National Aeronautics and Space Administration

Astrophysics




NASA Astrophysics Small Space Telescopes (SmallSats)

AAS Small Telescopes Workshop, Albuquerque, June, 2023

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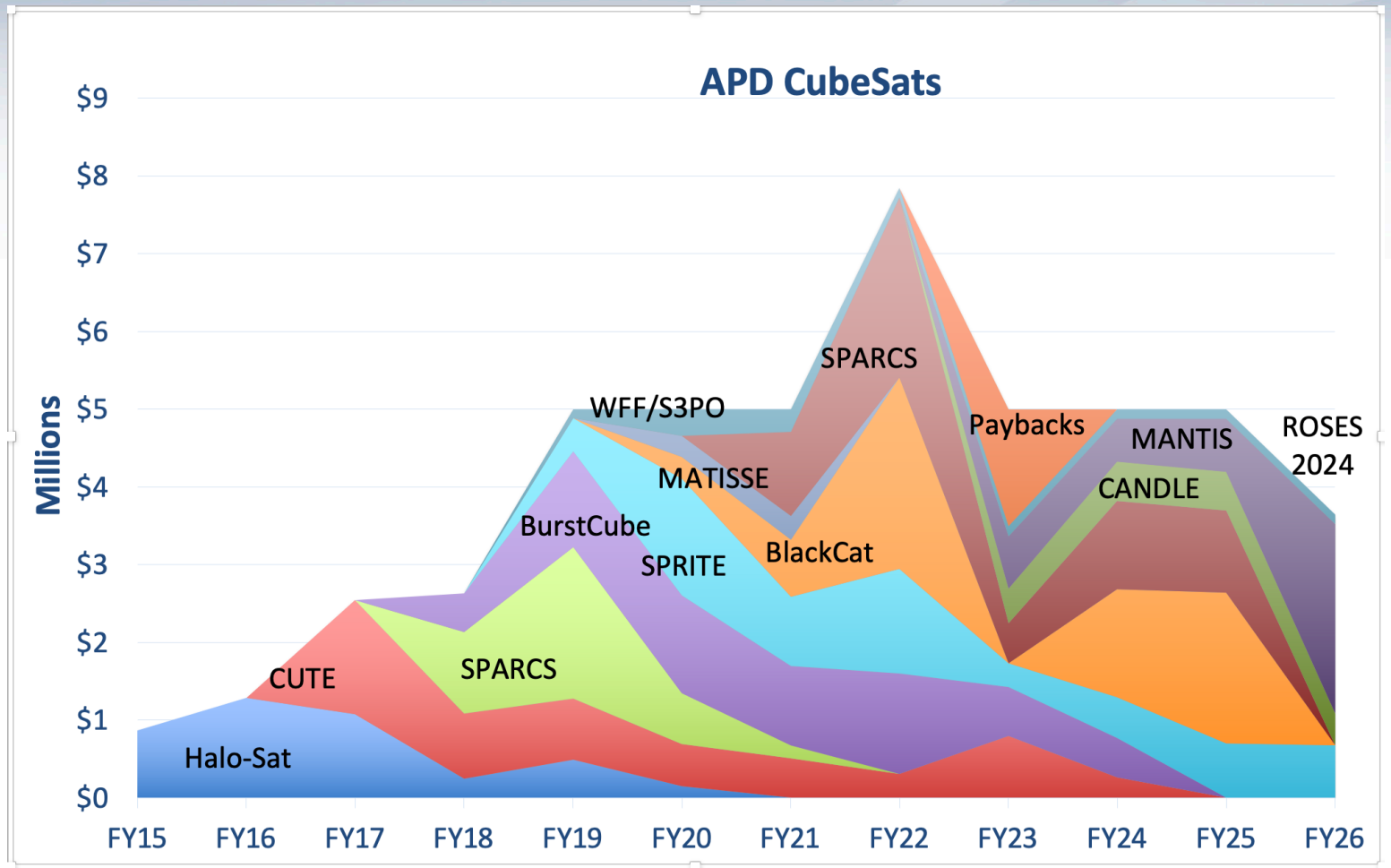
Rachel Cocks, Program Executive, SmallSats

NASA Astrophysics SmallSat Programs

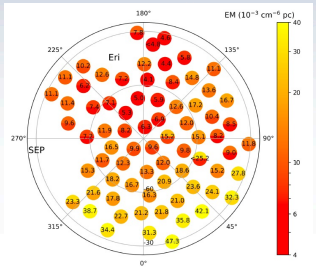
- APRA CubeSats
  - First solicited in 2012 (first funded in 2015)
  - Solicited annually via ROSES
  - 1 successfully completed, 1 successfully on orbit, 6 in development
  - 6U and 12U
  - Typical cost $5M (but increasing)
  - **1 new selection from APRA-2022 (announced of May 23) MANTIS**
- Astrophysics Science SmallSat Studies (AS^3)
  - Solicited via ROSES in 2018 and 2019
  - Paper studies funded at ~$120K
  - Targeted at Explorer MO SmallSats, cap of $35M
- Astrophysics Pioneers
  - First solicited in 2020 (4 selected, all passed CSR gate review)
  - Solicited annually via ROSES
  - ROSES-2021, 1 new selection (TIGERISS)
  - **ROSES-2022, review just complete, expect 2 new selections**
- Explorers – Some people include MO and SMEX, but budgets++

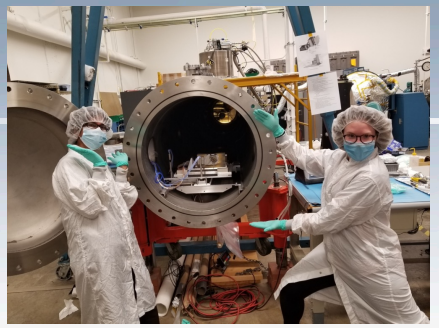
APD CubeSat Sand-chart



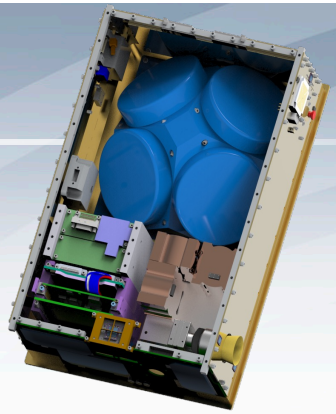
Increasing costs are putting pressure on our ability to select 1/year with the fixed $5M/year budget

HaloSat: PI Phil Karret U of Iowa,Launch 5/2018, reentry 2/2021, BCT OIV line, found unexpected structure of Halo

