CubeSat Launch Initiative Overview and CubeSat 101

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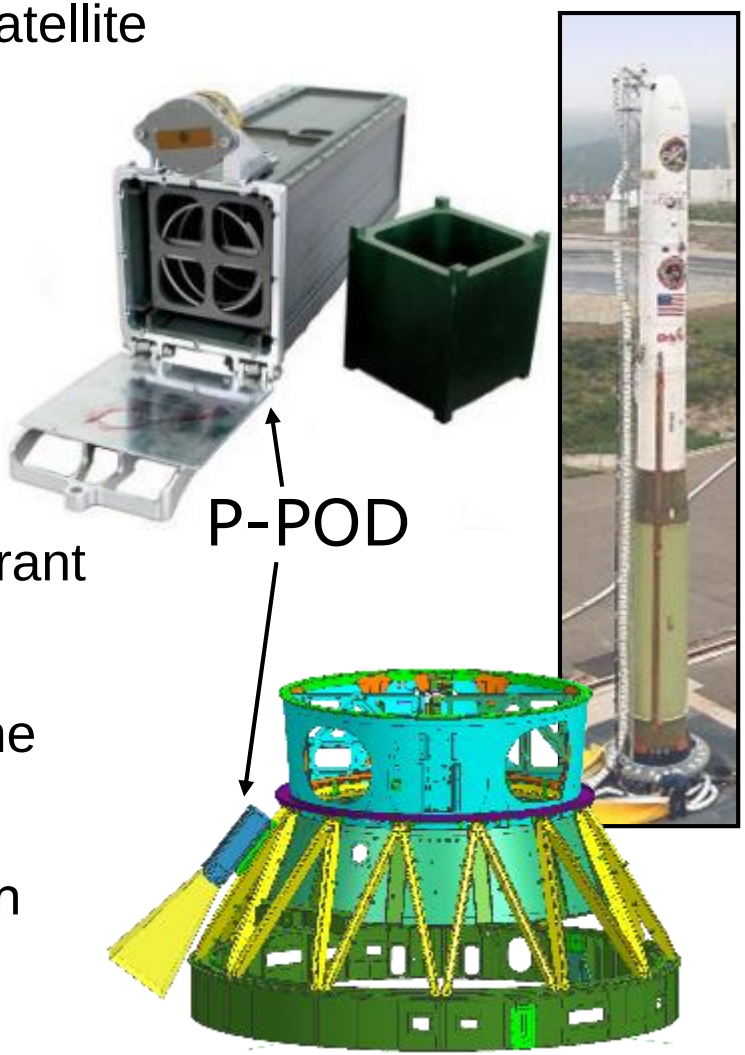
What is a CubeSat?

- A CubeSat is a type of space research nanosatellite
- The base CubeSat dimensions are 10x10x11 centimeters (one "Cube" or "1U"), or approximately four inches
- CubeSats are typically 1U, 2U, 3U, or 6U in volume and typically weigh no more than 1.33 kilogram (about 3 pounds) per 1U Cube
- CubeSats are typically low-cost, high risk-tolerant payloads
- Deployed from standard deployers, such as the “Poly-Picosatellite Orbital Deployer (P-POD)”
- P-POD’s versatile, small profile, tubular design holds three 1U CubeSats or can integrate CubeSats of different lengths (i.e., up to 3U)

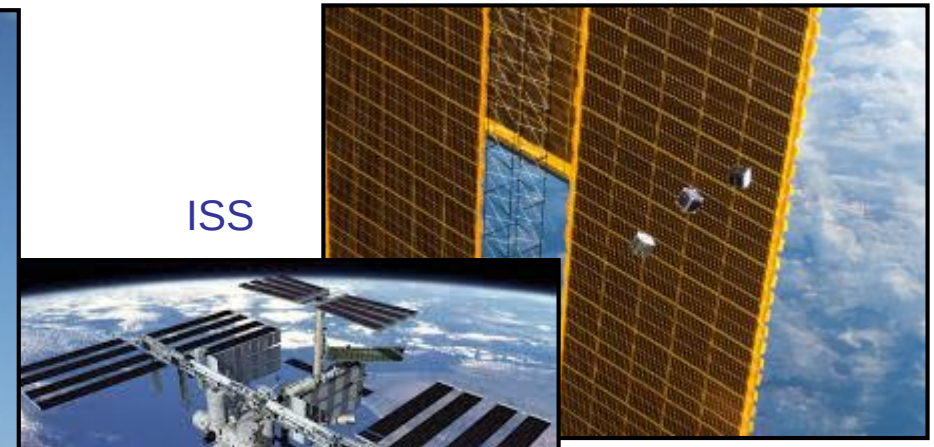


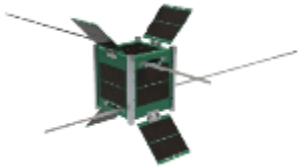
CubeSat Launch Initiative

NASA's CubeSat Launch Initiative (CSLI) provides launch opportunities to educational institutions, non-profit organizations and NASA Centers who build small satellite payloads that fly as auxiliary payloads on previously planned launches or commercial mission or as International Space Station deployments.

NASA
DoD
NRO

ISS





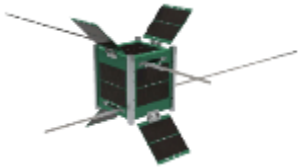
Benefit

Benefit to Educational Organizations and Non-profits:

- Enables students, teachers and faculty to obtain hands-on flight hardware development experience
- Advances the development of technologies
- Provides mechanism to conduct scientific research in the space environment
- Provides meaningful aerospace and educational experience

Benefit to NASA:

- Promotes and develops innovative public-private partnerships
- Provides a mechanism for low-cost technology development and scientific research
- Enables the acceleration of flight-qualified technology assisting NASA in raising the Technology Readiness Levels (TRLs)
- Strengthens NASA and the Nation's future STEM workforce



How It Works

NASA Announcement of Opportunity

- NASA solicits proposals through an Announcement of Opportunity (AO)
- Educational Organizations, Non-Profits and NASA Centers submit proposed CubeSat Missions in response to AO

NASA Review

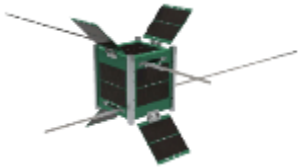
- A NASA Selection Committee made up of members of HEOMD (including the Launch Services Program), Space Technology Mission Directorate, Science Mission Directorate, and Education reviews proposals
- Selection Committee makes final recommendations on CubeSats
- NASA announces selection recommendations

Selectees Develop/Design/Build CubeSat

- Selectee builds satellite
- Selectee raises all funds necessary for satellite construction
- Selectee provides NASA completed satellite for integration for launch

NASA Assigns CubeSats to Manifested Launches

- NASA manifests CubeSat on available flights using excess lift capacity
- Cooperative Research and Development Agreement executed by NASA



Payload Eligibility

Benefit to NASA

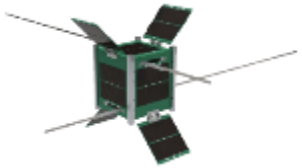
- Investigation must demonstrate a benefit to NASA by addressing goals and objectives of the NASA Strategic Plan and/or the NASA Education Vision and Goals.

