The TechEdSat-N and ETC Series

(and Subsequent Experiments)

M. Murbach, A. Guarneros Luna, R. Alena, P.Papadopoulos, T. Stone, A. Tanner, J. Wheless, C. Priscal, A. Dono Perez, A. Cianciolo, C. Glass, R. Powell, A. Bowes, S.Dutta,

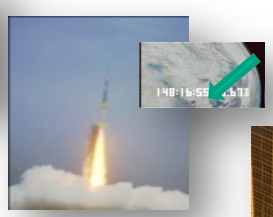
October 23rd , 2017

Relevant Flight Experiments

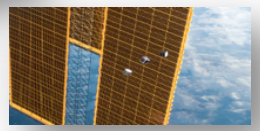
SOAREX/TechEdSat-N Team

Flight Experiments of Recent Years
(2008-2017):
9 Flights

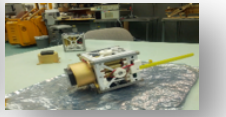
SOAREX-6
(2008)



SOAREX-7
(2009)



TES-1
Oct 4, 2012



TES-2
PhoneSat
Iridium-test
Aug 21, 2013

TES-3
Aug 3, 2013
(6 wk de-orbit)

TES-4
Mar 3, 2015
(4 wk de-orbit)

TES-5
Mar 6, 2017
(currently in orbit)

...here before

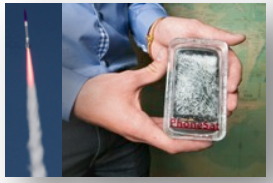
SOAREX-8
(2015)

SOAREX-9
(March 7, 2016)

PhoneSat Team

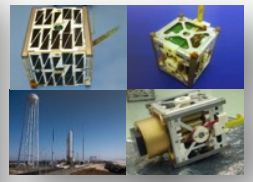
Flight Experiments of Recent Years
(2009-2015)

Balloon
June 9, 2011

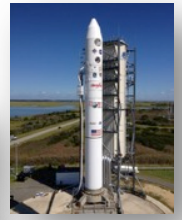


Intimidator-5
July 29, 2010

SpaceLoft-6
Apr 5, 2012

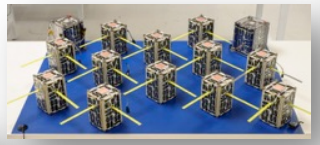


PhoneSat 1a, 1b,
2.0
Antares A-ONE
Apr 21, 2013



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

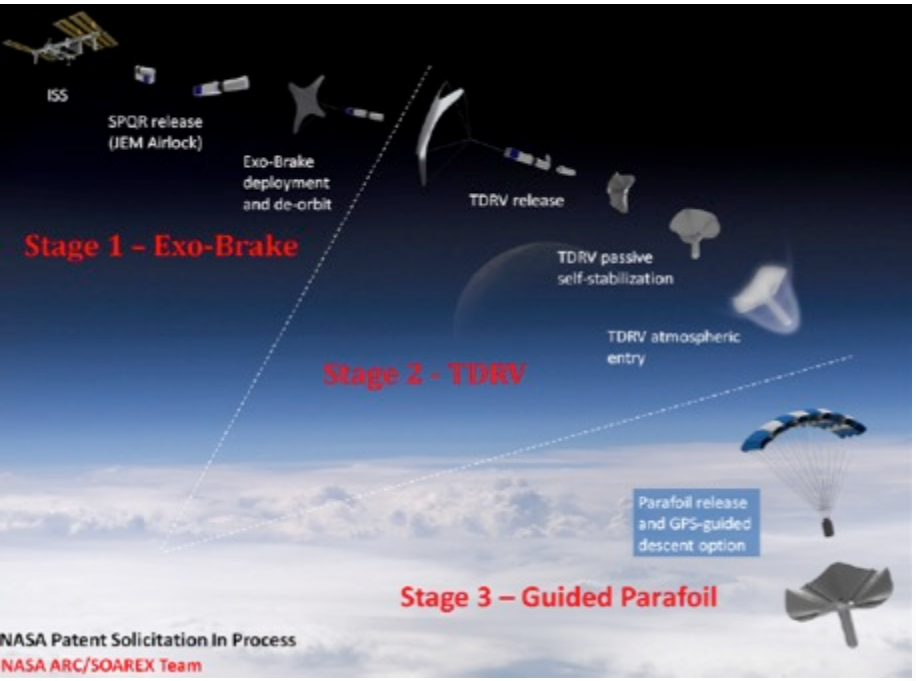
PhoneSat 2.5
CRS-3 Falcon 9
Apr 18, 2014



EDSN
Super Strypi
Oct 29, 2015

Nodes
Orb-4 Atlas V
Dec 3, 2015

SOAREX-8
Terrier/Black Brant
July 7, 2015



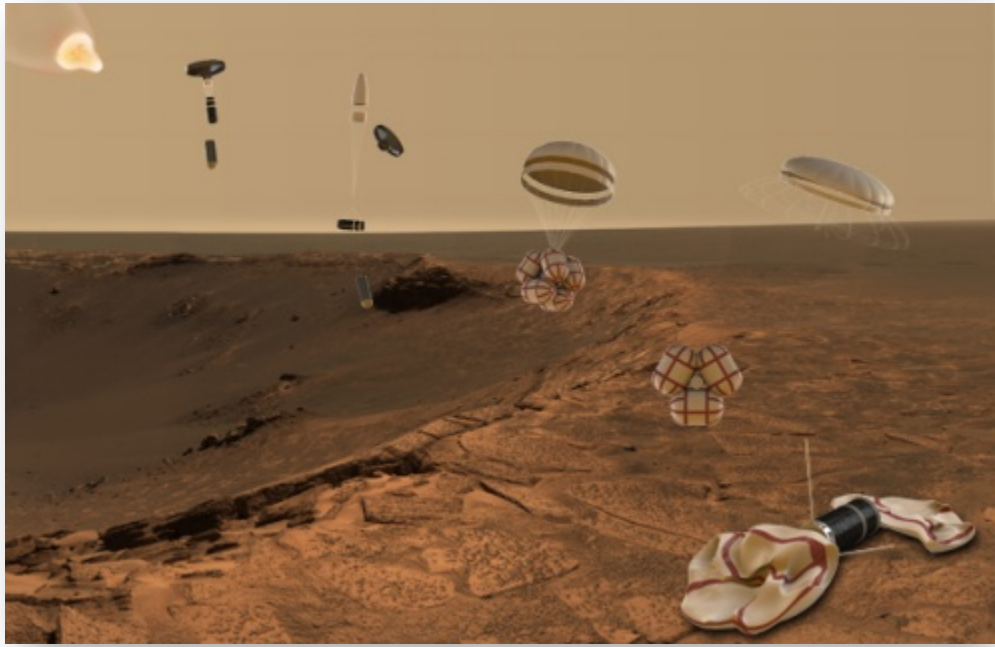
ISS Sample Return

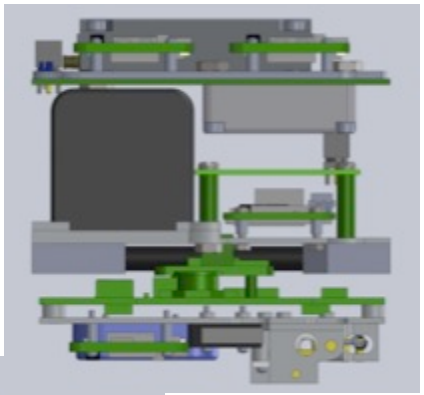
SPQR-Small Payload Quick Return

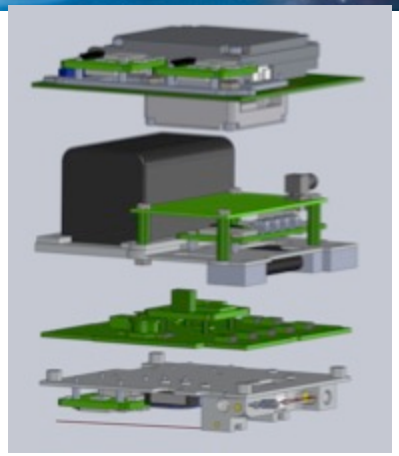
- 3 stage concept
- On-demand sample return

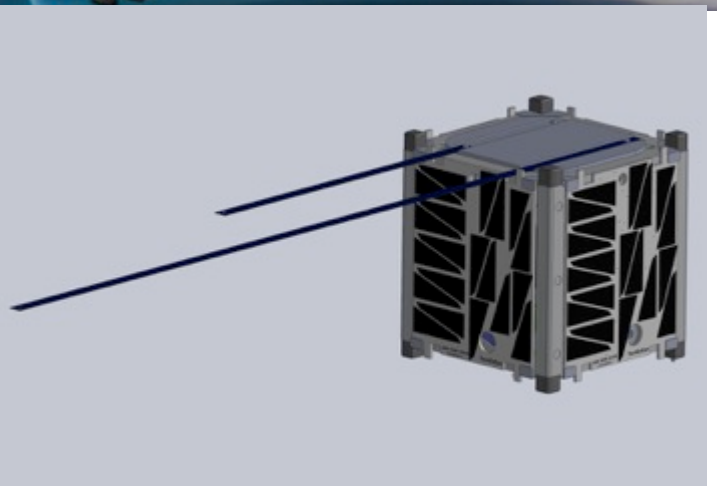
Atromos: Cubesat Mission to the Surface of Mars

