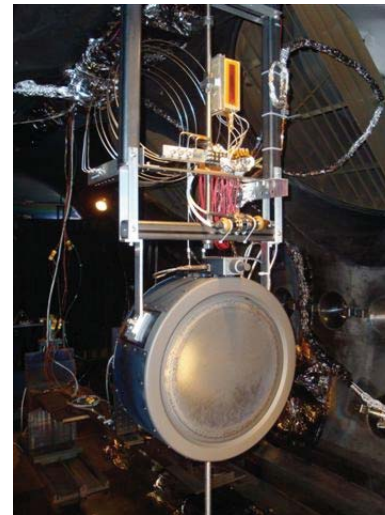
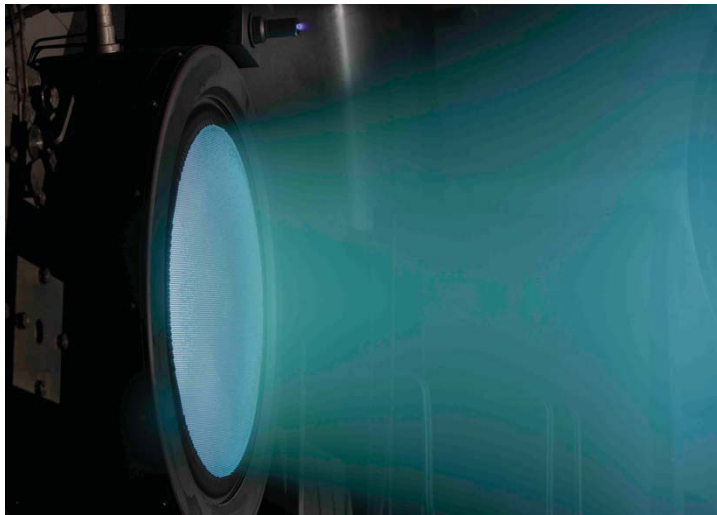




Recent Development Activities and Future Mission Applications of NASA's Evolutionary Xenon Thruster (NEXT)



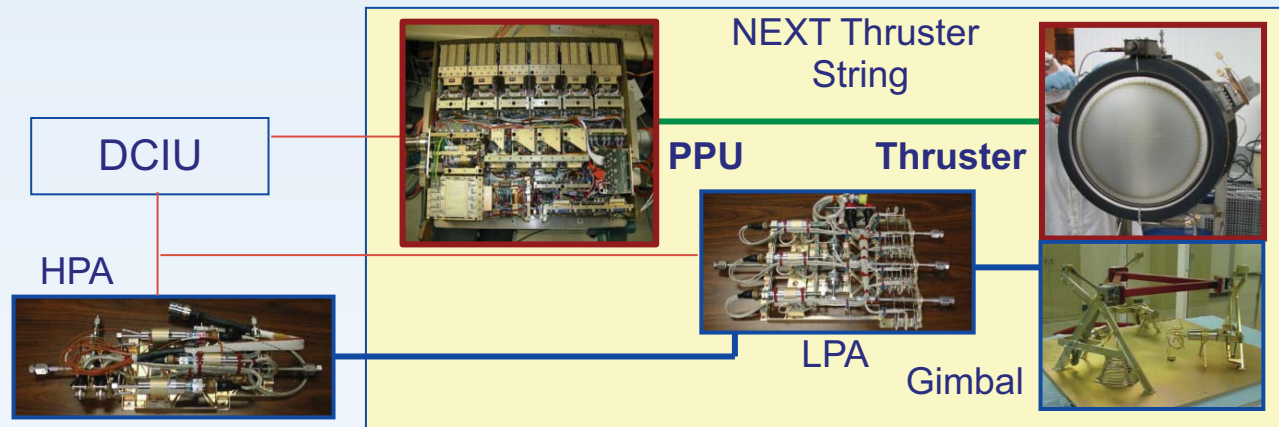
Michael Patterson and Eric Pencil
NASA Glenn Research Center

Space Propulsion 2014, Cologne, Germany
May 21, 2014

NASA's Evolutionary Xenon Thruster (NEXT)

