Flight Testing of a Low-Cost De-orbiting Device for Small Satellites

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• >21,000 objects larger than 10cm being tracked by U.S. Space Surveillance Network

• NASA Specification NASA-STD-8719.14
  - All new satellites must have known re-entry plan
  - 25 years until atmospheric reentry
RODEO
Roll-Out DE-Orbiting devices

Stowed RODEO Modules

Stowed

Deployed

Key Technology is Rolled Composite Boom
- Multifunctional
- High Specific Stiffness
- Simple & Reliable; few moving parts
Concept of Operations

- Inside the RODEO™ housing is a very simple electronic circuit board and battery. The board only has two inputs and a ground wire.
  - The first input is to initiate a commanded release by supplying spacecraft voltage.
  - The second input supplies a very small trickle charge to the battery and resets a timer circuit so that RODEO™ will remain stowed. However, if the spacecraft loses functionality and stops supplying the trickle charge, the timer circuit initiates and begins counting. After a pre-determined period of time with no trickle charge supplied, the timer circuit executes an automatic command to deploy the RODEO™ drag sail.

- Once the command to deploy is sent (either manually or via the timer circuit) an internal hot wire will release the spring-loaded hinged door, and the RODEO™ de-orbit wing will deploy.
  - Deployment occurs via the single-degree of freedom composite roll-out boom that is restrained by the hinged door of the RODEO™ canister.
CTD has developed a family of boom configurations that can meet most mission needs

- **Size**
  - 0.25” to 10” diameter
  - Up to 75ft (22m) in length

- **Architecture**
  - Open, overlapped, Slit-lock, zipper

- **Deployment method**
  - SMP, motorized, strain energy driven
# Sizing Analysis Summary

<table>
<thead>
<tr>
<th>System</th>
<th>Satellite Mass (kg)</th>
<th>RODEO Area*</th>
<th>25 years</th>
<th>5 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>3U CubeSat</td>
<td>6.00</td>
<td>0.150 m²</td>
<td>1.16 m²</td>
<td></td>
</tr>
<tr>
<td>Nanosatellite</td>
<td>15.0</td>
<td>0.526 m²</td>
<td>3.23 m²</td>
<td></td>
</tr>
<tr>
<td>ESPA-Class Small Satellite</td>
<td>100</td>
<td>3.74 m²</td>
<td>27.85 m²</td>
<td></td>
</tr>
</tbody>
</table>

*Assumed no other deployables; Random tumbling; Orbital Eccentricity = 0; Orbital Inclination 27 deg.
## RODEO Mass & Volume

<table>
<thead>
<tr>
<th>Satellite</th>
<th>RODEO Performance Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stowed Volume</td>
</tr>
<tr>
<td>3U CubeSat (6kg)</td>
<td>140 cm³</td>
</tr>
<tr>
<td>Nanosatellite (15kg)</td>
<td>175 cm³</td>
</tr>
<tr>
<td>Small Satellite (100kg)</td>
<td>270 cm³</td>
</tr>
</tbody>
</table>
RocketSat-8 Flight Experiment

- Eighth RocketSat student project at the Colorado Space Grant Consortium (COSGC) since the program began in 2006
- Sub-orbital rocket launched out Wallops Flight Facility in August 2012
- Launch achieved 180 seconds of stable microgravity at an altitude of approximately 160 km
Flight Configuration

- Flight configuration provides 0.15m²-
  - Sufficient area to de-orbit a 3U CubeSat in 25 years
- Three wings 120° apart provide area in multiple planes
- Wings wrapped around to one side of boom for stowage
Deployment Video
Flight Test

• Full deployment achieved
• Deployment was off-nominal
  - Moisture absorption due to extended exposure (a few weeks) to extremely high humidity prior to launch
  - Would not be an issue for orbital flight
Recent Improvements

- Alternative polymer matrix used in composite boom
  - Higher glass transition temperature
  - Low moisture absorption and reduction of moisture-induced effects

- Incorporation of Slit-Lock™ for improved stiffness and stability

- Root-rolled instead of tip-rolled boom design
  - Both motor-driven and strain-energy driven designs demonstrated
Slit-Lock™

- Results in a closed cross-section that improves performance
- Significantly increases bending & torsional stiffness/stability
- Edge features interlock upon deployment and remain engaged over all temperature ranges & loading cases
- Design provides a positive closing force at seam during the entire deployment
- Notches are “keyed” in the deployment mechanism to prevent “blooming”, provides precise rate control and enables high axial loads to be driven into boom

US Patent #8,863,369
Prototype Hardware

• Prototype has been fabricated
  - 0.5” diameter, 1.5m long
  - Incorporates Slit-lock
  - Motor driven
  - 175g, 3” x 2.5” x 1.5” envelope

• Technology can be used for a wide range of applications
  - Deployment actuator and structure for solar array, solar sail, drag sail, etc.
  - Gravity gradient boom
  - Instrument boom
  - Etc.
Conclusions

• Most responsible and pro-active way to mitigate orbital debris is to incorporate a de-orbiting device

• RODEO leverages lightweight, morphing composite structures to enable a low cost, proven, de-orbit solution

• RODEO deployed successfully from a sounding rocket as part of the Rocket-Sat X flight experiment
  - Off-nominal deployment caused by moisture saturation, would not be an issue for orbital flight

• Deployable boom technology is being improved upon and can be used for a wide range of applications

• Please come by CTD’s booth (#50) at SmallSat conference to see some cool hardware!