ELaNa – Educational Launch of Nanosatellite
Providing Routine RideShare Opportunities

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ABSTRACT

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Since the creation of the NASA CubeSat Launch Initiative (NCSLI), the need for CubeSat rideshares has dramatically increased. After only three releases of the initiative, a total of 66 CubeSats now await launch opportunities.

So, how is this challenge being resolved? NASA's Launch Services Program (LSP) has studied how to integrate P-PODs on Athena, Atlas V, and Delta IV launch vehicles and has been instrumental in developing several carrier systems to support CubeSats as rideshares on NASA missions. In support of the first two ELaNa missions the Poly-Picosatellite Orbital Deployer (P-POD) was adapted for use on a Taurus XL (ELaNa I) and a Delta II (ELaNa III). Four P-PODs, which contained a total eight CubeSats, were used on these first ELaNa missions. Next up is ELaNa VI, which will launch on an Atlas V in August 2012. The four ELaNa VI CubeSats, in three P-PODs, are awaiting launch, having been integrated in the NPSCuLite. To increase rideshare capabilities, the Launch Services Program (LSP) is working to integrate P-PODs on Falcon 9 missions. The proposed Falcon 9 manifest will provide greater opportunities for the CubeSat community.

For years, the standard CubeSat size was 1U to 3U. As the desire to include more science in each cube grows, so does the standard CubeSat size. No longer is a 1U, 1.5U, 2U or 3U CubeSat the only option available; the new CubeSat standard will include 6U and possibly even 12U. With each increase in CubeSat size, the CubeSat community is pushing the capability of the current P-POD design. Not only is the carrier system affected, but integration to the Launch Vehicle is also a concern. The development of a system to accommodate not only the 3U P-POD but also carriers for larger CubeSats is ongoing.

LSP considers payloads in the 1kg to 180 kg range rideshare or small/secondary payloads. As new and emerging small payloads are developed, rideshare opportunities and carrier systems need to be identified and secured. The development of a rideshare carrier system is not always cost effective. Sometimes a launch vehicle with an excellent performance record appears to be a great rideshare candidate however, after completing a feasibility study, LSP may determine that the cost of the rideshare carrier system is too great and, due to budget constraints, the development cannot go forward. With the current budget environment, one cost effective way to secure rideshare opportunities is to look for synergy with other government organizations that share the same interest.

A Brief History

Since 2008, NASA has generated an initiative which provides sustainable launch opportunities for CubeSats. The initiative does not guarantee specific launch time frames, but does offer CubeSats the chance to launch. At this time, there have been two ELaNa missions flown with three more scheduled to launch by the end of Fiscal Year 2013. Each of these missions will carry anywhere from three to six P-PODs. It is a tremendous accomplishment that NASA has been able to open up an average of two launch opportunities per year to the CubeSat community where previously there had been none.

The CubeSat Initiative

NASA's CubeSat Launch Initiative (CSLI) provides launch opportunities for small satellite payloads. These CubeSats are flown as auxiliary payloads on previously planned missions. CubeSats are a class of research spacecraft called nanosatellites. The cube-shaped satellites are approximately four inches long, have a volume of about one quart and weigh about 3 pounds. To participate in the CSLI program, CubeSat investigations should be consistent with NASA's Strategic Plan and the Education Strategic Coordination Framework. The research must address aspects of science, exploration, technology development, education or operations. The call for CubeSat proposals is released each August and the selection process is completed in February of the next year.

The ELaNa initiative helps NASA in its pursuit of three major education goals: Strengthening NASA and the Nation's future workforce; Attracting and retaining students in science, technology, engineering and mathematics (STEM) disciplines; and Engaging Americans in NASA's mission.

Who is looking for a Launch?

With the completion of three CubeSat initiative calls, there is now data which shows who is looking for a ride and what orbit they would like to be in. From the three calls, 97 proposals were received, 68 were selected, and, as of today, 23 have been manifested and 8 CubeSats have flown.

	# of Props Submitted	# of Props Seleced	# Manifested	# Launched
1st Selection	6	4	4	3
1st Initiative	16	12	10	5
2nd Initiative	32	20	9	0
3rd Initiative	43	32	0	0
Total	97	68	23	8

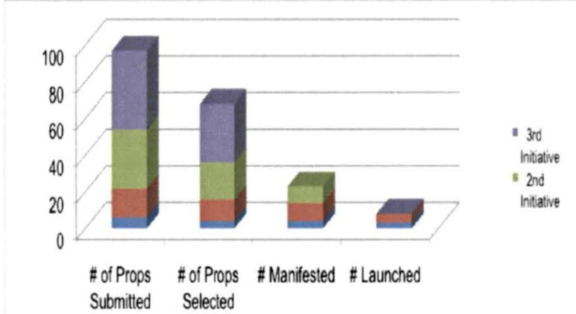

Figure 1 NASA CubeSat Initiative Proposals

The data collected can be used to help clarify where LSP should direct its efforts in launching CubeSats. The figures show that Universities, NASA, DoD and the private sector are all developing CubeSats, and looking to NASA to help them launch their satellites. It was anticipated that Universities would be the largest responders to the CSLI because the ELaNa program is aimed at students and education. However, we are seeing an increase in the number of CubeSats in the both Civil and Military space. With the increasing popularly of the ELaNa program, even the non-profit private sector is joining the team.

