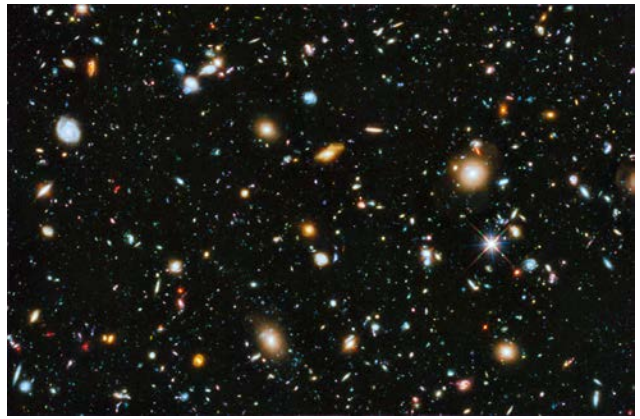
National Aeronautics and Space Administration

# ASTROPHYSICS

## NASA Astrophysics Research and Analysis Update

APAC Meeting
Washington, DC
July 24, 2018


**Stefan Immler**

Lead for Astrophysics R&A
Astrophysics Division
Science Mission Directorate

# Astrophysics Research and Analysis (R&A) Elements

## Supporting Research and Technology

- Astrophysics Research & Analysis (APRA)
- Strategic Astrophysics Technology (SAT)
- Astrophysics Theory Program (ATP)
- Theoretical and Computational Astrophysics Networks (TCAN)
- Exoplanet Research Program (XRP)
- Roman Technology Fellowships (RTF)

## Data Analysis

- Astrophysics Data Analysis (ADAP)
- GO/GI programs in ROSES for:
  - Fermi
  - Kepler/K2
  - Swift
  - NuSTAR
  - TESS

## Mission Science and Instrumentation

- SOFIA next-generation instrumentation
- Sounding rocket, balloon, cubesat, and ISS payloads through APRA
- XARM Participating Scientists

## Separately Solicited

- GO/GI/Archive/Theory programs for:
  - Chandra
  - Hubble
  - SOFIA
  - Spitzer
  - Webb
- Postdoctoral Fellowships (Einstein, Hubble, Sagan)
- Graduate Student Fellowships (NESSF)

# R&A News and Selections

# R&A in 2018/2019

- New ROSES element for LISA Preparatory Science (LPS)
  - Proposals due 6/14/18, 30 proposals received
- New ROSES element for Astrophysics Science SmallSat Studies
  - Proposals due 7/13/18, 43 proposals received
- Next Astrophysics Theory Program (ATP) solicitation in 2019
  - ATP solicitations are in alternate years
- ROSES element for TESS GI program
  - Cycle 1 closed 3/22/18, 33 proposals received
  - Cycle 2 proposals due 10/3/18 (though ARK/RPS)
- New ROSES element for NICER GO program is planned
  - After NICER completes prime mission this summer
- Continue best practices in managing our R&A programs, reviews, and awards, including:
  - Actively taking steps to advance diversity, inclusion, and equal opportunity in the NASA workforce and among NASA grantee institutions
  - Created a Code of Conduct for peer review Panelists and Chairs which is being used in all reviews

# ROSES-2018 Astrophysics Elements

| Program Element | | NOI due | Proposals due | Program Officer | Comments |
|---|---|---|---|---|---|
| D.1 | Astrophysics Overview | N/A | N/A | | |
| D.2 | ADAP | 3/28/18 | 5/17/18 | Doug Hudgins | |
| D.3 | APRA | 1/24/19 | 03/21/19 | Mike Garcia | mandatory NOIs |
| D.4 | ATP | N/A | N/A | Keith McGregor | solicited in ROSES-2019 |
| D.5 | Swift Cycle 15 | N/A | 9/27/18 | Martin Still | |
| D.6 | Fermi Cycle 12 | N/A | 02/20/19 | Stefan Immler | |
| D.7 | K2 Cycle 7 | N/A | TBD | Mario Perez | |
| D.8 | SAT | 1/24/19 | 3/21/19 | Mario Perez | mandatory NOIs |
| D.9 | RTF | see D.3 | see D.3 | Mario Perez | |
| D.10 | NuSTAR Cycle 5 | N/A | 1/16/19 | Bill Latter | |
| D.11 | TESS Cycle 2 | N/A | 10/03/18 | Martin Still | |
| D.12 | NICER Cycle 1 | N/A | TBD | Rita Sambruna | NEW! |
| D.13 | LISA Preparatory Science | 3/19/18 | 6/14/18 | Rita Sambruna | NEW! |
| D.14 | SOFIA Next Gen. Instr. | 6/1/18 | 8/1/18 | Kartik Sheth | |
| D.15 | SmallSat Studies | N/A | 7/13/18 | Mike Garcia | NEW! |
| E.3 | Exoplanet Research | 3/29/18 | 5/30/18 | Martin Still | |
| E.4 | Habitable Worlds | 11/15/19 | 1/17/19 | Martin Still | |

# Proposal Status Update

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Status: July 24, 2018

Average 114 days (44 – 175 days)

