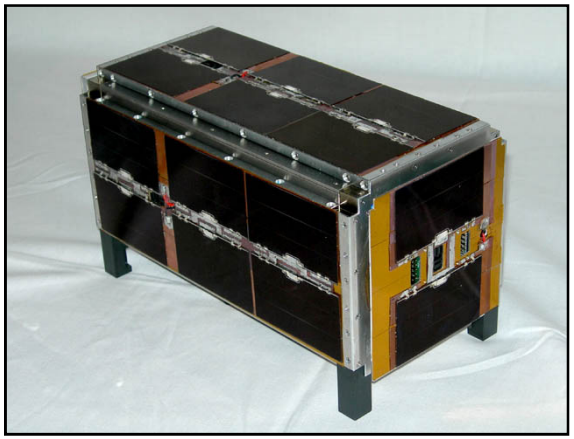
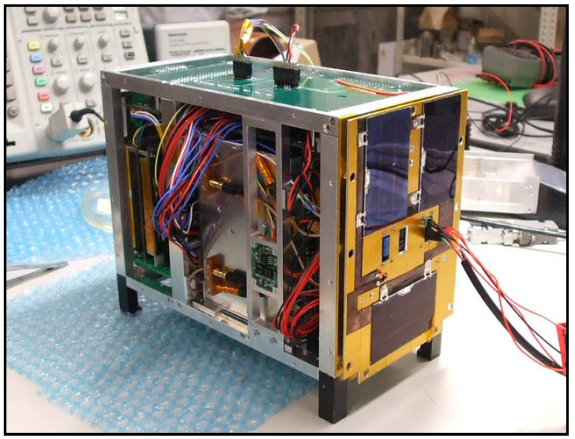
Tokyo Tech Nano-Satellite CUTE-1.7 + APD Flight Operation Results and the Succeeding Satellite





Ken Fujiwara, Kuniyuki Omagari, Thomas Iljic, Shinji Masumoto, Yasumi Konda, Tomio Yamanaka, Yohei Tanaka, Masaki Maeno, Taihei Ueno, Hiroki Ashida, Junichi Nishida, Yusuke Hagiwara, Kota Fujihashi, Takuro Ikeda, Shinichi Inagawa, Yoshiyuki Miura, Saburo Matunaga

Tokyo Institute of Technology, Laboratory for Space Systems

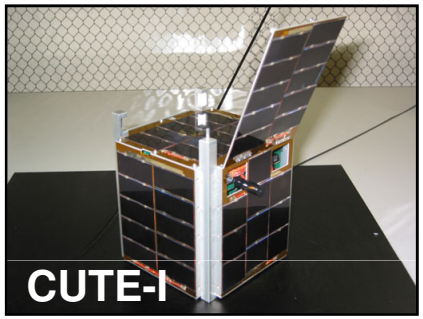
Jun. 28
ACA2007

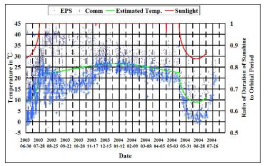
Introduction

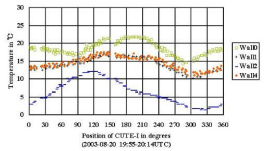
2003.6

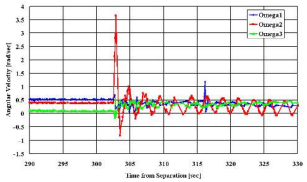
CubeSat Project (10cm cubed pico-satellite)

TokyoTech **CUTE-I** Launch



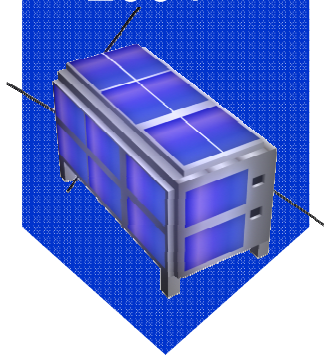






- Acquisition of satellite bus technologies

2004～



1. New design methodology
   - ☐ Very low-cost development
   - ☐ Short-term development
   - ☐ Intensive use of COTS components
2. Share orbital demonstration opportunities
   - ☐ Providing universal connectivity to the satellite

Tokyo Tech 2nd satellite
Cute-1.7

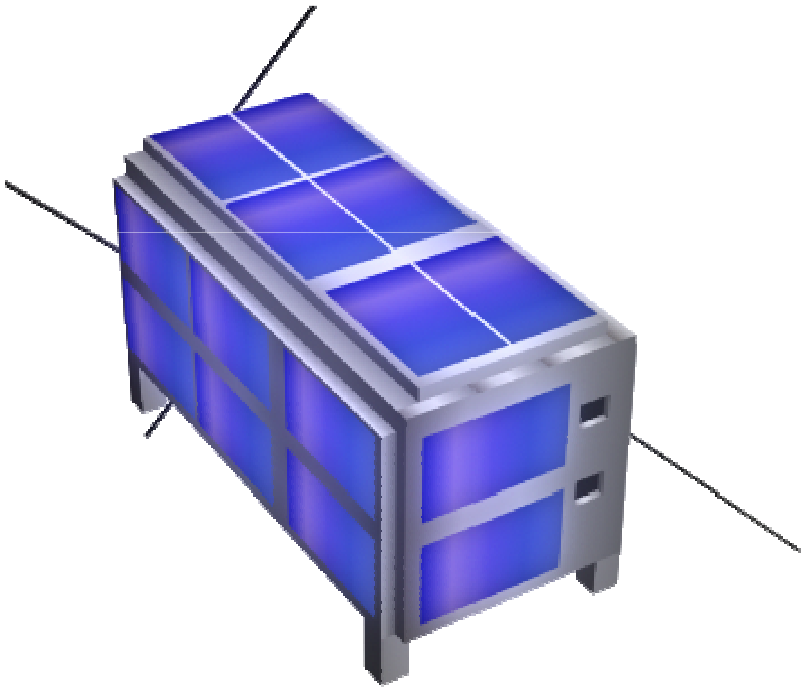
Contents

Cute-1.7 + APD:

- Development
  - Missions
  - Subsystems
- Flight Report
  - Accomplished missions
  - Encountered troubles

Cute-1.7 + APD #2:

- Modification
  - Missions and Design
- Launch information
  - Vehicle, date



Missions

1. Satellite bus development using COTS devices
2. Attitude control experiment
3. Amateur radio service
4. Tether deployment experiment
5. APD sensor demonstration
6. Nano-satellite Separation System demonstration

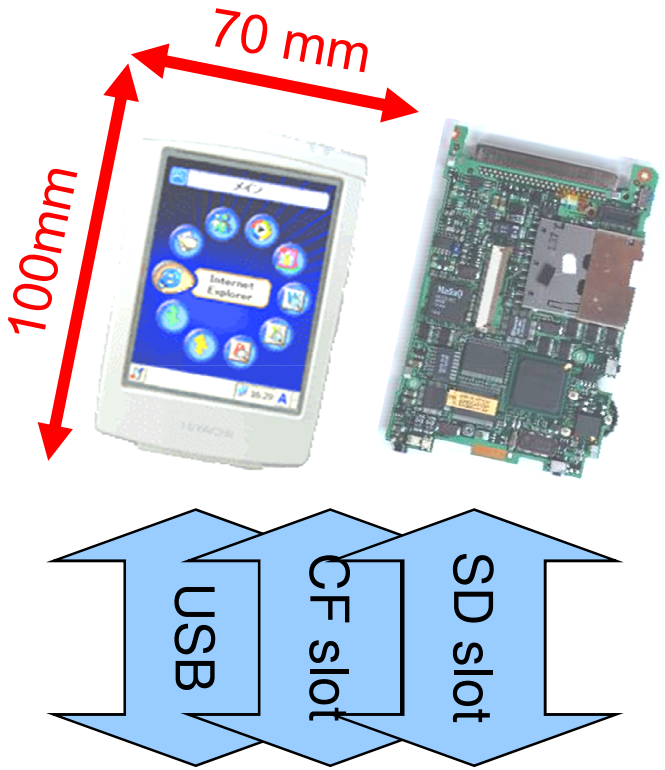
PDA-based OBC

COTS-based PDA as the main computer:

