National Aeronautics and Space Administration

ELaNa 23 International Space Station CubeSat Deployment
Launch May 2018 – Deployment July 2018

OVERVIEW
NASA enabled the deployment of seven small research satellites, or CubeSats, developed by six universities and the Jet Propulsion Laboratory. These CubeSat missions were selected through the CubeSat Launch Initiative (CSLI). The Educational Launch of Nanosatellite (ELaNa) 23 mission embarked on Orbital ATK's ninth Commercial Resupply Services mission to the International Space Station contracted by NASA, guided to space on an Antares rocket that lifted off May 21 from Cape Canaveral Air Force Station, Florida, at 4:44 a.m. EDT. Over the past three years, university students have been involved in the design, development and construction of these CubeSats that will be deployed from the space station via the commercially-developed NanoRacks CubeSat Deployer, or NRCSD.

CubeSats are playing an increasingly larger role in exploration, technology demonstrations, scientific research and educational investigations at NASA. These miniature satellites provide a low-cost platform for NASA missions, including planetary space exploration; Earth observation; fundamental Earth and space science; and technology demonstrations such as cutting-edge laser communications, energy storage, in-space propulsion and autonomous movement capabilities. They also allow educators an inexpensive means to engage students in all phases of satellite development, operation and exploitation through real-world, hands-on research and development experience on NASA-funded ride-share launch opportunities.

CSLI enables the launch of CubeSat projects designed, built and operated by students, teachers and faculty, as well as NASA Centers and nonprofit organizations. Managed by the Launch Services Program at NASA's Kennedy Space Center in Florida, ELaNa missions provide a deployment opportunity or ride-share launch to space for CubeSats selected through CSLI. ELaNa mission managers and their teams engage schools and colleges across the United States, providing spaceflight education through the preparation of payloads (licensing, integration and testing) flown in space. Since its inception in 2010, the initiative has selected more than 160 CubeSats and launched 69 CubeSats primarily developed by educational and government institutions around the United States. These miniature satellites were prioritized and selected through a formal NASA review of proposals submitted in response to CSLI announcements. NASA announced another call for proposals in early August 2018.

Basic CubeSat Facts:

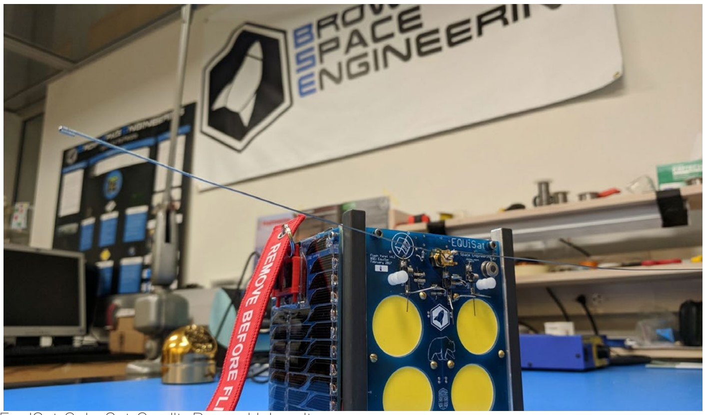
- CubeSats are small research spacecraft called nanosatellites
- Built to standard dimensions of 1 unit (1U), which is equal to 10x10x10 cm
- Can be 1U, 2U, 3U or 6U in size
- Typically, weighs less than 3 lbs (1.33 kg) per U – 6U may be up to 6.3 lbs (14 kg)
- Deployed from standard dispensers

CUBESAT DEPLOYMENT
In preparation for deployment, the CubeSats are placed inside the NRCSD, a stackable, modular, ground-loaded launch dispenser. Built by NanoRacks, LLC in Webster, Texas, each deployer accommodates up to 6.5U of CubeSat volume. Astronauts aboard the space station stack the NRCSDs into an eight-dispenser configuration, which are then mounted on the Japanese Experiment Module airlock slide table and moved outside of the station. The robotic arm captures the table and positions the facility toward Earth. After NASA and the Japan Aerospace Exploration Agency (JAXA) provide approval to proceed, the NRCSDs are commanded one-by-one. The dispenser doors open and the large internal spring releases, deploying the CubeSats into an orbit 400 km above Earth, slightly lower than the space station. After 30 minutes in orbit, the internal timers on the CubeSats allow their onboard computers to activate and begin transmitting. The CubeSat teams utilize ground stations to listen for

beacons to determine their small satellite's functionality and operational status. CubeSat missions are anticipated to last at least 120 days, although durations sometimes vary. Upon mission completion, the CubeSats begin a final fall through Earth's atmosphere, where tremendous heat generated by friction causes them to disintegrate.