GO Selection Rate = 35%

R&A Selection Rate = 21%

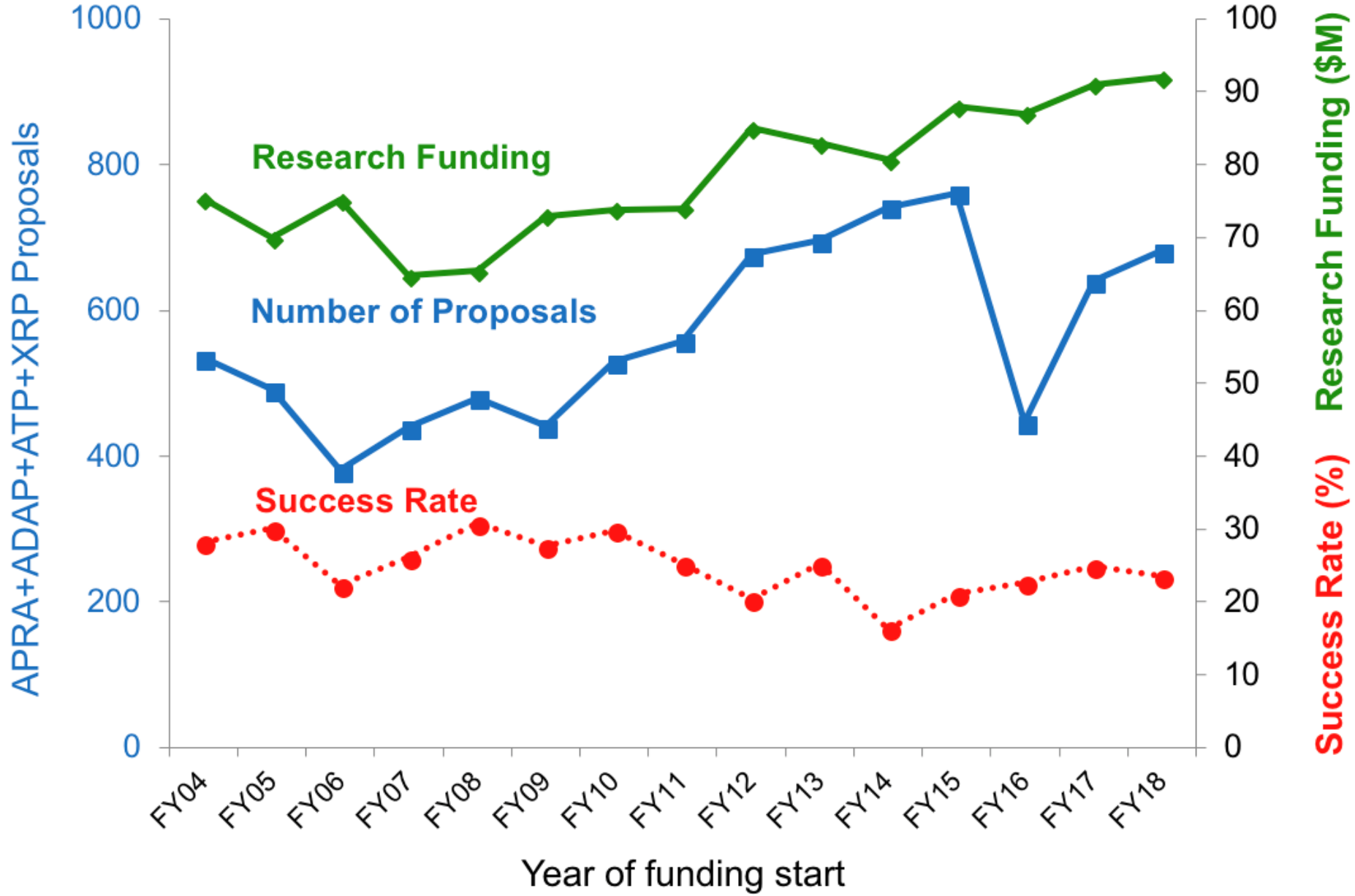
| Solicitation | Proposal Due Date | Notify Date | Days since received | Number received | Number selected | % selected |
|---|---|---|---|---|---|---|
| Roman Tech Fellowship | Mar 17, 2017 | Sep 8, 2017 | 175 | 12 | 2 | 17% |
| SAT (Technology) | Mar 17, 2017 | Sep 8, 2017 | 175 | 30 | 9 | 30% |
| APRA (Basic Research) | Mar 17, 2017 | Sep 8, 2017 | 175 | 141 | 53 | 38% |
| Hubble GO – Cycle 25 | Apr 7, 2017 | June 26, 2017 | 80 | 971 | 271 | 28% |
| ADAP (Data Analysis) | May 16, 2017 | Sep 11, 2017 | 118 | 264 | 35 | 13% |
| Exoplanet Research | May 25, 2017 | Oct 8, 2017 | 136 | 50 | 9 | 18% |
| SOFIA GI – Cycle 6 | June 30, 2017 | Nov 7, 2017 | 130 | 198 | 104 | 53% |
| Astrophysics Theory | July 27, 2017 | Dec 22, 2017 | 148 | 216 | 53 | 25% |
| Webb Early Release Science | Aug 18, 2017 | Nov 13, 2017 | 87 | 106 | 13 | 12% |
| Swift GI – Cycle 14 | Sep 28, 2017 | Jan 13, 2018 | 140 | 146 | 30 | 21% |
| TESS – Cycle 1 | Oct 6, 2017 | Feb 3, 2018 | 132 | 143 | 38 | 27% |
| K2 – Cycle 6 (Phase 2) | Apr 19, 2018 | June 25, 2018 | 67 | 41 | 23 | 56% |
| NESSF-18 | Feb 1, 2018 | May 15, 2018 | 103 | 176 | 9 | 5% |
| Chandra GO – Cycle 20 | Mar 16, 2018 | July 16, 2018 | 122 | 526 | 156 | 24% |
| XARM Participating Scientist | Dec 13, 2017 | Feb 21, 2018 | 64 | 39 | 5 | 13% |
| NuSTAR – Cycle 4 | Jan 19, 2018 | April 17, 2018 | 88 | 196 | 83 | 42% |
| TCAN | Jan 26, 2018 | June 21, 2018 | 146 | 32 | 3 | 9% |
| Segmented Telescope Design | Feb 1, 2018 | Mar 16, 2018 | 44 | 5 | 2 | 40% |
| Fermi GI – Cycle 11 | Feb 23, 2018 | May 26, 2018 | 92 | 138 | 42 | 30% |
| Spitzer GI – Cycle 14 | Mar 23, 2018 | May 29, 2018 | 67 | 116 | 50 | 43% |

# Theoretical and Computational Astrophysics Networks (TCAN)

- TCAN supports coordinated efforts in fundamental theory and computational techniques.
- TCAN aims to unite researchers in collaborative networks that cross institutional and geographical divides.
- Last call for proposals was in 2012. Issued a call for proposals for TCAN in ROSES-2017. $1.5M allocation.
- Proposals were due on January 25, 2018, selections made on June 19, 2018,
- 32 proposals received, 3 proposals selected, selection rate 9%.

| Title | Nodes | Project Description |
|---|---|---|
| Modeling Polarized Galactic Foregrounds for Cosmic Microwave Background Missions | Univ. CA, Berkeley | State of the art MHD simulations of the turbulent, dusty interstellar medium to model contamination of next-generation CMB observations by galactic foreground emission |
| | Princeton Univ. | |
| | Univ. CA, San Diego | |
| | Univ. Wisconsin | |
| Origin of the Giant Planet Dichotomy: Multi-Scale Modeling of Planetary Envelope Accretion | Univ. Colorado | 3D hydrodynamical modeling of the accretion of material from a protoplanetary disk by a rock-ice core to study the formation of extrasolar mini-Neptunes and gas giants |
| | Univ. Arizona | |
| | UNLV | |
| Advancing Computational Methods to Understand the Dynamics of Ejection, Accretion, Winds and jets in Neutron Star Mergers | RIT | Multi-code, general relativistic MHD simulations of binary neutron star mergers, from the inspiral before coalescence to the formation of a merged remnant just after |
| | NASA/GSFC | |
| | Johns Hopkins Univ. | |
| | West Virginia Univ. | |

