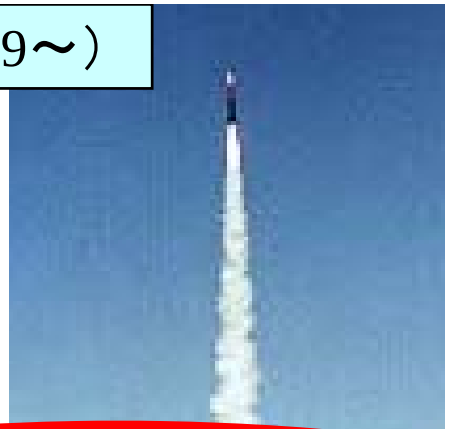
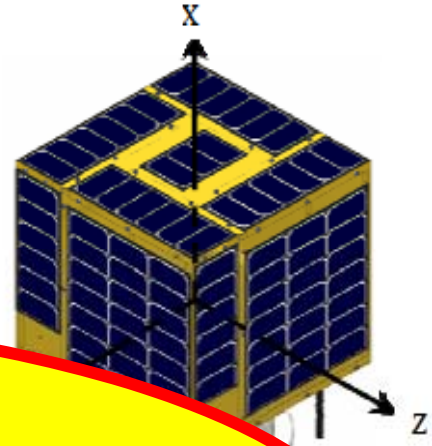
CanSat & Rocket Experiment(‘99～)





UNITEC-1 ’10 Venus

CanSat Lecture
- Its Educational Significance -

Shinichi Nakasuka
University of Tokyo

CubeSat 03,05

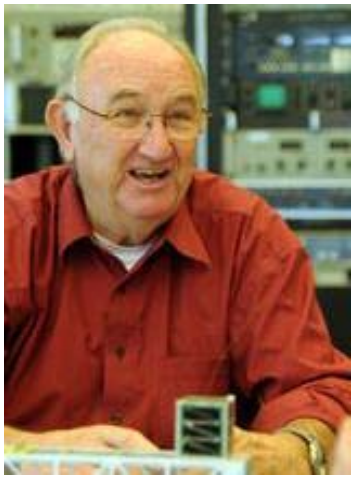
PRISM ‘09

Nano-JASMINE ‘11

Contents

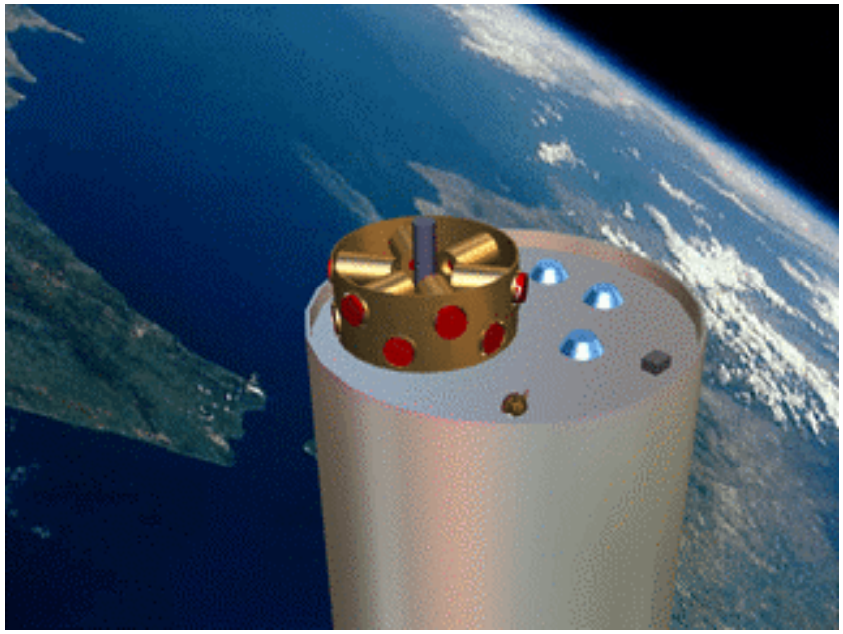
- What is CanSat ?
  - Birth of Concept and History
  - Variety of CanSat
- Significance of CanSat Based Training
- CanSat Systems and Operations
  - Basic Systems and Operations of CanSat
- CanSat Missions
  - Example missions
  - Tips for mission creation
- Common and different things with/from satellite
- Level of CanSat Training

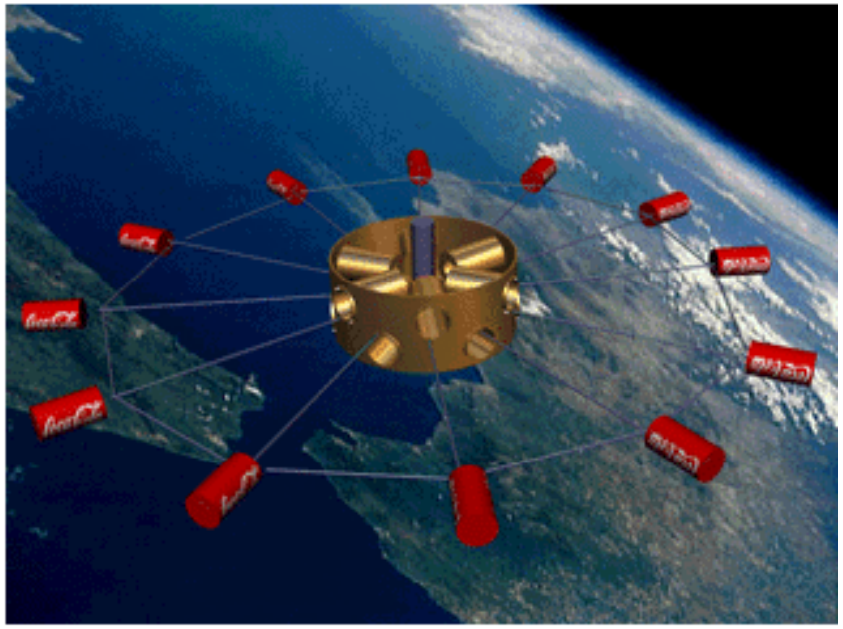
What is CanSat ?



- In November 1998 at the University Space Systems Symposium (USSS) held in Hawaii, Prof. Bob Twiggs (Stanford University Space Development Laboratory) proposed "CanSat" concept.
- A 350-ml can sized small satellite for educational purpose, which is launched into high altitude by rockets, balloons and/or model aircrafts; and experiments are performed during descent by parachute, simulating the satellite operations in space

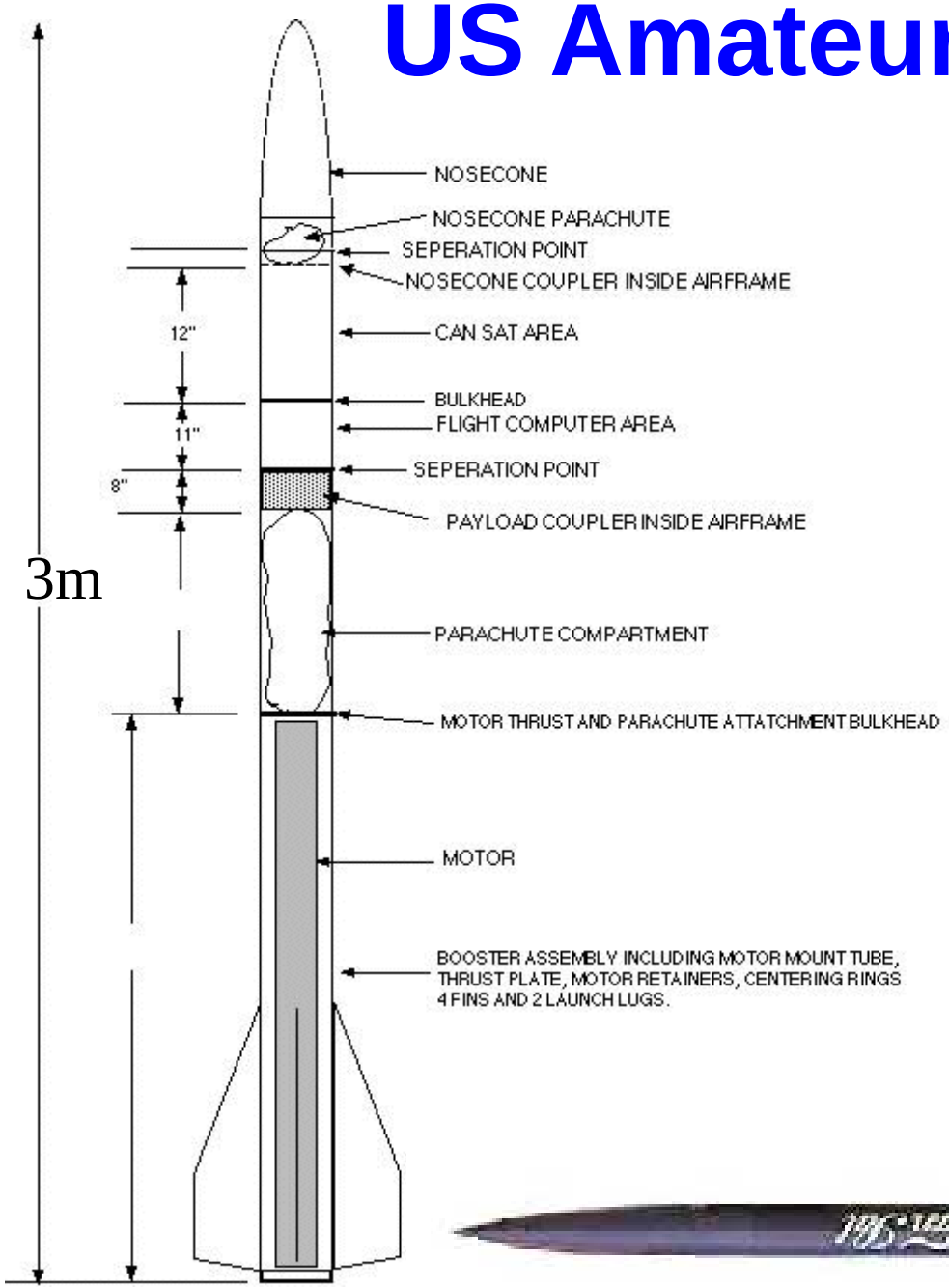
Initial Concept of CanSats Program (As of 1998 by Prof. Twiggs)



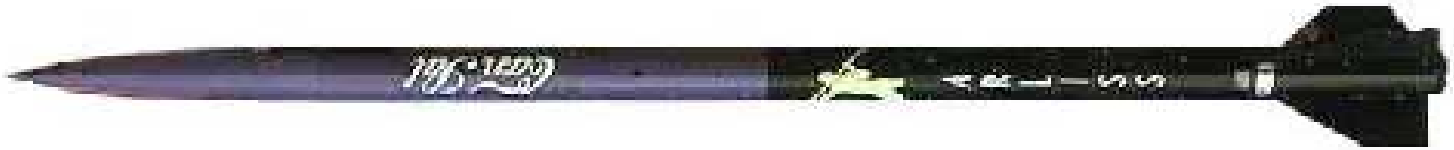


Each participating university will develop one CANSAT and launch them altogether

US Amateur Group Help Us !



- AEROPAC Amateur Rocket group
- 1 stage solid motor
- Lift 1.8 kg to 4 km
- Three 350ml sized cans or one “Large sized can”
- Cost $400 / flight
- Black Rock Desert (Nevada, USA)

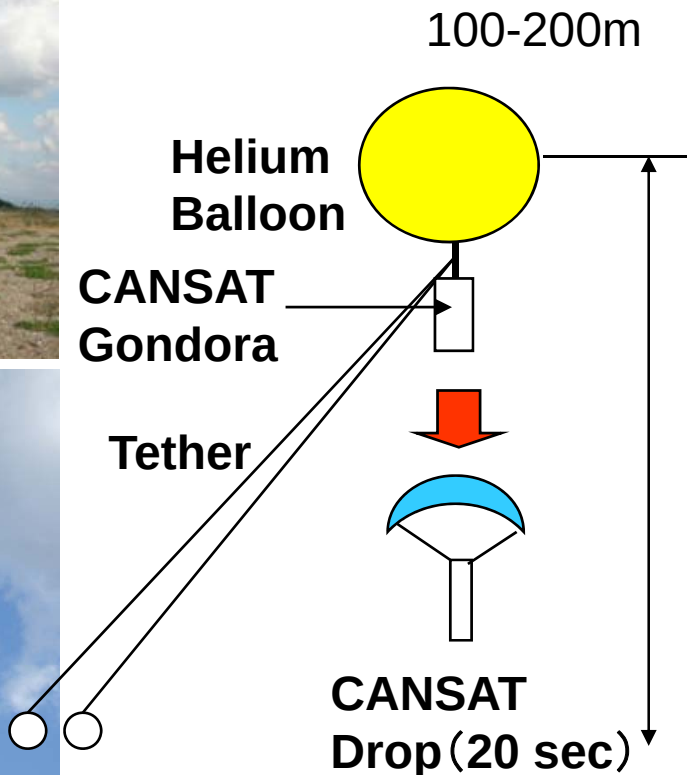


ARLISS (A Rocket Launch for International Student Satellites)
- Annual suborbital launch experiment -

- ARLISS 1999 : Sept. 11 (Japan:2, USA:2)
  - Univ.of Tokyo, Titech, Arizona State, etc.
- ARLISS 2000: July 28-29 (Japan:4, USA:3)
- ARLISS 2001: August 24-25 (Japan:5, USA:2)
- ARLISS 2002: August 2-3 (Japan:6, USA:3)
- ARLISS 2003: Sept.26-27 (Japan:6, USA:3)
- ARLISS 2004: Sept.24-25 (Japan:6, USA:3)
- ARLISS 2005: Sept.21-23 (Japan:7, USA:3)
- ARLISS 2006 Sept.20-22 (Japan:8 USA:3 Europe:1)
- ARLISS 2007 Sept.12-15 (Japan:10 USA:3 Korea:1)
- ARLISS 2008 Sept.15-20: 10th Memorial ARLISS !
- ARLISS 2009 Sept.15-19 (Japan:12 USA:3 Korea:1)
- ARLISS 2010 Sept.13-17 (Japan:13 USA:2 Korea:1)
- ARLISS 2011 Sept.12-16 (Japan:14 USA:2 Korea:1)
- ARLISS 2012 Sept.10-14

Balloon Experiment in Japan

- Itakura Competition 2002 (Thermal balloon)
- Noshiro Space Event 2005～
- IAC Fukuoka International Competition 2006 2005



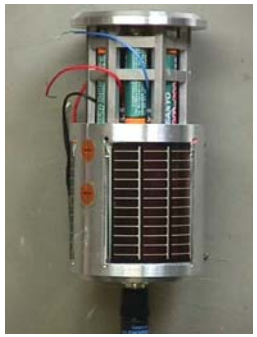
Noshiro Space Event

Noshiro-space-event is the most big competition of the rockets and also the can-sats and rovers for university students in Japan. Japanese university students around japan come to noshiro every year and work hard by competing with each other.

