Applied Space Education and Research at ITU CAL

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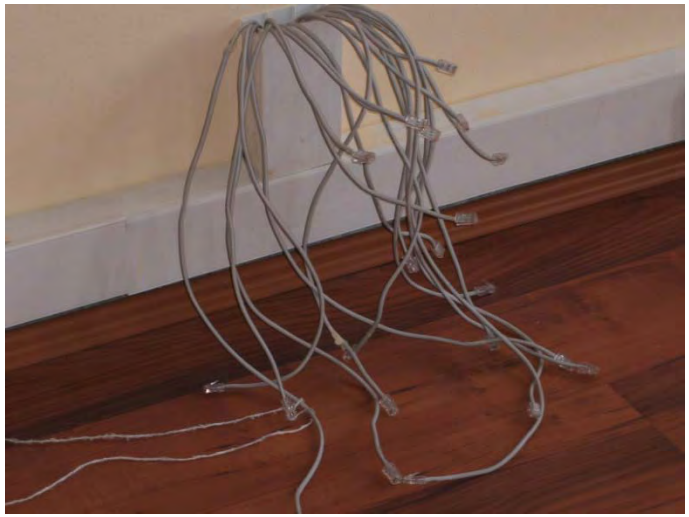
United Nations/Turkey/European Space Agency Workshop :
“Space Technology Applications for Socio-Economic Benefits”
14-17 September 2010, Istanbul Turkiye

New Generation of Aerospace Engineers

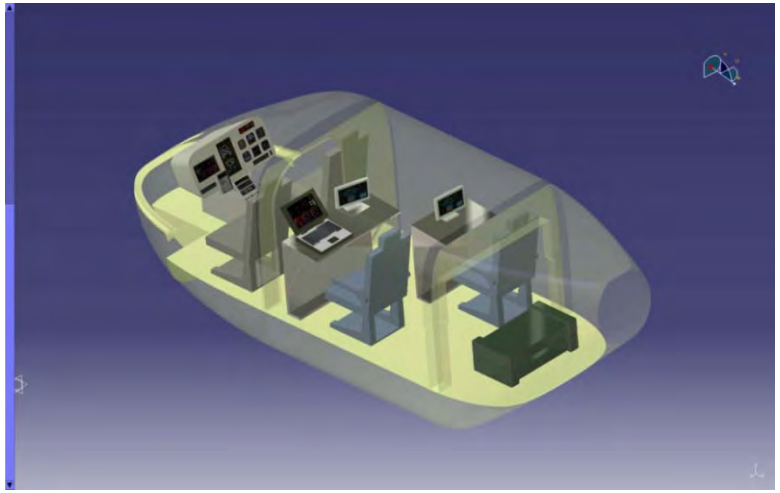
Controls and Avionics Lab of ITU

May 2006.....



Controls and Avionics Lab of ITU

ITU CAL Outlook – Industrial Projects



İTÜ LCH AVIONICS ARCHITECTURE

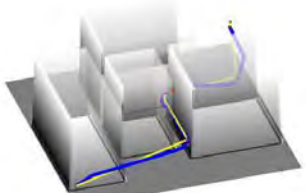
- Main Industry Projects Funded by
  - DPT
  - TÜBİTAK

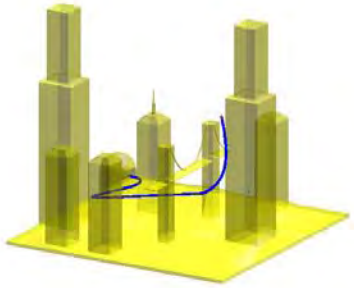
İTÜ ASELSAN HTD

İTÜ
Network Mission Flight Simulator

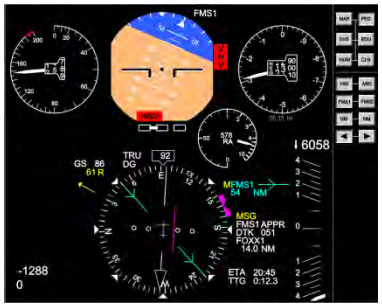
ITU CAL Research Projects - Graduate

Path planning in 3D at realtime

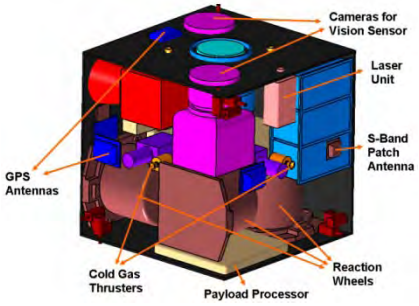


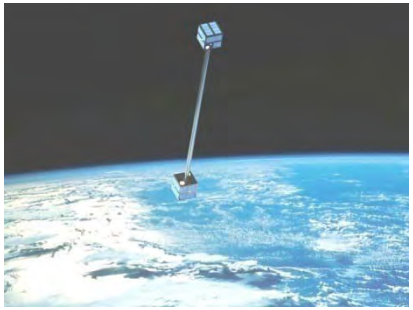


Human-Machine and Fleet Interfaces

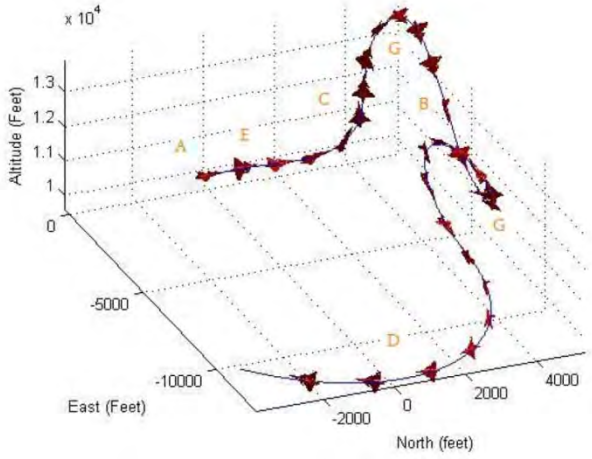


Spacecraft Design

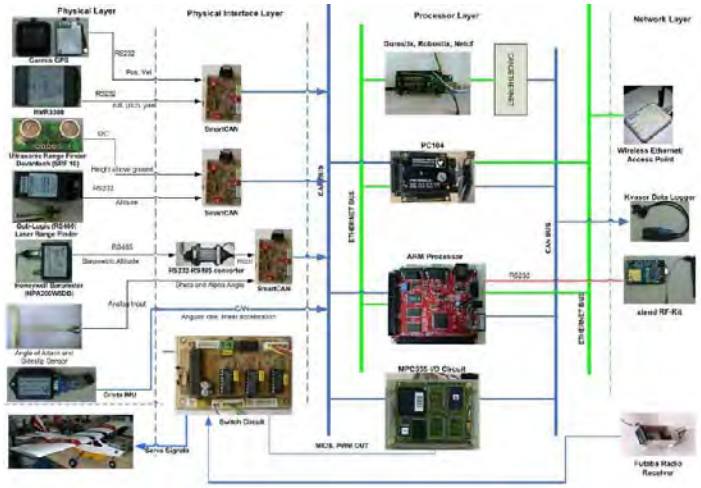




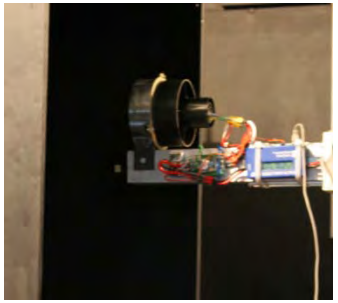
Nonlinear Autonomous Flight Controls For Agile Maneuvering



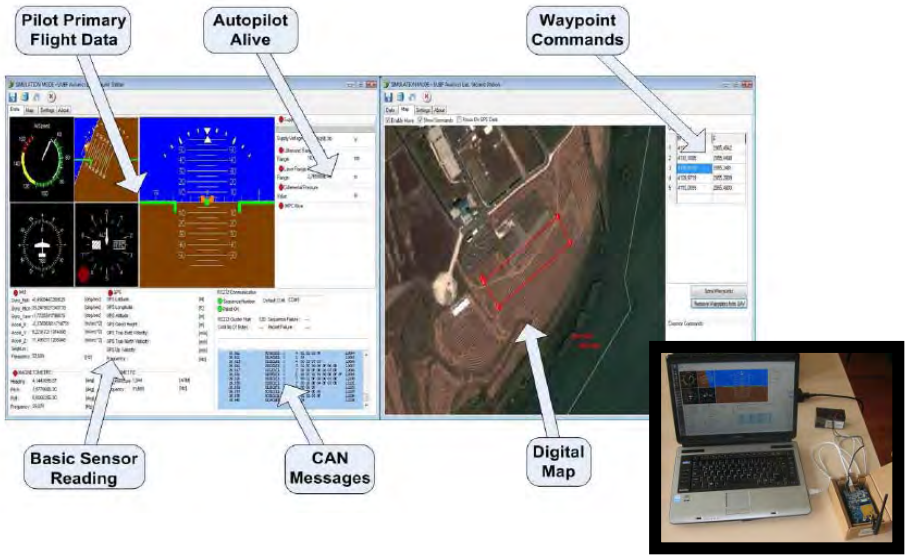
ITU CAL Research Projects - Graduate



Micro Avionics System



Unmanned Tail Sitter



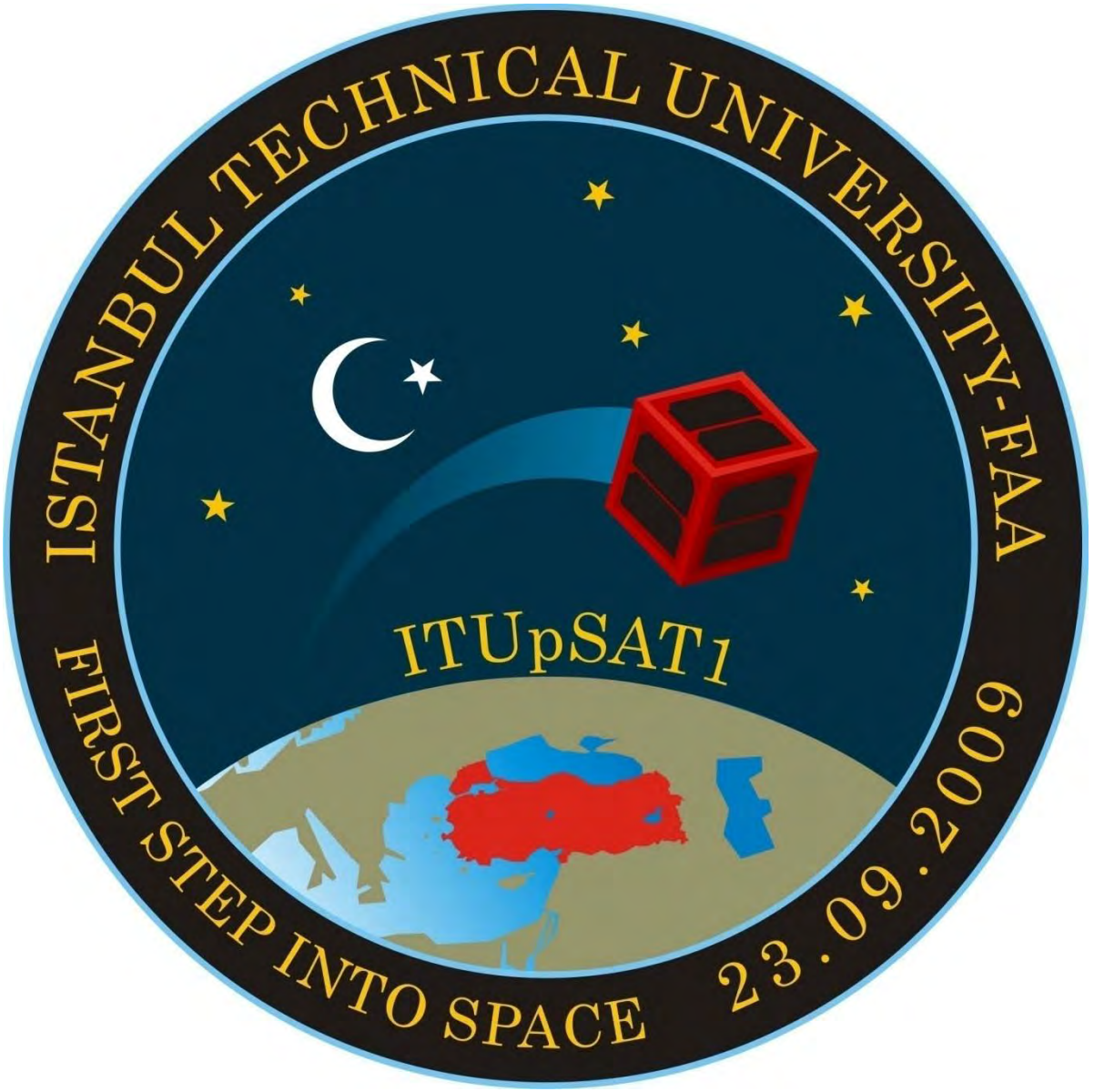
Aricopter

Trainer60

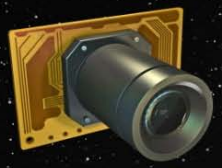
Microbee

Humvee

Where were we last time?

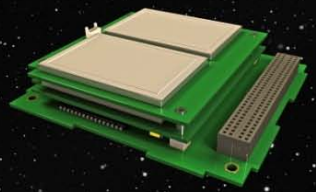


İTÜ pSAT-1



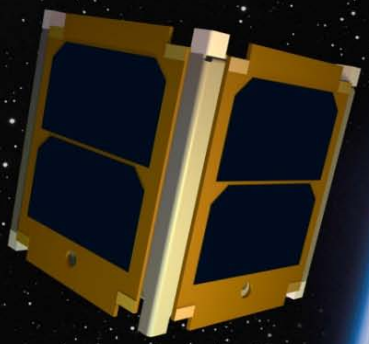
VGA Kamera

640x480 piksel
çözünürlük

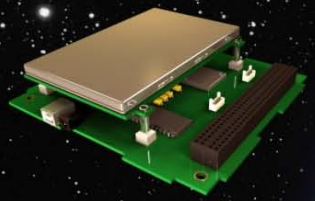


Güç Alt Sistemi

Güneş Paneli ve Piller
Clyde Space Inc.
Maks 6W, 1.2A
Lityum Polimer Piller
GaAs Güneş hücreleri

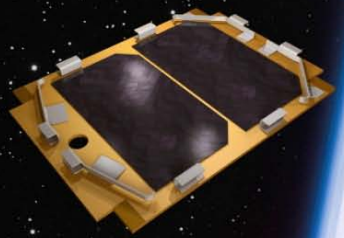


Fırlatma
Ocak 2009



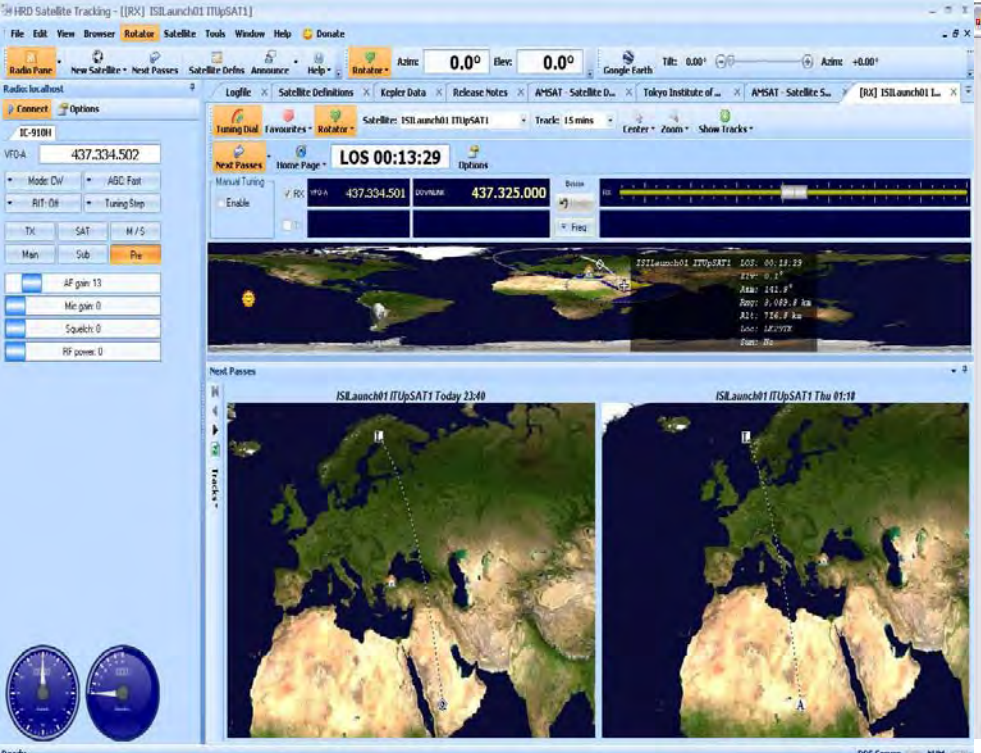
İletişim Alt Sistemi

Microhard MHX 425 RF modem
Amatör frekansta İşaret Sinyali
Açılabilir Anten Mekanizması

