TechEdSat 7,10,13,15:

EXO-BRAKE EXPERIMENTS ON THE ISS, FIRST VIRGIN ORBIT, AND FIRST FIREFLY-ALPHA TEST FLIGHTS

NOW The Nano Orbital Workshop

Rapid Flight Development Group

NASA SILICON VALLEY

AMES RESEARCH CENTER

SPACEFLIGHT DIVISION NASA AMES RESEARCH CENTER

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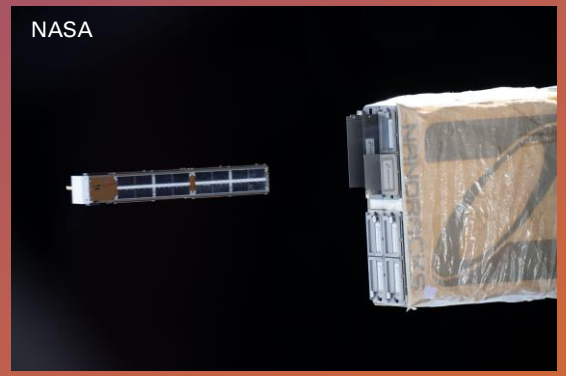
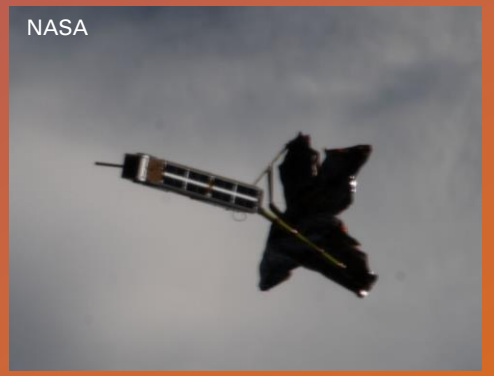
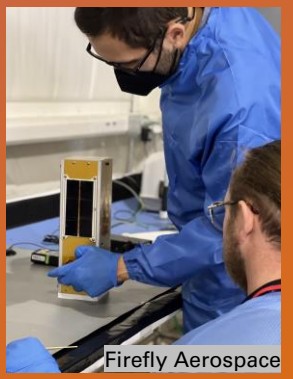
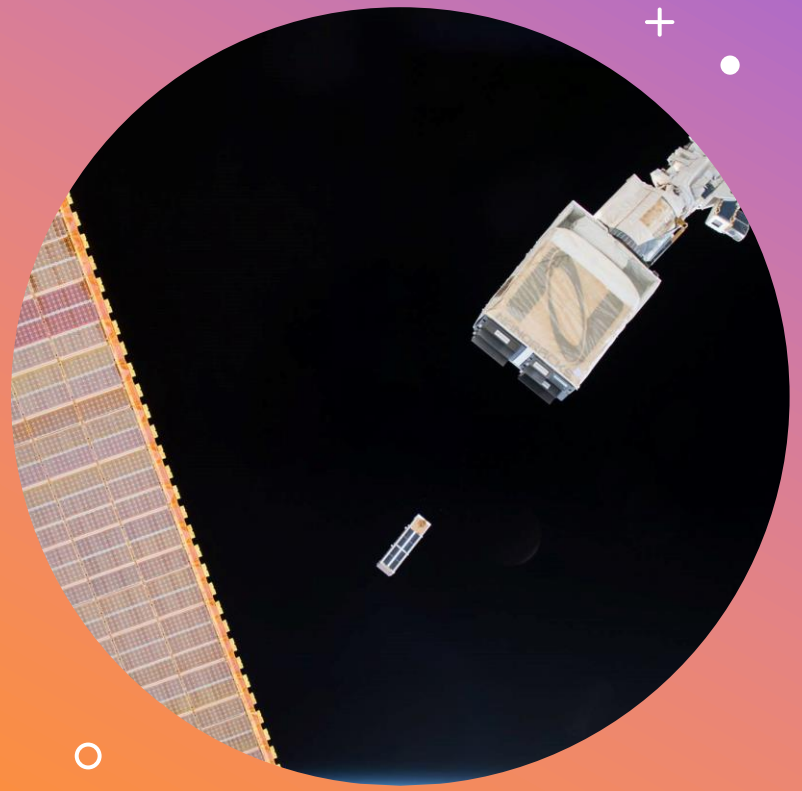








OUTLINE

TES and The Exo-Brake
TES-7, 10, 13, and 15
Upcoming Experiments


Firefly Aerospace


NASA-NOW

Who we are:
Innovative flight project focused on rapid design & innovation

- 2-3 flights a year, low cost, ISS standards
- LEO, Lunar, & Mars exploration proposals
- Payload pathfinder(s) for new space launch providers (ISS, VO, Firefly)
- 100% In-house development, over 90% experiment success rate
  - *Rapid development group for technology and people*

Key Innovations:
Communication

- Iridium SBD for quick command and control
- Custom ‘Lunar’ and ‘Mars’ S-Band SDR radios
- Satellite-internal mesh Wi-Fi network