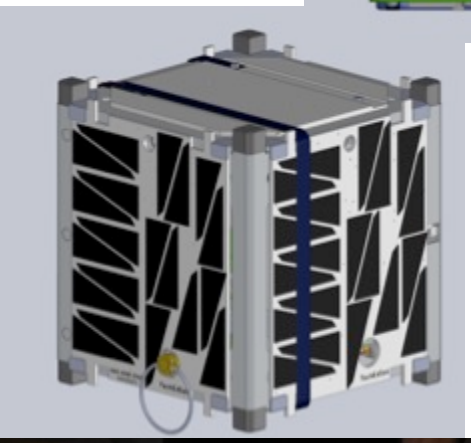
- Mission Attributes
- Self-stabilizing re-entry probe (TDRV-Tube Deployed Re-Entry Vehicle)
- EDL Technique for small probes
- Nuclear option for mission longevity



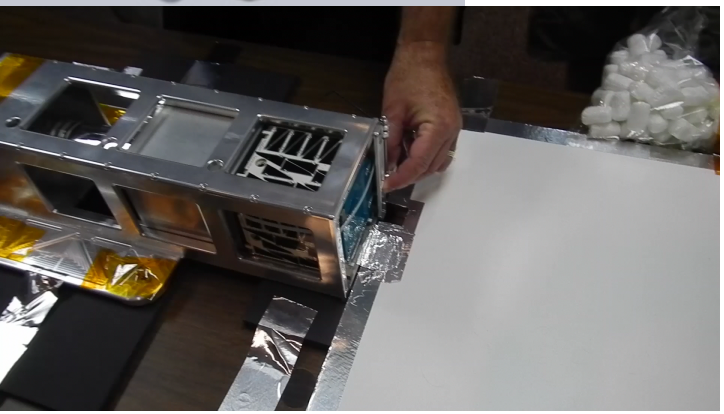


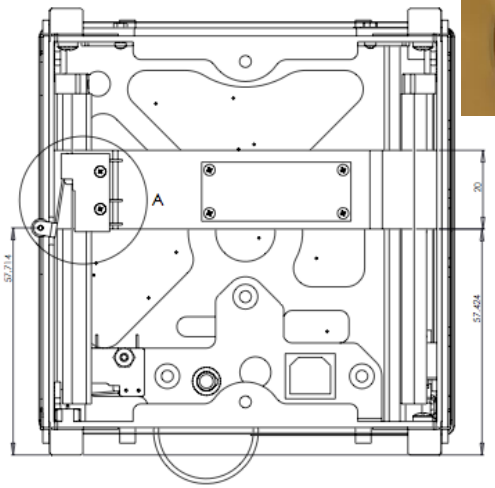




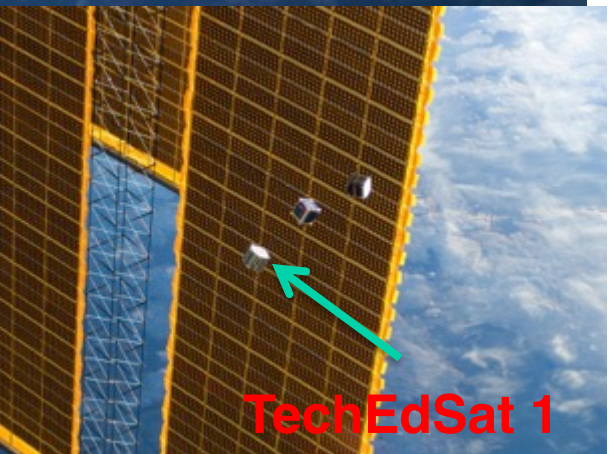


JSSOD and ISS





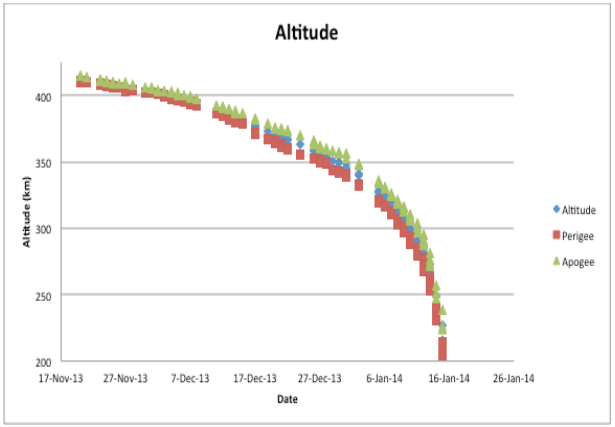
Before and after Jettison from ISS



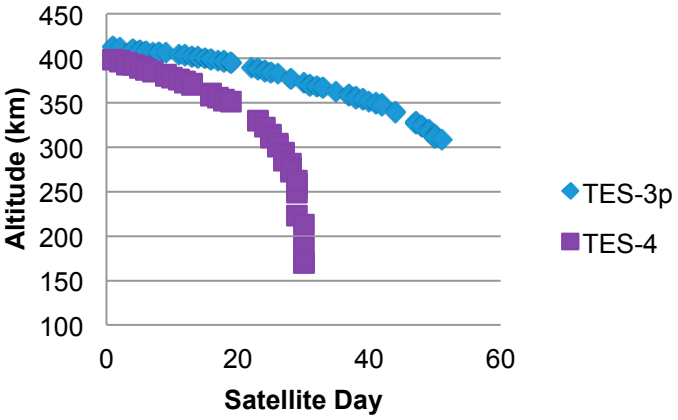
- We were 1st!
- Nominal Success Criteria
- Demonstrated ISS Safety Design for jettison from ISS
- Demonstrated 2-tier RAD-Tolerant Architecture (ÅAC Microtec)
- COM Experiment (UHF, Iridium, OrbComm)
- Launch Date on HTV3 August 14, 2012
- Jettison on October 4, 2012
- ~7 month duration
- Building, tested and certify with in 9 months

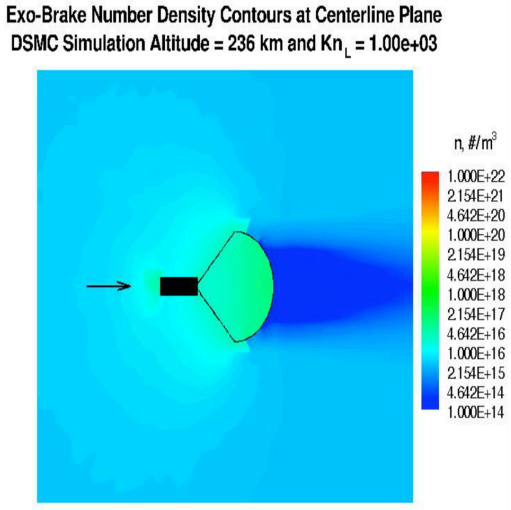
TechEdSat 3&4

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



TES-3/TES-4 Flight Test Data





- 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

How To Include University/Intern Involvement

Caveat-

-Once pulled into the NASA 'firewall' (due to EAR/ITAR considerations), the hardware/ software becomes 'NASA' (controllability, etc.)

- Spectrum authorization (critical!) is such that NASA is the single operator, and authorization occurs through the NTIA process.

Method 1. Interns work at NASA

-Through NASA internship program, direct-hire, or summer sponsorship through NASA grants.

The young professionals/ interns become part of the revolving TES-N team

Tiered approach keeps the more experienced helping to train next generation

Works best if projects < 1-2 years (scale of Master degree)

-Challenge – 'paperwork' must be distributed (nobody likes to work on this to exclusion

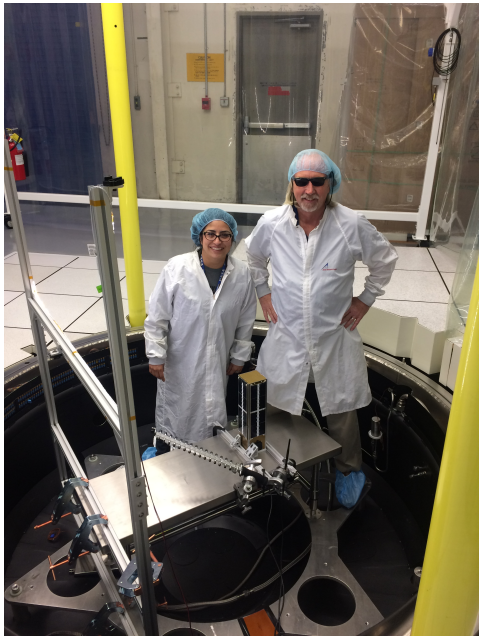
Method 2. Universities work with NASA through an SAA (Space Act Agreement) [Piggy-backing]

- University contributes an Experiment/Sub-system/Sensor (ESS) through defined interfaces

- EDUs are first developed, then the FU (Flight Unit) is delivered and becomes part of the TES-N

Guidance is provided on permitted materials, flight wire, solder, conformal coating, etc.