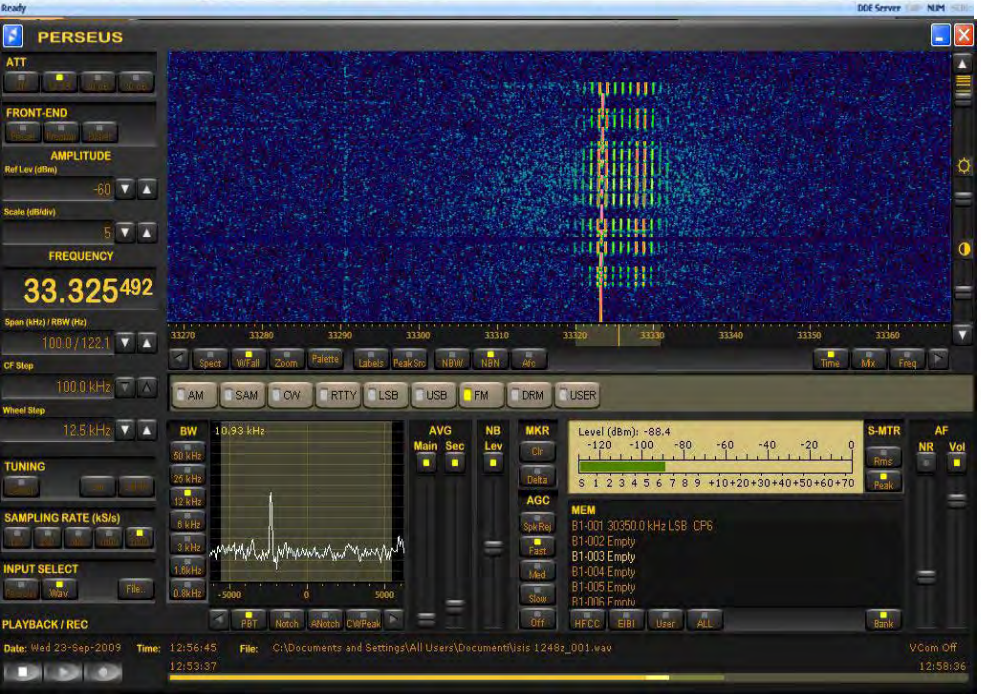


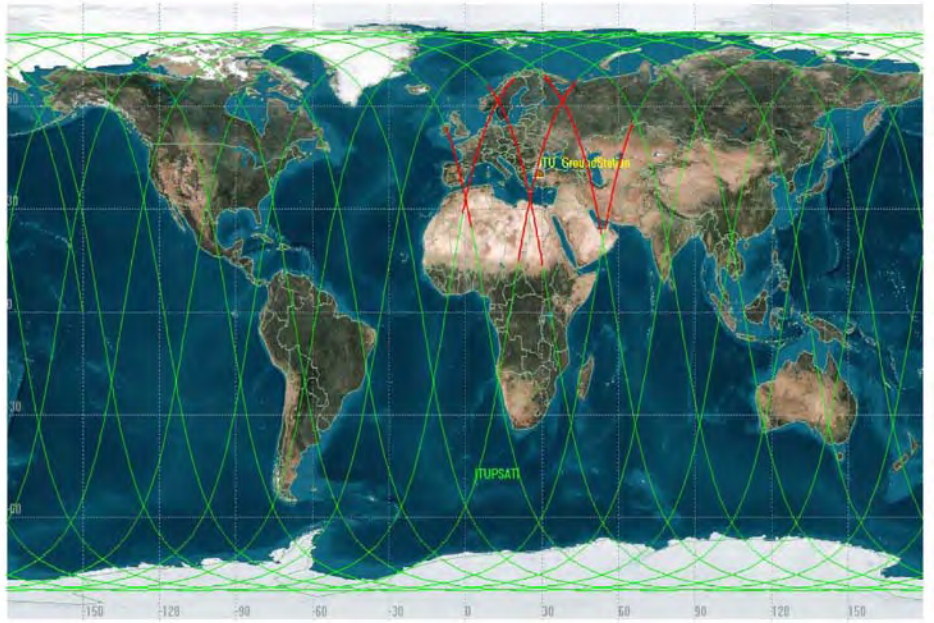
Yapı Alt Sistemi

Al 5052 Saç metal bükümüyle
imal edilmiş gövde


HRD Satellite Tracking - [[RX] ISILaunch01 ITUpSAT1]
LOS 00:13:29
437.334.502
437.325.000
ISILaunch01 ITUpSAT1 Today 23:40
ISILaunch01 ITUpSAT1 Thu 01:10


ITU Ground Station
COM Settings
Telemetry
Picture
Payload
Panel Y1 Voltage -0,225 V
Panel Y1 Current 5,346 mA
Panel Y1 Temp 4,560200 Deg C
Panel X2 Voltage -0,423 V
Panel X2 Current 5,346 mA
Panel X2 Temp -55,5047 Deg C
Panel X1 Voltage -0,40499 V
Panel X1 Current 5,346 mA
Panel X1 Temp -49,6763 Deg C
Panel Z1 Voltage -0,44100 V
Panel Z1 Current 5,346 mA
Panel Z1 Temp -42,067 Deg C
Panel Y2 Voltage -0,20700 V
Panel Y2 Current 5,346 mA
Panel Y2 Temp -35,7529 Deg C
Panel Z2 Voltage -0,40499 V
Battery Bus Current 237,3772 mA
Battery 2 Temp 9,313995 Deg C
Battery 2 Voltage 7,95995 V
Cell 2 Voltage 3,93394 V
Battery 2 Discharging
Battery 2 Current 135,82 mA
Battery 1 Temp 11,107 Deg C
Battery 1 Voltage 7,97873 V
Cell 1 Voltage 3,92518 V
5V Bus Current 211,3136 mA
3.3V Bus Current 46,70685 mA
Battery 1 Discharging
Battery 1 Current 142,22 mA
Panel Z2 Temp -37,5338 Deg C
Panel Z2 Current 5,346 mA


PERSEUS
FREQUENCY
33.325492
AM
SAM
CW
RTTY
LSB
USB
FM
DRM
USER
PLAYBACK / REC


ITU GroundStation
ITUPSAT1

ITU pSAT I educational impact

- This project served as a hands-on applied education platform for undergraduate and graduate students :
  - An excellent platform to build knowledge base, apply knowledge and gain confidence as a space systems engineer.
  - An excellent platform to build and see results (approximately +2 years....)
- ITU CAL alone had +10 B.Sc. graduation thesis, 4 M.Sc. thesis coming from this project.

ITU pSAT I educational impact

- ITU CAL graduated 9 people
  - 3 in industry (working on space projects!)
  - 1 did partial M.Sc. at TU Delft on space systems.
  - 3 doing Ph.D at MIT, Surrey and ITU at space projects.
  - Only 2 working on different engineering tasks.

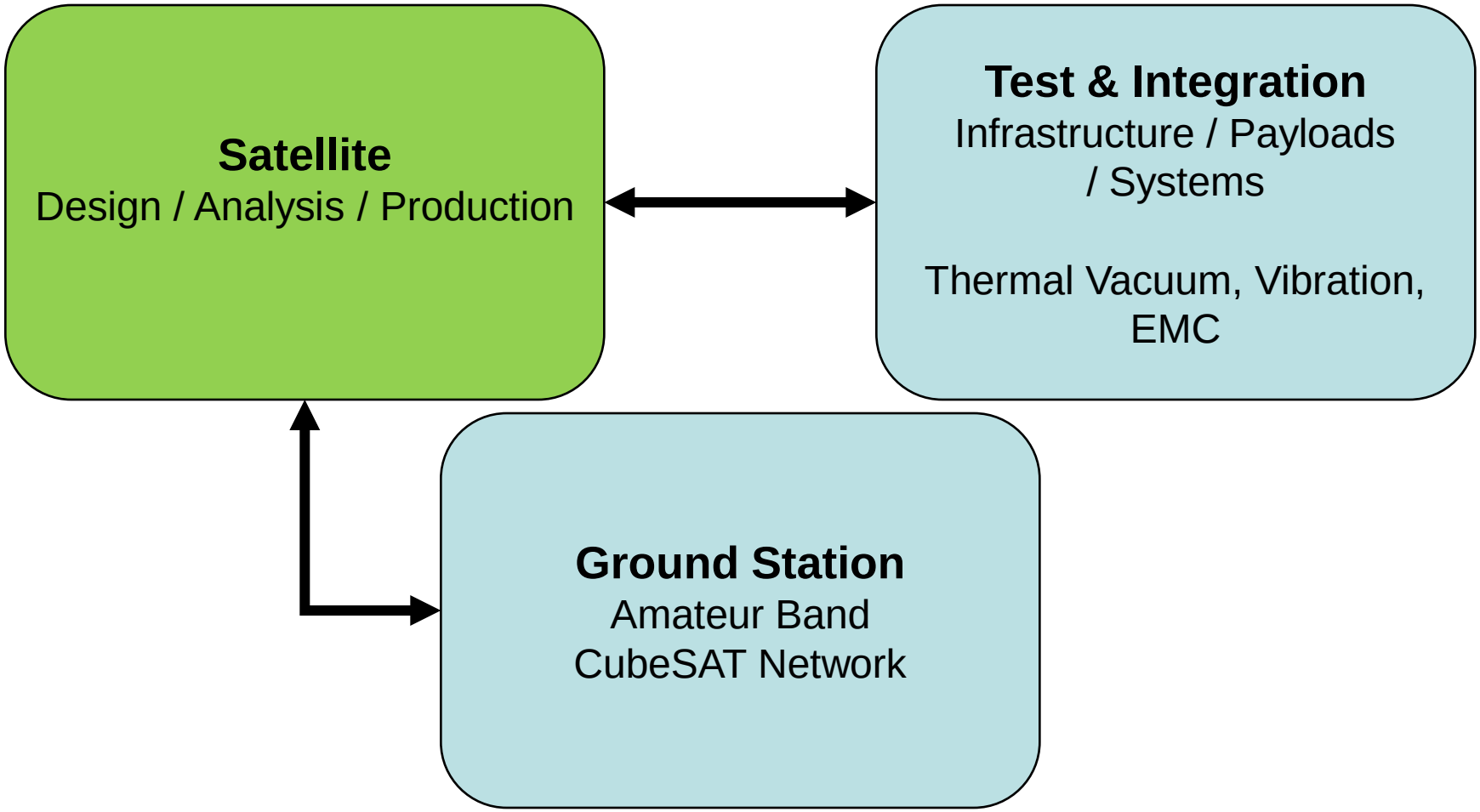
Current Status of ITU pSAT I

- ITU pSAT I is alive and kicking (355+ days and counting) even though we had a major ground station problem with
  - the modem malfunctions and
  - the software resets
- Clear beacon and health status bits
- Many thanks to people all over the world who are still keeping track of ITU pSAT I
  - US, Germany, Italy, Norway, Japan, amateur radios all over Turkey.... To name a few....

ITU pSAT I @ CAL

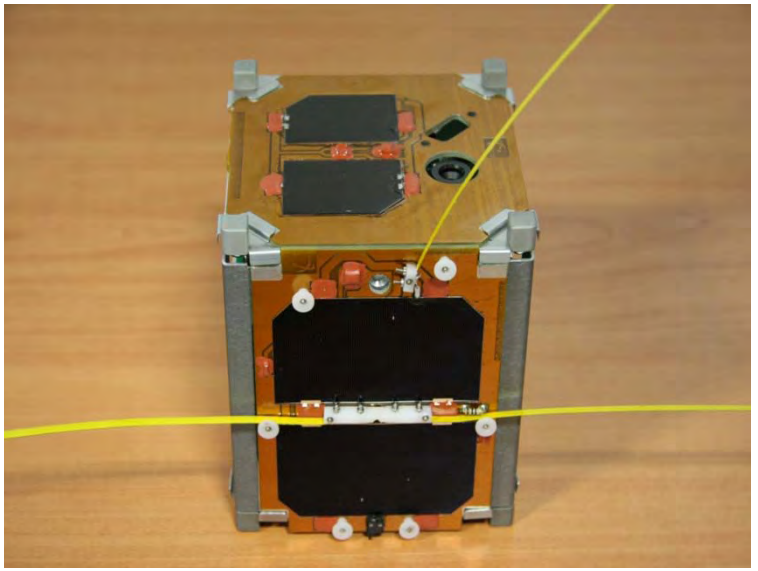
- ITU CAL
  - Designed ITU pSAT I architecture,
  - Integrated all the subsystems,
  - Completed software and hardware design of indigenous components such as payload boards, power boards, electronic boards and antenna mechanisms,
  - Designed and implemented the software, and
  - Served as the Technical Management for ITU pSAT I

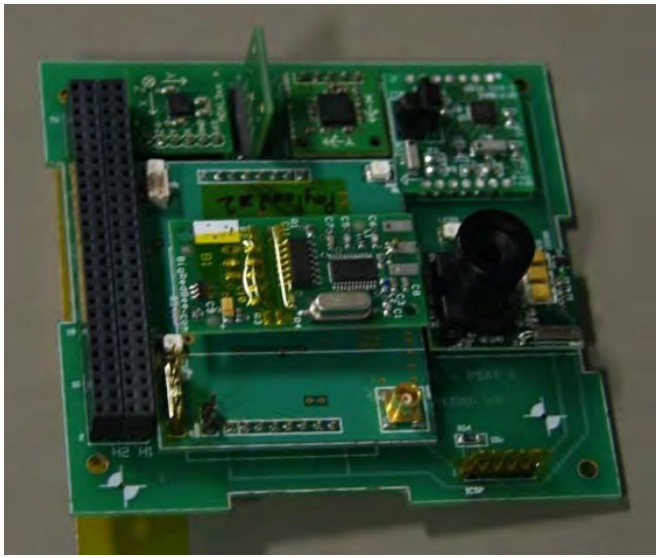
Project Realm

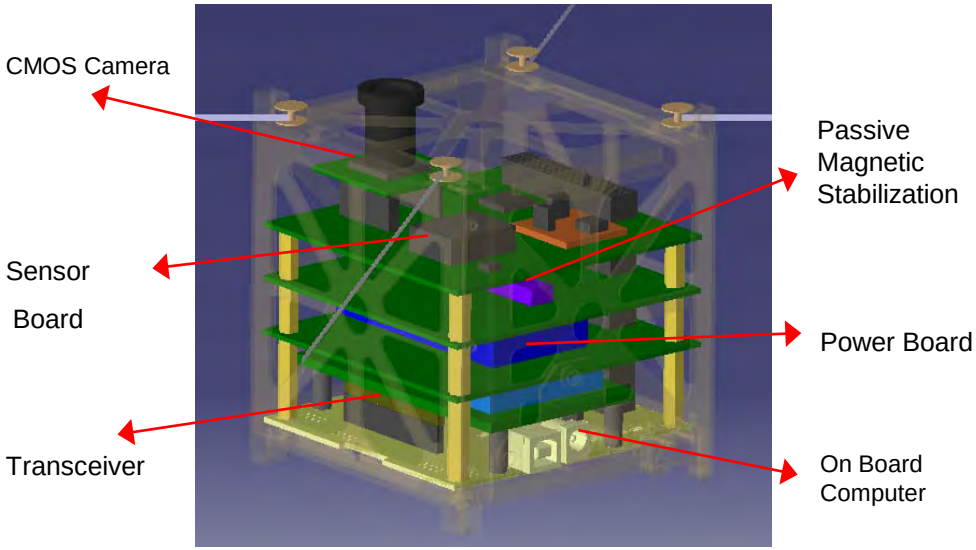


Design– İTÜ pSAT I

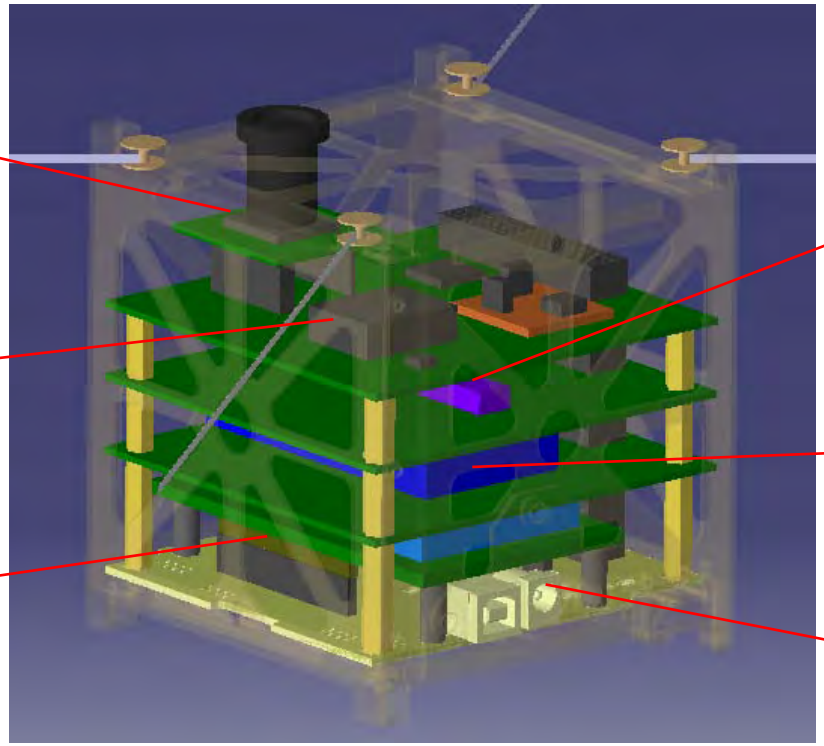
- First university research satellite of Turkey.
  - Payload and Objectives:
    - Passive Magnetic Stabilization
    - Low resolution image,
    - Inertial measurements and
    - Telemetry capturing





