Cal Poly Coordination of Multiple CubeSats on the DNEPR Launch Vehicle

Authors: Simon Lee, Armen Toorian, Nash Clemens, Jordi Puig-Suari

California Polytechnic State University
Aerospace Engineering Department
1 Grand Ave, San Luis Obispo, CA 93407
Phone: (805) 756-5087, Fax: (805) 756-5165, Email: STLee@calpoly.edu

Author: Bob Twiggs
Stanford University
Department of Aeronautics and Astronautics
Phone: (650) 723-8651, Fax: (650) 723-1685

ABSTRACT: California Polytechnic State University is coordinating the launch of multiple CubeSats on a DNEPR LV in the fall of 2004. This launch will include 14 CubeSats being developed by 7 U.S. and 4 international universities. At a cost of $40,000 per CubeSat, this launch will provide universities with affordable and reliable access to space. 5 standard CubeSat deployers (P-PODs) will transport and eject the CubeSats into orbit. This paper describes Cal Poly's role in coordinating this launch including the interface with both the launch provider and the CubeSat developers.

The Cal Poly CubeSat team benefited greatly from the experience acquired during the first CubeSat launch coordinated by the University of Toronto Institute for Aerospace Studies, Space Flight Laboratory in June 2003. This paper discusses how lessons learned during that launch influenced the current launch activities.

TABLE OF CONTENTS

1. Introduction
2. Lessons Learned: Redesigns
3. Launch Vehicle Interface
4. Export Licensing
5. Coordination with Launch Participants
6. Coordination of RF Frequencies
7. Satellite Tracking and Coordination
8. Future Work
9. Acknowledgements
10. References

1. INTRODUCTION

Simplicity and reliability are the cornerstones of the CubeSat standard. The standard provides universities with structural, dimensional, and operational guidelines.

California Polytechnic State University (Cal Poly) is coordinating an effort to launch multiple CubeSats on a DNEPR LV, a decommissioned SS-18. This effort provides universities cost-effective access to space. Cal Poly will interface with the launch provider, design and manufacture launch vehicle (LV) interfaces and deployment devices. Cal Poly also handles all ITAR and export license issues. This effort allows each university to focus on the development of their CubeSat.

Cal Poly's current launch effort includes 14 satellites from 7 domestic and 4 international universities.

- Their common form factor, 10x10x10cm and maximum weight of 1kg. The common form factor and weight of the CubeSats is necessary to ensure that they are properly integrated into the CubeSats deployer.
- Spring plungers between CubeSats.
- Deployment switches.

Figure 1: Cal Poly CP1 demonstrates the CubeSat standard.

The spring plungers provide the initial separation between the CubeSats after deployment from the P-PODs. Deployment switches ensure that all CubeSats are inactive during launch and pre-launch activities. CubeSats must remain inactive until 15 minutes after deployment, preventing any interference to the launch vehicle or primary spacecraft during injection into low-earth-orbit (LEO). Furthermore, this delay reduces the risk to other CubeSats due to premature radio frequency (RF) transmissions or physical damage from large deployables. A remove-before-flight (RBF) pin is required on all CubeSats and is only removed prior to P-POD/LV integration.

In large part the standard CubeSat dimensions are determined by the standard CubeSat deployer, the P-POD. The satellites are ejected from the P-PODs, using a spring plunger and travel on smooth flat rails. To prevent jamming, the interior of the P-POD is processed with a Teflon impregnated hard anodize. In addition material minimizations are external so as to leave smooth inner surfaces of the P-POD to prevent jamming in case of a possible premature antenna deployment or other unforeseeable event.

Figure 2: The P-POD MKII

2. LESSONS LEARNED: REDESIGNS

From the experience of the first CubeSat launch in June 2003, and through technical discussions with launch providers (LP), a number of modifications were made to the P-POD, the CubeSat standard, and the operational plan.

2.1 Eurockot CubeSat Launch

The first CubeSat launch was coordinated by the University of Toronto Institute for Aerospace Studies, Space Flight Laboratory on June 30, 2003. There were two P-PODs onboard with six CubeSats participating in the launch. Both P-PODs used a non-pyrotechnic, vectran line cutter developed by Planetary Systems. This release mechanism cuts the vectran line using redundant radiant heaters, producing no gas or debris. The line is cut in 30 +/- 5 seconds after the deployment signal is received.