# Proposal Pressure

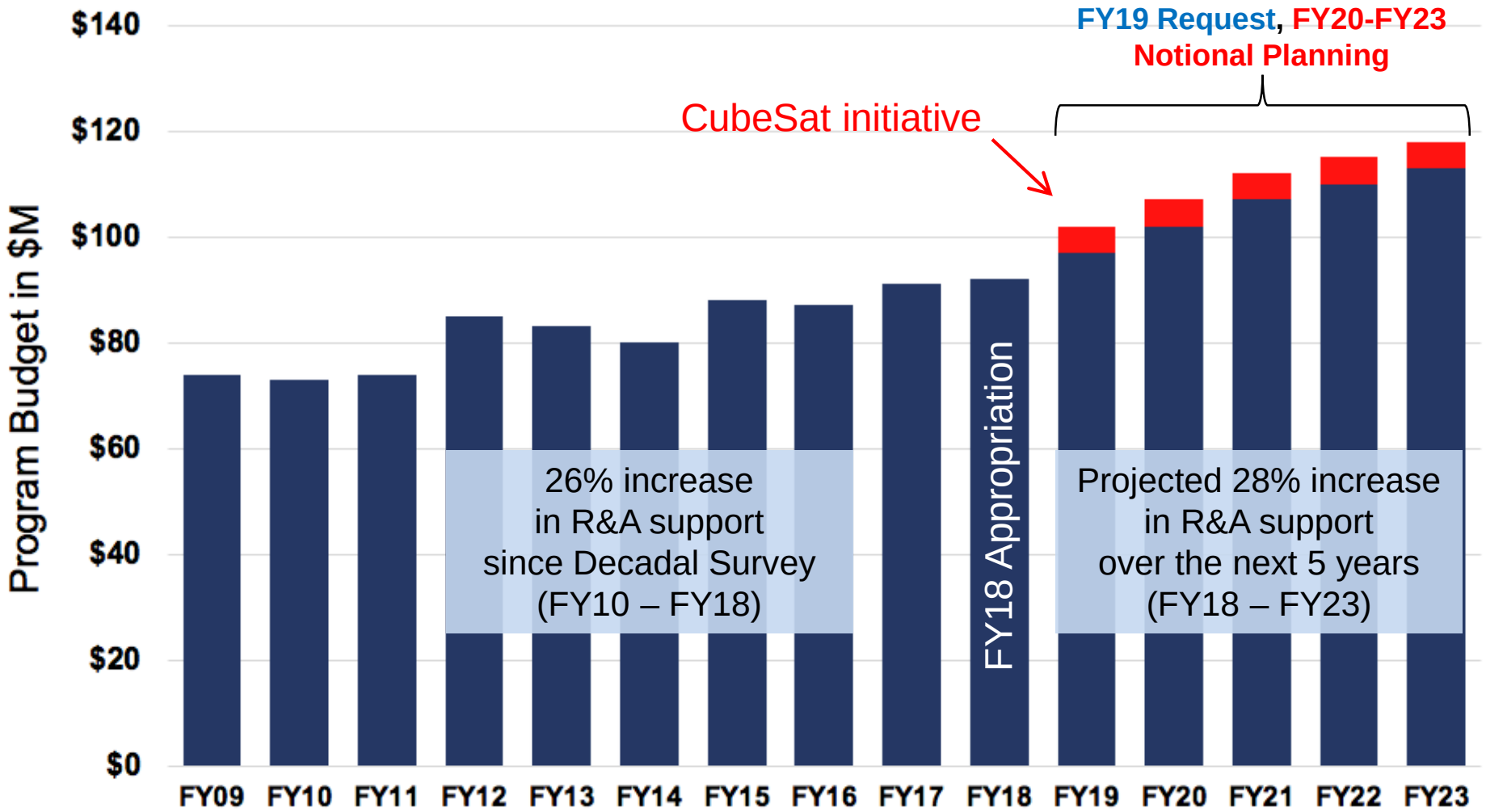


# R&A Budget

# Growth in R&A Funding ($M)

Notional

| Program | FY09 | FY10 | FY11 | FY12 | FY13 | FY14 | FY15 | FY16 | FY17 | FY18 | FY19 | FY20 | FY21 | FY22 | FY23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R&A | $74 | $73 | $74 | $85 | $83 | $80 | $88 | $87 | $91 | $92 | $97 | $102 | $107 | $110 | $113 |
| CubeSat | | | | | | | | | | | $5 | $5 | $5 | $5 | $5 |
| Total | $74 | $73 | $74 | $85 | $83 | $80 | $88 | $87 | $91 | $92 | $102 | $107 | $112 | $115 | $118 |



# Internal Scientist Funding Model

# Internal Scientist Funding Model (I)

Selected in FY18

| Center/Package | $/yr | Period of Performance | ISFM Package Summary |
|---|---|---|---|
| GSFC | | | |
| X-ray mirrors | 2.4 M | Extends FY20 | Develop X-ray mirror technologies to surpass Chandra by orders of magnitude |
| X-ray calorimeters | 0.9 M | Extends FY18-FY20 | Transition-edge sensors and magnetically coupled microcalorimeters for future missions |
| Gravitational waves | 0.3 M | New FY18-FY20 | Lay the groundwork for US LISA science. |
| SEEC Exoplanets | 0.1 M | New FY18-FY20 | Creation of a community-coordinated modeling database and analysis portal. |
| MSFC | | | |
| Advanced X-ray optics | 1.9 M | Extends FY18-FY20 | Provide unique test facilities support for both internal and external X-ray optics systems |
| Precision thermal control | 1.2 M | Extends FY20 | Develop, demonstrate and mature a thermally stable telescope towards TRL6 |
| ARC | | | |
| Coronagraphy | 0.5 M | New FY18 | Evolved Multi-Star Wavefront Control (MSWC) algorithm tuned for WFIRST |
| Speckle | 0.4 M | Extends FY18 | High-resolution imaging of exoplanet candidates |

