CubeSat: The Development and Launch Support Infrastructure for Eighteen Different Satellite Customers on One Launch

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ABSTRACT

Stanford University and California Polytechnic State University have combined efforts to develop a means of launching small picosatellites called CubeSat. The CubeSat is a 10cm cube weighting 1 kg or less. The launching system developed will provide launches for three satellites in one launcher tube. The first mission for this launcher will be to fly six tubes to launch eighteen CubeSats in May 2002 on a Kosmotras, Dnepr ELV from Bikinour, Ukraine.

Stanford and Cal Poly are providing active technical support for the CubeSat developers, which are mostly universities. Once the CubeSats have been developed by the universities and other customers, they will be sent to Cal Poly for final testing, insertion into the launcher then shipped to One Stop Satellite Solutions in Ogden, Utah where they will be mounted on the OSSS Multiple Payload Adapter, then sent to Russia and integrated onto the Dnepr.

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1. INTRODUCTION

"Smaller, Cheaper, Faster, Better" space missions are the trend in today's shrinking budgets, the failure of one major constellation communication systems and troubles of the second. With the "fall of the DOT.COMs there is a sharp curtailing of venture capital for commercial space programs. Now seems to be the time to start looking at missions for education, science and government with picosatellites.

To support some science missions and in proposing new missions, the trend is now to see what can be done by decreasing the spacecraft sizes by orders of magnitude. This is becoming more practical with the rapid electronics advances in decreasing size, in greatly increased capability and very low power consumption. This decrease in size also directly benefits the mission cost in lower launch costs.

This paper will describe the experience to-date with the CubeSat program and the participants in the first launch, now planned for May 2002.

2. CUBESAT DEVELOPMENT PROGRAM

The CubeSat program was started at Stanford University in early 1999 to meet an educational need to have a satellite that could be developed within one-two years, be very-low cost (much less than that $50,000 cost of microsatellites being developed at Stanford) and be very low weight for reduced launch costs.

Selecting the weight of a picosatellite (< 1 kg) as the starting basis and the size of a 10 cm cube a design was established and called the CubeSat (Figure 2.1).

A preliminary plastic launch tube was developed that could hold three of the picosatellites. This launch tube design was developed to provide a safe, easy way of holding the picosatellites. This launch tube would also be easy to attach in almost any location on the last stage of an ELV and require only one signal to open the launch tube door for release of the picosatellites.

