The Application of Small Satellites in Research and Teaching

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United Nations/Brazil Symposium on Basic Space Technology
"Creating Novel Opportunities with Small Satellite Space Missions"

September 11, 2018  Natal, Brazil
Charles Swenson

• Professor Utah State University since 1991

• Sabbaticals
  – 2000 to 2001 Aerospace Corporation
  – 2007 to 2008 NASA HQ SMD
  – 2016 to 2017 Aerospace Corporation

• Research Motivation
  – “How do we get the simultaneous measurements at multiple locations in the space environment that are needed to understand the physics of the Earth’s upper atmosphere?”
  – Plasma and optical instrumentation techniques for space weather
  – Small satellites, CubeSats, and constellations
  – Spacecraft subsystems (systems level)
USU Nanosatellite Programs

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>USUSat IV</td>
</tr>
<tr>
<td>2009</td>
<td>NS-5 Down select, March 2009</td>
</tr>
<tr>
<td>2009</td>
<td>Kickoff, November 2009</td>
</tr>
<tr>
<td>2011</td>
<td>Launch, October 28, 2011</td>
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<tr>
<td>2012</td>
<td>DICE Operations</td>
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<tr>
<td>2013</td>
<td>OPAL</td>
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<tr>
<td>2014</td>
<td>SPORT</td>
</tr>
<tr>
<td>2015</td>
<td>ASSP</td>
</tr>
<tr>
<td>2016</td>
<td>OPAL</td>
</tr>
<tr>
<td>2017</td>
<td>DICE Operations</td>
</tr>
<tr>
<td>2018</td>
<td>OPAL</td>
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</table>
What have I learned with time?

1) It takes a whole team of people to accomplish a space mission.

2) Students are best taught in “real” projects.

3) A single purpose is essential for every space mission.
Brief History of the USU SmallSat Conference

Started in 1986 (33rd year)

https://www.smallsat.org/
http://digitalcommons.usu.edu/smallsat/
The Concept of the Big Satellite BUS

Save time and money by putting lots of payloads on the same bus?

Alphabus, ESA
The Motivation For the Small Satellite Community

• **Satellites were becoming bigger and more complex**
  – Multiple payloads and multiple purposes
  – Costs were increasing
  – The ability to build such satellites was concentrated in a few organizations
  – Time between launches was increasing.
  – Young people felt shut out of careers in space.

• **There has to be a better way!**

• **1986 the small satellite conference organized to promote smaller less complex satellites. ~50 people attended.**
  – Dr. Frank Redd.
<table>
<thead>
<tr>
<th>Small Satellite 2016</th>
<th>Small Satellite 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2300 total head count</td>
<td>• 3050 total head count</td>
</tr>
<tr>
<td>• 680 organizations</td>
<td>• 900 organizations</td>
</tr>
<tr>
<td>• 140 exhibiting organizations</td>
<td>• 206 exhibiting organizations</td>
</tr>
<tr>
<td>• 286 Students</td>
<td>• 313 Students</td>
</tr>
<tr>
<td>• 40 countries represented</td>
<td>• 42 countries represented</td>
</tr>
</tbody>
</table>
CubeSats

Are nanosats and picosats feasible?

Ariane Launch

Russian

US Launch

NSF

NASA, CubeSats

NASA, ELaNa
• BY G.G. Rei baldi etal, SmallSat 1988

• ABSTRACT

In preparing for the future, the European Space Agency (ESA) has identified a growing shortage of flight opportunities for secondary payloads. This was most directly felt in the execution of the In-Orbit Technology Demonstration Program (TOP), which is aimed at the demonstration of new technologies in orbit, before their application in projects, thereby reducing the overall risk.

Figure 5 ARIANE Secondary Payload Adapter (ASAP) Mechanical Concept
USU Small Satellite Conference

Attendance

Year


- Ariane Launch
- Russian
- US Launch
- NASA, CubeSats
- NSF
- CubeSats
- NASA, ELaNa

Are nanosats and picosats feasible?
“CubeSat”

- Proposed in 1999 by Professor Twiggs, Stanford
Cubesats: Change of mindset

Powerful concepts:
- Building to a standard
- Containerized launch

New paradigm:
- Low cost
- Higher risk acceptance

Broad participation:
- High influx of innovation
- Widespread expertise
NSF Cubesat Program since 2008

- Geospace & atmospheric science and education
- ~2 new projects per year
- 5 competitions; 122 proposals
- 15 projects funded
- Grants $900,000 total cost and 3 year duration
Are nanosats and picosats feasible?  

- **1985**: Ariane Launch
- **1990**: Russian
- **1995**: US Launch
- **1995**: CubeSats
- **2000**: NSF
- **2005**: NASA, CubeSats
- **2010**: NASA, ELaNa

**USU Small Satellite Conference**
Earth Science & Heliophysics CubeSat Missions

- IceCube
- HARP
- MiR-TA
- RAVAN
- LMPC
- CIRJ
- Rain
- CIRiS
- TEMPEST-D
- CubeRRT
- MiR-TA
- CeReS
- TBEx
- ELFIN
- MinXSS
- CuSP
- petitSat
- LLITED
- CURIE
- SPORT
1. How do solar wind/magnetospheric energy energize the ionosphere and thermosphere (I-T)?

2. How does the I-T system respond and ultimately modify how the magnetosphere transmits solar wind energy to Earth?

3. How is solar-wind energy partitioned into dynamical and chemical effects in the I-T system, and what temporal and spatial scales of interaction determine this partitioning?

4. How are these effects modified by the dynamical and energetic variability of the ionosphere upper atmosphere introduced by atmospheric wave forcing from below?
What is REALLY needed

120 Satellites
A linescanner for the planet

- 100+ Satellites
- 3-5m resolution 4 band imagery
- 26 Ground Stations
Students At Utah State University

There is more going on then just space missions
Conclusion

• The most significant advances in solar and space physics, or Heliophysics, over the next decade are most likely to derive from new observational techniques.

• One of the most promising new observational techniques becoming available are miniaturized sensors and satellite systems called small satellites and CubeSats.

• Small Satellites represent a opportunity for many new space endeavors and many new countries.
Backup
Small, Mini, Micro, Nano, Pico Satellites

Sir Martin Sweeting

<table>
<thead>
<tr>
<th>Class</th>
<th>Mass (kg)</th>
<th>Cost ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large satellite</td>
<td>&gt; 1000</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>Small satellite</td>
<td>500 - 1000</td>
<td>50 - 100</td>
</tr>
<tr>
<td>Mini-satellite</td>
<td>100 - 500</td>
<td>10 - 40</td>
</tr>
<tr>
<td>Micro-satellite</td>
<td>10 - 100</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Nano-satellite</td>
<td>1 - 10</td>
<td>0.5 - 2</td>
</tr>
</tbody>
</table>

An Advanced Standard For Cubesats
Ryan Hevner, et al 2011,
USU Small Satellite Conference

Payload Mass and Volume by separation system

An Advanced Standard For Cubesats
Ryan Hevner, et al 2011,
USU Small Satellite Conference