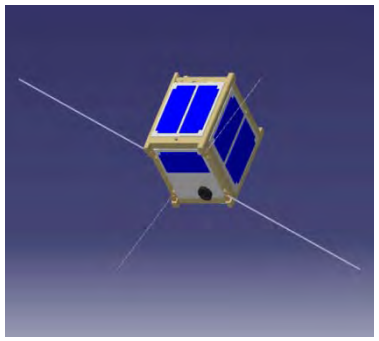


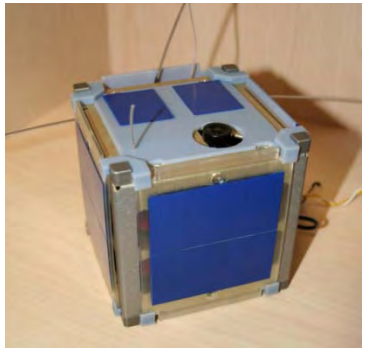
Subsystems of ITU pSAT I



Mass : 995 mg
Power : 6 W
Current : 1.5 A

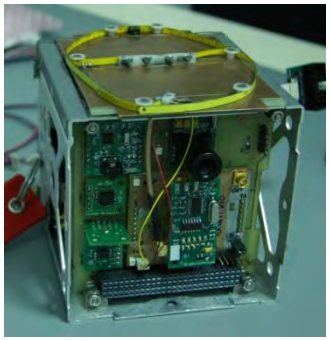
ITU pSAT I Production Phasing

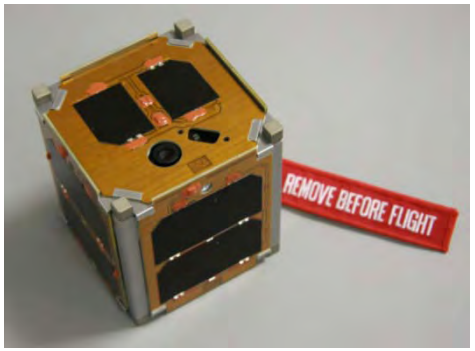




Design and Prototyping – Desktop Models

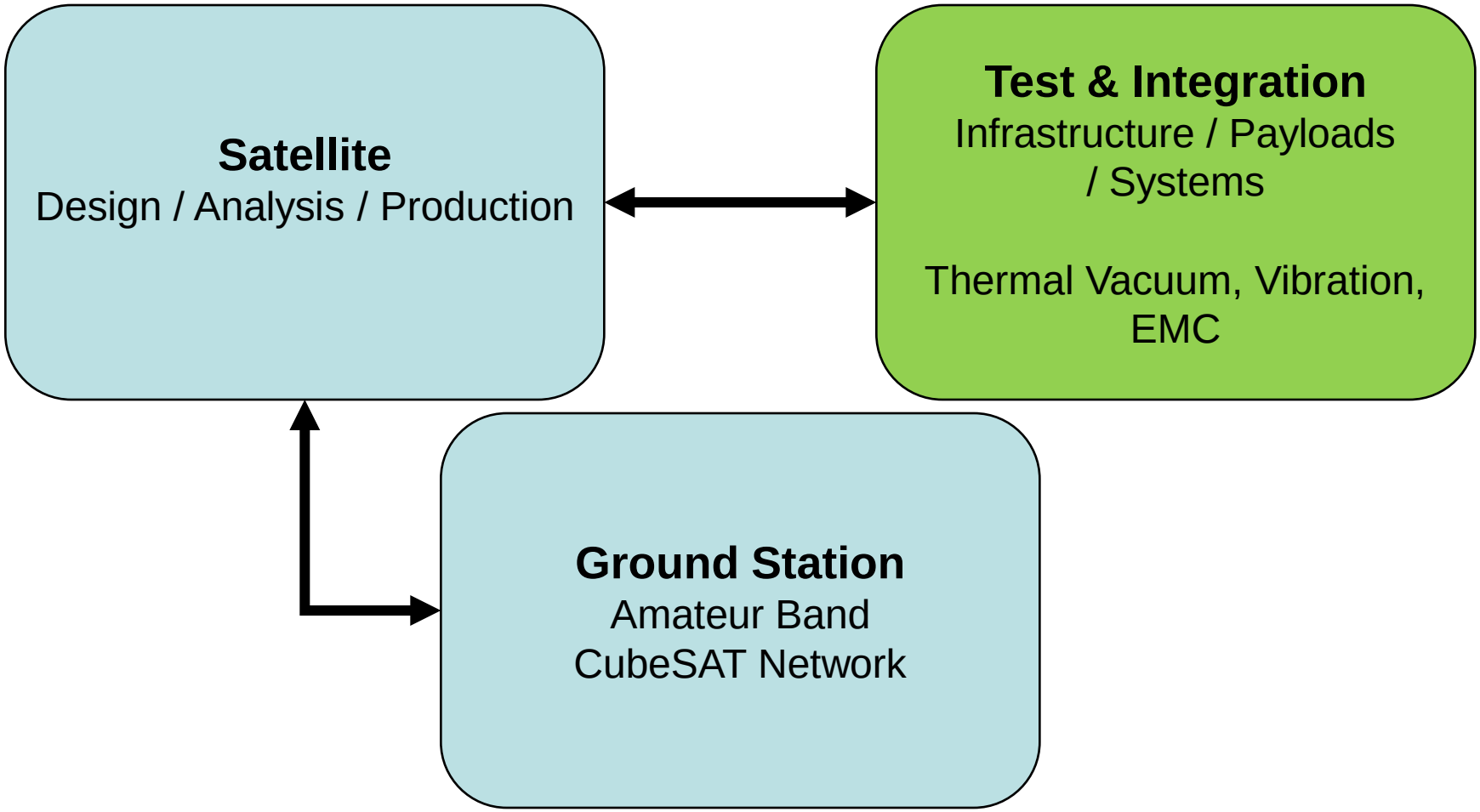
Analysis and Testing – Engineering Models





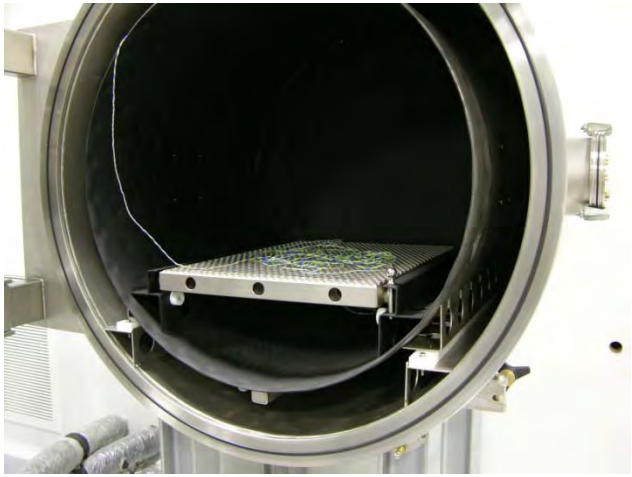
Launch – Flight Models
Orbit 720 km sun-synchronous

Project Realm



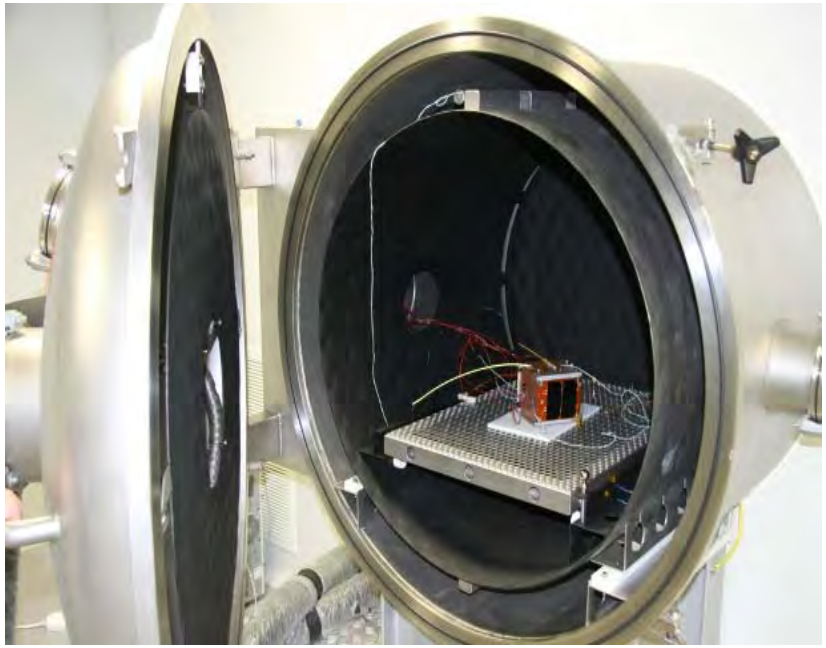
Thermal Vacuum Testing

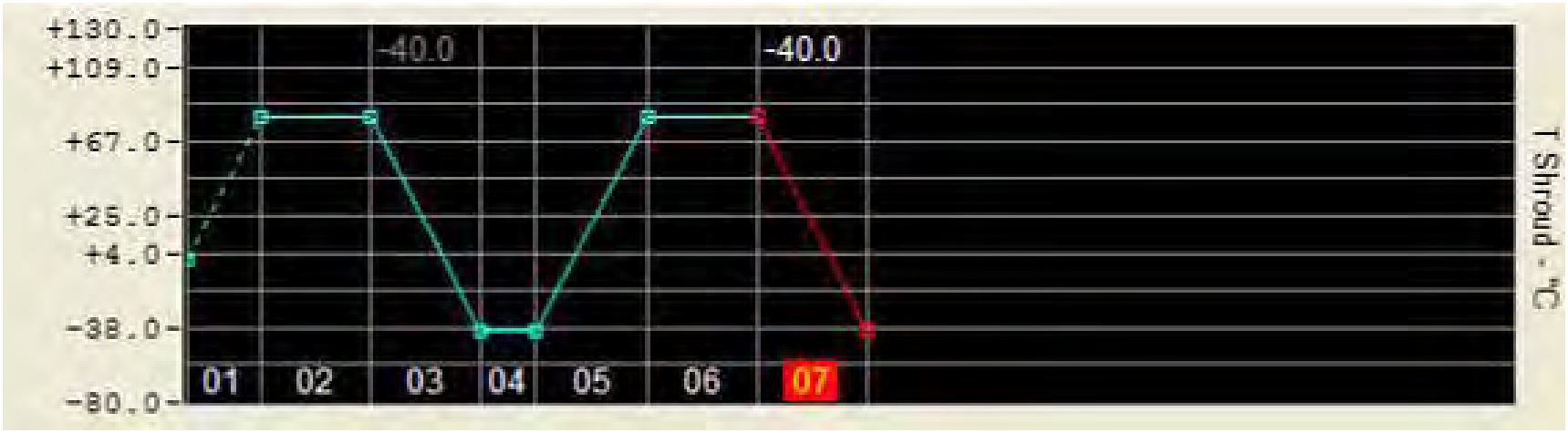
- 350 lt. Thermal Vacuum Chanber
  - 10 -6 torr pressure,
  - -60 C – 125 C temperature range
  - 1 deg per second control



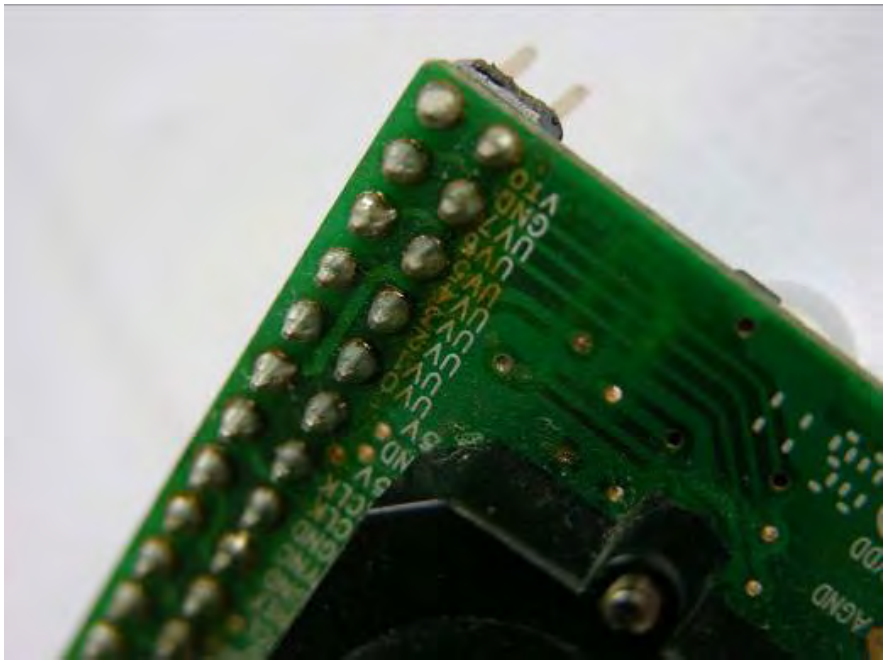
Thermal Vacuum chamber opens up to Class 1000, 25 meter square clean-room