Exo-Brake

- Precision deorbit and reentry
- Space debris mitigation via EoM disposal

AI/ML Testbed

- Neuromorphic processing, cognitive communication, and health monitoring

TECHEDSAT TEAM


NASA-NOW

Support:
Ames Research Center
Glenn Research Center
Goddard Space Flight Center
Air Force Research Laboratory
NASA STMD
NASA SST Program
NASA CSLI Program

University Partners:
San Jose State University
University of Minnesota
University of Idaho

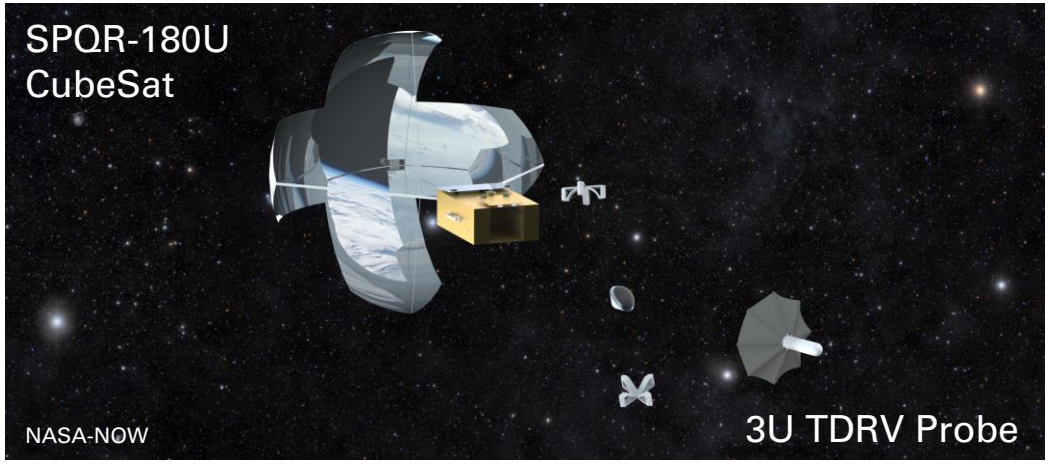
What is the Exo-Brake?

An Exo-Atmospheric drag device technology designed to provide either:

- Non-Propulsive Debris Mitigation for five-year orbital end-of-life requirement
- Guided sample return, or V-LEO flight operations

Debris Mitigation 'Disposal-Type' Exo-Brake

- ❑ Lower spacecraft ballistic coefficient to less than $2\frac{kg}{m^2}$ for a very rapid de-orbit
- ❑ High drag profile in a small packing volume
- ❑ Fixed-struts of inflatable or rigid design for simple construction, integration, and deployment



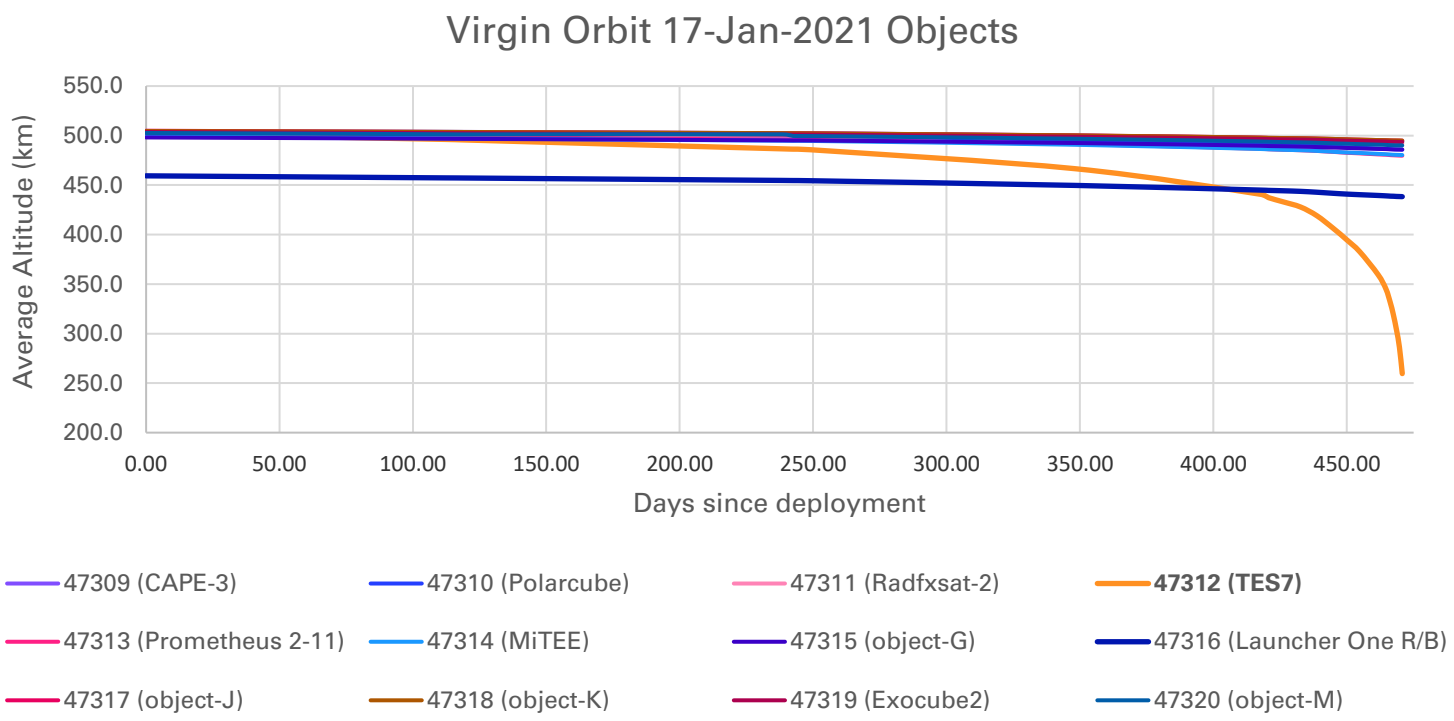
Sample Return 'Modulated-Type' Exo-Brake