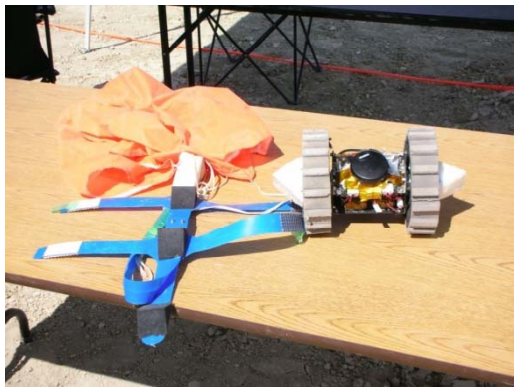
Then, students will become important persons who will carry space world in Japan.

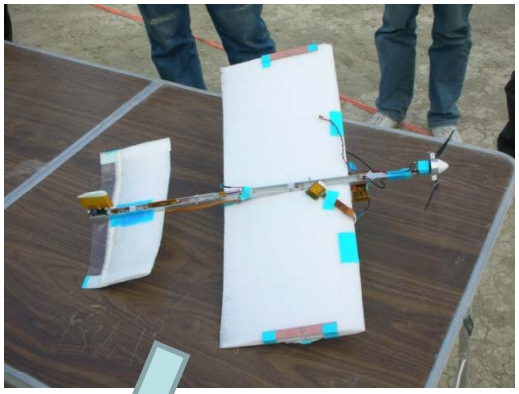
Rocketeers!!

Variety of CanSat



Nominal 350ml Juice Can size
(3 CanSats can be launched
by one ARLISS rocket)





“Open Class”: One CanSat can be
launched by one ARLISS rocket

Significance of CanSat Based Training

Educational Significances of CanSat/Micro/Nano/Pico-Satellite Projects

- ***Practical Training of Whole Cycle of Space Project***
  - Mission conceptualization, satellite design, fabrication, ground test, modification, launch and operation
  - Know what is important and what is not.
- ***Importance for Engineering Education***
  - Synthesis (not Analysis) of an really working system
  - Feedbacks from the real world to evaluate design, test, etc.
  - Learning from failures (while project cost is small)
- ***Education of Project Management***
  - Four Managements: "*Time, human resource, cost and risk*"
  - Team work, conflict resolution, discussion, documentation
  - International cooperation, negotiation, mutual understanding
- ***Also contributions to other technology areas !***

Special Features of CanSat

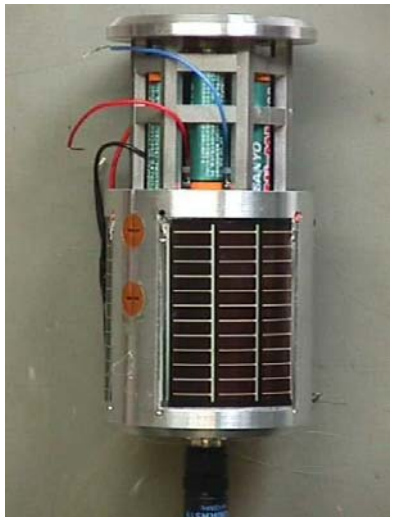
- **Very Short Period Required for One Whole Project**
  - *5-6 months for mission conceptualization, satellite design, fabrication, ground test, modification, launch, operation with variety of hands-on*
  - *Launch date is usually fixed: no delay is allowed*
- **Very Low Life Cycle Cost for One Project**
  - *$200 - $1,000 budget for one team (typically)*
  - *Helium balloon test requires $150 and Rocket launch requires $400 (ARLISS), etc.*
  - *No need for actual launch into space*
- **Small, but Still Can be “a Satellite”**
  - *All the satellite functions + mission can be packed*
- **CanSat can be Retrieved after Experiment**
  - *Analysis of the causes of failures is easy*
- **Possibility of sponsorship from juice/cola company**

Example of Failure (2000)

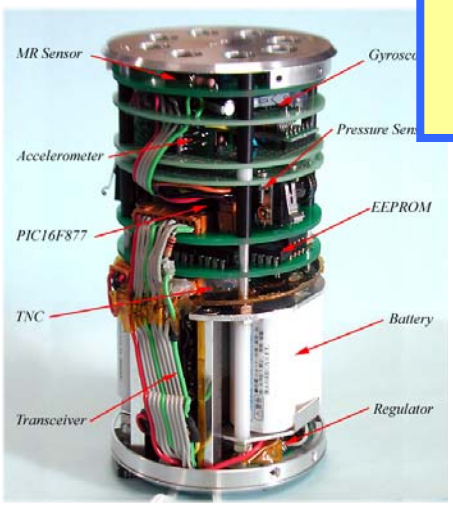
Parachute part and body was separated by the shock of the deployment of the parachute

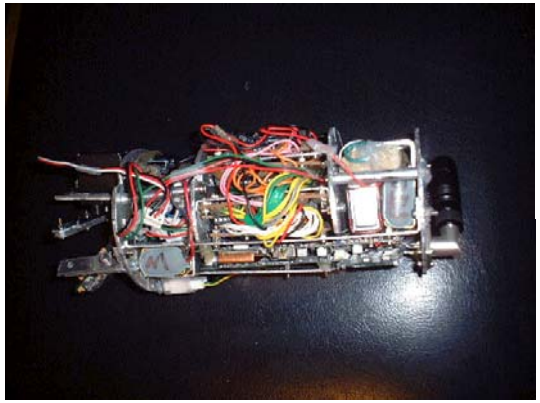
Failure should be experienced many times and fully analyzed <u>while project size is small</u> !

CanSat Systems and Missions

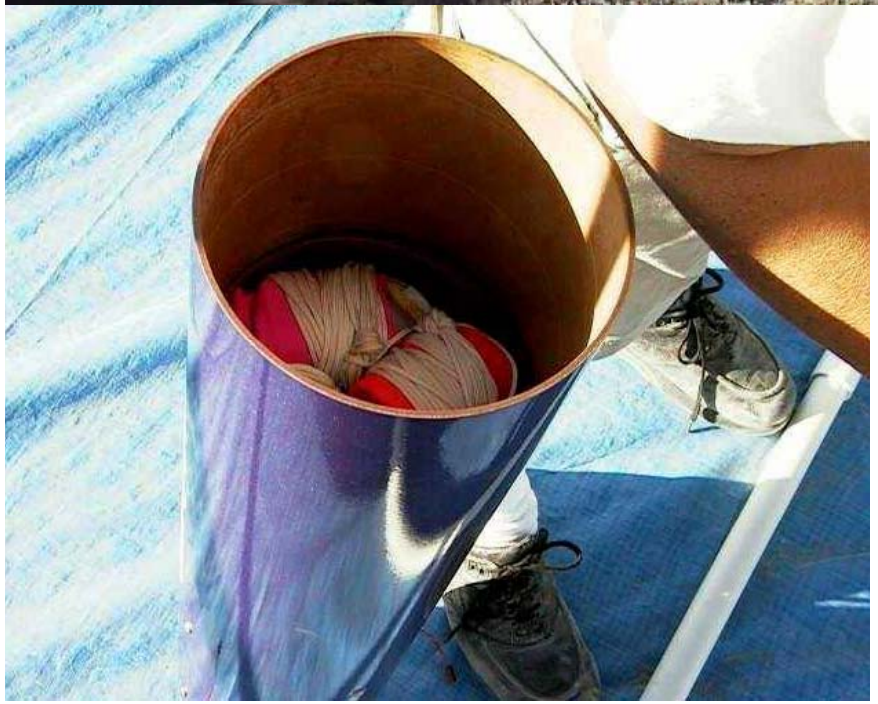


Various Missions of CanSat (since 1999)