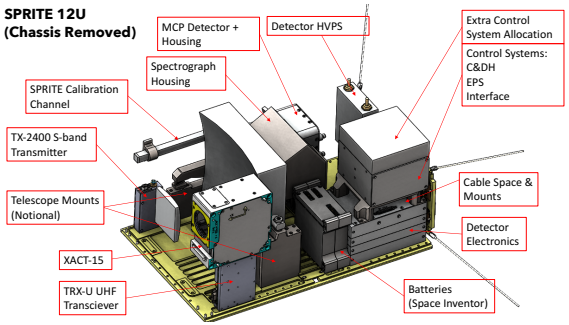




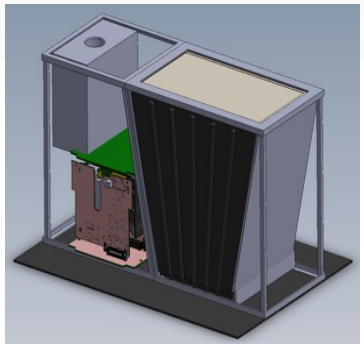
CUTE: PI Kevin France U CO,
In operation
UV Imaging of Hot Jupiter ablation,BCT bus, Arika Egan & Ambily Suresh in lab



BurstCube:
PI Jeremy Perkins GSFC,
Launch ~2/2024
GRB monitor w/ TDRSS real-time event notification, GSFC Bus

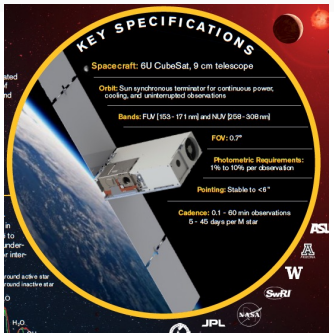


SPRITE, PI Brian Fleming U CO,
Launch 9/2024,
First APD 12U, UV spectra of ionizing radiation from star forming galaxies, Bus in house

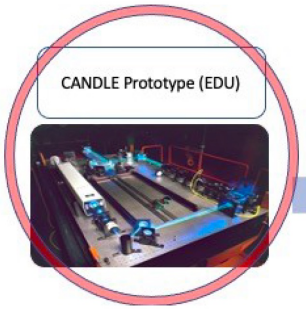


BlackCat: PI Abe Falcone Penn St.,
Launch NET 3/2024,
2-20 KeV wide FOV localization of X-ray Transients, real-time 'cell phone' downlink, NanoAvionics bus

SPARCS:
PI Evgenya Shkolnik ASU, Launch NET 2/2024,Two UV band monitoring of M-star flares to investigate planetary habitability effects, BCT bus



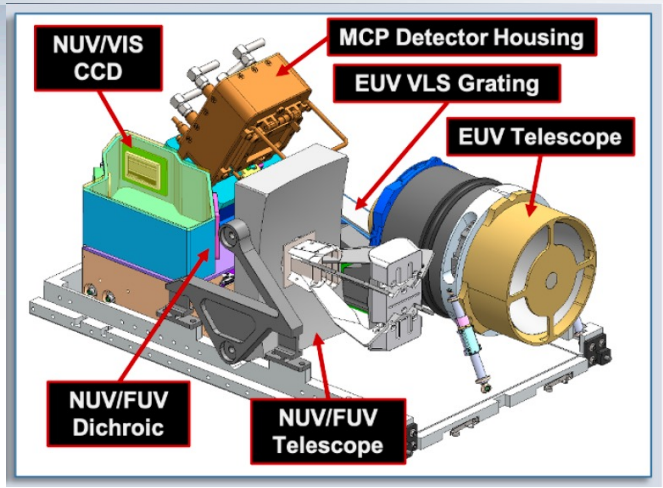
MANTIS



CANDLE:
PI Susana Deustra NIST, three year build of EDU, goal is 0.1% absolute calibration of 0.4u-2.5u flux scale for astronomy

MANTIS

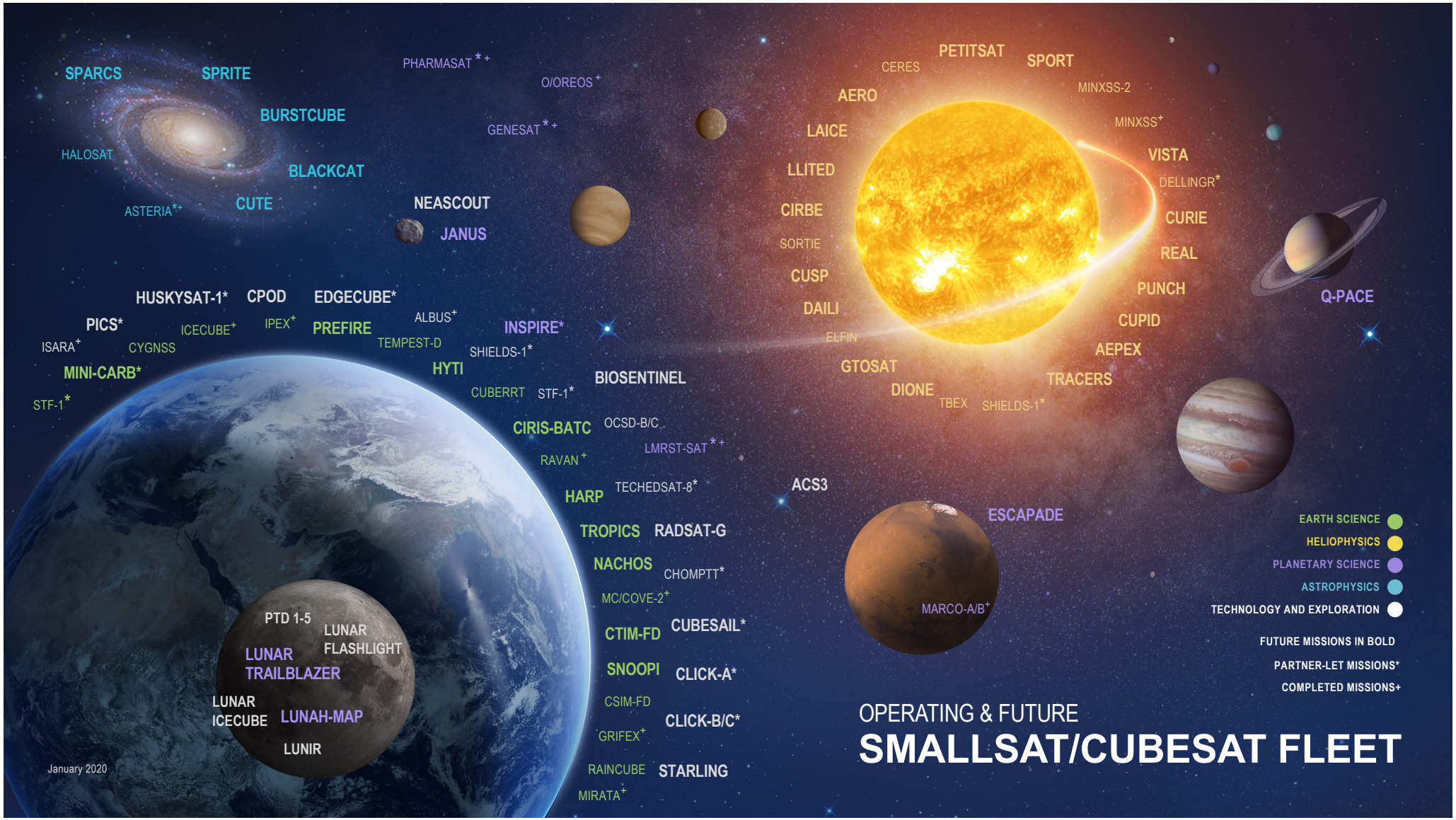
Monitoring **A**ctivity from **N**earby s**T**ars with UV **I**maging and **S**pectroscopy.