Expanding SEP Applications For Science Missions

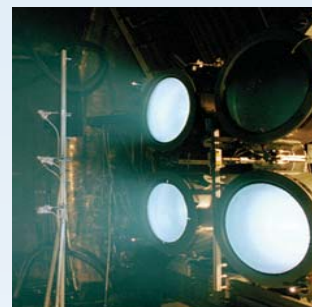
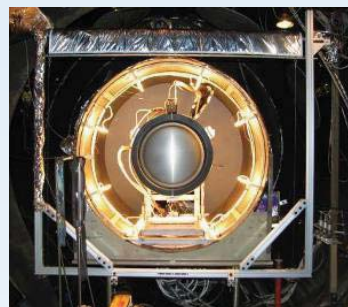
***Objective:** Improve the performance and life of gridded ion engines to reduce user costs and enhance/enable a broad range of NASA SMD missions*



- NEXT developed critical components for ion propulsion system, including:
 - thruster,
 - power processing unit (PPU),
 - xenon feed system (HPA/LPA),
 - gimbal, and
 - spacecraft computer interface (DCIU).

Characteristic300	NSTAR (SOA)	NEXT
Thruster Power Range (kW)	0.5= 2.3	0.5-6.9
Max. Thrust (mN)	92	236
Max. Specific Impulse (sec)	>3100	>4100
Max. Thruster Efficiency	>61%	>70%
Total Impulse (x10 ⁶ N-sec)	>5	35.5
Propellant Throughput (kg)	135	918
PPU Specific Mass (kg/kW)	6.0	4.8
PMS Single String Mass (kg)	11.4	5.0
PMS Unusable Propellant Residual	2.40%	1.00%