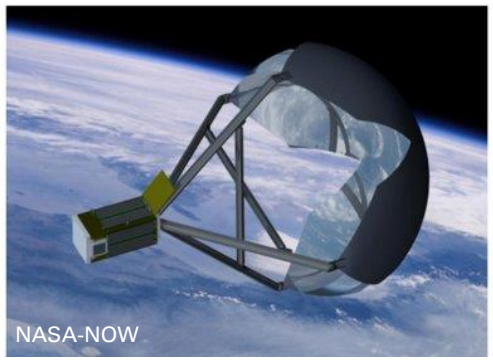
- ❑ Survive high dynamic pressure and temperature
- ❑ Modulated rigid struts enable active control of ballistic coefficient to change entry trajectory
- ❑ Small Payload Quick Return (SPQR) Concept

TES-7

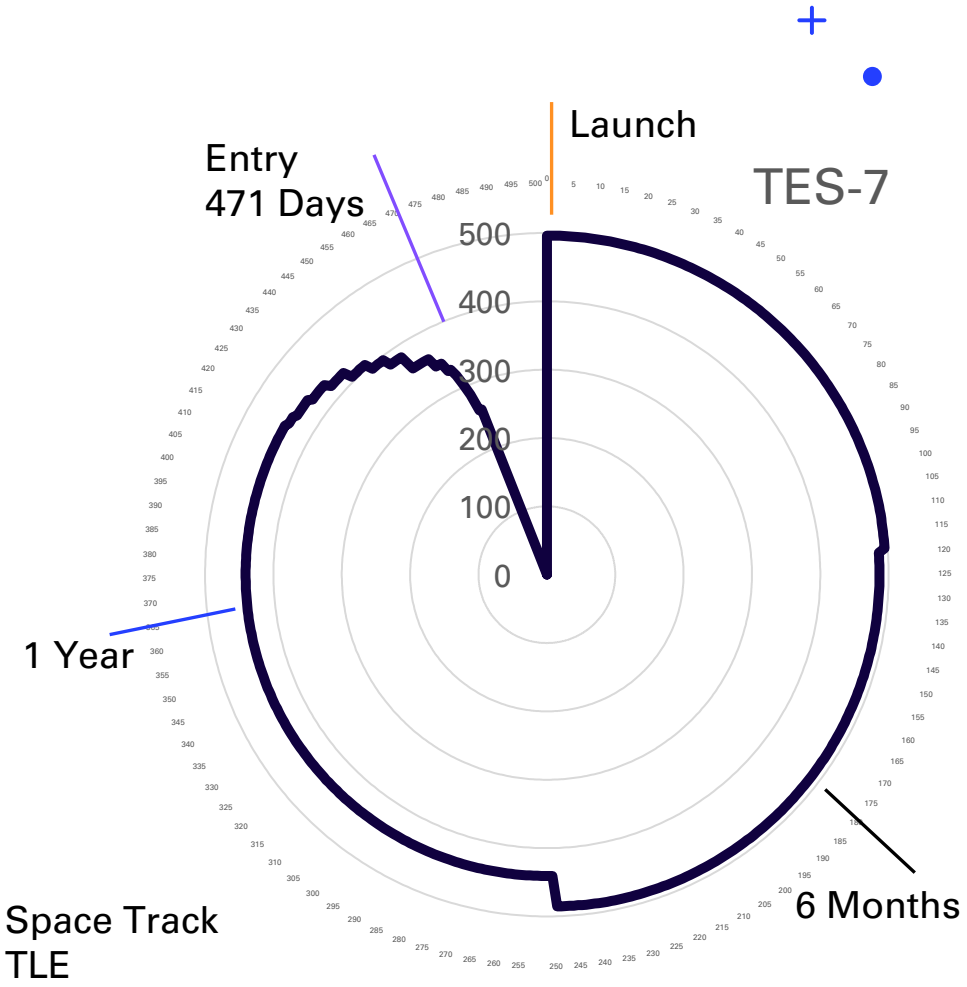
- **Size:** 2U – 217mm
- **Virgin Orbit 'Demo 2'**
  - January 17th, 2021 – May 4th, 2022
  - 500km, 61° Orbit
- **Disposal-Type Mylar Exo-Brake**
  - Spring-loaded ejection plate
  - Hydrogen-cell and water vapor-inflated strut design