	# of Univ	# of NASA	# of DoD	# of Private
1st Selection	4	0	0	0
1st Initiative	12	0	0	0
2nd Initiative	9	5	6	0
3rd Initiative	20	4	7	2
Total	45	9	13	2

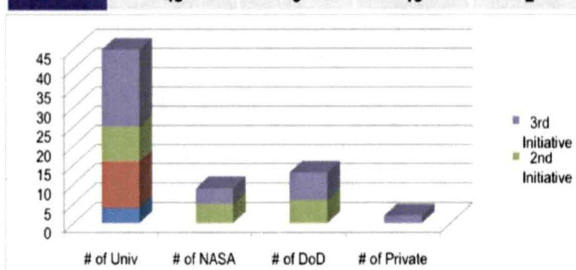

Figure 2 NASA CubeSat Initiative Proposers

The current P-POD is designed to hold a 3U CubeSat, which allows a single 3U or multiple 1Us, 1.5Us or 2Us to be integrated together in one P-POD. LSP must take the CubeSat size into account when manifesting upcoming missions. An equal number of

1U and 3U CubeSats were selected as a result of the first and second CSLI calls. The response to the third call indicates that 3Us have now become the dominant size for CubeSat missions. The third call also produced three 6U candidates. Mapping the trend, this seems to indicate that future CSLI calls will result in more 6U CubeSat proposals; therefore the standard 3U P-POD needs to be modified into a system that can hold twice the current volume of the CubeSats.

	1U	1.5U	2U	3U	6U
1st Selection	4	0	0	0	0
1st Initiative	7	2	0	4	0
2nd Initiative	6	4	3	9	0
3rd Initiative	5	3	4	20	3
Total	23	9	7	33	3

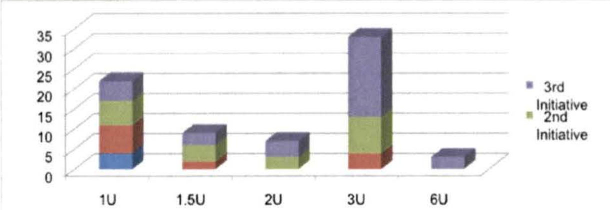

Figure 3 NASA CubeSat Initiative CubeSat Sizes

One of the most important of pieces of data collected is the CubeSats requested orbit in order to perform their science. Currently the P-PODs we launch are auxiliary payloads dependent upon the orbit of the primary mission; the CubeSats are restricted to the primary payload's orbit. CubeSat teams do not have to change their orbit requirements in order to be manifested; however there is a better chance to fly sooner if they can accomplish their mission in a variety of orbits.

	51° at 325km	LEO Sun Sync	LEO Non-Sun Sync	GTO
1st Selection	0	4	0	0
1st Initiative	5	0	6	0
2nd Initiative	3	4	12	1
3rd Initiative	13	4	15	1
Total	21	12	33	2

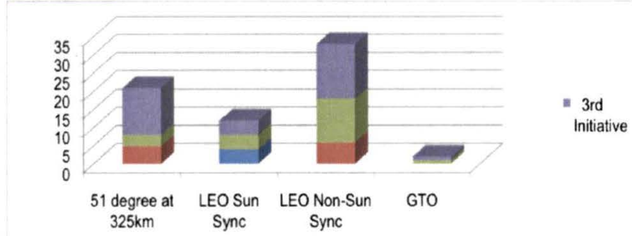

Figure 4 NASA CubeSat Initiative CubeSats by Orbit

Our First Success – ELaNa III

After the loss of ELaNa I on the Glory mission the team rebounded in a professional manner to focus on ELaNa III. Even though telemetry showed that the ELaNa I P-POD had functioned correctly, the ELaNa team knew that the next ELaNa mission had to be a success. ELaNa III was the first flight on a Delta II launch vehicle which meant that the team had to perform the Non-recurring engineering for the development of a carrier system to be mounted to the struts of the second stage of the Delta II launch vehicle.

RAX II (University of Michigan/SRI), DICE (Utah State University), AubieSat-1 (Auburn University), Explore-1[Prime} F2 (Montana State University) and Mcubed/COVE (University of Michigan) were the five CubeSats selected and flown in three P-PODs on ELaNa III. After the successful placement of the primary mission, the Delta II second stage released the CubeSats in an orbit of 420kmx810km at 102 degrees of inclination. Once the CubeSats had been released, each of them started their system power-up in order to begin their mission.