- Advantages to accelerate the development
  - High computing performance
  - Easy software development
  - Many external interfaces
  - Availability and low price

- Drawbacks of COTS devices
  - Radiation tolerance
  - Reliability

→ Radiation test
Redundant use of two PDAs

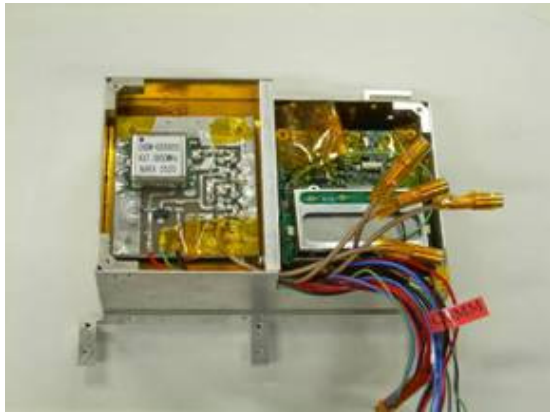


DAQ, COMM
Camera, 1-wire I/F, APD,
SD Card (Data Storage)

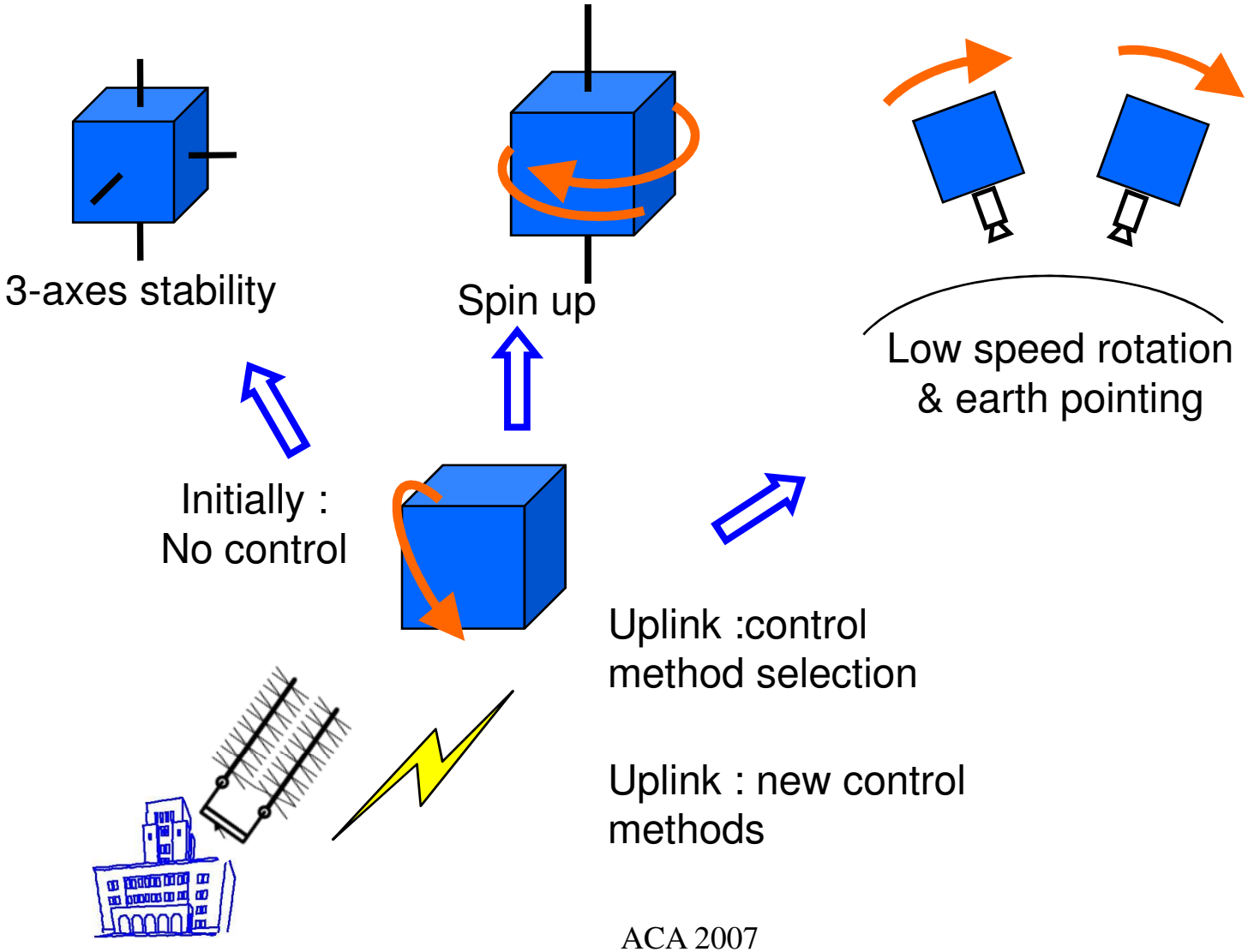
Communication Devices

- COTS-based handheld transceivers
  - Small though High performance
  - Easy to use, available at low-cost

- Communication channels
  - 144MHz AFSK/GMSK for uplink
  - 1200MHz GMSK for amateur service
  - 430MHz AFSK/GMSK for downlink
  - 430MHz CW for beacon

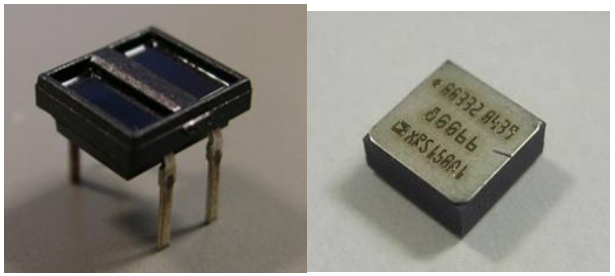


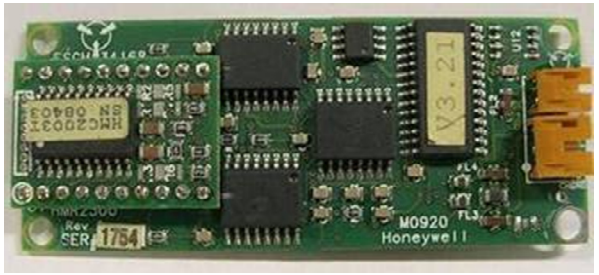
Attitude control mission

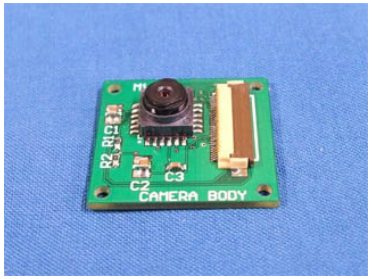


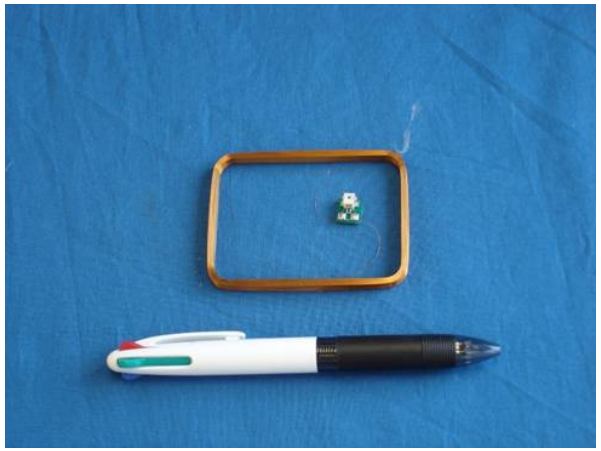
Attitude determination and control system