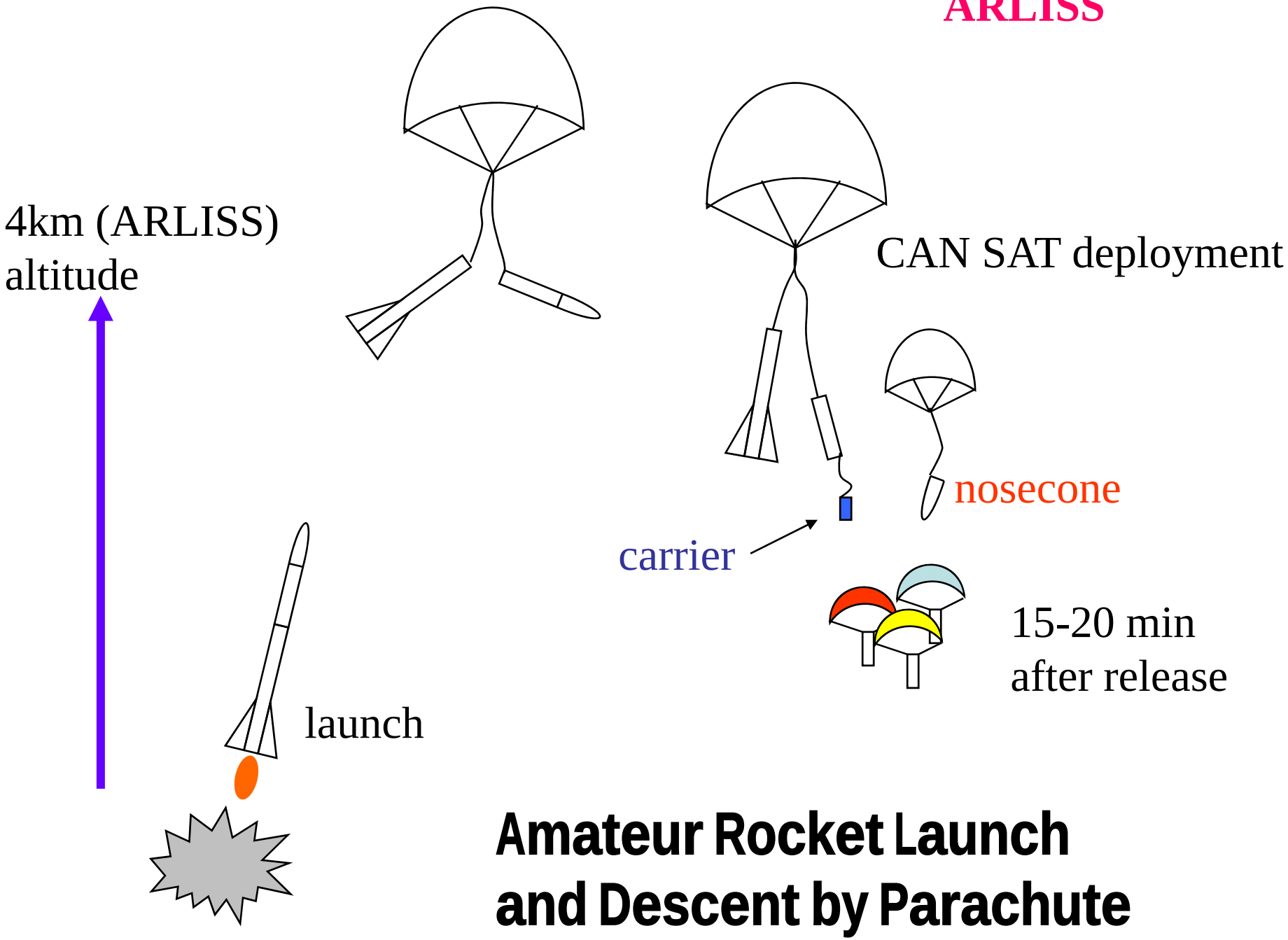


Loading to inside of rocket nose-corn



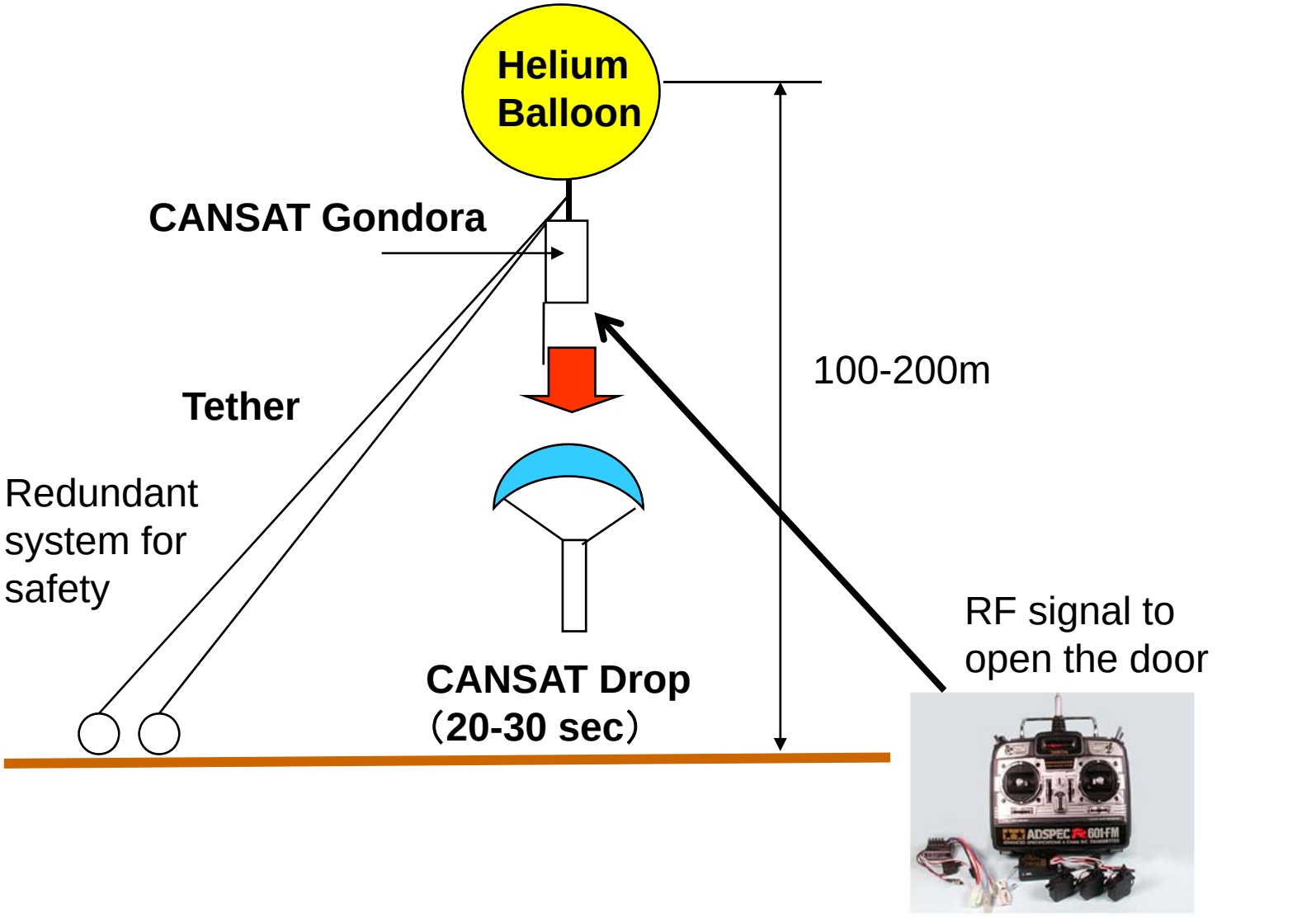

27

ARLISS

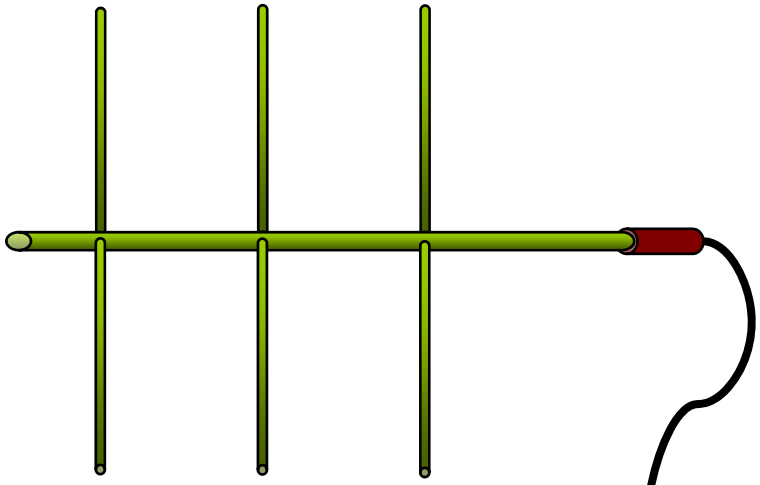


Amateur Rocket Launch and Descent by Parachute

CanSat Deployment using Helium Balloon



Handy Ground Station
(for ARLISS Project)



Yagi-Antenna

·Frequency : 144MHz
·Gain : 8dBi
·length : 87cm
·weight : 530g

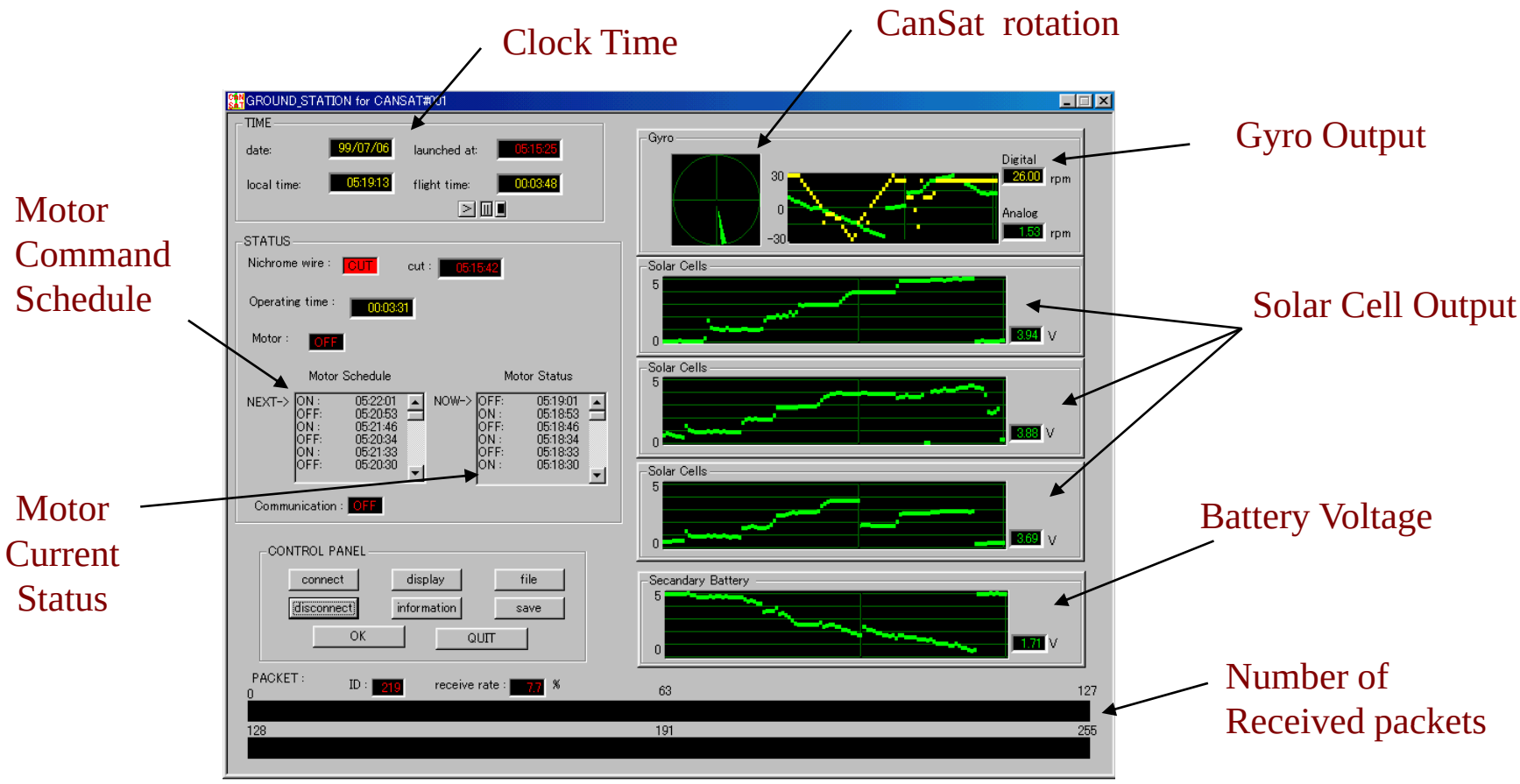
•Reception of downlinked signal, monitor the satellite status, and store the data in computer

Transcever

·with TNC
·144/430MHz dual band
☆TNC
AX.25
1200 / 9600bps

Note PC

GS Software on PC (1999)



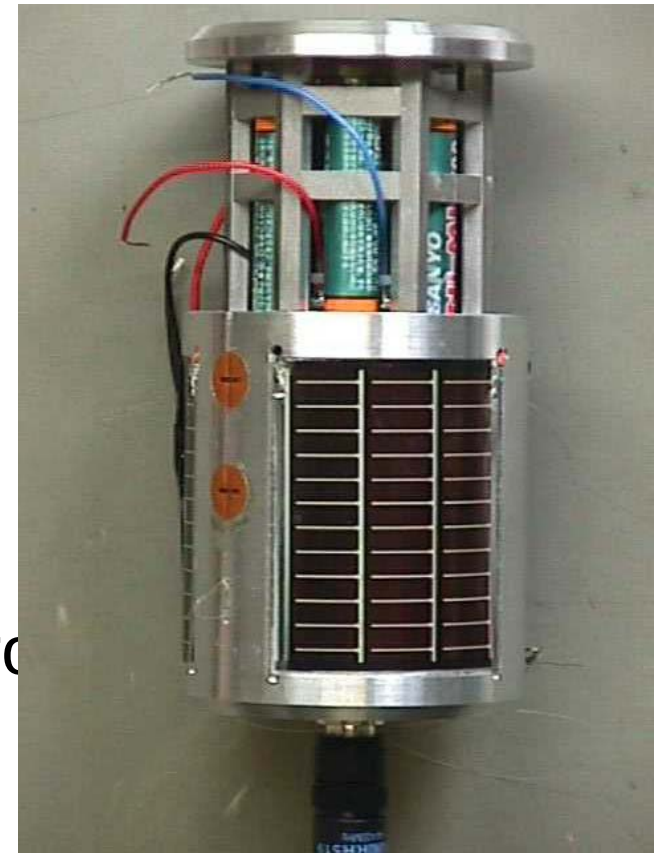
Data Logging on Memory.

“Non-maintainable System”

- A satellite, even a CanSat cannot be contacted until the end of its mission once it is loaded on a rocket or balloon
  - “non-maintainable system”
- Sometimes it should survive in space for more than 10 years without any human interactions, so
- Imagine all the possible events and anomalies which may happen on Satellite or CanSat and prepare countermeasures for them as many as possible
- Try as many ground test as possible in various settings to ensure normal operations of CanSat

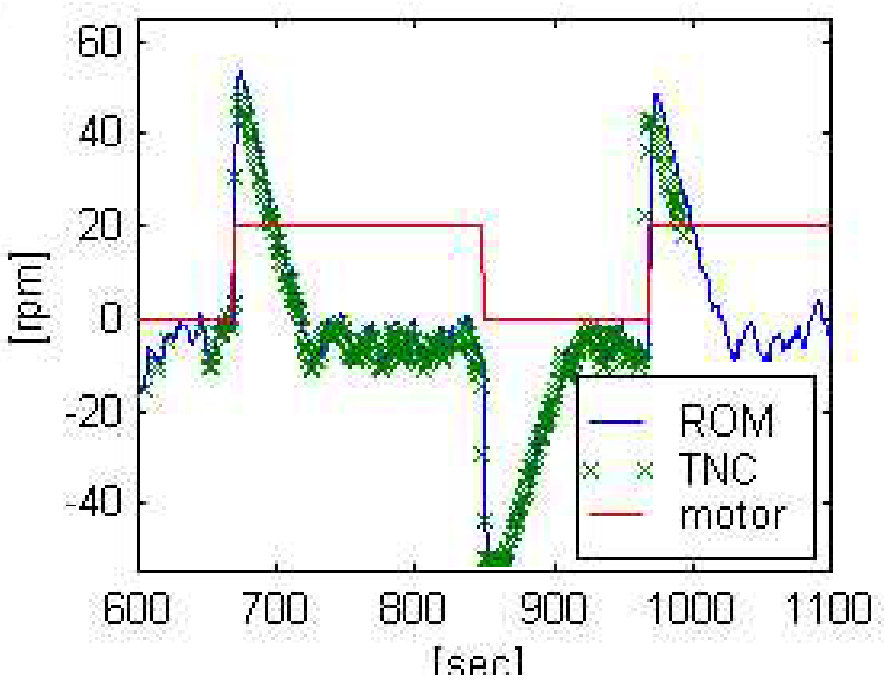
CanSat #001 (1999)

- Experiment of whole satellite functions in 350 ml can size
  - On board CPU using PIC
  - Reaction Wheel
  - Launch-lock by Nylon/Nicrom
  - Solar Cell/Battery Charge
  - Attitude Motion Sensing by Gyro
  - RF Communication (downlink)
  - On-board EEPROM

