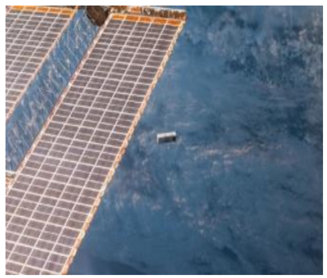
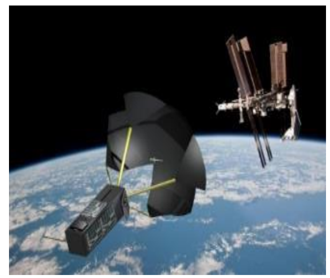
TechEdSat 5 / PhoneSat 5 (T5/P5)

SmallSat Presentation 2016

TechEdSat-1



TechEdSat-2



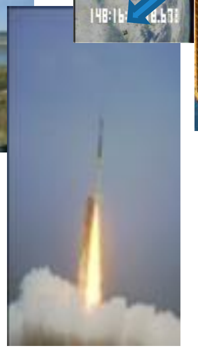
TechEdSat-3

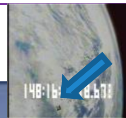
TechEdSat-4

SOAREX-8

M.Murbach, R. Alena, A. Guarneros Luna
C. Priscal, J. Wheless, F. Tanner, R. Morrison, K. Oyadomari
P. Papadopoulos/SJSU, D. Atkinson/UofIdaho
TES/PSAT-Team
NASA Ames Research Center

Relevant Flight Experiments TES-N





SOAREX-6
2008

SOAREX-7
2009

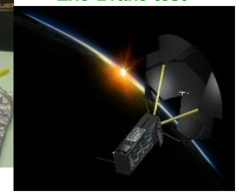
TES-1
Oct 4, 2012

First US Nanosat deployed off ISS
PSRP process mastered
Rad-tolerant processor demo

TES-2
Iridium test
Aug 21, 2013

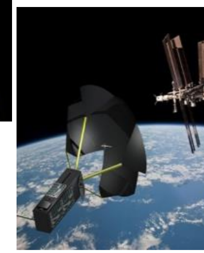
First Iridium in-space COM demonstration

First US 3U Nanosat deployed off ISS First Exo-Brake test



TES-3
Aug 3, 2013
(6 wk deorbit)

Evolution of TES-3
Iridium modem
Uplink/via email demonstrated
Exo-Brake II



TES-4
Mar 3, 2015
(4 wk deorbit)

WSM1, AIM Camera
X-Band, ISM-Band, P5 alpha, ISM-Camera and Full ExoBrake

SOAREX-8 During test (WFF)
July 7, 2015

WSM2, AIM Camera
ISM-Band, P5 alpha, ISM-Camera

SOAREX-9 (WFF)
March 3, 2016

Modulated Exo-Brake
Improved positional/target accuracy
Improved Targeting, WSM2, ISM Band

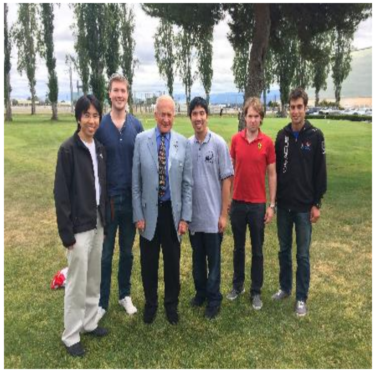
TechEdSat5/PhoneSat5
Coming up this year!!

Recent Years of Flight Experiments (2008-2015):
6 Flights +1(SOAREX8) +PhoneSats 1-4

…here before

SOAREX/TechEdSat-N Team

Relevant Flight Experiments PhoneSat

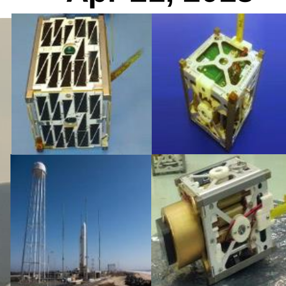


Recent Years of Flight Experiments (2009-2015)

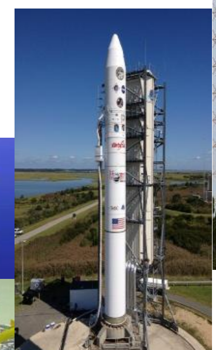
Intimidator-5
July 29, 2010

Balloon
June 9, 2011

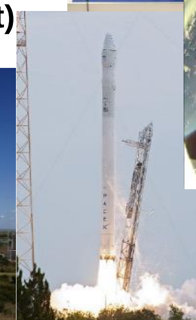
SpaceLoft-6
Apr 5, 2012



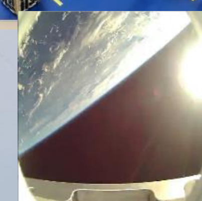
PhoneSat 1a, 1b, 2.0
Antares A-ONE
Apr 21, 2013



PhoneSat 2.4
ORS-3 Minotaur 1
Nov 20, 2013
(still in orbit)