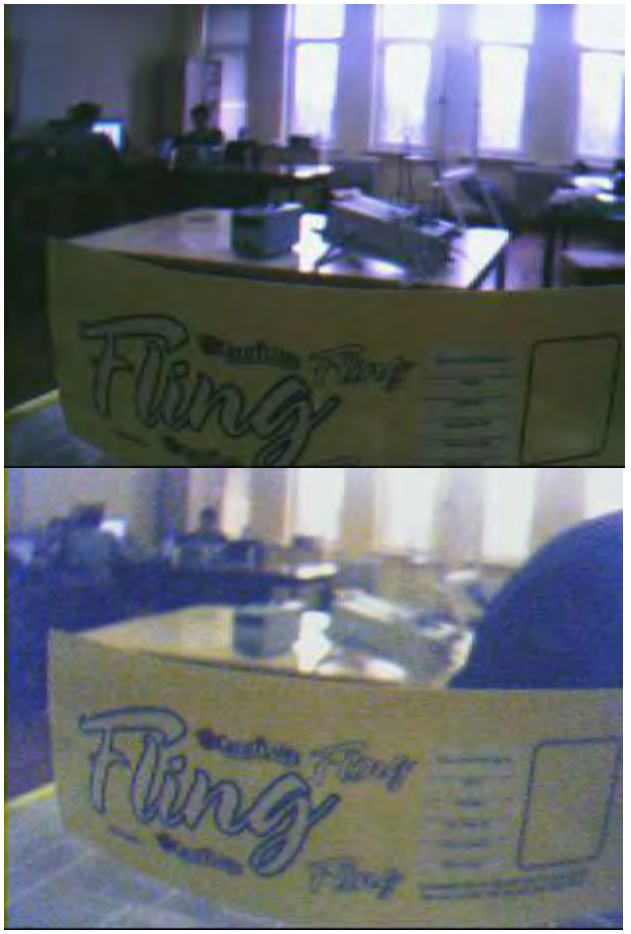
Typical Test Scenario





After Thermal & TV Tests



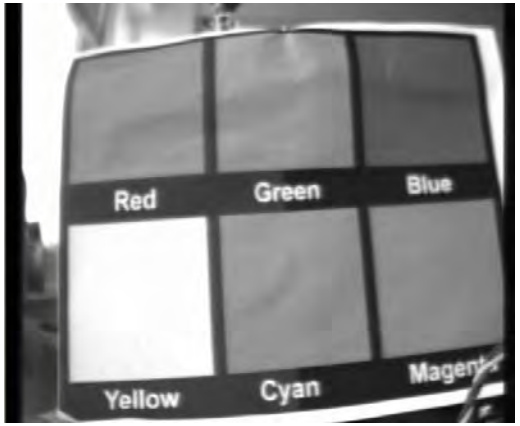


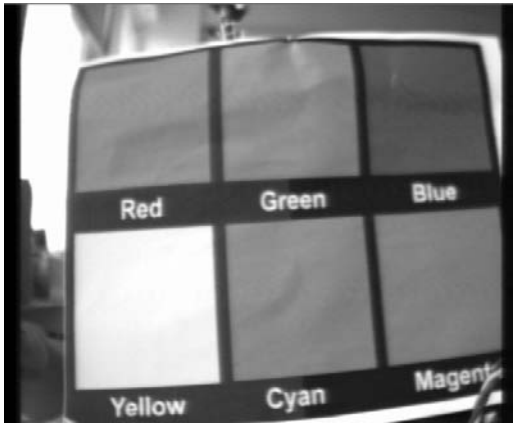
Outgasing

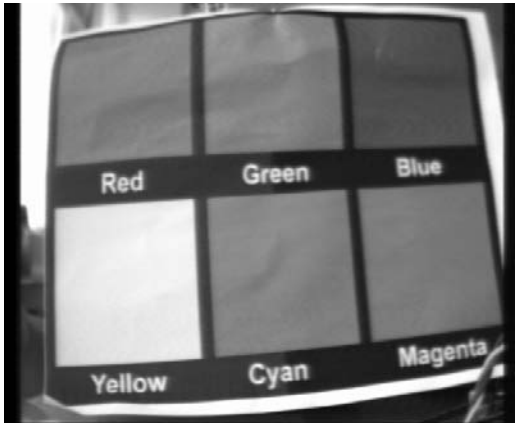
Comparison

Before Test

After Test







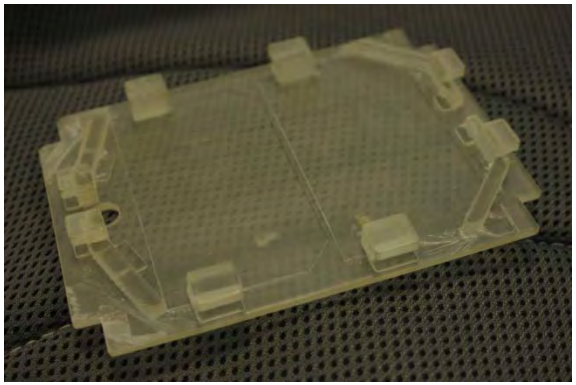
System Integration

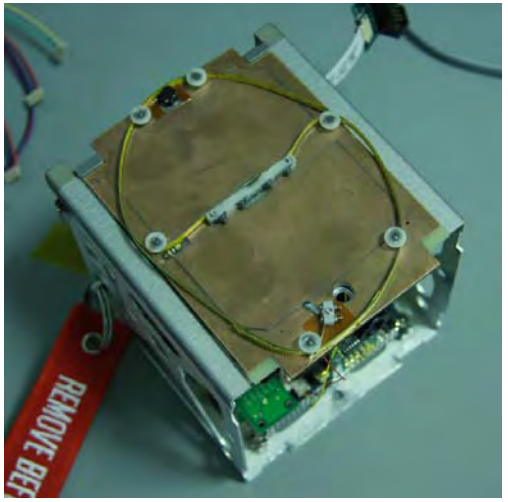
- Clean Room (Class 1000) : 25 meter square
  - Embeds the thermal vacuum chamber also
- Clean Room (Class 10000) : 8 meter square
  - For experimental and educational purposes

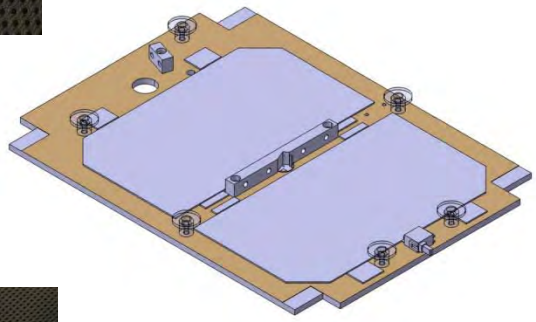
Rapid Prototyping – Structural, Mechanical, Electronics

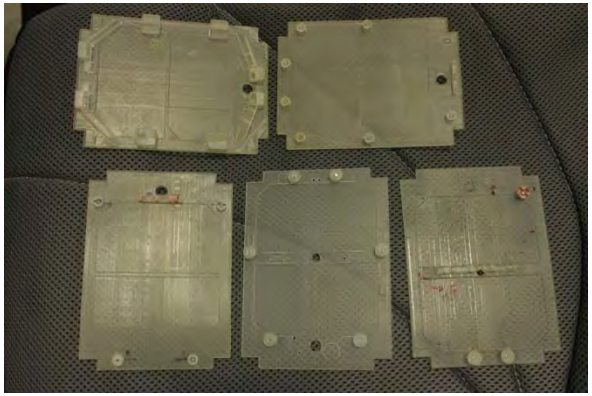
- CNC table
- Laser cutters
- 3D prototyping machine
- 3D scanning machine
- Circuit Prototyping machine

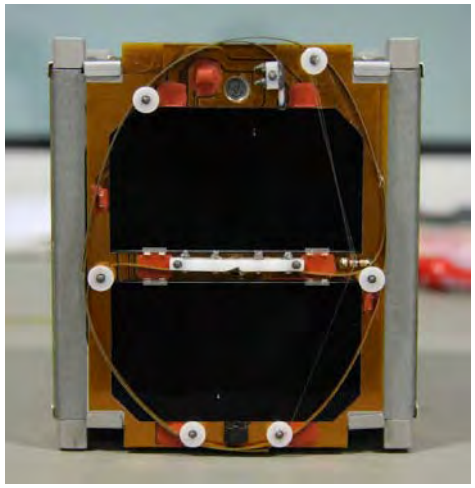
Example : Antenna Opening Mechanism





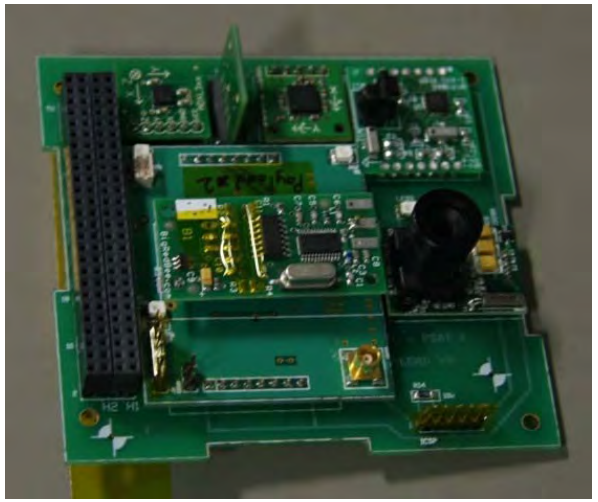






Example : Payload Board

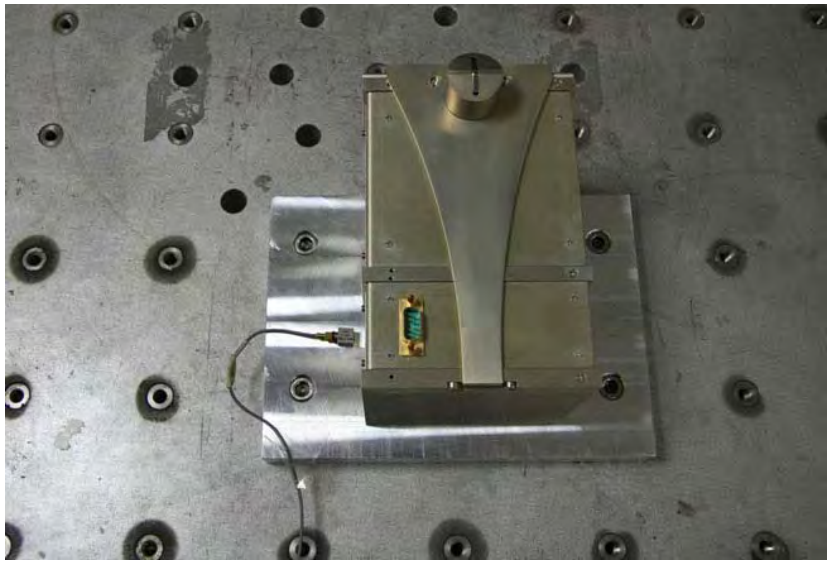
- Space qualification and modification of COTS components