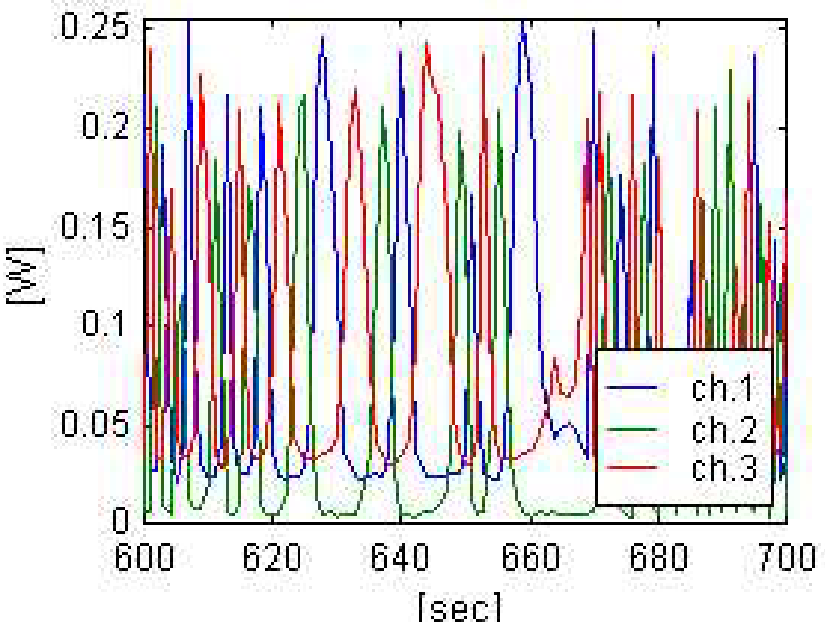


CanSat #001 Result

- CANSAT rotation and solar power data



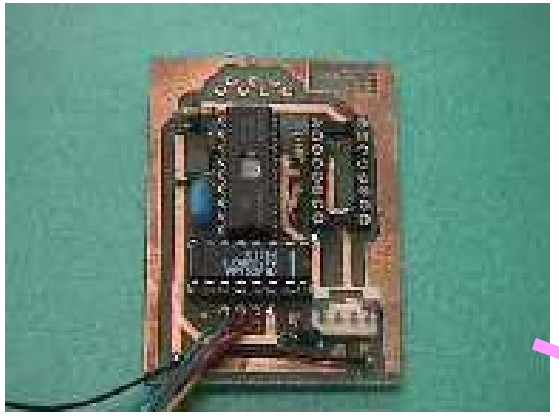
Rotational velocity（Gyro output）



Solar power generation

Very Simple CANSAT

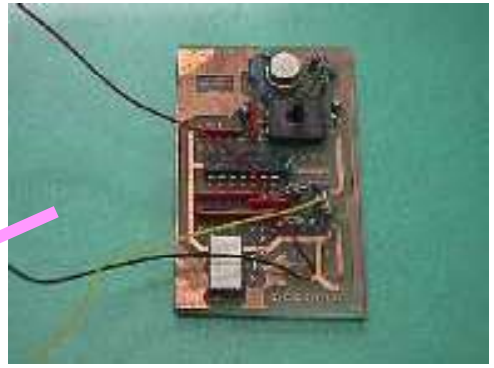
CanSat #002



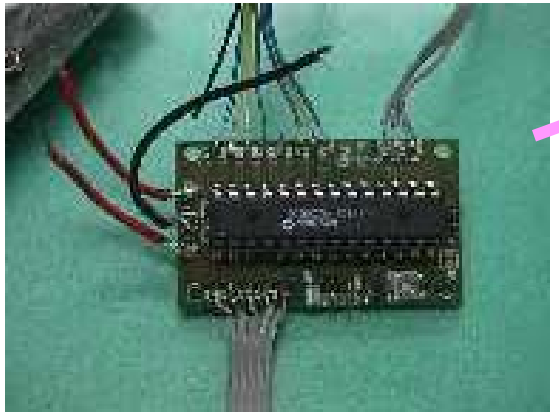
Main CPU PCB

parachute **Battery(Li-Ion)**

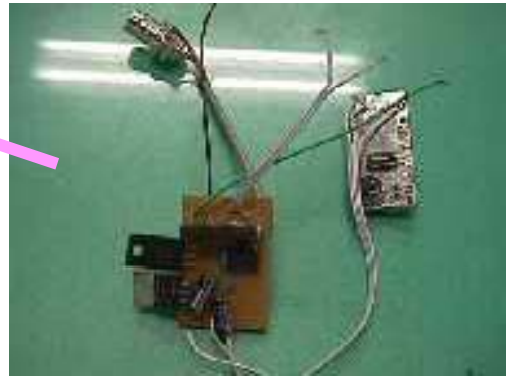
350ml Juice Can



Sensor PCB



TNC



Transmitter

Antenna

CanSat #003

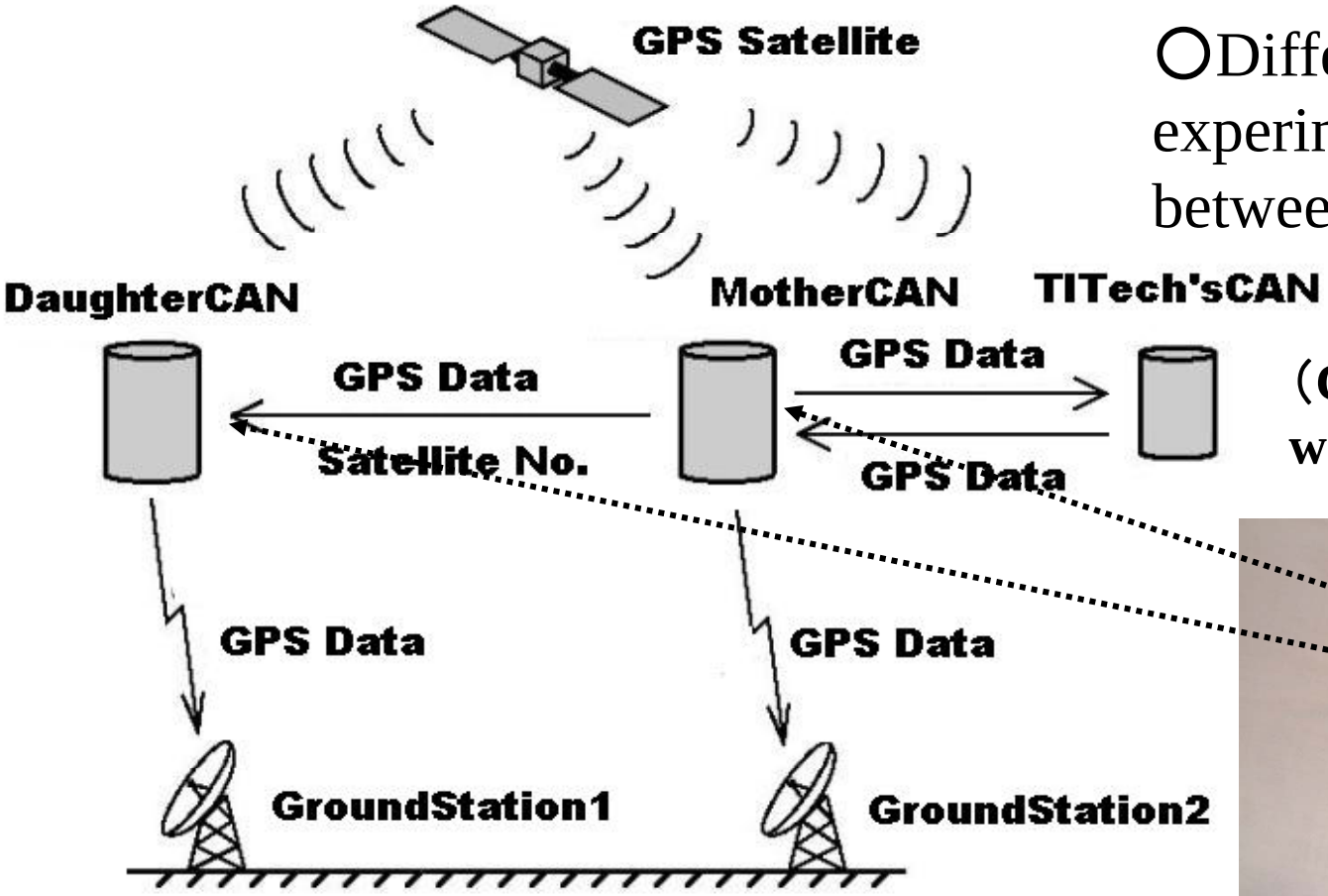
- CCD Camera capture video image from Sky
- Downlink captured video image to ground


2000年限定
Fanta
さっぱり
リンゴ
enjoy

DGPS Experiment (2000)

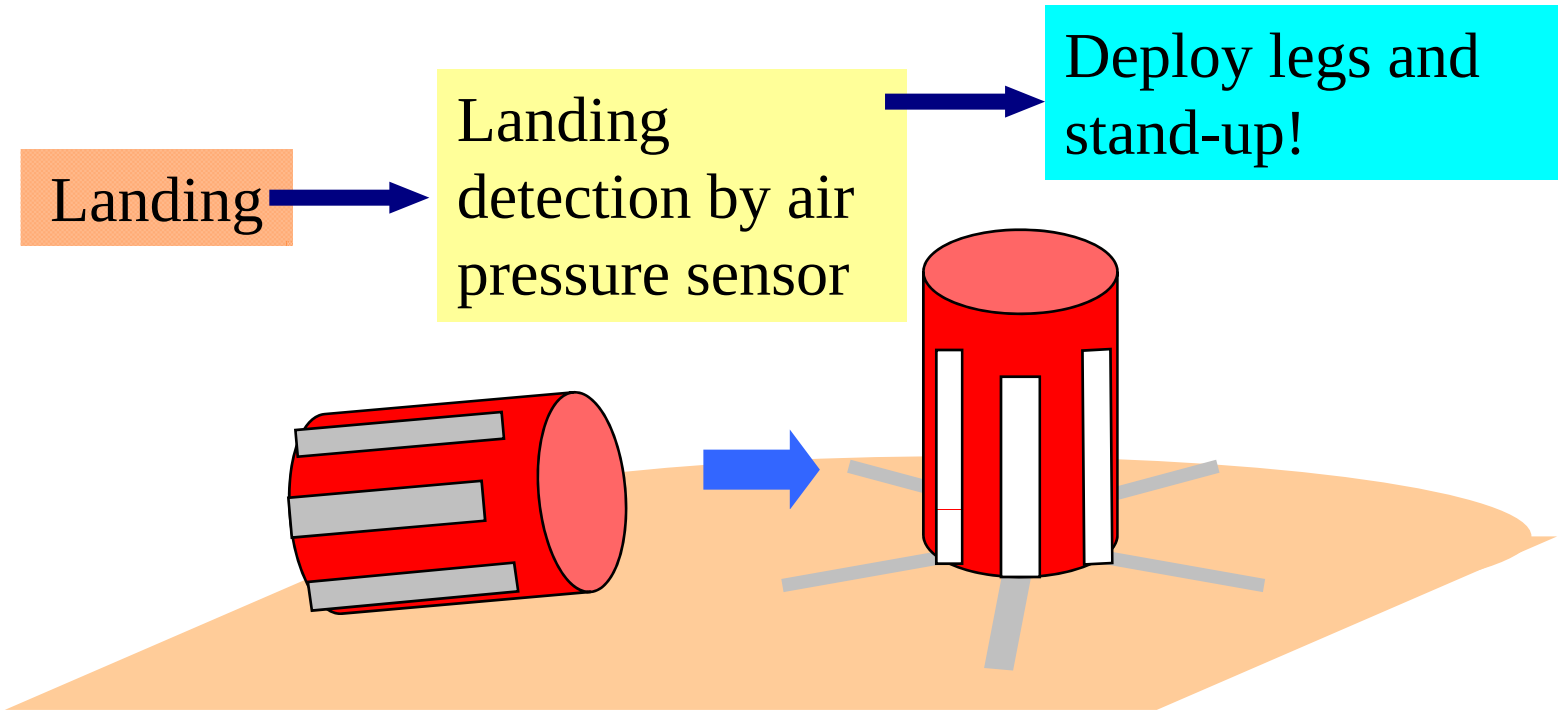
Pre-experiment for future Formation Flying in Space

- GPS measurement and downlink
- Differential GPS experiment by crosslink between three CanSats



（Collaboration with Titech）

Stand-up ! CANSAT (2000)