Merit Review

- Prior to submission each CubeSat investigation must have passed an intrinsic merit review. In the review, goals and objectives of the proposed investigation must be assessed to determine scientific, educational or technical quality of the investigation.

Feasibility Review

- Prior to submission each CubeSat investigation must have passed passed a feasibility review in which the technical implementation, including feasibility, resiliency, risk and probability of success, was assessed.



Selection Process

NASA Selection Recommendation Panel
(1 representative from)

Science

Space Technology

Human Exploration and Operations

Education

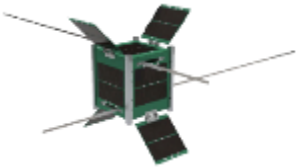
LSP provide technical expertise for compliance with LSP-REQ-317.01

Panel reviews combined scores and collectively determines selection* of missions and prioritization

*NASA sponsored missions that have already been reviewed and funded are automatically considered selected and the panel determines manifest prioritization

Copies of final CLSI manifest list are provided to SMD, STMD, Education and HEOMD (LSP, Spectrum)

Launch Services Program (LSP) is responsible for implementation of the prioritized list for NASA and commercial integration on ELVs and ISS deployments



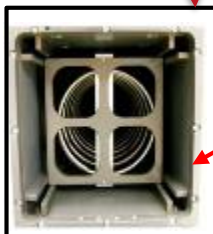
Post Selection

CubeSats are Developed/Designed/Built

CubeSats are placed in dispenser

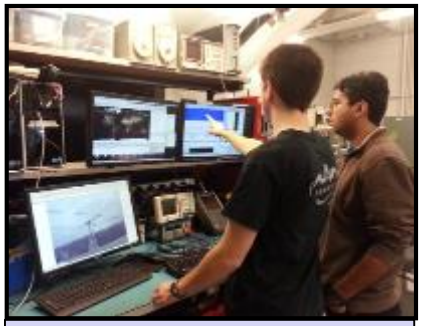
Dispenser is integrated on the Launch Vehicle

Mission Launches



Deployment spring and pusher plate

Signal Sent to LV, spring-loaded door is open, CubeSats deployed



Students or Center track and operate CubeSat from Ground Station

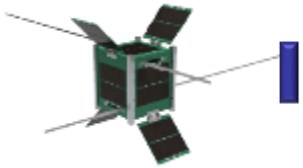
CubeSat burns up on re-entry after completion of mission

Students or Center analyze data, write technical papers, provide results and data to NASA

OA-4 Launch

ELV Deployment

ISS Deployment



Implementation Partnerships

Other US Government Agencies/Departments

- NASA has established inter-agency agreements with United States Air Force (USAF) and National Reconnaissance Office (NRO) for CubeSat integration onto non-NASA launches
- NASA assists non-government CubeSat developers in seeking Federal Aviation Administration (FAA), Federal Communications Commission (FCC) and National Oceanic and Atmospheric Agency (NOAA) licenses (as necessary)

Commercial Entities

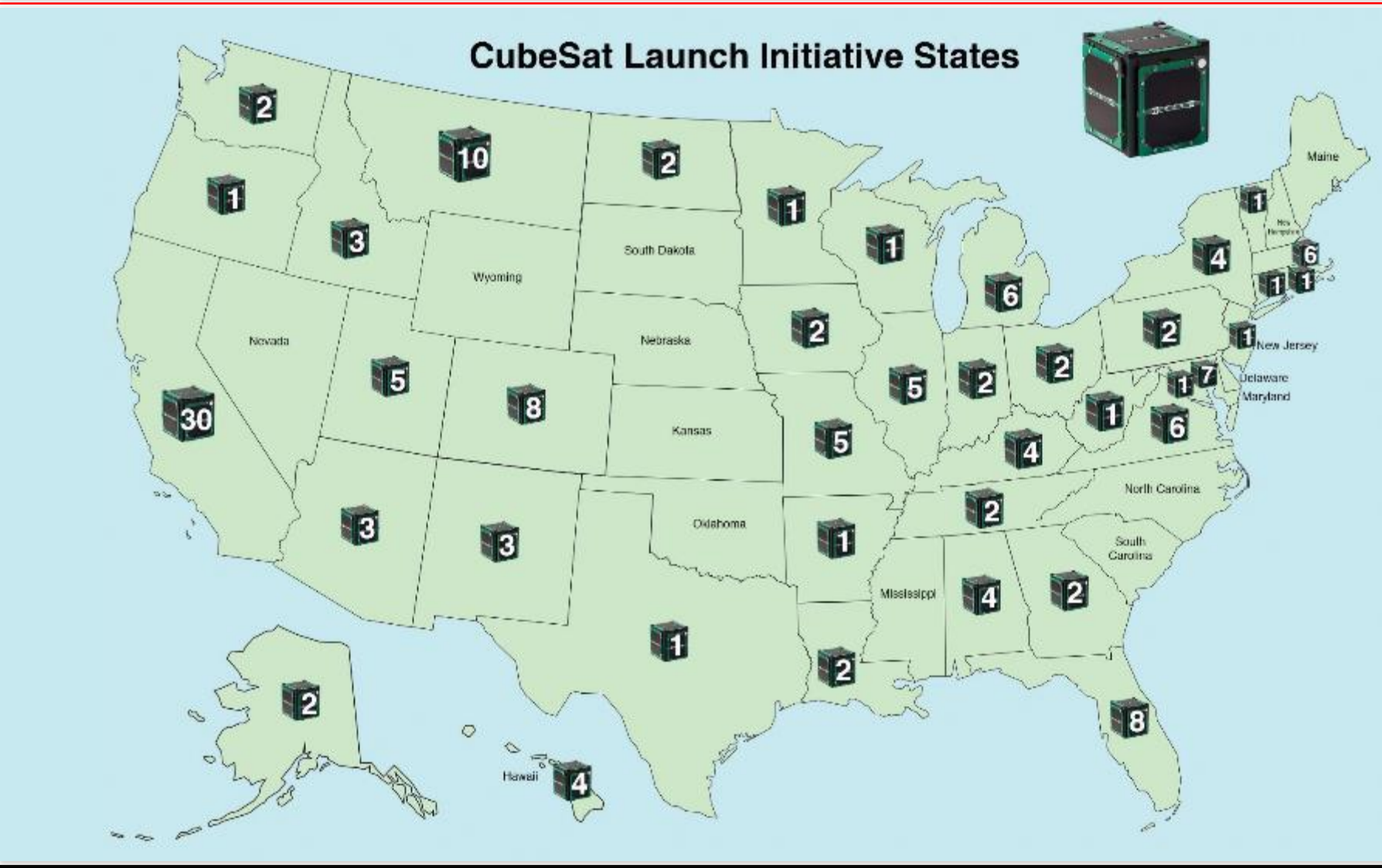
- NASA has established CubeSat Dispenser Hardware and Integration Services (CSDHISC) IDIQ contract to provide integration hardware and perform integration activities