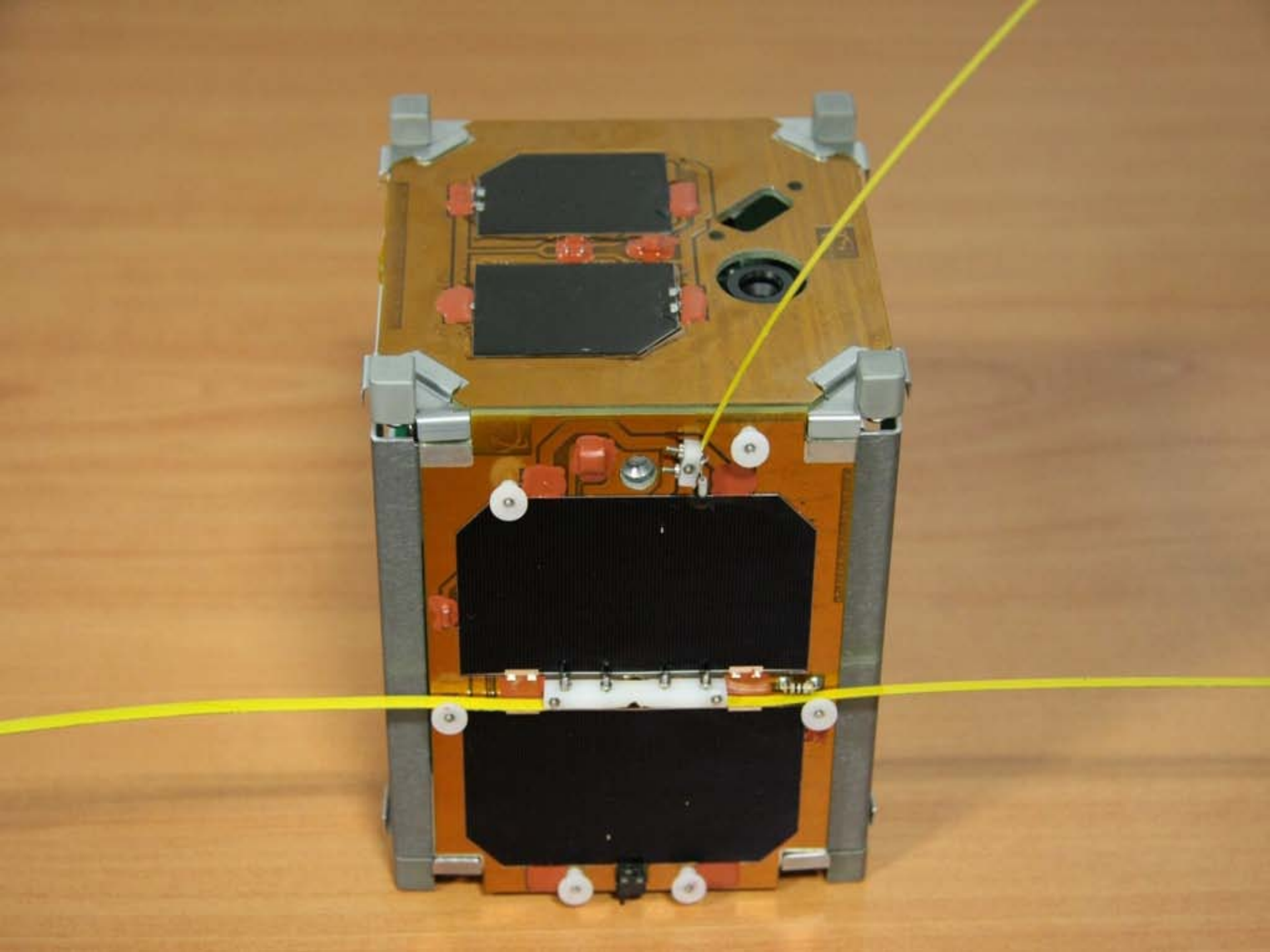
- Unique designs and prototypes

Circuit Rapid Prototyping

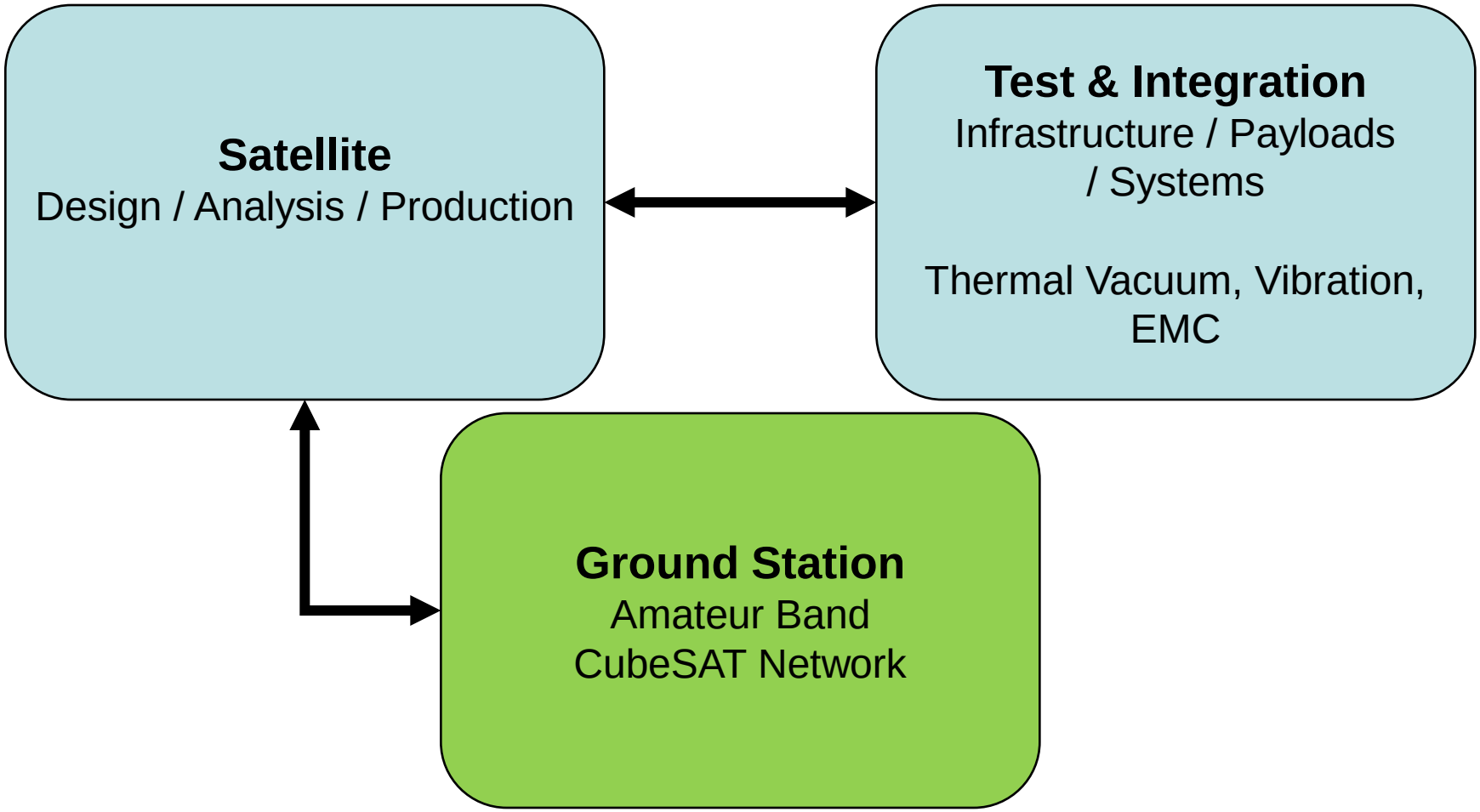
Shake Table



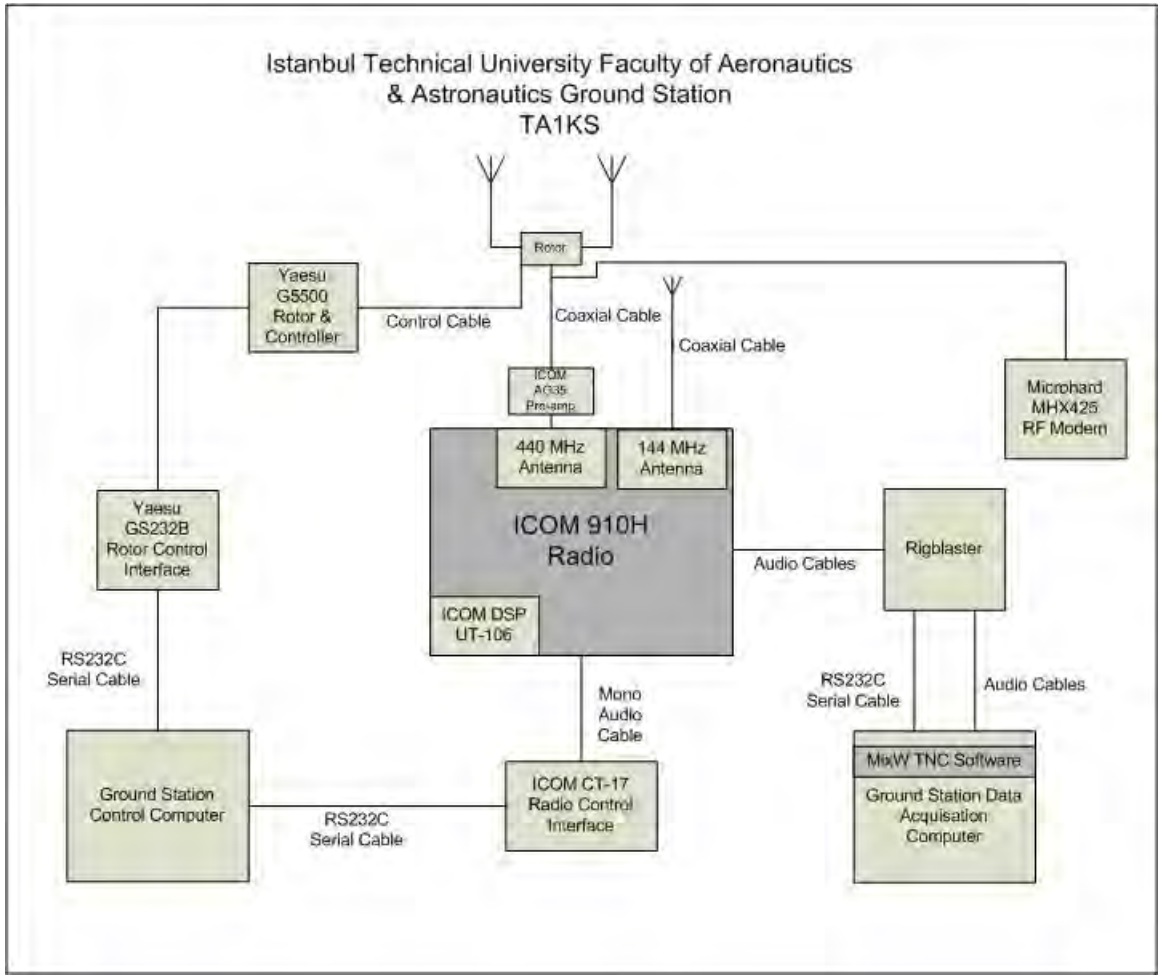
- Up to 300kg of spacecraft of components can be tested for launch vibration



Project Realm

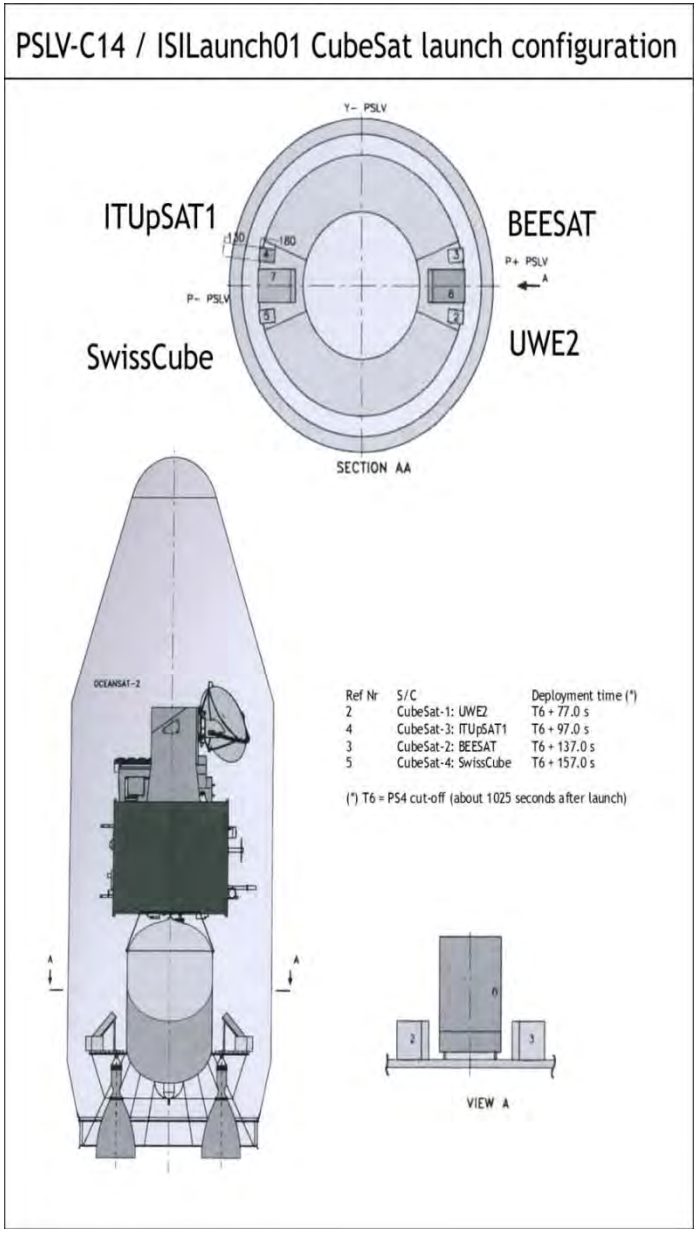


UUBF Ground Station



- UHF-VHF Bands
- Amateur Radio
- Member of GENSO

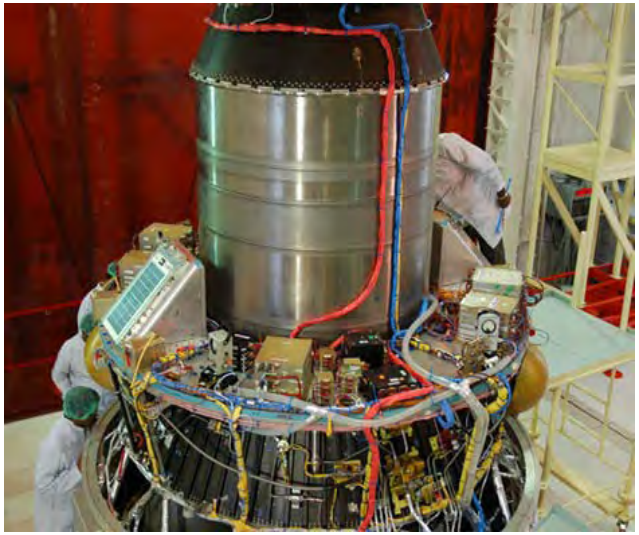
PSLV C-14 : Launch 23.08.2009



POLAR SATELLITE LAUNCH VEHICLE (PSLV)

Rubin 9.1, Rubin 9.2, UWE-2, Beesat, ITUpSAT1 and Swisscube

PSLV C-14



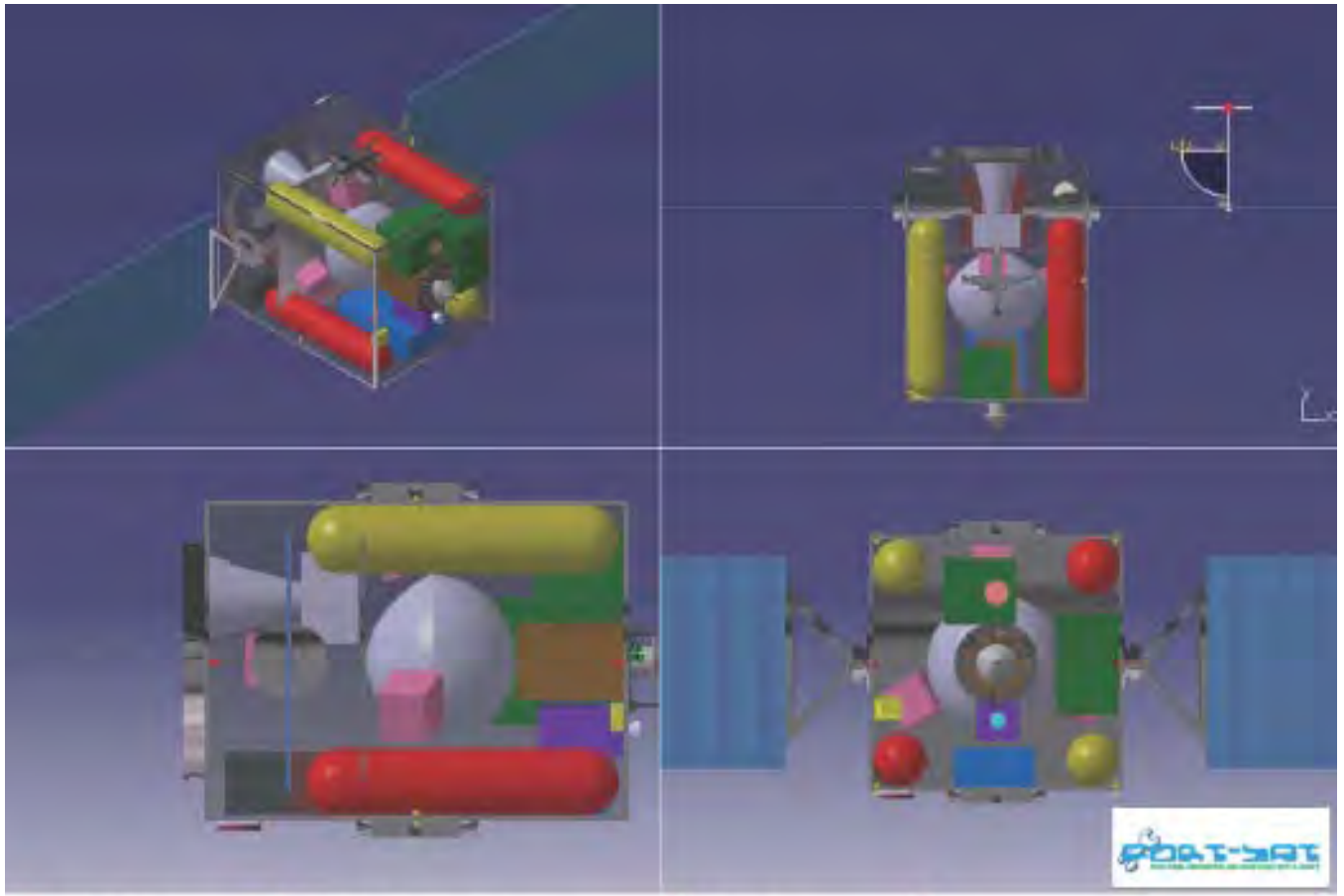
Educational Programs @ ITU
FAA and ITU CAL

New Generation of Aerospace Engineers

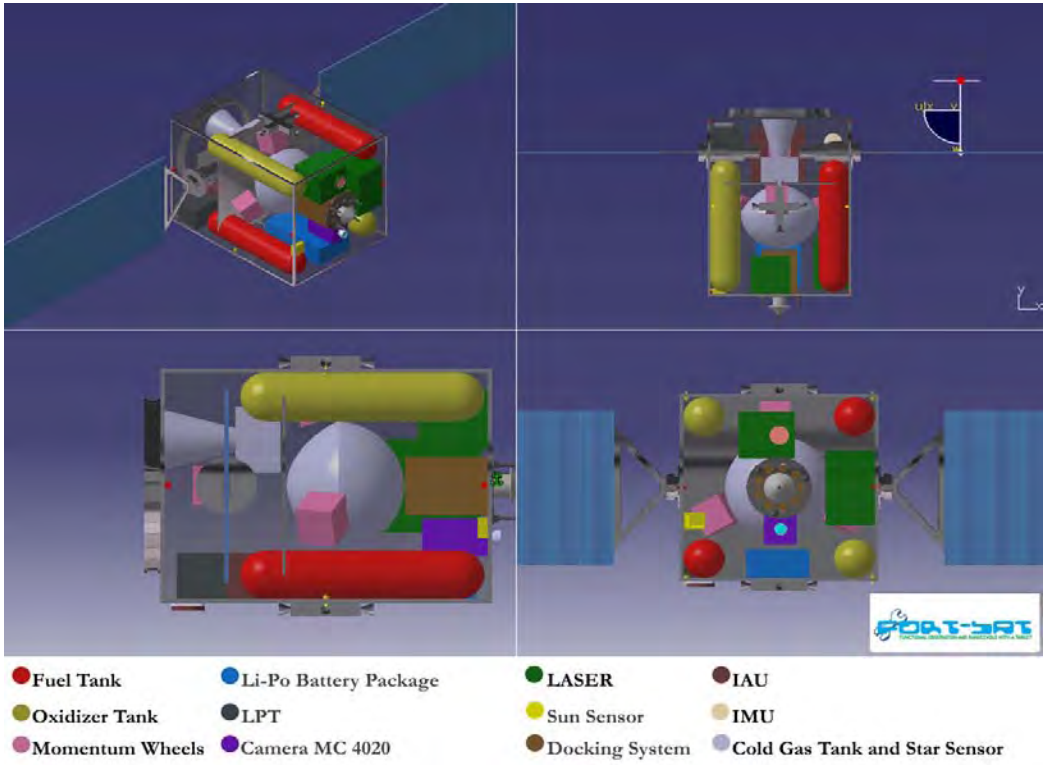
ITU CAL @ Space Education

- Re-designed and gave the UZB422E Spacecraft Systems Design course (2006-2010)
  - Basically the last course for space engineers before graduating from class.
  - First 7 lectures focuses on all the aspects of spacecraft systems with project homeworks for the "Graduating Class Spacecraft Design Competition"
  - Last 7 lectures focuses on building protoypes of major components...

Spacecraft Systems Design Course – and the winner is … 2006-2007



Education– Spacecraft Systems Engineering

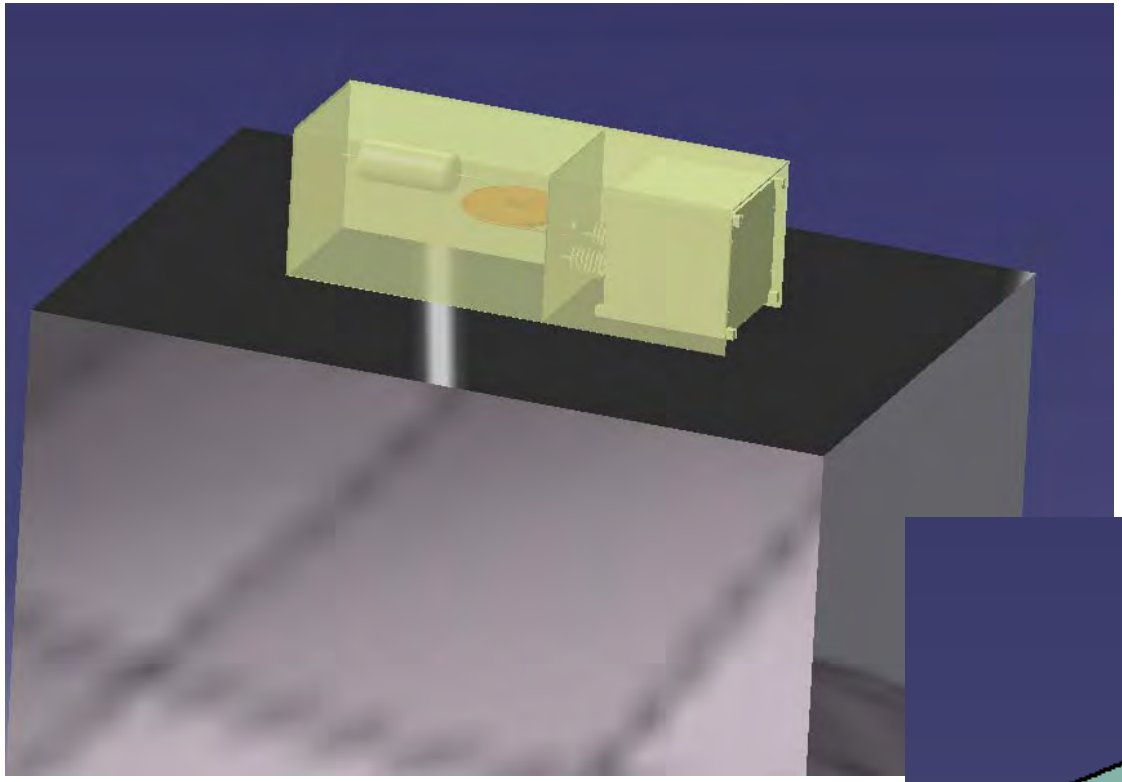


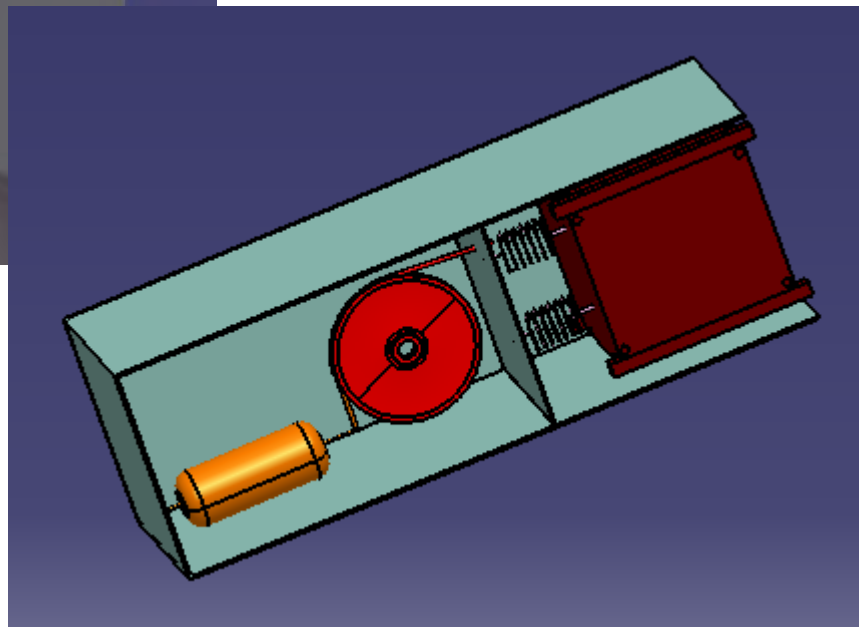
The winner of the 2007 Graduating Class Conceptual Spacecraft Design Contest