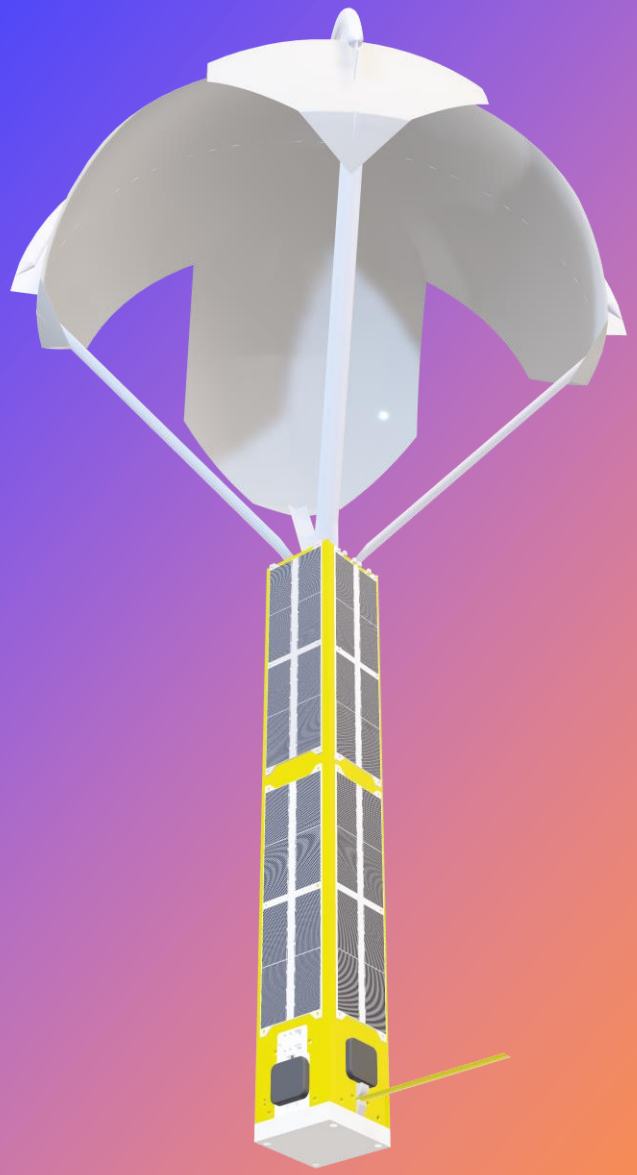
Spacecraft Mass	3.51 kg
Exo-Brake Area	0.75 m^2
Estimated Drag Coefficient	1.5
Ballistic Coefficient	3.12 kg/m^2





Successfully demonstrated hydrogen-inflation Exo-Brake design and new TES avionics