Both P-PODs deployed their CubeSats successfully. P-POD NLS-2 contained Quakefinder, which was successfully transmitting after deployment. P-POD NLS-1 contained 3 CubeSats as shown in Table 1. Of the 3 CubeSats, transmissions were only received from Aalborg University's CubeSat.

Table 1: CubeSats in 2003 Eurockot launch

NLS-1	1xCubeSat	University of Toronto
NLS-1	1xCubeSat	Technical University of Denmark
NLS-1	1xCubeSat	Aalborg University
NLS-2	3xCubeSat	Quakefinder
Other	1xCubeSat	University of Tokyo
Other	1xCubeSat	Tokyo Institute of Technology

Following the launch several concerns needed to be addressed.

1. Large deflection of the P-POD door (approximately 3mm) could create undesired shock loads on the CubeSats during launch.

2. The spring plungers on the CubeSats did not provide sufficient separation of the satellites after deployment.

3. There was no telemetry information on successful deployment.

4. Vibration during launch may have caused the flexing of the thin side panels of the P-POD to contact the sides of the CubeSats.

5. It was difficult to track the CubeSats after deployment.

6. The deployment mechanism requires a large operational window from trigger signal to deployment.

7. The separation of the satellites was insufficient to prevent the satellites transceivers from overloading neighboring satellites.

2.1.1 Door deflection of the P-POD MKI

Planetary Systems Vectran Line Cutter was used as the deployment mechanism on P-POD MKI. The mechanism closed the door with a 300lbf preload on the line. This placed a large moment at the tips of the door without any constraints in the center causing the door to bow, see .Figure 3

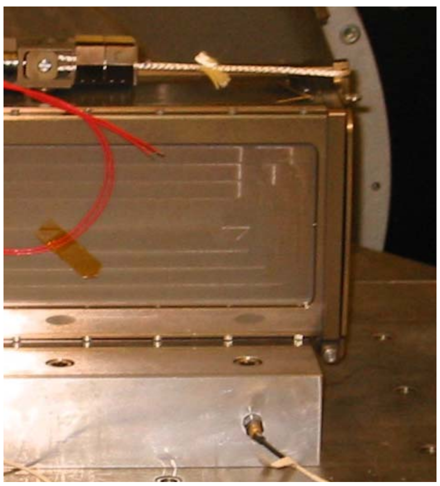

Figure 3: Door deflection of P-POD MKI

The door was redesigned to meet several requirements.

- The deflection of the door must be decreased with a 300lbf load.
- The door must be able to accommodate the new release mechanism, the Starsys Qwknut.
- As a system, the mass of the P-POD MKII must not exceed the mass of P-POD MKI

The new door is shown in Figure 4. The door accommodates the new release mechanism and the added ribbing minimizes the deflection of the door decreasing the shock loads on the CubeSats during launch. The mass of the new door is 152.29g, approximately 30g heavier then the door used on the P-POD MKI.

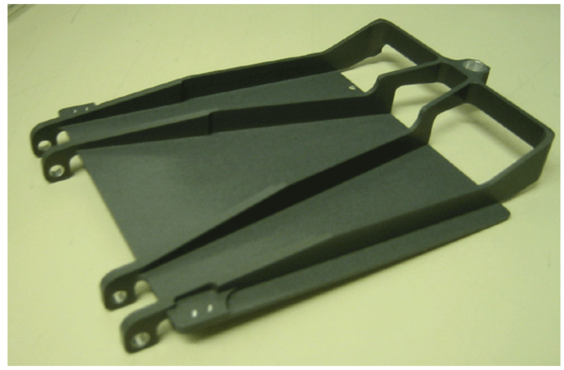

Figure 4: Redesigned door used on P-POD MKII

2.1.2 Spring Plungers and Separation

Spring plungers, shown in Figure 5, are required for all CubeSats and are located on the top of the standoffs, as shown in Figure 6. As the CubeSats are integrated together the spring plungers are compressed between neighboring CubeSats. The spring plungers provide an initial impulse to separate the CubeSats after deployment from the P-POD.