On a typical LSP primary mission the Integration Engineer must manage roughly 125 to 150 ICD requirements verifications. ELaNa III had five CubeSats in three P-PODs and so the number of verifications required grew to well over 500, each of which had to be verified before the Certification of Flight Readiness could be provided.

A month before the CubeSat-integrated P-PODs were to be delivered to the launch provider for integration with NPP, one of the universities encountered several issues with their CubeSat, jeopardizing their place on the mission. The ELaNa III team worked closely with the CubeSat team, assisting them with anomaly resolution and providing rapid turnaround on ICD requirements verifications. The CubeSat was verified ready for integration and was able to remain part of the ELaNa III mission. Just days before launch, another university determined that they had not completed all necessary licensing requirements. Again, the ELaNa team was called upon and was able to complete the required paperwork and secure licensing approval for the university. Had the licensing approval not been granted, the P-POD containing that university's CubeSat would have been pulled from NPP and not been part of the mission.

OUTSat and GEMSat

ELaNa VI is currently integrated on an Atlas V launch vehicle scheduled to launch in August of 2012 and is a subset of a larger CubeSat mission called OUTSat. ELaNa VI consists of 4 CubeSats; CSSWE from the University of Colorado at Boulder, CINEMA from the University of California at Berkeley, CXBN from Morehead State University, and CP5 from California Polytechnic State University, San Luis Obispo. There are seven additional CubeSats from various U.S. organizations, which completes the OUTSat complement. All eight P-PODs are mounted into the NPSCuL structure built by the Naval Postgraduate School in Monterey CA and attached to United Launch Alliance's Aft Bulkhead Carrier (ABC) on the aft end of the Centaur upper stage. Cal Poly and SRI International partnered together to lead the overall integration effort as the Auxiliary Payload Integrating Contractor (APIC). LSP partnered with the National Science Foundation to fly their space weather experiments, CSSWE and CINEMA. By leveraging partnerships with other US Government agencies, NASA LSP is able to increase flight opportunities for educational CubeSats and create a unified payload rideshare effort within the government.

ELaNa VI and OUTSat is the first CubeSat flight opportunity on an Atlas V launch vehicle and, as such, has proven to be the most challenging CubeSat mission thus far. OUTSat and the ELaNa VI mission kicked off in April of 2011, with flight hardware delivery to the launch vehicle in March 2012.

Figure 5: OUTSat Flight Hardware Ready for Delivery

The eleven CubeSats were tested and delivered to Cal Poly in January 2012 and final integration and testing of the entire OUTSat spacecraft was completed in February 2012. The extremely short timeline proved to be difficult, but was made possible by the close working relationship of all the OUTSat/ELaNa team members. Most of the P-POD and NPSCuL hardware was built by full time students taking classes. As with all ELaNa missions, students are heavily involved in all aspects of the mission from developing, assembling, and testing CubeSats payloads to working with NASA and the launch vehicle integration teams.

GEMSat/ELaNa II, the follow on mission to OUTSat/ELaNa VI, will carry an additional eight P-PODs worth of CubeSats on another Atlas V launch vehicle. The mission kicked off in the summer of 2012.

ORS-3

The ORS-3 mission is unique because will carry some 19 small payloads into orbit. NASA is fortunate to be apart of such an exciting opportunity; LSP's ELaNa IV will launch eight more educational CubeSat missions. The ELaNa IV CubeSats were originally manifest on the Falcon CRS-2 flight. When NASA received word that the P-PODs on CRS-2 needed to be de-manifested LSP immediately started looking for other opportunities to launch this complement of CubeSats as soon as possible. When three additional P-POD slots became available on the ORS-3 mission, we were able to place eight of the thirteen CubeSats from the de-manifested CRS-2 flight. The other five CubeSats will be placed on CRS-3.

Cargo Resupply Services Missions

With the success of the first Falcon 9 Dragon flight to the International Space Station, additional CubeSat opportunities are available. ELaNa P-PODs are slated to launch on the upcoming NASA CRS missions. The first mission to be manifested on a Falcon 9 CRS flight will be ELaNa V on CRS-3. The plan is to carry up to five P-PODs per CRS mission to an orbit of approximately 325km circular at 51.6 degrees inclination. While this is not a high orbit for a CubeSat and their life on orbit will be relatively short, it will allow routine access to space for CubeSats. After the Dragon is released, the second stage will reorient and then release the CubeSats. The current estimate for the life on orbit is roughly 30 days during the solar maximum period.

The current schedule has SpaceX launching a least two CRS mission per year with the possibility of more if necessary. This provides the opportunity for ten P-PODs of CubeSats to be launched to the lower orbit on a routine basis. This is great for CubeSat missions that only need the 30 days on orbit to verify or demonstrate a new technology.