Educational and Non-Profit Institutions

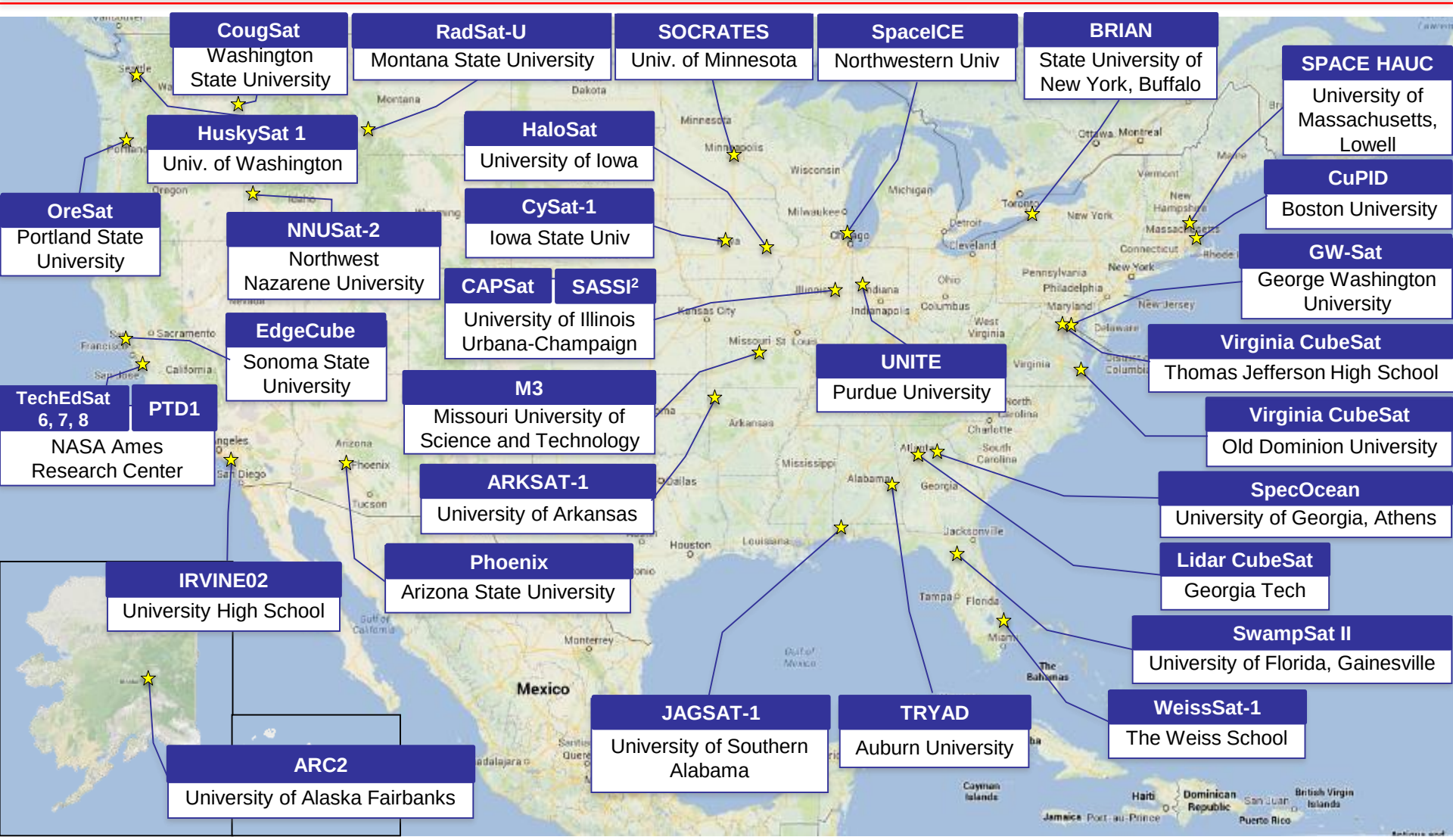
- Public-Private Partnerships – Cooperative Research and Development Agreements (CRADA) to defines terms and responsibilities of each party
- 151 projects involving 68 universities, 6 non-profits and 7 NASA Centers

2009–2017 CubeSat

150 Selections – 85 Organizations – 38 States

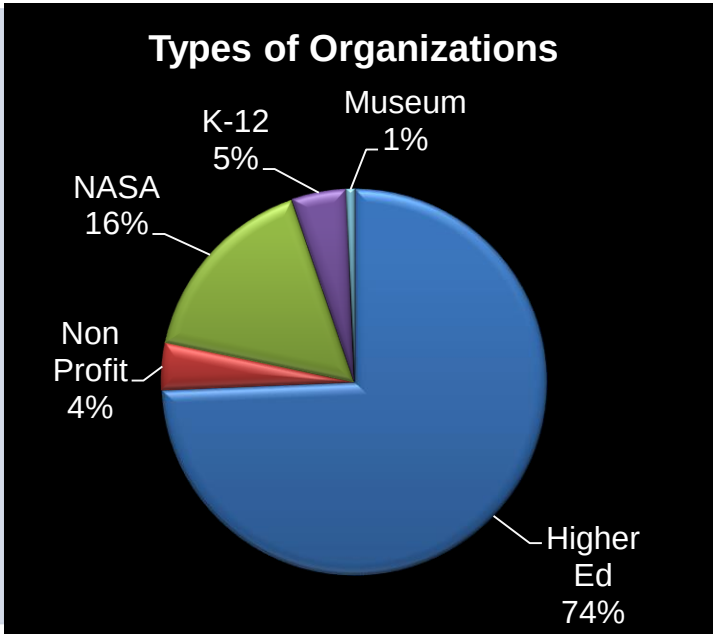


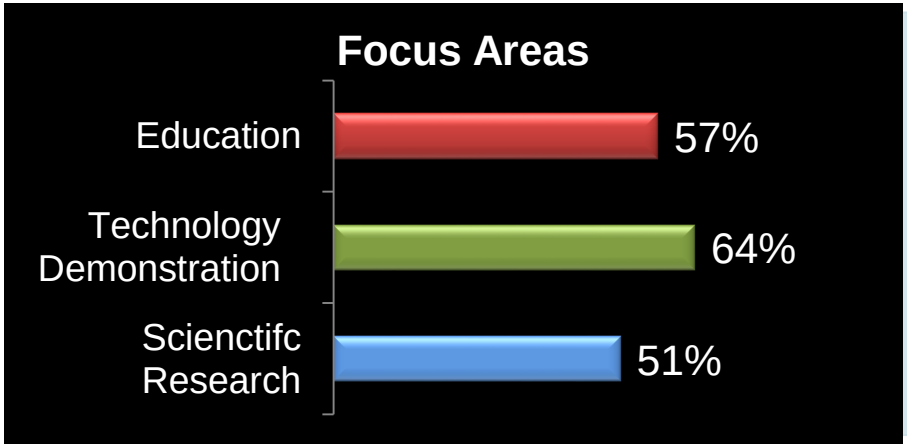
CubeSat Launch Initiative 2017 Selections