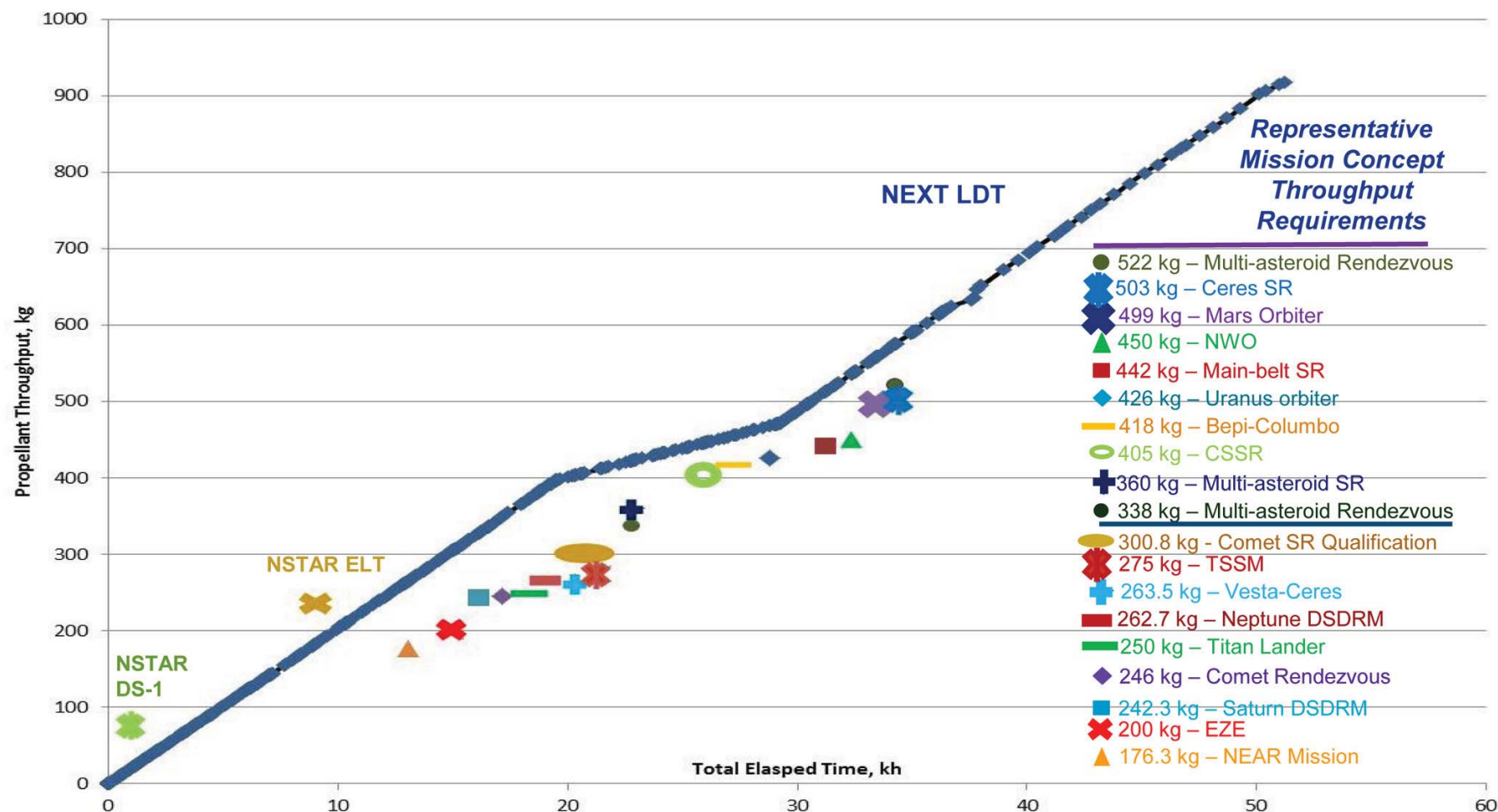
NEXT Mission Benefits & Applicability



CHARACTERISTIC	NSTAR (SOA)	NEXT	Improvement	NEXT BENEFIT
Max. Thruster Power (kW)	2.3	6.9	3x	Enables high power missions with fewer thruster strings
Max. Thrust (mN)	91	236	2.6x	
Throttling Range (Max. / Min. Thrust)	4.9	13.8	3x	Allows use over broader range of distances from Sun
Max. Specific Impulse (sec)	3120	4190	32%	Reduces propellant mass, enabling more payload and/or lighter spacecraft
Total Impulse (10^6 N-sec)	4.6	>35.5	>7x	Enables low power, high ΔV Discovery-class missions with a single thruster
Propellant Throughput (kg)	150	918	>4x	

* NOTE: NSTAR used on DS-1 and Dawn missions

NEXT Mission Benefits & Applicability



Equivalent Qualification Level: 612.1 kg
Original NEXT Design Goal : 300 kg

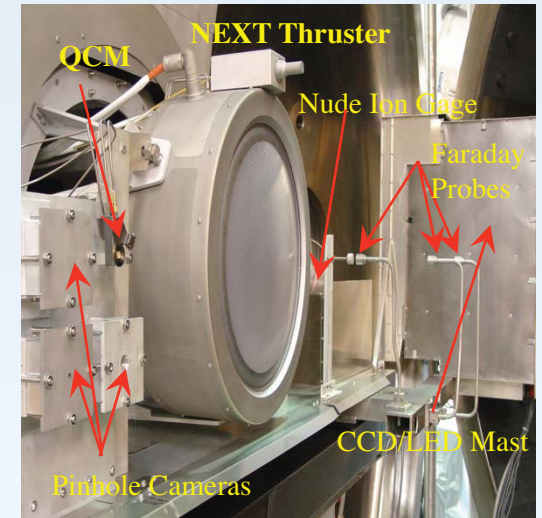
NEXT LDT Demonstrated (as of 3/28/2014): 918.2 kg
Original NEXT Qualification Requirement: 450 kg