PhoneSat 2.5
CRS-3 Falcon 9
Apr 18, 2014



SOAREX-8
Terrier/Black Brant
July 7, 2015

EDSN
Super Strypi
Oct 29, 2015

Nodes
Orb-4 Atlas V
Dec 3, 2015

SOAREX-9 (WFF)
March 3, 2016

PhoneSat Team

TechEdSat Process/Document Tree

TechEdSat Project ARC

- Project Plan (7120.5-lite)
  - Requirements
  - SEMP
  - Ground Ops/Safety
  - Flight Ops
  - Test Plan/Procedures
  - TM Summary
    - ODAR
    - SpaceCap Data Form
    - FCC Submittal;
    - SBD Letter of Awareness (Orbcomm and Iridium)
- ICD
- CDR
- FRR

ISS Safety (JSC)

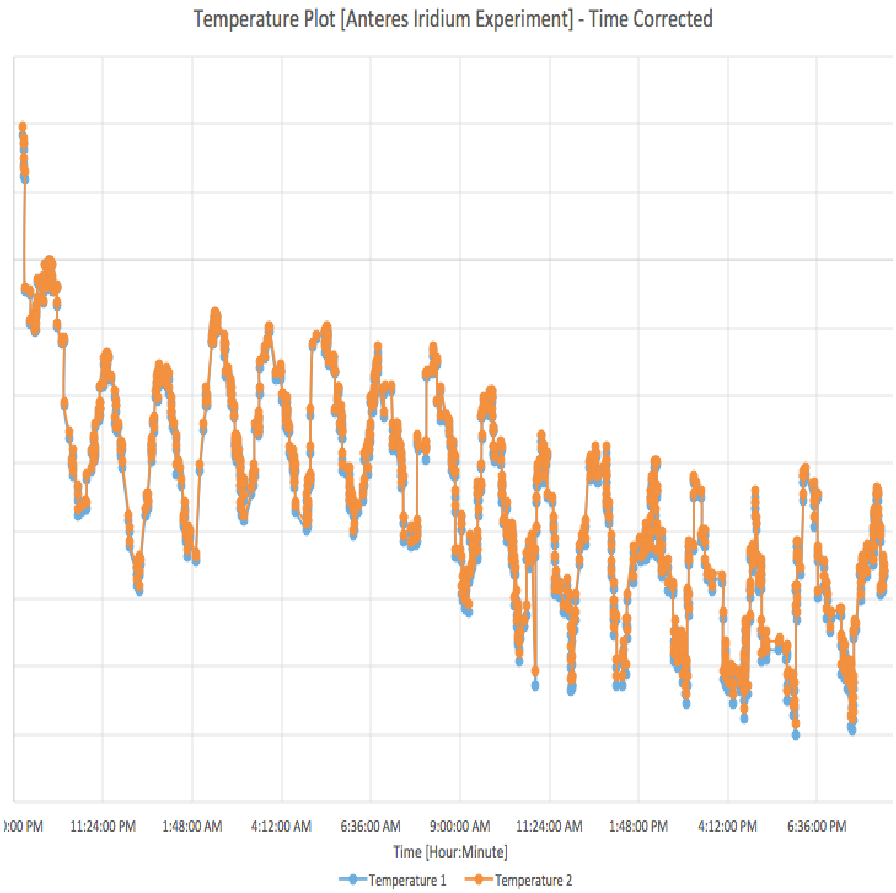
- Standard/Reference Safety Document
  - ICD Verification
- PSRP Documentation
  - HR/UHR (Hazard Reports)
    - Standard Hazards
      - Shatterable Materials, Outgasssing, Flammable Materials, Structural Failure of Vented Containers
    - Unique Hazards (2)
      - Battery and Structural Failures

COC (Certificate of Compliance)

COFR

Delivery Launch

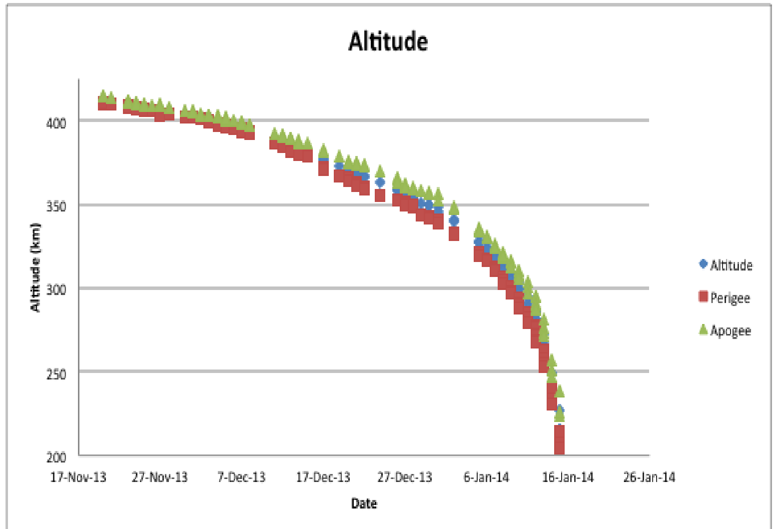
TES 2: Initial Iridium Flight Data

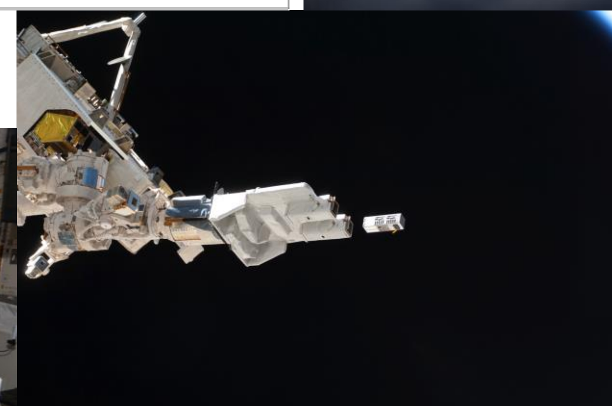


- Launched on April 21, 2013
- Produced excellent data
- Met all success criteria.

