6 Flights +1(SOAREX8) +PhoneSats 1-4

TES-1
Oct 4, 2012
First US Nanosat deployed off ISS
First Iridium test
Aug 21, 2013
(TES-2)
Iridium test
Aug 3, 2013
(6 wk deorbit)
TES-3
Aug 3, 2013
First Iridium in-space COM demonstration
TES-4
Mar 3, 2015
(4 wk deorbit)
TES-5
During test
WSM2, ISM Band, P5 alpha, ISM-Camera
TES-6
WSM2, AIM Camera ISM-Band, P5 alpha, ISM-Camera
TES-7
WSM1, AIM Camera X-Band, ISM-Band, P5 alpha, ISM-Camera and Full ExoBrake
TES-8
During test
WSM1, AIM Camera X-Band, ISM-Band, P5 alpha, ISM-Camera and Full ExoBrake
TES-9
WSM2, AIM Camera ISM-Band, P5 alpha, ISM-Camera

First US 3U Nanosat deployed off ISS First Exo-Brake test
Evolution of TES-3 Iridium modem Uplink/via email demonstrated Exo-Brake II
WWM1, AIM Camera X-Band, ISM-Band, P5 alpha, ISM-Camera and Full ExoBrake
WWM2, AIM Camera ISM-Band, P5 alpha, ISM-Camera
Modulated Exo-Brake Improved positional/target accuracy
Improved Targeting, WSM2, ISM Band
TechEdSat5 PhoneSat5 Coming up this year!!

SOAREX/TechEdSat-N Team

...here before
Recent Years of Flight Experiments (2009-2015)

- **Intimidator-5**: July 29, 2010
- **Balloon**: June 9, 2011
- **SpaceLoft-6**: Apr 5, 2012
- **PhoneSat**: 1a, 1b, 2.0 (still in orbit) Apr 21, 2013
- **PhoneSat 2.4 ORS-3 Minotaur 1**: Nov 20, 2013
- **PhoneSat Team**: Apr 18, 2014
- **EDSN Super Strypi** Oct 29, 2015
- **Nodes Orb-4 Atlas V**: Dec 3, 2015
- **SOAREX-8 Terrier/Black Brant**: July 7, 2015
- **SOAREX-9 (WFF)**: March 3, 2016
- **CRS-3 Falcon 9**: Apr 18, 2014
- **Antares A-ONE**: Apr 21, 2013
Status of Analysis TES-3 and TES-4

TES-3/TES-4 Flight Test Data

*Active work in progress to refine models based on flight data – including uncertainty analyses (F10.7; geometric variables)

- for NASA internal use
TechEdSat-4

- 1st NASA NanoSatellite 3U Jettisoned from the NRCSD (July 2014)
- Exo-Brake Demonstration
  - $\beta=8\text{kg}/\text{m}^2$
- Advanced Manufacturing
- COM Experiment III + GPS
- Two-tier Architecture

- for NASA internal use
T5/P5 Flight System Architecture and Dataflow

Ground Segment

Monitoring and Analysis Applications

Sensor Data Display and Analysis Applications

Iridium Data Distribution Server

Sensor data stream
As e-mail

USB Video Stream
WSN data

Iridium Messaging

Iridium Network

Iridium Data Stream
As e-mail

Space Segment

Iridium-1 Transceiver

POWER Board

T5/P5 Avionics

PWR Subsystem
Solar Panels
8.4 V Batteries

Door and Panel Actuators
Winch

802.15.4

Crayfish GPS/COMM

Iridium-3 Transceiver

P5 Board
WiFi CAM
Zigbee sniffer

ISM-band
Ground Station

2.4 GHz
High-Rate Downlink

Camera1 Camera2

ISM

XBe WSM

Wireless Sensor Module
(WSM Gen-2)

Pressure
Temp
IMU

Ground Segment

Iridium-1
Transceiver

Iridium-3
Transceiver

P5 Board
WiFi CAM
Zigbee sniffer

Camera1 Camera2

ISM

XBe WSM

Wireless Sensor Module
(WSM Gen-2)
TES-5 Science/Mission Objectives

- Establish improved uncertainty analysis for eventual controlled flight through the Thermosphere (perform detailed comparison to the TES-3 and TES-4 with respect to key Thermosphere variable uncertainty).
- Improve prediction of re-entry location.
- Provide the base technology for sample return technology from orbital platforms.
- Provide the eventual testing of independent TDRV-based planetary missions
- Provide engineering data for an On-Orbit Tracking Device that could improve the prediction of jettisoned material from the ISS (per discussions with the TOPO group).

TES-5/P-5 Flight Unit
(READY to Integrate)
# Frequency Coordination

<table>
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<th></th>
<th>TES-1</th>
<th>TES-2</th>
<th>TES-3p</th>
<th>TES-4</th>
<th>SOARE X-8</th>
<th>SOARE X-9</th>
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<tr>
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<td>N/A</td>
<td>2410 MHz</td>
<td>2410 MHz</td>
<td>2410 MHz</td>
</tr>
</tbody>
</table>

- for NASA internal use
De-Orbit/Targeting Interest

Sample Return/Re-entry Targeting With Modulated Exo-Brale: Validation – it WORKS!

Application to larger payloads
What is Next?

ISS Sample Return

SPQR-Small Payload Quick Return
- 3 stage concept
- On-demand sample return
- COM IV experiment
- EDL test platform

Atromos: Nano-sat Mission to the Surface of Mars
- Mission Attributes –local climatology and surface characterization of areas not accessible to large missions (most of Mars!)
- Self-stabilizing re-entry probe (TDRV-Tube Deployed Re-Entry Vehicle)
- EDL Technique for small probes
- Dual probe demonstration 2018-2020
Summary

• TES-N/Phone-N series has helped to train ~40 individual now at NASA, SpaceX, Boeing, Lockheed and ...Start-ups!

• Several ‘Firsts’ for ISS-deployed experiments

• Numerous Technologies Advanced
  • COM [LOW data rate up/downlink – Iridium; MEDIUM and HIGH data rate]
    ✓ Commanding the nanosat via EMAIL
  • Fabrication
  • De-Orbit Systems (Exo-Brake – MODULATED!)
  • Evolving 2-tier Architecture
    ✓ Arduino/Intel-Edison-Linux based platforms

• Pioneered Safety Processes for ISS Satellite Jettison

• Future Work leads to ISS Sample Return, Advance Re-entry Development ..... And Mars!