Overview of Nano-satellite Environmental Tests
Standardization Project:
Test Campaign and Standard Draft

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August 15, 2012, Small Satellite Conference
Micro/Nano/Pico satellite reliability

Mission success / still operational

Days survived in orbit

Satellite Mass (kg)

Satellite life in orbit vs satellite mass

10kg barrier university satellites

Agency/Traditional Makers

University/ New Makers

H. Satio, JSASS-2010-4050
Needs of testing standard

- Low success rate of micro/nano satellites
  - Acceptable to a certain degree, but
- Cannot ignore reliability if the satellites are for commercial purpose
  - One satellite still costs $1 million or more
  - “Failure is not an option”
- Low success rate may hurt reputation of micro/nano satellites
  - Scare off investment in micro/nano satellite applications
- Needs of improving reliability while balancing with low-cost and fast-delivery

Standard of test suitable for micro/nano satellites
Merit of environment test standard

• Improve the reliability of nanosatellites
• Promote worldwide trade of nanosatellite products
  – Procurement of components from the market with more confidence
• Serve contractual needs by providing reasonable test methods agreeable
  – between a satellite developer and a launch provider
  – between a satellite developer and a customer
• Guideline of environment tests for newcomers to space
NETS Project

• “Nanosatellite Environment Test Standardization” (NETS) project
  – Sponsored by Ministry of Economy, Trade and Industry (METI), Japan, starting September 2011
  – 4 members
    • International Standard Innovation Technology Research Association (IS-INOTEK)
    • Kyushu Institute of Technology (KIT)
    • The Society of Japanese Aerospace Industries (SJAC)
    • AstreX
  – 3 years project until March 2014
Project Goal

• ISO standards on nanosatellite testing
  – Including
    • Environment Tests of Nanosatellite System
    • Documentation of Nanosatellite Environment Tests
    • Environment Tests of Nanosatellite Components

Target date of completion: 2015

Definition of “nanosatellite” here;
A satellite mostly made of non-space qualified COTS components, typically less than 50kg, 50cm
**Approach**

**Existing test standard for large/med satellites**
- Very expensive, but highly reliable

**GOAL**
- Test standard for nanosatellites
  - Affordable and reliable

**Rationales**
- Basic researches using nanosatellites and their components

**Tailoring**
- Based on 50 year’s experience

**New inventions**
Approach

- Study of existing standards of satellite tests
- Interview with nanosatellite developers
- Basic research to obtain the supporting data
- International workshop
- Drafting standard
Interview with developers

• 15 nanosatellite developers
  – space agency (1), private companies (5), universities (9)
  – 18 satellite launched or under development
  – Cubesat (5), 10kg (4), 30kg (1), 50kg (7), 100kg (1)

• Launch as auxiliary payloads
  – Extensive mechanical tests following the launcher user manual
  – Vibration tests effective to detect the design and workmanship defects
  – Shock test by 13 developers
Interview with developers

• Interview with 15 nanosatellite developers

• Thermal vacuum tests
  – Often skipped for Cubesats
    • a) Schedule not enough
    • b) Facility not available
    • c) Judged unnecessary
  – All of 50kg-class or larger did or plan to do

• Radiation test
  – Single event by 3 developers only (no university)
  – Total dose by 8 developers
  – Shortage of know-how, facility & schedule
Interview with developers

• Interview with 15 nanosatellite developers (18 satellites)

<table>
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<tr>
<th></th>
<th>Cubesat</th>
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<td>2</td>
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<tr>
<td>Total loss*</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>To be launched</td>
<td>2</td>
<td></td>
<td>4</td>
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</table>

• All 5 satellites suffered infant mortality.
• 4 out of 5 had deployable mechanisms
  • Serious effects on the mission failure
Basic research

Power Control Unit

- Carry out
  - Thermal vacuum
  - Thermal cycle
  - Radiation
  - Vibration
  - Shock
  - Others

X-band RF transmitter

- 200W input with MPPT control
- 28V/3A output
- 196mmx200mmx56.5mm

- 3W output, 16~36V input,
- 153mmx94mmx34mm
Basic research

- Dummy satellites
  - 50kg micro-satellite bus
  - Flight hardware (OBC, PCU, Battery, COM)
  - Dummy mass (11) with internal heater
- Identify acceleration and temperature distribution within the satellite
  - Derive appropriate test levels of the components
  - Thermal balance
    - Measure 50 points
  - Modal survey and shock
    - Measure 32 points (x3 directions)
  - Compare with analysis and generalize the findings to other structural styles
Workshop

• 1st Workshop on International Standardization of Nanosatellite Technologies
• December 13, 2011 @KIT Tour
• December 14, 2011 @Kitakyushu International Conference Center
• Attended by 90 people
  – 56 Japanese, 34 from abroad

1. Needs and merits
2. Tasks
3. Stakeholder
4. Framework
5. Roadmap
Scope of testing standard

- Test requirements and methods to improve (maintain, achieve, etc) the reliability of nanosatellites
  - **Prevention of infant mortality**
    - Not to fail soon after the launch
  - Assure mission success in orbit
    - Guarantee the long life
  - **Try not to prevent new inventions**

- Test stages
  - Development
  - **Design qualification**
  - Acceptance
  - Launch-site

Key

**Affordable and reliable tests**
Mostly environmental, but other tests, e.g. functional, end-to-end, etc may be addressed
Resolution