TechEdSat 3

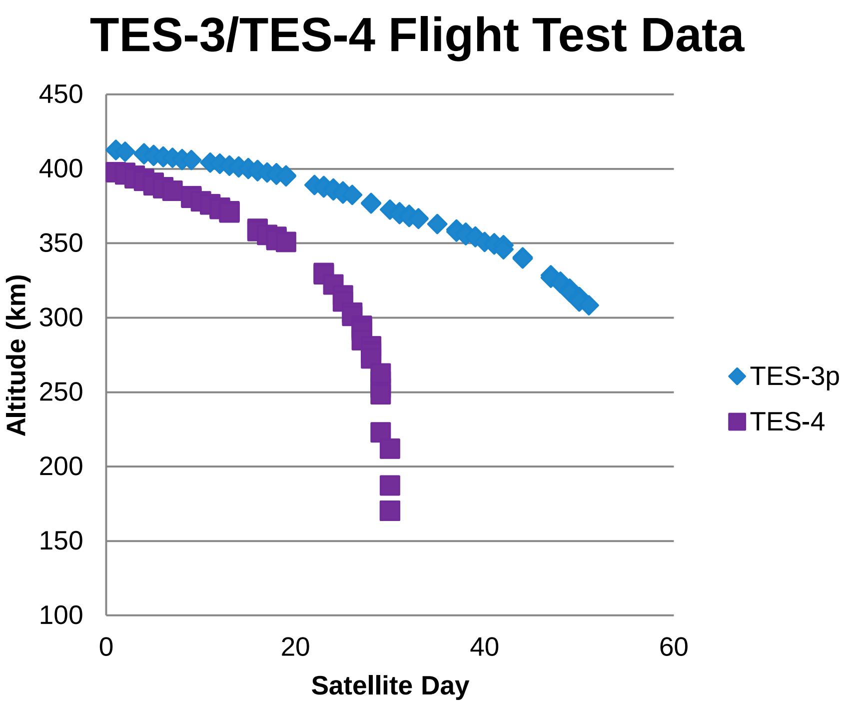
- We were 1st 3U Jettisoned from ISS
- Nominal Success Criteria
- First Exo-Brake Demonstration
- Advanced Manufacturing
- COM Experiment II
- Two Tier Architecture
- Launch August 20, 2013 on HTV4
- Jettison on November 23rd, 2014
- Re-entry on January 6, 2014

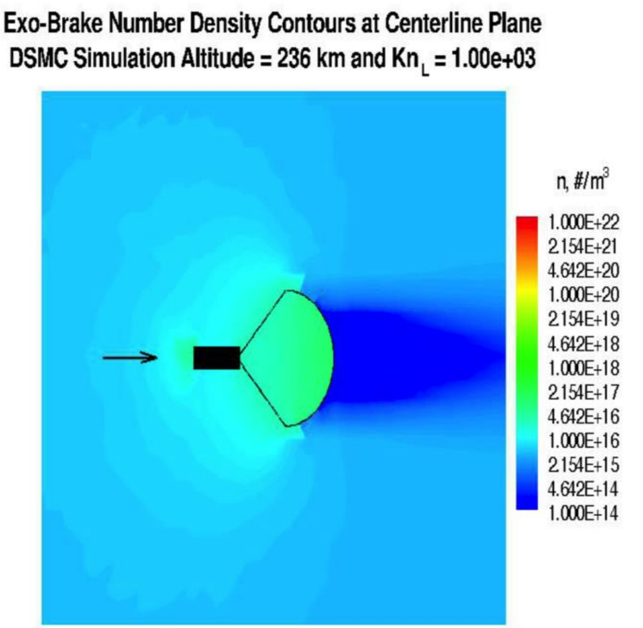




Other Key Contributors: A. Reuter, J. Mojica, M. Scales, J. Benson, J. Seneris.