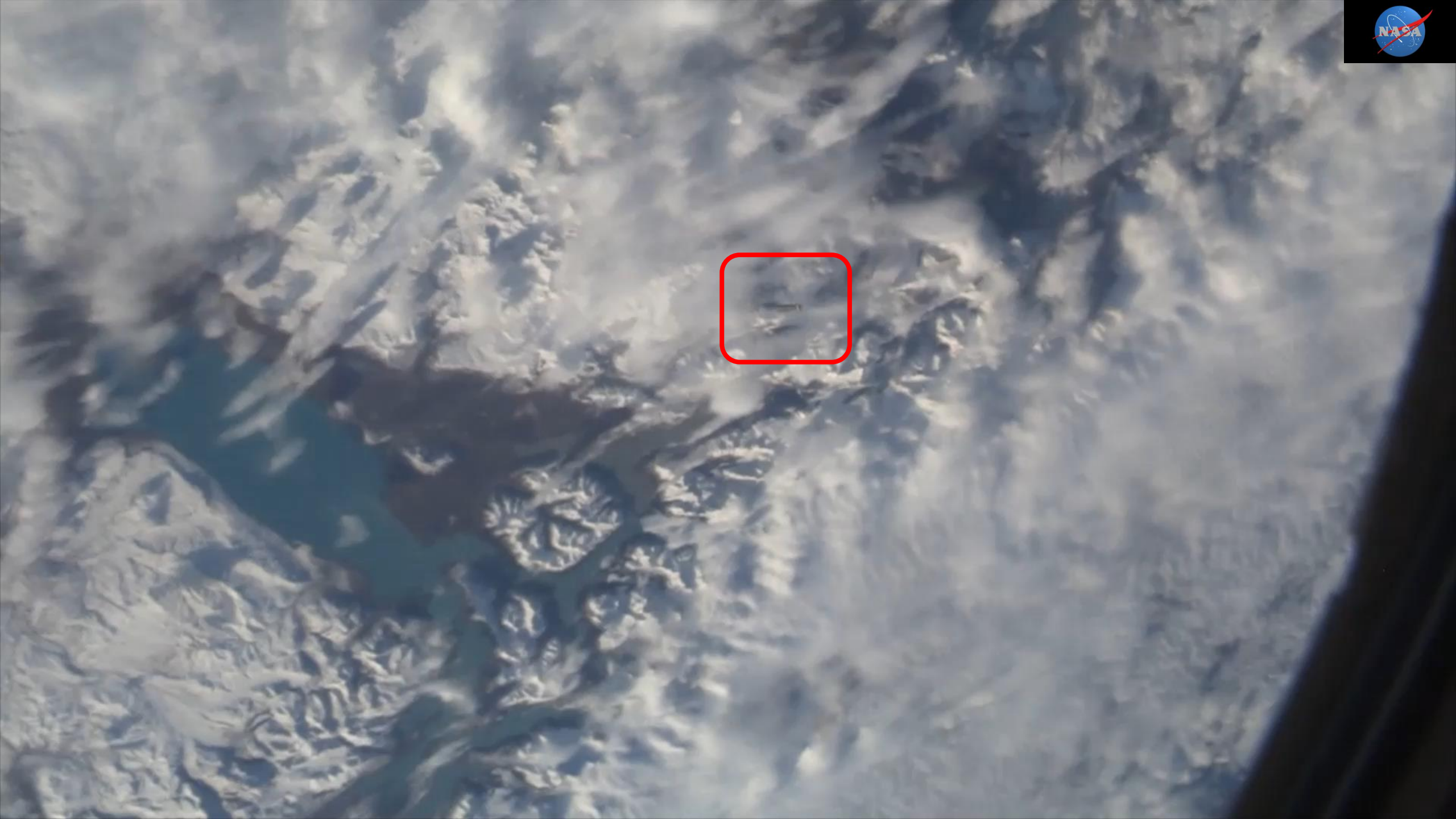
TES-10

- **Size:** 6U-Long, 740mm
- **ISS Deployment, Nanoracks**
  - July 13th, 2020 - March 15th, 2021
  - ISS orbit: 422km x 413km, 51.64°
- **Primary Payload:** NOAA Radio
- **Modulated-Type Mylar Exo-Brake:**
  - Rigid spring-steel strut design
  - Spring-loaded ejection plate

AIAA SmallSat Mission of the Year 2021

Spacecraft Mass	6.45 kg
Exo-Brake Area	0.44m²
Estimated Drag Coefficient	2.2
Ballistic Coefficient	6.32 kg/m²