Manifesting

Since the beginning of the the iniative, the manifesting process for CubeSat missions has been very successful. The success of the ELaNa program is due in large part to NASA's parnership with the DoD and NRO. These relationships have produced 16 CubeSat missions on three different non-NASA sponsered primary missions.

The CLSI results in a list of seclected CubeSat missions in priority order. LSP uses this list during their nominal manifest process. Using the priority list as a guide, and dependent upon the readiness date and orbit requirements gathered from proposals, LSP manifests CubeSats on missions as opportunities become availible. Once manifested, the CubeSat team is notified to determine if the selected orbit will meet the requirements of the CubeSat mission. If it is determined that the orbit is not acceptible or the CubeSat mission will not be ready in time to support integration the next mission on the list is then contacted.

From Figure 6 you can see the CubeSat missions that are currently manifested and in the integration process. This is a huge accomplishment compared to just two years ago. CubeSat missions have become almost routine and are accepted within the areospace community, including NASA, NRO and DoD, not only because they are an instrument for education but also for having their own uses within each agency.

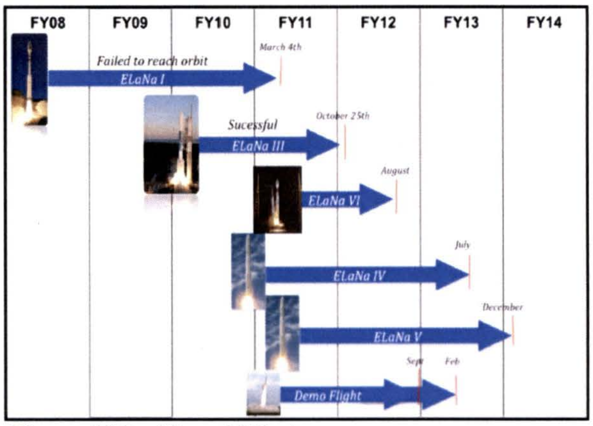

Figure 6 Manifested Missions

Figure 7 shows primany missions for which a launch vehicle has not yet been selected but which have a high probablility of supporting CubeSat-integrated P-PODs. After a launch vehicle is selected, the mission will then be considered for potentail CubeSat missions.

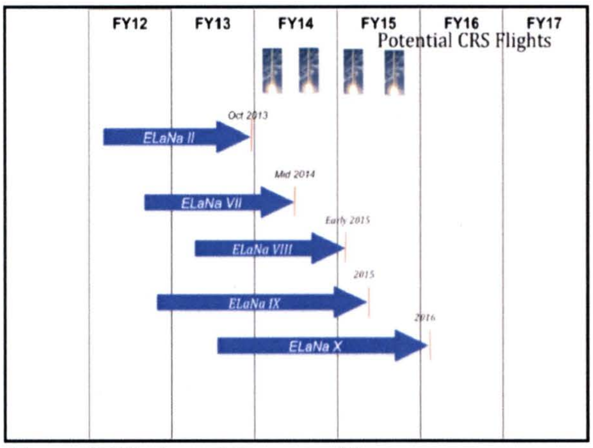

Figure 7 Mission of Opportunities

There can be Launch Delays

Because the CubeSat mission is a part of a primary mission any delays to the primary results in a delay for the CubeSats. LSP discusses this with the CubeSat teams during their first meeting to ensure that they understand the possibility of delays to the original launch date. The ELaNa I CubeSat teams experienced this first hand with the Glory. Due to the failure of the OCO Taurus flight, the Taurus vehicle had to be evaluated to determine the cause of the failure. These evaluations caused a 12 month delay in the Glory mission.

Another issue that CubeSat missions face is, as secondary missions, they are the first to be removed if there is a mass concern. The primary mission of CRS flights is to deliver cargo to the ISS. If additional mass is required for the cargo, the P-PODs may be removed from the mission, as happened on CRS-2.

How Does the Future Look?

While NASA has primarily used government launch vehicles to provide rides for its selected CubeSats, it may be time to explore the possibility of placing NASA CubeSats on commercial missions. In order to fly on a Government Launch Vehicle, the CubeSat and P-POD must not increase the baseline risk to the primary spacecraft or launch vehicle. To prove that the CubeSats meet this requirement a tremendous amount of extra work is required by all parties. Additionally, the CubeSats are limited to orbit of the primary mission; often the CubeSat teams would prefer a different orbit, if available. The growing market of commercial U.S. launch vehicles may give CubeSats an additional flight options. Also being considered is the possibility of a dedicated Nano Launch system for CubeSats.

So how does ELaNa move forward? How do we fly CubeSats with unique requirements and orbits? How do we remove the 'do no harm to the primary/launch vehicle' requirement?