# Internal Scientist Funding Model (II)

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## Selected for FY19

| Center/Package | $/yr | Period of Performance | ISFM Package Summary |
|---|---|---|---|
| GSFC | | | |
| Exoplanet spectroscopy technologies | 1.68 M; 2.32 M; 1.47 M | FY19-FY21 | Development of spectroscopic technologies to enable efficient & broadband characterization of imaged exoplanets |
| Time-domain multi-messenger astronomy | 0.55 M; 0.55 M; 0.63 M | FY19-FY21 | Creation of a coordination hub; expansion of GCN inputs; multi-database searches; develop system for joint localization with gamma-ray detectors |
| MSFC | | | |
| Hybrid X-ray optics | 0.41 M; 0.41 M | Augments FY18-FY20 | Development of ultra light-weight, replicated optics and ultra-thin substrate using additive manufacturing |
| ARC | | | |
| Laboratory astrophysics: PAH spectral database | TBD (potential cost sharing with PSD) | FY19-FY21 | To support long-term Ames' PAH database; increase its contents and impacts; to continue make available to the community all needed analysis tools |

- All ISFM packages were peer reviewed.
- Three new ISFM work packages selected for start in FY19.
- Would have been submitted in 10 individual APRA/ADAP/SAT proposals.
- One ISFM is cross-division and pending review.

# R&A Code of Conduct

# R&A Code of Conduct

- APD has developed R&A Code of Conduct.
- Starting in May, the Code of Conduct is presented during the Opening Plenary Sessions and poster boards are prominently displayed at all peer reviews.

APRA review May 30, 2017

## R&A Code of Conduct for Panelists

NASA strives for an inclusive and professional environment for all participants in its activities.
As a panel member, **we expect you to:**

1. Be prepared and contribute to the panel review
2. Evaluate the merit of the proposals and the strength of the proposing team not the people as individuals.
3. Evaluate expertise and not "experience"
4. Be an active participant in the discussions
5. Not interrupt others or talk over others
6. Keep comments succinct and to the point and thus give everyone the opportunity to contribute to the discussion.
7. Be mindful of bias in all contexts
8. Step in to address abusive or bullying behavior
9. Be respectful of all regardless of differences (professional or otherwise)
10. Actively help create an environment free of harassment

**At any time, feel free to talk to a NASA panel monitor if you have any concerns.**

## R&A Code of Conduct for Chairs

In addition to the code of conduct for panelists, **as chair we expect you to**:

1. Lead the panel by example in creating an environment for free and professional discussion.
2. Lead the panel in an inclusive and welcoming way and step in to address any abusive, bullying or unprofessional behavior
3. Proactively solicit input from each panel member in the discussion of each proposal; ensure that the discussion is <u>not</u> dominated by a few reviewers
4. Proactively encourage participation of reviewers who may be less experienced at reviews
5. Keep the discussion moving and end on time to allow for sufficient time and discussion for all the proposals in the panel
6. Keep the discussion focused on the strengths and weaknesses of the proposal, and not on the individuals or other tangential topics

**At any time, feel free to talk to a NASA panel monitor if you have any concerns.**

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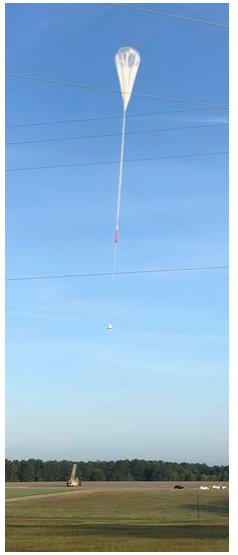
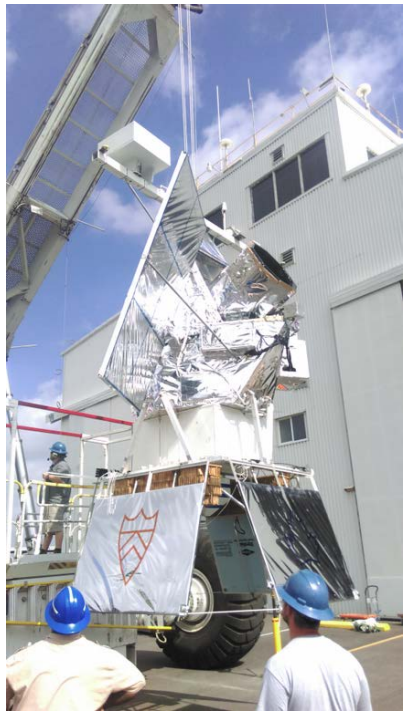
# R&A Suborbital Programs
## 1) Balloons

# Balloon Program FY2018 Manifest

| Principal Investigator (PI) / Institution / Instrument | Discipline | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **McMurdo, Antarctica** | **Winter 17** | | | | | | | | | | |
| **Binns / WUSTL / SuperTIGER** | Cosmic Ray/Particle | ⇨ | | **MANIFESTED FY19** | | | | | | | |
| **Esrange, Sweden** | **Summer 18** | | | | | | | | | | |
| **Clem / UDel / AESOP-lite** | Heliophysics | | | | | ◆ | **Launched** | | | | |
| **Wu / NCAR / HIWIND** | Upper Atmosphere | | | | | | ◆ | **Launched** | | | |
| **Fritts / GATS / PMC-Turbo** | Heliophysics | | | | | | | ◆ | **In Flight** | | |
| **Palestine, Texas** | **Summer 18** | | | | | | | | | | |
| **Jones / Princeton / SuperBIT** | IR-Submillimeter | | | | | | ◆ | **Launched** | | | |
| **Kogut / GSFC / PIPER** | IR-Submillimeter | | | | | | ◇ | **Cancelled** | | | |
| **Bloser / UNH / ASCOT** | Gamma Ray | | | | | | | ◆ | **Launched** | | |
| **Kogut / GSFC / PIPER** | IR-Submillimeter | | | | | | ◇ | **Cancelled** | | | |
| **Fort Sumner, New Mexico** | **Fall 18** | | | | | | | | | | |
| **Fischer / GSFC / Big 60 Qual** | Test Flight | | | | | | | | ◇ | | |
| **Moore / GSFC / USIP** | Student Flight Project | | | | | | | | ◇ | | |
| **Fischer / GSFC / Big 60 Qual** | Test Flight | | | | | | | | ◇ | | |
| **Stuchlik / GSFC / SIFT** | Test Flight | | | | | | | | ◇ | | |
| **Guzik / LSU / HASP** | Student Flight Project | | | | | | | | | ◇ | |
| **Martin / Caltech / FIREBALL** | UV / Visible | | | | | | | | | ◇ | |
| **Toon / JPL / Remote** | Upper Atmosphere | | | | | | | | | ◇ | |
| **Chakrabarti / UMass / PICTURE-C** | UV / Visible | | | | | | | **Cancelled** | | ◇ | |
| **Kogut / GSFC / PIPER** | IR-Submillimeter | | | | | | | | | ◇ | |
| **Kogut / GSFC / BOBCAT** | IR-Submillimeter | | | | | | | | | ◇ | |