SAFETY AND MISSION ASSURANCE

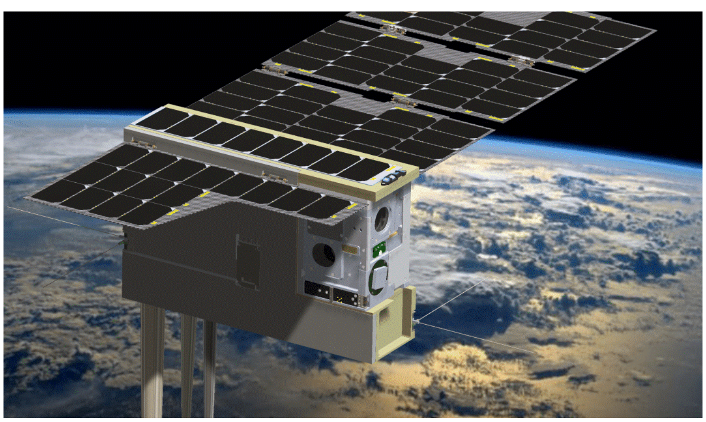
Each CubeSat developer has verified that their satellite is compliant with the NRCSD requirements. Each ELaNa CubeSat complies with U.S. and NASA orbital debris mitigation standard practices.



EquiSat CubeSat Credit: Brown University

EquiSat
Brown University – Providence, Rhode Island

EquiSat is an educational CubeSat mission with the goal of lowering the barriers of entry to the aerospace industry by increasing the accessibility of satellite design. It will prove the feasibility of low cost spaceflight through the use of student designed and manufactured components. Brown University will develop open source technical documentation for developers. EquiSat will be visible to observers on the ground and be accessible to Amateur Radio enthusiasts.

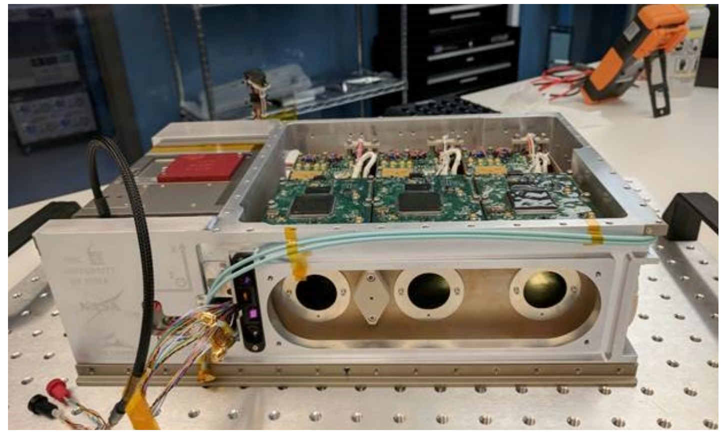


CubeRTT CubeSat. Credit: Blue Canyon Technologies

CubeRTT
CubeSat **R**adiometer **R**adio Frequency Interface **T**echnology Validation Mission

The Ohio State University – Columbus, Ohio

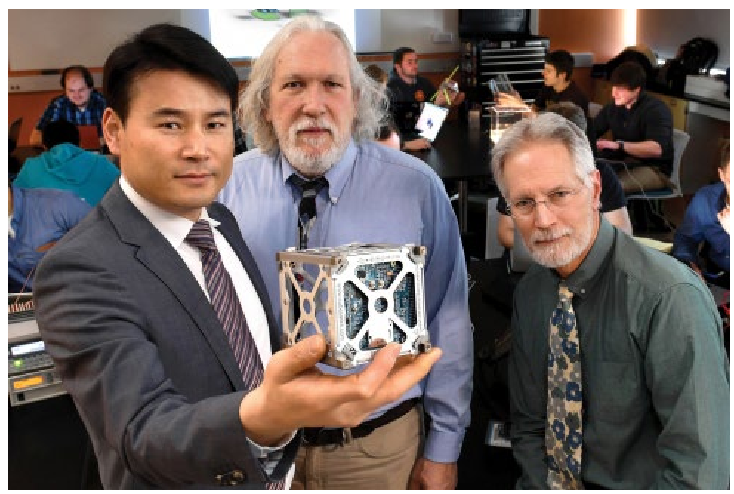
CubeRTT is a technology demonstration mission that observe, detect, and mitigate radio frequency interference (RFI) for microwave radiometers. RFI is a growing concern for Earth science observations due to its negative impact on science measurements with microwave radiometers. It is a space borne TRL 7 demonstration of real-time RFI mitigation in the global RFI environment. Successful space borne demonstration of this technology will reduce risk for all future missions that utilize observations from microwave radiometers



HaloSat CubeSat during integration testing. Credit: University of Iowa

HaloSat
University of Iowa – Iowa City

HaloSat is a scientific investigation mission to map the distribution of hot gas in the Milky Way and determine whether it fills an extended halo or the halo is compact with no contribution to the total mass of the galaxy. It will measure the oxygen line emission from the hot Galactic halo. Investigating constraints on the hot galactic halo will help address the problem that one-third of the matter from early astronomical observations cannot be found. This missing matter may be in very hot halos of gas surrounding galaxies.