Status of Analysis TES-3 and TES-4

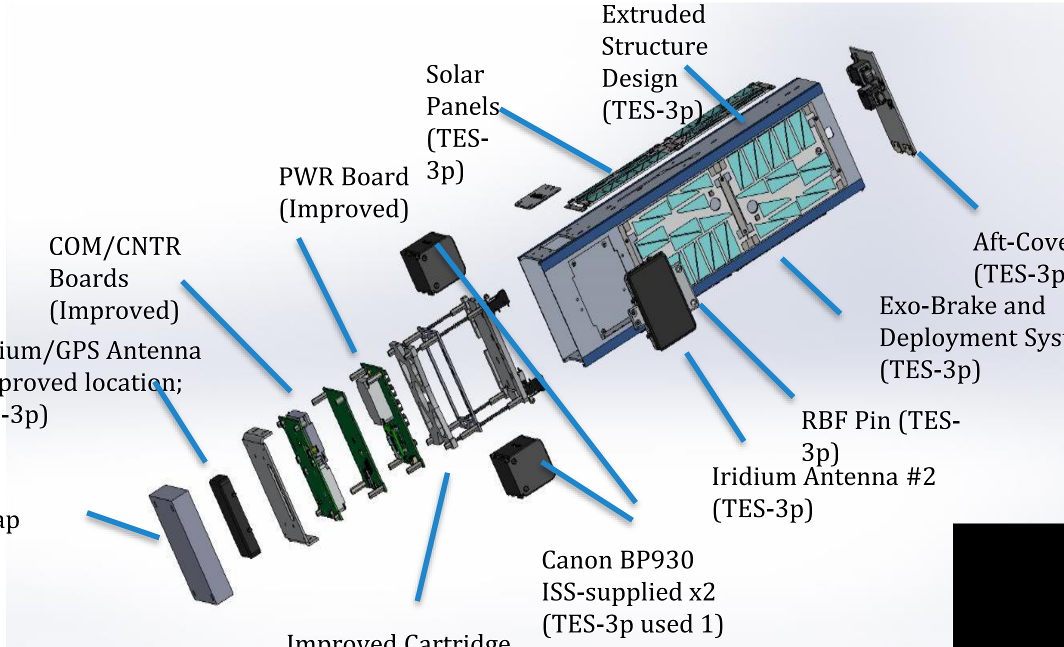




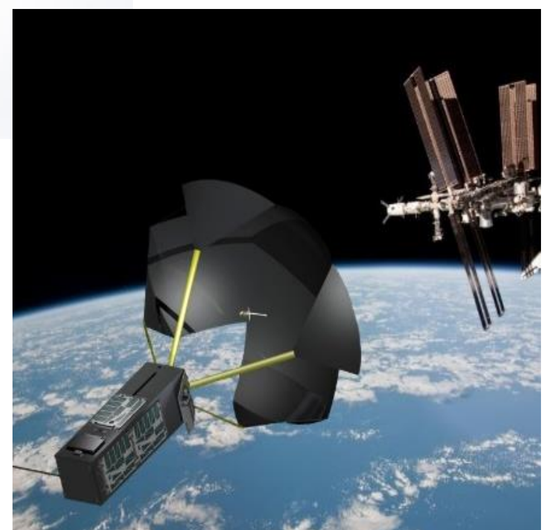
C.Glass/LaRC [DAC/DSMC]