- Undergraduate students reach PDR level maturity in their designs

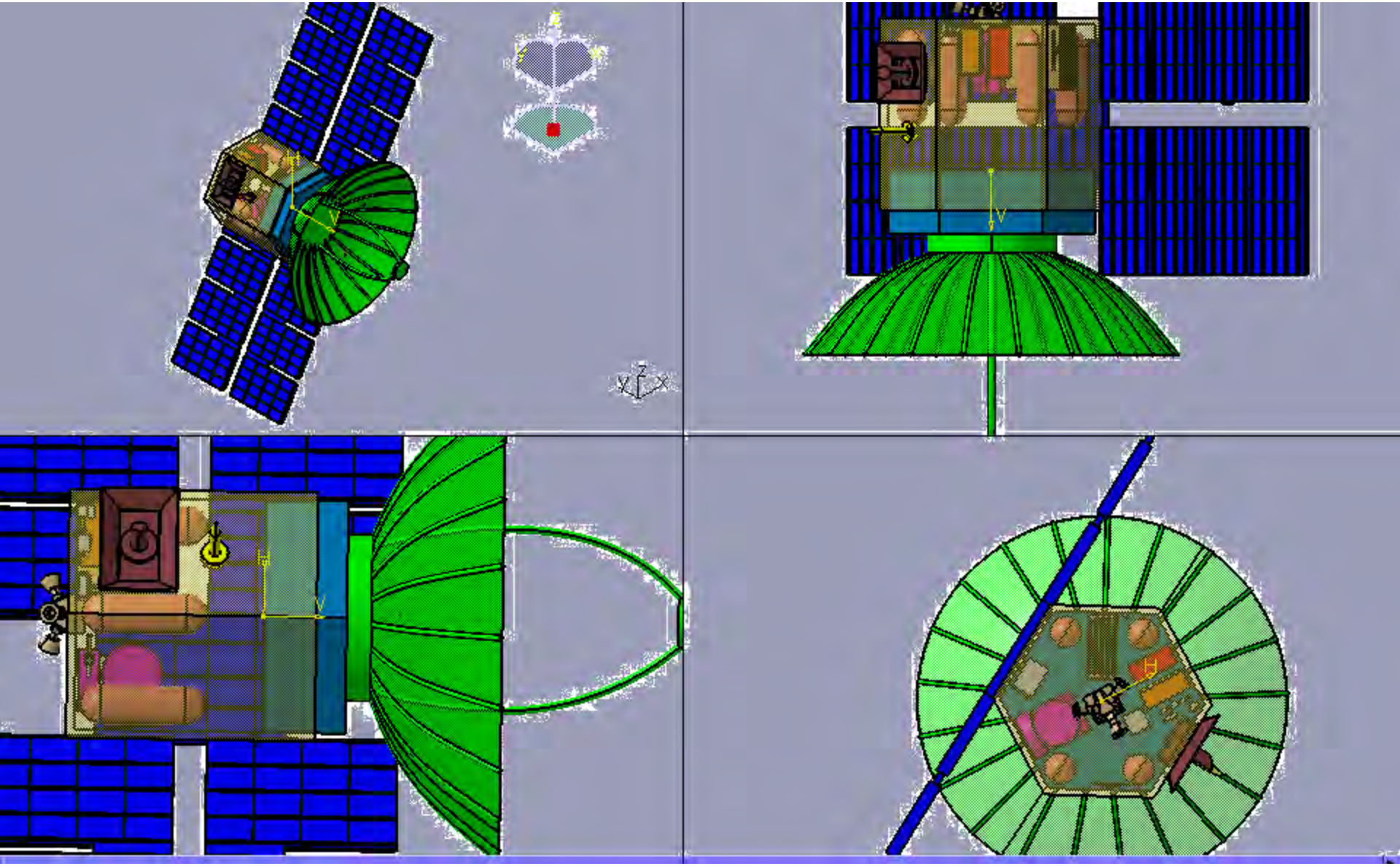
Desktop level proof-of-concept Hands-on development

SSD – and the winner is 2007-2008

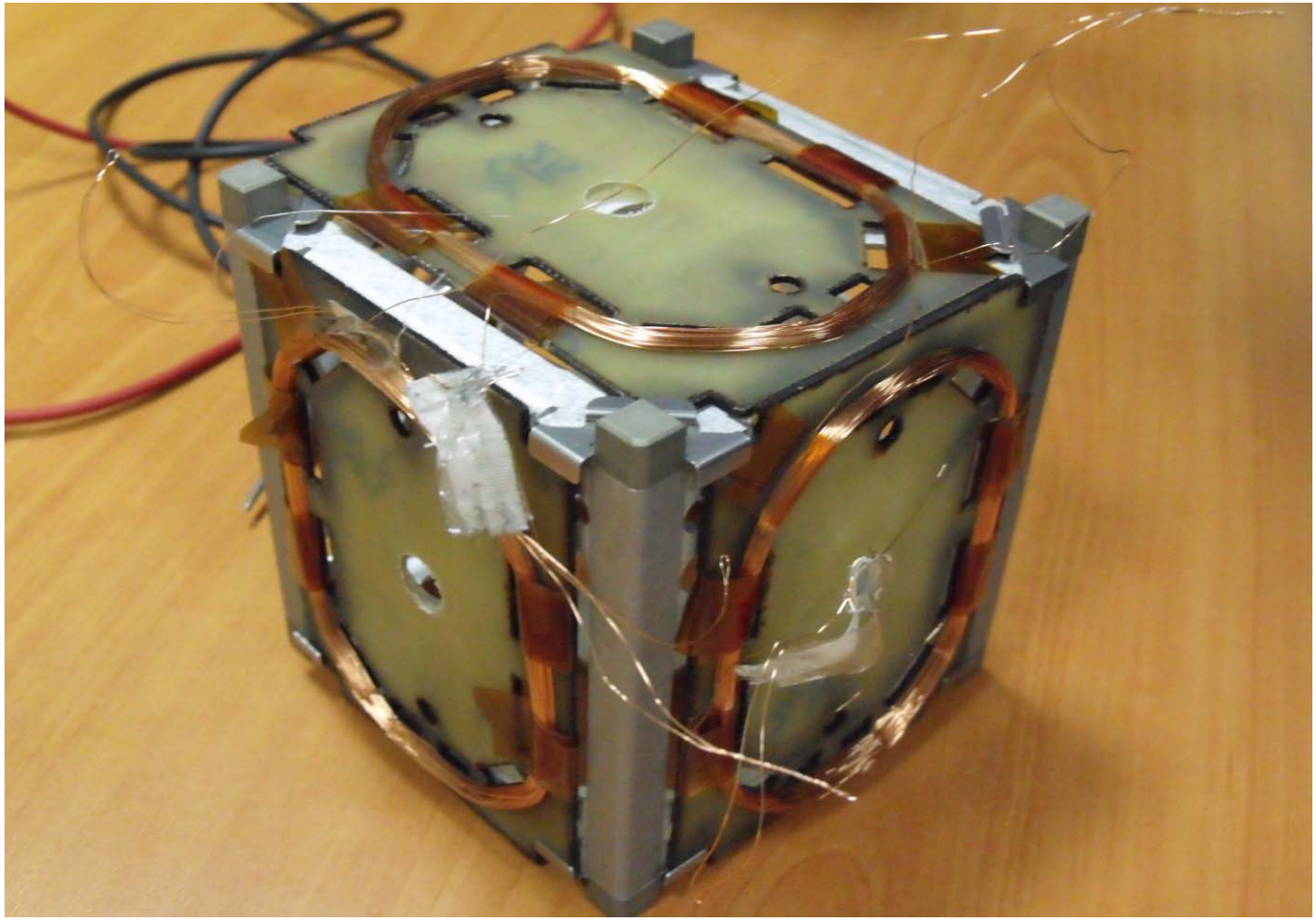




SSD – and the winner is … 2008-2009



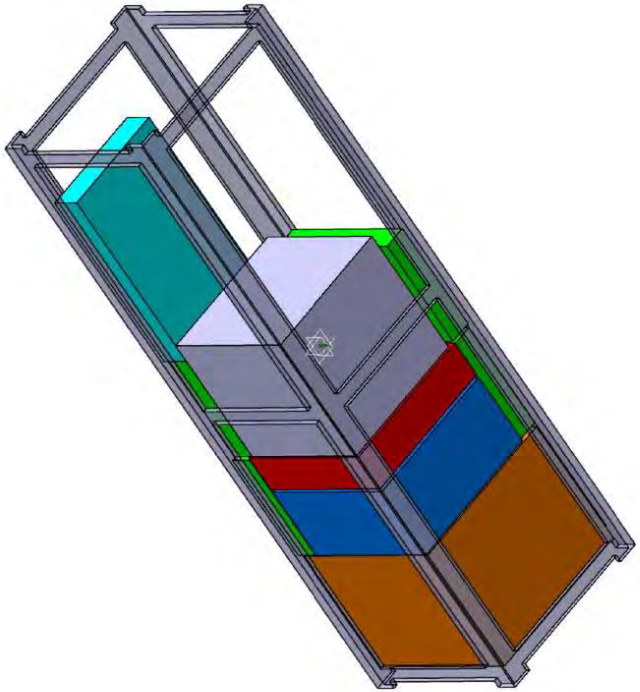
SSD – and the winner is …. 2009-2010



Next Step... ITU pSAT II

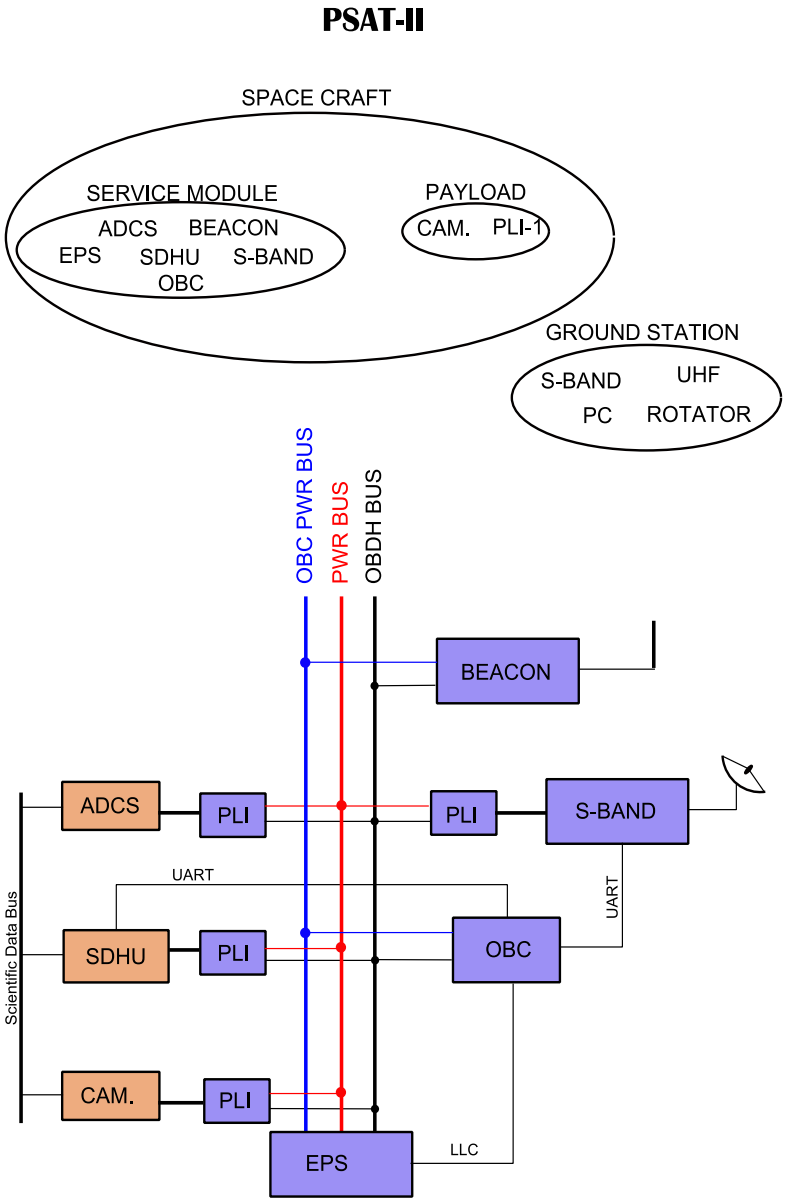
ITU pSAT II

- ITU pSAT II is the second nanosatellite project coming from ITU FAA Controls and Avionics Laboratory :
  - 3U form factor with three axis precise attitude control



ITU pSAT II Design Philosopy

- This project aims to develop a standardized platform (bus and payload interfaces) for pico and nano sized satellites (1-10 kg) for application such as
  - On orbit test and verification of new electronic, controls and material technologies
  - On orbit scientific experiments
  - Medium resolution imaging (scale of 50m-500m)

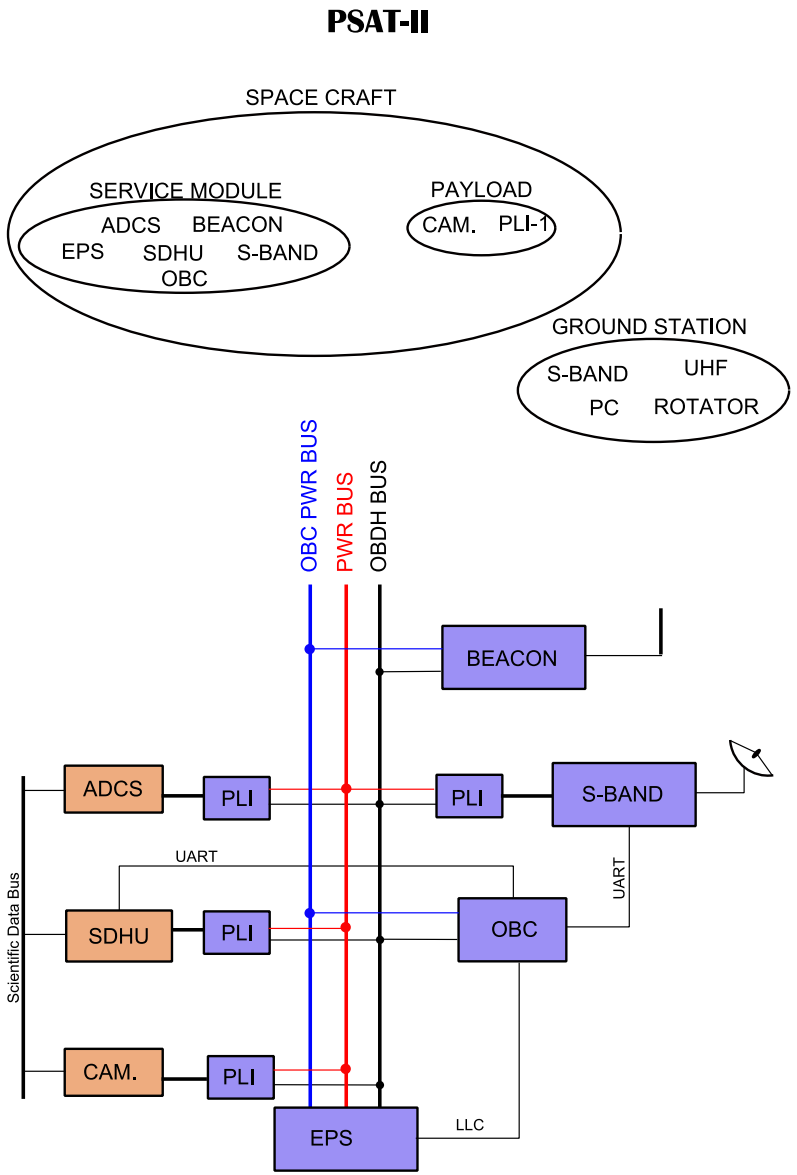


ITU pSAT II

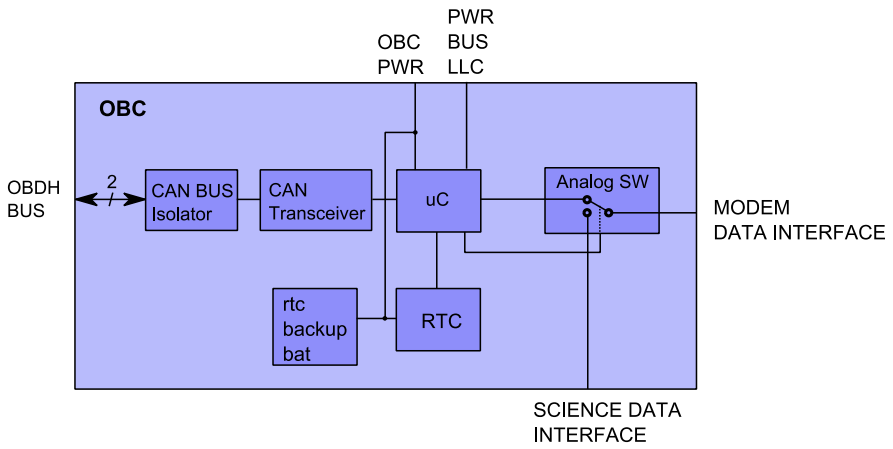
- Serves another step towards strengthening the hands-on applied space education and research at ITU FAA.
- Serves as a means to build infrastructure specifically for ADCS design and testing.