- **APRA-22 CubeSat Proposal #0121**
- **PI**: Briana Indahl, CU Boulder, ECR
- **LRD**: 3 years from initiation
- **Science Objectives:** Determine influence of EUV-NUV stellar flux on ExoPlanet Habitability. Would be first EUV capable telescope since EUVE 20 years ago, w/ 2x the effective area. Heritage from CUTE and SPRITE.
- **Operations**: 1 year to complete full survey,
- **Cost**: $8.5M over 4 years

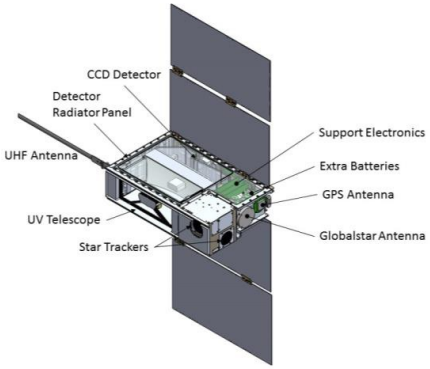
Key Facts:

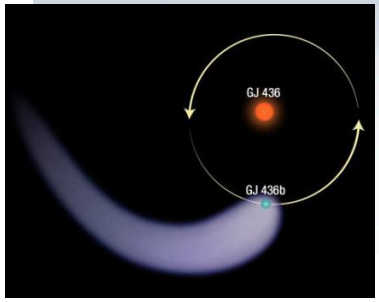
- **Science**: How does EUV-VIS stellar flux effect habitability of ExoPlanets? Simultaneous observations at EUV (100–900Å), FUV (900–2000Å), NUV(2000–3200Å), and VIS (3200–10000Å). Two surveys: one for UV monitoring of exoplanet systems contemporaneous with JWST transit observations, and one for surveying FGKM stars in mass and age
- **Technologies:** 12U CubeSat, next-generation photon-counting microchannel plate (MCP) detector for EUV and FUV, NUV/VIS on NUV optimized CCD. Rectangular telescope, compact R~1500 imaging spectrograph. BCT ACS, LASP bus and Comm.
- **Orbit**: LEO, >40 degrees inclination.
- **Telescope:** Rectangular NuTek, Wolter II EUV from INAF


SPARCS
SPRITE
PHARMASAT*+
O/OREOS+
BURSTCUBE
GENESAT*+
HALOSAT
BLACKCAT
ASTERIA*+
CUTE
NEASCOUT
JANUS
HUSKYSAT-1*
CPOD
EDGECUBE*
PICS*
ALBUS+
ICECUBE+
IPEX+
PREFIRE
INSPIRE*
ISARA+
CYGNSS
TEMPEST-D
SHIELDS-1*
MINI-CARB*
HYTI
BIOSENTINEL
STF-1*
CUBERRT
STF-1*
CIRIS-BATC
OCSD-B/C
LMRST-SAT*+
RAVAN+
HARP
TECHEDSAT-8*
TROPICS
RADSAT-G
NACHOS
CHOMPTT*
MC/COVE-2+
CTIM-FD
CUBESAIL*
SNOOPI
CLICK-A*
CSIM-FD
CLICK-B/C*
GRIFEX+
RAINCUBE
STARLING
MIRATA+
PTD 1-5
LUNAR FLASHLIGHT
LUNAR TRAILBLAZER
LUNAR ICECUBE
LUNAH-MAP
LUNIR
January 2020
PETITSAT
CERES
SPORT
MINXSS-2
AERO
MINXSS+
LAICE
VISTA
LLITED
DELLINGR*
CIRBE
CURIE
SORTIE
REAL
CUSP
PUNCH
Q-PACE
DAILI
CUPID
ELFIN
AEPEX
GTOSAT
TRACERS
DIONE
TBEX
SHIELDS-1*
ACS3
ESCAPADE
MARCO-A/B+
EARTH SCIENCE
HELIOPHYSICS
PLANETARY SCIENCE
ASTROPHYSICS
TECHNOLOGY AND EXPLORATION
FUTURE MISSIONS IN BOLD
PARTNER-LET MISSIONS*
COMPLETED MISSIONS+
OPERATING & FUTURE
SMALLSAT/CUBESAT FLEET

Colorado Ultraviolet Transit Experiment (CUTE)

A CubeSat to study atmospheres and B-fields in ExoPlanets





- **APRA-15 CubeSat Proposal**
- **PI**: Kevin France, CU Boulder
- **Launch:** CSLI on LandSat-9, Sept 27, 2021
- **Science Objectives:** The Colorado Ultraviolet Transit Experiment (CUTE) will take multiple medium resolution UV spectra of hot Jupiters during transit, in order to measure the composition of the atmosphere being ablated away. Magnetic fields may be detected via the presence of tori or bow shocks
- **Operations**: 1 month minimum, 8 month full survey of 12 exoplanets

Key Facts:

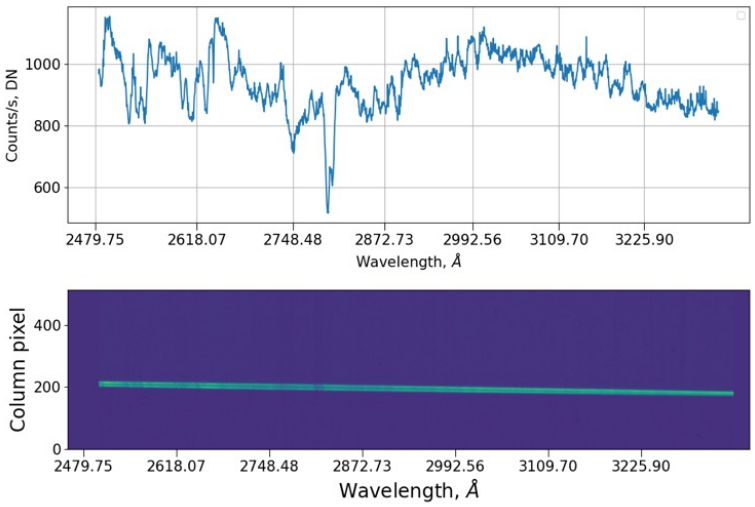
• **Science**: Extreme atmospheric mass loss has been detected by HST on a small sample of short-period planets. The UV has multiple diagnostic lines which can determine the structure and geometry of the escaping atmospheres. This would be the first UV survey of hot Jupiter atmospheres

• **Technologies:** 6U CubeSat advancing science, using COTS technologies. **Blue Canyon Technologies (BCT)** bus, e2v UV-CCD, exiting CU cubesat downlink station.