NASA Glenn Research Center



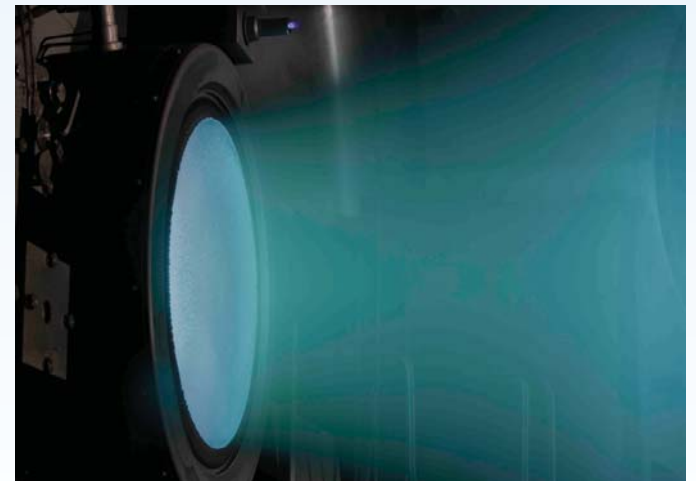
What the NEXT LDT Demonstrated in 9 yrs of Testing

- NEXT Long Duration Test (LDT) was voluntarily concluded on 1 April 2014.
 - End-of-test data with repaired and fully functional diagnostic suite was collected to compare with beginning-of-life data.
 - Post-test inspection and analysis is underway.
- The NEXT thruster exceeded design requirements.
 - Thruster throttled to a deep space mission profile.
 - Goal $\geq 450\text{Kg}$ qualification level propellant throughput
 - Operation characterized over a wide throttle table.
 - NEXT LDT sets Throughput & Duration World Records.
 - **51,200 hours** of operation
 - **918.2 kg Xenon** throughput
 - **35.5 MN-s of total impulse** delivered



What the NEXT LDT Demonstrated in 9 yrs of Testing

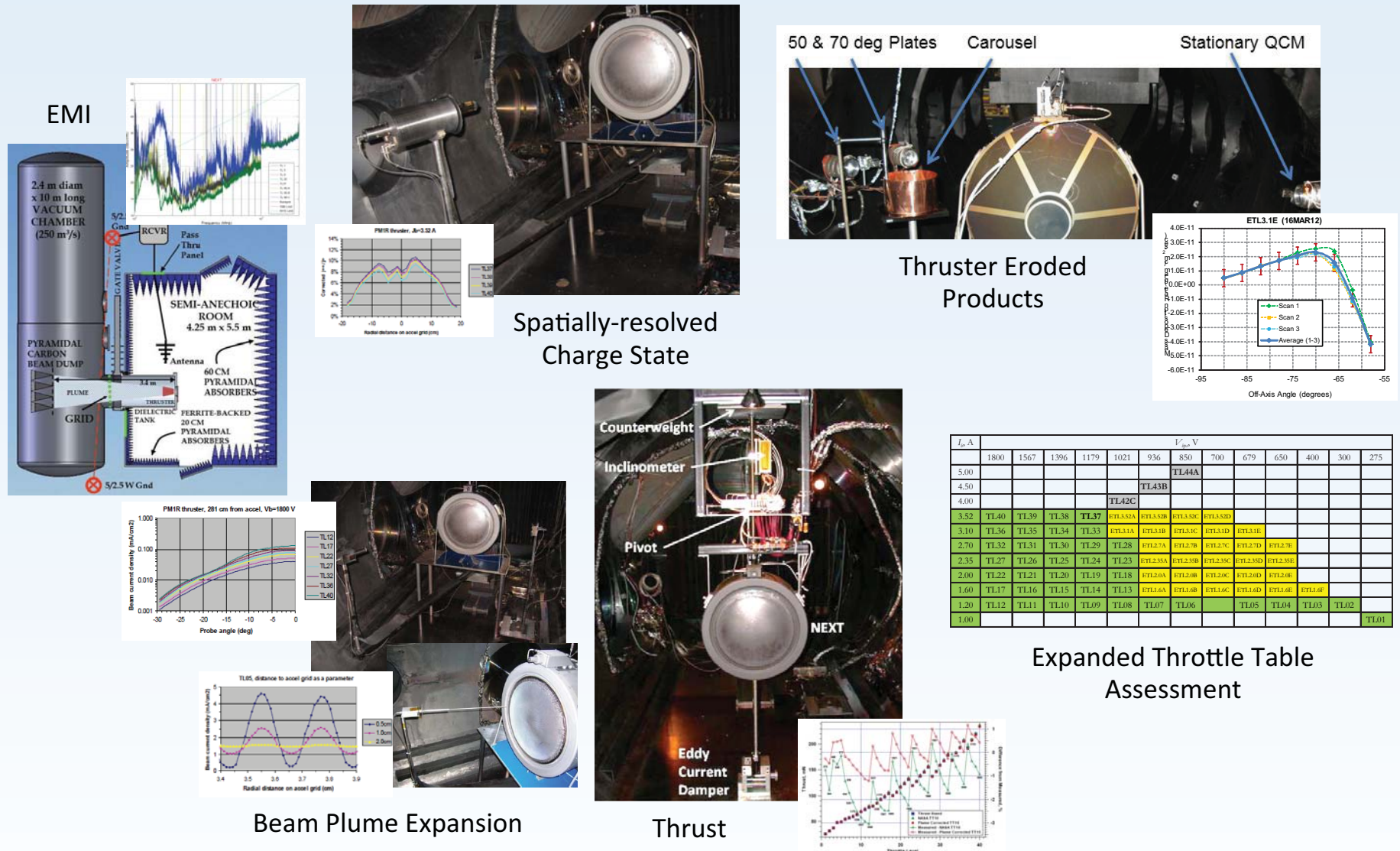
- LDT demonstrated that thruster life-limiting phenomena and wear mechanisms associated with ion thruster operations have been addressed in the NEXT design.
 - NEXT LDT post-test inspections/analysis will help confirm.
- LDT results improved models for future mission planning and operation.
 - Thruster wear rates were measured and compared with those predicted from life models.
- Initial carbon back-sputter and enhanced charge-exchange facility impact analyses completed.
 - Results will be updated with post-test inspection findings.