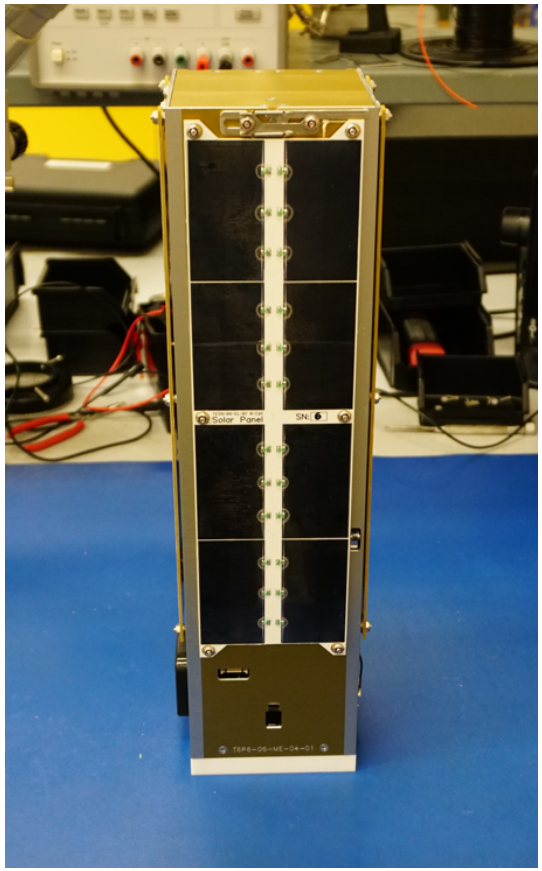
- The ESS is controlled by NASA (and the frequency part of NTIA if applicable) but may have a separate Success Criteria



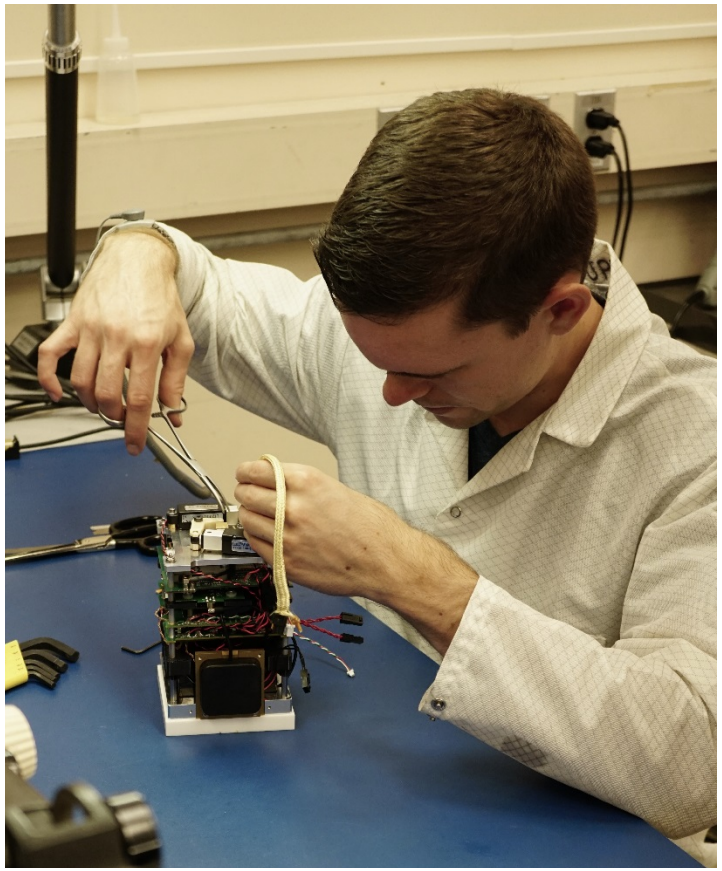
Management/Execution

Nano-Sats

How it's MANAGED/controlled/integrated/built/flown (Briefly)

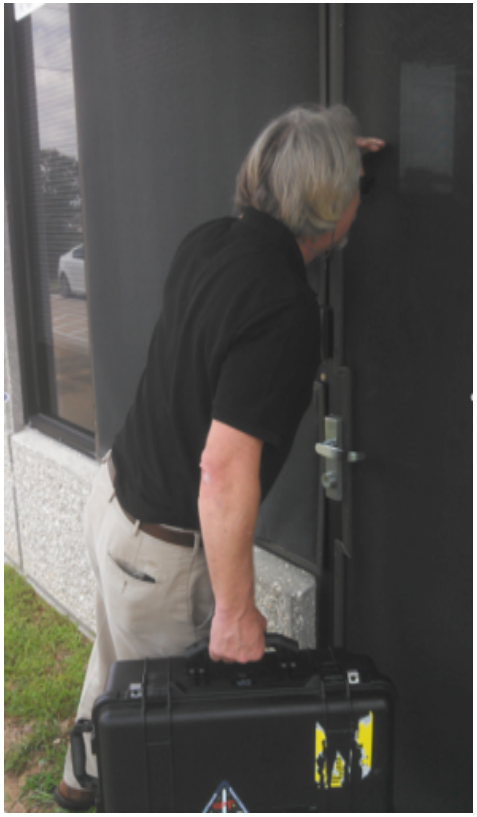


TES-6



JSC Nano-Sat Drive-up Window!

TES-6 launches on Nov11 (OA-8)



…It looks easy!!!

(Ok – what does it really take..)

TES-N Document Tree

TechEdSat Project ARC

- Project Plan
  - 7120.5 class-sub D
  - 7150.2B class-sub D SW
  - Configuration Control
  - Requirements
  - SEMP
  - Ground Ops/Safety
  - Flight Ops
  - Test Plan (13 subsystem, 9 flight)
  - Procedures, Logs, and Reports (31)
  - TM Summary
    - ODAR
    - NTIA
    - FCC Submittal; Approval
    - SBD Letter of Awareness (Iridium)
- ICD
- CDR
- FRR

Total Docs: 64

ISS Safety (JSC)

- Standard/Reference Safety Document
  - ICD Verification
- PSRP Documentation
  - 622 Re-flight Documentation (1)
  - 906 Certification of Flight (1)
  - SDP (1)
  - HR/UHR (Hazard Reports)
    - Standard Hazards (16)
      - Sharp edges, Shatterable Materials, Off-gassing, Flammable Materials, Touch Temperature
    - Unique Hazards (2)
      - Battery, Structural Failures, Deployment Failure, EMI

Total Docs: 21

COC (Certificate of Compliance)

Delivery Launch

COFR

TES-N Documentation Control

MCS/Hardware

- Traceability of Product
- Documentation of Requirements by QA after Review of Engineering Drawings or Requirements
- QA inspections of Product

ITAR Control Librarian

- Design
- Drawings
- Pictures
- Presentations
- Procedures and Logs
- Procurements