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

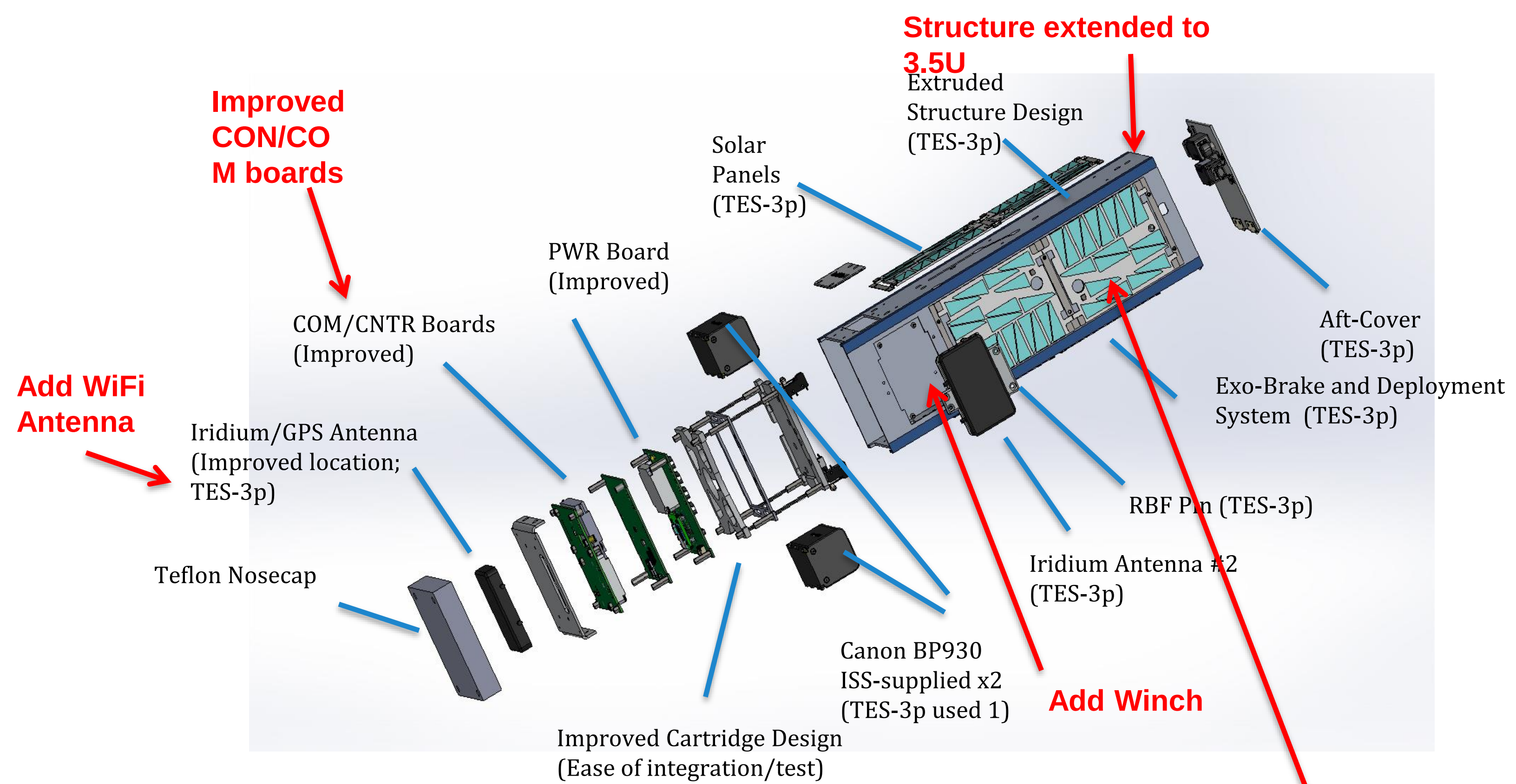
TechEdSat-4



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

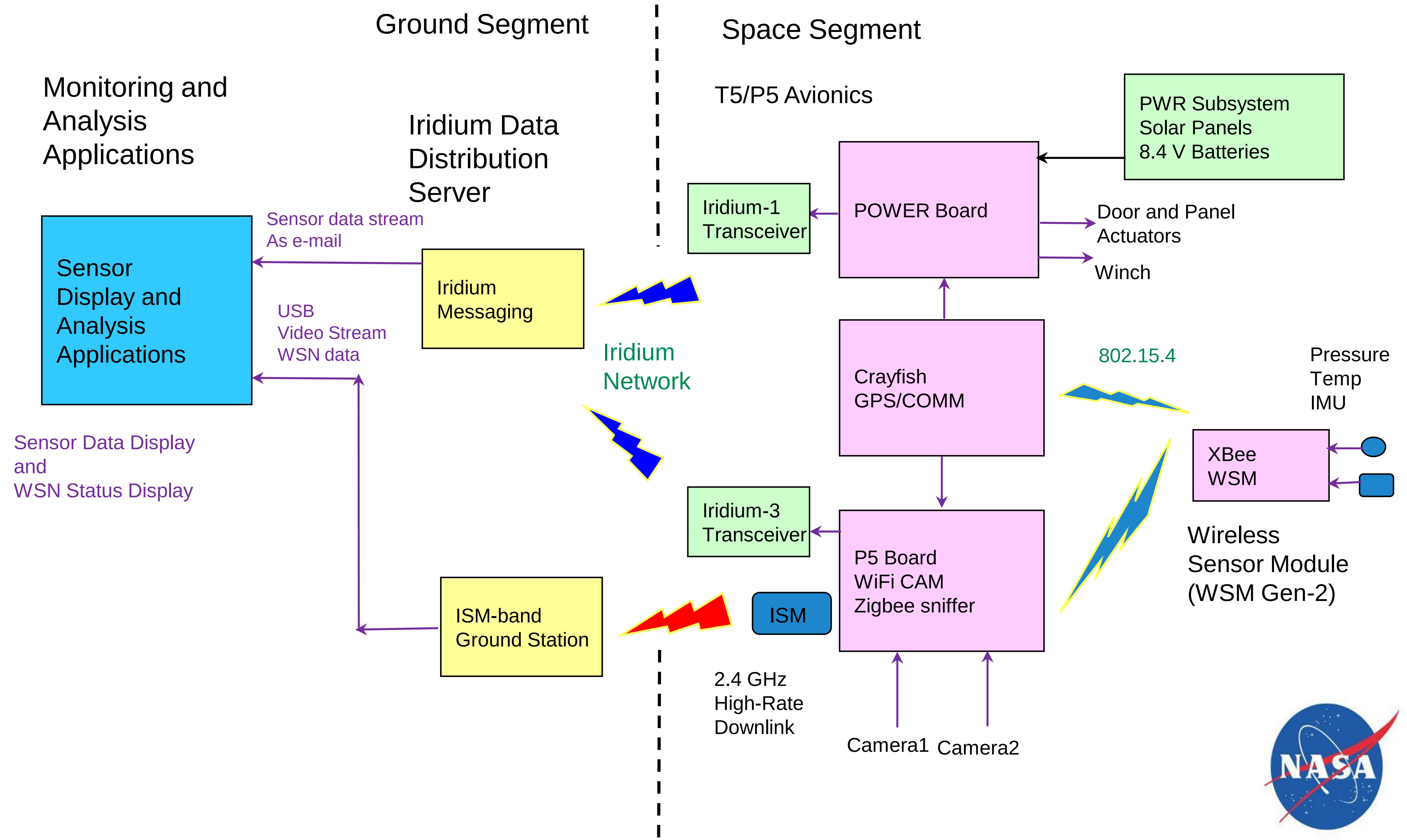


TechEdSat-5

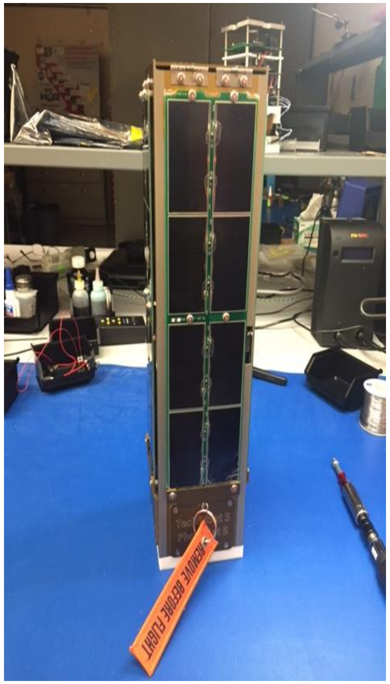


2-12-2016Update Note -Added:
-Body mounted solar panels; tested in TVAC
-Cameras aft/side pointing for WFF over-flight

T5/P5 Flight System Architecture and Dataflow



TES-5 Science/Mission Objectives



TES-5/P-5 Flight Unit

-Establish improved <u>uncertainty analysis</u> 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).

SOAREX 8

SOAREX-8 Flight Test Conclusions

The SOAREX-8 payload functioned properly producing data from all elements