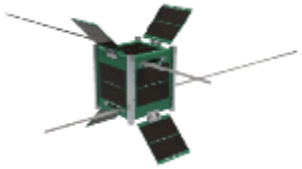
Selectee Demographics

- Majority of proposing organizations are universities
- 85 Unique Organizations Selected
- 42% of the universities utilize NASA Space Grant and Experimental Program to Stimulate Competitive Research (EPSCoR) Funding
- TJ3Sat, first CubeSat built and launched into space by a high school
- STMSat-1, first CubeSat built and deployed into space by a primary school





- Biological Science
- Earth Science
  - »Snow/Ice Coverage
- Near Earth Objects
- Orbital Debris Tracking
- Space Based Astronomy
- Space Weather
- In-Space Propulsion
- Space Power
- Radiation Testing
- Tether Deployment
- Solar sails
- Material Degradation
- Additive Manufacturing



Launch Vehicles

Super Strypi
Minotaur I
Taurus XL
Delta II
Antares
Falcon 9
Atlas V

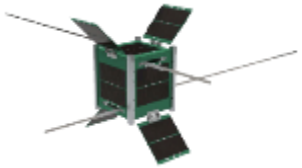
58.3 m

17 m

ROCKET LAB

Virgin GALACTIC

	A	B	C	D	E	F	TOTAL BY STATUS
MANIFESTED	9	0	3	0	13	22	47
LAUNCHED	12	13	1	18	10	0	54
TOTAL	**21**	**13**	**4**	**18**	**23**	**22**	**101**



Past Missions

CubeSat Mission	Primary Mission	Launch Date	Dispensers	CubeSats
ELaNa I	Glory	Mar 4, 2011	1	3
ELaNa II	NROL-39*	Dec 5, 2013	2	5
ELaNa III	NPP	Oct 28, 2011	3	5
ELaNa IV	ORS-3*	Nov 19, 2013	4	11
ELaNa V	CRS SpX-3	Mar 16, 2014	4	5
ELaNa VI	NROL-36*	Sep 13, 2012	3	4
ELaNa VIII	ORB-3	Oct 21, 2014	NanoRacks	1
ELaNa X	SMAP	Jan 30, 2015	3	4
ELaNa XI	AFSPC-5	May 20, 2015	1	1
ELaNa XII	NROL-55*	Oct 8, 2015	2	4
ELaNa VII	ORS-4*	Oct 29, 2015	2	2
ELaNa IX	OA-4	May 16, 2016	NanoRacks	3
ELaNa XVII	OA-7	April 18, 2017	NanoRacks	3
ELaNa 22	SpX-12	August 14, 2017	NanoRacks	3
			Total Launched	**54**

* Consistent with the National Space Policy of 2010, NASA has agreements with the national security space community to leverage our respective launch capabilities.

Missions Examples

CSSWE
University of Colorado – Boulder, Co.

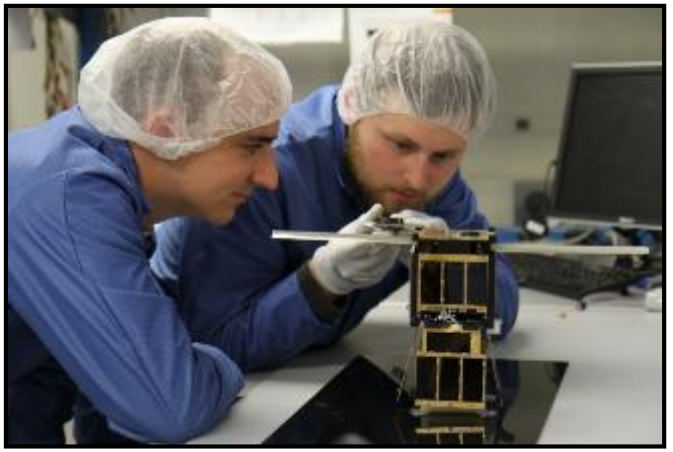
- Measure the directional flux of Solar Energetic Protons (SEPs) and Earth's radiation belt electrons in support of NASA's Radiation Belt Storm Probe Mission
- Space Weather - Heliophysics
- Payload: Relativistic Electrons and Proton Telescope

GOAL: Understand the relationship between SEPs flares and coronal mass ejections

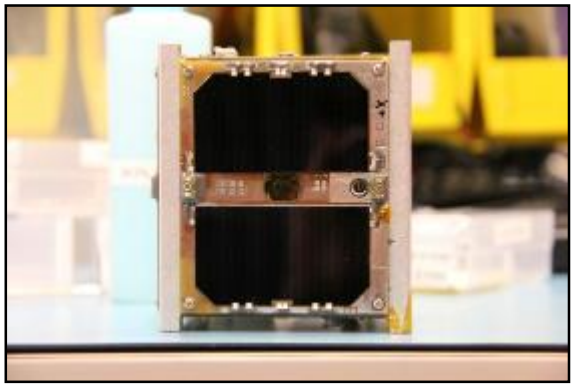
KySat-2
University of Kentucky – Lexington, Ky.
Morehead State University – Morehead, Ky.

- Test components of a novel attitude determination system called a Stellar Gyroscope that uses sequences of digital pictures

GOAL: Determine the three-axis rotation rate of the satellite



Missions Examples



M-Cubed
University of Michigan – Ann Arbor, MI.