Have our own Nano-Launcher. That's right, have our own dedicated launch vehicle where CubeSats are primary. The CubeSats would no longer have to abide by the restrictions levied by a primary rideshare. CubeSats could be placed in an orbit where they can meet their science requirements sooner and complete their mission earlier, thus reducing orbital life requirements. Development of a Nano Launcher system is currently underway and is expected to be completed in FY 14.

6U CubeSat Carrier

The CubeSat Standard was started in 1999 by Professor Bob Twiggs and Dr. Jordi Puig-Suari and primarily focused on allowing academic institutions the ability to build a satellite within the 2-4 year academic career using available COTS components. With the advancement in CubeSat complexity over the past decade and the growing number of CubeSats performing "real operational and scientific" missions, there is the need to look at a new CubeSat form factor. This added volume and mass would allow for a much needed increase in power and propulsion capability, as well as payload volume. The new 6U CubeSat essentially combines two 3U CubeSats side by side, creating an approximate 10cm x 20cm x 30cm volume. This is the next logical step on the path to CubeSat growth since it would have the least amount of impact on existing CubeSat launch opportunities. The 6U volume cannot be supported by some of the current CubeSat launch capabilities, but efforts like the ABC/NPSCuL, CRS, and ORS/CubeStack launches provide opportunities to fly 6U CubeSats. The drawback of the 6U CubeSat will be an increase in the overall cost of the project, including integration to the LV and launch. NASA LSP and Cal Poly are currently working to integrate these new 6U CubeSat Deployers onto future missions, one of which is built by Planetary Systems Corporation. The 6U CubeSat standard is not meant to replace the already existing and successful 1U-3U CubeSat standard, but to increase options for developers IF they need extra mass and volume.

Summary

One of NASA's key goals and visions is strengthening the Science, Technology, Engineering, and Mathematic disciplines. The CubeSat Initiative and the ELaNa mission are a testament to how STEM can be increased within the U.S. educational system. For years students were building CubeSat without the potential of launching. However, because of the lack of flight opportunities, the rate at which CubeSats were being developed dramatically diminished until CubeSats almost vanished. When the first request for CubeSats, for the Glory mission, was sent out only six responses were received. In the 2011 CubeSat Initiative Call, NASA received 43 proposals requesting an opportunity to fly.

With the emergence of ELaNa, CubeSat teams know that launches will be available on a routine basis to support their development efforts. Educational CubeSats have flown on Taurus XL and Delta II launch vehicles and are manifested to launch on Atlas V and Falcon 9 in the near future. This is quite an achievement for a community that just a few years ago had no flight opportunities in the United States.

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LAUNCH SERVICES PROGRAM

ELaNa

Educational Launch of Nanosatellite Providing Routine RideShare Opportunities

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ELaNa Project Manager

Launch Services Program

NASA

Roland Coelho

PPOD Project Manager

California Polytechnic State University

"Launching Education into Space"

ELaNa

Educational Launch of Nanosatellite

"Science, Technology, Engineering, and Mathematics"

"Launching Education into Space"

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ELaNa III Launched Oct 25 2011

LAUNCH SERVICES PROGRAM

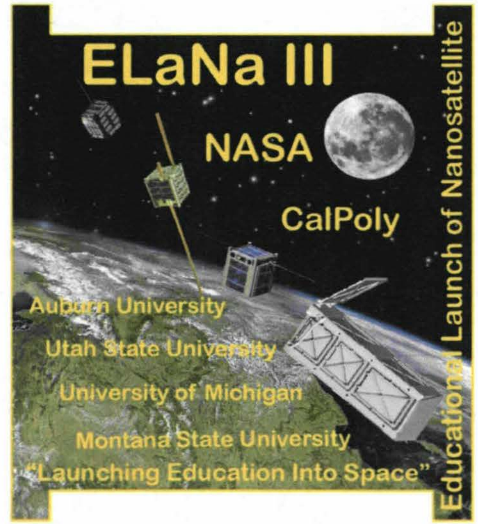
PRIME
EXPLORER
SPACE SCIENCE AND ENGINEERING LABORATORY
MONTANA STATE UNIVERSITY

DICE
ASTRA
USU/SDL
Clemson
Embry Riddle

AubieSat-I
AU

DELTA 2 | VANDENBERG AFB, CALIFORNIA | ELaNa
RADIO AURORA EXPLORER
RAX
MMXI
UNIVERSITY OF MICHIGAN | SRI INTERNATIONAL
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATIONAL SCIENCE FOUNDATION