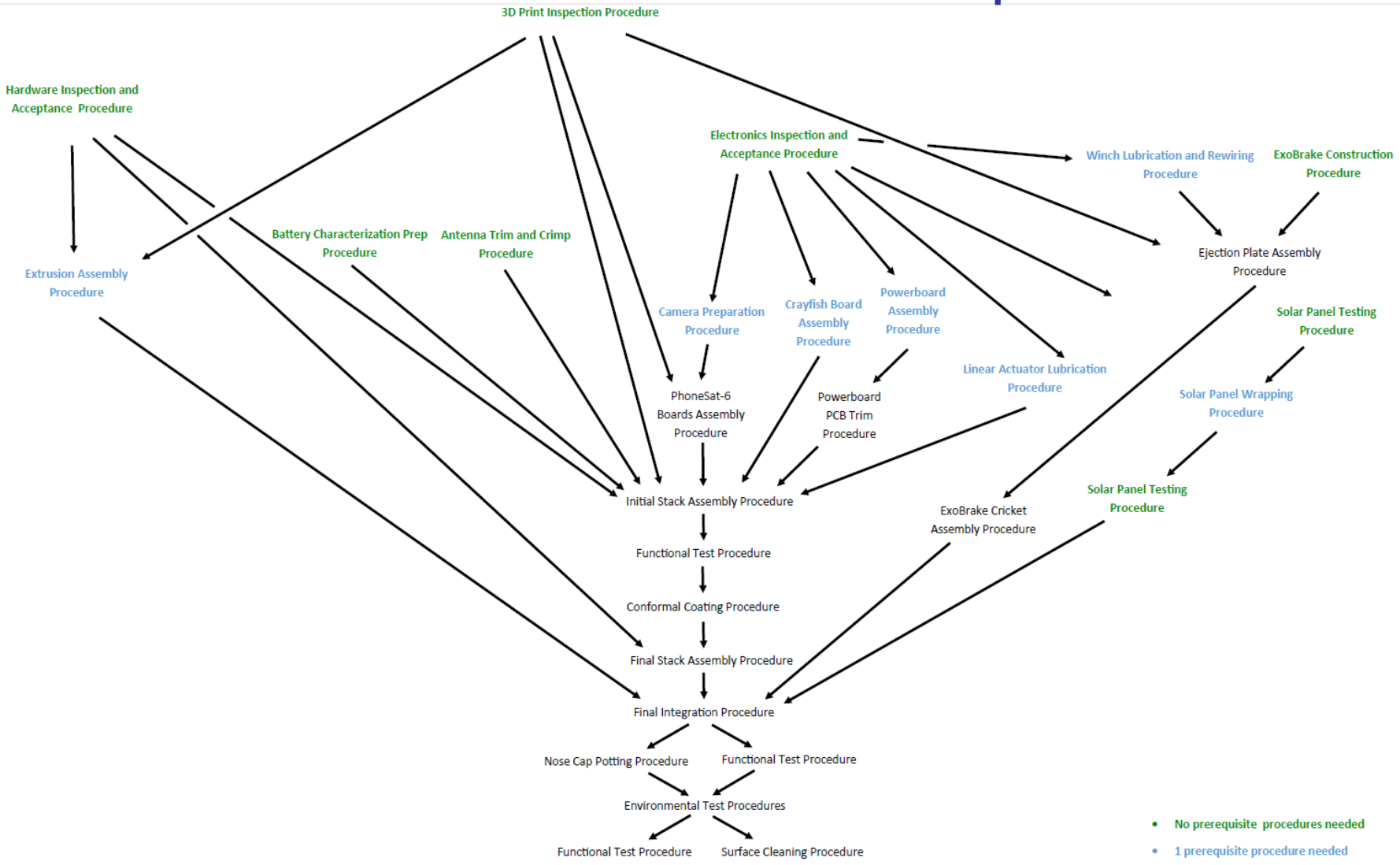
MINX

- Final Drawings
- Approved Procedures and Logs
- Executed Procedures with Logs
- Presentations

SVN

- Software
- CAD modeling

TES-6 Procedure Map



TES-6 Review Cycle/Schedule

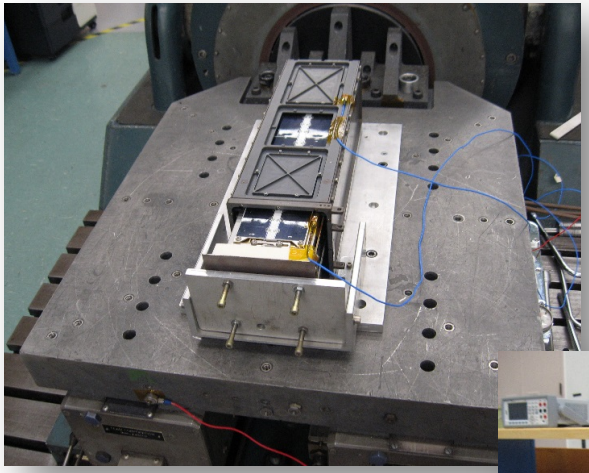
Dec-May 2017/18	PSRP p3 TES7 (Review of TES6)	*Originally TES7 was launching before TES6!
March 21, 2017	Review of TES-7,8	
June 29, 2017	Review of TES-5 Flight and Anomaly	
Sept 15, 2017	Review of Flight Readiness/Progress on Anomaly Resolution	
Sept 22, 2017	ISS Hazard/Safety Closure	
Sept 25, 2017	ACE Pre-Shipment Review	
Sept 27, 2017	NanoRacks Hand-over	** IF other customer didn't show up.. (99.99% certain would)
Oct 7, 2017	NanoRacks hand-over to JSC	
Nov 11, 2017	Flight of OA-8	
Week of Nov 14, 2017	Jettison of TES-6	

*Note – this IS the proverbial '**stand-by**' ticket. The 'new' SPIRE nano-sat would have to miss the deadlines.

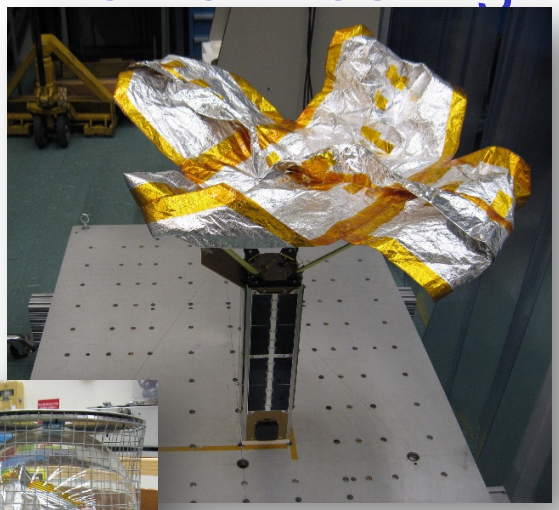
Nov 10, 2017Hand-over to NR for SPX-14
Feb X, 2018 Jettison of TES7

*Conferences/Papers: Calpoly/ IPPW/ Smallsat/ IAC

TES-6 Environmental Testing

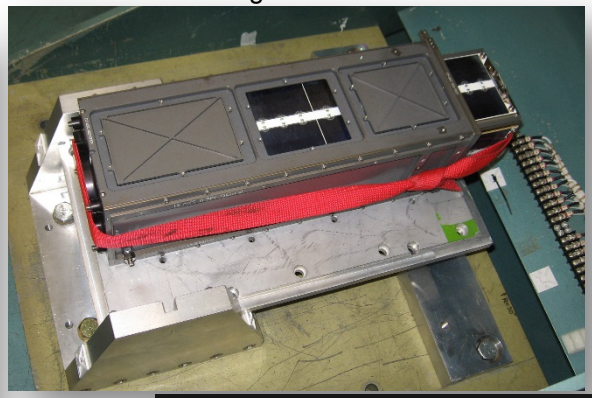


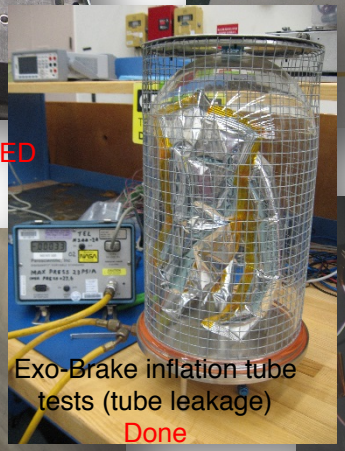
Vibration at >Protoflight 9.47Grms PASSED



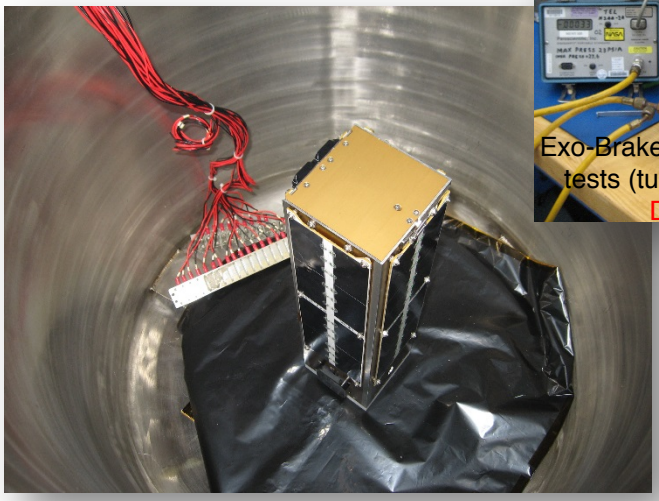
Mass measurement (PASSED)

Static Loads at >Protoflight 10.35G at 3mins PASSED

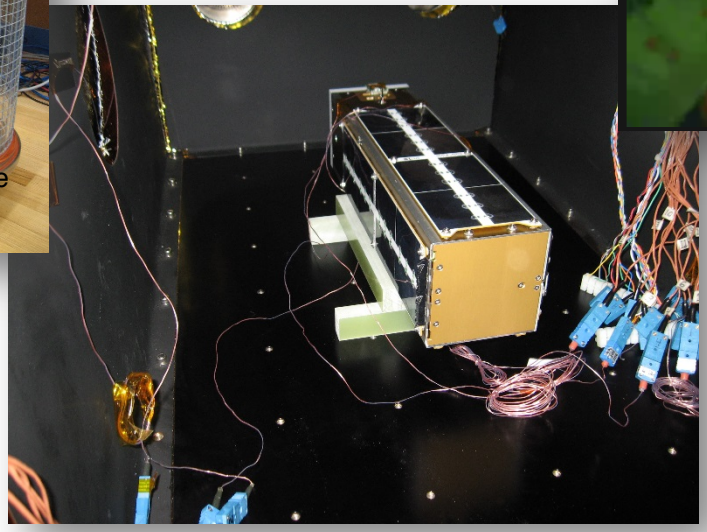




Exo-Brake inflation tube tests (tube leakage) Done



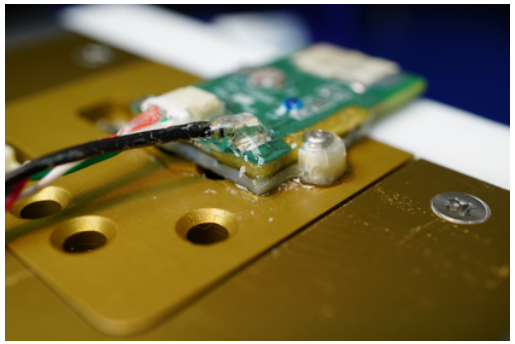
Press/De-Press PASSED



TVAC PASSED

Long SW tests 10hr / (DONE; command tests in progress)