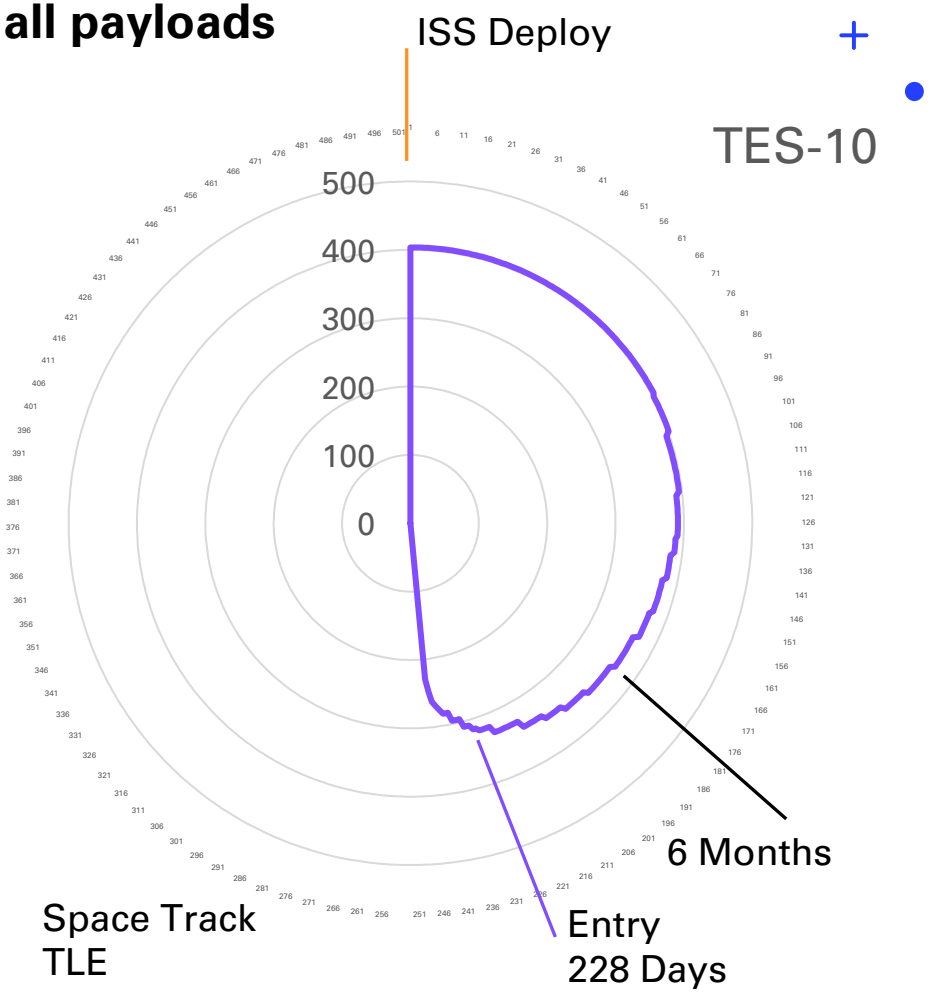

KEEP CLOSED

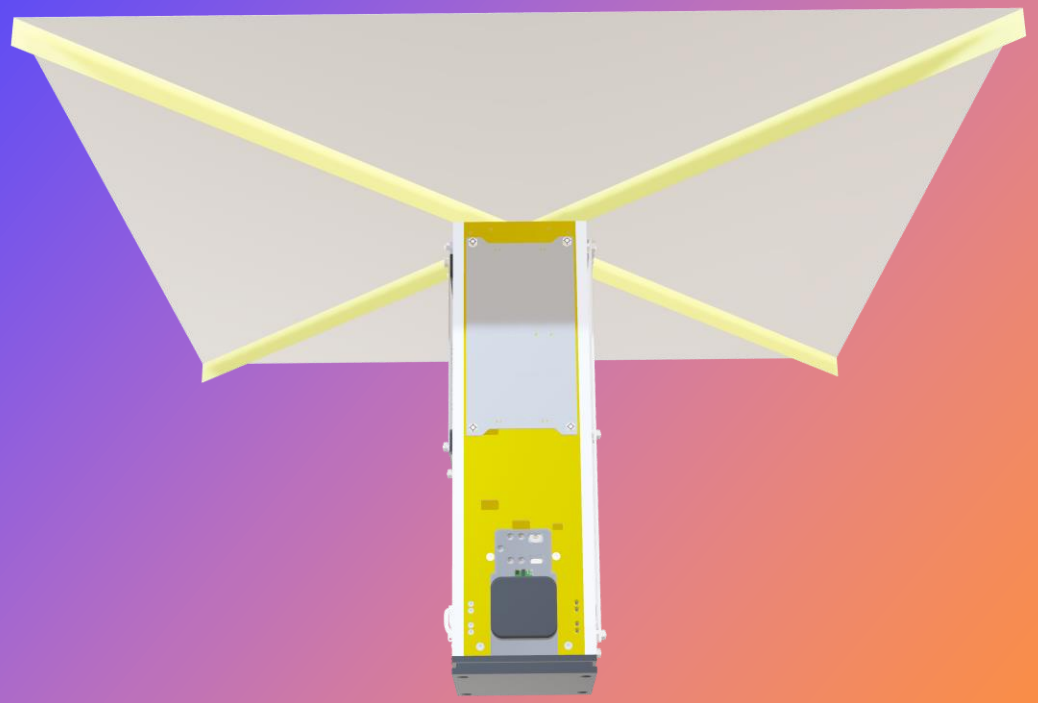


Successfully demonstrated Exo-Brake modulation effect on drag, along with all payloads and avionics

Modulation scheme was generated by Dr. Sanny Omar, NASA Research Fellow (now Millennium Space)