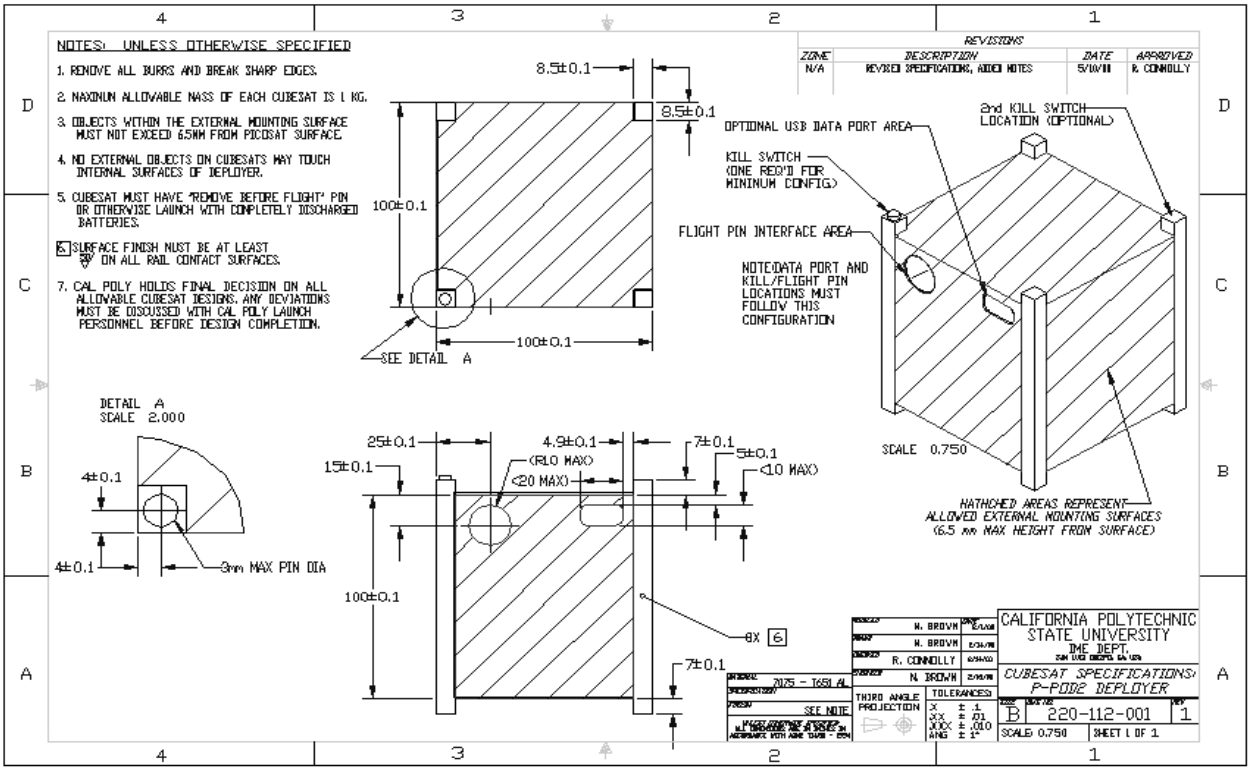

Figure 2.1 CubeSat Physical Drawing

In order to make the cost for the launch of one picosat low, multiple launchers would have to be carried on one launch mission.

Since the students at Stanford University were all occupied building microsatellites, it was decided to form a collaborative relationship between Stanford and California Polytechnic State University (Cal Poly). Cal Poly also had a reputation as a very hands-on undergraduate engineering university. This collaborative effort was established in the fall of 1999 where Cal Poly would complete the launcher design, build a prototype and evaluate for improvements. The first prototype of this launch and mass model CubeSats is shown in Figure 2.1

The CubeSat program was announced to many of the organizations, educational and amateur groups that were interested in building low cost picosatellites.
The launcher tube, P-POD, developed by Cal Poly will hold three CubeSats and is designed to be attached to many different launch vehicles show in Figure 2.1. The double P-POD shown in Figure 2.2 will hold six CubeSats and uses a common wall to save weight

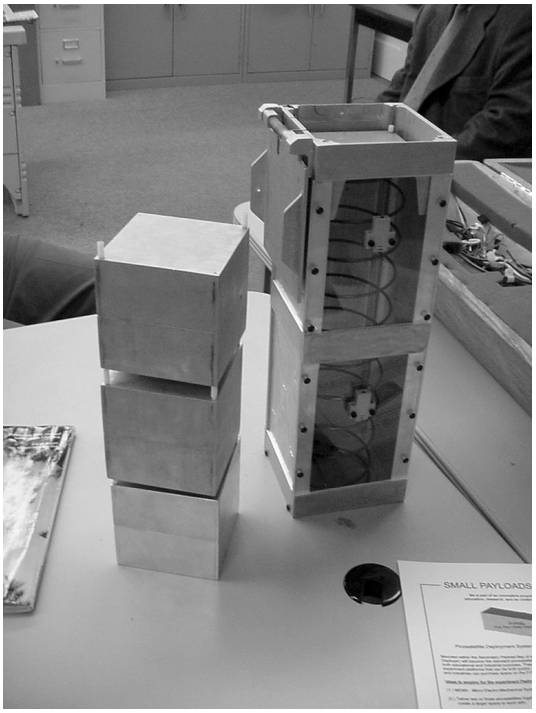

Figure 2.1 Prototype CubeSat Launcher and Mass CubeSat Models

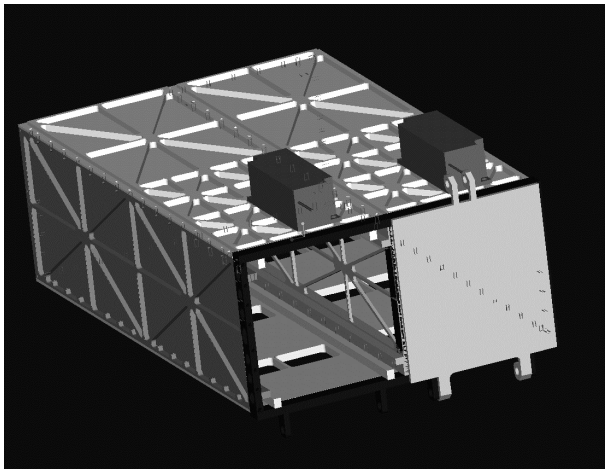

Figure 2.2 Dual Tube Launcher

3. PARTICIPANTS IN CUBESAT PROGRAM

3.1 First Mission CubeSats

The following CubeSats are scheduled for the first launch in May 2002.

