NEXT Single String Integration Tests in Support of the Double Asteroid Redirection Test Mission

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DART Mission

• Demonstrate kinetic impactor deflection of a representative threat asteroid

• A controlled impact experiment to increase confidence of kinetic impact predictions and improve understanding of asteroid physical properties and high speed collisions

• Binary target allows measurement of deflection by ground-based observatories

• The primary launch period extends from 22 July to 11 August 2021

• DART will launch on a SpaceX Falcon 9 from Vandenberg Air Force Base

• The arrival dates vary from 30 September to 02 October 2022, optimized to achieve the impact geometry requirements
NEXT Use on DART Mission

- Once the NEXT system has been checked-out, the DART mission will use it for TCMs and then exercise it using several “neutral burns”
  - the burn has the objective of demonstrating NEXT-C without risking the ballistic impact
  - NEXT will be operated for a total of ~ 1400 hours

- The neutral burns are achieved by pointing DART’s +X axis to the Sun and rotating about the Sun-line with a 12 hour period
  - Over the full period, the induced orbit change integrates to nearly zero change in velocity
  - Fixes spacecraft geometry (solar arrays locked)
  - Gives consistent low-gain-antenna gain to Earth
  - Given its constant attitude state, it requires little propellant for attitude control

- At any point, if NEXT-C thruster is turned off, the original impact conditions can be recovered for < 3.5 m/s with a TCM
Test Objectives

• Evaluate system performance across anticipated DART flight conditions

• Characterize drift in thrust vector across Xe flow envelope

• Demonstrate functionality and fault detection of command and data handling system

• Provide baseline PPU/thruster for flight hardware tests (fall 2019)
Test Matrix

- Tests conducted at a beam current of 2.70 A, at three different voltage levels

<table>
<thead>
<tr>
<th>Test Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPU Baseplate Temperatures</td>
<td>-24 °C, 40 °C, 55 °C</td>
</tr>
<tr>
<td>Propellant Flow Rates</td>
<td>Main: +7% and -5% of nominal flow value</td>
</tr>
<tr>
<td></td>
<td>Disch. Cathode: +/- 6% of nominal flow value</td>
</tr>
<tr>
<td></td>
<td>Neut. Cathode: +21% and -6% of nominal flow value</td>
</tr>
<tr>
<td>PPU High Power Bus Input Voltages</td>
<td>80 V, 100 V, 125 V</td>
</tr>
<tr>
<td>PPU Low Power Bus Input Voltage</td>
<td>28 V</td>
</tr>
<tr>
<td>Throttle Levels</td>
<td>DETL2.7A, DTL28, DTL29</td>
</tr>
</tbody>
</table>
Test Setup
Thruster Performance

- Thruster performance invariant with high/low input power bus PPU voltages, PPU baseplate temp.
- Performance in-family with risk reduction data obtained with EM4 engine and commercial power supplies
Thrust Vector Behavior at Various Throttle Levels

- Thrust vector varies by less than 0.2 deg. across all DART operating conditions
  - within the uncertainty of the measurement
Thruster Behavior During Automated Start-up

• Several parameters of interest with regards to thruster performance/life:

1. Discharge voltage, $V_d$
2. Discharge current, $J_d$
3. Beam current, $J_b$
4. Accelerator current, $J_a$
5. Coupling voltage, $V_g$
SWIL Simulator Performance
PPU Efficiency at Various Throttle Levels

- PPU efficiency > 90% at all conditions, increased performance at colder temps. and lower input voltages
Summary

• Single string integration test was conducted across anticipated DART flight conditions

• Test included demonstrations of system performance, functionality, and fault handling

• Thruster performance was in-family with prior NEXT data
  - minimal variations in thrust vector across different operating conditions

• SWIL simulator successfully executed DART flight algorithms and captured fault sequences

• PPU efficiency > 90% at all conditions, increased performance at colder temps. and lower input voltages

• Overall tests was successful, results fed into the development of the flight build of software