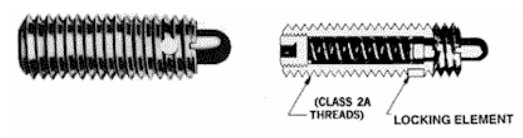

Figure 5: Standard Spring Plunger

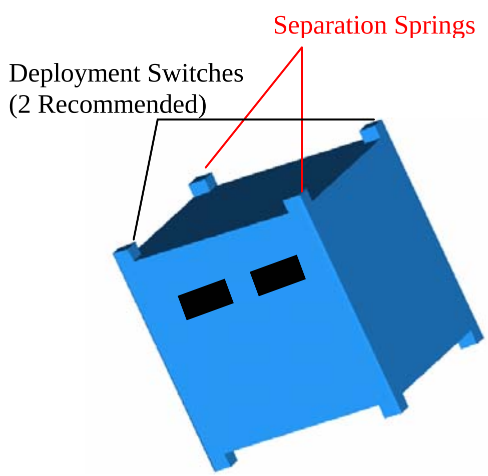

Figure 6: Separation Spring Locations

The initial CubeSat specification included delrin tipped plungers. During vibration testing of the P-POD MKI, deterioration of the delrin plungers was observed. The particulates from the delrin can contaminate the solar cells and other satellite components. This would cause a decrease in the performance of the CubeSat.

The material of the nose of the spring plunger was changed from delrin to stainless steel. Stainless steel does not the deterioration this problem, as it is a harder material, and being a dissimilar metal to aluminum it is not prone to cold welding.

In addition to the tip material change a longer nose length was used. Since the energy in the spring is dissipated over a longer period of time, the probability of the spring plungers being uncompressed prior to full ejection of the CubeSats is reduced. The thread diameter remained unchanged.

2.1.3 Deployment Signal for the P-POD

On June 30, 2003 no deployment confirmation was provided by the P-PODs to determine whether the P-PODs had successfully deployed. A deployment sensor is attached to P-POD MKII which will send a signal back to the launch vehicle. Successful deployment is defined by the door opening 90 degrees, the minimum angle required for the CubeSats' to be cleared of any obstruction.

Telemetry data is provided by means of a mechanical switch riding on a guide at the front of the P-POD MKII as shown in Figure 7.

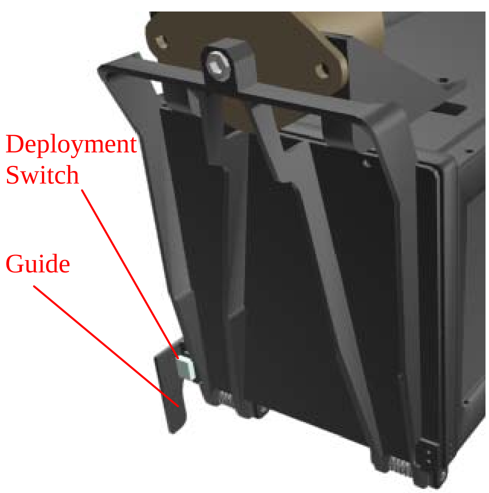

Figure 7: Guide and deployment switch located on the P-POD MKII

2.1.4 Deflection of the Side Panels

There were concerns that the side panels could deflect and damage the CubeSats during launch. Testing was performed at California Polytechnic State University's Mechanical Engineering Vibration Laboratory to verify that the deflection of the panels posed no threat to the CubeSats.

A testing scheme was devised to simulate the launch and determine how the flexing affected the CubeSats. First, a mass model was modified to match the maximum dimensional limits of the CubeSat standard. Then a copper based lubricant was applied to all faces of the mass model. This lubricant would transfer upon contact but was viscous enough to avoid running.

Finally, vibration testing was done to NASA GEVS levels. Upon completion of the test, the mass models were de-integrated, and the inside of the P-POD was inspected. Copper lubricant was not detected on any of panels inside the P-POD MKI. Therefore, the flexing of the side panels did not damage the CubeSats inside the P-POD MKI.

2.1.5 Satellite Tracking

During the launch on June 30, it was difficult to track the CubeSats due to their close proximity after deployment from the P-POD. It is crucial to distinguish the CubeSats in the first few orbital passes.

