National Aeronautics and Space Administration

TechEdSat-11 Mission Summary and Survey of Upcoming TES-n Missions

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1. NASA Ames Research Center, 2. Millenium Engineering and Integration, 3. Metis Technology Solutions LLC, 4. KBR Wyle, 5. University of Idaho, 6. ASRC Federal

21 April, 2025

CubeSat Developers Workshop, San Luis Obispo, CA

Logo:
Stanley Krześniak

Technology Education Satellite (TechEdSat) Flight Series

The team consists of the TES-n Rapid Flight Development group at NASA Ames, located within the Engineering Directorate. Consisting of several experienced individuals, mid-career, early-career, and interns, it has successfully launched and operated 13 nano-sats. As of March 2025, the group is operating 2 nano-sats and is building the next set of nano-sats. The team produced the first NASA CubeSat deployed from the ISS (then first 3U, long 6U). The team also collaborates with several universities to develop flight tests of Experiments, Sensors, and Subsystems.

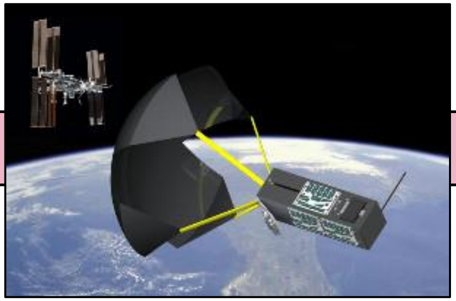
Current team members include:
Key Collaborators: K. Ling/ARC, J. Briones/GRC, L. Schisler/KSC, O. Hatamleh/ARC, M. Campola/GSFC, E. Barszcz/ARC, M. Rudolph/ExpInst, T. Taha/UofDayton, P. Papadopoulos/SJSU, M. Lowry/ARC, A. Gillete/ARC, N. McDonald/AFRL

Core TES-n Team: M. Murbach/*PI, PM***,** A. Dave/*DPM*; J. Alvarellos/*Flight Dynamics*; T. Hector/ *S&MA*; A. Salas/*Lead CS*; M. Mooney-Rivkin/*Lead ME*; A. Brock/*Lead EE*; K. Boateng/*Lead SE*

Universities: San Jose State University, University of Minnesota, University of Idaho, University California/Davis, University of California/Santa Cruz, University of Dayton

Reporting/Reviews: All TES-n spacecraft are formulated as NPR7120.8 projects. Each spacecraft undergo design reviews (PDR, CDR, FRR) with the Ames Chief Engineer. The team reports monthly on progress to the Ames Spacecraft Projects Office (SPO).

TES Mission History (2015-2025)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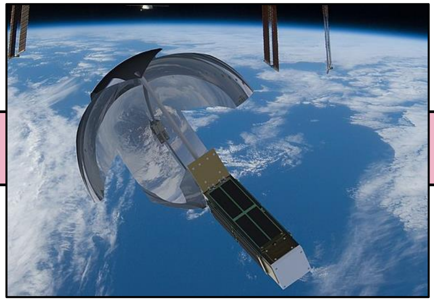
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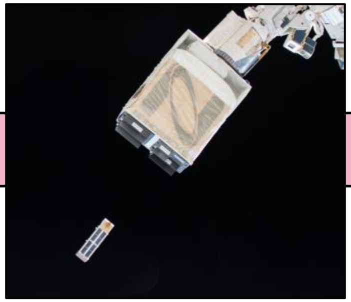
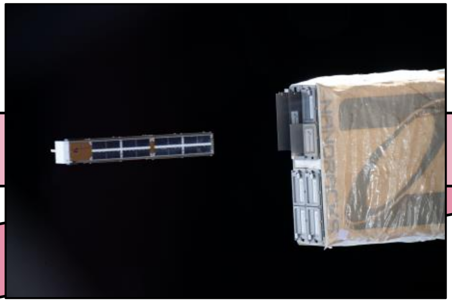

TES-6 (2017)