- **Budget:** $5.6M over 6 years (includes 2 years operations)
- **Telescope:** **NuTex** Rectangular, optimized for UV spectroscopy, ~120cm^2 or ~12cm diameter

Colorado Ultraviolet Transit Experiment (CUTE)
In Science Operation

- CUTE is a 6U cubesat with an NUV (255 – 330nm) telescope and spectrograph to study transiting planets around bright stars
- Launched September 27, 2021, as a secondary payload on the LANDSAT-9 mission. Spacecraft tracked and communications established within 2 days in coordination with amateur satellite community

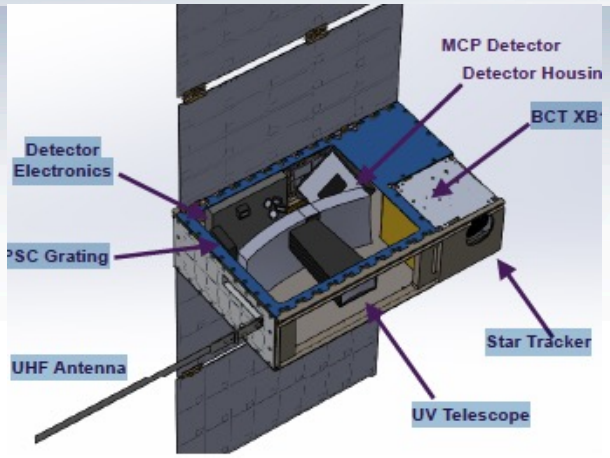


- Completed spacecraft and instrument commissioning in February 2022. Science operations underway now
- **Talks:**
  - Arika Egan, 2:20 Wed, 327.03

Left: Flux calibration spectrum from CUTE (K. France/University of Colorado)
Right: CUTE on secondary payload adapter

SPRITE

Supernova remnant and Proxies for ReionizationTestbed Experiment.



- **APRA-17 CubeSat Proposal** (ARTEMIS)
- **PI**: Brian Fleming, CU Boulder.
- **LRD**: 2.5 years from initiation
- **Science Objectives:** Determine ionization rate of IGM from galaxies and AGN, trace feedback within galaxies driven by star-forming regions, using low-resolution imaging UV spectrograph.
- **Operations**: 1.5 years to complete full survey,
- **Cost**: $4.5M over 4 years

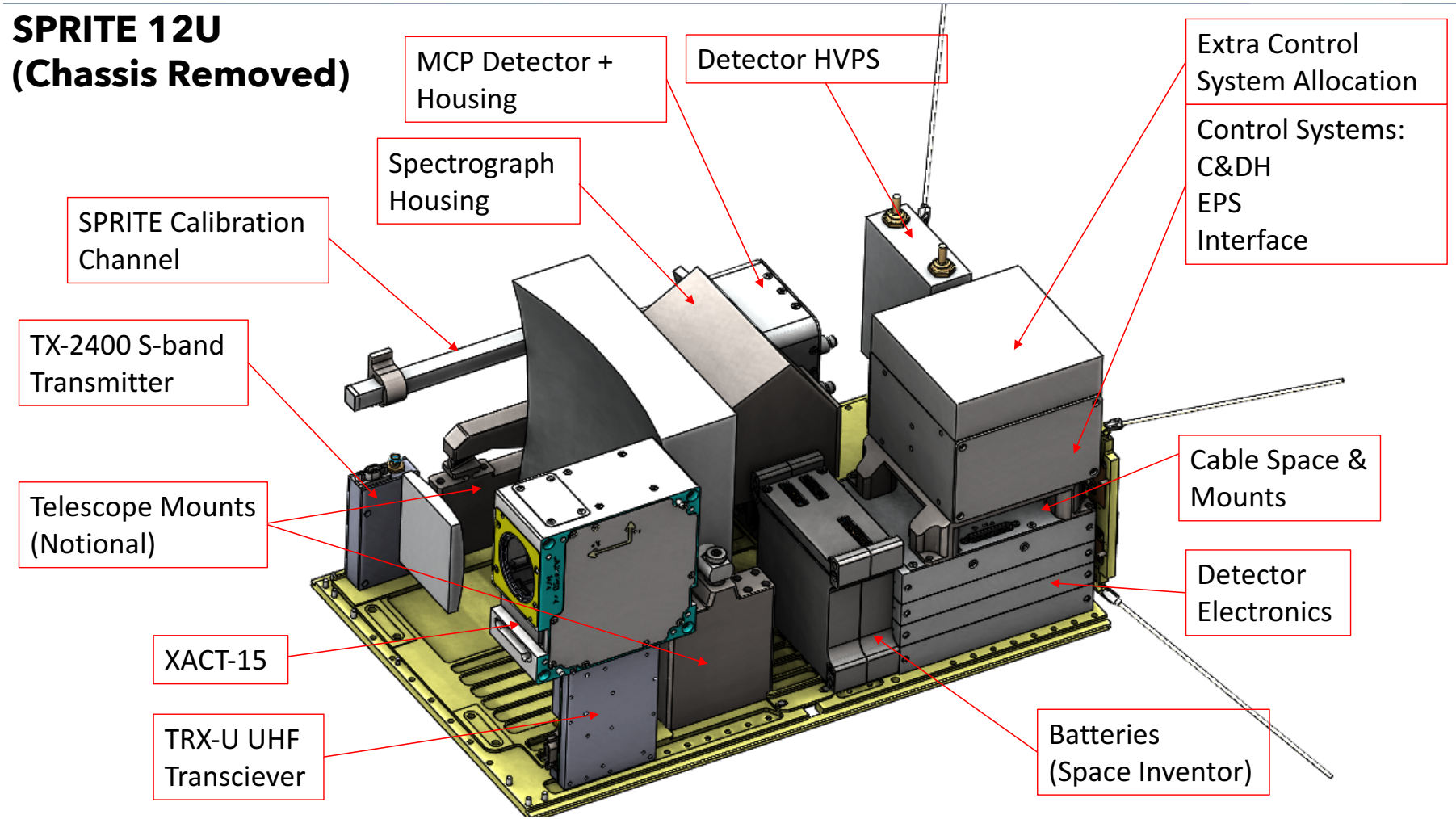
Key Facts:

• **Science**: How do galaxies provide ionizing radiation to the IGM? Even JWST cannot solve one critical aspect of the problem: How much of this radiation actually escapes galaxies to reionize the IGM? SPRITE will directly measure the ionizing spectrum in 100 $0.15 < z < 0.3$ galaxies and AGN, a sample that will surpass in number and precision all ionizing escape measurements to date and provide critical interpretive tools for core JWST science.