M-CUBED
MICHIGAN MULTIPURPOSE MINISAT



ELaNa VI Schedule Aug 02, 2012

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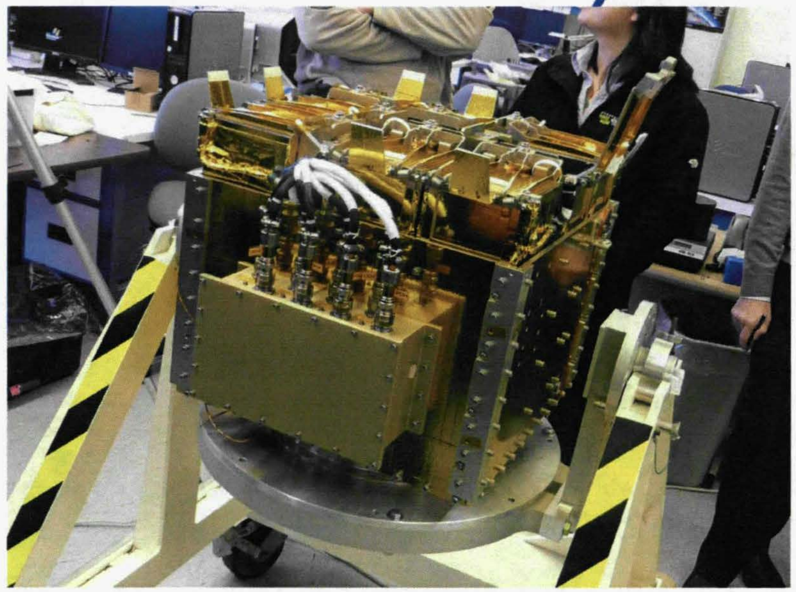
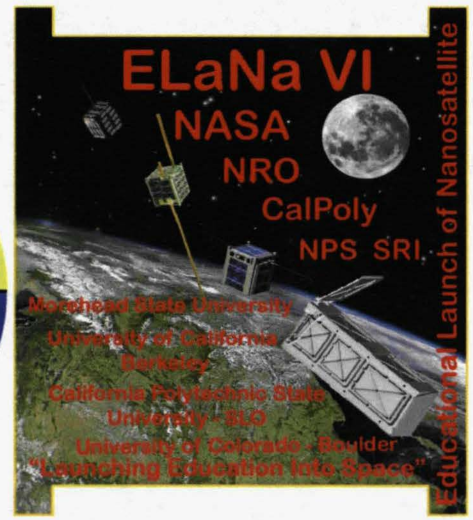
LAUNCH SERVICES PROGRAM



Space Sciences Laboratory, UC Berkeley
Kyung Hee University of South Korea
Puerto Rico Space Grant Consortium
Imperial College London



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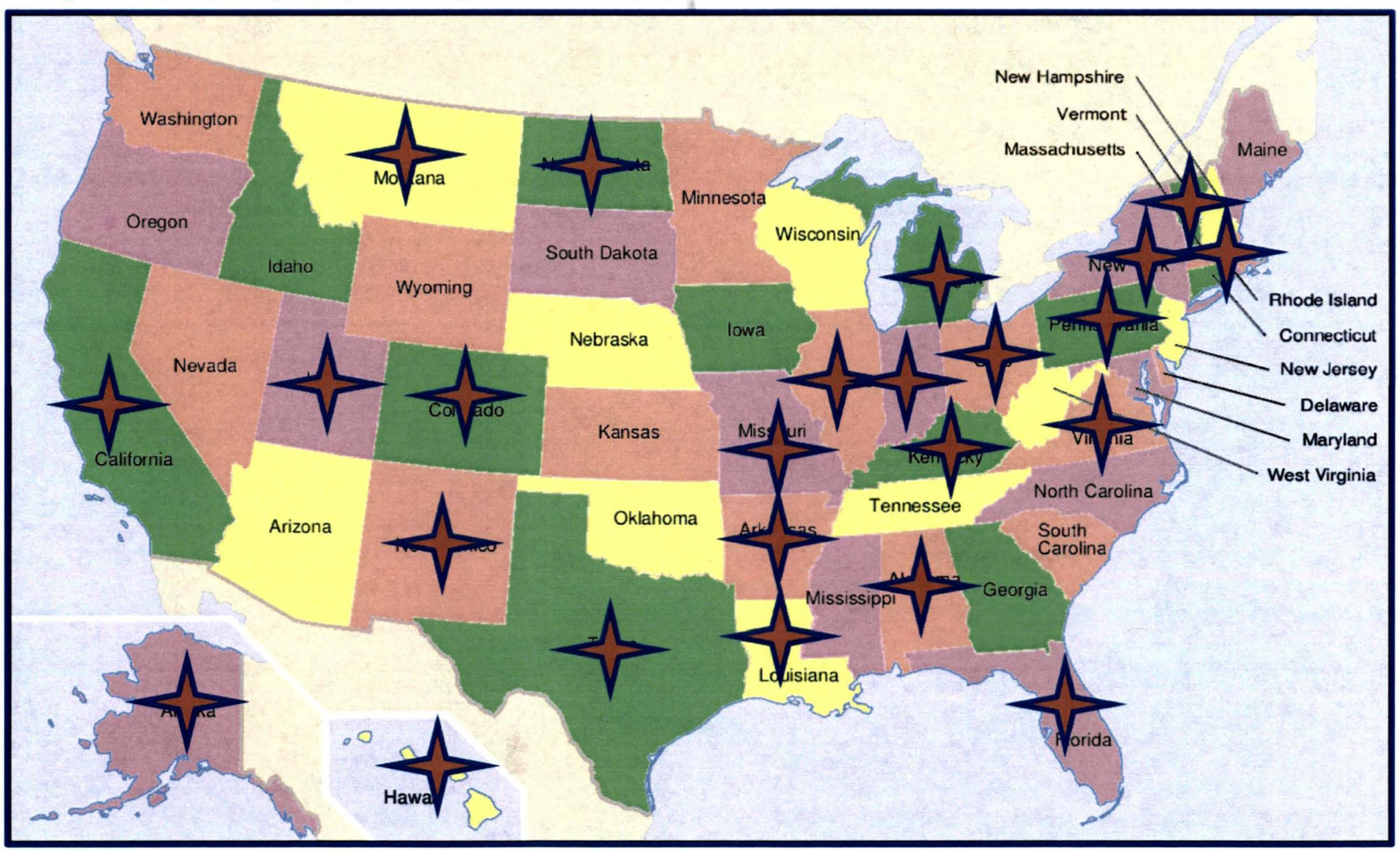
NASA CubeSat Initiative