TES-8 (2018)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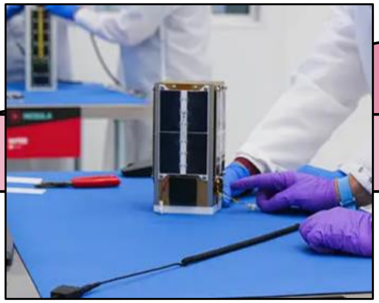
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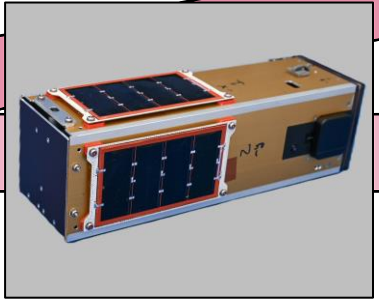
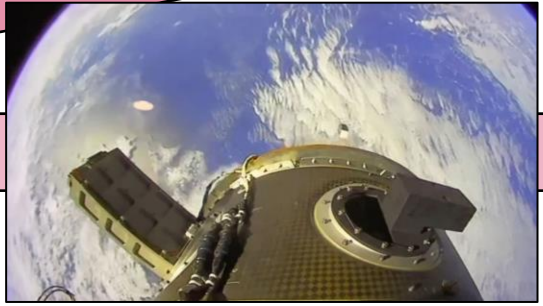
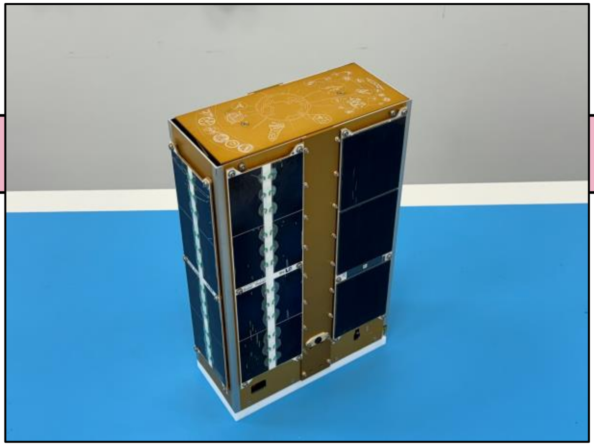
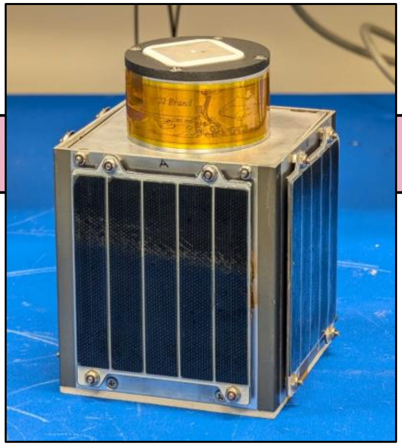

TES-13 (2022)


TES-15 (2022)


TES-11 (2024)


TES-22 (2025)

Images courtesy of NASA

TechEdSat-11: Overview

Mission

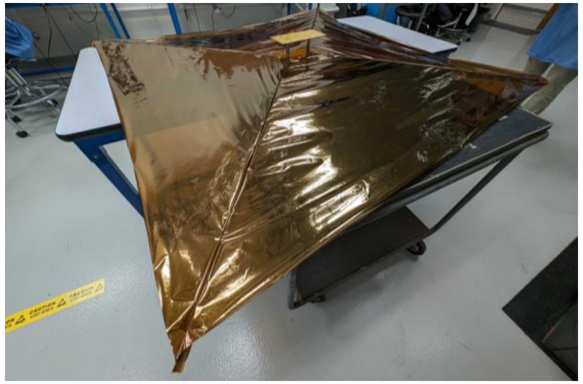
- Launched on July 3, 2024 on board Firefly Alpha Flight 5
- Successfully operational for 9+ months

Specifications

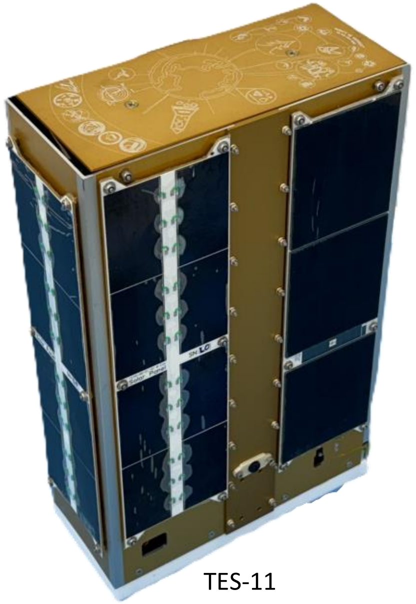
- 6UXL cubesat bus with $2m^2$ Exo-Brake
- Power: 150 W/Hr battery system
- Communication: S-Band, UHF, L-Band

Developments and Demonstrations

- New low-cost TES-N double wide 6U bus
- Next iteration of the disposable Exo-Brake
- Updated TES-N high power system
  - New TES-N low-cost solar panels
  - Updated battery system with containment unit
- Initial test of the cognitive engine-1
  - UIS (User Initiated Service) software
  - HDTN (High Delay Tolerant Networking) software
- Next iteration of the NOAA Doppler correction payload