MemSat team leaders Dr. Sangho Shin, Dr. John Schmalzel, and Dr. Robert Krchnavek. Credit: Rowan University

MemSat
Memristor-based memory technology demonstration

Rowan University – Glassboro, New Jersey

MemSat is a technology demonstration CubeSat mission to fly a memristor evaluation payload to characterize and compare the behavior of memristor memory devices against standard, silicon-based memory technologies to determine potential advantages—and/or disadvantages—of memristors for space applications. Memristors are a new class of fundamental electronic devices exhibiting multistate impedances, which can be used to create basic electronic elements and systems to implement a range of functions including computer systems, memory elements and sensors.

RadSat-G CubeSat Credit: Montana State University

RadSat-G

Montana State University – Bozeman, Montana

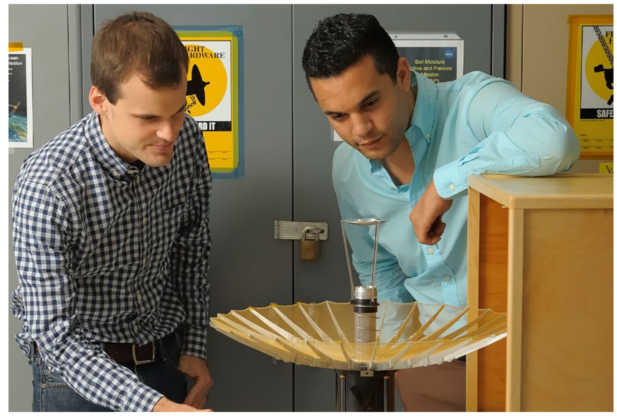
RadSat-g is a technology demonstration mission to evaluate radiation tolerant computer technology in Low Earth Orbit in order to demonstrate a Technology Readiness Level (TRL) of 9. The technology is based on commercial off the shelf (COTS), Field Programmable Gate Arrays. RadSat-g deploys a novel single event effect (SEE) mitigation strategy based on spatial avoidance of faults using an array of redundant processors with selective activation and background repair through partial reconfiguration.

RainCube

Radar **in** a **Cube**Sat

Jet Propulsion Laboratory – Pasadena, California

RainCube is a technology validation mission to demonstrate the operation and performance of, a miniaturized Ka-band Atmospheric Radar for CubeSats (miniKaAR-C) in the space environment on a low-cost, quick-turnaround platform. The proposed mission is to develop, launch and operate a 35.75 GHz radar payload on a 6U CubeSat. This mission will validate a new architecture for Ka-band radars and an ultra-compact deployable Ka-band antenna in a space environment. This new instrument will enable constellation missions and revolutionize climate science and weather forecasting.



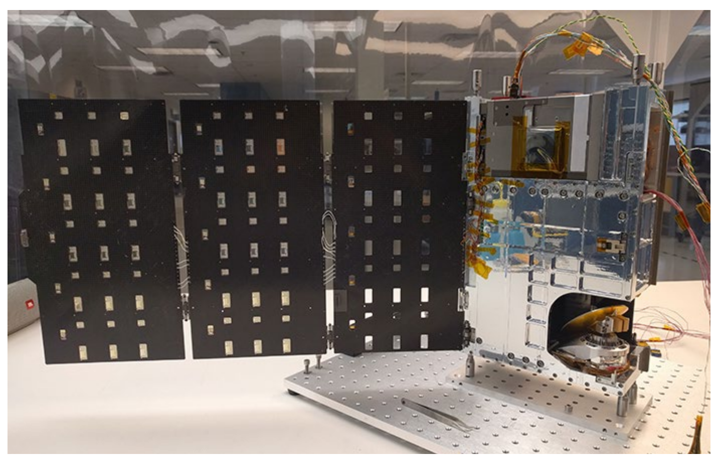
RainCube Team observing antenna deployment. Credit: NASA/JPL-Caltech

TEMPEST D,1

TEMPoral **E**xperiment for **S**torms and **T**ropical **S**ystems **- D**emonstrator

Colorado State University – Fort Collins, Colorado

The Temporal Experiment for Storms and Tropical Systems – Demonstrator (TEMPEST-D) mission objective it to reduce the risk, cost and development time for a future TEMPEST that will provide the first temporal observations of cloud and precipitation processes on a global scale. These observations are important to understand the linkages in and between Earth's water and energy balance, as well as to improve our understanding of cloud model microphysical processes that are vital to climate change prediction. TEMPEST-D consists of two of the proposed TEMPEST 6U CubeSats, launched in tandem to raise the technology readiness level of the system to TRL 9 and to demonstrate its measurement capabilities.



TEMPEST D,1 CubeSat deployed during testing. Credit: Blue Canyon Technologies

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To contact the ELaNa 23 Launch Public Affairs Office, call 202-358-1100

For more information about NASA's CubeSat Launch Initiative, visit: http://go.nasa.gov/CubeSat_initiative

For more information about the ELaNa 23 CubeSats, visit:

EquiSat: https://brownspace.org/equisat/
CubeRTT: https://www.jpl.nasa.gov/cubesat/missions/cuberrt.php
HaloSat: http://halosat.physics.uiowa.edu/
RainCube: https://www.jpl.nasa.gov/cubesat/missions/raincube.php
TEMPEST-D,1: https://www.jpl.nasa.gov/cubesat/missions/tempest-d.php

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