- Attitude Sensors
  - Sun sensor: 5 planes (photodiodes)
  - Gyro sensor: 3 axis
  - Magnetic sensor: 3 axis
- Attitude determination algorithms
  - Geometrical
  - REQUEST
- Actuator
  - Magnet torquer (0.037Am2): 3 axis
- Control algorithms
  - B-dot
- Camera
  - CMOS camera: 320x256 pixel



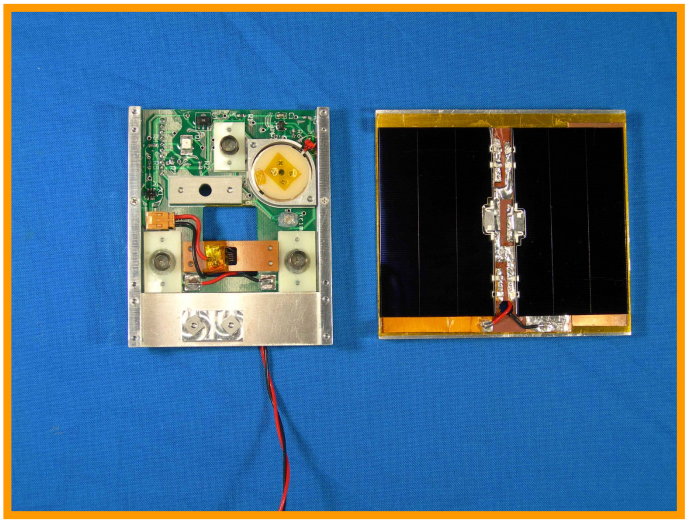


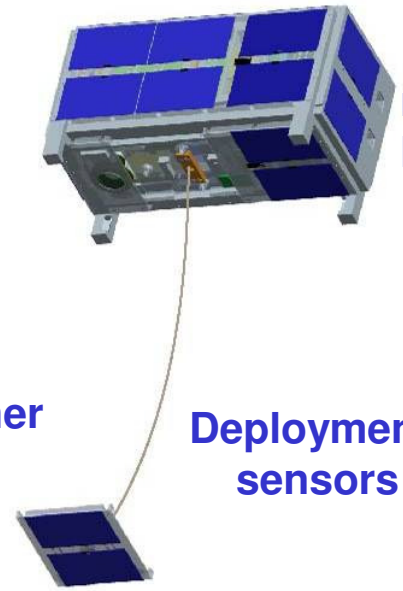




Tether Deployment Mission

Objective of this mission : fundamental tether deployment for future missions





By cutting the nylon thread holding a plate

10m copper tether

Deployment detection by sensors and camera

Initial velocity from the push-out springs : 30cm/sec
(data obtained from micro gravity experiment at MGLAB, Japan)

APD Mission (Science)

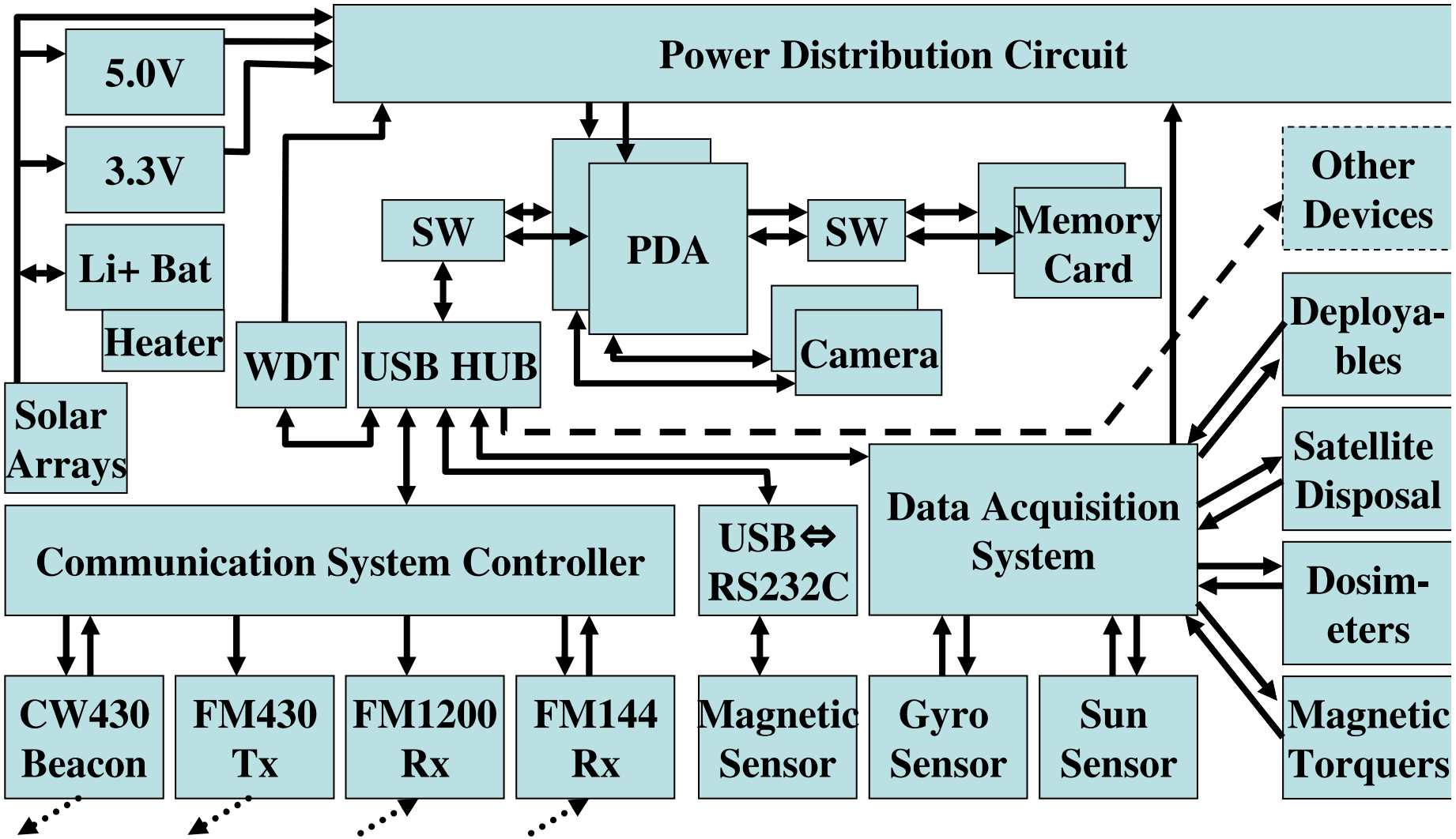
Objective:

experiment and demonstrate a new Avalanche Photo Diode sensor to detect charged particles on orbit.