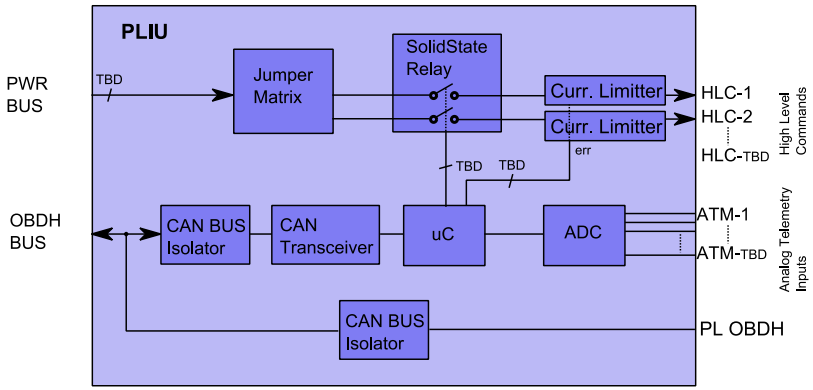
ITU pSAT II Bus

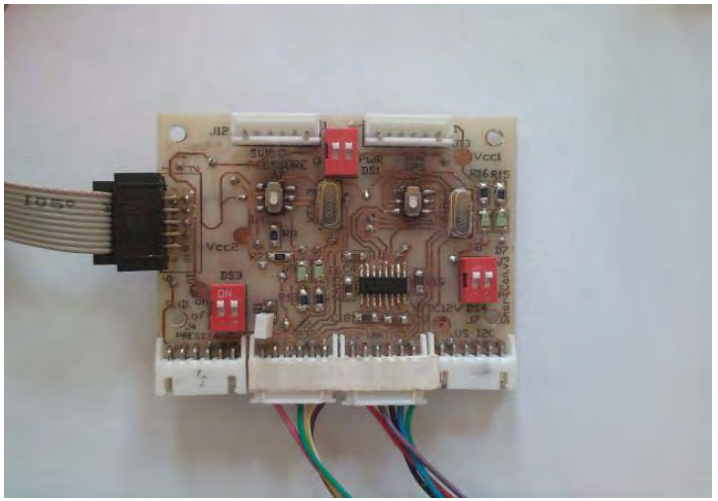
- A unique bus based design
  - Structured around a dual redundant CAN Bus and power bus
  - Flexible and scalable across form factors
- Bus consists of mostly in-house, in-development parts
  - OBC
  - EPS
  - ADCS
  - Scientific Data Handling Unit (SDHU)
  - COM (UHF, S-Band, Beacon)
  - Payload Interface Unit (PLIU)



ITU pSAT II Bus Preliminary Design

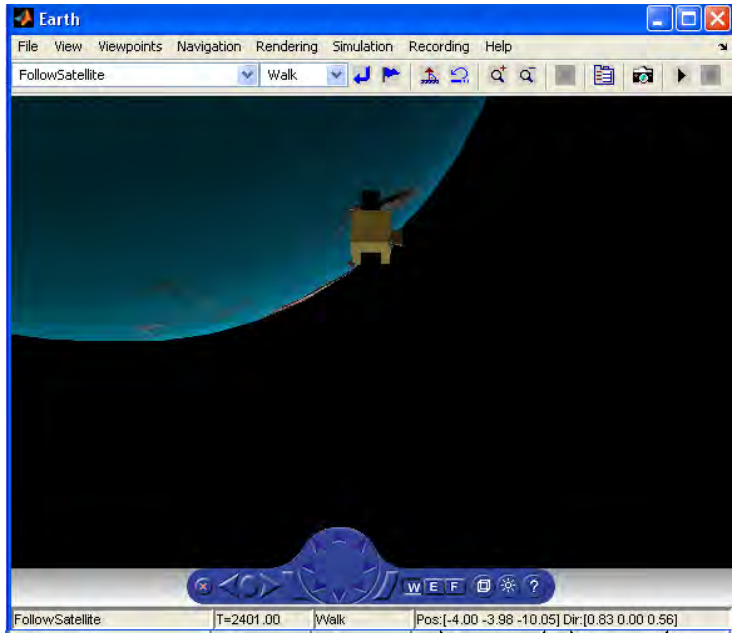


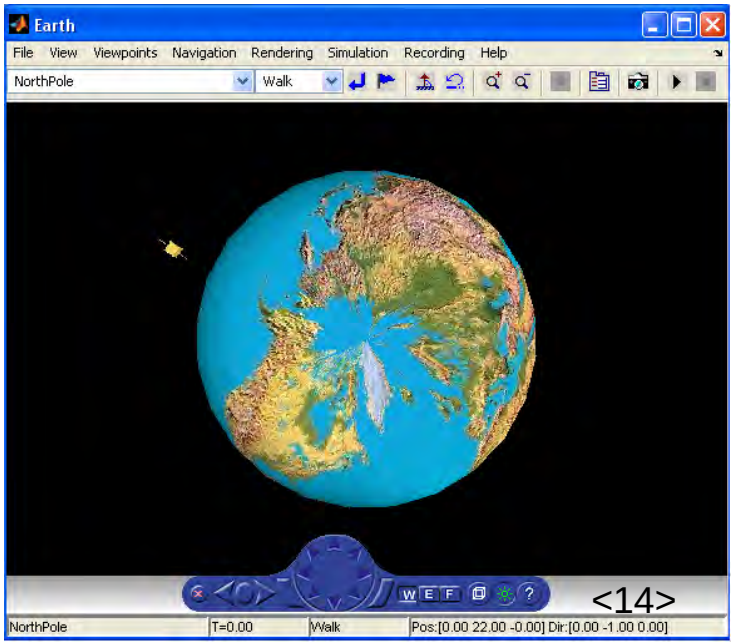




ITU pSAT II ADCS

- Attitude Determination and Control System (ADCS) consists of mostly in-house and in-development
  - **Sensors** (inertial, magnetic, earth sensor, sun sensor, experimental star tracker and GPS),
  - **Actuators** (3 reaction wheels, 3 magnetic torquers, and experimental CMG, experimental uPPT set)
  - **ADCS Computer** running Control and Estimation Algorithms (on-orbit propagator, attitude estimation,attitude control algorithms)

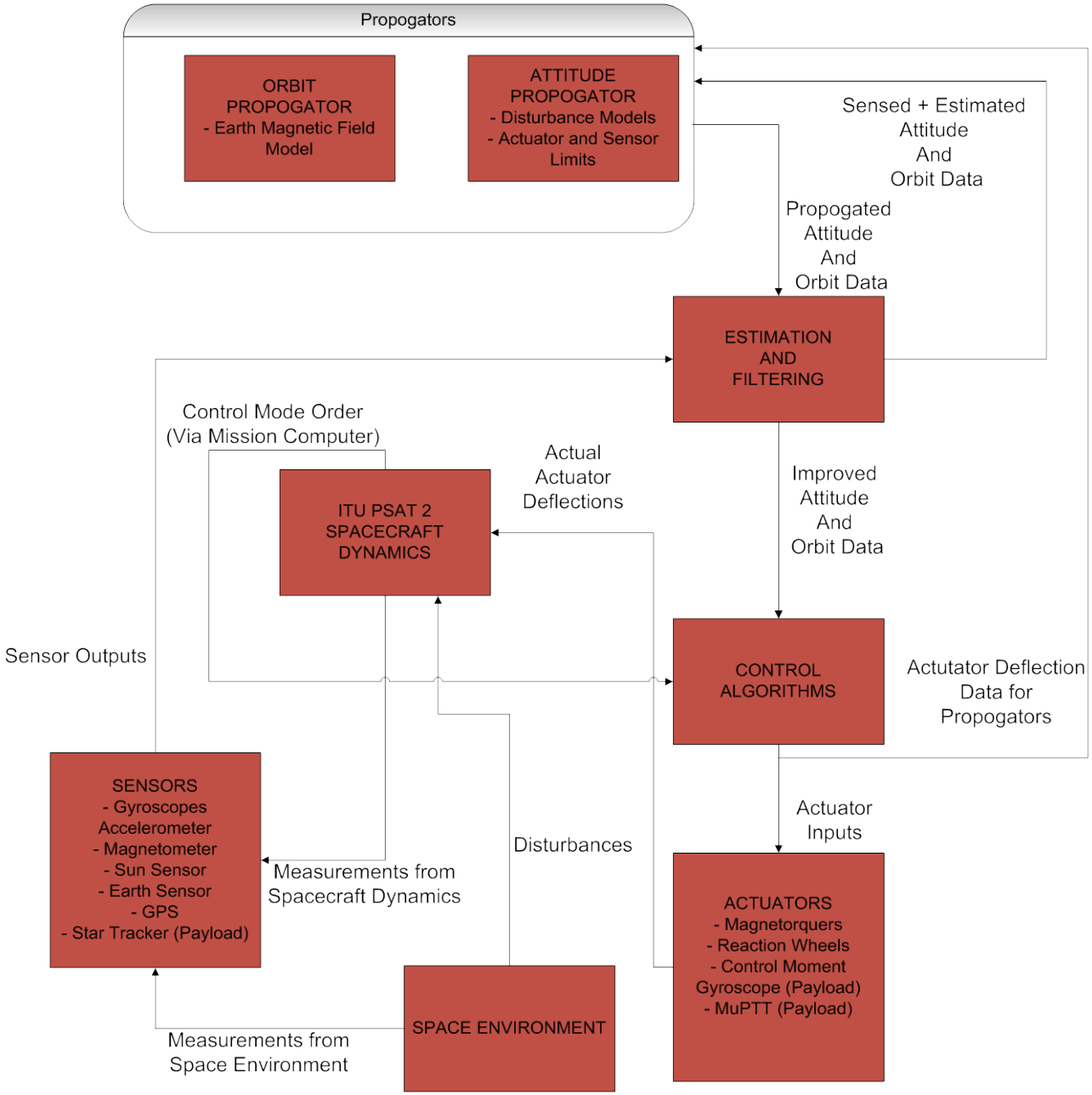




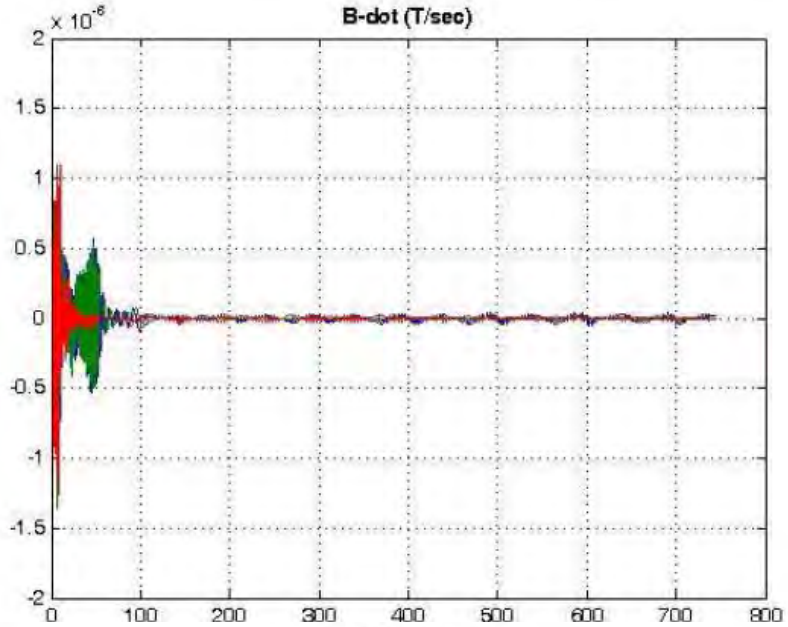
ITU pSAT II ADCS Test Facilities

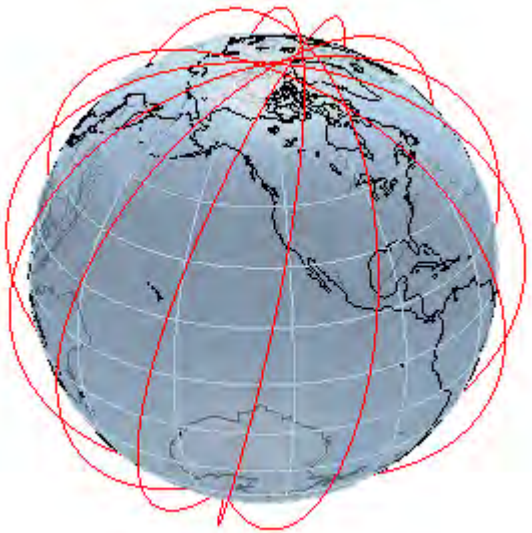
- Test units are being built/integrated for ADCS and bus specific functional tests :
  - a tri-axial Helmholtz Coil (Magnetic Subsystems)
  - a tri-axial Air Table (ADCS)
  - a Hardware-in-the-Loop Simulator (Bus)