For the DNEPR launch, all universities have been informed of their position in the P-PODs as well as the deployment sequence of the P-PODs. To increase the probability of locating a CubeSat, all CubeSats are equipped with beacons (i.e. CW beacons) that transmit 15 minutes after deployment from the P-POD.

2.1.6 Release Mechanism

Technical discussions with launch providers quickly made it clear that a faster release mechanism was needed. As mentioned previously, the Planetary Systems Line Cutter, shown in Figure 8, was used on the P-POD MKI. The resistive heaters used for deployment required 30 +/- 5 seconds to operate. [1]

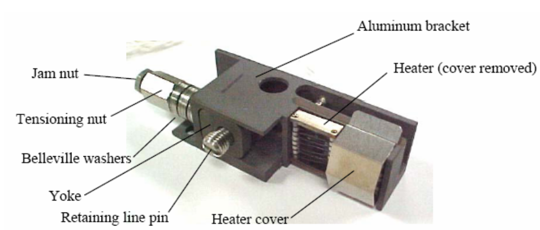

Figure 8: Planetary Systems Line Cutter

The DNEPR LV requires the deployment of the CubeSats within one second of receiving the deployment signal. Using the line cutter as the release mechanism was not adequate. The P-POD was redesigned to incorporate a Qwknut manufactured by Starsys Research Corporation, shown in Figure 9.

In addition to being a very common mechanism with a lot of flight heritage, there are a number of benefits to using the Qwknut.

- Deployment in 35 seconds.
- Guaranteed for 100 deployments.
- Relatively compact.
- Full redundancy.
- Easy installation and interface.
- Resettable.

By being user resettable, the Qwknut proved invaluable during design and testing. Since it could be reset quickly with no added expense, we were able to deploy the device numerous times while modifying our design to reach an optimal configuration. What results is confidence in the system that has undergone extensive environmental and operational testing.

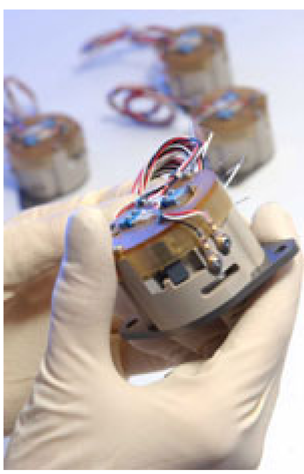

Figure 9: Starsys Qwknut

2.1.7 Inactivity of CubeSats During Launch

There are two problems associated with premature activation of the CubeSats.

- Deployables damaging other CubeSats.
- Close-range transmissions overloading neighboring RF equipment.

To alleviate these problems, CubeSats must remain inactive 15 minutes after deployment. Thereafter, they can enter into Low Power Transmission Mode (LPTM), where a beacon can be transmitted every minute.

Thirty minutes after deployment, CubeSats can enter High Power Transmission Mode (HPTM). In this mode, CubeSats are allowed to use the full functionality of their transreceivers.

As a safety measure, similar rules are in place for deployables. Antennas may be deployed after 15 minutes, whereas larger deployables (i.e. 1m booms) maybe deployed 30 minutes after deployment from the P-POD.

3. LAUNCH VEHICLE INTERFACE

The P-PODs must be mounted to a structural member of the launch vehicle. There are 6, 10-32 screws used as attachment points per P-POD. The P-POD can be mounted on either of the 4 sides.

3.1 Mechanical Interface

A standard adapter ring is used to connect all spacecraft (SC) to the Space Head Module (SHM) of the DNEPR launch vehicle as seen in Figure 10. The P-POD MKII will be attached to the inside of a custom designed adapter ring. One deployment signal will be sent to each P-POD MKII from the upper stage. The design of the adapter can be modified to accommodate different number of P-PODs. One possible configuration of the adapter ring is shown in Figure 11. The wall thickness will be determined based on criteria of deflection and due to dynamic loading. The goal is to decouple the P-PODs from the launch environment as much as possible. The back of the P-POD MKII will mount flush with the bottom surface of the Space Head Module.