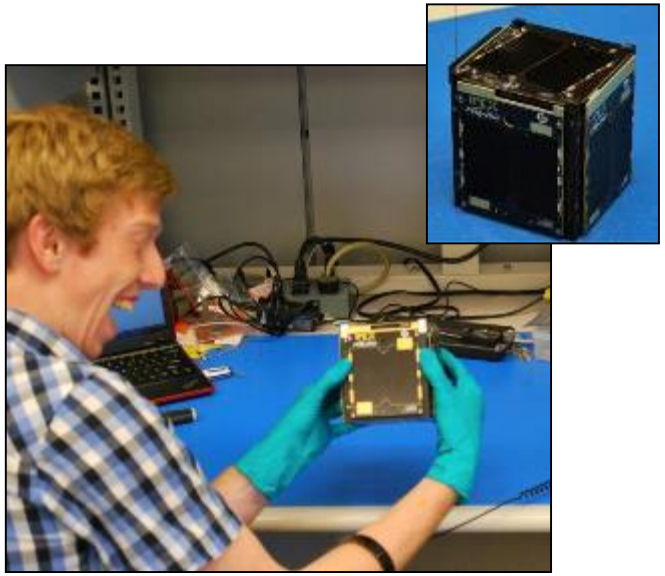
- Obtain mid-resolution imagery of the Earth's surface and carry the JPL/Caltech CubeSat On-board processing Validation Experiment (COVE)

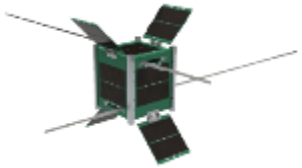
GOAL: COVE will advance technology required for real-time, high data-rate instrument process for future Earth Science

IPEX
JPL/Cal Poly – Pasadena, Calif

- Demonstrate Intelligent Payload Module (IPM) technologies including autonomous onboard instrument processing, downlink operations, and automated ground operations

GOAL: Validate IPM technologies which is a baseline for the HyspIRI Decadal Survey Mission



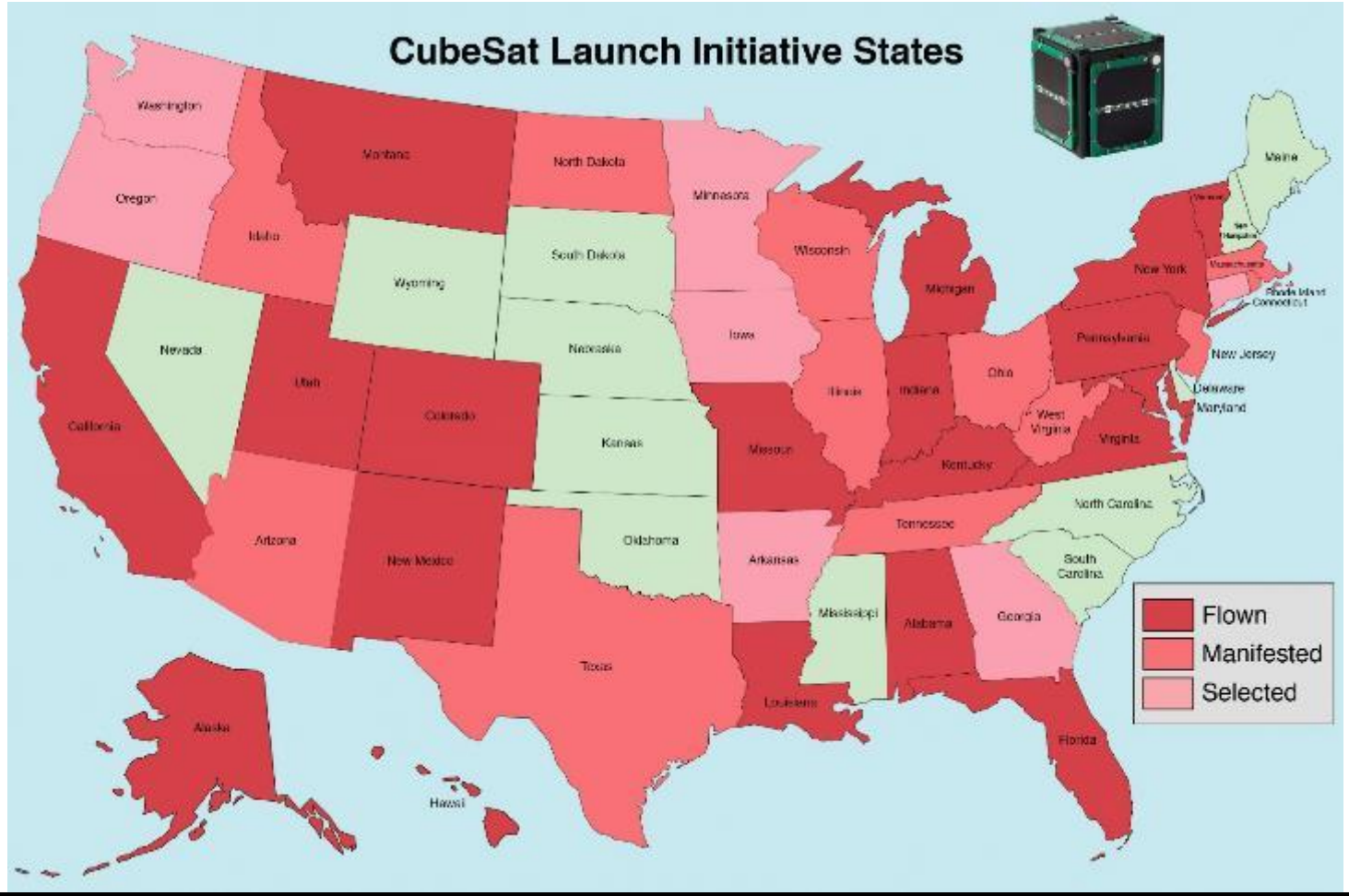


ELaNa Mission Schedule

CubeSat Mission	Primary Mission	Launch Vehicle	NET Launch Date	Cubes
ELaNa XIII	OA-8	Antares II	October 11, 2017	3
ELaNa XIV	JPSS-1	Delta II	November 10, 2017	5
ELaNa 21	SpX-14	Falcon 9 FT	January 26, 2018	1
ELaNa 23	OA-9	Antares II	March 14 2018	9
ELaNa XV	STP-2	Falcon 9 Heavy	April 30, 2018	3
ELaNa XIX	VCLS	Rocket Lab	1 Q 2018	10
ELaNa XX	VCLS	Virgin Galactic	TBD 2018	12
ELaNa XVIII	ICESat- 2	Delta II	September 12, 2018	4
			Total Manifested	47

50 CubeSats from 50 States

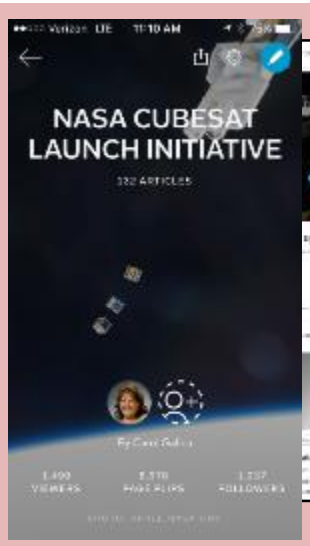
Goal to broaden NASA's CubeSat Launch Initiative to reach all states by targeting the 12 "rookie states" that have had no previous presence in space.