TES-11 Deployed Exo-Brake



TES-11

Images courtesy of NASA

TechEdSat-11: Bus Developments

Avionics

- First demonstration of low-cost, COTS 25% efficiency PV cells

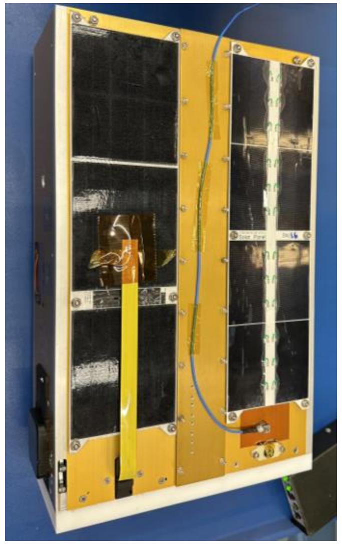
Structures

- First demonstration of TES-n 6U(2x3U) structure
    - Adaptation of TES-N monocoque structure
- Enlarged Exo-Brake ($2.0m^2$)
    - Stitched Kapton construction, utilizing MLI fabrication techniques

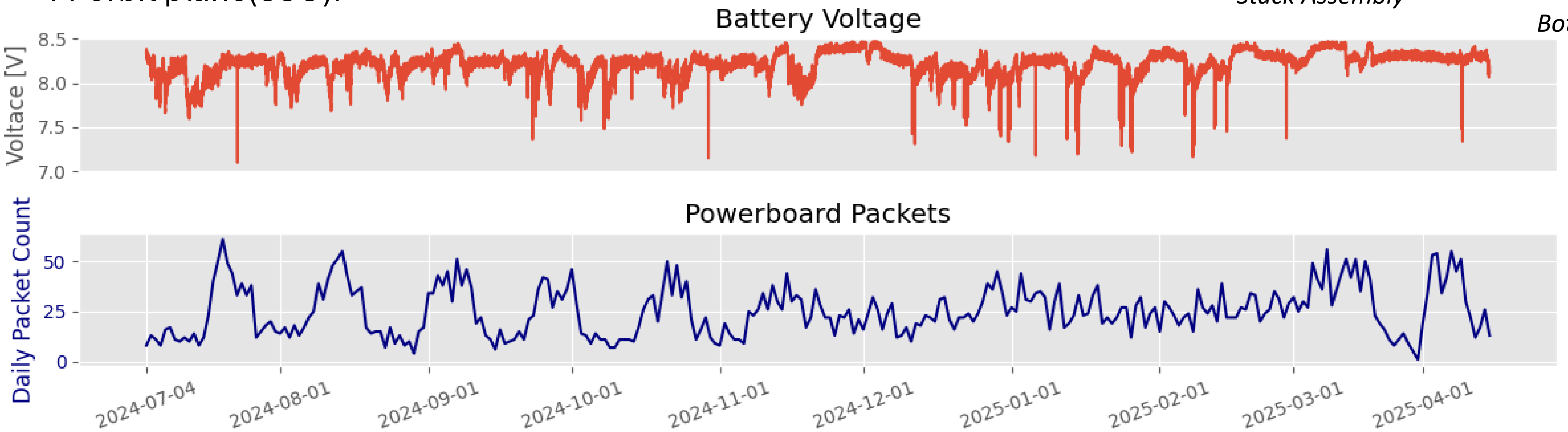
Iridium Reception

- Perturbations in packet rate observed, hypothesized to be related to relative precession rates between Iridium orbit planes(86.4°) and TES-11 orbit plane(SSO).

Stack Assembly



Top: Legacy solar panel
Bottom: new solar panel



Images courtesy of NASA

TechEdSat-11: Cognitive Engine 1 (CE-1)

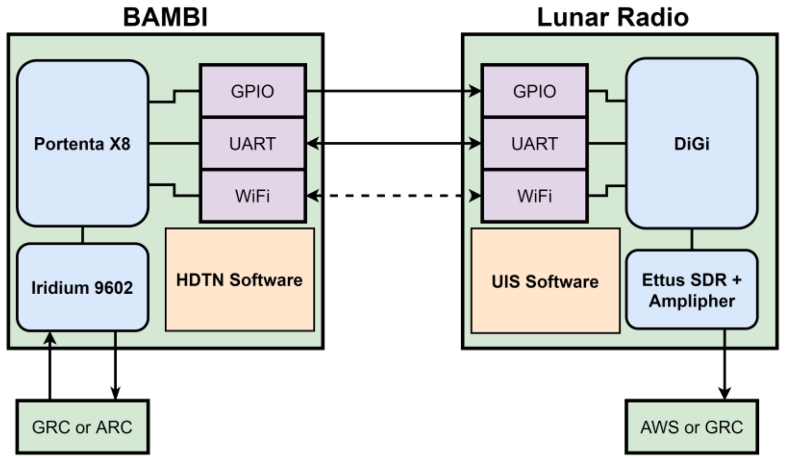
Software payload developed by the cognitive communication team at NASA Glenn