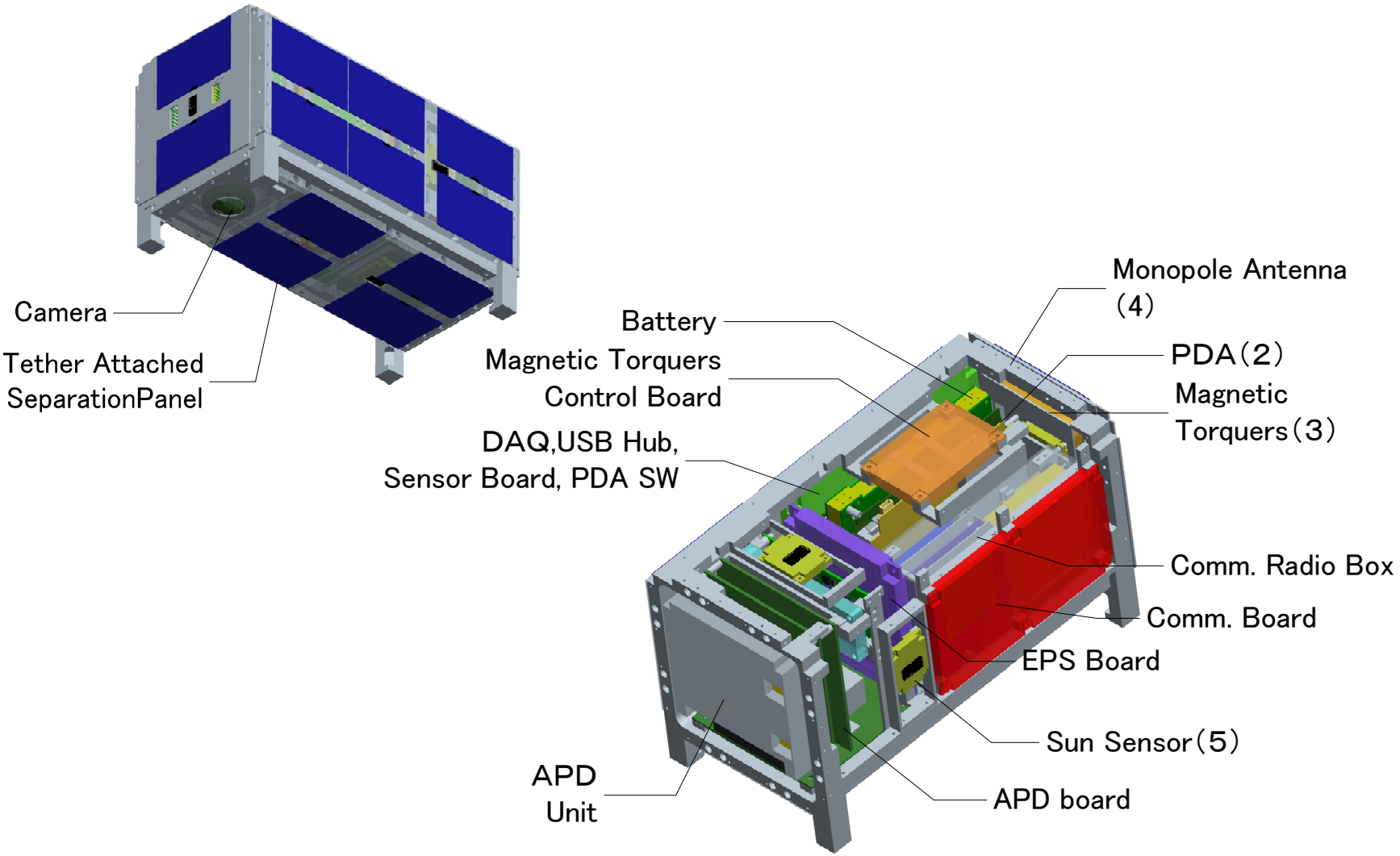
APD by Tokyo Tech astronomy lab.