ASCOT balloon payload

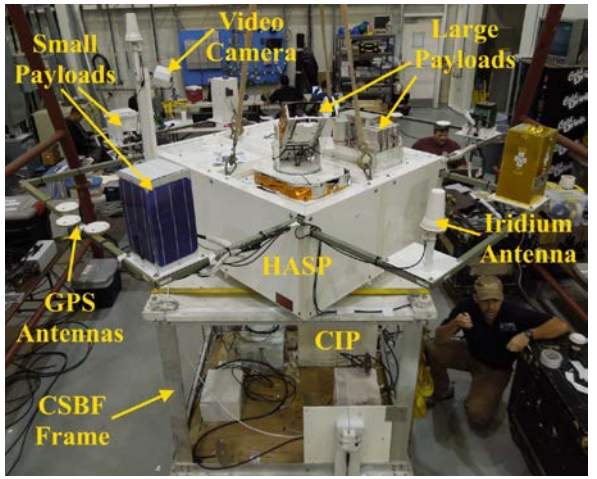


SuperBIT balloon payload

# Balloon Program FY2019 Manifest

| Principal Investigator (PI) / Institution / Instrument | Discipline | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **McMurdo, Antarctica** | **Winter 18** | | | | | | | | | | | | |
| **Binns / WUSTL / SuperTIGER** | Cosmic Ray/Particle | | | ◊ | | | | | | | | | |
| **Krawczynski / WUSTL / X-Calibur** | Gamma Ray | | | ◊ | | | | | | | | | |
| **Devlin / Univ Penn / BLAST-TNG** | IR-Submillimeter | | | ◊ | | | | | | | | | |
| ***Salter / CSBF / GUSTO Pathfinder*** | *Test Flight* | | | ◊ | | | | | | | | | |
| **Wanka, New Zealand** | **Spring 19** | | | | | | | | | | | | |
| **Fairbrother / WFF / SPB** | Test Flight | | | | | | ◊ | | | | | | |
| **Palestine, Texas** | **Summer 19** | | | | | | | | | | | | |
| **Jones / Princeton / SuperBIT** | IR-Submillimeter | | | | | | | | | ◊ | | | |
| **Kogut / GSFC / PIPER** | IR-Submillimeter | | | | | | | | | ◊ | | | |
| **Chakrabarti / UMass / PICTURE-C** | UV / Visible | | | | | | | | | ◊ | | | |
| **Kogut / GSFC / BOBCAT** | IR-Submillimeter | | | | | | | | | ◊ | | | |
| **Kogut / GSFC / PIPER** | IR-Submillimeter | | | | | | | | | ◊ | | | |
| **Fort Sumner, New Mexico** | **Fall 19** | | | | | | | | | | | | |
| **Fischer / GSFC / Big 60 Qual** | Test Flight | | | | | | | | | | | ◊ | |
| **Gopalswamy / GSFC / BITSE** | Solar and Heliophysics | | | | | | | | | | | ◊ | |
| **Bailey / VaTech / GLO** | Upper Atmosphere | | | | | | | | | | | ◊ | |
| **Young / SwRI / THAI-SPICE** | UV / Visible | | | | | | | | | | | ◊ | |
| **Guzik / LSU / HASP** | Student Flight Project | | | | | | | | | | | ◊ | |
| ***Livesey / JPL / SWITCH*** | *UP / Upper Atmosphere* | | | | | | | | | | | ◊ | |
| **Martin / Caltech / FIREBALL** | UV / Visible | | | | | | | | | | | | ◊ |
| **Toon / JPL / Remote** | Upper Atmosphere | | | | | | | | | | | | ◊ |
| **Chakrabarti / UMass / PICTURE-C** | UV / Visible | | | | | | | | | | | | ◊ |
| **Kogut / GSFC / PIPER** | IR-Submillimeter | | | | | | | | | | | | ◊ |
| **Kogut / GSFC / BOBCAT** | IR-Submillimeter | | | | | | | | | | | | ◊ |

X-Calibur integration test @ WFF, March 1




HASP balloon payload

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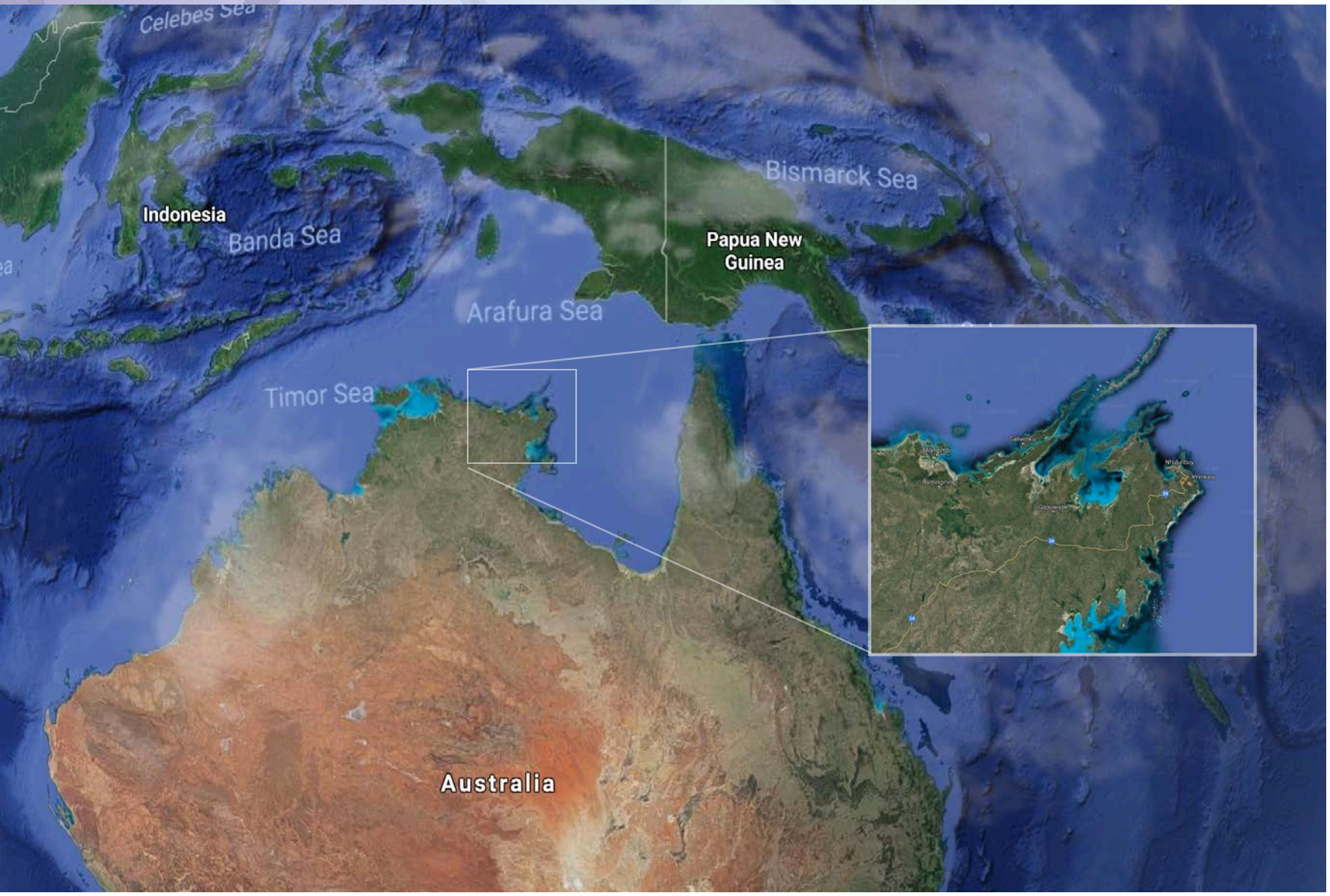
# R&A Suborbital Programs
## 2) Sounding Rockets