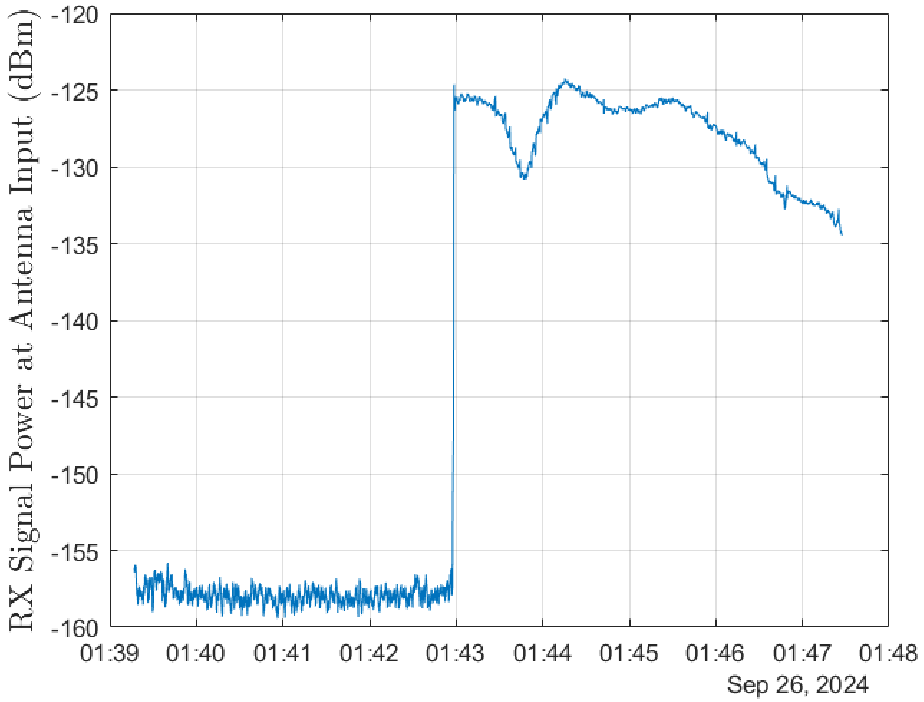
- **UIS** – User initiated service
  - Allows the spacecraft to automously schedule and execute downlink passes
- **HDTN** – Hyper Delay Tolerant Networking
  - Allows the spacecraft to automously determine how to best package on board data
- UIS is responsible for determine when to send data, while HDTN is responsible for what data to send

CE-1 was hosted on the TES-11 flight computers

- **Lunar Radio –** custom S-Band radio that was used by UIS to downlink spacecraft telemetry
- **BAMBI** – TES-N payload computer that hosted HDTN and controlled the operation of the Lunar Radio

Both UIS and HDTN were successfully tested both individually, and together multiple times during the TES-11 mission.





TechEdSat-11: NOAA Radio Payload

Radio payload developed by NOAA and MicroCom

- Objective is to test satellite to satellite communication between TES and the NOAA Geostationary Operational Environmental Satellites (GOES) constellation
- Spacecraft telemetry will be logged and stored using the NOAA Data Collection system

Satellite Conops

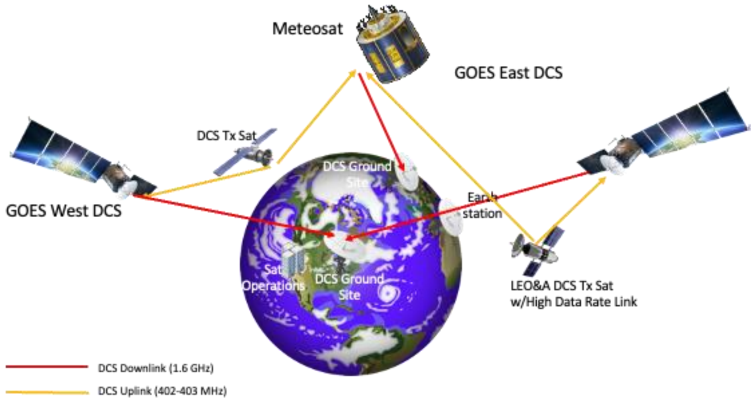


Image courtesy of NOAA/Aerospace

NOAA Radio Payload

Images courtesy of NASA

Radio Specifications

- Power .1W – 10W RF, 45W Electrical
- Frequency: UHF 401-402MHz
- Data Rate: 300 bits/second, 1200 bits/second