Joint Activities with The Aerospace Corporation

- Three year Space Act Agreement activity (2009-11) is followed by 24 months of contracted activity.
- Joint activities are providing independent, expert quantification of NEXT thruster interactions with host spacecraft.
 - Unique expertise, facilities and diagnostics
 - Assessing all key potential impacts to spacecraft systems
 - Extensive plume and thrust characterization
 - Optical emissions, microwave plume transmission
 - Erosion & deposition, eroded products measurements
 - EMI
- Joint activities are broadening exposure to DoD customers & spacecraft primes, and dramatically lowering technical risks to potential users.

Joint Activities with The Aerospace Corporation

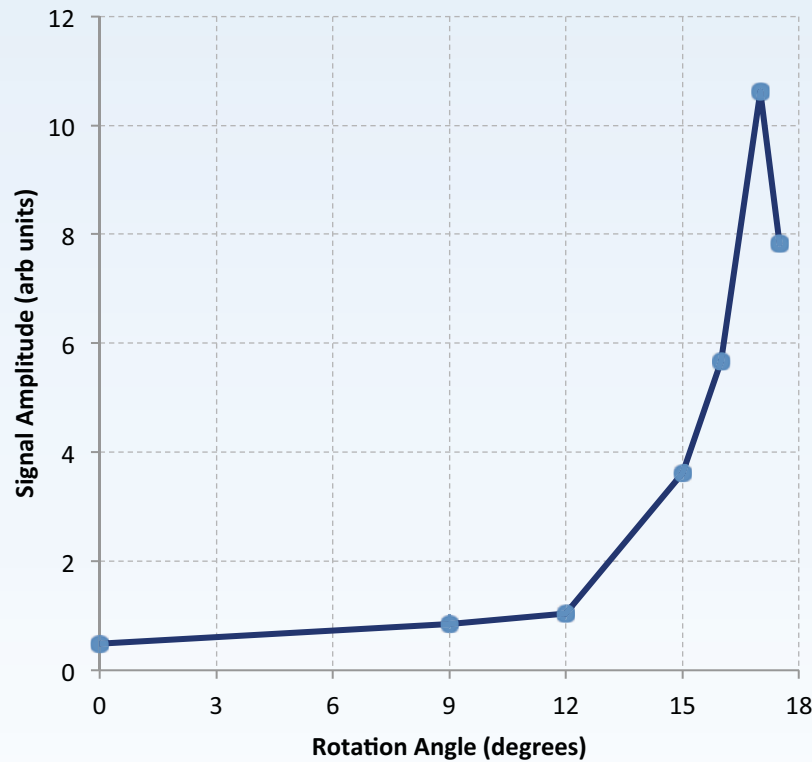


- Tests at the Aerospace Corporation have investigated many thruster aspects.