1 – California Polytechnic State University
6 - Government – NASA Ames
1 - Leland High School - San Jose, CA
1 - Montana State University
1 - Private
1 - Stanford University
2 - Taylor University
1 - Tokyo Institute of Technology
2 - University of Arizona
1 - University of Tokyo
1 - Wilcox High School - Santa Clara, CA

3.2 CubeSat Developers

3.2.1 California Polytechnic State University

Cal Poly is building a CubeSat in addition to their P-POD launcher. The project is a large interdisciplinary program with undergraduate students from nearby Cuesta College

3.2.2 NASA Ames Research Center

The NASA Ames Research Center in collaboration with Stanford University is developing a nanosat-sized spacecraft weighting 6 kg that will be used for biological experiments. This nanosatellite called BioExplorer-1 uses the CubeSat launching system, but occupies the space of six CubeSats in the doublewide launcher shown in figure 2.2.

The primary mission will be to characterize the BioExplorer concept over a period of 160 hours of experiments.

3.2.3 Leland High School – San Jose, CA

Leland High School in San Jose, California is the first know high school to take on the task of building their own satellite. The five student team of junior and senior students are self organized and managed with very little input from mentors.

They have selected a mission to launch a beaconing system with primary batteries using an Alinco DJ-C5 radio and a Clements Engineering MIM module. They will broadcast temperature information using the amateur AX.25 protocol at the frequency of the US VHF APRS stations.

3.2.4 Montana State University

The Montana State University program is being directed by the Physics Department with help from the School of Engineering. Graduate students in the Physics department with a total team of about 40 students are directing this program.

The primary experiment will be mapping radiation levels.

3.2.5 Private

This is a private project being managed by One Stop Satellite Solutions.

3.2.6 Stanford University

The Stanford University CubeSat is being directed by local amateur radio mentors and will have a primary payload of a magnetometer from Dr. Robert Strangeway at UCLA.

3.2.7 Taylor University

Taylor University is a small liberal arts university in Indiana. A student-managed team of undergraduate students in Physics is building the CubeSat. This experiment is the length of two CubeSats and primary science is plasma density and temperature measurements and a communications system demonstrating data transfer rates of 1 Gb/sec.

3.2.8 Tokyo Institute of Technology

Tokyo Institute of Technology's student group will use the CubeSat to demonstrate communications, sensors and a special adjustable deployment mechanism on one solar panel.

3.2.9 University of Arizona

The University of Arizona will be building two CubeSats. One will have optical reflectors for experiments using lasers for ground tracking. The second will

3.2.9 University of Tokyo

The University of Tokyo CubeSat will have the following mission goals. Gathering the satellite health information via beacon signal, command uplink & data downlink, telemetry data broadcasting service and on-orbit verification of the commercial-off-the-shell (COTS) components.

3.2.10 Wilcox High School – Santa Clara, CA

Mentors from Lockheed Martin, Hewlett-Packard and Trimble Navigation support Wilcox High School in Santa Clara, California.

4. LAUNCH OPPORTUNITIES AND COSTS

There is a flight opportunities for CubeSats in May 2002. The first launch opportunity is with Thiokol Corporation in a joint Venture with Kosmotras on the converted Russian SS-18 called the Dnepr from the Russian launch site at Baikonour. The first flight for CubeSats is scheduled for May 2002. This launch is being coordinated through One Stop Satellite Solutions in Ogden, Utah. It is expected that flights will continue to occur at least twice a year.

