CanSat and CubeSat History in Japan - How they started and contributed to education and technologies

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Japanese Recent History of University Micro/Nano Satellite Activities

Satellite Design Contest (1993-): 1st step paper work training

USSS (University Space Systems Symposium: 1998-): Real satellite projects formed by Japan-US students

CanSat (1999-): Sub-orbital (4km) experiment of quasi-real satellites. Real operation

CubeSat (2000-): Real Pico-satellite to be launched to orbit

Follow-on projects by many universities

2003.6 Launch

2002 UNISEC

2001

2000

2003.6 Launch

1998

1999

1998

1993

Satellite Design Contest (1993-): 1st step paper work training
USSS 1998 ~ 2005
University Space Systems Symposium

US-JAPAN University discussion workshop
to create real space projects in Hawaii
USSS has been held annually in many islands under JUSTSAP

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Birth of CanSat at 1st USSS 1998

“Let’s make a satellite out of this Coke-can !!”

Prof. Bob Twiggs, Stanford University
Changed to Suborbital Launch
(at Stanford, April 1999)

- AEROPAC Amateur Rocket group
- Lift 1.8 kg to 12000ft
- Three 350ml sized cans or one “Large sized can (open class)”
- One flight cost: $400
- at Black Rock Playa (Nevada, USA)
Amateur Rocket Launch and Descent by Parachute

4km (ARLISS) altitude

ARLISS

CAN SAT deployment

nosecone

carrier

15-20 min after release

Amateur Rocket Launch and Descent by Parachute
1st ARLISS Launch, Sep. 1999
Dr. Pius Morozumi’s rocket
Initial Training for satellite development
CanSats 1999 - now
ARLISS (A Rocket Launch for International Student Satellites)
- Annual suborbital launch experiment in USA -

- 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 2016: 18th (Japan:12, USA:2, Korea, Egypt)
- ARLISS 2017: 19th Sept. 13-17 (Japan:13 USA:2 Korea)
- ARLISS 2018: 20th Memorial!!
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
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)
Automatic Stand-up Experiment (2000)
Significance of CanSat Program

• Very Short Period Required for One Whole Project
  – 5-6 months for mission conceptualization, satellite design, fabrication, ground test, modification, launch, operation
  – Launch date is fixed in ARLISS: no delay is allowed

• Very Low Life Cycle Cost for One Project
  – $500 - 1,000 budget for one team (typically)
  – Helium balloon test requires $200/day and Rocket launch requires $400/flight, etc.

• Small, but Still Can be “a Satellite”
  – All the satellite functions + mission can be packed

• Can be Retrieved after Experiment
  – Analysis of the causes of failures is easy

• Possibility of Sponsorship from Juice or cola company
CanSat / Satellite Systems

- **Thruster**
- **Torquer**
- **Motor**
- **Actuator**

**Mission Subsystem**
- Sensors, experimental system, camera, etc.

**C&DH**
- Bus controller

**OBC**
- Memory

**Communication**
- Receiver
- Transmitter

- **Comm. Computer**
- Command
- Data

**Sensor data**
- S1, S2, S3, S4, S5
- Voltage, temperature, attitude sensors

**Command**
- uplink
- downlink

**Power System**
- Battery

**Thermal Control System**

**Structure and Mechanism System**
Handy Ground Station (for ARLISS Project)

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

**Yagi-Antenna**
- Frequency: 144MHz
- Gain: 8dBi
- Length: 87cm
- Weight: 530g

**Transceiver**
- with TNC
- 144/430MHz dual band
- AX.25
- 1200 / 9600bps

**Note PC**
Data Logging on Memory.
Failure in 2000
Parachute and main body were separated and the main body crashed on the ground.

- Students can learn many things from failures
- Engineers should experience failures while the project size is small
2001年～ Comeback Competition

Competition

Call Back Your CANSAT!!

ARLISS2001 PROJECT
Come-Back Competition 2002

Participating Universities 2002

Univ. of Tokyo

Kyushu Univ.

Nihon Univ.

Tohoku Univ.

Tokyo Institute of Technology

Stanford Univ.

ROVER
Currently AXELSPACE
CEO Dr. Yuya Nakamura

Target

Landed CanSat

Flyback Record 45m in 2002
The flyback CanSat was flown by the wind in 1500-3000m altitude, but came back in the lower altitude where the wind became weak.
Come-Back Competition 2008

Fly-backers

University of Tokyo ISSL

Titech Matunaga Lab B

Kyushu Tech. Cho Lab A

Kyushu Tech. Cho Lab B
Come-Back Competition 2008

Fly-backers

Akita University

Titech Matunaga Lab A

Soka University C

Nihon University
Come-Back Competition 2008

Rovers

University of Tokyo B3

Tsuyama College

Tohoku University

Univ. for Electro Comm.
History of Flyback vs. Rover

Come-Back Competition 2007

Year
Minimum Distance (m)
Flyback
Rover

2001
2002
2003
2004
2005
2006
2007
2008

3000
2500
2000
1500
1000
500

No Control

0 m !!
6 m
45 m
0 m !!
In 2006, Tohoku University's Rover made "6 m to the target"
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
After 2008, rover has been dominating until now.