• Participants of 1st Workshop of International Standardization of Nanosatellite Technologies recognize that
  – International standardization for nanosatellite testing has a great merit for the growth of worldwide nanosatellite activities and utilization

and agree to

  – Cooperate as experts toward establishment of an ISO standard on nanosatellite testing

December 14, 2011

Passed unanimously
How to proceed

• NETS project team will lead the standardization efforts on behalf of the community

• Set-up a mailing list server @KIT
  – nets-project@langmuir.ele.kyutech.ac.jp

• Set-up a file server @KIT
  – http://cent.ele.kyutech.ac.jp/nets_web.html
  – Distribute
    • Proceedings of the workshops
    • Standard draft
    • Others
How to proceed

- 2\textsuperscript{nd} Workshop (December 10 to 14, 2012 @ Kitakyushu)
  - Test demonstration at KIT (2 day)
  - Presentation of research results by participants (1 day)
  - Discussion of working draft ver.1 (2 day)
Draft outline

• Outline of the working draft ver.1 released in April, 2012
• Available at http://cent.ele.kyutech.ac.jp/nets_web.html
• Space systems —Design Qualification and Acceptance Tests of Micro/Nano Satellite and Units

Table of contents can be found in the paper
Conclusion

• Urgent need to improve the reliability of micro/nano satellites
• International standardization of micro/nano satellite environment testing will provide reliable test standards while keeping the low-cost and fast-delivery nature.
• “Nano-satellite Environment Test Standardization” (NETS) project started
• If you want to join the project mailing list, please send your intent to nets_office@langmuir.ele.kyutech.ac.jp
• The project web page is now open at http://cent.ele.kyutech.ac.jp/nets_web.html
• The second workshop will be at Kitakyushu from Dec. 10 to 14, 2012
  – Test Demonstration
  – Research presentation
  – Line-by-line discussion of the working draft ver.1
Interview with developers

• Interview with 15 nanosatellite developers (18 satellites)
• Most of the universities referred only to the launcher user manual
• The private companies referred to JERG-2-002, GSFC-STD-7000, ECSS-E-ST-10-03C and others.
  – Not exactly followed the traditional standards.
• Universities commented the importance of not binding the educational satellites, especially Cubesat-class by the testing standards.
• Developers of >10kg satellites welcomed the idea of standard and expressed the needs of standard that helps the procurement of the satellite units.
  – Want more clear data of temperature range and mechanical properties for the products sold in the market.
Satellite Contractual Needs

• Nanosatellite application provider (Buyer of satellite)
• Nanosatellite manufacturer (Seller of satellite)
  – Unsure about an appropriate level of reliability balanced with the cost and schedule
  – Buyer may want the same level of test/verification processes as large/med satellites
  – Seller may want to minimize the cost/schedule for the test/verification
  – Needs of agreed-upon criteria of test/verification
    • Defacto standard may evolve over time. But can we wait?
    • Needs of research to support the criteria
Needs from newcomers

• Newcomers to space through nanosatellite development
  – Local small business
  – Developing countries
  – Universities

• Needs of a guideline of test/verification methods which are affordable and reliable
Launch Contractual Needs

• Philosophy on test methods of piggy-back satellites differs among launch provider
  – Example: Shock test

• Satellite developer wants to design independent of launcher

• Needs for a reasonable test method agreeable between a satellite developer and a launch provider
  – In Interface Control Document (ICD), simply refer to “ISO-???” as a test method
Countries attended workshop

- Austria
- Brazil
- Canada
- China
- Egypt
- England
- France
- Germany
- India
- Indonesia
- Israel
- Italy
- Japan
- Korea
- Malaysia
- México
- Mongolia
- Netherlands
- Nigeria
- Peru
- Singapore
- Spain
- Thailand
- Turkey
- UK
- USA
- Viet Nam

Attended by 27 countries

Participant list is available on Web
<table>
<thead>
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<td>October, 2012</td>
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<td><strong>December, 2012</strong></td>
<td><strong>2\textsuperscript{nd} Workshop @kitakyushu</strong></td>
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| March, 2013         | Working Draft ver.2
|                     | **New Work Item Proposal**                 |
| May, 2013           | ISO/TC20/SC14 Plenary Meeting              |
| **Summer, 2013**    | **3\textsuperscript{rd} Workshop @Tokyo**  |
| Fall, 2013          | Committee Draft ver.1 (CD/C)                |
|                     | ISO/TC20/SC14/WG1 Meeting                  |
| **March, 2014**     | **Committee Draft ver.2 (CD/V)**            |
| Fall, 2014          | DIS/V registration and voting              |
| **Spring, 2015**    | **DIS/V voting ends, FDIS for editing**    |
| Fall, 2015          | ISO publication                            |
Study of existing standards

• Comparison of
  – ISO-15864
  – SMC-S-016
    • US Space and Missile Systems Center Standard
  – NASA-STD-7002A
    • NASA PFT
  – GSFC-STD-7000
    • Goddard Space Flight Center (NASA)
  – ECSS-E-ST-10-03C
  – JERG-2-002
    • JAXA
• Comparison tables are found in the paper
Basic research

- Comparison between thermal vacuum and thermal cycle
  - 14 cycles of -24°C~+61°C
  - Cold start at -40°C

Example of temperature profile during thermal cycle test