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

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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).

**Characteristics Comparison**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>NSTAR (SOA)</th>
<th>NEXT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thruster Power Range (kW)</td>
<td>0.5-2.3</td>
<td>0.5-6.9</td>
</tr>
<tr>
<td>Max. Thrust (mN)</td>
<td>92</td>
<td>236</td>
</tr>
<tr>
<td>Max. Specific Impulse (sec)</td>
<td>&gt;3100</td>
<td>&gt;4100</td>
</tr>
<tr>
<td>Max. Thruster Efficiency</td>
<td>&gt;61%</td>
<td>&gt;70%</td>
</tr>
<tr>
<td>Total Impulse (x10^6 N-sec)</td>
<td>&gt;5</td>
<td>35.5</td>
</tr>
<tr>
<td>Propellant Throughput (kg)</td>
<td>135</td>
<td>918</td>
</tr>
<tr>
<td>PPU Specific Mass (kg/kW)</td>
<td>6.0</td>
<td>4.8</td>
</tr>
<tr>
<td>PMS Single String Mass (kg)</td>
<td>11.4</td>
<td>5.0</td>
</tr>
<tr>
<td>PMS Unusable Propellant Residual</td>
<td>2.40%</td>
<td>1.00%</td>
</tr>
</tbody>
</table>
## NEXT Mission Benefits & Applicability

![Image 1](image1.png) ![Image 2](image2.png)

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>NSTAR (SOA)</th>
<th>NEXT</th>
<th>Improvement</th>
<th>NEXT BENEFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Thruster Power (kW)</td>
<td>2.3</td>
<td>6.9</td>
<td>3x</td>
<td>Enables high power missions with fewer thruster strings</td>
</tr>
<tr>
<td>Max. Thrust (mN)</td>
<td>91</td>
<td>236</td>
<td>2.6x</td>
<td></td>
</tr>
<tr>
<td>Throttling Range (Max. / Min. Thrust)</td>
<td>4.9</td>
<td>13.8</td>
<td>3x</td>
<td>Allows use over broader range of distances from Sun</td>
</tr>
<tr>
<td>Max. Specific Impulse (sec)</td>
<td>3120</td>
<td>4190</td>
<td>32%</td>
<td>Reduces propellant mass, enabling more payload and/or lighter spacecraft</td>
</tr>
<tr>
<td>Total Impulse (10⁶ N·sec)</td>
<td>4.6</td>
<td>&gt;35.5</td>
<td>&gt;7x</td>
<td>Enables low power, high ΔV Discovery-class missions with a single thruster</td>
</tr>
<tr>
<td>Propellant Throughput (kg)</td>
<td>150</td>
<td>918</td>
<td>&gt;4x</td>
<td></td>
</tr>
</tbody>
</table>

*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
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 >450Kg 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.

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Joint Activities with The Aerospace Corporation

Laser Induced Florescence (LIF) measurements

High erosion at grid edge for TL12 throttle Level

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

Doppler profiles for TL12 confirm erosion pattern

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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.
• 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.