• **Technologies:** advanced UV/optical coatings and next-generation photon-counting microchannel plate (MCP) detector, compact R~900 imaging spectrograph. **BCT** ACS. Comm, power **in-house build.**

- **Orbit**: ISS-like is fine.
- **Telescope,** Rectangular telescope from NuTek

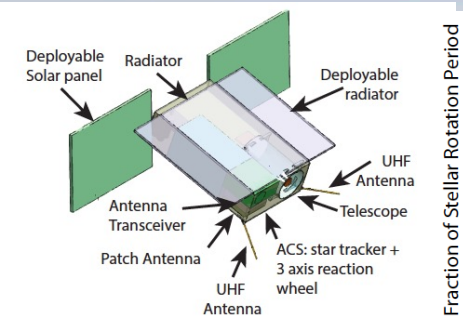
SPRITE 12U (Chassis Removed)

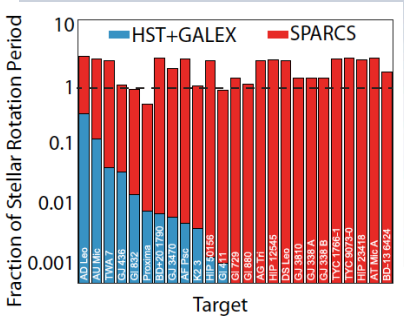


Telescope: rectangular, optimized for UV spectroscopy**,** ~270 cm^2, 18 cm diameter

SPARCS

Star-Planet Activity Research CubeSat





- **APRA-16 APRA-20 CubeSat Proposal**
- **PI**: Evgenya Shkolnik, AZ State U.
- **LRD**: NET 2/2024
- **Science Objectives:** Determine rate, strength and color of bright UV flares from a select 25 M dwarfs, with an eye towards how these flares effect the habitability of planets within their habitable zones.
- **Operations**: 2 years to complete full survey, which will cover 1 to 3 complete rotations of each star (periods 4-45 days); 6 months to do threshold mission.
- **Cost**: $10.4M/6 years

Key Facts:

- **Science**: First mission dedicated to provide the time-dependent spectral slope, intensity and evolution of M dwarf stellar FUV and NUV radiation. These measurements are crucial to interpreting observations of planetary atmospheres around low-mass stars. Target list includes young, old, (in)-active, (non)-planet hosting M stars. 1.8 degree FOV allows much ancillary science.
- **Technologies:** 6U CubeSat, BCT bus, JPL delta-doped e2V CCD, red-leak suppressing filters.
- **Orbit**: sun synchronous to ensure 2 year life-time.
- **Telescope:** 9 cm R-C telescope, Hexagon in MD

Astrophysics Pioneers

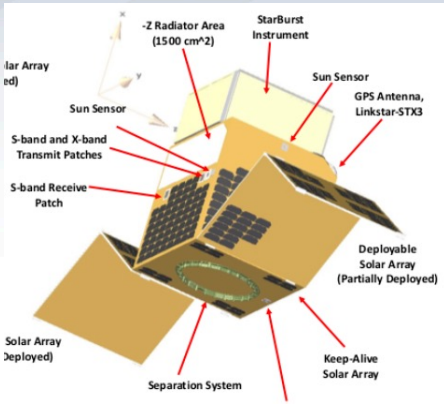
- NASA anticipates anticipates that major extended duration balloon payloads, CubeSats larger than 6U, and CREAM-class ISS payloads will be more expensive than ROSES/APRA can accommodate. (~$10M maximum).
- Pioneers: A new class of small missions annually via ROSES, $20M maximum PI cost cap.
- First solicited APRA-2020 (4 selections), APRA-2021 (1 selection), APRA-2022 review just complete, expect 2 selections.
- Include ESPA-sized SmallSats, CubeSats >6U, major balloon payloads, and modest ISS attached payloads, and (cis)-Lunar payloads via CLPS with a $20M cost cap, not including launch.
- Fill in the gap between existing ROSES investigations (<$10M for APRA) and existing Explorers MO investigations (~$35M for SmallSats).
- Solicited through ROSES; relieves burden of writing full Explorers MO proposal.
- Managed as Research and Analysis projects with enhanced research project processes with defined gates and light touch management from WFF and HQ, rather than flight project processes appropriate for a SMEX.
- Supports early career teams, scored as 25% of total. First selections all early career PIs, 50% female, 50% Hispanic.
- Program will change due to lessons learned! Example: CSR was first gate, now deferred to SRR/MDR.
- Active sharing of lessons learned among PIs+: LEARN forum, S3VI webinars, APRA PI Program Review

Astrophysics Pioneers

- $20M PI cost cap excluding launch, ROSES 2020 (4 selections) ROSES 2021 (1 selection) ROSES 2022 review just complete, expecting 2 selections

PUEO: A Long-duration Balloon-borne Instrument for Particle Astrophysics at the Highest Energies, PI Abigail Vieregg, U Ch
Launch 12/2024 Antartica

Figure 10: A rendering of the PUEO payload, including a design for the low-frequency drop-down instrument.



StarBurst: Gamma-ray ASM, Simultaneous detection of NS/NS mergers with LIGO, PI Daniel Kocevski MSFC, SFL bus, 300kg ESPA-Grande, 0 inclination preferred

Pandora: Multiwavelength Characterization of Exoplanets and their Host Stars, PI Elisa Quintana, GSFC, BCT Bus

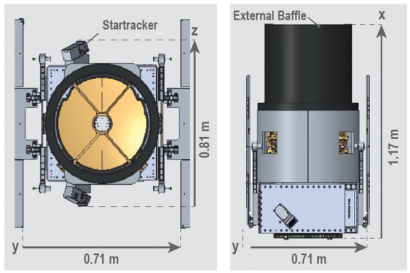


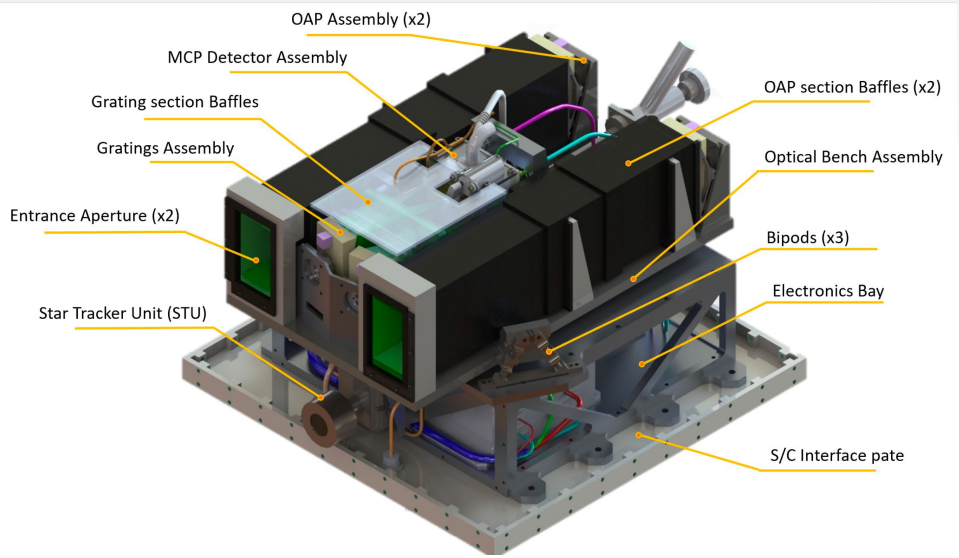
Figure 13: BCT X-SAT-9 is accommodated by an EELV Secondary Payload Adapter (ESPA) Grande 5-m fairing The stowed volume is 1,173.7 mm in X-axis, 809.2 mm in Z-axis, and 709.9 mm in Y-axis. Shown here with arrays deployed (left panel) and stowed (right).