Measures Low-E(E>3 kev) charged particles distributions in SAA and aurora band

System Block Diagram

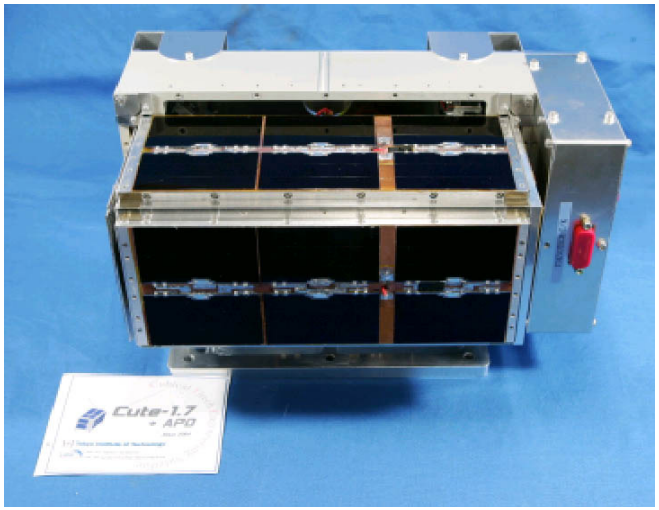


Components Allocation

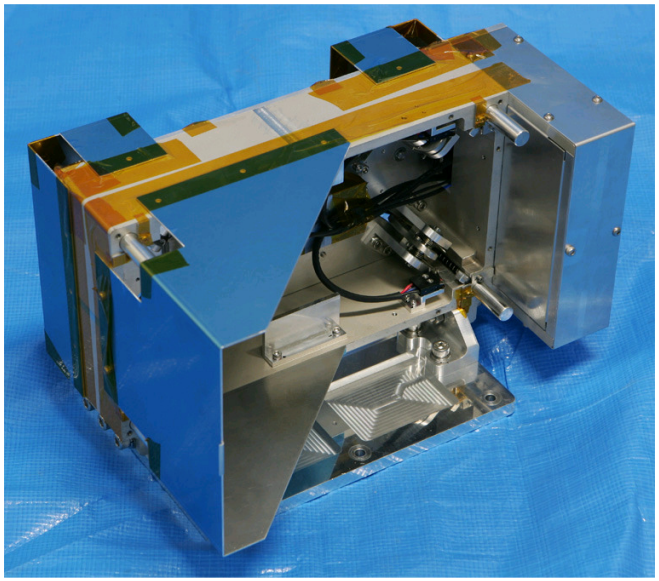


Specification

- Satellite
  - Size : 226x112x133mm
  - Weight : 3.6kg
  - Power : 3W

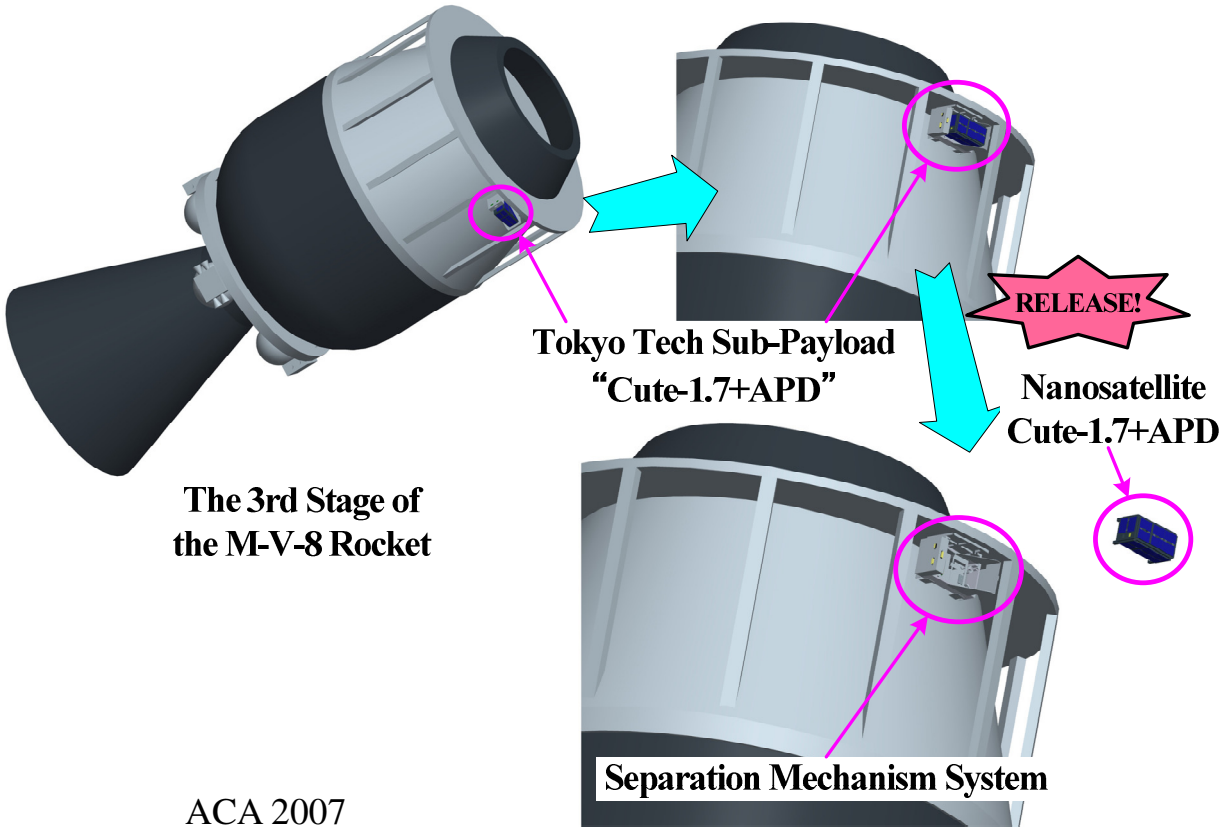


- Separation mechanism
  - Weight : 2.5kg
  - Deployment speed : 0.3-0.6m/s
  - Attitude disturbance : max. 0.4rad/s

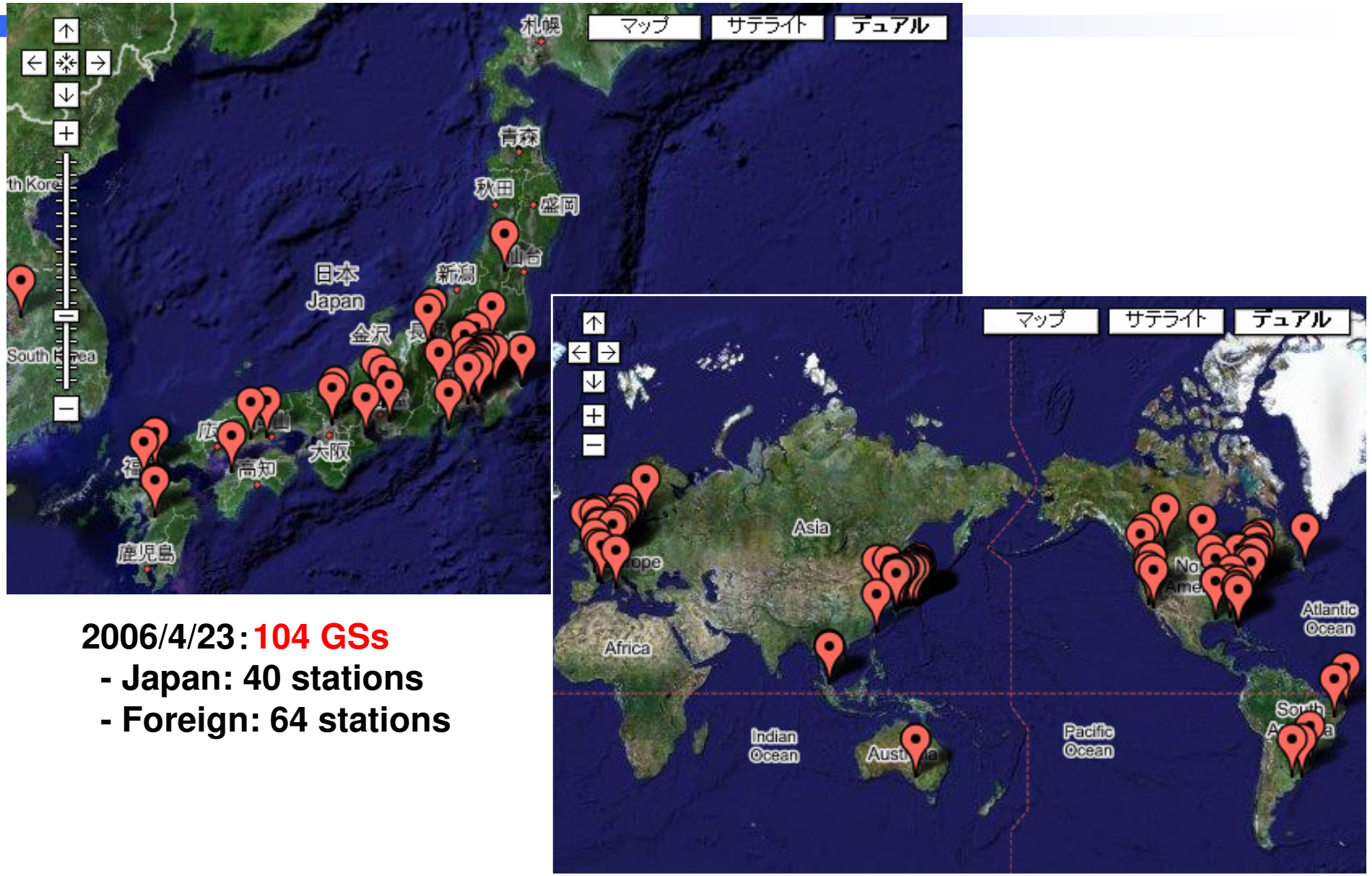


Cute-1.7 + APD launch opportunity

Cute-1.7 + APD was launched as a subpayload on Feb 22, 2006 from the Uchinoura Space Center (JAXA) in Kagoshima Prefecture.
The launcher was the JAXA M-V-#8.