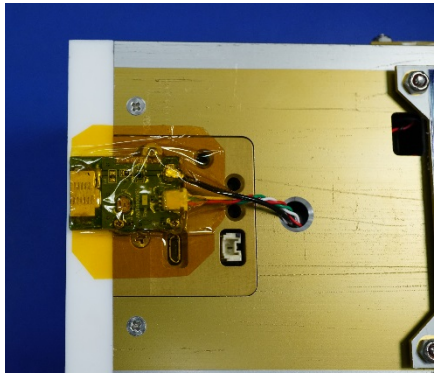
TES-6 Anomalies



TES6/CUBIT-1 Antenna Attachment Issue
9/27/2017

Conversation with Ala Shuhatovich/ JSC

"**Not a structural failure**" – but an anomaly
emergency case" send PSRP Safety Engineer
the result of the suggested solution (below)

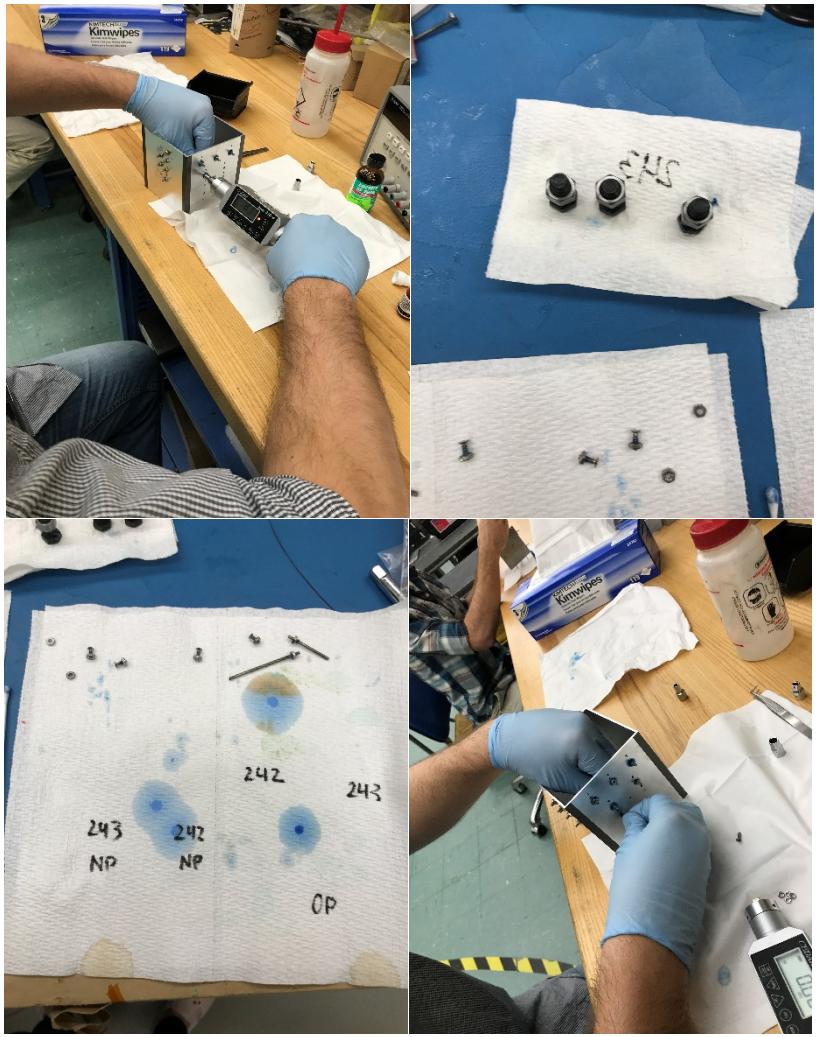


Notes:
-**Survived Proto-flight** levels of test (9.47G rms)
-More DP100 was added after the crack was noted
-Crack may have originated during installation of CUBIT-1

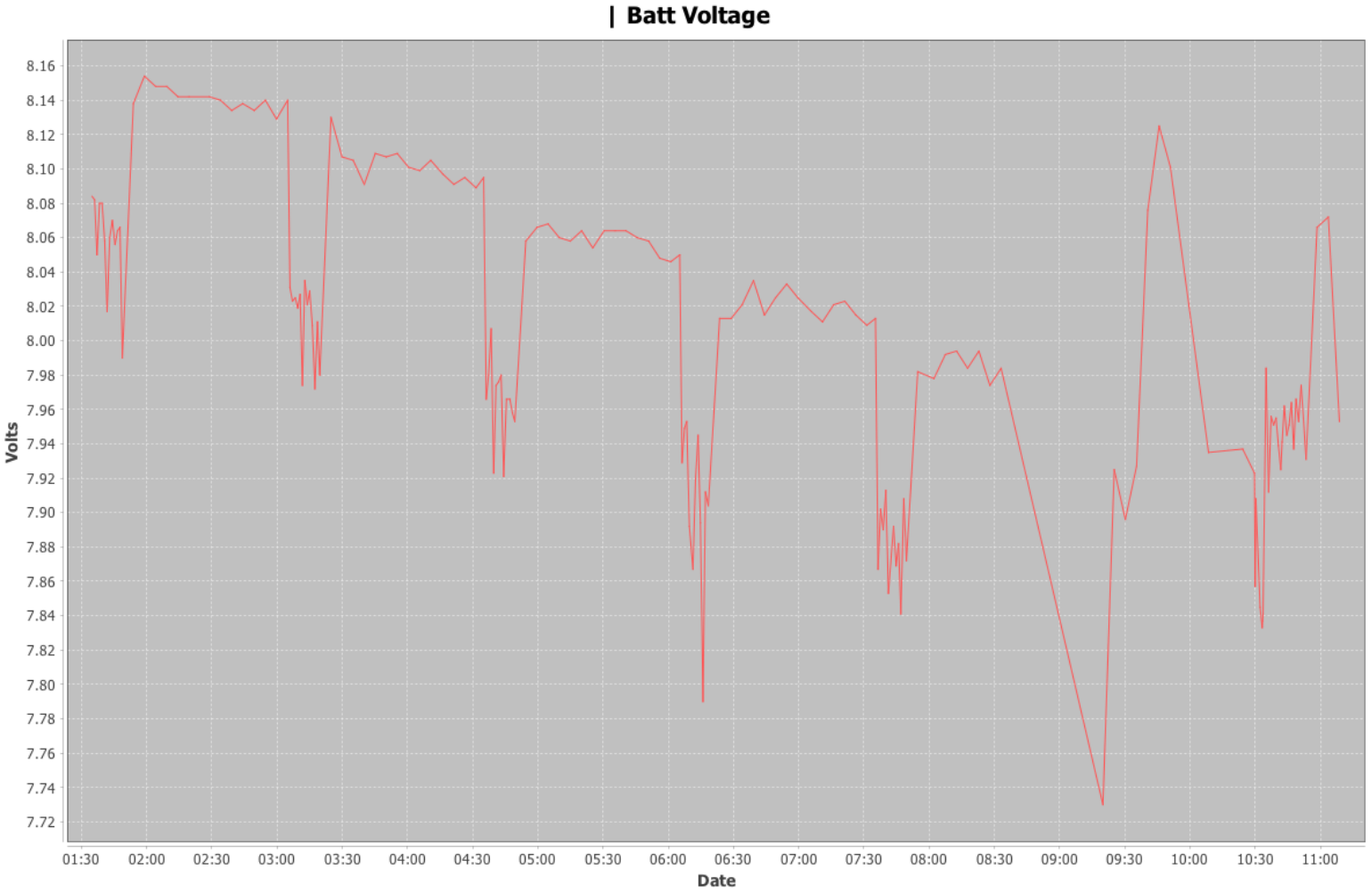
Solution:
-Cover further with Kapton tape (except for hole for photocell)
-Submit 'anomaly' (NOT structural failure) to PSRP
-Ala will inspect once more prior to installation
-CUBIT-1 shall be removed if there is any question (DARPA understands this is a 'best-effort' activity

9 PRACAs

Loctite [control: Loctite 243; long cure cycle; protoflight vibration/accel; post-inspection] CLOSED



TES-6 Battery Voltage (Final Functional Test/Iridium)