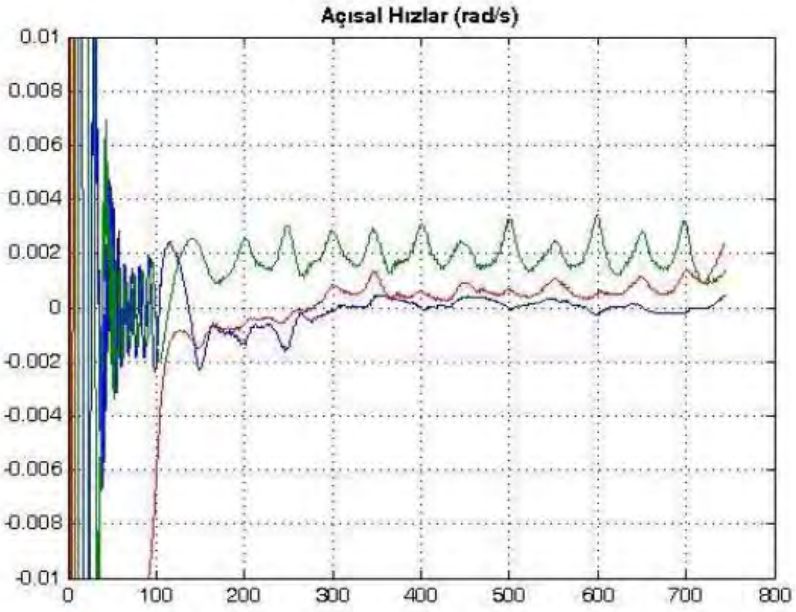
ADCS Algorithmic Framework

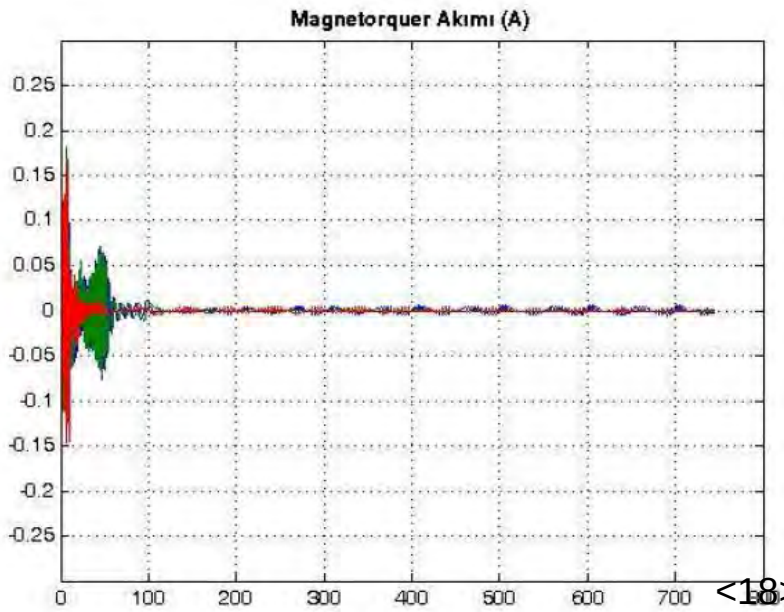


ITU pSAT II AttCon







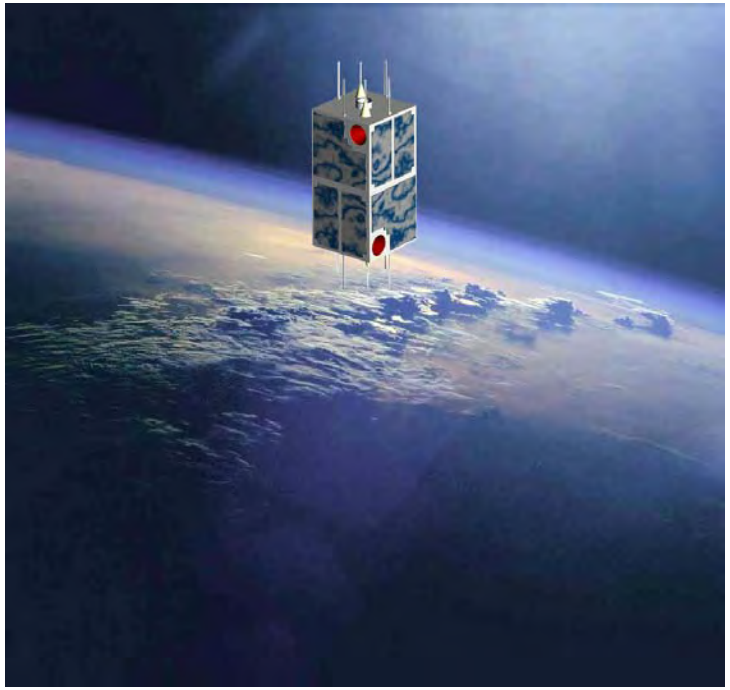


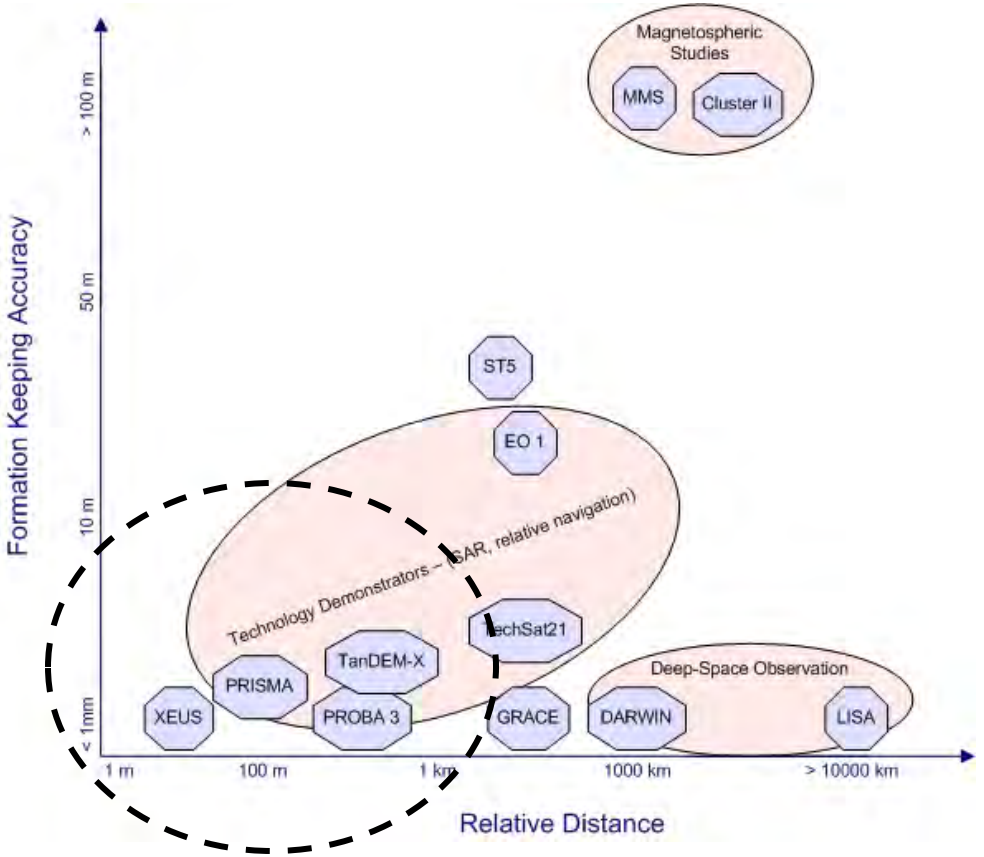
ITU pSAT II Next Steps

- We have entered into the protyping phase of the project in which we aim to
  - complete the ADCS Test infrastructure before November 2010
  - complete the prototypes of the bus components and the ADCS before May 2011

To come... ITU NXG

ITU-NXG Concept



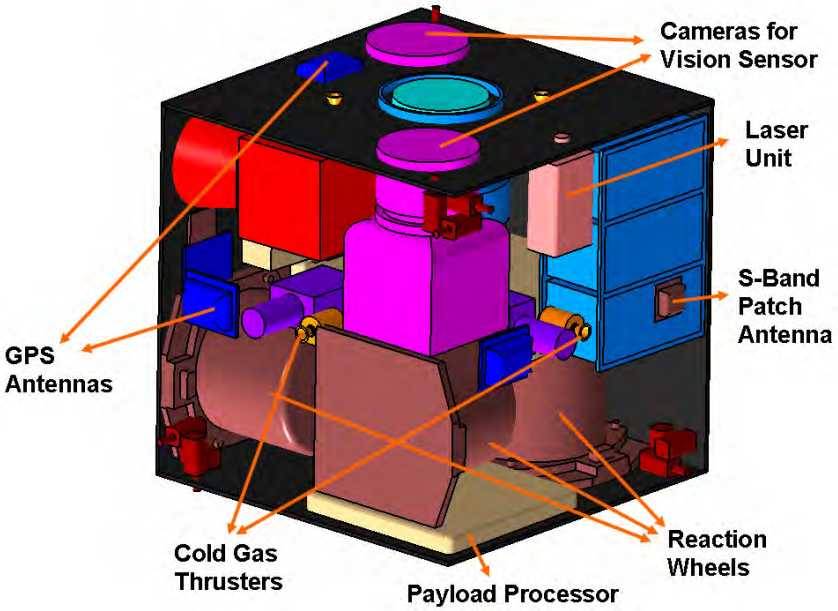


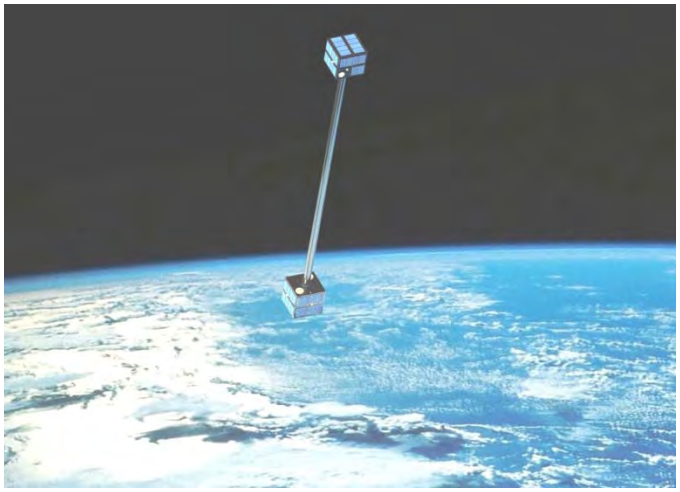
Need for cheap on-orbit demonstration against key technologies.

What will the mission do?

- Demonstrate and space mature technologies necessary for tightly controlled FF
- Examine flexible s/c structures

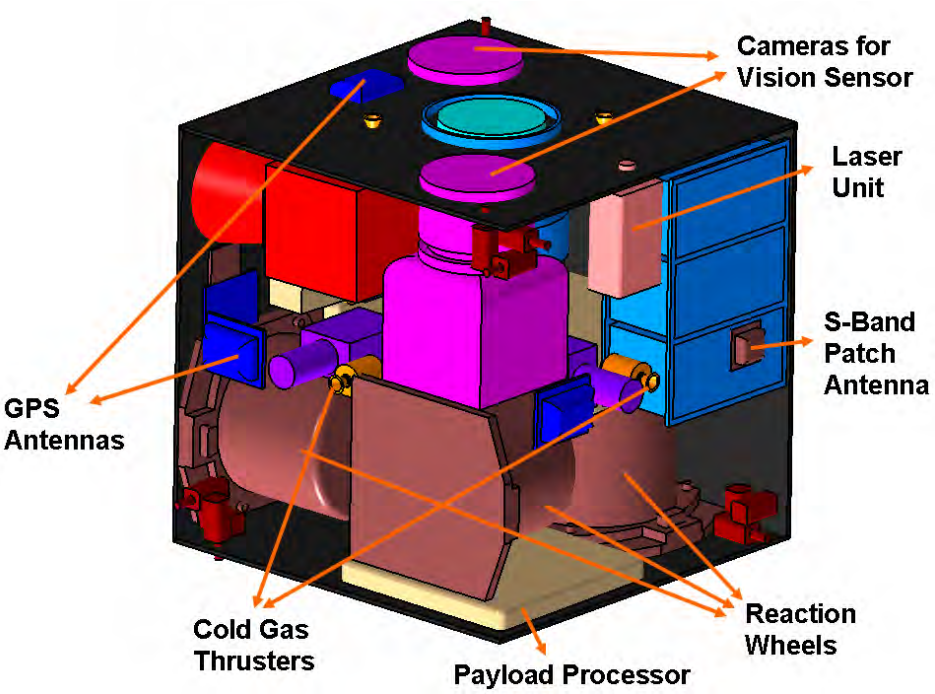
Research – Conceptual Design : ITU - NXG

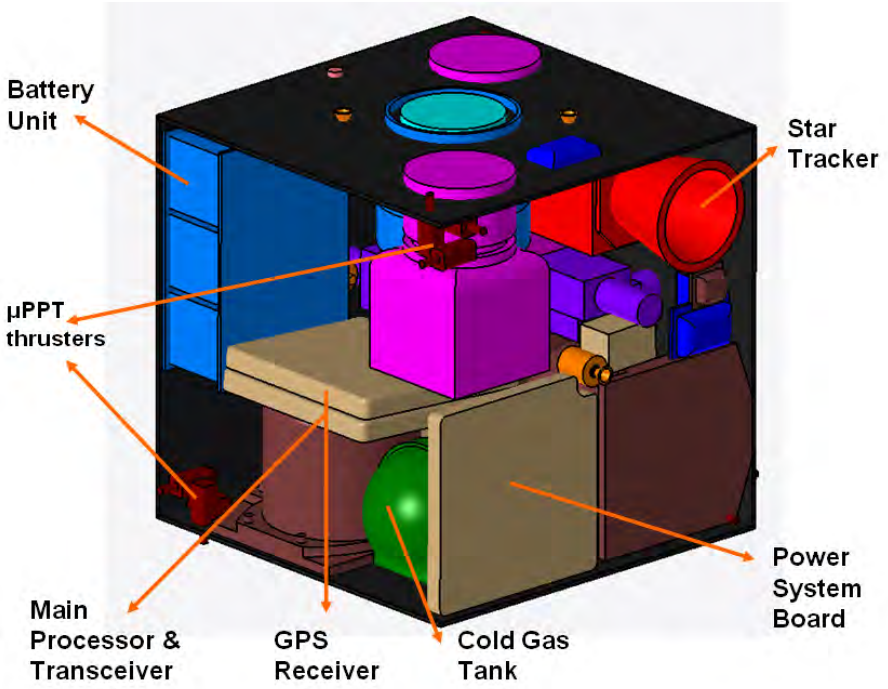




- Second Generation System
  - In-space experiment for monolithic structure control
  - Formation Flight

System Overview

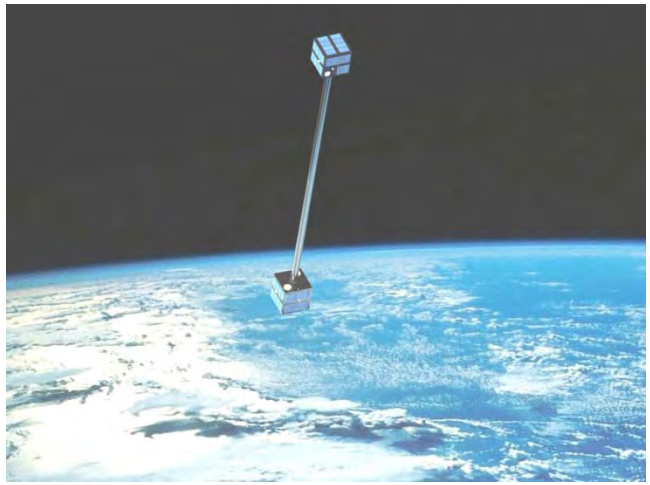




Mission Modes

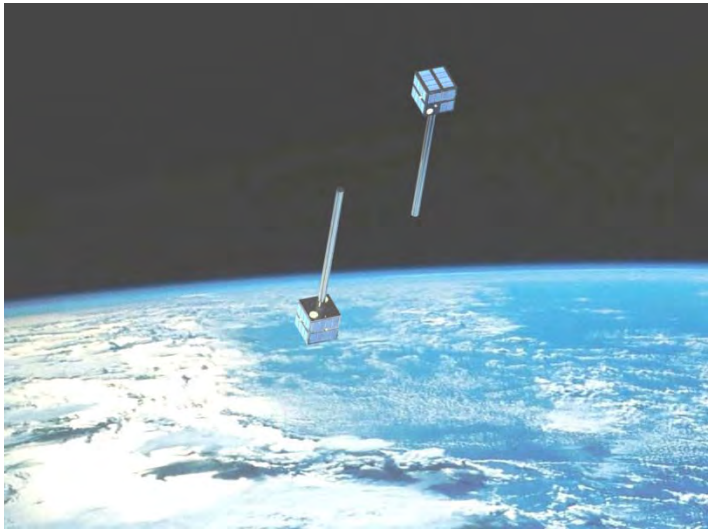
Modes	Experiments	Precision
A: Launch Configuration	Orbit Checkout & System Verification	
B: Flexible Monolithic Structure	Coordinated Attitude Control of Flexible Structures High Precision Relative Positioning & Attitude Metrology Test Cross - Navigation Verification	<0.1° control 10 μm relative distance knowledge 5 - 0.05 mm relative distance knowledge
C: Free Formation Flight	Precision Formation Planning and Control	< 10 cm relative distance control

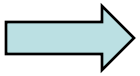
Mode A

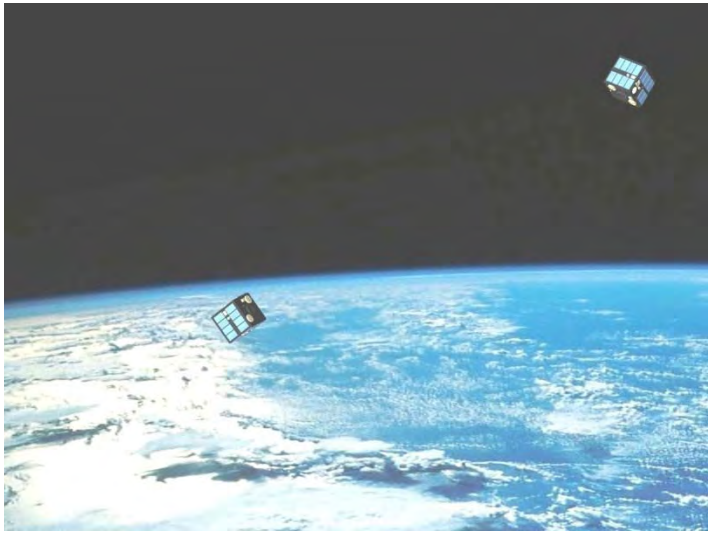


Mode B

Mission Modes - 2







Mode C

Thanks for your time!

We would like to acknowledge our sponsor for space projects ;

Scientific and Technological Research Council of Turkey

TÜBİTAK

This work is funded under TUBITAK 108M523 Project