EDL

Landing Mechanism

Stand-up mechanism

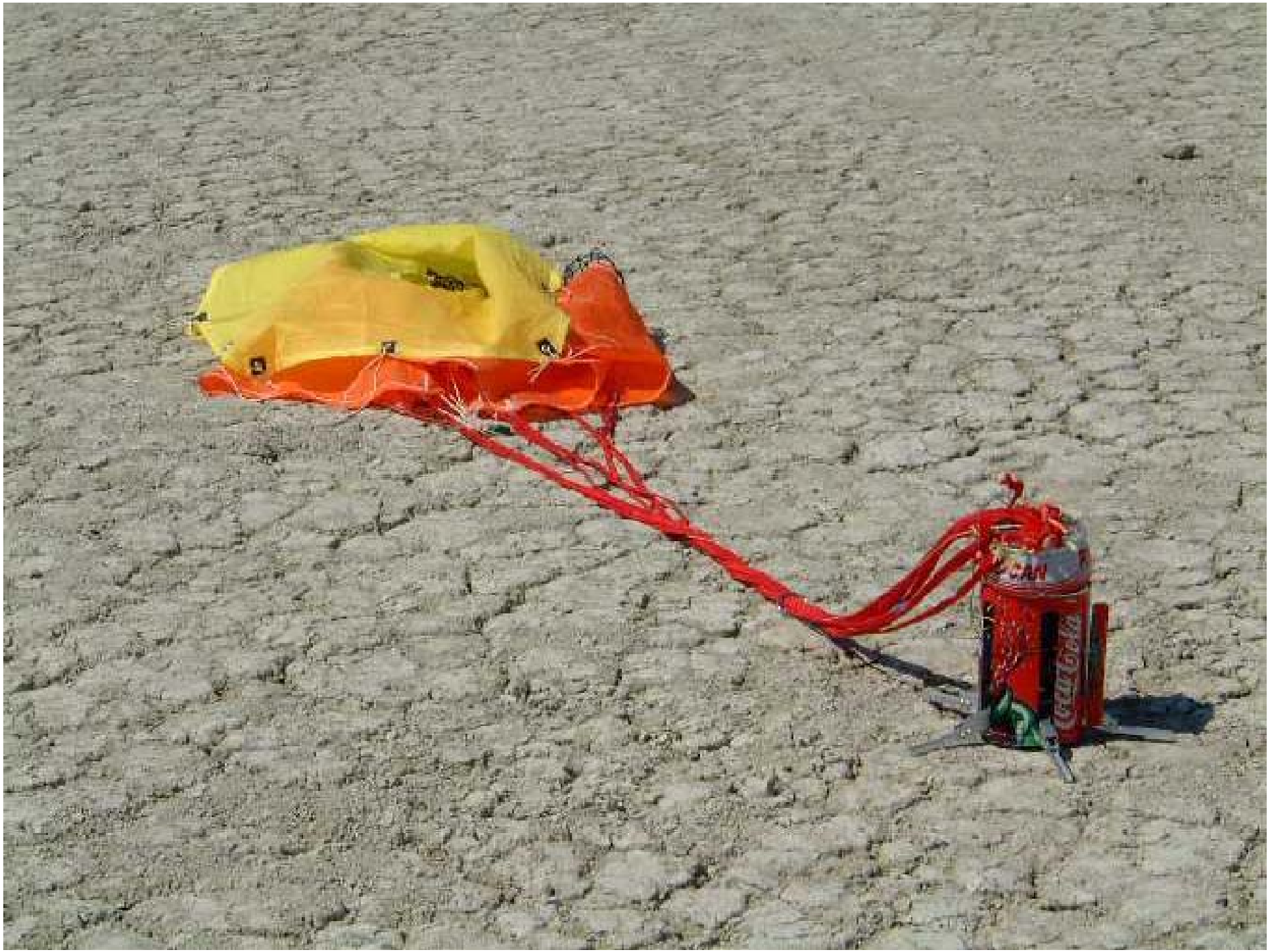
Leg

Stopper

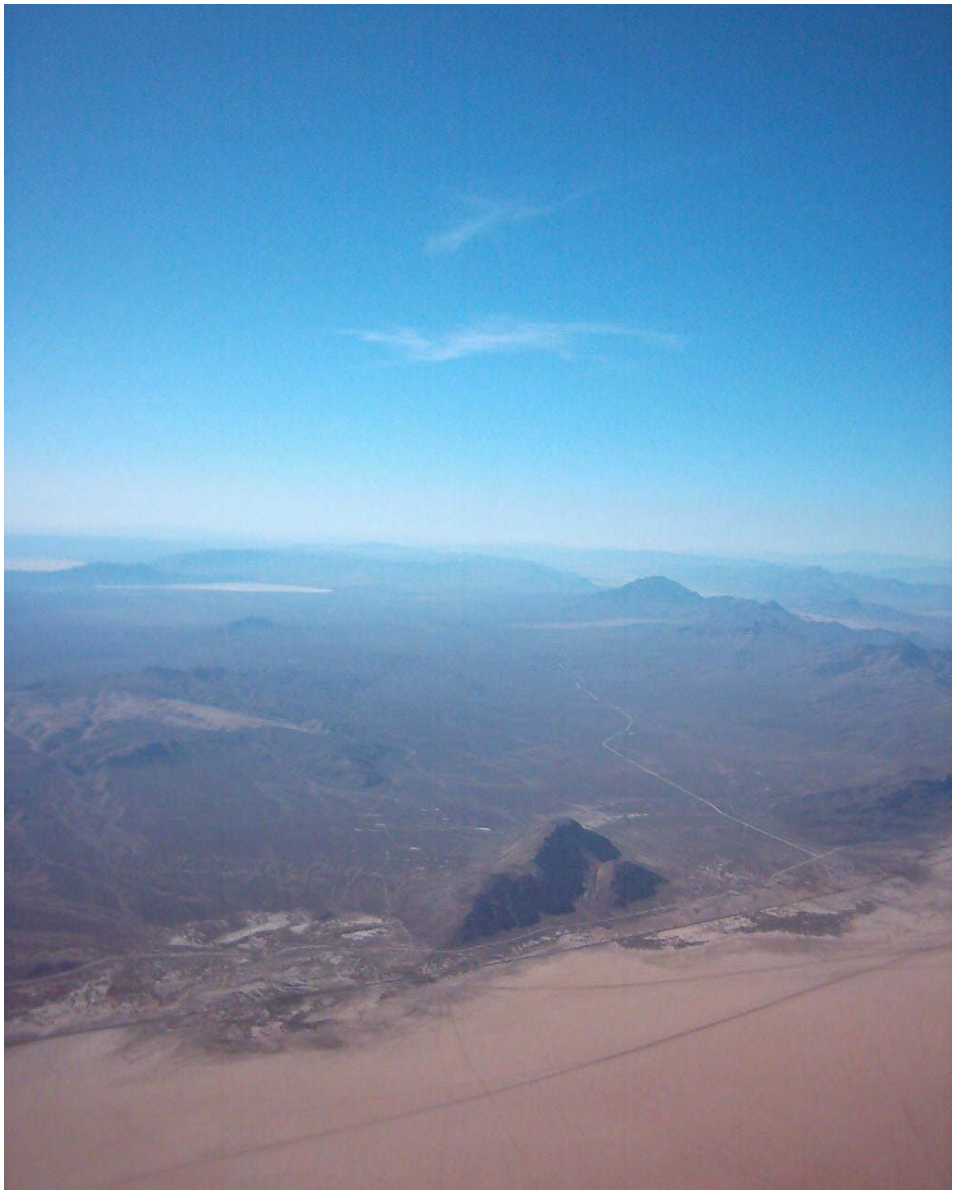
Extension!

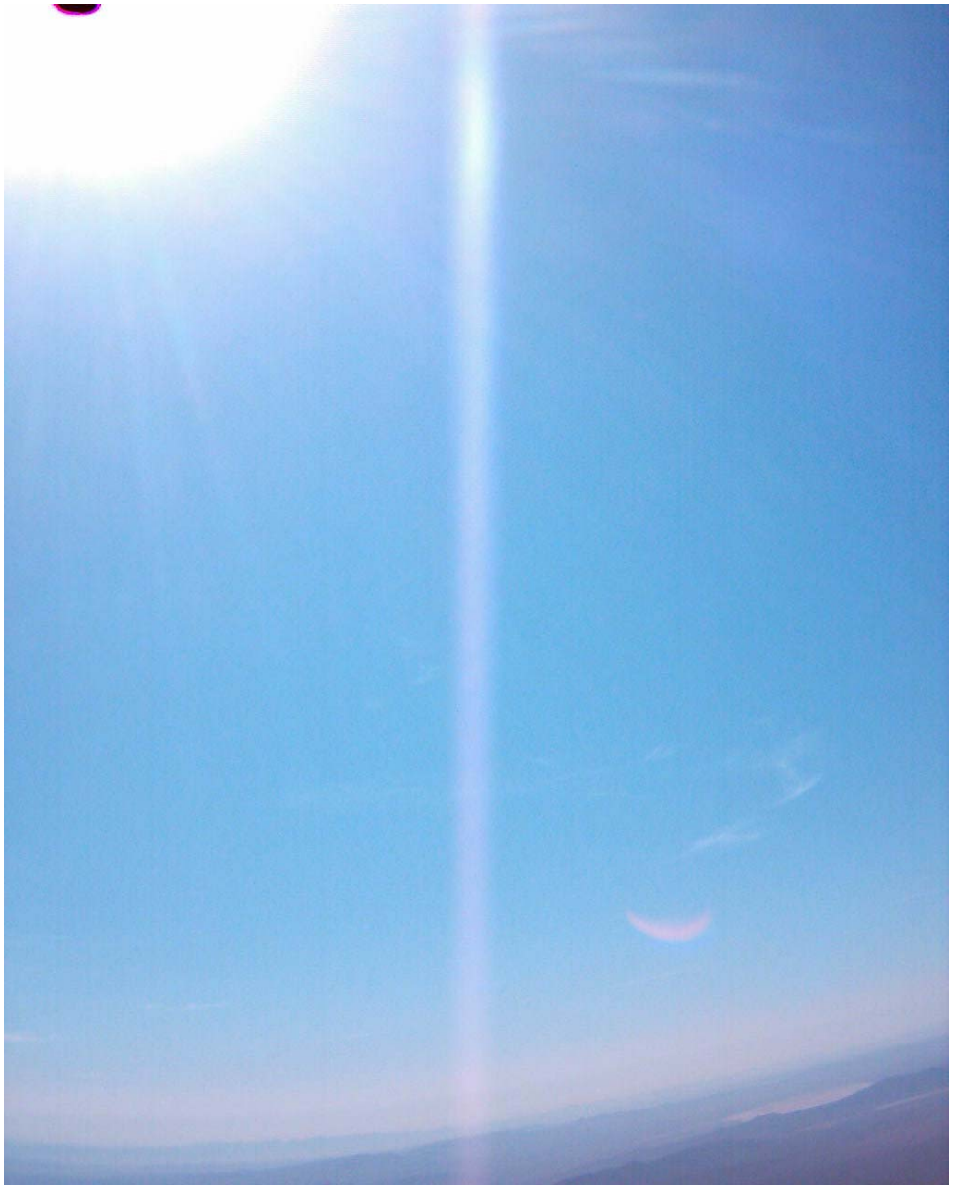
EDL

Landing Mechanism



Picture From the Sky (2005)

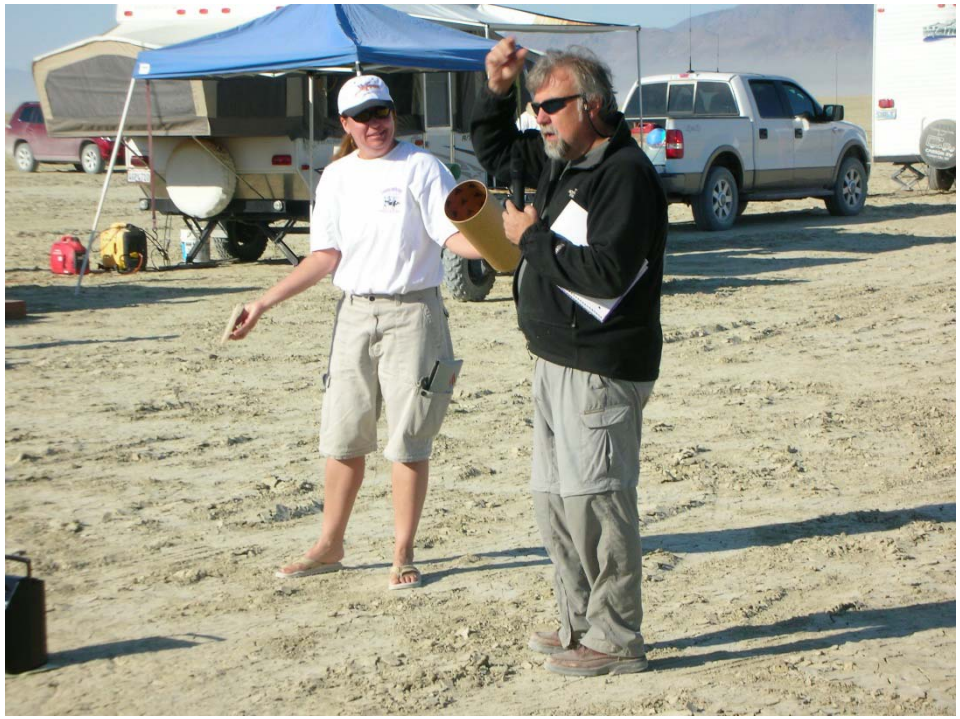




Simple criteria, Competition makes motivation

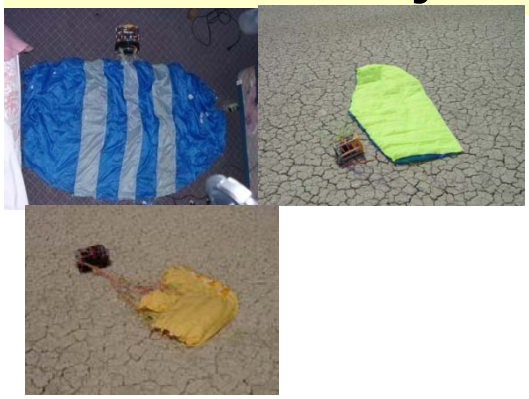

Students aimed for this flag !

Briefing on Tuesday



Participating Universities 2002

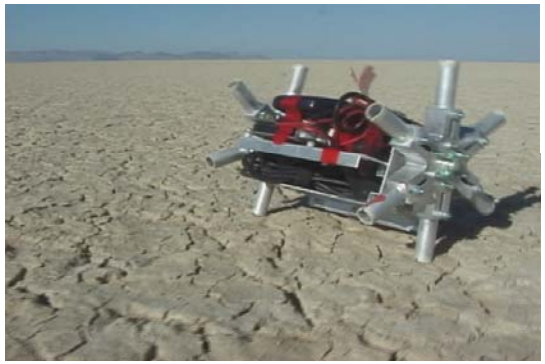
Univ. of Tokyo



Kyushu Univ.

Nihon Univ.

Tohoku Univ.