# APD Sounding Rocket Launch Manifest

| PI | PROJECT | RANGE | DATE | DISCIPLINE |
|---|---|---|---|---|
| FRANCE | CHESS | WSMR | 2017-06-27 | UV/OPTICAL |
| GREEN | DEUCE | WSMR | 2017-10-30 | UV/OPTICAL |
| GALEAZZI | DXL | PFRR | 2018-01-19 | HIGH ENERGY |
| MCENTAFFER | WRX-R | KWAJ | 2018-04-04 | HIGH ENERGY |
| FRANCE | CHESS | KWAJ | 2018-04-16 | UV/OPTICAL |
| FIGUEROA | MICRO-X | WSMR | 2018-07-22 | HIGH ENERGY |
| GREEN | DEUCE | WSMR | 2018-12-03 | UV/OPTICAL |
| BOCK | CIBER-2 | WSMR | 2019-01-01 | UV/OPTICAL |
| FRANCE | SISTINE | WSMR | 2019-06-01 | UV/OPTICAL |
| MCCANDLISS | FORTIS | WSMR | 2019-06-11 | UV/OPTICAL |
| NUTH | DUST | WSMR | 2019-11-01 | UV/OPTICAL |
| FRANCE | SISTINE | AUS | 2020-04-01 | UV/OPTICAL |
| MCENTAFFER | WRX-R | AUS | 2020-04-01 | HIGH ENERGY |
| MCCAMMON | XQC | AUS | 2020-04-01 | HIGH ENERGY |
| GREEN | DEUCE | AUS | 2020-04-01 | UV/OPTICAL |

Micro-X integration review @ WFF, June 11

# Australia Site for Astrophysics April/May 2020 Launches




Sounding Rocket Program Office (SRPO) expects that the commercial Equatorial Launch Australia (ELA) site will available starting in April – May 2020. Science teams that can see their targets in a narrow 2 – 3 week window:

| | |
|---|---|
| **MW Center:** | **McCammon** |
| **NGC796:** | **McCandliss** |
| **A Cen B:** | **France, Green** |
| **Vela SNR:** | **McEntaffler** |

SRPO anticipates to have Australia launches every 1.5 – 3 years. An additional commercial launch site further south is presently being explored for potential future use.

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# R&A Suborbital Programs
## 3) CubeSats/SmallSats

# CubeSats

- Solicited via ROSES APRA, up to 12U allowed
- Launch free to PI, LCAS/RideShare
- Four 6U CubeSats have been selected to date, typically 3 years from start to launch, <~$5M

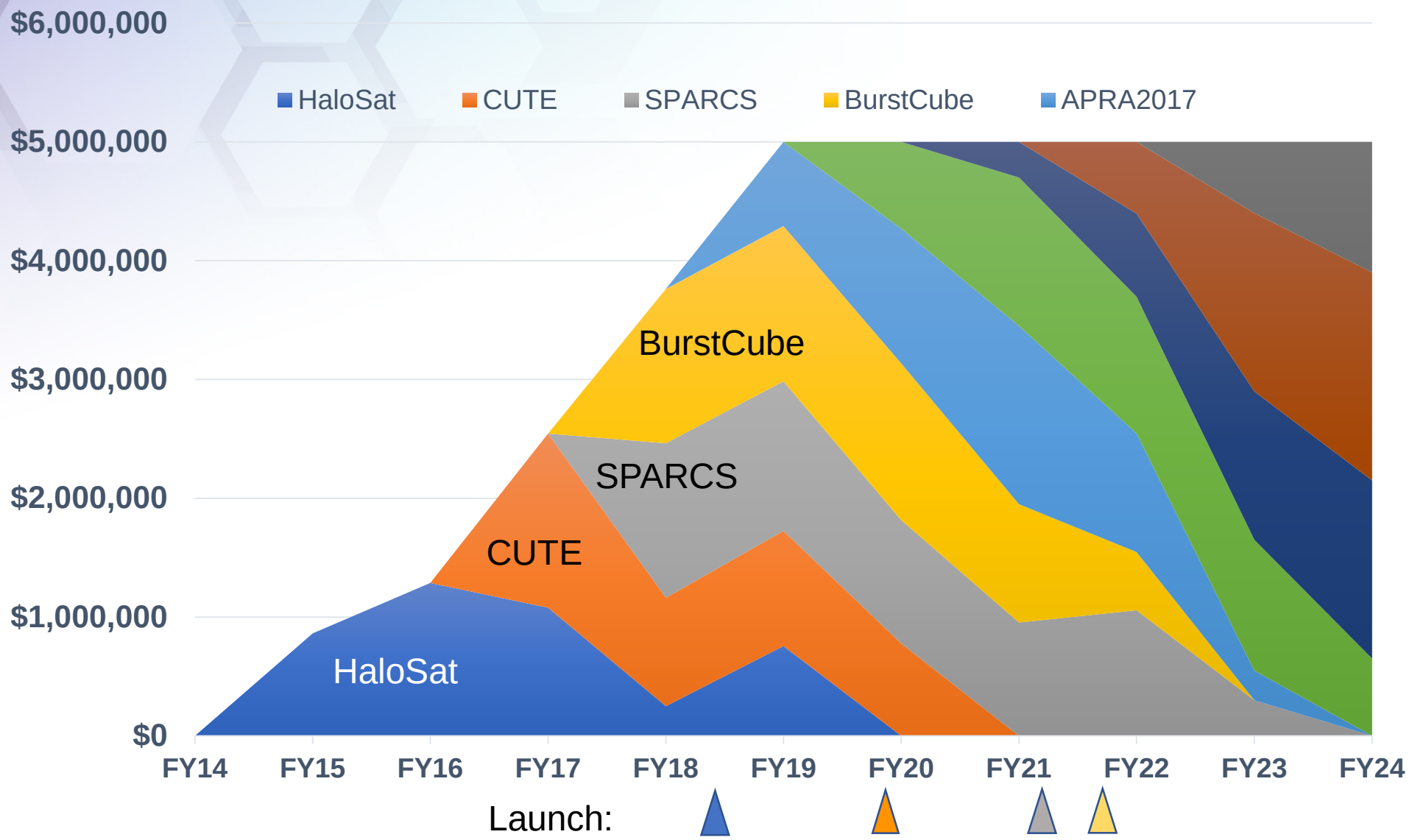
- **HALOSAT, PI**: Phil Kaaret, U Iowa
- **Energies**: soft X-rays
- **Science Objectives:** HaloSat will map the distribution of hot gas in the Milky Way and determine whether it fills an extended, and thus massive halo, or whether the halo is compact, and thus does not contribute significantly to the total mass of the Milky Way.
- **Launch**: **Deployed from ISS July 13, 2018**