TES-10 aft-imaging captures Exo-Brake deployment

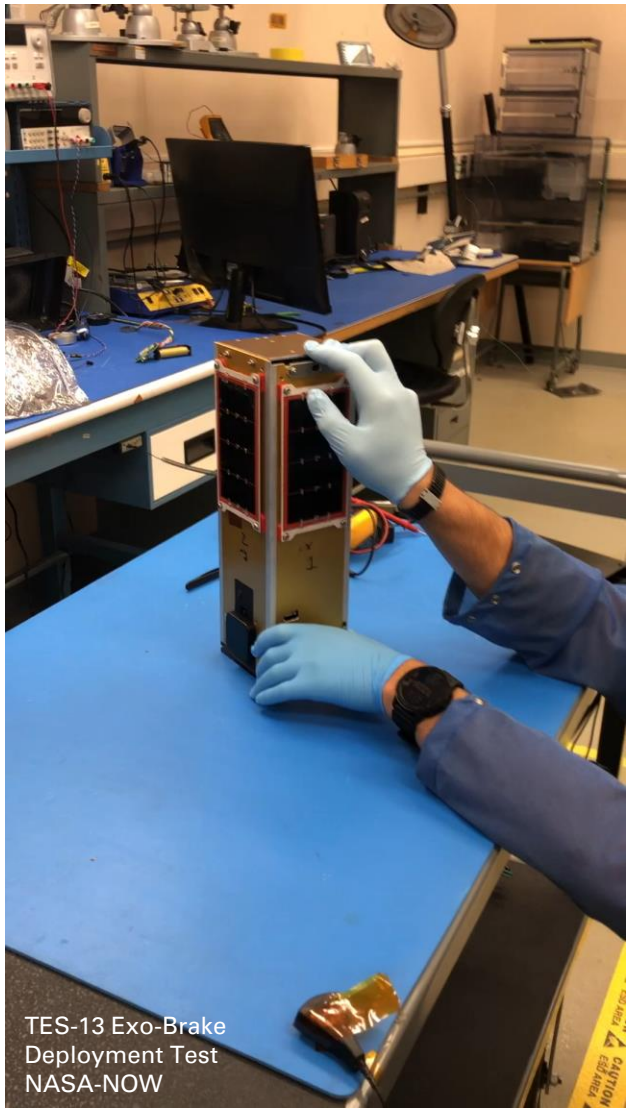




TES-13

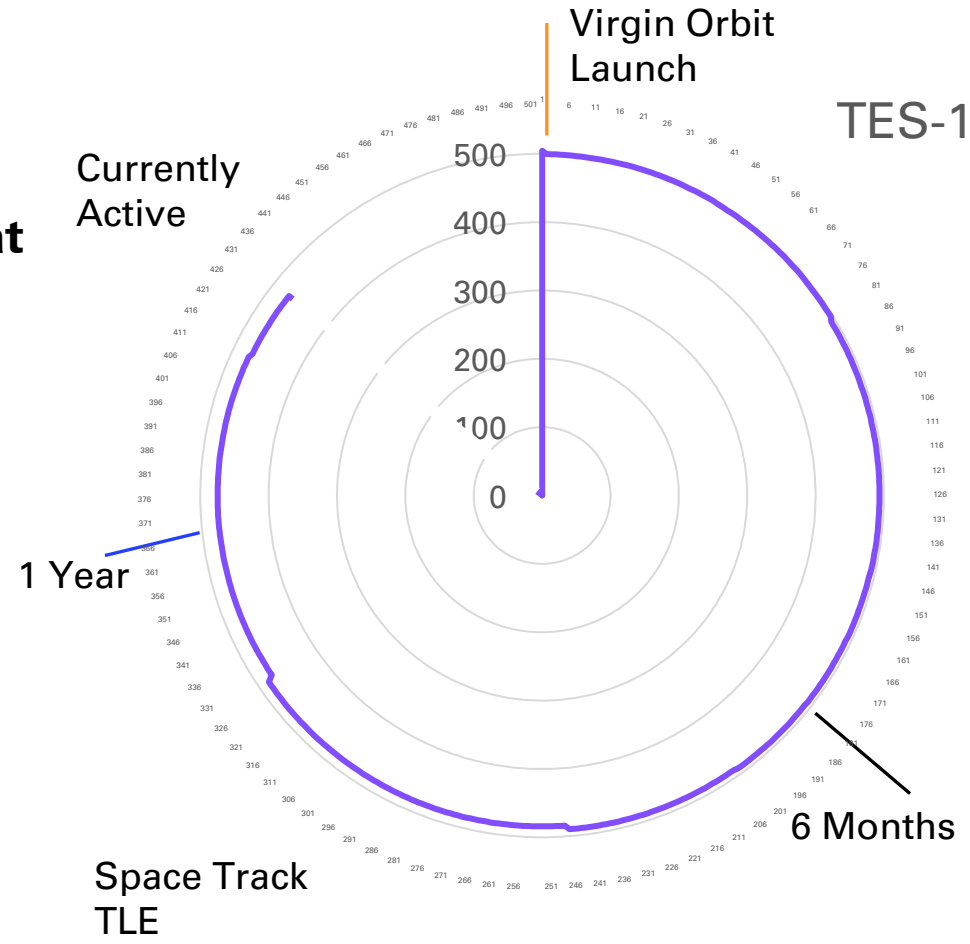
- **Size:** 3U - 340mm
- **Virgin Orbit 'Above the Clouds'**
  - January 13th, 2022 – **Present**
  - 500km Circular Orbit, 45°
- **Primary Payload:** AI/ML Brainstack with Intel® Neuromorphic Processor
- **Disposal-Type Kapton Exo-Brake**
  - Spring-loaded spring-wound ejection plate
  - First rigid-strut disposal Exo-Brake
  - First non-metalized RF-transparent design

Spacecraft Mass	3.0 kg
Exo-Brake Area	0.372 m^2
Estimated Drag Coefficient	2.0
Ballistic Coefficient	4.0 kg/m^2



Comprehensive Mission Success

Mission is ongoing and currently active at 468km, decaying at 162 m/day



TES-15

- **Size:** 3U - 340mm
- **Firefly Alpha-2 ‘Back to the Black’**
  - October 1st, 2022 – October 6th, 2022
  - 270km x 215km, 137° Orbit
- **High-Temperature Disposal-Type Exo-Brake:**
  - Rigid spring-steel strut design
  - Spring-loaded ejection plate
  - Space Shuttle TPS material construction

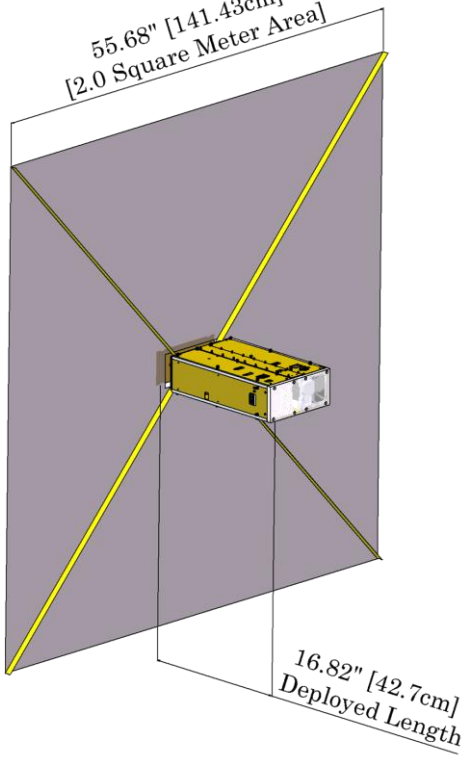
Spacecraft Mass	3.55 kg
Exo-Brake Area	0.24 m^2
Estimated Drag Coefficient	1.5
Ballistic Coefficient	9.86 kg/m^2