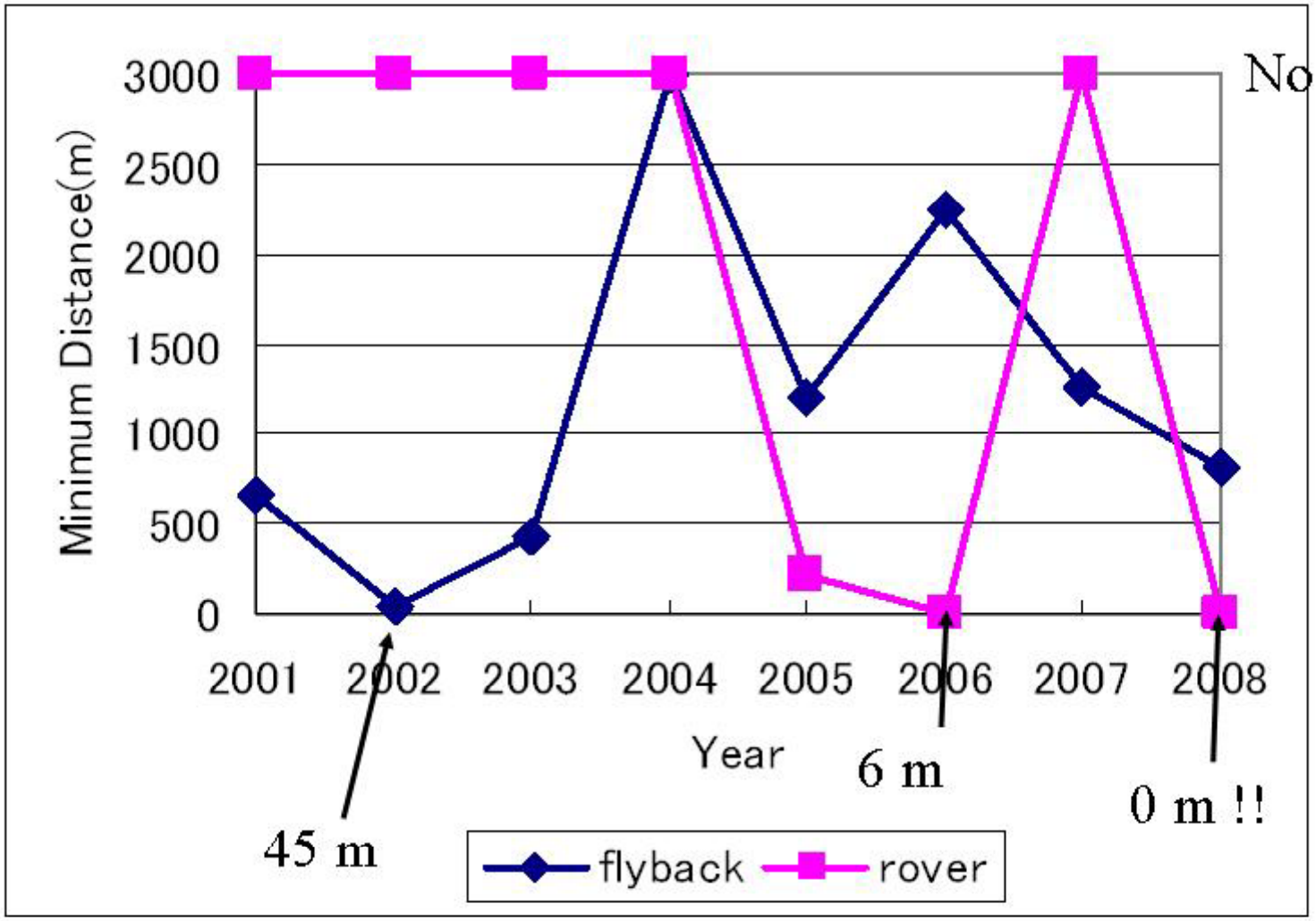


Tokyo Institute of Technology

Stanford Univ.

