The Story of a High Strain Composite Tip-Rolled De-Orbit Sail

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The Orbital Debris Problem

The severity of this problem is only growing

https://www.orbitaldebris.jsc.nasa.gov
Existing De-Orbit Systems

1. Propulsion
2. Drag Devices
3. Others

- Chemical / Electric
  - Membrane Sails
  - Tethers
    - Electrodynamic
- Inflatables
  - Spacecraft Body
  - Wrapped Boom
  - Root Rolled Boom
  - Root Articulated Boom

- Others
  - MMA: Dragnet
  - AFRL: FURL
  - NASA: ECHO
  - Canfield/SSTL: TechDemoSat-1
  - JAXA: IKAROS
  - Spin Deployed (No Booms)
Origin of ROC-FALL

• Roccor was approached to design and implement a de-orbit system
  » 140kg ESPA class spacecraft, BOL ~750km
  » Deploy 4m² of projected surface area
  » Interface with a mature spacecraft system,
    - Little leeway for envelope changes

• Drag Sail Strategy:
  » Has to be low risk:
    - Utilize COTS / legacy hardware
    - Minimize moving parts
    - Incorporate high sail robustness
  » Ensure a stand-alone system
    - Simply bolt hardware onto spacecraft
Roccor and High Strain Composite Materials

High Strain Composites (HSC)
Thin-gage flexible composites to replace traditional mechanical-based systems:

- Tailored mechanical properties meeting deployed-state requirements
- Substantially reduced-part count vs. traditional mechanical-based systems
- Low-cost manufacturing
The ROC-FALL System

• Utilize a co-wrapped boom and structural sheet

  » Strain energy deployment, HSC enables controlled roll-out
  » Restrained with a single release band, deployed via TiNi actuator
  » Rigid sail, no lateral support needed and robust to tearing
Existing De-Orbit Systems

1. Propulsion
2. Drag Devices
3. Others

- Tethers
- Inflatables
- Sheet Sails
  - Tip Rolled HSC Boom

Chemical / Electric

- Membrane Sails
- Spacecraft Body Wrapped Boom
- Spin Deployed (No Booms)

Root Rolled Boom
Root Articulated Boom

Tethers Unlimited Terminator Tape
NASA: ECHO
Roccor: ROC-FALL

AFRL: FURL
MMA: Dragnet
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Flight Build of ROC-FALL
Lessons Learned

• Demonstrated a simplistic deployable drag architecture
  » Design passed flight qualification testing, (vibe & thermal)
  » Two units currently integrated into spacecraft
  » Technology reviewed by FCC

• Working with High Strain Composites
  » Advanced a new space application for HSCs
  » System challenges identified:
    - Susceptibility to stress relaxation and need to fully characterize laminate arch.
    - Need for inspections to ensure clean bill of health
What’s Next?

• Lets keep mitigating space debris!
  » Please consider the ROC-FALL architecture in future de-orbit mitigation trades

• One fundamental solution to orbital debris mitigation is ensuring a robust portfolio of viable drag systems

Roccor: ROC-FALL, 4m²

Roccor: Root Rolled 1000m² Sail (under dev.)