The Iridium modem sent three SBD messages

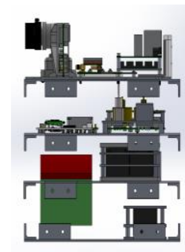
The WiFi downlink sent data the entire mission from activation until LOS

- Packets captured and archived
- Video stream displayed on Ground Station Laptop

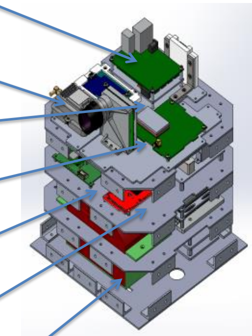
The WiFi downlink set a record for range to 334 km/206 miles altitude

The WiFi downlink transmitted valid video for entire mission duration

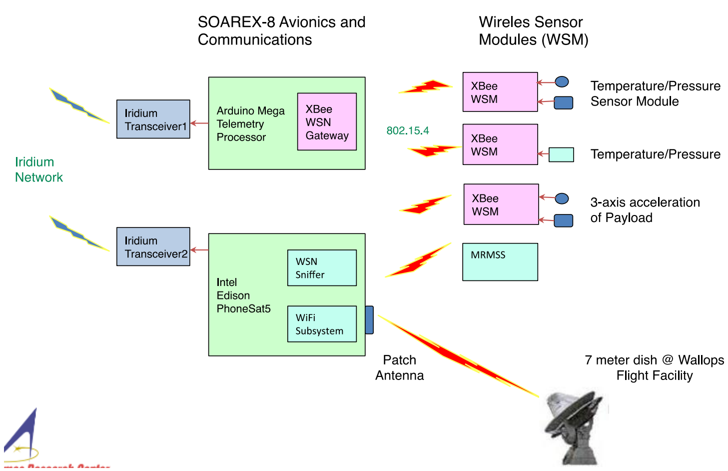
SOAREX-8 Innovation/Experiments



- Modular Nanosat X-band TM (10 Mbs Soln/ BitBeam)
- Thompson/RESOLVE Camera
- PhoneSat 3.0 Flight Test
- WiFi TM Demonstration (1 Mbs Soln)
- TechEdSat-5 BUS Flt Test
- Wireless Protocol Flight Test (Xbee Ser 1)
- Milwaukee 28v Power System!