Results

- Successfully completed 1000+ transmits to the GOES system at varying power RF power levels
- Successfully completed transmission so the European counterpart constellation Eumetsat

TES-11 Test Packets

NETLISTS & FILTERS [FILTER] SMALLSAT_TES11 NETLISTS FILTER CLEAR EXPORT 100

ADDRESS	GROUP	CHAN	BAUD	SIGNAL	NOISE	QUALITY	FREQ	CAR TIME	END TIME	TIME	ARM	SCID	TYPE	LEN	MESSAGE DATA
FFE086B0	TECHED	429	300	38.4	4.1	86.8	-181.0	24/212 23:26:35.813	24/212 23:26:38.777	2.964	G	18	CS2	80	010+8.1+6.7+10.0+0.3 +1.25+1.00+4.0+4.6+4.0+6.8 ...
FFE086B0	TECHED	129	300	38.4	3.2	95.0	-102.0	24/212 23:25:35.943	24/212 23:25:38.777	2.835	G	18	CS2	80	009+8.1+6.7+10.0+0.3 +1.00+0.75+3.7+4.2+3.7+6.1 ...
FFE086B0	TECHED	428	300	37.4	4.9	85.3	-10.1	24/212 23:24:35.800	24/212 23:24:38.773	2.972	G	18	CS2	80	008+8.1+6.7+10.0+0.3 +0.75+0.50+3.3+3.7+3.3+5.4 ...
FFE086B0	TECHED	128	300	35.1	5.3	80.6	84.9	24/212 23:23:35.803	24/212 23:23:38.773	2.972	G	18	CS2	80	007+8.1+6.7+10.0+0.4 +0.50+0.50+2.7+2.6+2.7+4.7 ...
FFE086B0	TECHED	427	300	33.0	13.2	26.3	196.1	24/212 23:22:35.817	24/212 23:22:38.907	3.092	?	18	CS2	15	9h$nGf\|y$xtQ$$$
FFE086B0	TECHED	427	300	33.0	13.2	26.3	196.1	24/212 23:22:35.817	24/212 23:22:38.907	3.092	A	18	CS2	158	DADDS: PLATFORM [FFE086B0] OWNER [TECHED] LOCATI...

1 2 3 4 5 6 7 8 9 10 ... PAGE 1 OF 11 PAGE SIZE: 6 1 - 6 OF 63 MESSAGES

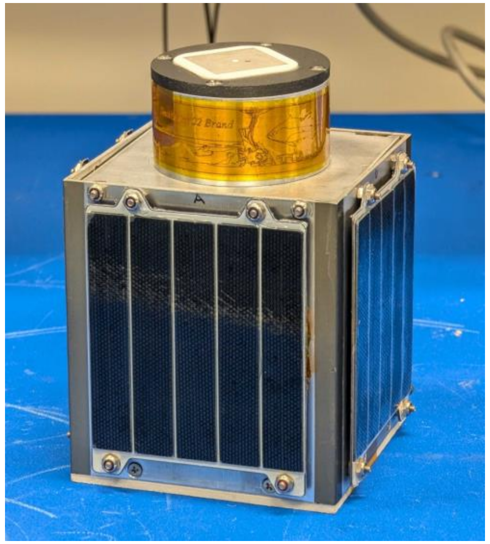
TechEdSat-22: Overview

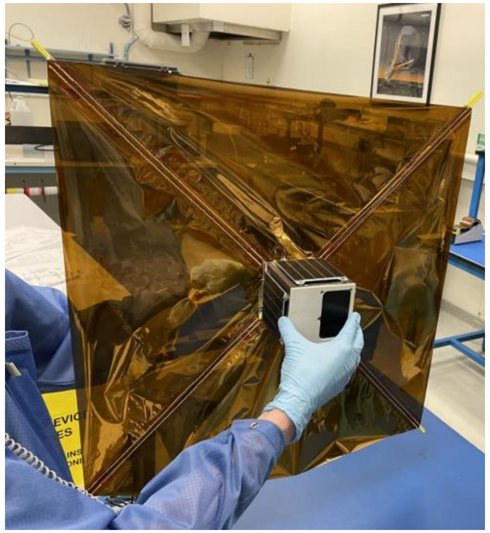
Mission
- 13 January 2025 Launch, Transporter-12 Rideshare
- Pathfinder mission for Thermosphere Test Probe (TTP)
- ~21RPM Tip-off rate delayed initial communications
- Successfully operated for 3+ months

Specifications
- 1U cubesat bus with $0.6m^2$ Exo-Brake
- Power: 37.5 W-Hr
- Communication: L-Band