Cute-1.7 Telemetry Reception

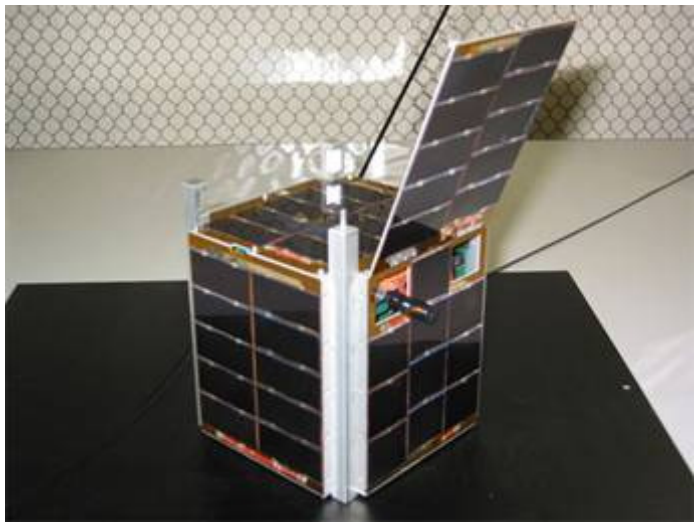


2006/4/23 : 104 GSs

- **Japan: 40 stations**
- **Foreign: 64 stations**

OSCAR Number

10/3/2006 : CUTE-I, Cute-1.7 + APD got OSCAR-numbers



CUBESAT-OSCAR-55(CO-55)
CUTE-I
(Jun. 30, 2003 launched)

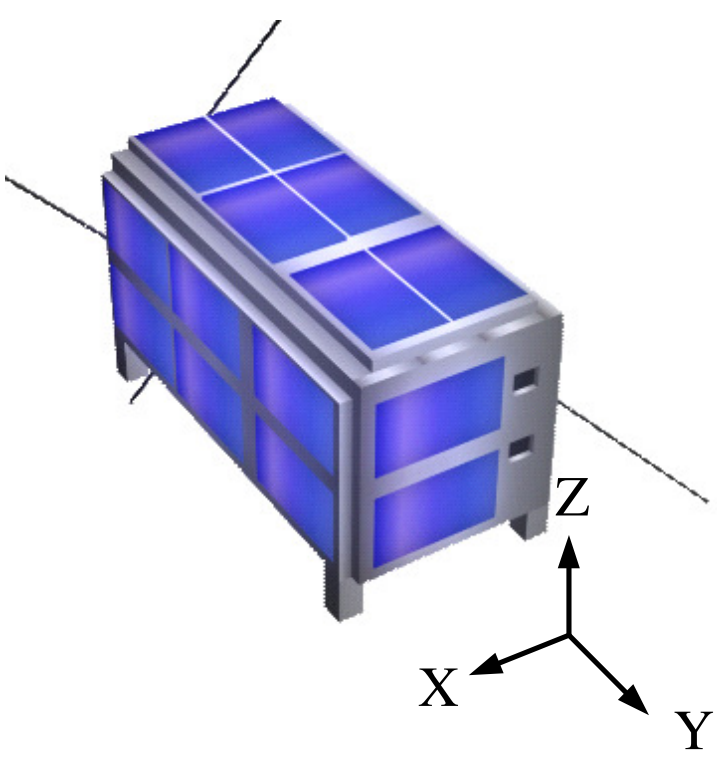
Over 1000 days operational

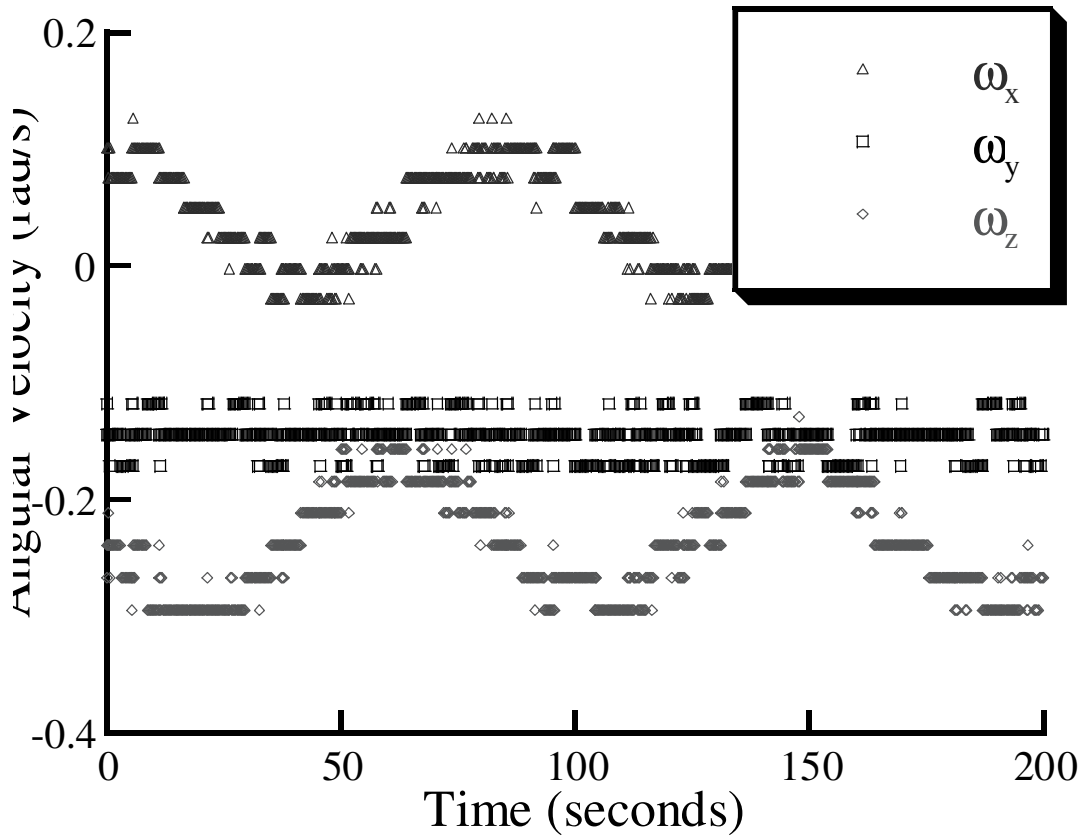
CUBESAT-OSCAR-56(CO-56)
Cute-1.7 + APD
(Feb. 22, 2006 launched)

Attitude Determination : Raw Gyro Data

Gyro data:

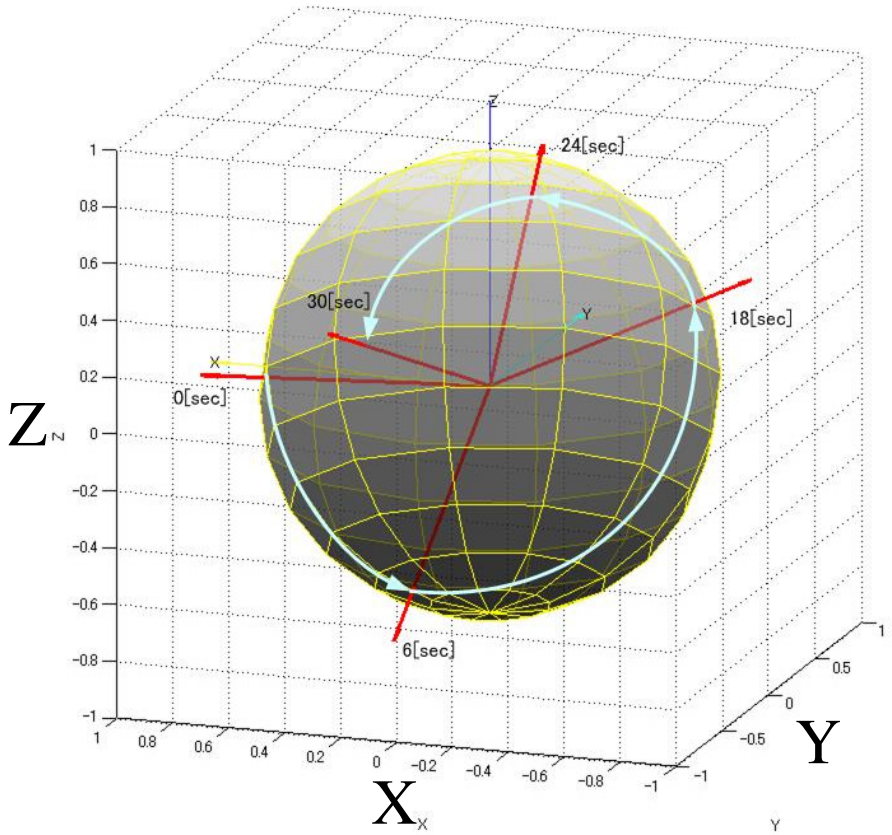
- Largest rotation about X axis
- Angular velocity, 0.28 rad/s