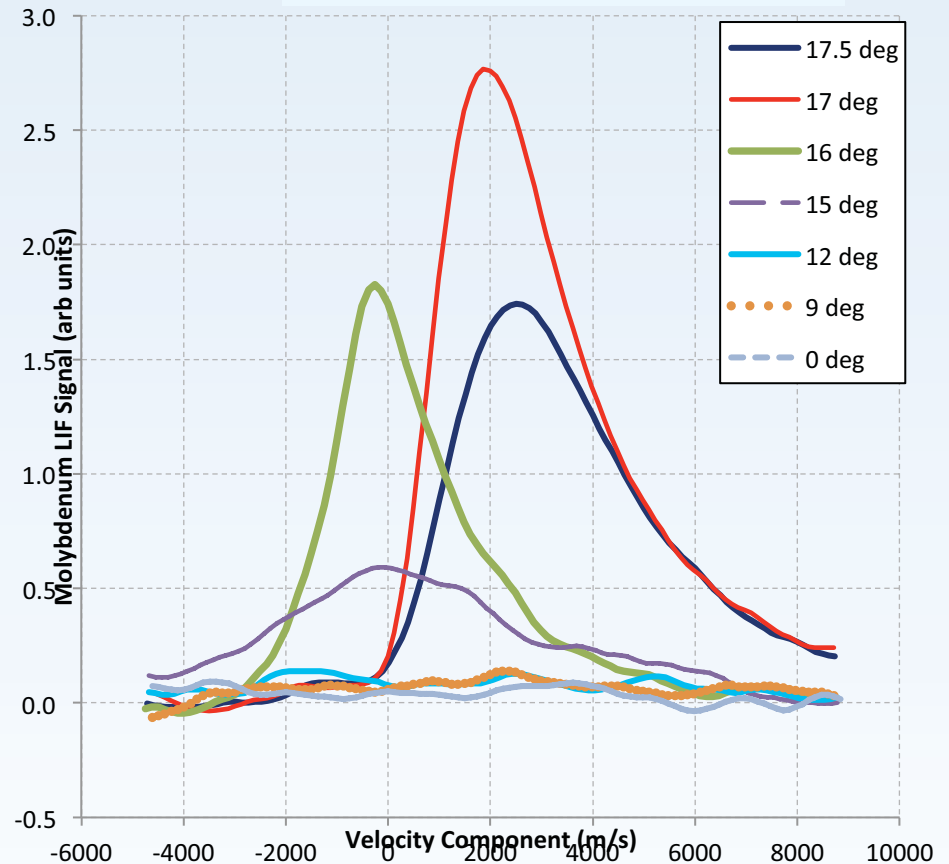
Joint Activities with The Aerospace Corporation