ROVER

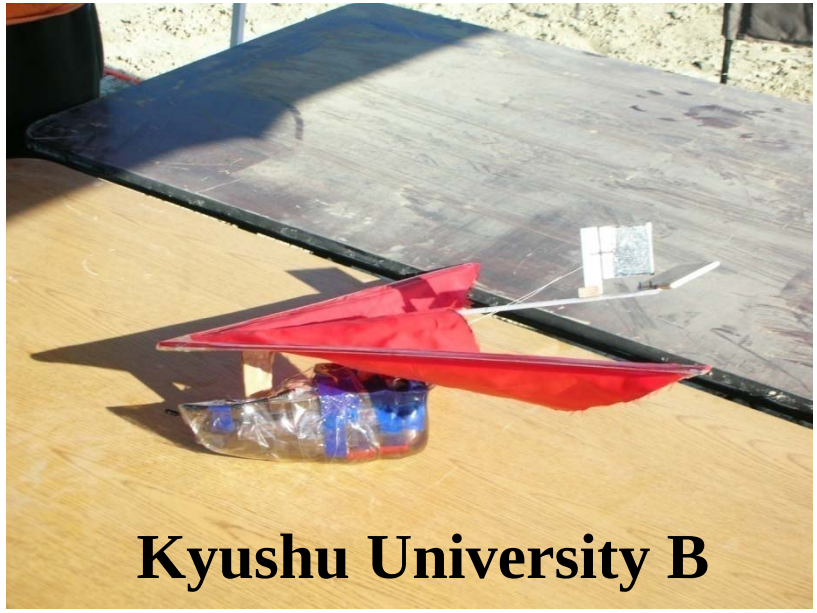
History of Flyback vs. Rover

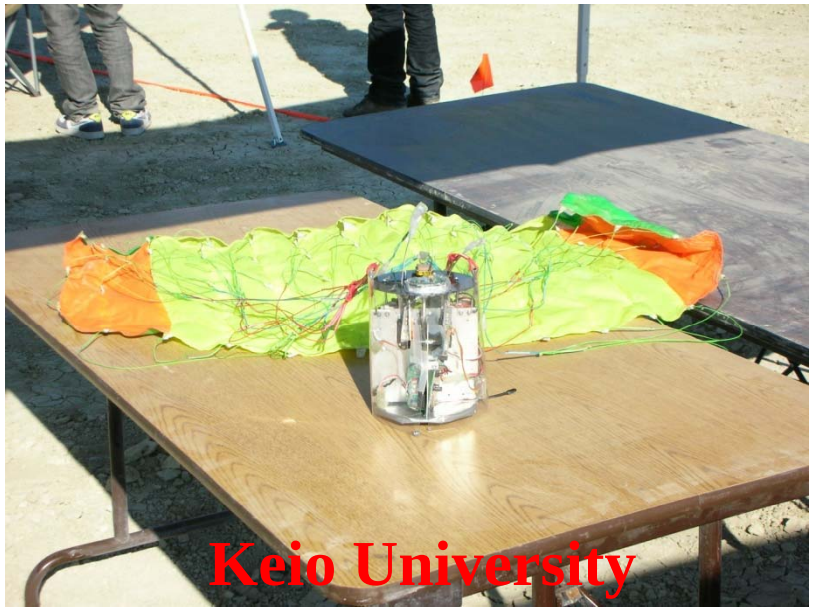


Fly-backers

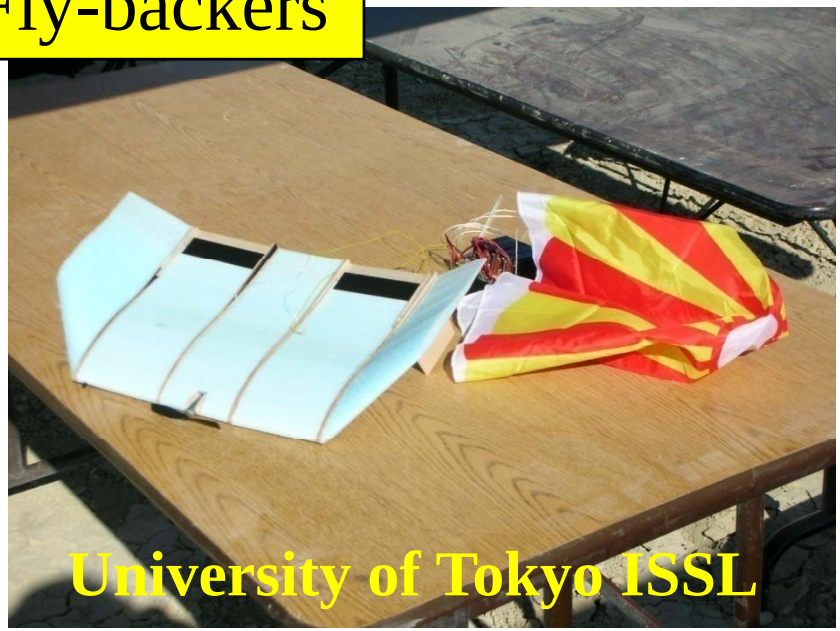

Kyushu Tech KINGS


Titech Str. Dynamic Lab


Kyushu University B


Keio University

Fly-backers


University of Tokyo ISSL

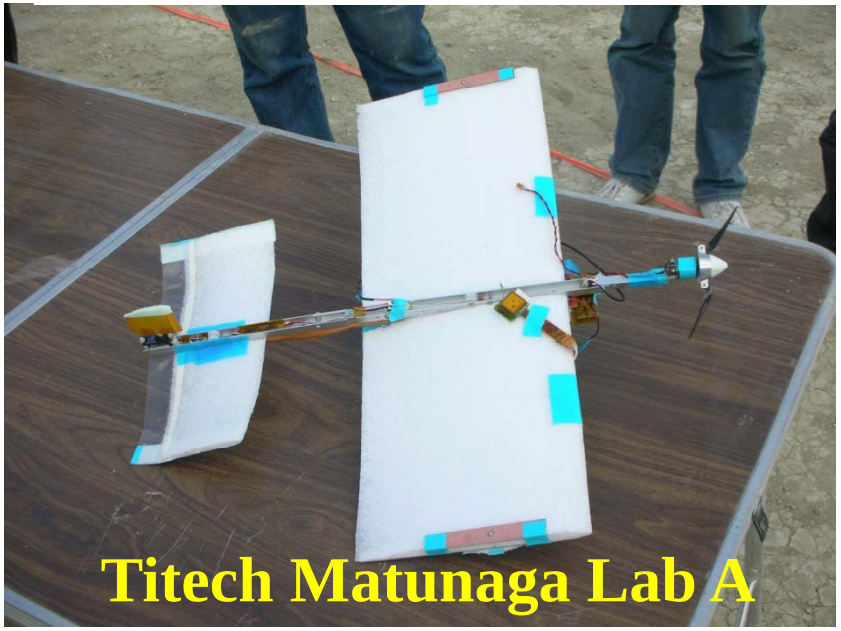

Titech Matunaga Lab B

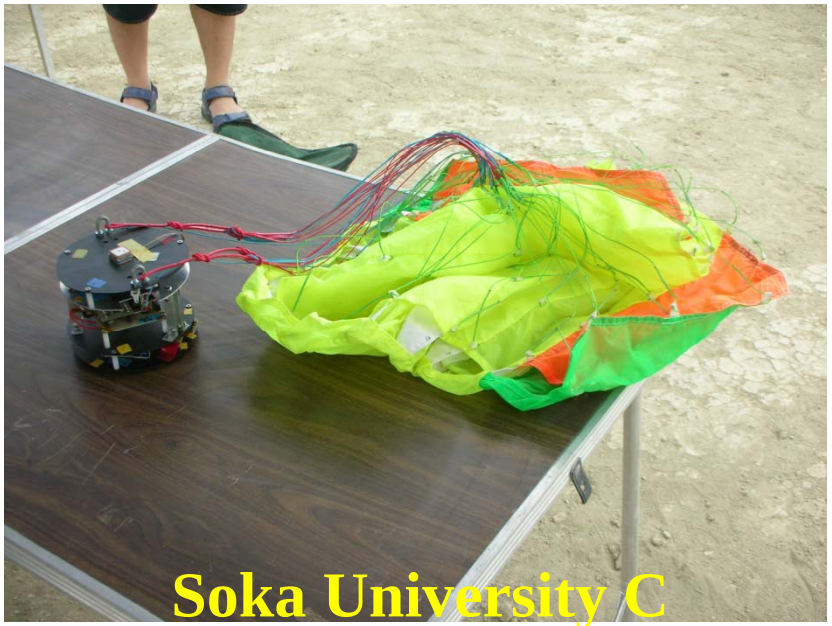

Kyushu Tech. Cho Lab A

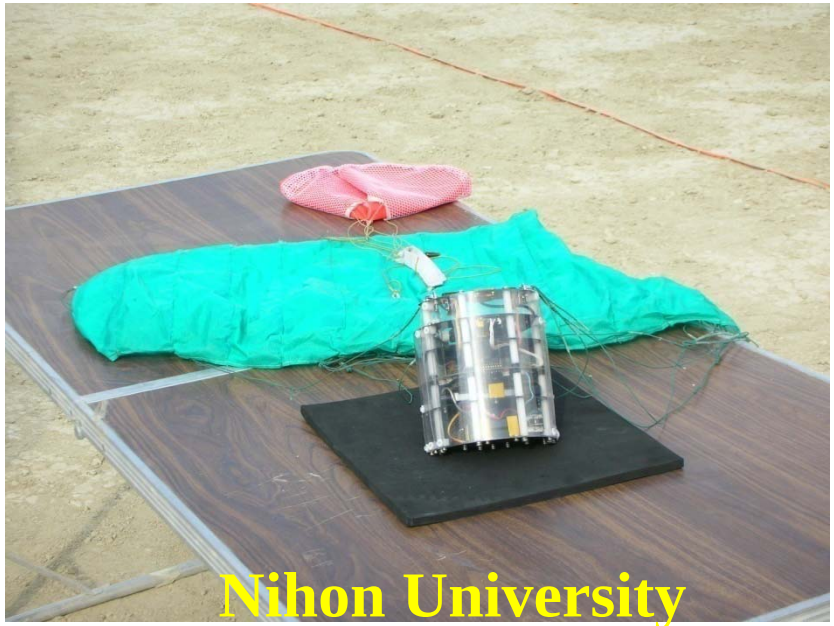

Kyushu Tech. Cho Lab B

Fly-backers


Akita University


Titech Matunaga Lab A


Soka University C


Nihon University

Come-Back Competition 2008

Fly-backers

Flyback CanSats:	12
Rover CanSats:	6
Hybrid:	1
Non-comeback:	4
Total:	23

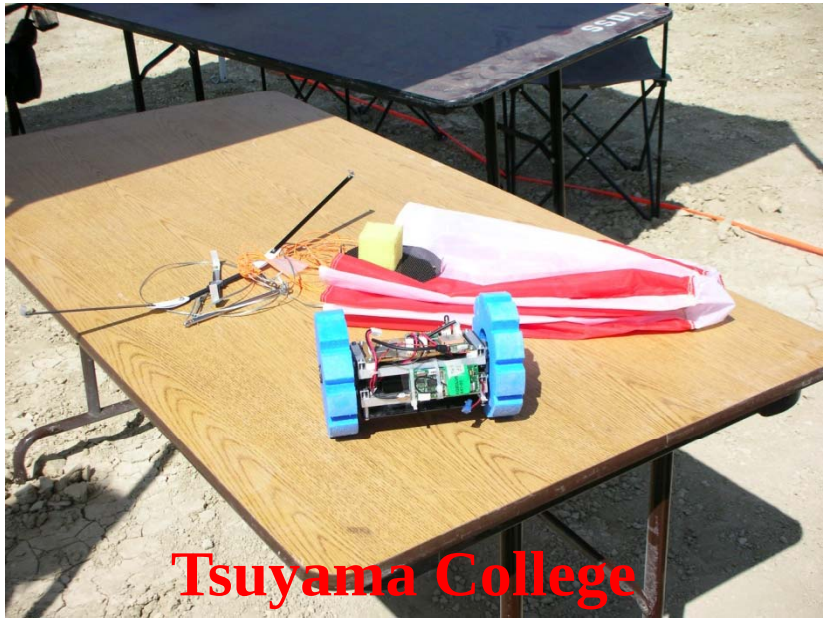
Non-comebackers

Need photo !

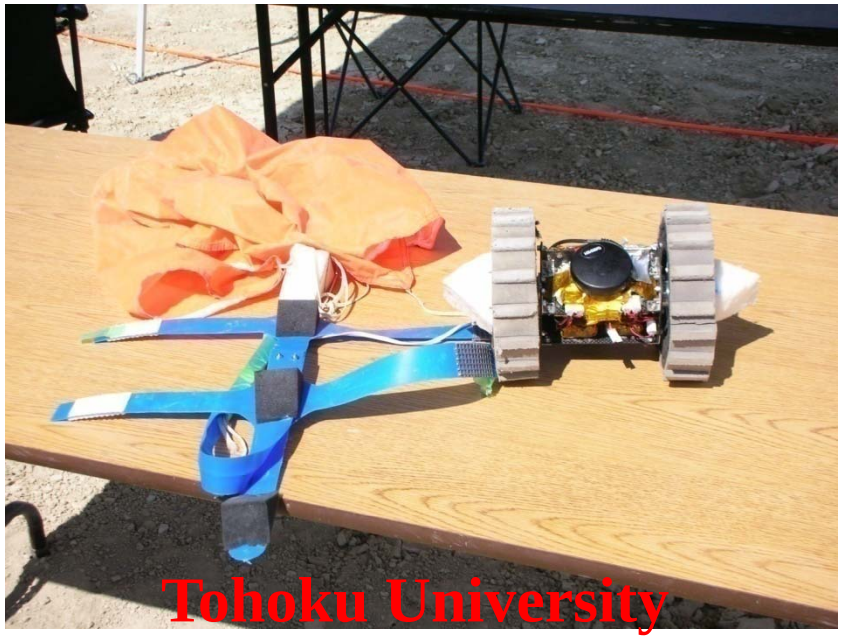
Soka University C

Rovers

University of Tokyo B3



Tsuyama College



Tohoku University

Univ. for Electro Comm.

Rovers

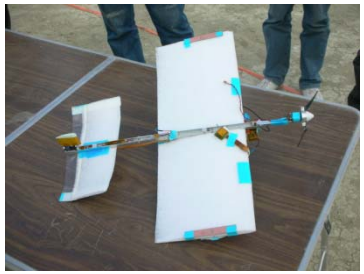
Flyback CanSats:	12
Rover CanSats:	6
Hybrid:	1
Non-comeback:	4
Total:	23

2008 Comeback Competition Ranking

1st Place: Tohoku University (R): 0 m

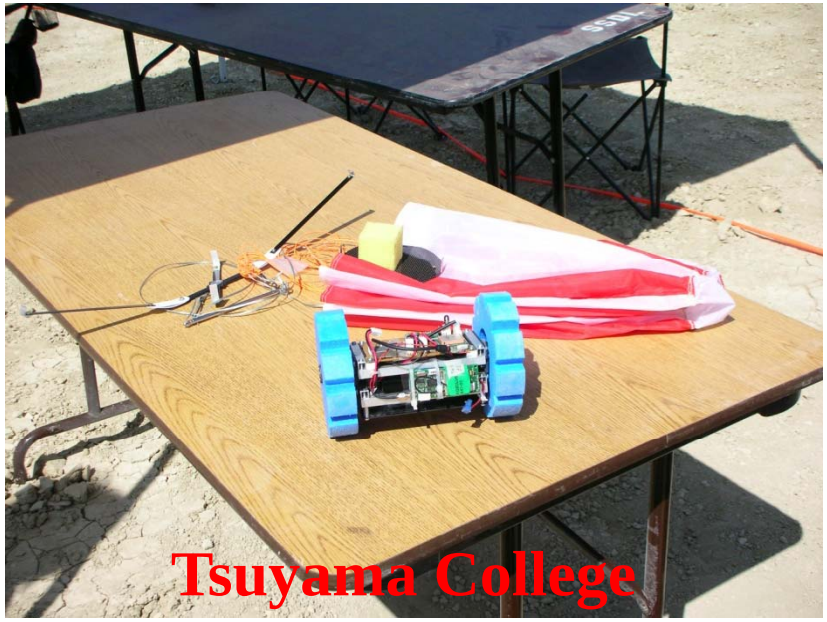
2nd Place: Nihon University (F): 818 m

3rd Place: Titech Matunaga Lab (F): 903 m

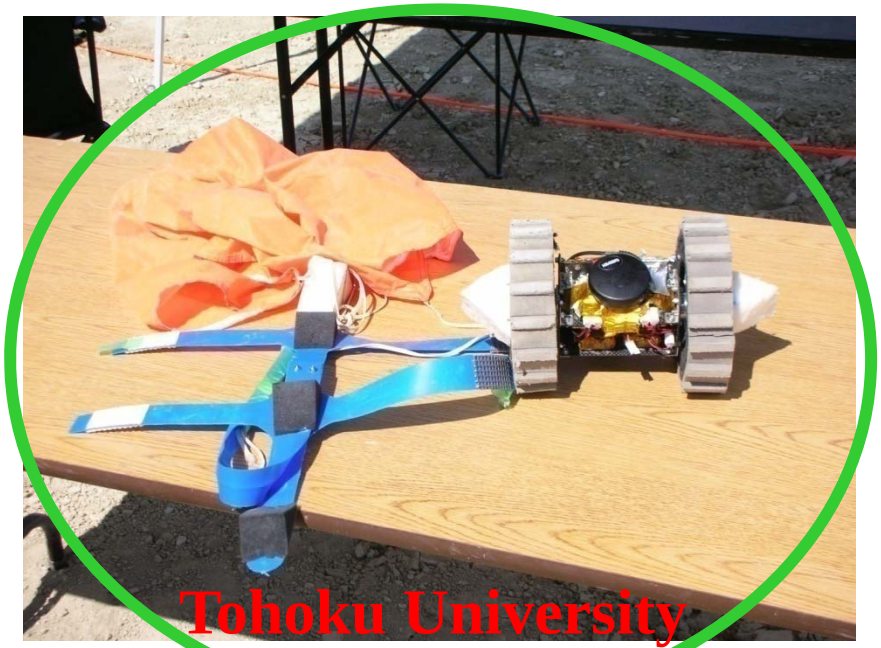


Rovers

University of Tokyo B3



Tsuyama College



Tohoku University

Univ. for Electro Comm.

Tips to create CANSAT missions

- Sensoring: to be decided considering what kind of sensors are available and how easy to implement
  - Temperature, pressure, GPS, accelerometer, sun light, gyro, ultra violet, sound, infra red…….
- Actuation: available actuators, power, force, etc.
  - Motor, nychrom line to cut nylon wire, magnet, utilization of shock of landing, spring, gravity…
- ON/OFF switching
  - Triggered by; command uplink, timer, events…
- High level actions
  - Guidance/control with GPS(comeback), camera, LED, stand-up, moving after landing……

Important Consideration in Mission Creation

- Aiming at interesting, but not so high (within your ability) technological level
  - Should finish within the lime limit, considering human resource and expertise
  - Consider what you can do in the laboratory facility and available components
- The most important thing is to make what really works as designed
- Usually task requires almost twice as long time as expected: add schedule margin!
- Step-up from easy level to higher levels
- Consider how to verify your design by tests

Create Mission Sequence !

1）Set up CANSAT and put it into a rocket and turn on switch A (something start operation)

2）Rocket side prepare launch (you cannot contact and not predict the time in this phase precisely)

3）Launch with high acceleration (CanSat may measure something in a rocket and write in memory)

4) CanSat starts certain operation triggered by some switch at the timing of release from the rocket

5) Downlink mission data as well as write in memory

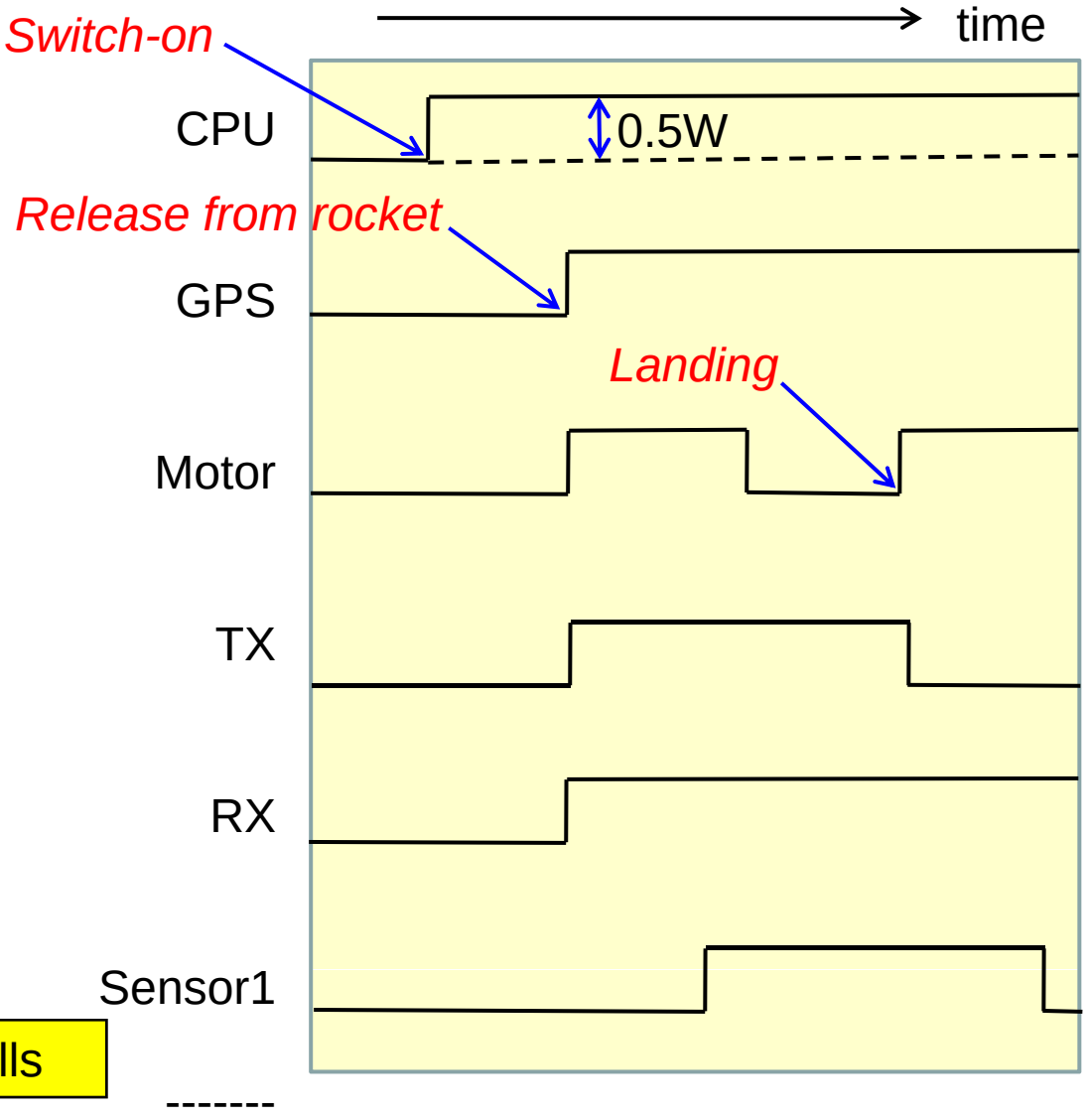
6) Uplink command may tell CanSat to do something

7) Landing may trigger also another actions

System Analysis: Power Budgeting(2)

- Based on the mission sequence
- Calculate the total power consumption (--Wh or --Ah)
- Add some margin (such as x1.5)
- Estimate the required battery type and size (e.g. 500mWh x 3)
- Do sequence test in real situation !