CubeSat Launch Initiative
Social Media

Flipboard

Collection of of media articles

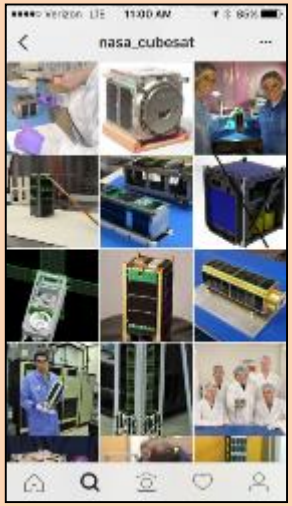


flickr

Collection of images of all ELaNa launched CubeSats

Instagram

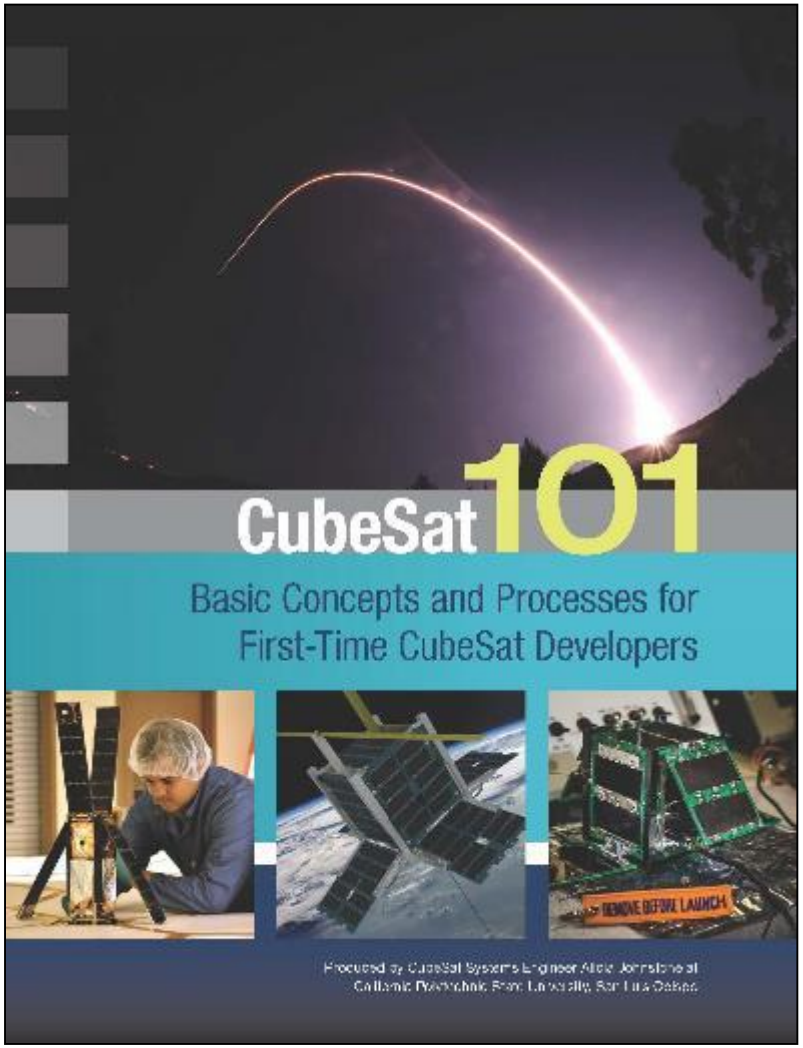
Images of all ELaNa launched CubeSats

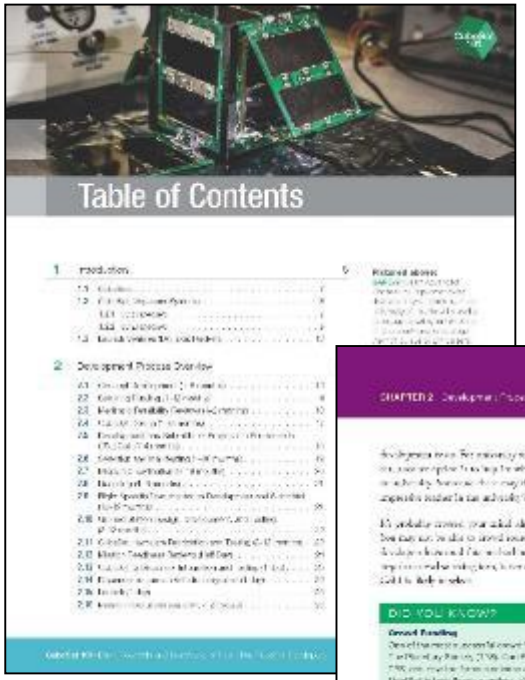


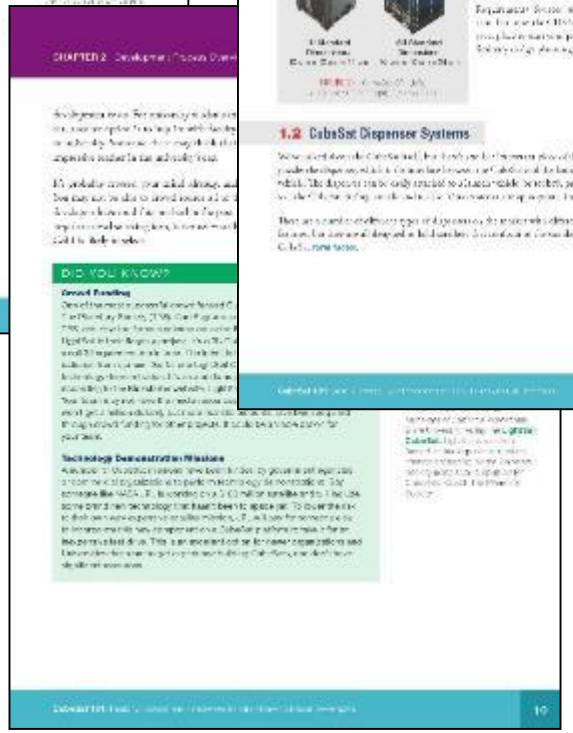
http://www.nasa.gov/directorates/heo/home/CubeSats_initiative

http://www.nasa.gov/mission_pages/smallsats/elana/index.html

CubeSat 101 Document (coming soon)



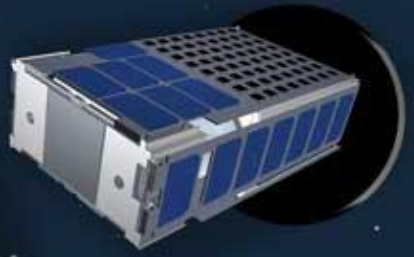




EXPLORATION MISSION-1: LAUNCHING SCIENCE & TECHNOLOGY SECONDARY PAYLOADS

13 CUBESAT EXPLORERS

GOING TO DEEP SPACE WHERE FEW CUBESATS HAVE EVER GONE BEFORE.