2016 UT won with 3.8m

2018
The University of Tokyo
Won with 5.8m

The University of Electro-Communications

Tohoku University
Opening Ceremony and Briefing (September 10, 2018)
Loading CanSat to Rocket
Setting Rocket to Launcher
Launch to 3600m Altitude
Landing of CanSat
Pushed away by strong wind

How about making this a speed contest?
Envelope opened and escaped, but....
In the Second Run, they achieved 3.8m to the target and won!
In 2017, University of Tokyo team approached 1.34m to the target, when it automatically started image navigation. But because of bad direction of sun light, it gave up.
After modification of software, it achieved 0m to the target in the second run!

2nd 0 m Achievement

Presented as a Gift to AEROPAC in 2018
2018, Students Challenge “Flyback”

Result was 900m and was awarded Best Comeback Technology Award
20th Anniversary Gifts to AEROPAC (Sept 14, 2018)
Balloon Experiment in Japan

- Itakura Competition 2002 (Thermal balloon)
- Noshiro Space Event 2005～
- IAC Fukuoka International Competition 2005
CanSat Workshop (2007.2)

- 16 Countries
- Contest started in Europe (Spain, Norway---)
- Strong desire for educational support from Japan to emerging countries
CLTP (CanSat Leaders Training Program) History

CLTP1 (Wakayama Univ. in Feb-March, 2011)
12 from 10 countries, namely Algeria, Australia, Egypt, Guatemala, Mexico, Nigeria, Peru, Sri Lanka, Turkey (3), Vietnam.

CLTP2 (Nihon Univ. in Nov-Dec, 2011)
10 from 10 countries, namely Indonesia, Malaysia, Nigeria, Vietnam, Ghana, Peru, Singapore, Mongolia, Thailand, Turkey.

CLTP3 (Tokyo Metropolitan Univ. in July-August, 2012)
10 from 9 countries, namely Egypt (2), Nigeria, Namibia, Turkey, Lithuania, Mongolia, Israel, Philippines, Brazil.

CLTP4 (Keio Univ. in July-August, 2013)
9 from 6 countries, namely Mexico(4), Angola, Mongolia, Philippines, Bangladesh, Japan.

CLTP5 (Hokkaido Univ. in Sept 8-19, 2014)
7 from 5 countries, namely Korea (2), Peru, Mongolia, Mexico (2), Egypt.

CLTP6 (Hokkaido Univ. in August 24-Sept 3, 2015)
8 from 8 countries, namely Bangladesh, Egypt, Mexico, New Zealand, Angola, Turkey, Tunisia, Austria

CLTP7 (Hokkaido Univ. in Sept 21-Oct 1, 2016)
8 from 7 countries, namely Egypt, Peru, Mongolia, Nepal, Myanmar, Serbia, Dominica Republic

CLTP8 (Nihon Univ. in Sept 7-16, 2017)

CLTP9 (Nihon Univ. in Aug 20-31, 2018)
What CanSat Contributed?

• Even in small scale, the following important technologies and skills were learnt:
  – System analysis and design
  – Project management and team work
  – How to avoid failures and make recoveries

• We should develop from parts, not by buying components, by which we could learn:
  – How to make components from parts or by modifying the COTS components

• Systems usually do not work as expected. Many many test/refine process required.
Continued to Real Orbital Project - CubeSat -
USSS has been held annually in many islands under JUSTSAP

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by Prof. Twiggs again
Emerge of Nano/pico-Satellites in Japan

World First CubeSats launch by Univ.Tokyo and Titech (2003.6.30)
- University level budget (30K$)
- Development within 2 years
- Surviving in space for >15 years
- Ground operations, frequency acquisitions, launch opportunity search processed by ourselves

Many Japanese universities start developing their own satellites through UNISEC network
UNISEC started during CubeSat development
(UNIversity Space Engineering Consortium)

• Founded in 2002 (5 universities), became NPO in 2003
• In 2017, 72 laboratories from 50 universities
  – 892 students, 259 individual/company members
• UNISEC Missions:
  – Education and human resource training for space
devolution/utilization
  – Innovative space technology “seeds” development
• Activities to be Supported:
  – Joint experiment, joint purchase of parts/ground tests, etc.
  – Workshop, symposium, technology exchange, etc.
  – Consultation on legal matters (frequency, export law, etc.)
  – Finding “rivals” within the community!
  – “UNISEC Lecture Series”

http://www.unisec.jp
Launch of the World First CubeSat (XI-IV, CUTE-1) by “ROCKOT”

2003/06/30 18:15:26 (Russia, Plesetsk time)

Contribution to human resource training was more than expected!
700+ pictures downlinked for 15+ years
XI-IV is still perfectly working after 15 years in orbit

Recently Downlinked Photos

Degradation of lens material by ultra-violet
Key strategy to be world first CubeSat

- No components on web-site for CubeSat
  - Everything should be internally-made
- No ground test facilities in our university
- We only have little money ($55,000)
- **Key strategies employed in our first CubeSat**
  - Find out and pursue what we can do within our limited resources, not aiming at supreme level
  - Find outside supporters (technical, part donation)
  - Make it as simple as possible *(start from very very simple CubeSat)*
  - Implement *survivability* as much as possible
Satellite’s Key Technological Issue
“non-repairable system”

How to realize a certain level of reliability within limited resources (size, weight, power)??