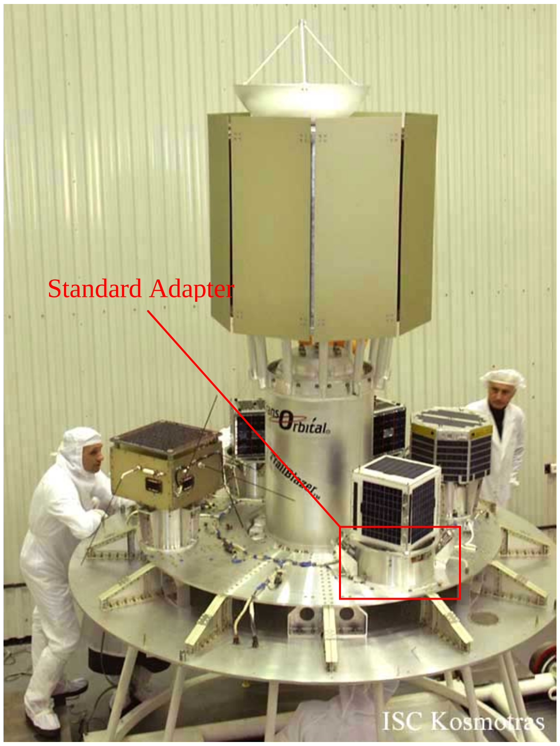

Figure 10: DNEPR Space Head Module

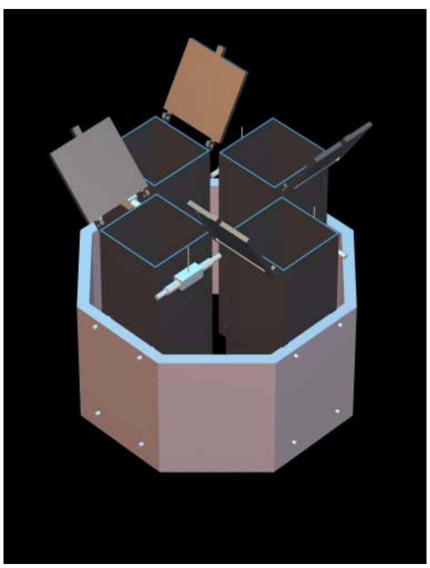

Figure 11: A 4 P-POD configuration.

3.2 Electrical Interface

Separate electrical connections are provided to each P-POD from the DNEPR Launch Vehicle. There are 5 wires between the P-POD and LV as follows:

- Deployment Signal
- Redundant Deployment Signal
- Deployment Signal Ground
- Telemetry Line
- Telemetry ground.

The Starsys release mechanism accepts a standard deployment signal at 5A, 28V. Each P-POD will have its own deployment signal from the LV.

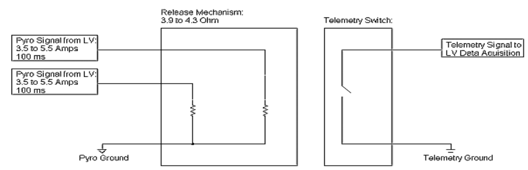

Figure 12: P-POD Electrical Interface

4. EXPORT LICENSING

4.1 ITAR

In order to comply with ITAR regulations for importing and exporting defense articles that is in the US Munitions List in ITAR 22 CFR Section 123.8, which includes satellites and all associated ground support equipment.[8] Cal Poly was required to register with the Department of State at the Directoriate of Defense Trade Commission (DDTC). Once registered with the DDTC Cal Poly was able to submit an export license application and a Technical Assistance Agreement (TAA). These documents contained information as to what hardware and technical knowledge can be transferred between Cal Poly and ISC Kosmotras.

4.2 Documentation to ISC Kosmotras

ISC Kosmotras requires documentation from all satellites. All documents must be sent to Kosmotras 6 months before the launch period.[5] Documentation of each CubeSat was received from each university and compiled by the CubeSat coordinator. Document examples can be provided. Please contact the CubeSat coordinator at http://cubesat.calpoly.edu/contacts.htm

"2.1.1.1 Spacecraft purpose document and its basic specifications;"

This document provides an overview of the satellite and its basic specification. A brief discussion of the CubeSat and an overview of each subsystem is described.

"2.1.1.2 Spacecraft mechanical environmental test results;"

Each university needs to perform environmental testing on their CubeSat, which the results are sent to Cal Poly for review. ISC Kosmotras requires that the environmental characteristics of the P-POD follow the profile of the launch vehicle. Only the environmental data of the P-POD will be sent to ISC Kosmotras.