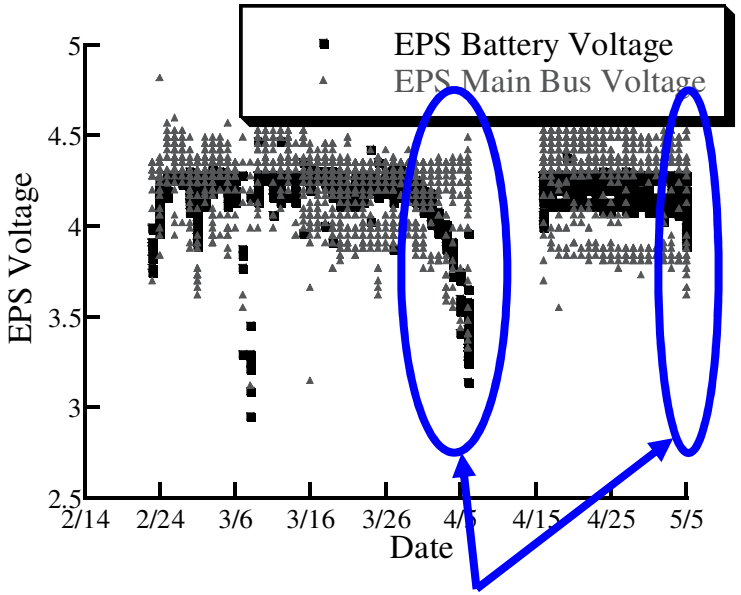
Sun sensor data

The sun sensor data also showed the rotation about x axis. The time cycle was about 30 seconds that correspond to gyro data



Conducted missions and encountered problem

- Demonstration of PDAs as onboard computer
- Amateur radio cooperation
- Attitude sensor data acquisition
- Nano-satellite Separation System demonstration



Decreasing battery voltage

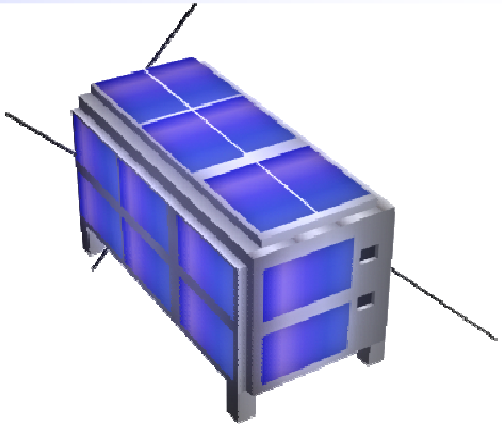
After 2 months operation:

- No reception to uplink command
- Increasing power consumption

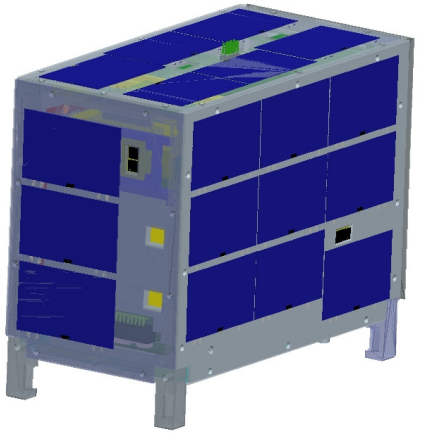
- Radiation effect on communication controller MPU

Cute-1.7 + APD #2 Project Outline

- Cute-1.7 + APD #1
  - Transmitting non-modulated continuous wave
  - Continuing recovery operation

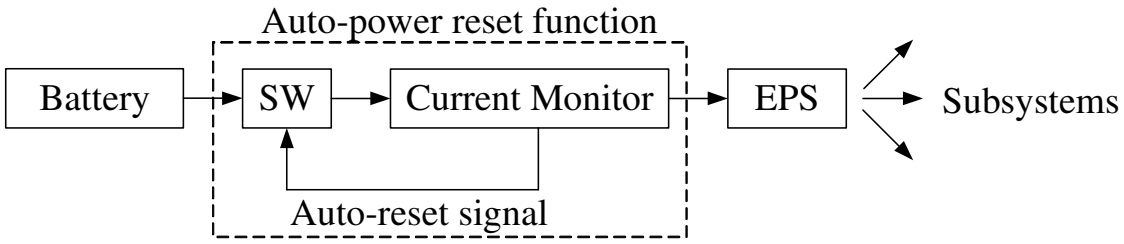


- Cute-1.7 + APD #2
  - Conducting same missions except tether deployment
    - Use of PDAs
    - Attitude control
    - Amateur radio service
    - APD sensor demonstration
    - Separation mechanism demonstration
  - Using basically same bus components
  - Applying some modifications to the 1st design

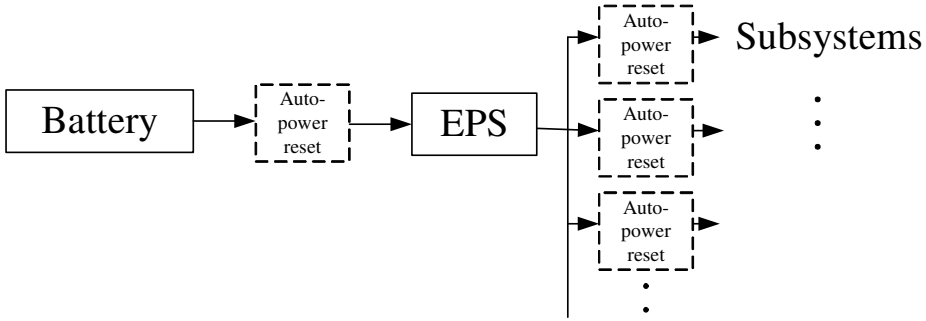


Modification: Radiation tolerant circuit

- Distributed auto-power reset functions
  - Detect slight current increase caused by SEL
  - Automatically restart unusual components



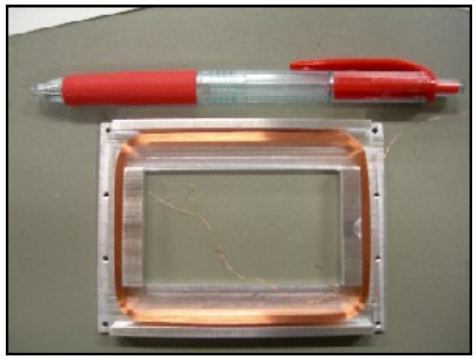
Cute-1.7 + APD #1 EPS system



Cute-1.7 + APD #2 EPS system

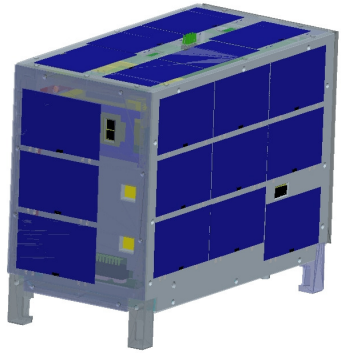
Modification: ADCS

- Attitude determination algorithm
  - QUEST
  - REQUEST
  - Extended Kalman Filter (newly implemented)
- Attitude control algorithm
  - B-dot
  - Quaternion feedback (newly implemented)
- Magnetic torquer
  - Enhanced (tripled) magnetic dipole 0.112 [Am2]
- Camera
  - Increased resolution (640x480pixel)