“Die Hard” system is essential!!
- Mutual monitoring or hierarchical monitoring
- “Reset (power off-on)” operation
- Solar power generation possible in any attitude
- Under voltage control (UVC) and recovery from dead battery situation
- Appropriate definition of “safe mode”
University of Tokyo’s History
- 9 satellites developed (8 launched) -

2003 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18

[1] Education, Camera test

CubeSat XI-IV (ROCKOT) 2003/6

[2] Education, CIGS solar cells

[3] 30m GSD Remote sensing

PRISM (H-IIA) 2009/1

[9] Astrometry (top-science)

NANO-JASMINE (TBD)


TRICOM-1R (2018/2)

[4][5][6] Remote sensing, S&F

HODOYOSHI-1,3,4 (DNEPR) 2014/6,11

[7] Deep space exploration

PROCYON (H-IIA) 2014/12

[1]-[8]: Launched  [9]: Waiting for launch

MDG (remote sensing, 50kg), 2 x 3U CubeSat
EQUULEUS (14kg, deep space) are being developed.

[1] World First CubeSat!

Hodoyoshi-3 (left) and Hodoyoshi-4 before Shipment (April, 2014)

Target: 50kg class satellite to be developed within $3M and 2 years

Size: 50x50x80cm 60kg  Downlink: 10Mbps  Power: max 100W  average 50W

Attitude Control Capability:
- Stability 0.08 deg/s (Roll, Pitch)  0.8 deg/s (Yaw)
- Pointing accuracy 0.2 deg  2 deg
- Determination accuracy 0.0048 deg  0.048 deg
“Store & Forward” collects ground information

Application areas: disaster prediction, water level monitoring, soil moisture, PH.....

Key Issue: **How to send data with very low RF power to the satellite?**

8mW low RF power, low data rate (300bps) transmission is tested in TRICOM-1R.
Launch of TRICOM-1R by SS-520-5

• Launched on 3/2/2018 by the world smallest orbital rocket by JAXA/ISAS
• S&F and camera experiments successful
  – 8mW transmission from Japan, RWANDA, etc
• Plan to develop low cost/quick development version to support foreign countries
MOU to develop 3U CubeSat to be launched in mid 2019

News from Africa (09/05/2018)
Smart Africa, Rwanda Sign Deal With Tokyo University For Satellite Technology
EQUULEUS
EQUilibriliUm Lunar-Earth point 6U Spacecraft (6kg)
One of 13 EM-1 CubeSats onboard NASA's SLS-rocket

Mission to Earth Moon Lagrange Point
Intelligent Space Systems Laboratory, 2016/08/01
Solar Array
Paddles with gimbal

Ultra-stable Oscillator
Propellant (water) Tank
Transponder

X-Band MGA
X-Band LGA
Water resistojet thrusters
Attitude control unit

CDH & EPS

PHOENIX (plasma-sphere observation)
DELPHINUS (lunar impact flashes observation)

Condensed 14kg!!
University Satellites in Japan
48 university satellites launched in 2003-2017

From CanSat to CubeSat, Nano-Satellite
From Educational purpose to Practical application

- **Foreign Rockets**: 12
  - ROCKOT (Russia) 2 (2003)
  - COSMOS (Russia) 1 (2005)
  - PSLV (India) 3 (2008, 2012)
  - DNEPR (Russia) 6 (2014)

- **Japanese Rockets and ISS**: 36
  - M-V 2 (2006)
  - H-IIA 19 (2009～)
  - HTV⇒ISS deployment 15 (2012～)

JAXA supported University satellite projects!
Attaching CubeSat to ISS (on “i-SEEP”)

- CubeSat module: 100W × 100L × 113.5H, 3U is acceptable
- 8 Units can be implemented on one side of i-SEEP
- Power and communication service is provided via USB
  - Power: 5V 4W
  - Comm.: 100kbps (Ethernet)
- Thermal: connected to cold plate. Total system is covered by MLI
- Each CubeSat module is launched separately and attached to i-SEEP by crew

Note) These parameters are tentative ones.

Coming soon!!
Check JAXA website.
Summary and Proposal in UNIGLO

• We followed reasonable steps;
  – Satellite design contest to learn system design
  – CanSats to learn basic satellite-like development
  – CubeSat to learn simple yet real space system development
  – More sophisticated satellites for practical applications

• Making components from basic parts would be difficult, but eventually it will contribute to the growth of our technologies and skills

• Keep UNISEC-mind: strong will, never-give-up mind, rivalry feeling, honest as to engineering--