"2.1.1.3 Spacecraft safety document to include information on its fire-safety and explosion proofness;"

Universities must provide a document stating all explosive and thermal hazards (i.e. batteries). Specifications of components that may be hazardous should be listed.

"2.1.1.4 Statement that the Spacecraft will not be for military purposes from the appropriate government organization (e.g., the national space agency) in the country where ownership will reside after the satellite is placed into orbit;"

Each university must provide an official letter from the government agency associated with the CubeSat stating that the CubeSat will not be used for military purposes.

"2.1.1.5 Written statement from the appropriate government organization (e.g., the national space agency) in the country where ownership will reside after the satellite is placed into orbit stating that the Spacecraft to be launched by the Russian Launch Vehicle will be registered in the national register of space objects;"

US university space registration will be handled by Cal Poly. International universities must obtain a letter from the appropriate government and mailed to Cal Poly.

"2.1.1.6 List of Equipment temporarily imported by Customer for the launch and its mass and dimensional characteristics;"

A detailed list of all ground support equipment that will be provided to Cal Poly for any diagnostic testing. The description of all equipment will be used for the export license and will be imported as necessary to the launch facility.

"2.1.1.7 Document on Spacecraft radio frequency bands and maximum levels of UHF emission;"

This is a brief document detailing the uplink and downlink frequencies that the CubeSat has been assigned. This can include bandwidth and power output of the CubeSat. This document needs to be completed upon frequency coordination with IARU.

"2.1.1.8 Spacecraft owner's document on the insurance details."

All CubeSats are under a best-effort basis and is not insured. This has been stated to the launch provider.

5. COORDINATION WITH LAUNCH PARTICIPANTS

5.1 Overview of the Launch Timeline

The following is a preliminary timeline for the DNEPR Winter 2004 project. The following timeline is heavily dependent on the launch date. ISC Kosmotras will inform Cal Poly and other launch participants of a more refined launch date, 2 months prior to the launch period.

May 27, 2003: Technical Discussion with Kosmotras to discuss launch integration details.

August 15, 2003 - November 30, 2003: Initial Memorandum of Understanding with all participating Universities.

April 9 & 10, 2004: CubeSat Fit-Check for all participating universities at Cal Poly.

October 1, 2004: Delivery of CubeSats to Cal Poly for integration and testing.

October – November 2004: Integration and acceptance testing of all Poly-CubeSat Orbital Deployers (P-POD)

September or December 2004: Dimensional and electrical fit-check at Kosmotras facilities.

October-March 2005: Scheduled launch period. Delivery occurs one month before launch date.

5.2 CubeSat Fit-Check

The fit-check was performed 4 to 6 months before the delivery of all CubeSats to Cal Poly. Universities were required to bring a physical external mockup of their CubeSat.

A CubeSat fit-check serves several purposes. First, a fit-check allows developers the chance to actually see the interaction between their CubeSats and the P-POD MKII. During this check, any assumptions and restrictions can be discovered and discussed. The interaction between CubeSats can be investigated further.

Instead of working through Cal Poly Launch Personnel, the developers can talk to the developers of neighboring CubeSats in the P-POD MKII. Any concerns can be directly addressed to the CubeSat developer.

The first CubeSat fit-check was held at California Polytechnic State University on April 9 and 10. The fit-check was coordinated to occur concurrently with the 1st annual CubeSat Developers Workshop. Each fit-check session was located in the Litton Mechatronics Laboratory in the Advanced Technology Labs at Cal Poly, San Luis Obispo. A total of 5 sessions were held, one for each P-POD MKII. Due to ITAR concerns, each session was closed to the public and only CubeSat Personnel and the developers involved in each P-POD MKII were allowed to attend.

Figure 13: The Fit-check was held during the 1st Annual CubeSat Workshop

Figure 14: South Korea's CubeSat, HAUSAT-1, is removed from the test pod to proceed with the fit-check.