ORION STAGE ADAPTER

SUPPORTS BOTH PRIMARY MISSION AND SECONDARY PAYLOADS

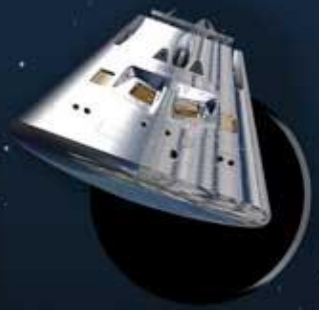
1

PRIMARY MISSION

TESTING SLS AND ORION

SPACE LAUNCH SYSTEM (SLS)

LIFTS MORE THAN ANY EXISTING LAUNCH VEHICLE



ORION SPACECRAFT

TRAVELING THOUSANDS OF MILES BEYOND THE MOON, WHERE NO CREW VEHICLE HAS GONE BEFORE

2

SECONDARY PAYLOADS

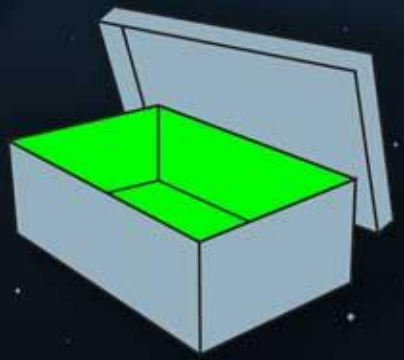
THE RING THAT WILL CONNECT THE ORION SPACECRAFT TO NASA'S SLS ALSO HAS ROOM FOR 13 HITCHHIKER PAYLOADS

SHOEBOX SIZE

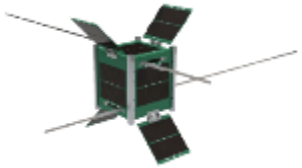
PAYLOADS EXPAND OUR KNOWLEDGE FOR THE JOURNEY TO MARS

AVIONICS

(SELF-CONTAINED AND INDEPENDENT FROM THE PRIMARY MISSION) SEND CUBESATS ON THEIR WAY

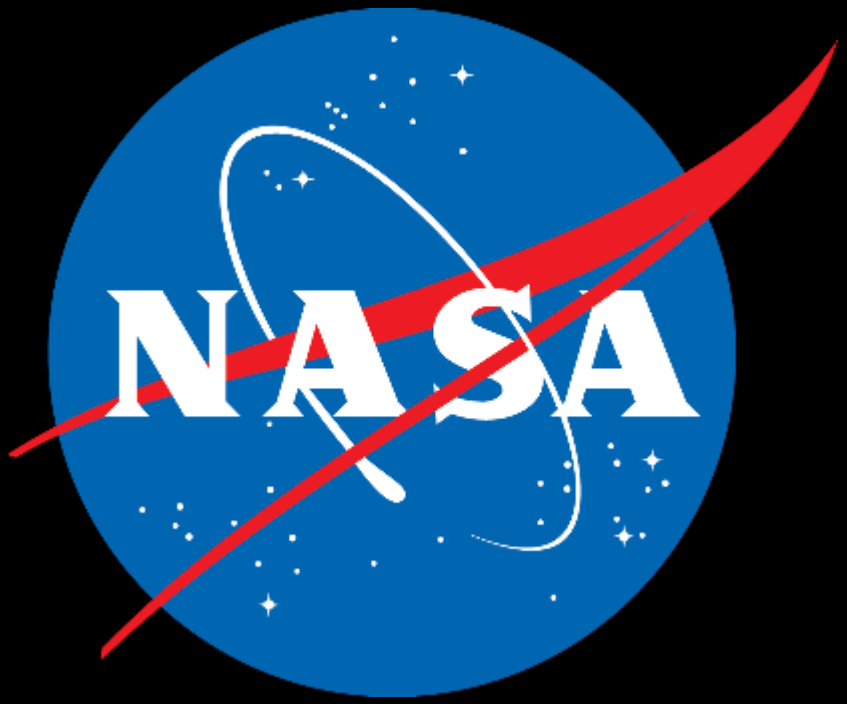


#RIDEONSLS



Summary

- CubeSats provide an important proving ground for advancing scientific and technology research while lowering the risk for subsequent flight projects.
- CubeSats can carry out significant science investigations and serve as a technology test bed in the relevant environment at a fraction of the cost of larger orbital flights.
- NASA is fostering a stable customer base for an emerging commercial small spacecraft market by sponsoring of industry and university research and providing reliable access-to-space.
- CubeSat efforts are cultivating the next generation of researchers and technologists.
- CubeSats are travelling farther in the solar system than ever before


NASA

CubeSat 101

- **A "CubeSat 101" guidance document is in development**
  - **Expected release is in October of 2016**
  - **Will provide background, process information, and advice for prospective CubeSat developers**
- **If you are interested in getting a copy, get me your e-mail address and I'll send you one when it is available**
- **In the following charts, I will walk you through the end-to-end process, from concept development to mission operations, hitting the highlights and giving you some important tips along the way**
- **I can't possibly cover everything today, so don't hesitate to ask me questions now or later (see my contact information at the end of the presentation)**
- **I'm from the Government and I'm here to help you…seriously! ☺**

CubeSat Development Cycle

- Concept Development / Project Formulation
- Acquisition of Funding
- CubeSat Flight Hardware / Ground Station / Mission Design
- CSLI Proposal and Selection
- Manifesting
- CubeSat Flight Hardware / Ground System Assembly and Test
- Mission Integration (Analytical and Physical)
- Launch
- Mission Operations

Concept Development / Project Formulation

- **Got a "killer" idea?**
  - **Make sure that it is relevant to at least one and preferably many of NASA's objectives for technology development, science, or education**
- **Do you have the will and the wherewithal to get the job done?**
  - **This is a big commitment of time and resources and the process could take years**
    - » **Be prepared for student turnover – How will you retain corporate knowledge?**
    - » **Environmental test equipment is expensive – Do you have it in house or will you need to pay someone else to do it?**
  - **There could be financial penalties to your institution if you don't follow through**
  - **Consider partnering with another institution (share wealth and pain)**
  - **Excellent technical and project management skills will be required**
- **How are you going to manage your team?**
  - **Recruitment, Retention, Incentives, Communication, etc.**