4.1 Launch Costs and Procedure

The initial launch cost per CubeSat that weigh one kilogram or less is $30,000. This is based on the known launch and integration cost using the Kosmotras Dnepr. The present arrangements being made for launches on the Dnepr is a collaborative effort between Stanford University, Cal Poly and One Stop Satellite Services in Ogden, Utah. Contractual arrangements will be made with Stanford University; Cal Poly will provide P-POD test fixture to the customer, provide the flight P-POD, integrate the CubeSat into the P-POD upon delivery to Cal Poly at San Luis Obispo, CA, perform final thermal and vacuum testing; then the P-POD will be shipped to One Stop Satellite Services at Ogden, Utah. One Stop Satellite Solutions will then be responsible for all export licensing, shipping to Kosmotras and integration onto the Dnepr.

5. CONCLUSIONS

The new picosatellite, CubeSat, now being developed as a standard that can be launched with the launcher tube developed by Cal Poly, the P-POD will provide low cost opportunities for a new era in space experimentation.

These new CubeSats and the low cost make it practical for even universities and private groups such as amateur radio clubs to have access to space. The future of these space devices based on the CubeSat design will now depend upon how innovative the science and general community can be.

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6. USEFUL REFERNCES

1 "CubeSat: A new Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation", H. Heidt, J. Puig-Suari, A. Moore, S. Nakasuka, R. Twiggs, Proceedings of the Thirteenth Annual AIAA/USU Small Satellite Conference, Logan, UT, August xx 2000,

2 "Initial Developments in the Stanford SQUIRT Program", Christopher A. Kitts and Robert J. Twiggs, EUROPTO, European Symposium on Satellite Remote Sensing, Rome, Italy, September 26-30, 1994.

3 "The Satellite Quick Research Testbed (SQUIRT) Program", Christopher A. Kitts and Robert J. Twiggs, 8th Annual AIAA/USU Conference on Small Satellites, Logan Utah, August 29 - September 1, 1994.

4 “Initial Developments in the Stanford SQUIRT Program”, Christopher A. Kitts and Robert J. Twiggs, EUROPTO, European Symposium on Satellite Remote Sensing, Rome, Italy, September 26-30, 1994.

5 “The Satellite Quick Research Testbed (SQUIRT) Program”, Christopher A. Kitts and Robert J. Twiggs, 8th Annual AIAA/USU Conference on Small Satellites, Logan Utah, August 29 - September 1, 1994.

6 "SAPPHIRE, A University Student Built Satellite for Space Experimentation", Twiggs, Robert J., and Christopher A. Kitts, November 1, 1995, The AMSAT Journal, November/December 1995.

7 "Picosat Free Flying Magnetometer Experiment", Clarke, D.S., M.T. Hicks, A.M. Fitzgerald, J.J. Suchman, R. Twiggs, T.W. Kenny, and J. Randolf, June 15, 1996, Proceedings of the Tenth Annual AIAA/USU Small Satellite Conference, September 16-19, 1996. Presented by Michael T. Hicks at the Tenth Annual AIAA/USU Small Satellite Conference, New Missions I Session, Logan, UT, September 16, 1996

8 Motohashi, S., Nakasuka, S., Aoki, T., Narusawa, Y., Nagashima, R., Kawakatsu, Y. and Kinoshita, T., On-orbit Dynamics and New Control Scheme for Large Membrane "Furoshiki" Satellite. Proceedings of 21st ISTS, 98-e-20, 1998

9 Narusawa, Y., Aoki, T., Nakasuka, S., Motohashi, S., Nagashima, R., Kawakatsu, Y. and Kinoshita, T., Behavior of Membrane Structure under Microgravity Environment, Proceedings of 21st ISTS, 98-b-16, 1998

10 Motohashi, S., Nakasuka, S., On-orbit Dynamics and Control of Large Scaled Membrane with Satellites at its Corners, Proceedings of IFAC Symposium on Aerospace Control, pp. 146-151, 1998

7. RELATED URLS

1. NASA Ames Research Center
2. California Polytechnic State University
   www.calpoly.edu/~aero/polysat/
3. Leland High School - San Jose, CA
   Lelandcubesat.org
4. Montana State University
   www.ssel.montana.edu/merope/
5. Stanford University
   www.sbarasat.org
6. Taylor University
   www.css.tayloru.edu/~physics/picosat
7. Tokyo Institute of Technology
   horse.mes.titech.ac.jp/srtlssp/cubesat/index.html
8. University of Arizona
   uasat.arizona.edu
9. University of Tokyo
   dat15.t.u-tokyo.ac.jp/cubesat/index-e.html
10. Wilcox High School - Santa Clara, CA
    www.golotech.org/