SOAREX-8 Flight Configuration

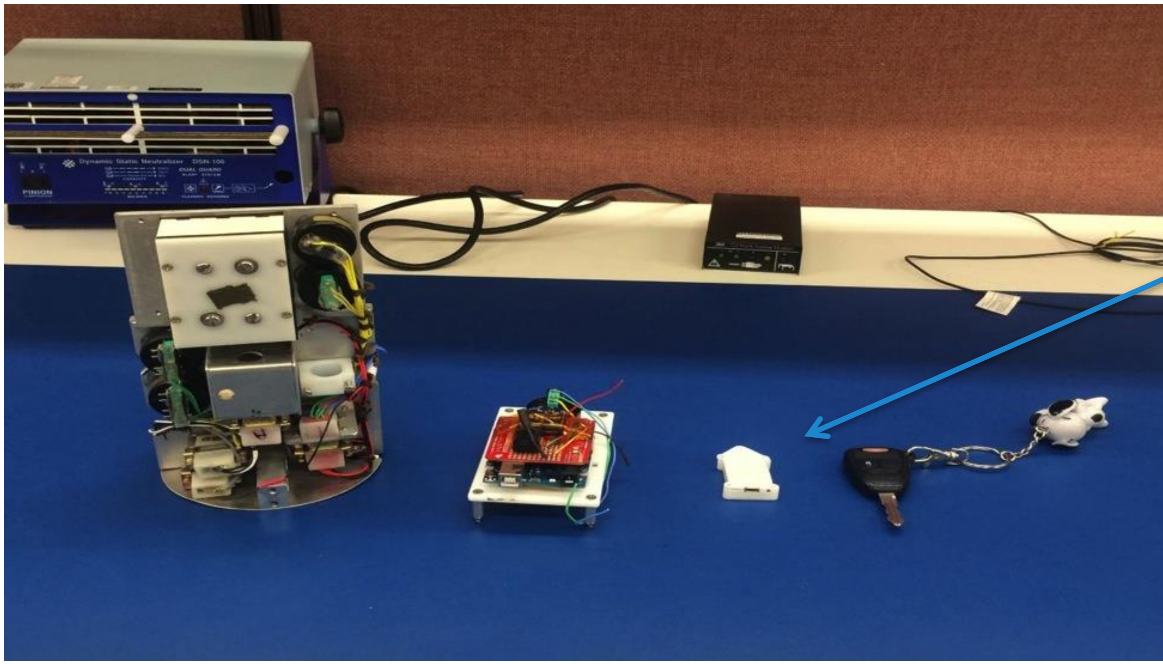


Modified WiFi for Space Communications

- Modified WiFi is particularly useful for low-cost University-led missions
  - Use is within FCC guidelines for 2.4 GHz ISM band
- IEEE 802.11b protocol u**Modified WiFi for Space Communications**
- sing selected commercial-grade components
  - Components selected for performance and compatibility
  - Components tested in thermal/vacuum and for shock/vibration
- The SOAREX-8 WiFi was downlink only
  - Set up MAC layer for half-duplex operation
  - Broadcast mode: No acknowledgement from the ground
  - Rate set to 1 Mbps to maximize link margin
- Video was sent as VGA resolution at 5 frames/sec rate
  - H.264 video stream
  - Packet level transfer using Real-Time Transport Protocol (RTP)
  - DVB packet retransmission for error compensation
- Range Extension
  - Wallops Flight Facility tracking 7.3 m dishes used for 42 dBi gain
  - Patch antenna on payload
  - Receiver in telemetry room N162

SOAREX-9 Flight Payload

WSM Experiment
(Internet of Rockets; Pico-Satellite)



WSM 2.0 Experiment on TES-5

Evolution of unique Wireless Sensor Module

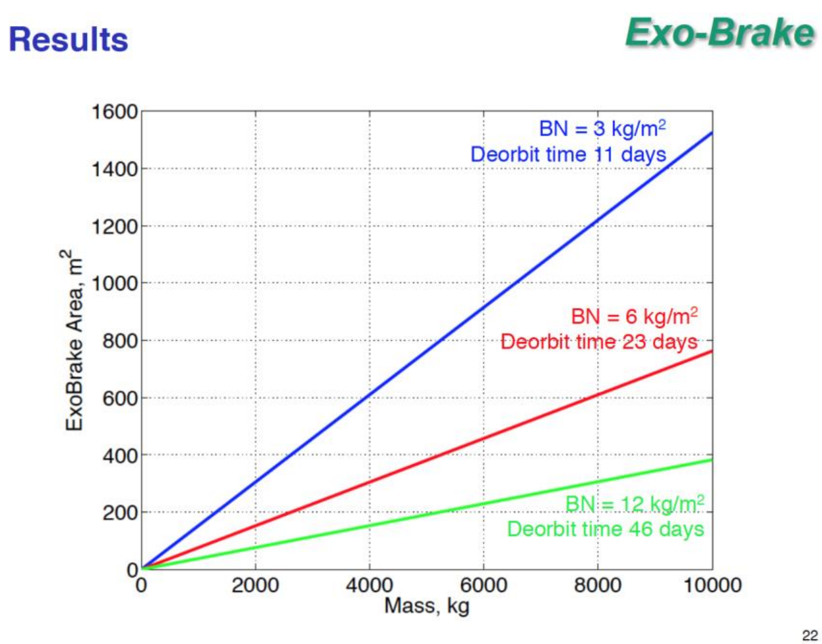
Far left: Original SOAREX-1 data acquisition module
Second from left: SOAREX-9 WSM 1.0 trial version
Third from left: currently developed system for SOAREX9 and TES-5
Fourth from left: Marc's key chain…

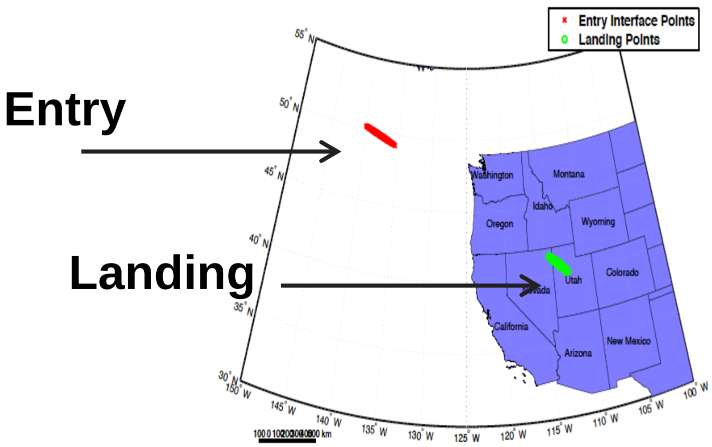
Frequency Coordination

	TES-1	TES-2	TES-3p	TES-4	SOARE X-8	SOARE X-9	TES-5
Iridium	N/A	1616-1626.5 MHz	1616-1626.5 MHz	1616-1616.5 MHz	1616-1626.5 MHz	1616-1626.5 MHz	1616-1626.5 MHz
StenSat	437.465 MHz	N/A	437.465 MHz	N/A	N/A	N/A	N/A
ISM	N/A	N/A	N/A	N/A	2457 MHz	2457 MHz	2457 MHz
WSM	N/A	N/A	N/A	N/A	2410 MHz	2410 MHz	2410 MHz