Laser Induced Florescence (LIF) measurements

High erosion at grid edge for TL12 throttle Level



Doppler profiles for TL12 confirm erosion pattern

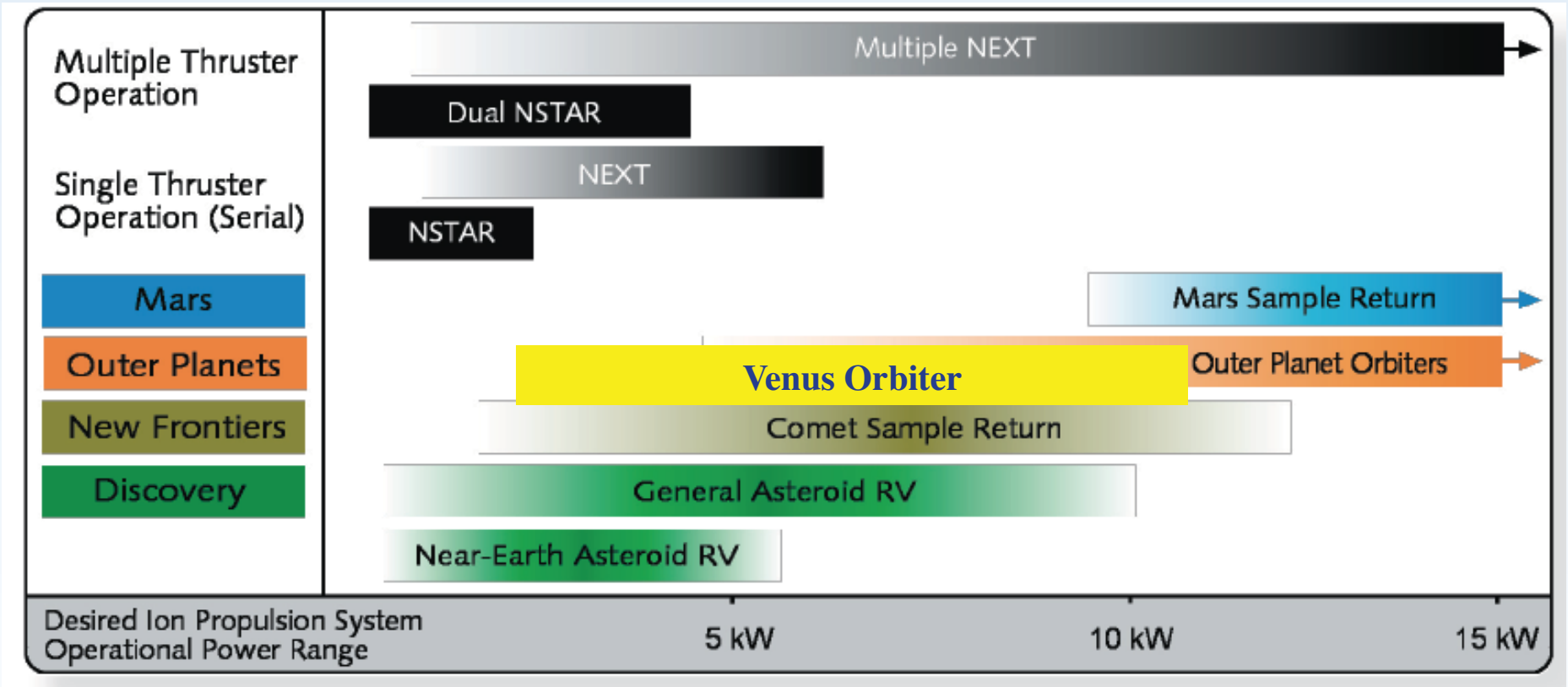


- Molybdenum grid erosion efflux detection by LIF demonstrated.
 - Measurements conducted across grid surface at multiple throttle conditions.

Future Mission Applications

- NEXT project will continue to support flight infusion opportunities.
 - NASA Science Mission Directorate (SMD) Discovery Announcement of Opportunity (AO) draft release is planned for May 2014.
 - NEXT Thruster and PPU are being offered as Government Furnished Equipment (GFE) for upcoming Discovery AO.
 - Industry hardware provider will be selected through an open competition.
 - Earth-orbit applications are being examined.
 - Extended throttle table conditions being characterized.
 - Higher thrust-to-power conditions can be achieved using existing hardware capabilities.
 - Studies for multiple mission applications will be conducted.
- NEXT hardware will be ready for future NASA SMD New Frontiers and Flagship mission opportunities.

International Planetary Missions and NEXT



- NEXT is a good propulsion option for many international missions.

Summary

- NEXT Long Duration Test has been concluded.
 - Thruster design exceeded expectations with record-setting demonstration of 900+ kg throughput over 51,000 hours of operation.
 - Post-test inspections and documentation are underway.
- Testing at the Aerospace Corporation has investigated many phenomena.
 - Molybdenum erosion efflux were characterized through LIF technique.
 - Plasma/thrust characterization over NEXT extended throttle table were made.
- NEXT will be provided as Government Furnished Equipment in the upcoming round of Discovery proposal call.
 - 2 NEXT thrusters and 2 NEXT PPUs will be provided at no cost to mission proposers.
- NASA investments in NEXT have expanded ion propulsion system capabilities for Planetary Science missions.