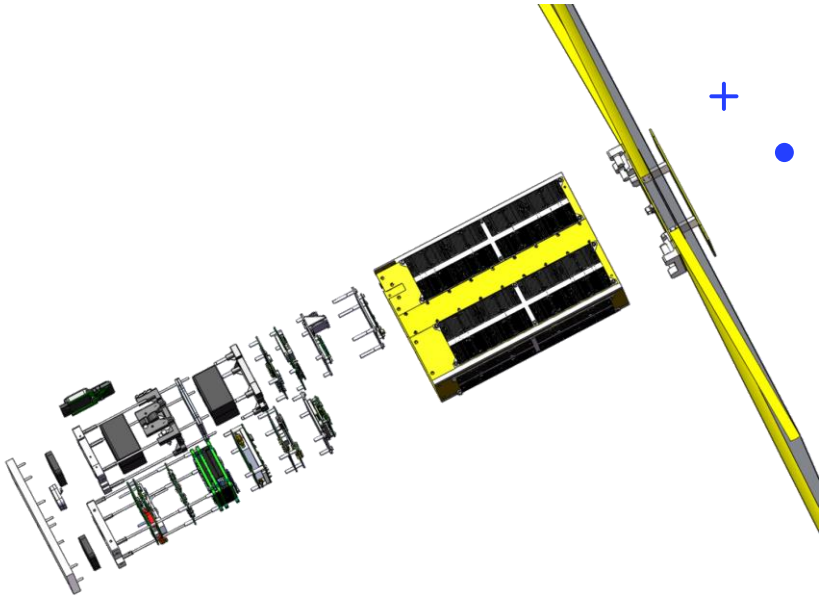
Eighty-orbit mission helped to advance the next Exo-Brake modulation design scheme

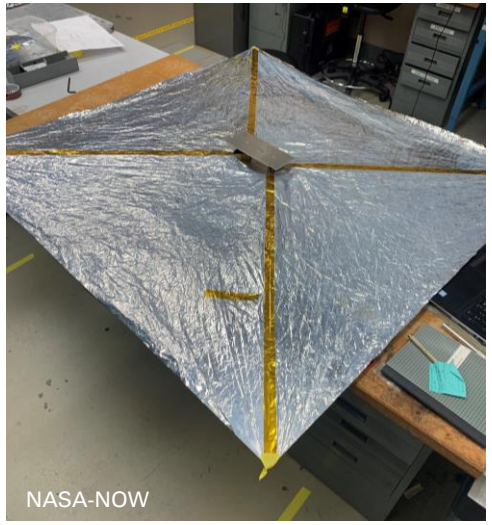
Space Force 18th SpCS and CARA relationships strengthened regarding Exo-Brake use:

- Continue pre-coordination of Exo-Brake deployment timeline to better validate collision assessment profile
- For modulating designs, modulation can begin once orbital altitude is low enough that risk is not posed to other spacecraft per CARA assessment and approval
- Future modulating flights will involve autonomous navigation and targeting below a defined altitude for safe operation

Successful test of new flight software and data collection systems







TES-11

- 6U-XL bus size, NASA CSLI VCLS Demo-2/Firefly, NET August 8/29/23
- Largest TES Exo-Brake Yet: 2.0m²
- Gen-2 TES SDR S-band Radio, NOAA Radio

2024 Plans:

- 12U Upcoming tech-demo in development, with 12U Exo-Brake validation

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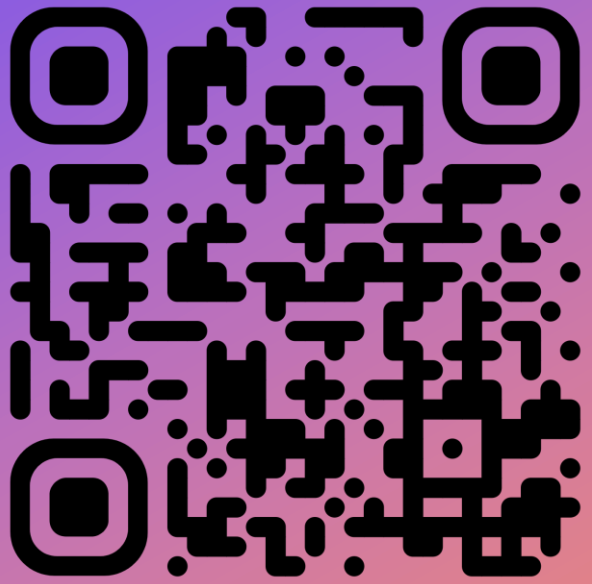
TechEdSat Missions



Exo-Brake Data

TechEdSat Website

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