Developments and Demonstrations
- Rapid Proto-flight development of a 1U TES-n CubeSat (First since TES-1)
- Development/demonstration of a $0.6m^2$ disposal Exo-Brake
- New TES-n low-cost solar panels
    - 4.29W Total, 1.23W per Panel
    - Solar cells based on Heritage design (TES-11)
- Demonstration of U of Idaho Radiation Experiment
    - Cesium-Iodide MacroPixel scintillator
    - Early iteration of TES RadStack
- Demonstration of novel Solid-State LiS^{2-} battery design – BEAM

TES-22 Spacecraft and Launch





Images courtesy of NASA, Video courtesy of SpaceX

TechEdSat-22: Bus Developments

Software

- 2nd Flight of TES-OS, standardizing/simplifying interface between subsystems

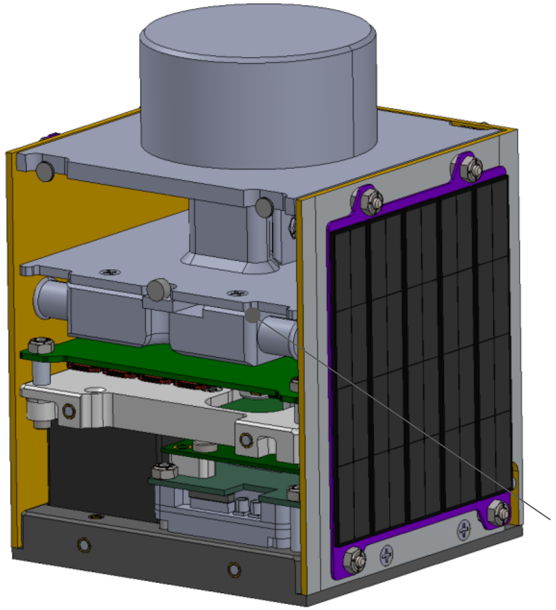
Avionics

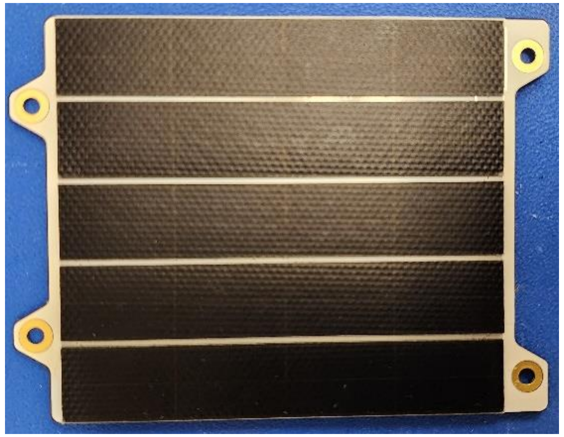
- Low-cost, 25% efficiency COTS Si PV cells
  - 4.29W total, 1.23W/Panel
- Powerboard PCB: updated to include PV MPPT circuitry,

Structures

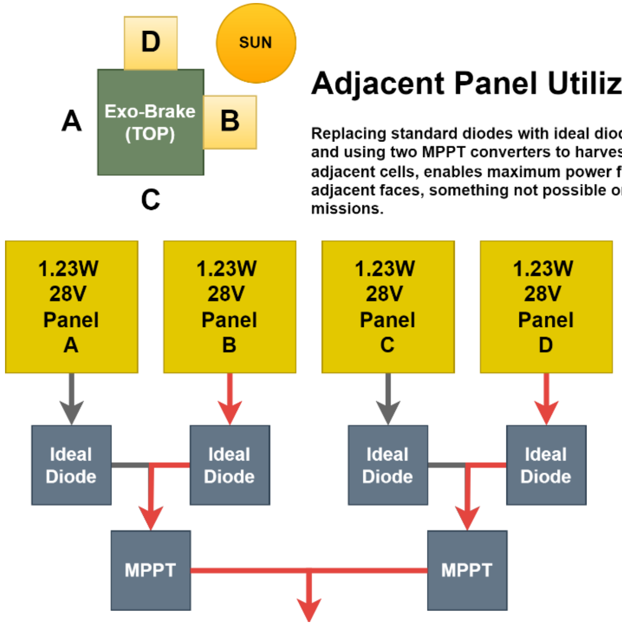
- Miniaturization of Exo-Brake mechanism resulted in packing density of ***~1.3m² / U***
- Low Ballistic Coefficient ($\sim \mathbf{1.2}\ \boldsymbol{kg/m^2}$)
- Single-actuation deployment based on heritage design (TES-11 & 13)