LAUNCH SERVICES PROGRAM

3 Calls for CubeSats has reached 24 States
68 CubeSats Selected with 25 Manifested



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NASA CubeSat Initiative

LAUNCH SERVICES PROGRAM

Proposals				
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By Orbit				
	51° at 325km	LEO Sun Sync	LEO Non-Sun Sync	GTO
Total	21	12	33	2

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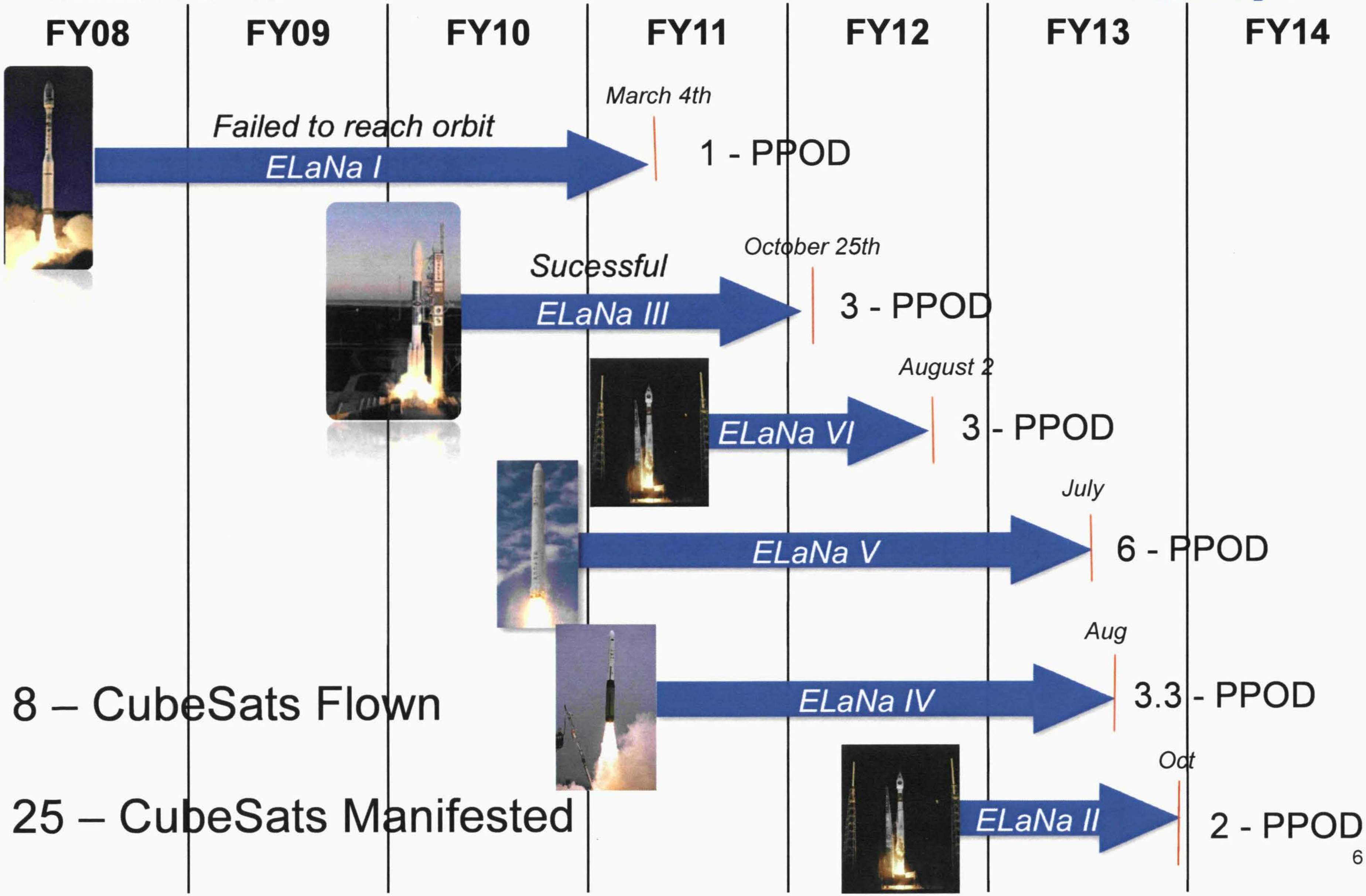
Manifested Missions



