Communications for the TechEdSat/PhoneSat Missions

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Marcus Murbach, PI
Ali Guarneros-Luna, Co-I

Rick Alena, Co-I
Jon Wheless, Engineer
SOAREX/TechEdSat/PhoneSat Teams

Flight Experiments of Recent Years (2008-2017):
- SOAREX-6 (2008)
- SOAREX-7 (2009)
- TES-1 Oct 4, 2012
- TES-2 PhoneSat Iridium-test Aug 3, 2013 (6 wk de-orbit)
- SOAREX-8 (2015)
- TES-3 Aug 3, 2013 (4 wk de-orbit)
- TES-4 Mar 3, 2015 (4 wk de-orbit)
- SOAREX-9 (2016)
- TES-5 Mar 6, 2017 (deorbited Jul 29)
- TES/PS Team, 2014
- TES/PS Team, Summer 2017
What is an Exo-Brake…?

Simple, drag-modulated de-orbit system based on tension elements

TechEdSat5 was deployed from ISS on March 6, 2017 by NanoRacks
The TechEdSat 5 Exo-Brake Experiment

• The Exo-Brake is an exo-atmospheric braking and de-orbit device which has successfully flown twice before in a fixed configuration on TechEdSat-3 and 4.

• The TechEdSat rapid prototype flight series is conducted as a hands-on training environment for young professionals and university partners.

• The project helps verify Entry Systems Modeling by gathering real-world data aboard sounding rockets and CubeSats.

• In the future, passive Exo-Brake systems may be used for small-sat disposal and the development of technologies to permit on-demand sample return from Low Earth Orbit (LEO) scientific/manufacturing platforms.
TechEdSat 5 (TES5)
Avionics, Software and Communications

• The 3.5 U CubeSat contains a low-level AVR microprocessor for power control and a high-level Atom processor for fast data processing.

• The primary Command and Telemetry (C&T) link is provided by the Iridium constellation through on-board Short Burst Data (SBD) modems.

• A modified Wi-Fi transceiver allows scheduled downlink at 1 Mbps when over our Wallops Island ground station.

• TES5 includes a Wireless Sensor Module for inertial, magnetic, air pressure and temperature sensing.

• TES5 had two cameras which downlinked images via Wi-Fi or, with heavy compression, via Iridium constellation.
TechEdSat-5 Anatomy

- Teflon Nosecap
- Iridium Antenna #2 (Standard TES)
- COM/CNTR Boards (Improved)
- Solar Panels (Standard TES)
- Iridium/GPS Antenna (Improved location; Standard TES)
- PWR Board (Improved)
- PhoneSat5 Board Stack
- Improved Cartridge Design (Ease of integration/test)
- Inhibit Switches (Standard TES)
- Canon BP930 ISS-supplied x2 (Standard TES)
- Exo-Brake and Deployment System
- Aft-Cover (Standard TES)
- Extruded Structure Design (3.5 U) (Standard TES)
TechEdSat-5 Communications Overview

FEATURING: Iridium SBD Modems ISM-Band high-rate downlink
Previous Experience: TES-2

First successful Iridium in-space nanosat experiment

Shows distribution of handshakes over 100 hours (fwd patch; tumbling)
Previous Experience – TES-4

Direction from the Iridium Constellation Perspective

TES-4 messages vs. elevation and azimuth (from forward patch antenna)

Sent ~100 packets per day; received 25 out of 25 commands sent
Previous Experience – TES-4 Ortho Antenna

100-400 hits/day when the 2nd level Avionics was turned on

Note: Orthogonal patch antenna orientation zenith was not known, but was expected to be slowly rotating
Data Packets from T5/P5 via Iridium

Initial Data from TES/PS show “IT WORKS”
✓ WSM-”Cricket”
✓ GPS
✓ PhoneSat

WSM-Cricket
MOMSN>1271
41 88 07 ad de ef be ba 0f 00 52 5f 6a 00 15 07 00 00 5b 0a 2e ff 0c ff
05 ff fe ff ff 00 07 00 07 ff fc 00 16 ff bb 00 51 00 19 40 00 fc 3c 62

CricketID: BABE
TimeStamp (s): 5398.378
PacketNumber: 5383
Pressure (kPa): 0.091
OnBrdTemp (°C): 26.06    Temp1 (°C): -24.4    Temp2 (°C): -25.1
Accel (G): -0.002, -0.001, 0.007    Gyro (Deg/s): 0.07, -0.04, 0.22
Mag (uT): -10.346, 12.146, 3.749    Light (lux): 0.00    Bat (V): 3.26

Temp1 is the thermocouple on the solar panel and Temp2 is the one embedded in the Teflon nose cap.

Phonesat GPS
Iridium metadata:
MOMSN>1268 MTMSN>0
session_time=148832376552 lat>0.07239 lon>72.99772
TES-5 is in a ‘nose-down’ orientation, Iridium antenna provides -10 dB gain at 180 degrees

Link margin analysis shows nose-down attitude compromises communication

Number of packets/day was slowly changing, perhaps due to slow changes in AoA
STK Iridium Comms Analysis – Coverage

Active Iridium Satellite Constellation Ground Tracks

Six belts of eleven Iridium satellites in polar orbit

Pattern offers 100% ground coverage
Iridium Comms Analysis – TES5 Forward

Elevation from TES5 to all Iridium satellites – 4000 Km maximum range

For FWD attitude: all possible contacts are from -12 degrees to ~80 degrees – good telemetry and command links
For nose-down attitude: all contact from 0 to -11 degrees: link margin constraints show lower probability of successful handshake
Wireless Sensor Module Experiment

Evolution of Wireless Sensor Module

Far left: Original SOAREX-1 data acquisition module
Second from left: SOAREX-8 WSM concept trial version
Third from left: currently developed system for SOAREX9 and TES-5
Fourth from left: Marc’s key chain
**Future Missions: TechEdSat 6, 7, 8**

**TechEdSat-6 [3U]**
2nd Modulated Exo-Brake Test
Improved Exo-Brake Tensioner
New Ops/Schedule Plan
Drag Coeff. = 5 kg/m²
CUBIT-1 Test

**TechEdSat-7 [2U]**
High Packing-Density Exo-Brake
Novel strut design – no modulation
Drag Coeff. = 1 kg/m²
CUBIT-2 Test

**TechEdSat-8 [6U]**
‘Hot’ Exo-Brake
Modulated with beta=4 kg/m²
‘Deep Dive’ into atmosphere
Drag Coeff. = 5 kg/m²
Novel Comm. Equipment

* All CSLI Approved
Communications Summary

Objectives Met:

- Telemetry was received every day for 78 days
- Telemetry downlink rate (mobile-originated) was about 30 packets per day, representing about 1% completion rate
- No commands were received, although many were sent
- Each successful downlink resulted in a command transmission – problem was reception by TES5

Objectives not Met:

- Minimal PS5 Iridium interaction – telemetry received
- No ISM-band downlink – requires commanding