Aspera: IGM Inflow/outflow from galaxies via OVI 10^5K emission line imaging. PI Carlos Vargas, U of A, SFL bus, eLiFl mirror coating

TIGERISS: measuring ultra-heavy (r-process) cosmic rays on ISS, PI Brian Rauch, Wash U.

Aspera: A $20M UV Space Telescope in build

Aspera: Detecting the CGM in OVI emission, PI Carlos Vargas, U of AZ, SFL Bus



- Inspired by FUSE design
- 2 x Identical Rowland Circle-like spectrographs
- Primary: 6.9 cm x 3.68 cm OAP each
  - ULE, coated with Al+eLiF+MgF_2 capping
- FoV: 60 arcmin x 30 arcsec each
  - Slit dimension: 3 mm x 25 micron
- Grating: 4800 l/m ion-etched holographic toroidal
  - ULE, coated with Al+eLiF+MgF_2 capping
- Detector: Micro-channel Plate (MCP)
  - UV-sensitive & photon-counting

- Wavelength: 1,030 – 1,040 Å
- Final Spectral Resolution ($\lambda/d\lambda$): > 1,500
- Final Spatial Resolution: < 120 arcsec

[arcmin]

UV throughput much improved and robust with Al+eLiF+MgF coatings, allowing
Greatly improved science throughput with modest apertures

Pandora: A $20M 0.5m Space Telescope in build

Pandora: Multiwavelength Characterization of Exoplanets and their Host Stars,
PI Elisa Quintana, GSFC, s/c bus by BCT

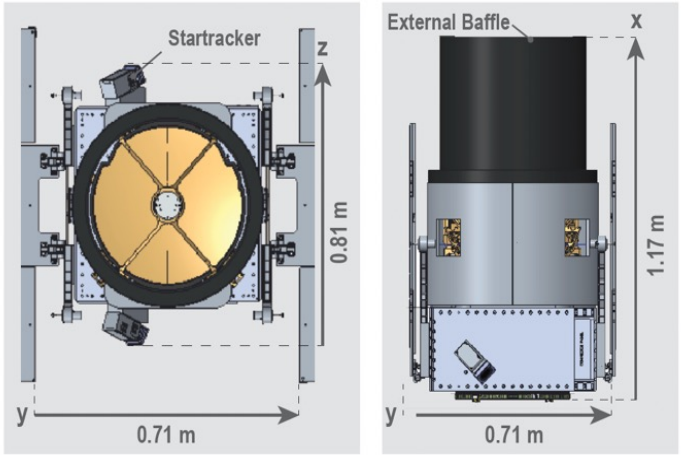
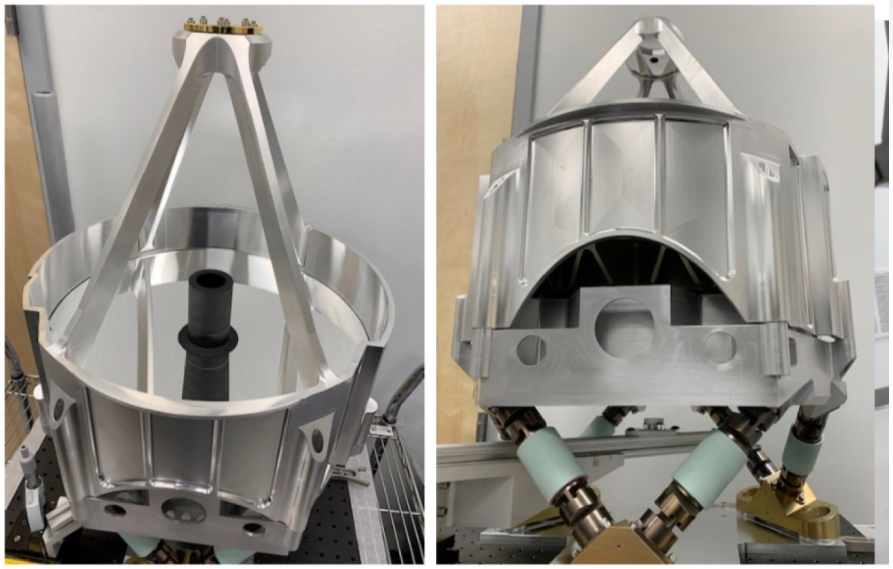


Figure 13: BCT X-SAT-9 is accommodated by an EELV Secondary Payload Adapter (ESPA) Grande 5-m fairing The stowed volume is 1,173.7 mm in X-axis, 809.2 mm in Z-axis, and 709.9 mm in Y-axis. Shown here with arrays deployed (left panel) and stowed (right).



CODA telescope, ~0.5m, all Aluminum 6061-T6 alloy, Manufactured by Corning with hopes to mass produce and lower costs.

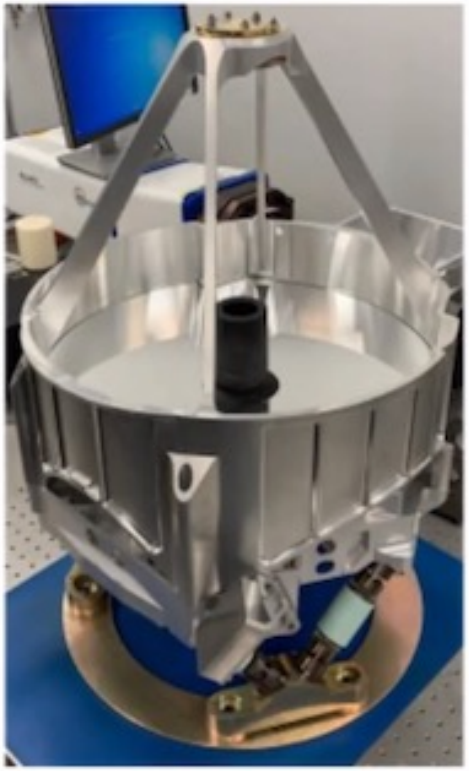
Pandora: A $20M 0.5m Space Telescope in build

CODA 40-50cm Aluminum Cassegrain

You are viewing Aaron Tohuvavohu's scr

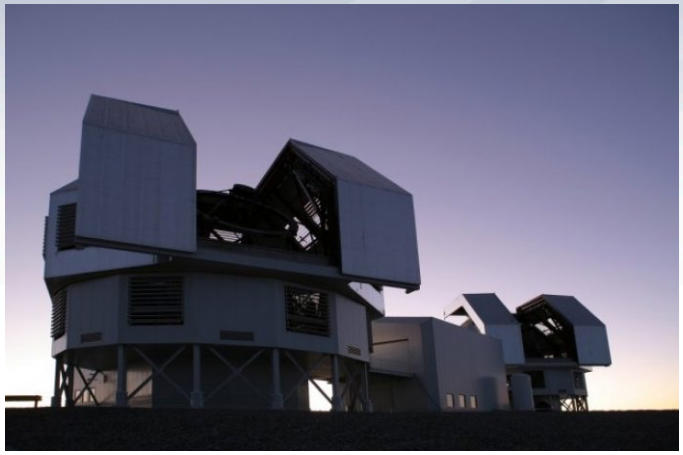
- Program Goal: Produce an inexpensive telescope that could be produced in large quantities for ESPA Grande class missions with minimal NRE
- Features
  - Fabricated from readily available 6061 Aluminum
  - Bulk materials allow for multiple sets of mirror to be produced quickly
  - Flexible relay design allows for multiple channels & wide variety of detectors to be hosted
  - Utilizes existing state of the art processes and coatings for optical elements