De-Orbit/Targeting Interest…

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





S. Dutta, A. Cianciolo, R. Powell , (LaRC)

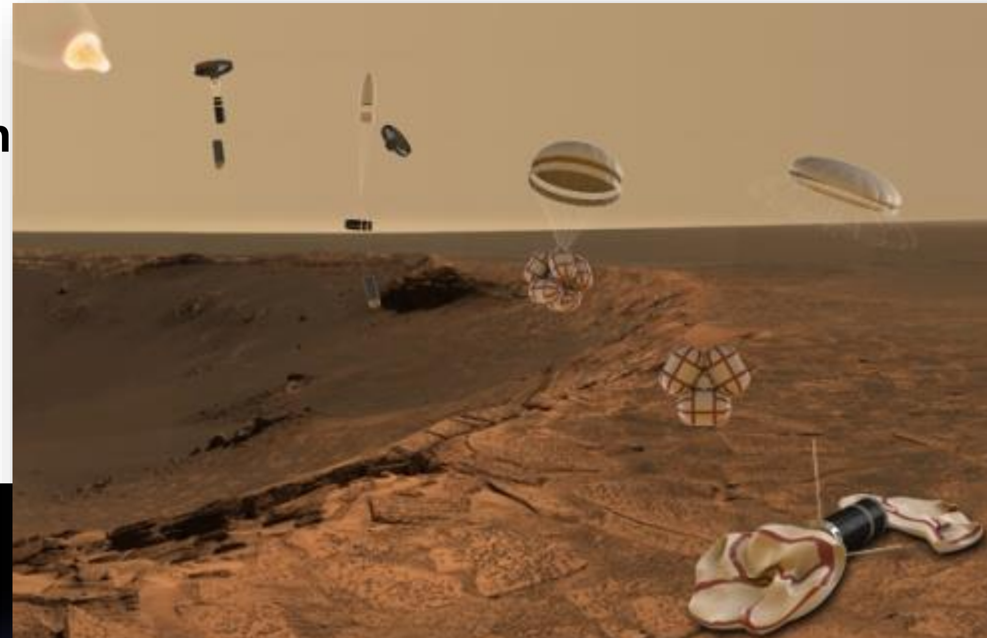
Application to larger payloads

What is Next?

ISS Sample Return

SPQR-Small Payload Quick Return

- 3 stage concept
- On-demand sample return
- COM IV experiment



Atromos: Cubesat Mission to the Surface of Mars

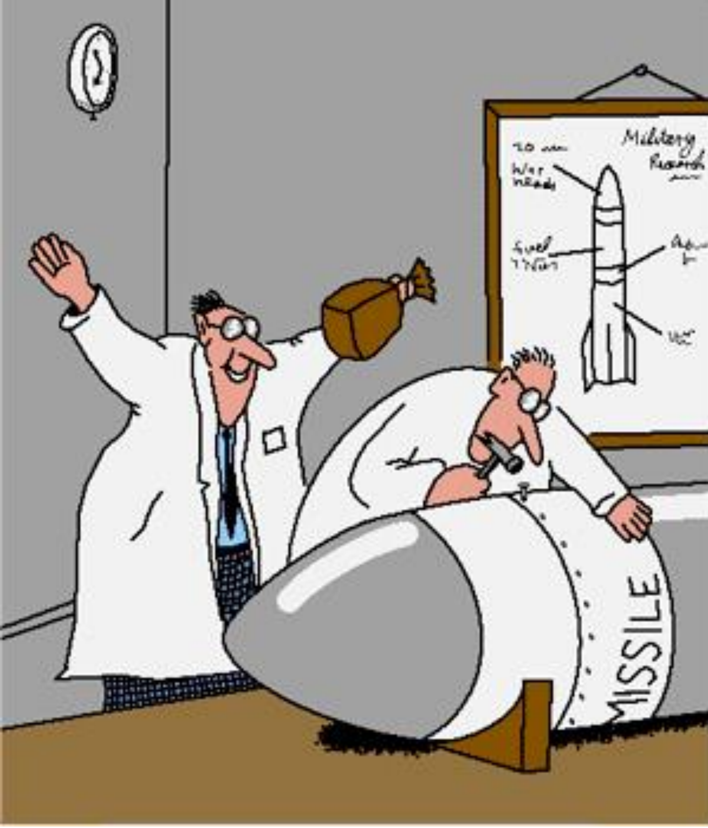
- Mission Attributes
- Self-stabilizing re-entry probe (TDRV-Tube Deployed Re-Entry Vehicle)
- EDL Technique for small probes
- Nuclear option for mission longevity

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!**

Ames Research Center

SOAREX



Lighter Moments!!