5.3 Monthly Status Reports

Monthly surveys are emailed to each participating university. This survey provides Cal Poly information to determine whether any university is behind in the development of their CubeSat. All surveys are reviewed and universities are notified on a case by case basis of any concerns on their ability to meet the delivery date to Cal Poly. Monthly status reports are posted online. All participating universities in the DNEPR 2004 launch are encouraged to review their neighboring CubeSats progress. Any questions and concerns can be directed to the universities.

6. COORDINATION OF RF FREQUENCIES

6.1 IARU Coordination of RF Frequencies

The International Amateur Radio Union (IARU) maintains the frequency used by amateur radio operators. They coordinate the use of the radio spectrum for amateur radio operators throughout the world.

Since the IARU International Satellite Forum held in Toronto, Canada on October 19, 2003, IARU has since streamlined their process for coordinating university satellites. All 14 CubeSats participating in the launch were required to resubmit their frequency application to IARU. All CubeSats were coordinated with 2-3 months after resubmitting their application. Not all universities were assigned the frequencies that they requested. To avoid potential problems, future CubeSats should have the ability to modify the frequency of their communication system to accommodate any changes.

6.2 IARU Process

6.2.1 Frequency Coordination Application

Frequency coordination application can be downloaded at:

http://www.iaru.org/satellite/coord-request.html

The process above can take 2-3 months. During this time regular updates can be viewed on the IARU website. Further questions can be forwarded to the IARU coordinator at satcoord@iaru.org.

6.2.2 Notification to the FCC

After receiving the frequency from IARU each university must notify the FCC. To notify the FCC download the SpaceCap program at the link below:

http://www.itu.int/ITU-R/software/space/spacecap/

Complete the SpaceCap form and email directly to the Robert Nelson for review at the FCC International Bureau, Robert.nelson@fcc.gov . Note that you will need to file one SpaceCap form for receiving and one for transmission.

A link budget for your CubeSat must be included as an attachment. Include the call sign, point of contact, address for the receiving groundstation.

7. SATELLITE TRACKING AND COORDINATION

NORAD provides 2 line elements for each satellite. During the initial injection into orbit the CubeSats cannot be individually identified by the tracking information provided by NORAD. Though the information provided by NORAD cannot distinctly identify each CubeSat, having the elements provide the groundstations an approximate area of where specific CubeSats are located.

For the DNEPR launch, all universities have been informed of their position in the P-PODs as well as the deployment sequence of the P-PODs. To increase the probability of locating a CubeSat, all CubeSats have been equipped with beacons (i.e. CW beacons) that will transmit 15 minutes after deployment from the P-POD MKII.

On earth, Cal Poly will create a repository of information for each CubeSat that will provide any university groundstations as well as amateur radio operators the ability to search for satellites after injection into LEO. A web interface will provide universities and amateur radio operators with real time updates of each CubeSat.

Figure 15: 2, 20 feet Yagis antennas provide high gain and directional pointing for satellites.

8. FUTURE WORK

Several milestones are still pending completion for this launch.

- The launch configuration of the P-PODs needs to be finalized with Kosmotras.
- The TAA and export license for all university CubeSats need to be obtained from the state department.
- A technical fit-check needs to be performed at Kosmotras facilities. For this task dimensional models of the P-PODs need to be manufactured. Also electrical equivalents need to be provided to Kosmotras.
- Delivery of all participating CubeSats will occur on October 1, 2004. After delivery a month long campaign of integration and acceptance testing will be performed.

8.1 Acceptance Testing Overview

With the delivery of the participating CubeSats they will be integrated and undergo acceptance testing in a Test Pod provided by Cal Poly, shown in Figure 16. Each P-POD will be integrated in a class 100,000 cleanroom or better. After integration the P-POD MKII will be packaged and be ready for vibration testing. After vibration testing diagnostics of each CubeSat will be performed at Cal Poly. Thermal vacuum testing will be performed on each satellite prior to delivery to Cal Poly. After the completion of acceptance testing the P-PODs will be ready for delivery to ISC Kosmotras.