Acquisition of Funding

- **CSLI pays for your mission integration support, the dispenser hardware, and launch and the rest is up to you.**
- **Your costs will likely include flight/ground hardware, tools, commodities, clean room supplies, labor, test equipment or services, lab space, IT resources, travel, etc.**
- **How much $?...it depends!**
- **Generate with a conservative cost estimate, then seek sources**
- **Potential funding sources include:**
  - **Internal institutional funds**
  - **US Government**
    - » **NASA (USIP, Research Opportunities/Announcements, etc.)**
    - » **DoD (UNP, etc.)**
    - » **NSF (Research Opportunities/Announcements)**
  - **Corporate Sponsors**
  - **Wealthy alumni**
  - **Crowd funding, bake sales, car washes, etc.**

CubeSat Flight and Ground Hardware / Mission Design

- **Preliminary design should begin in parallel with Concept Development**
- **A preliminary design is necessary for a successful Feasibility Review, a required component of a CSLI proposal**
- **Some keys to a successful design:**
  - **Simplicity**
  - **Avoidance of hazardous materials**
  - **Accessibility**
  - **Ample margins**
  - **Flight heritage**
  - **UL listed batteries**
  - **Low melting point and outgassing materials**
  - **Dispenser and orbit flexibility**

CSLI Proposal and Selection

- Annual call for proposals typically comes out in August and responses are due in November
- Be sure to follow RFP instructions and schedule to the letter
- A successful proposal demonstrates:
  - Availability of adequate funding/resources and skills
  - Conduct of effective/thorough Feasibility and Merit Reviews
    - » Review panels must be independent
    - » Be sure to show how you addressed/closed all review action items
  - Alignment to NASA objectives (all of them, if possible)
  - Compliance with applicable requirements document
  - Mission flexibility (altitude, inclination, dispenser, etc.)
- Selections are typically announced in February of the following year
- Selected proposals will be prioritized

Manifesting

- **Generally speaking, CSLI CubeSats are manifested in priority order, however CubeSat projects with more flexible mission concepts may "jump ahead"**
- **Be prepared to wait up to three years to get manifested, particularly if you need an atypical orbit**
- **Once manifested, you will work directly with a Government selected/funded Mission Integration Contractor**
- **This Contractor will:**
  - **Serve as your interface to the Launch Vehicle provider**
  - **Develop the Dispenser to CubeSat Interface Control Document (ICD)**
  - **Assist you in proving that your hardware meets all applicable Launch Vehicle, Dispenser, programmatic, and safety requirements**
  - **Provide the flight and test Dispensers and perform CubeSat to Dispenser integration**
  - **Ship the integrated Dispensers to the launch site and facilitate installation onto/into the Launch Vehicle**

Manifesting (continued)

- **After manifesting, NASA HQ will work with your institution to craft a Cooperative Research And Development Agreement (CRADA)**
  - **Essentially, this document is a contract between your team and NASA**
  - **This agreement will document data rights, reporting requirements, liability limits, non-compliance penalties and such…stuff only a lawyer can love...however, nothing will happen without it so it is important that you get it approved promptly**
  - **It is highly recommended that you have your institution's legal department assist in the review and approval of this agreement**

CubeSat Flight/Ground Hardware Assembly and Test

- Use good record keeping practices during assembly and test
  - Use written procedures with steps and “buys”
  - Take photos often, especially during final integration
  - Document all lost or found items
- Testing requirements and levels will be captured in the applicable Mission Requirements Document and Dispenser to CubeSat ICD
  - These tests (random vibration, vacuum bake out, “day in the life”, shock, etc.) are to ensure that your hardware will do no harm, not to ensure the success of your mission
  - Be sure to have you Mission Integration Contractor review your test procedures before you run them
  - Additional mission success testing (like thermal cycle testing) is at your discretion and should be performed incrementally in as flight like conditions as possible (aka “test like you fly”)
- Don’t neglect testing of your Ground Station
  - Tracking of other’s satellites can provide excellent training

Mission Integration

- **The Mission Integration Contractor will hold periodic teleconferences with all of the teams on your mission – It is critical that you participate**
- **If you have questions or concerns…speak up!**
- **There are a large number of reports/documents that you will be required to complete and submit to the Mission Integration Contractor to prove your compliance with mission/interface requirements, some key examples include:**
  - **Orbital Debris Assessment Report (ODAR) Inputs**
  - **Transmitter Surveys**
  - **Materials List**
  - **Mass Properties Report**
  - **Battery Report**
  - **Dimensional Verifications**
  - **Electrical Report**
  - **Venting Analysis**
  - **Testing Procedures/Reports**
  - **Compliance Letter**
  - **Safety Package Inputs**

Templates for these products are typically provided by the Mission Integration Contractor

Mission Integration (continued)

- **All deliverables are typically due no later than two months prior to Dispenser integration**
- **In addition to these deliverables, each CubeSat team is responsible for obtaining any required frequency utilization licenses from the FCC and any required remote sensing licenses from NOAA**
  - **Failure to obtain licenses in time is the number one cause of de-manifesting**
  - **The Mission Integration Contractor will typically assist you in the preparation/submission of the frequency license application and will point you in the right direction for obtaining a remote sensing license**
- **A Mission Readiness Review will typically be held approximately one month prior to Dispenser integration**
  - **This review is usually held in person at the Mission Integration Contractor's facility**
  - **Each team presents it's readiness to proceed with integration, launch, and mission operations – a chart template will be provided**
  - **All action items taken at this review must be closed prior to integration**

Mission Integration (continued)

- **Installation of the CubeSats into their respective Dispensers will typically take place no later than one month prior to installation of the Dispensers onto the Launch Vehicle**
- **Installation of the integrated Dispensers onto the Launch Vehicle will typically take place no later than two weeks prior to launch**

Launch and Mission Ops

- **Once the integrated Dispensers are mounted on the Launch Vehicle, all you have to do is wait, and cross your fingers, and watch the fireworks!**
- **Launch viewing is usually available for CubeSat teams, but travel to the launch site is at your expense, so start having those bake sales now!**
- **Shortly upon ejection into orbit, preliminary tracking information will be provided to each team and the search for everyone's individual CubeSat will begin – the USAF will assist in the search**
- **At this point, your CubeSat is yours to control right up until the bitter end**
- **Within six months of launch, each CSLI team must provide a report back to NASA HQ on the results of their mission (as required per the CRADA)**

A few extra words to the wise…

- **The ISS is an awesome deployment platform, however if you are planning on or protecting for a deployment from the ISS, be sure to read/understand the NanoRacks ICD and design your hardware accordingly – ISS requirements are NOT the same as those typically enforced for ELV missions**
- **Orbital debris mitigation isn't just a good idea…it's the law – design your hardware and mission for compliance**
- **No CubeSat team is an island – Talk to those who have gone before you to avoid repeating their mistakes and share lessons learned whenever you can**
- **No license, no launch – start working you regulatory license applications AS SOON AS POSSIBLE to avoid unpleasantness**
- **Please be patient with the manifesting process, matchmaking takes time**