Time in PST, 1:30am to 11am, 11/27/17

TechEdSat 6,7,8, 9

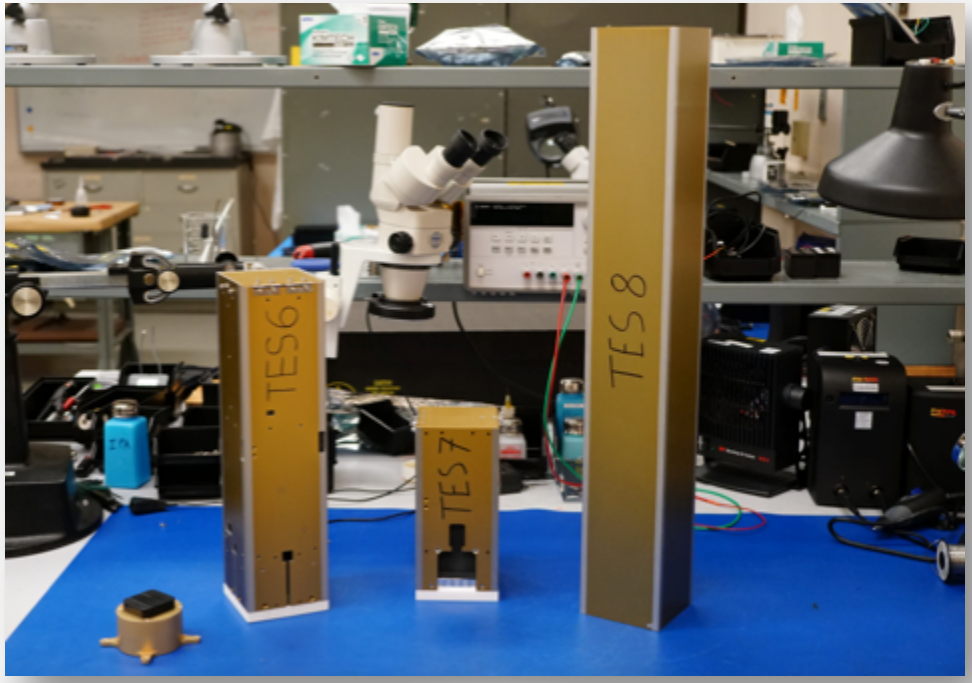
TechEdSAt-6 [*3U*]
2nd Modulated Exo-Brake Flight Test
Exo-Brake Tensioner
New OPS/Schedule
CUBIT-1
Possible OA-8 Oct1, 2017

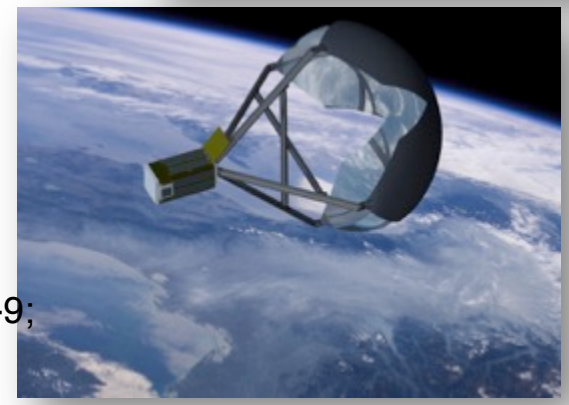
TechEdSat-7 [*2U*]
High Packing Density Exo-Brake
[Novel strut design – no modulation]
Beta= 1kg/m2; 450 km
CUBIT-2
2nd Virgin Orbit Flight Feb, 2018

TechEdSat-8 [*6U*]
Hot Exo-Brake
Modulated with beta=4kgm2
'Deep Dive'
Novel COM
ISS/NRCSD July, 2018 TBD

TechEdSat-9
3U proposed on 1st VO flight

* All CSLI Approved (not TES-9; proposed as ballast!)

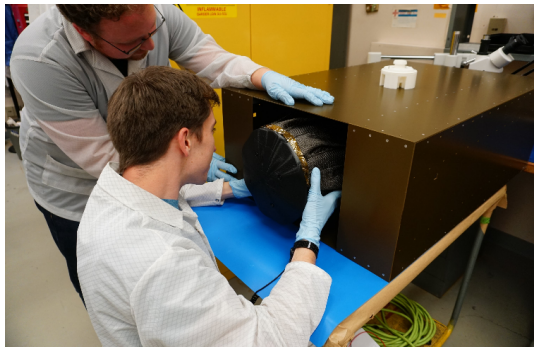




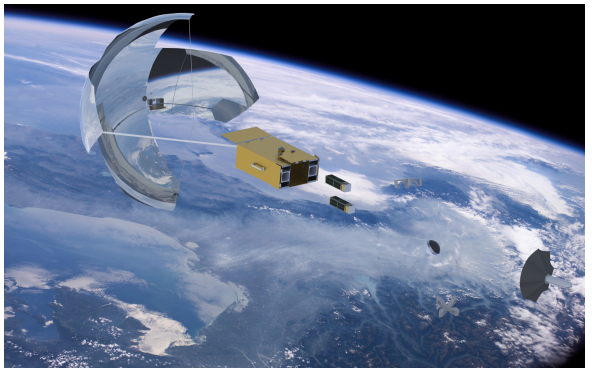
Bigger Platform Possibilities

IRAD Proposal: ARCxSAT

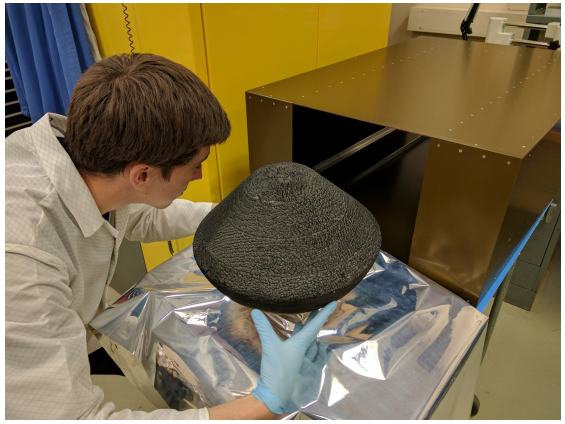
Proposed as ARC smallsat multi-platform development tool; EDL entry system flight tests could include ADEPT, HIAD, TDRV – and other concepts… **AT EARTH ORBIT ENTRY VELOCITY**



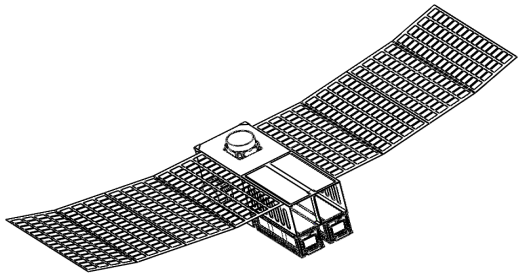
A. ARCXSAT design layout with ISS Cyclops/Kaber Compatibility. Critical interface through micro-conical Is shown on right.



B. ARCXSAT deployed from the ISS with Exo-Brake, EDL And satlet/swarm experiments deployed.



C. Partial EDU plus EDL experiment in ARCxSAT mult-use cavity (12x12x26in).

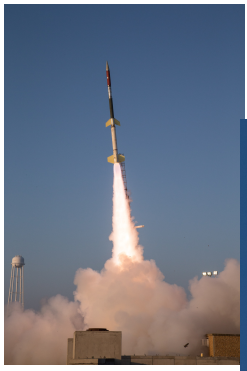


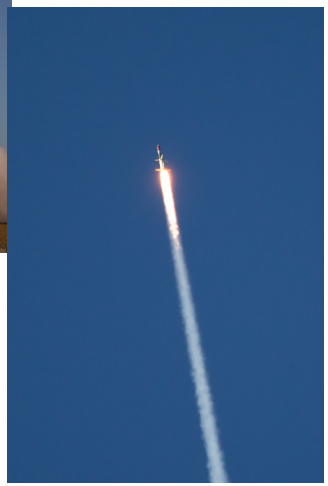
D. GEO-POD Mars concept based on ARCxSAT/ISS Dimensions (deployed at >GEO with SSL launcher. Part of Propsed easibility study.