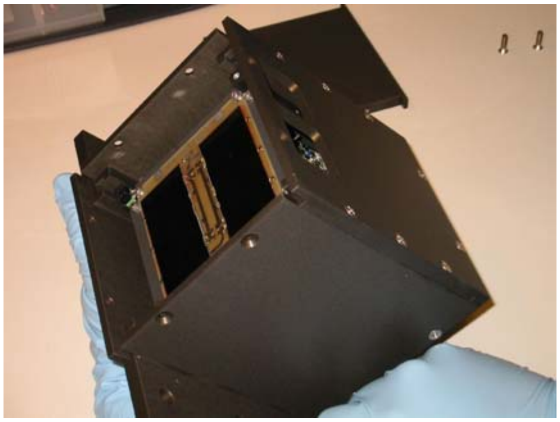

Figure 16: Test Pod used for vibration testing of CubeSats.

8.2 P-POD Acceptance Testing

Acceptance testing will occur at 100% of DNEPR launch vehicle levels. Random vibration testing will occur at 7.323 G_{rms} for 35 seconds and 3.98 G_{rms} for 14 minutes in all axes. This profile will simulate the environmental conditions of the launch vehicle.

8.3 Thermal Vacuum – Bake-out

Bake-out in a thermal vacuum chamber must be performed on each CubeSat prior to delivery to Cal Poly. This will prevent any contamination of neighboring CubeSats within the P-POD. CubeSats using Cal Poly's thermal vacuum chamber will undergo a high vacuum of $5x10^{-4}$ Torr. The bake-out procedure is described as the following:

- The chamber must be in a high vacuum of $5x10^{-4}$ Torr.
- The CubeSat will reach a temperature of 80^oC and soak for 2 hours; then the CubeSat is brought back to room temperature
- The temperature of the CubeSat is again ramped up to 80^oC and soaked again for another 2 hours.
- The CubeSat is brought back to room temperature.

The pressure should remain relatively constant and should not exceed $+1x10^{-4}$ Torr from the pressure at room temperature. If pressure continues to increase another cycle is needed.

9. ACKNOWLEDGMENTS

Cal Poly would like to acknowledge all the sponsors of the CubeSat project that has made this launch possible, not only for Cal Poly but multiple universities from around the world.

- California Space Authority
- California Space Grant Consortium
- Lockheed Martin
- Northrop Grumman
- Office of Naval Research
- QuakeFinder LLC.
- Raytheon
- The Boeing Company

10. REFERENCES

1. Wasserzug, S., "Line Cutter Assemby (LCA) Interface Control Document," PSC DOCUMENT 2000469 Rev A, September 3, 2002 , pp. 1-12 http://cubesat.calpoly.edu/documents/lca_icd.pdf

2. Nason, I., Creedon, M., Lee, S., Puig-Suari, J., "CubeSat Design Specifications Document," Revision VIII, August 2003, pp. 1-6. <http://CubeSat.calpoly.edu>.

3. Bashbush, V., "Characterization of the Internal and External Environments of the CubeSat P-POD and the Test Pod," Masters Thesis, Cal Poly; January 2004

4. Toorian, A., "CubeSat Acceptance Checklist," September 5, 2003, <http://cubesat.calpoly.edu/documents/cubesat_checklist.pdf>

5. ISC Kosmotras, "DNEPR Space Launch System User's Guide," Issue 2, November 2001, http://www.kosmotras.ru/dneprlv.zip

6. Lorenzini, D., "Affordable Access to Space Using Russian Dnepr Launch Vehicle: Twists and Turns in the Road to Export Approval and Launch," 17th Annual AIAA/USU Small Satellite Conference, August 2003

7. Pranajaya, F., et. al., "An Affordable, Low-Risk Approach to Launching Research Spacecraft as Tertiary Payloads," 17th Annual

AIAA/USU Small Satellite Conference, August 2003

8. Society for International Affairs, “International Traffic in Arms Regulations (ITAR),” 22 CFR120-130, June 2001. <http://www.gpoaccess.gov/index.html>

9. Nason, I., Puig-Suari, J., Twiggs, R., “Development of a Family of Picosatellite Deployers Based on the CubeSat Standard,” IEEE Conference 2002

10. Puig-Suari, J., Turner, C., Twiggs, R., “CubeSat: The Development and Launch Support Infrastructure for Eighteen Different Satellite Customers on One Launch,” 15th Annual AIAA/USU Small Satellite Conference, August 2001

11. Armbruster, M., “D10533 Qwknut Operational Manual,” Starsys Research: Boulder, Colorado; December 1, 2003