- **CUTE, PI:** Kevin France, CU
- **Energies**: UV
- **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. 14 targets.
- **Launch**: FY20 to SSO

- **SPARCS, PI**: Evgenya Shkolnik, AZ State U
- **Energies**: UV
- **Science Objectives:** Determine rate, strength and color of bright UV flares from a select 25 M dwarfs, with an eye towards how these flares affect the habitability of planets.
- **Launch**: September 2021

- **BurstCube, PI:** Jeremy Perkins (GSFC)
- **Energies**: hard X-rays
- **Science Objectives:** Rapid localizations for high-significance LIGO/Virgo detections coincident with short GRBs; Correlate short GRBs with LIGO/Virgo sub-threshold signals, increasing volume; Search of gamma-ray transients
- **Launch**: Fall 2021

# CubeSats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BurstCube
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CUTE
SPARCS
BurstCube
FY14
FY15
FY16
FY17
FY18
FY19
FY20
FY21
FY22
FY23
FY24
Launch:

# Astrophysics SmallSats for Smaller Price Points

- Astrophysics RFI for SmallSats asked for ideas to do high priority Astrophysics science projects at a price point between typical R&A and Explorer MOO projects ($10M-$35M).
- The RFI also asked for advanced mission concepts for which “significant” investments in instrument and/or platform technologies would be required, without budget constraints, in order to inform future STMD solicitations.
- 55 replies received by Nov 30, 3017, were responsive to Astrophysics science and/or technology.
- ROSES/NRA D.15, due July 13, 2018, solicited Astrophysics Science SmallSat Studies. Between 6 and 10 proposals will be selected for 6 month studies to start Sept  2017 and end March 10, 2018; $1M total budgeted.
- End date set to allow completion prior to release of 2019 SMEX/MOO.
- 43 proposals received. Representative science areas include: exoplanets, GRM/EM counterparts, UV/X-ray surveys, WHIM, 21cm.

# Backup Slides

# Astrophysics Division R&A Staff

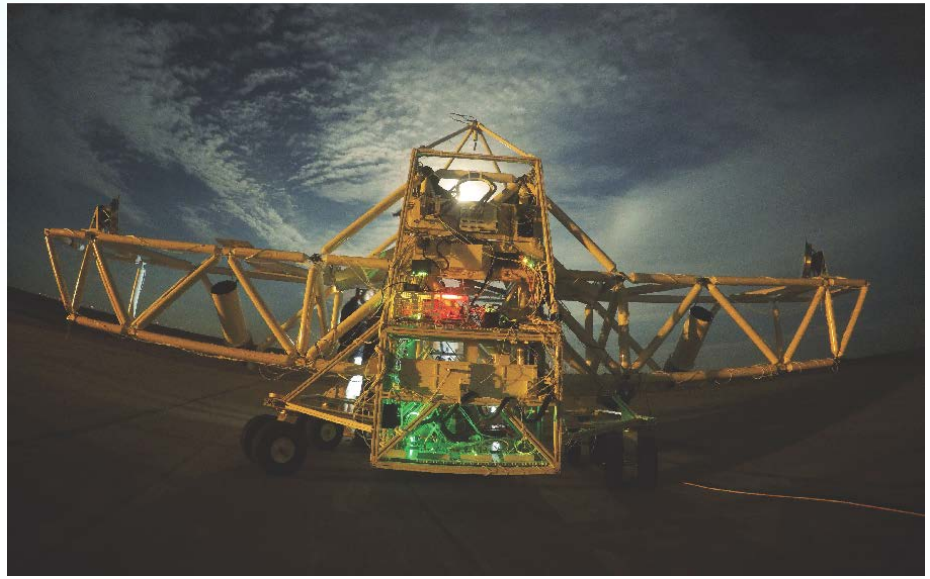
| | |
|---|---|
| **Program Manager:** | **Stefan Immler*** |
| Deputy Program Manager: | Linda Sparke |
| Program Support: | Ingrid Farrell* |
| Astrophysics Data Analysis: | Doug Hudgins |
| Astrophysics Theory: | Keith MacGregor* |
| Exoplanet Research: | Martin Still* |
| APRA: | Michael Garcia* |
| Cosmic Ray, Fund Physics: | Thomas Hams*, Vernon Jones, Keith MacGregor*, Rita Sambruna |
| Gamma Ray/X-ray: | Valerie Connaughton*, Michael Garcia*, Stefan Immler*, Rita Sambruna |
| Optical/Ultraviolet: | Michael Garcia*, Hashima Hasan, Patricia Knezek*, Mario Perez*, Martin Still* |
| IR/Submillimeter/Radio: | Dominic Benford, Doug Hudgins, William Latter*, Kartik Sheth, Eric Tollestrup* |
| Lab Astro: | Doug Hudgins, William Latter* |
| Theory & Comp Astro Net: | Keith MacGregor* |
| Roman Tech Fellows: | Nasser Bargoughty* |
| Data Archives: | Hashima Hasan |
| Astrophysics Sounding Rockets: | Thomas Hams* |
| Balloons Program: | Vernon Jones (PS), Mark Sistilli (PE) |
| CREAM: | Vernon Jones (PS), Jeff Hayes (PE) |