CODA is not a revolutionary telescope design in terms of performance, its purpose is to be revolutionary from a manufacturing and acquisition perspective with a target cost of <$1M per unit

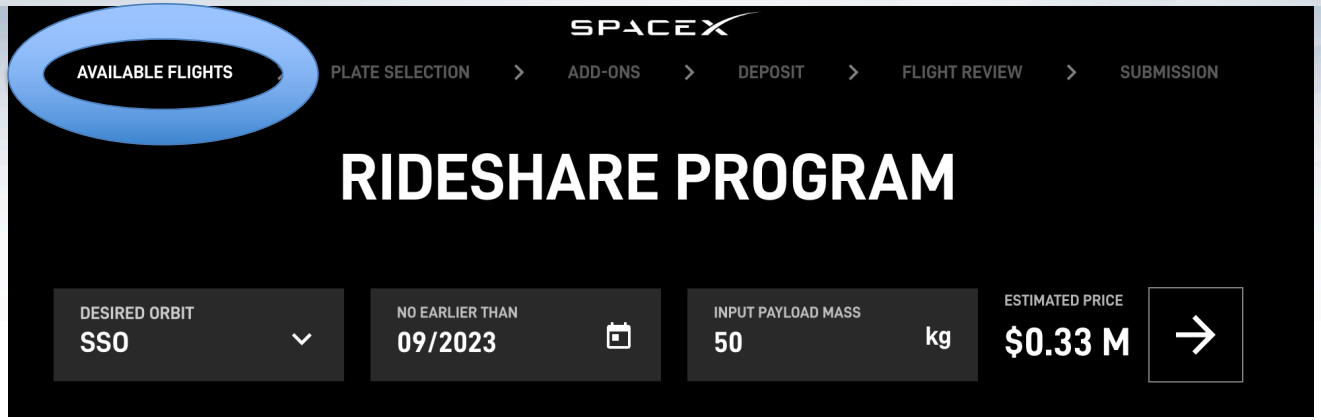


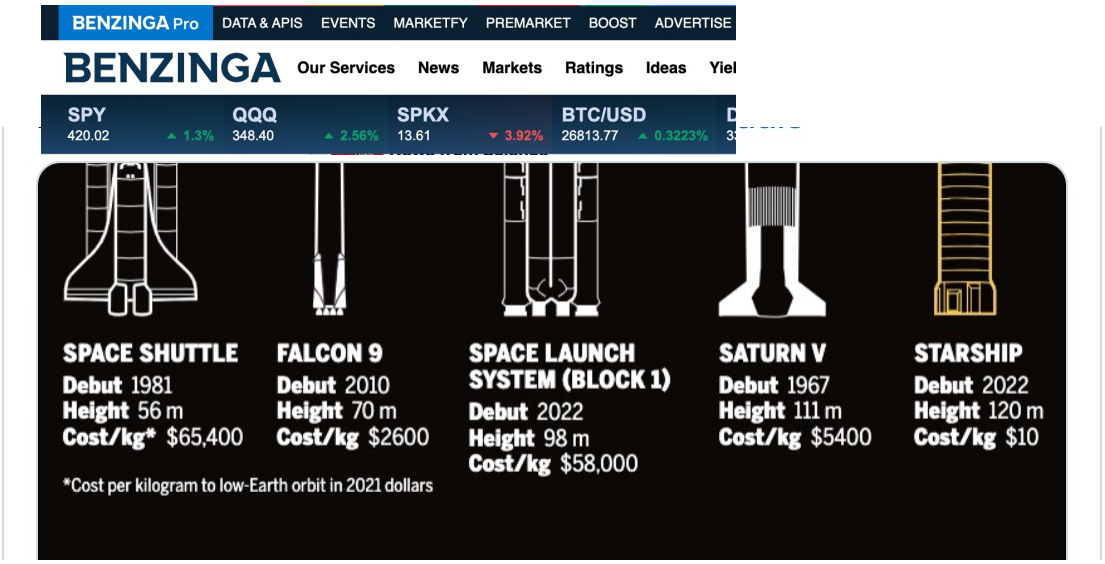
People with $$ love giving to Telescopes

Keck – Oil
Magellan Clay telescope - investment advice/mining
Lick – real estate
Allen radio array – Microsoft



Launch costs are down 20x, going for 4000x!





People with $$ are interested in space telescopes

Forbes

FORBES > INNOVATION > SCIENCE

NASA And SpaceX Consider Daring Plan To 'Reboost' The Hubble Space Telescope

Jamie Carter Senior Contributor

I inspire people to go stargazing, watch the Moon, enjoy the night sky

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Jan 4, 2023, 08:00pm EST

Listen to article 6 minutes

Can NASA and SpaceX help give the Hubble Space Telescope a new lease of life? GETTY

Polaris, Jared Issacman, Shift4 Payments

SMD Bridge Program Seed Funding

FUNDING OPPORTUNITY: Research Posting

NASA SMD Bridge Program Seed Funding

The new Science Mission Directorate (SMD) Bridge Seed Funding Program Element of ROSES-2023 (F.23) (Short URL: https://go.nasa.gov/applybpsf) solicits proposals to provide support for faculty investigators and their students at under-resourced institutions (URIs) to carry out NASA-relevant research. Through the BPSF program, SMD aims to facilitate new and expand ongoing partnerships between students and faculty at URIs and researchers at NASA Centers that could be expected to grow into Bridge partnerships and become well-positioned to submit a proposal to the future SMD Bridge Program opportunity in ROSES-2023.

UNM Taos, URI, MSI, new public telescope plans

UNM TAOS

UNM-TAOS OBSERVATORY AND ASTRONOMY CENTER FACT SHEET

CAPITAL OUTLAY REQUEST
LEGISLATIVE ID# 2705

A new observatory at UNM-Taos which will house the largest operable public telescope in New Mexico to allow college and K-12 students, community members and visitors to the region to observe thousands of celestial objects across the northern New Mexico sky. The Center will include a planetarium, observation deck, auditorium, classroom, and weather station.