Integrated Shell Assembly; Section View





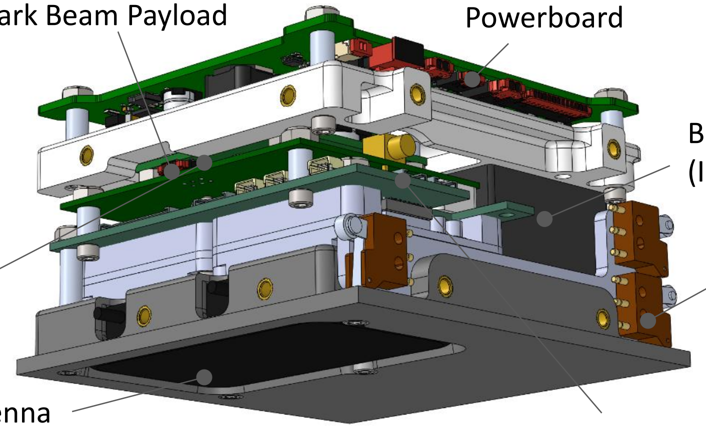
COTS 1U Solar Panel



Adjacent Panel Utilization

Replacing standard diodes with ideal diode modules, and using two MPPT converters to harvest from adjacent cells, enables maximum power from adjacent faces, something not possible on prior TES missions.

Avionics Stack

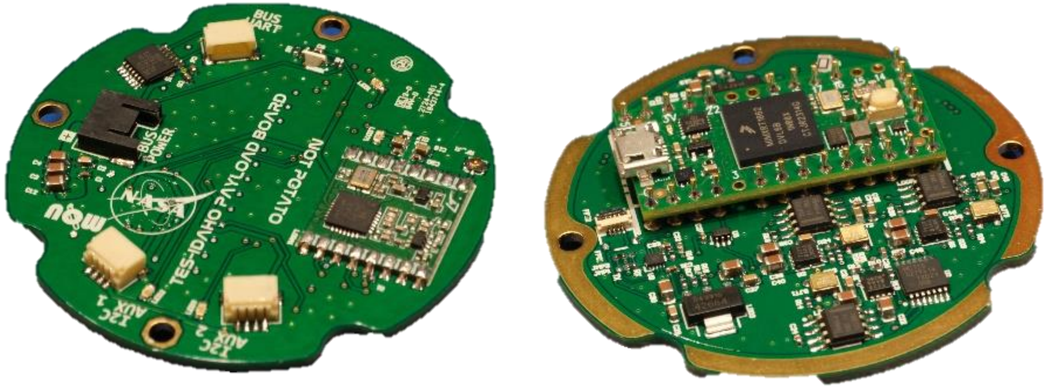


Images courtesy of NASA

TechEdSat-22: Payloads

Tuna-Can Payload Interface PCB

- C&DH for both RadStack and DARKBEAM Payloads
- First TES flight demonstration of Teensy 4.1
- Power convertors and switches for payload subsystems



Tuna Can Payload Interface PCB

RadStack-1

- Capesym CsI Scintillator
- Initially calibrated by U of I, generates energy spectra from 1-4095keV, expected sensitivity from 40keV

DARKBEAM Solid-state Battery Demonstration

- Flight demonstration TRL advancement of NASA Solid-State Lithium Battery
- On-demand discharge cycle experiment to evaluate battery capacity lifespan on orbit (2032 Coin Cell, Lithium-Sulfur)