National Aeronautics and Space Administration

Ames

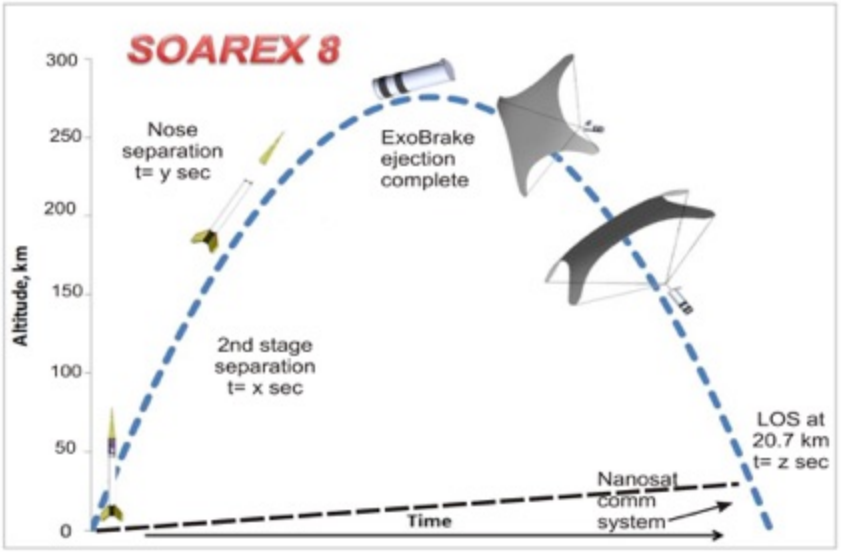
Discovery Innovations Solutions

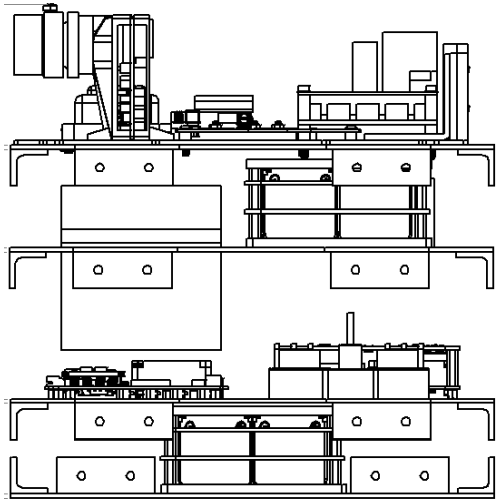


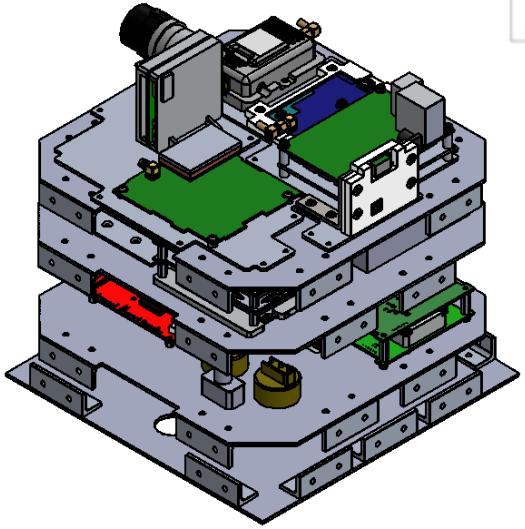


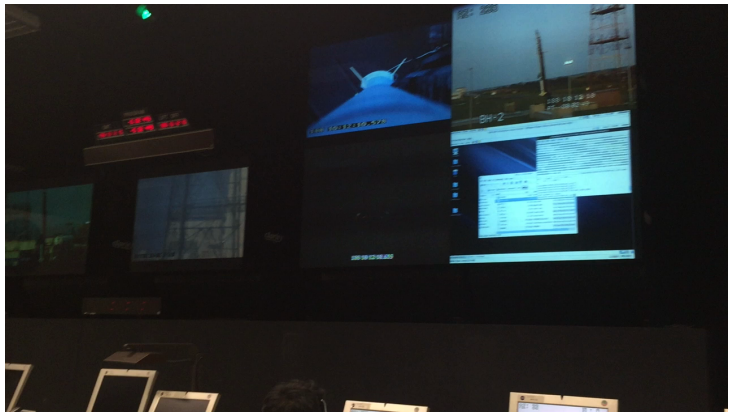
SOAREX-N Sub-Orbital Experiments

SOAREX 8 Mission









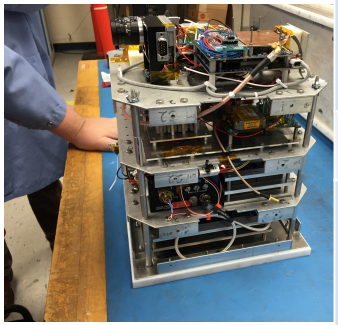
2:42 launch
10:48 EXO-Brake Deployment

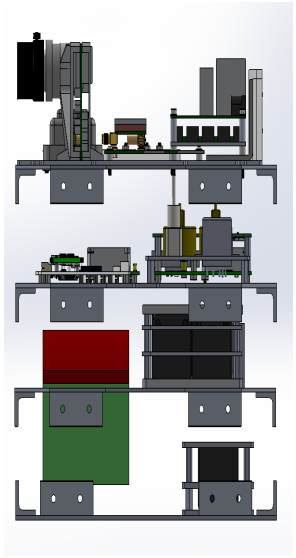
SOAREX 8 results of all experiments

National Aeronautics and Space Administration

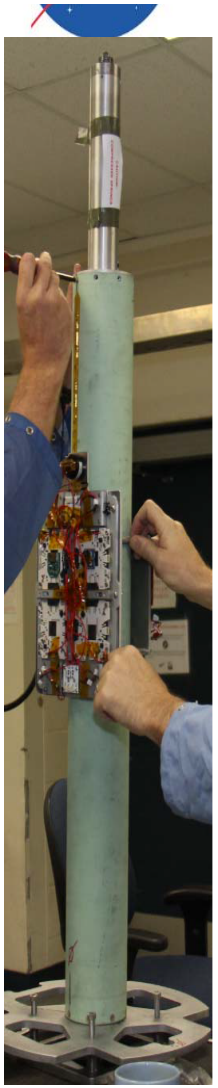
Ames

Discovery Innovations Solutions

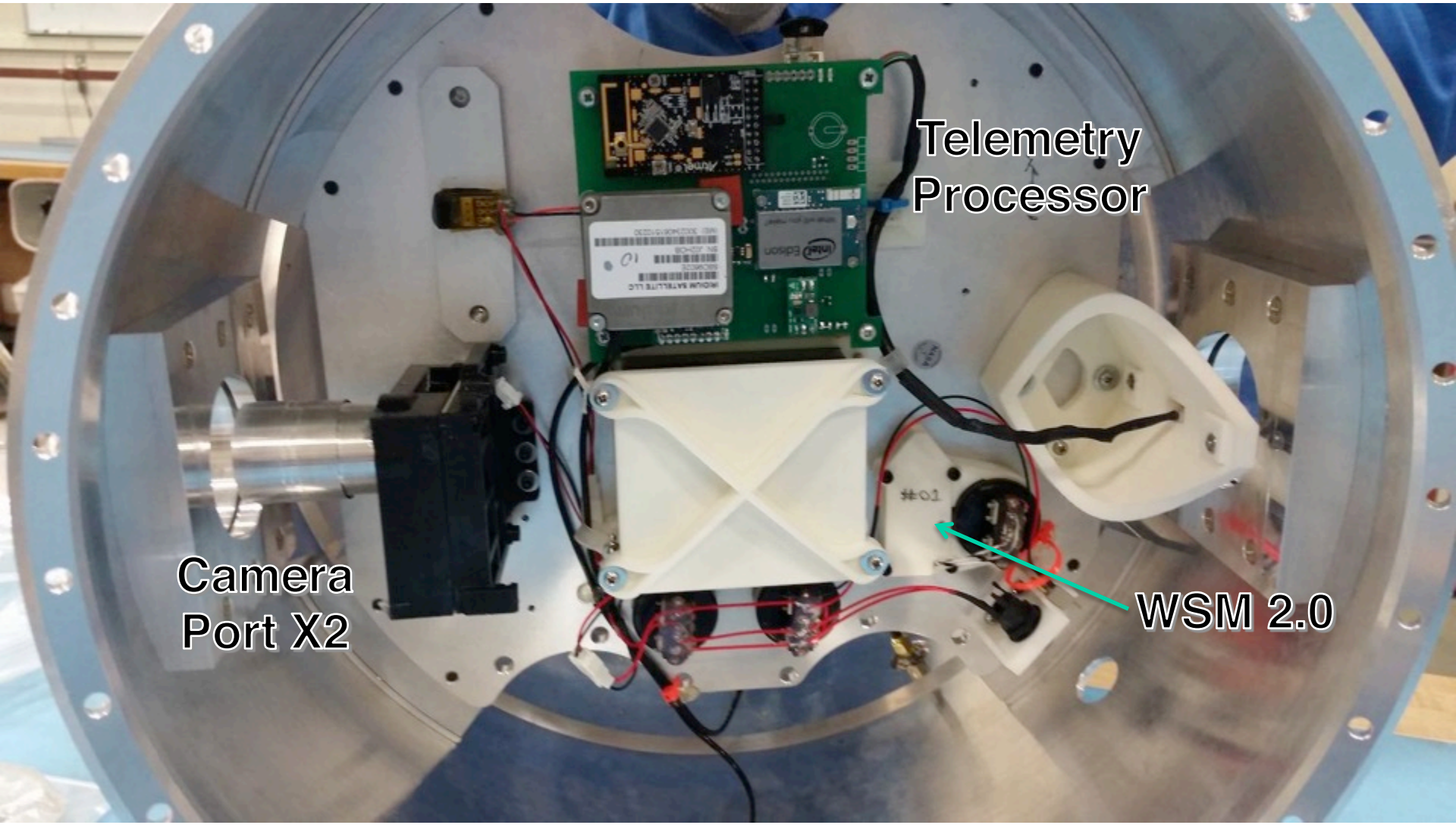




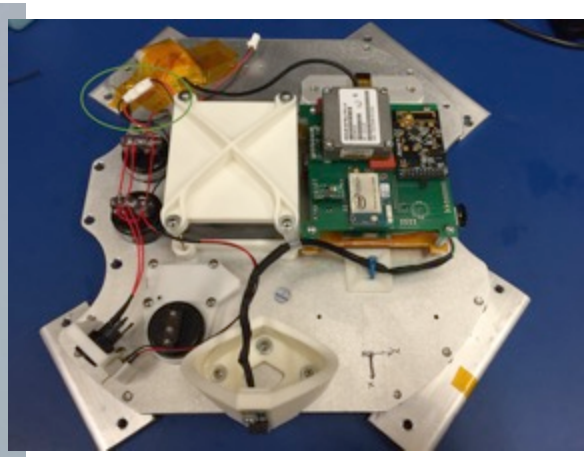
Element	Status	Comment	Applied To Future Project
S-Rocket Deck Battery/PWR (Milwaukee!!) [first time!]	**Worked!** Yes	Simplifies on-pad Ops/ Interface	Sub-orbitals
C-band	**Worked!**	Independent Tracking	Ubiquitous
Module 1 [first time!] T5 core Irid-1 WSM Coord1	**Worked!** Yes Yes Yes	Robust	TechEdSat5/P5 [COM paradigm for nano-sats]
Module 2 [first time!] P5 Core ISM-Band Camera WSM Coord2	**Worked!** Yes Yes Yes Yes	Robust Dual Irid and Coord	TechEdSat5/P5 [1 Mbs solution- Future NanoSats!]
Module 3 [first time!] X-band NanoSat AIM/Thompson CAM	**Delayed** No No	Late delivery; EDU **Worked on bench!** **NEN failed to track!!**	TechEdSat6/P6 SOAREX-9 [10-50 Mbs solution] Future NanoSats/ Interplanetary COM
NoseCone System [first time!] MRMSS WSM3	**Worked!** Yes Yes	New design; future piggy-back flights (first time)	SOAREX-9
Exo-Brake Deployment [first time!]	**Worked!**	42ft2 pneumatic-aided erection	SPQR Planetary Probes
S8 Box Deployment	**Partial!**	Partial ejection from ejector after apogee; stiction!	SPQR Planetary Probes