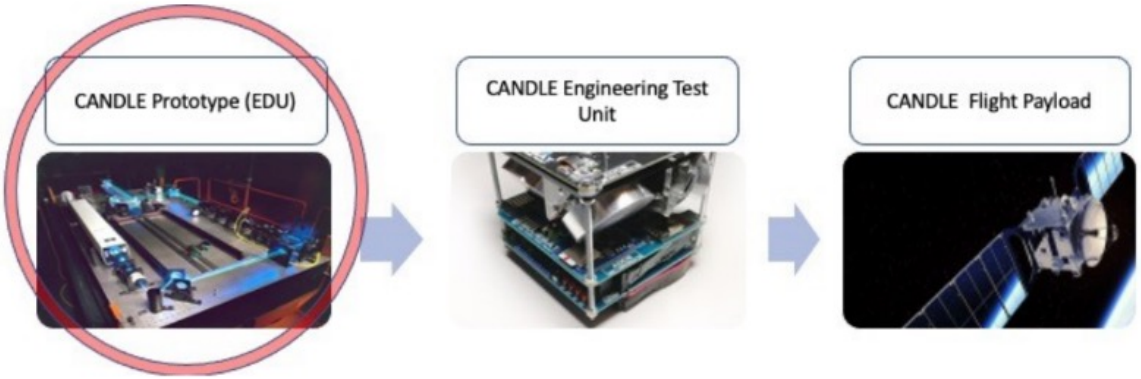
WHAT: UNM-Taos has received the donation of a 36" Dobsonian telescope.
Once installed, this telescope will be the largest public telescope (vs. those devoted strictly to research purposes) in New Mexico and among the largest public telescopes in the country. Less than 1% of the population of the US and Europe are able to experience dark skies, so vast dark skies visible from campus, where you can see the Andromeda Galaxy, 2.5 million light years away, is a precious resource. The telescope will not only be used to show students and visitors some of the wonders of the universe, but will also be used to educate them on the consequences of light pollution, such as wasted energy, the enforced disconnection of people from their cultural heritage, and the disruption to wildlife and the ecosystem.

backup

APRA-2021 new CubeSat selection

CANDLE, PI Susana Deustua of NIST
Calibration using an Artificial star with NIST-traceable Distribution of Luminous Energy. An Engineering Demonstration Unit for Astrophysics

Dark energy investigations need absolute flux calibration with a precision that is **10 times better** than achieved to date. A solution … is a NIST-traceable calibrated light source that behaves as an artificial star and is accessible to our space based observatories like JWST, … or ground-based systems like Rubin Observatory. We propose to design, build and test an SI-traceable, artificial star engineering demonstration unit (EDU) designed to fit in a volume less than 12U (1U=1000cc), where the technology readiness levels of its components can be raised to at least TRL 4. CANDLE (Calibration using an Artificial star with NIST-traceable Distribution of Luminous Energy) will provide calibrated light between 0.4 and 2.5 microns.

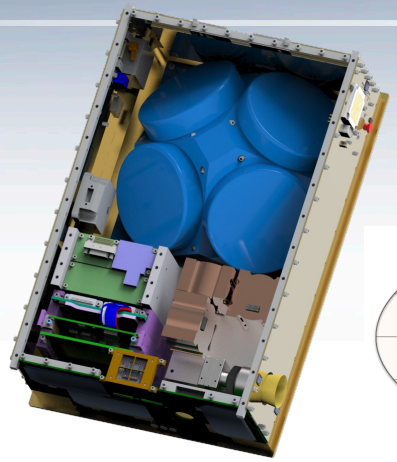


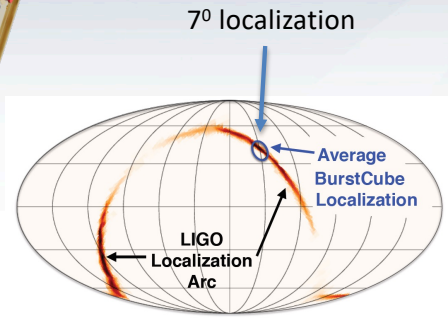
HaloSat launch at WFF

The day before the launch, the Iowa HaloSat team met Astronaut Kay Hire.

BurstCube

6U CubeSat with four CsI detectors sensitive to gamma-rays from 10 keV to 1 MeV





- **PI:** Jeremy Perkins (GSFC)
- **Science Objectives:**

1) Rapid localizations for high-significance LIGO/Virgo detections coincident with short GRBs
2) Correlate short GRBs with LIGO/Virgo sub-threshold signals, increasing volume
3) Search of gamma-ray transients
4) Positions to ~7degrees, few dozen NS-NS detections per year

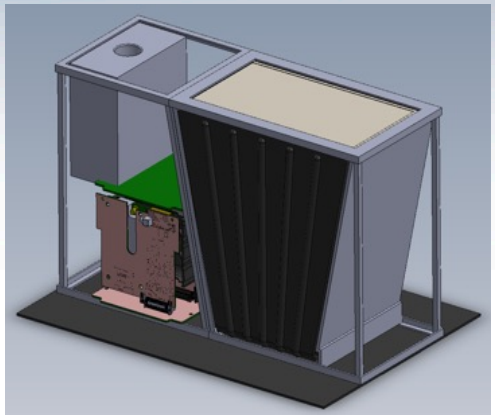
- **Operations**: 4 years development, 1 year operations. S-band to TDRS for alerts, NEN for bulk data

Key Facts:

- **Science**: BurstCube autonomously detects GRBs onboard, rapidly downlinking data for timing and localizations that are disseminated to ground-based observers to maximize the chances of detecting afterglows. BurstCube will increase the rate of concurrently detected sGRBs and GWs by enhancing the sky coverage beyond current sensitive instruments.
- **Technology:** 6U divided into a 4U instrument package and 2U spacecraft subsystems. Spacecraft highly leverages Dellingr, developed at GSFC. Instrument is similar to Fermi-GBM, except BurstCube uses CsI for 10 keV – 1 MeV.
- **Orbit**: Low earth orbit with no major orbital or observational constraints

BlackCAT: Black Hole Coded Aperture Telescope

A CubeSat Mission to explore the transient sky



- **APRA-2018 CubeSat Proposal**
- **PI**: Abe Falcone, Penn State University
- **LRD**: 3 years from initiation
- **Science Objectives:** Detect bursts from high redshift GRBs arising from early universe stars, look for EM counterpart to gravity wave events, X-ray Sky Monitor for transients and flares, and High-energy Multimessenger Astrophysics
- **Operations**: checkout + 1 year nominal operations, with possibility of extended life

Key Facts:

Science: Probe distant and nearby black holes from stellar mass to >10^9 M_{solar}. Will discover high redshift GRBs, enabling studies of star formation rate and properties; monitor/finder for ground-based follow-up. Transient finder of Galactic transients, short GRBs (during ALIGO epoch), tidal disruption events, XRFs, supernova shock breakouts, blazar flares (possible neutrino event counterparts), etc. Optimum combination of wide FOV and X-ray sensitivity with rapid position alerts will allow gravity wave EM counterpart searches and general multi-messenger event monitoring.

Technologies: Wide-sky near-continuous X-ray monitoring Coded Aperture Telescope with filter made by Luxel; operates in 0.5-20 keV band. Next generation hybrid CMOS X-ray detector technology. Rapid event alerts use **Globalstar 24/7** coverage while bulk science data use 1/day S-band passes, **Clyde-space bus.**

Orbit: Sun Sync polar