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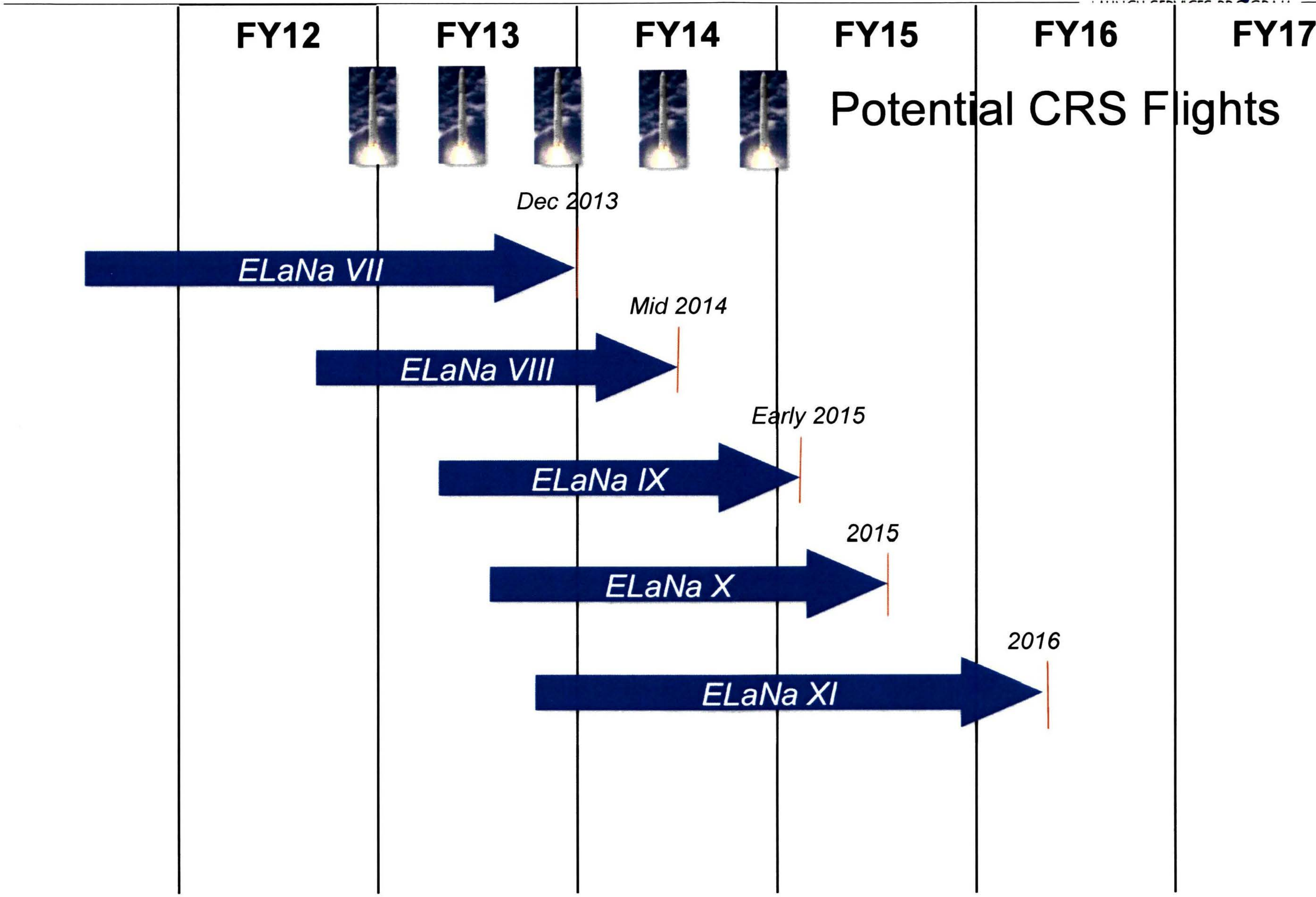
Mission of Opportunities



Questions