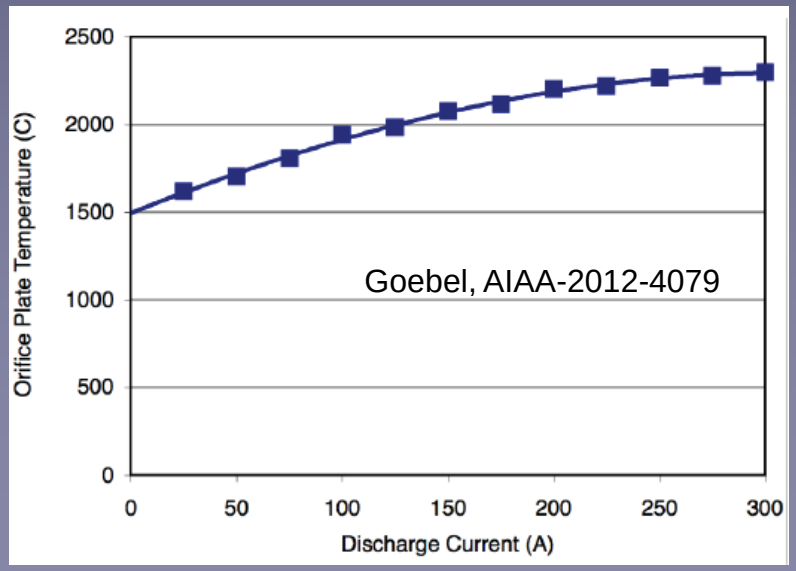
High Current Hollow Cathode Development at NASA Glenn and JPL

Porus Tungsten Impregnated Emitter NASA Glenn



LaB6 Emitter, JPL





A 100-kW Class NHT — Next Steps

-Production

->1/2 all major components fabricated

-Assembly

-Shakedown test

-Validation and high power test

References

[1] PEPL Thrusters: D-55 TAL , http://pepl.engin.umich.edu/thrusters/D55.html (July 2011)

[2] SNECMA Satellite Propulsion-Plasma Thrusters, http://www.snecma.com/-satellite-propulsion-.html?lang=en (July 2011)

[3] Hofer, R., Randolph, T., Oh, D., Snyder, J., and de, K., "Evaluation of a 4.5 kW Commercial Hall Thruster System for NASA Science Missions." AIAA-2006-4469, 42nd AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Sacramento, California, July 9, 2006.

[4] Jankovsky, R., Tverdokhlebov, S., and Manzella, D., "High power Hall thrusters." AIAA-1999-2949, 35th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Loss Angeles, CA, June 20, 1999.

[5] Jacobson, D., Manzella, D., Hofer, R., and Peterson, P., "NASA's 2004 Hall Thruster Program." AIAA-2004-3600, 40th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Fort Lauderdale, Florida, July 11, 2004.

[6] Busek Hall Effect Thrusters, http://www.busek.com/technologies__hall.htm

[7] Liang, R., and Gallimore, A., "Far-Field Plume Measurements of a Nested-Channel Hall-Effect Thruster." *AIAA-2011-1016*, 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, Orlando, Florida, January 4, 2011.

[8] Donahue, B., "Solar Electric and Nuclear Thermal Propulsion Architectures for Human Mars Missions Beginning in 2033." *AIAA-2010-6819*, 46th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Nashville, TN, July 25, 2010.

[9] Randolph, T., Dougherty, R., Oleson, S., Fiehler, D., and Dipprey, N., "The Prometheus 1 Spacecraft Preliminary Electric Propulsion System Design." *AIAA-2005-3889*, 41st AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Tucson, Arizona, July 10, 2005.