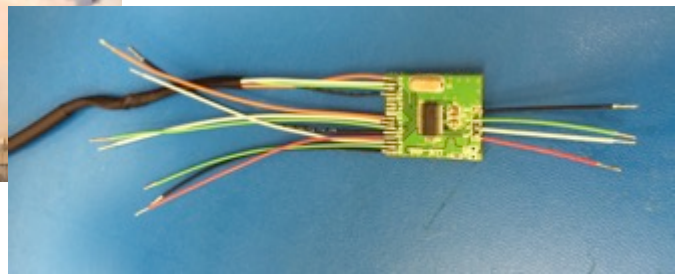
SOAREX-9 Flight Payload

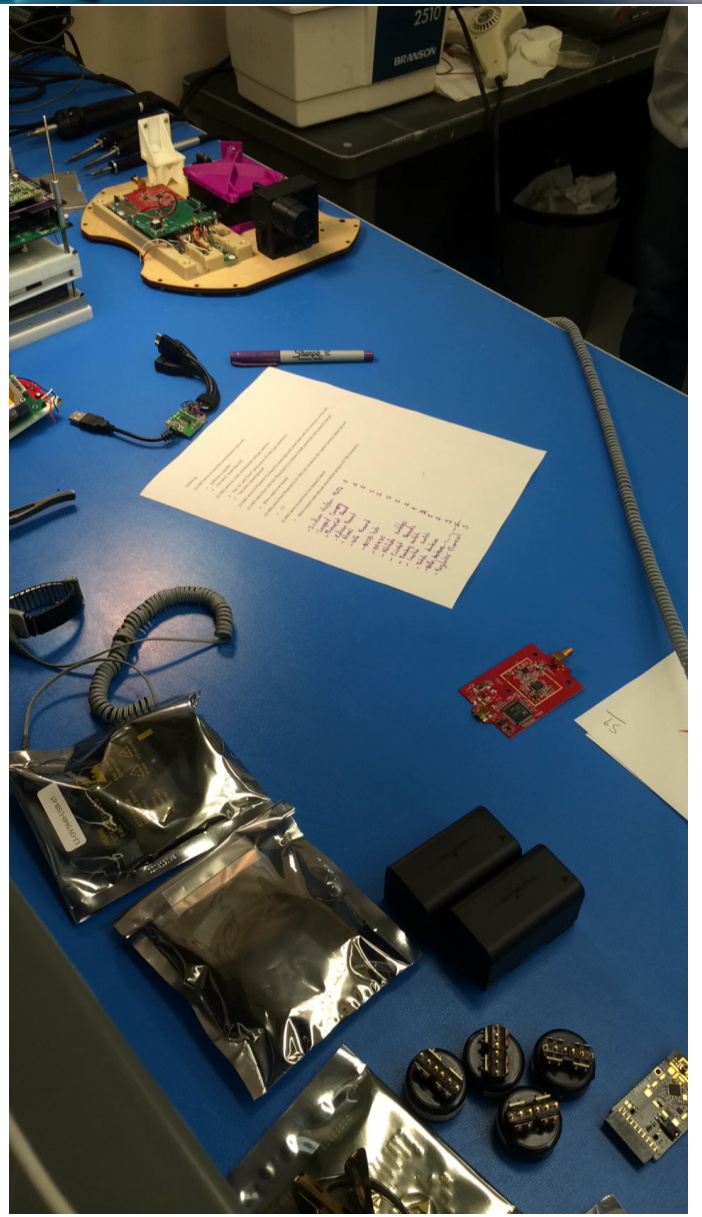


SOAREX 9 Mission

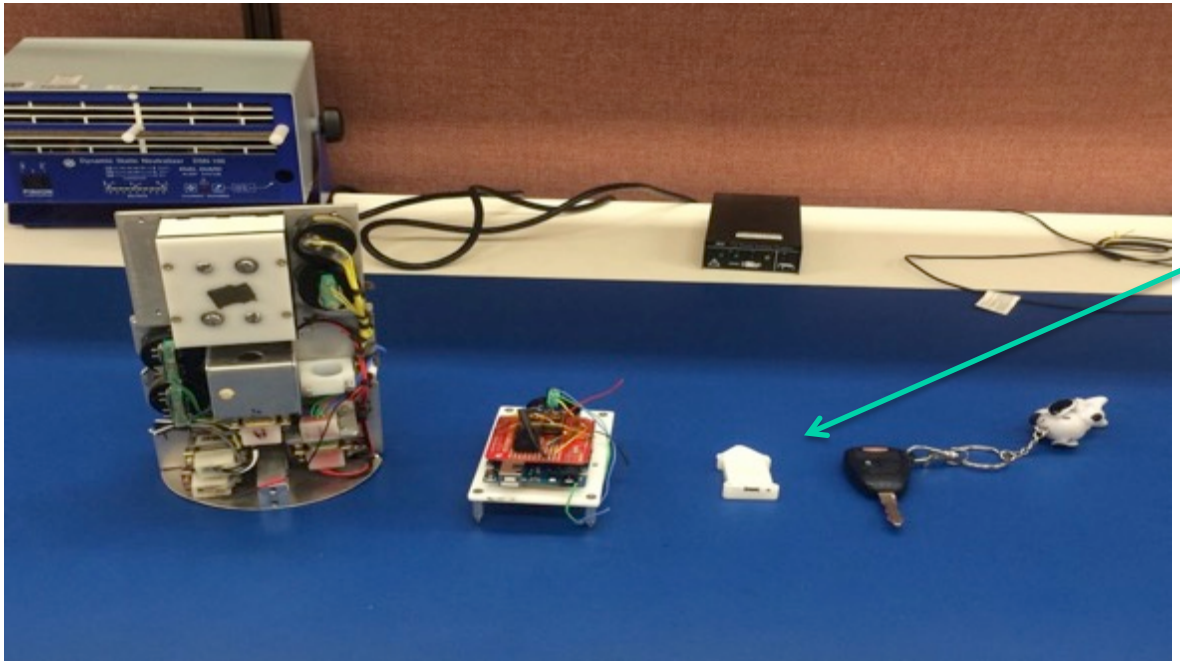


Flight Mission





WSM Experiment



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…

Summary

TES-N and SOAREX-M flight projects have included interns/universities since the beginning.

At present, there are 3 'platforms' used for university collaboration/interaction

- **Balloon to 30km**
- **Sub-orbital (SOAREX) to 300km**
- **Orbital (TES-N) to 400km**

Team management stems from a 'steady core' with young professional/intern in two tiers.

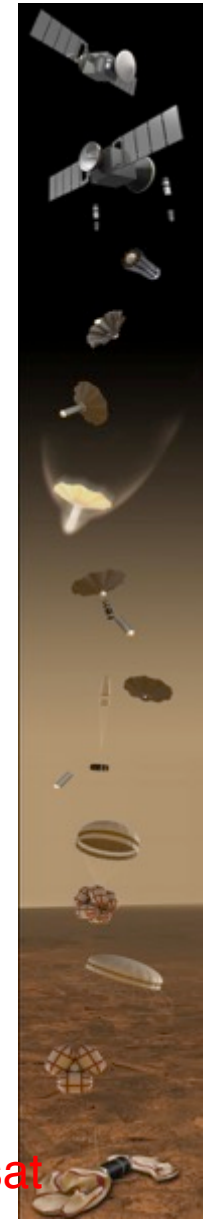
The two proposed Tiers

- **NASA core projects/internships**
- **SAA (contributing an Experiment/Sub-system/Sensor set to a concise ICD)**

Creating a 'flow' of flight opportunities (TES-6 delivered; TES-7,8,9 in development)

Hyperspectrals!!

- **Longer view/incremental approach suggested**
- **TechEdSat has an antecedent in 1995 SMARTSAT Scanning Interferometer study; ARC/Stanford**
- **CHALLENGES are POWER and COM/DATA Transfer!!!**
  - **(We have x-band, TDRS transmitters, ETC !!)**



Interplanetary Nanosat