Case for CanSat without Solar Cells



Common/different Things with/from Actual Satellites

Space Environment

■ **Vacuum**	**Vaporization, cold welding, friction, electric discharge, change of material, heat spot….**
■ **Radiation**	**Electronics parts malfunction and breakdown, Degradation of solar cells and materials…..**
■ **Thermal**	**Large temperature differences/cycles, heat shock, heat spot…..**
■ **Launch**	**Vibration, shock, acceleration, sound vibration…..**
■ **Distance**	**No maintenance possible, long range communication, tracking required…..**

Others: Atomic Oxygen, Debris/Meteoroids, Ultraviolet rays

Satellite Development & Operation Facilities

Clean Booth (class 10,000)

Vibration Table (25g rms)

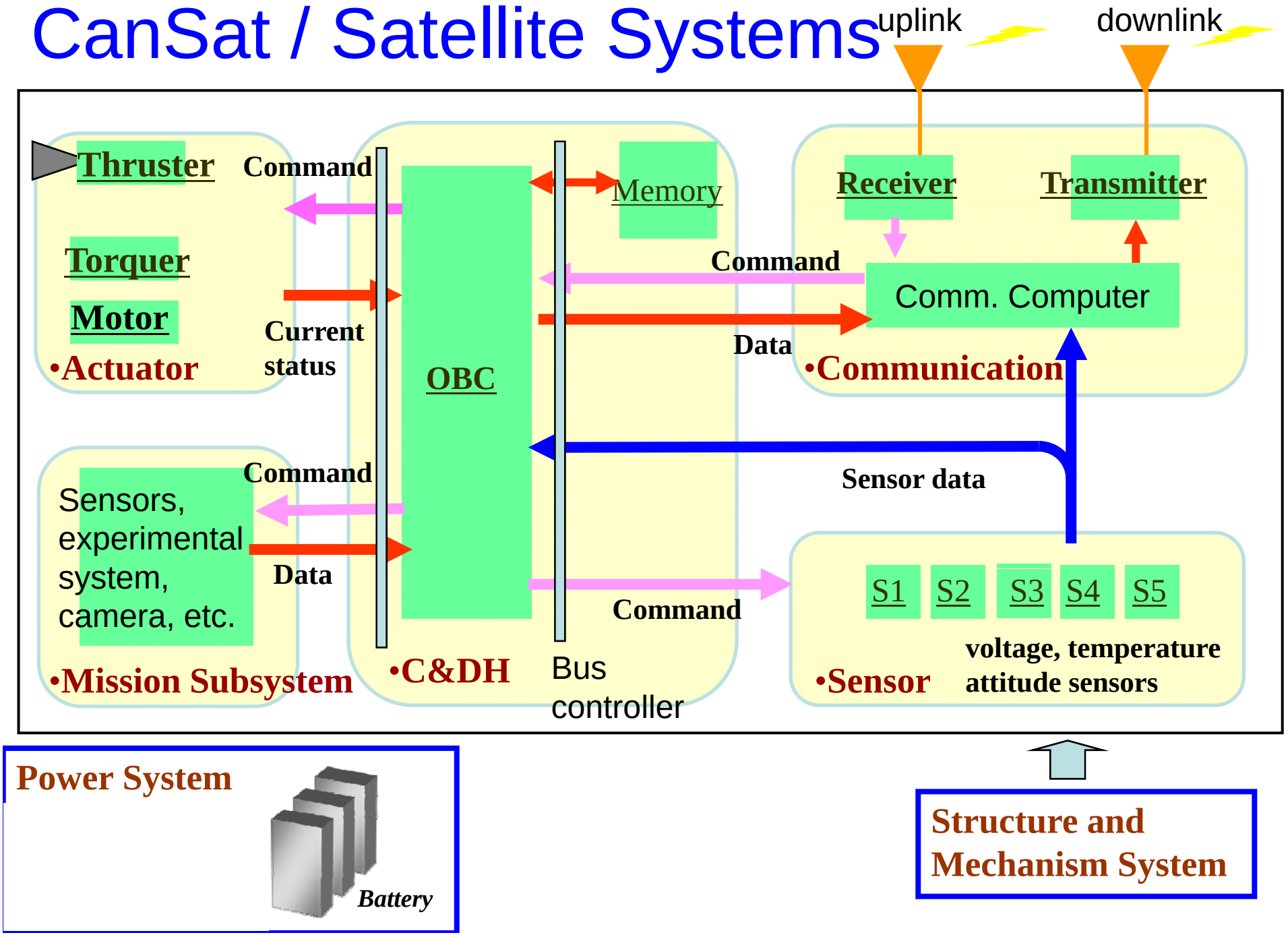
Thermal bath
(-70 ～100 ℃)

Thermal Vacuum Chamber

at NAOJ

- Solar Simulator
- Attitude free motion table
- RF test room
- Vacuum Chamber

CanSat / Satellite Systems



Ground Station Facility

Main Screen

Orbit Analysis

Command Uplink
Tx/Rx Equipment Control
Telemetry Server

Radio Equipment

Telemetry Distribution Network

FLIGHT

INCO

EECOM

EGIL

HK Data Distribution

Terminal for Subsystems

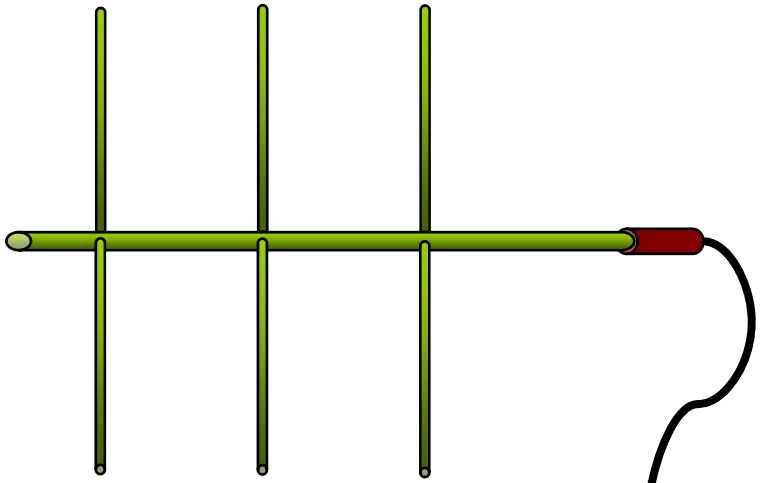
Ground Station Antenna

ISSL ground station (Tokyo)
(completed in 2009)

Mizusawa ground station (Iwate)

Swedish Space Corp. (Kiruna) is ready to receive telemetry at initial phase.

Ground Operation



Yagi-Antenna

·Frequency : 144MHz
·Gain : 8dBi
·length : 87cm
·weight : 530g

•Reception of downlinked signal, monitor the satellite status, and store the data in computer

Transcever

·with TNC
·144/430MHz dual band
☆TNC
AX.25
1200 / 9600bps

Note PC

BBM – EM – FM Development Process

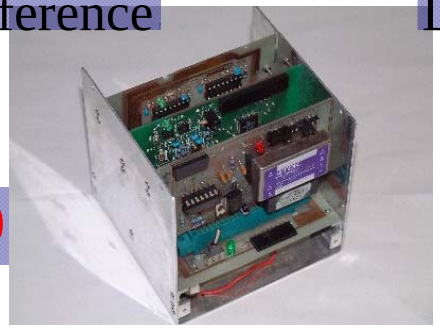
2000 9 11 — 2001 1 2 4

Conceptual Design

USSS Conference

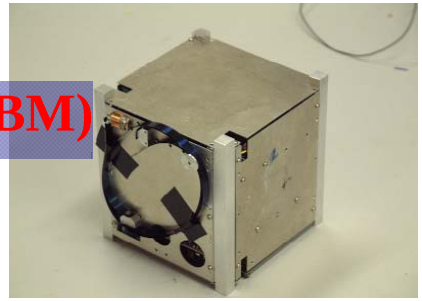
Radiation Test

XI-I（BBM)



Mission Defined

XI-II（BBM)



CDR

Thermal Vacuum

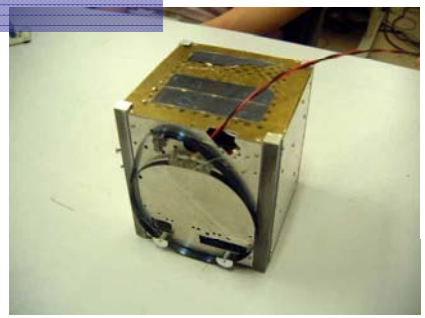
5 6 9 11 12

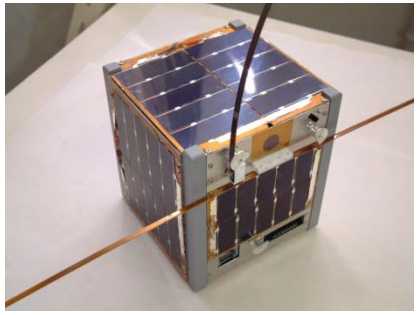
Long Range Comm. Test (ISAS Balloon)

XI-III（EM)

Thermal Vacuum

Vibration





Const. Temp. Oven

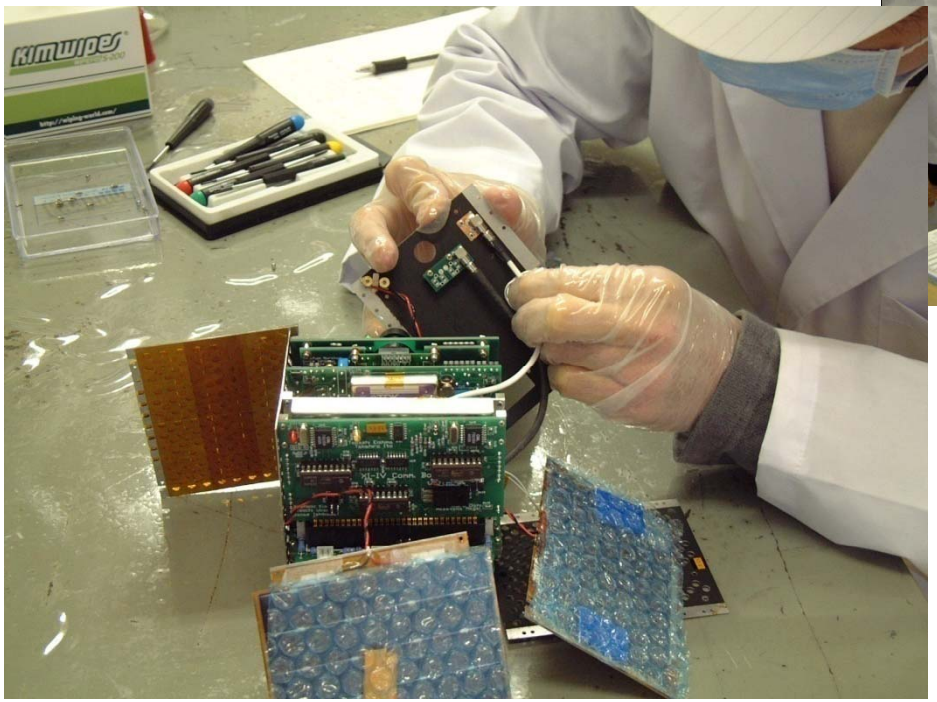
Vacuum

XI-IV,V (FM)

Operation Practice

Integration

Mounting solar cells on the flight model in the clean booth



Final Integration Procedure

CanSat: Differences from Satellites

- System architecture
  - No thermal system
  - Minimum or no redundancy (short time span)
- Required ground tests
  - Vibration/shock test for rocket launch
  - Sequence test
- Ground operation
  - Short range: small hand-held Yagi-antenna
- Development process
  - No clean booth required
  - BBM/EM + FM or EFM type simple process

What you can learn in CanSat ?

- Mission creation and sequence generation
- Satellite architecture design
- System analysis (power/weight budgeting)
- Subsystem design and fabrication
- Development process (BBM/EM/FM, Design Review) and Project Management
- Assembly, Integration and Test (AI&T)
- How to do “Field Test” (rocket or balloon)
- Ground operation (uplink/downlink/console)

Various Levels of CanSat Development

1) Assemble “kit” with fixed mission, ground test and launch/balloon experiment
   - 1-1) Add original mission with new components
2) Create mission, obtain(buy) subsystem components, ground test and launch/balloon experiment
   - 2-1) Design/fabricate some components
   - 2-2) Design/fabricate all the components

Find adequate level considering you and your team’s expertise !

Expertise to be Obtained

	Mission creation	Architec-ture design	System Analysis	Sub system design	Project manage-ment	AI&T
1)					y	y
1-1)	y	y	y		y	E
2)	E	E	E		E	E
2-1)	E	E	E	y	E	E
2-2)	E	E	E	E	E	E

Note) **AI&T** **A**ssembly, **I**ntegration and **T**est y:small effect E:large effect

Substems-based Teaming

- "Bus" and "Mission" Subsystems
- CanSat Subsystems
  - Command & Data Handling System (C&DH)
  - Software
  - Power System (battery, charge/discharge system)
  - Communication System (incl. antenna)
  - Ground Station
  - Sensors (may be elements of mission)
  - Actuators (may be elements of mission)
  - Mission
  - Structure & Accessories (incl. parachute)

CanSat Teaming

- Based on subsystems
  - “C&DH + software + power” group, etc.
- Based on administrative roles:
  - Project Manager (PM), Sub-manager
  - Budget management
  - Parts/components search and purchase
  - Documentation and data control (Web, ICD….)
  - Outer relationships & promotion (permission, regulations, seeking for fund, etc.)

CanSat is the Best First Step towards Space