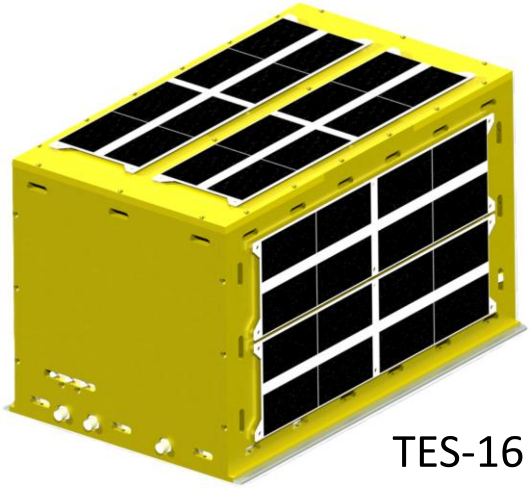
Dual-Channel Battery Evaluation Lab

Images courtesy of NASA

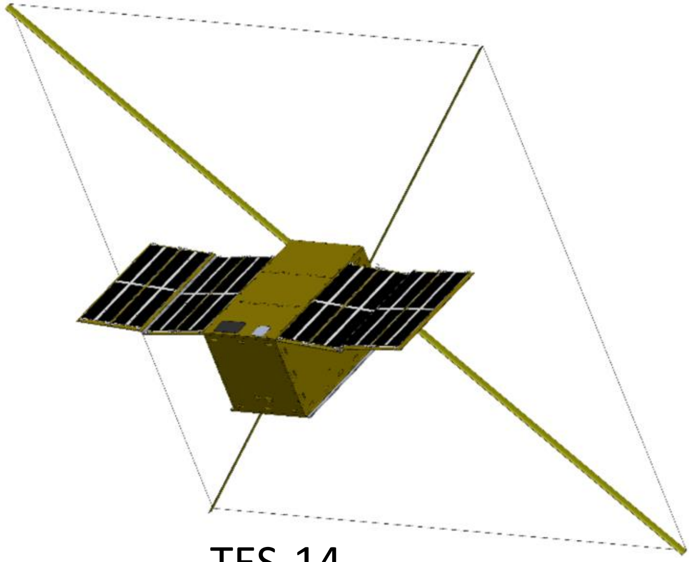
TechEdSat-N: Upcoming Missions

TechEdSat-16

- First flight of custom 12U bus with tabbed interface
    - Q3 2025 on a Firefly mission
- Upgraded 300WHr power system
- BrainStack-2 payload
    - Intel Loihi Neuromorphic processor
    - NVIDIA Jetson Orin NX



TES-16



TES-14

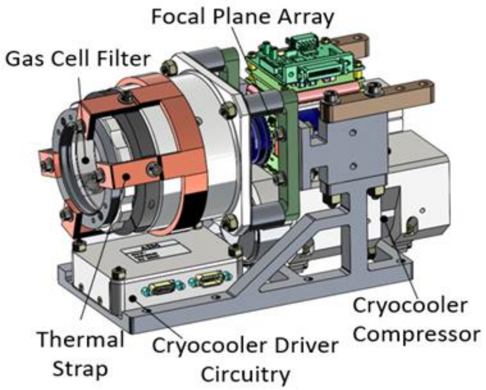
TechEdSat-14

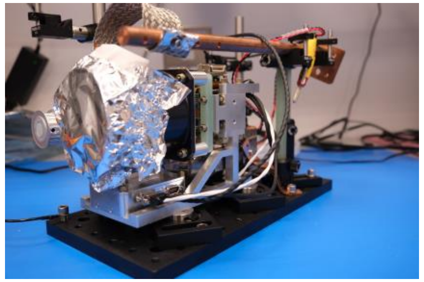
- First satellite to enter a GTO orbit
    - Q3 2026 on a ULA Vulcan Centaur mission
- BrainStack-3 payload
    - NASA HPSC radiation test
    - Intel Loihi-2 Neuromorphic processor
- RadStack-2 Payload to sense radiation effects of a GTO orbit

Doppler Wind and Temperature Sounder

Improved atmospheric observation and data collection

- More complete understanding of the atmosphere from the ground and from orbit





DWTS

Images courtesy of NASA

TechEdSat-N: BrainStack

Objectives

- Adding large brains to little boxes
- Performing collaborative first flight tests with powerful next generation AI/ML processors on GPU, neuromorphic or other platforms.
- Performing the first flight tests of the new NASA HPSC (High Performance Space Computer) effort in the space/radiation environment.

Image courtesy of Microchip

Image courtesy of Intel

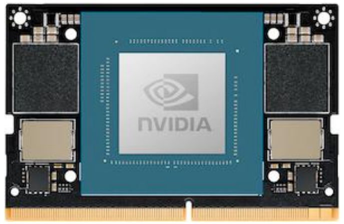


Image courtesy of NVIDIA

Image courtesy of Vorago

Image courtesy of Google

Potential Payloads

Name	Type	Description
NASA HPSC	CPU	8-core CPU designed to succeed the RAD750. Based on RISC-V architecture in a dual core lockstep configuration to increase its fault-tolerance.
Intel Loihi 1 and 2	NPU	Neuromorphic processors designed to implement ML inference with high parallelism. Features an asynchronous spiking neural network (SNN) to facilitate self-modifying computations.
NVIDIA Jetson Orin	CPU + GPU	AI-embedded computing device designed with the 1024-core NVIDIA Ampere GPU architecture. High memory bandwidth and a comprehensive I/O suite.
Vorago VA7320	CPU + GPU	Dual-core CPU with integrated GPU capable of AI and ML tasks. Designed for operating in space.
Google TPU	TPU	Tensor processing unit designed by Google and optimized for training large AI models. Not rad tolerant or hardened by default.
Apple A or M SOC	CPU + GPU	ARM processors designed by Apply for their iPhones and Macs. Industry leading performance for the form factor. Not rad tolerant or hardened by default.