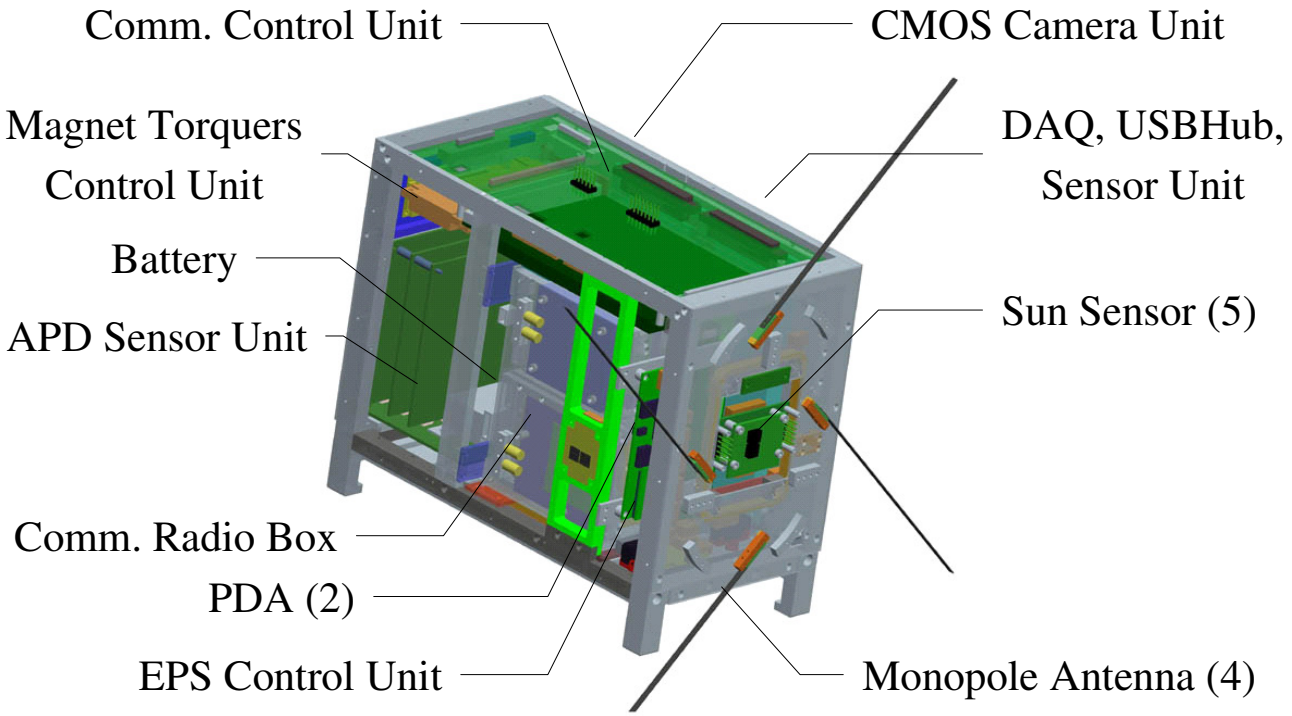
Modification: Structure

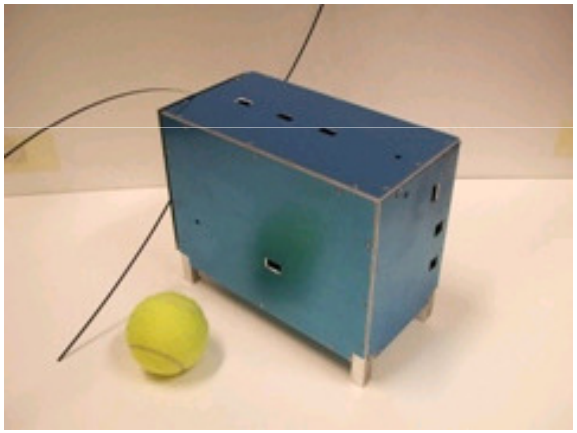
- Size up
  - 115x180x220mm
  - Power generation increase



- Simplified assembling procedure
- Frequent mission operation

Components Allocation





Launch information

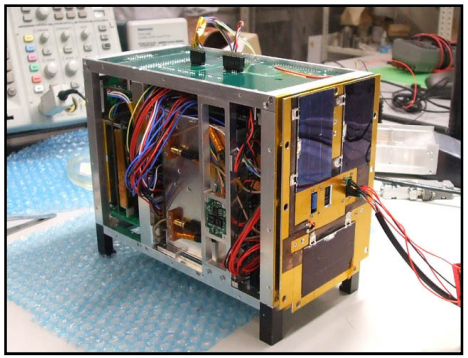
- Rocket
  - ISRO PSLV
- Orbit
  - Altitude: 635km, Sun synchronous
  - Inclination: 97.89 deg
- Satellites:

  Oceansat 2 (India) -Main payload
  AAUSAT II (Aalborg University)
  CanX-2 (University of Tronto)
  COMPASS-1 (University of Aachen)
  Cute-1.7 + APD II (Tokyo Tech)
  Delfi-C3 (Technical University of Delft)
  SEEDS (Nihon University)
- Launch date
  - September, 2007 or later

From http://www.isro.org/pslv.htm

Summary

- Cute-1.7 + APD #1
  - Developed to demonstrate a new design methodology
  - Launched on Feb. 22, 2006
  - Conducted part of its missions
  - Encountered SEL problem
- Cute-1.7 + APD #2
  - Enhanced model of the first satellite
  - Planned to be launched soon



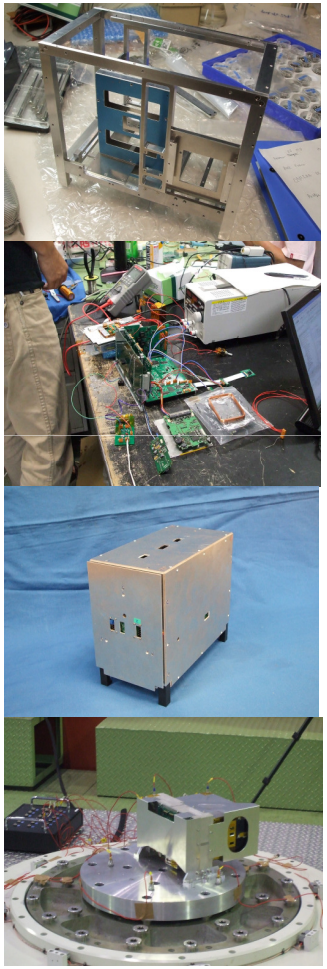
Cute-1.7 + APD #2 project webpage:
http://lss.mes.titech.ac.jp/ssp/cute1.7/index.php

Contact:
fujiwara@lss.mes.titech.ac.jp

Thank you !

Development schedule

2006	Apr.	Design review
	May	Radio tolerance test
	Jul.	Integration test
	Aug.	Vibration test 1
	Nov.	Vibration test 2
	Dec.	Thermal test
2007	Jan.	Vibration test 3
	Feb.	Vacuum test
	Apr.	Sensor calibration
	May	Interface test at VSSC, India
	Jun.	Long-term operation test (3 weeks)
	Jul.	Residual magnetic flux measurement



Gyro data: Quaternion form

These results have shown that :

-The x axis has the largest rotation

- The average angular velocity is of 0.28[rad/s]