* Detailee, IPA, or contractor

# Astrophysics Division R&A Portfolios

| Portfolio Name | Program Officer |
|---|---|
| Astrophysics Research and Analysis High Energy | Stefan Immler |
| Astrophysics Research and Analysis Particle Astrophysics | Thomas Hams |
| Astrophysics Research and Analysis Fundamental Physics | Thomas Hams |
| Astrophysics Research and Analysis UV/Vis | Mike Garcia |
| Astrophysics Research and Analysis IR/Radio | Eric Tollestrup |
| Astrophysics Theory Program | Keith McGregor |
| Exoplanet Research Program | Martin Still |
| Roman Technology Fellows | Mario Perez |
| CubeSats/SmallSats | Mike Garcia |
| Astrophysics Data Analysis Program | Doug Hudgins |
| Mirror Technologies | Mario Perez |
| Technology Development for Exoplanet Missions | Doug Hudgins |
| Strategic Astrophysics Technology Cosmic Origins | Mario Perez |
| Strategic Astrophysics Technology Physics of the Cosmos | Rita Sambruna |
| Astrophysics Probes | Rita Sambruna |

# Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII)
## PI: S. Rinehart (NASA/GSFC)



**Description and Objectives:**
8-meter far-IR (30-100 μm) interferometer to:
(a) Study star formation in clusters, and to potential break degeneracies between competing models.
(b) Provide the key system-level demonstration of a free-flying interferometer, to help pave the way for future space-based spatial interferometry (see the Astrophysics Roadmap!)

**Key Challenge/Innovation:**
Demonstrating a free-flying interferometer as a **system** – individual technologies are demonstrated and well-understood, but lacking is a system demonstration.

**Approach:**
Rapid development achieved by combining design and build phases (this has drawbacks).

**Development period:**
2011: Project start
2016: Deployed for first flight; scrubbed due to poor weather.
2017: Launched on engineering flight out of Palestine, TX; anomalous termination resulted in loss of payload. Funding cut post-flight.
2018: New proposal submitted, including flights in **2020, 2021, and 2022**.
2018: **Rebuild under way** with GSFC support, recovered components, flight spares, etc. Full program contingent on ARPA selection.

**Key Collaborators:**
GSFC, University of Maryland, Cardiff University, the FITE team in Japan

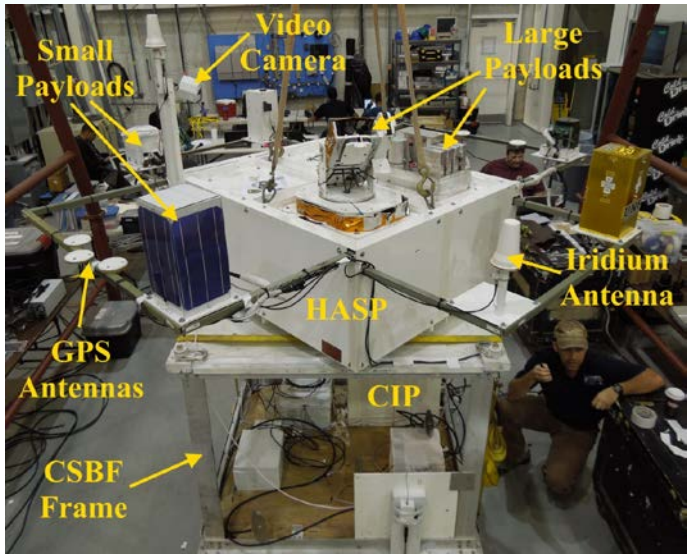
**Accomplishments/Milestones:**
**Flight**: ~90% of systems function as expected
2 on-flight problems observed, diagnosed, with known fixes
Demonstrated closed-loop pointing control, H4RG operation with new data modes, full end-to-end electrical operation, good thermal behavior, and optical stability
**Students**: 2 PhD students (both completed); 5 M.S. students; ~35 undergraduate students. Robert H. Goddard Team Award for Mentoring given to the BETTII team.
**Publications**: 4 peer-reviewed (1 in prep); ~20 conference papers (e.g. SPIE)

**Application:**
Use of the developed technique and/or technology into future suborbital and/or space missions

# High Altitude Student Platform (HASP) 2006 - 2018

**Description and Objectives:** HASP supports multiple advanced student team payloads with an annual flight opportunity to provide a real-world science and engineering project development experience.

**Key Challenge/Innovation:** First balloon carrier designed with a standard mechanical, electrical, and telemetry interface to carry multiple experiments to high altitude for an extended time. Developed to provide university students with a flight opportunity intermediate between small sounding balloons and Earth-orbiting satellites.




**Approach:** Support >12 instrument payloads --
(8) Small payloads (<3 kg, < 0.5 A @ 30VDC, 1200 bps downlink & uplink, 15cm x 15cm x 30 cm)

(4) Large payloads (<20 kg, < 2.5 A @ 30VDC, 4800 bps downlink & uplink, 38cm x 30cm x 30cm)

(3-4) Self-contained payloads in CSBF frame

Real-time video during flight to confirm operation

**Development period:** Annual flight opportunity

**Key Collaborators:** Louisiana Space Grant Consortium, NASA Balloon Program Office, and Columbia Scientific Balloon Facility

**Accomplishments/Milestones:**

12 missions since 2006 for a total exposure at altitude of more that 7 days.

Close to 1,200 students from 43 institutions across 21 states plus Puerto Rico & Canada have been involved in a HASP experiment

~75% of accepted payloads have flown and ~90% of flown payloads are successful.

In 2011 flew HASP twice with different complements of student payloads within 7 days.

Student experiments cover a wide range of topics.

# Primordial Inflation Polarization Explorer (PIPER)
# PI A. Kogut, NASA/GSFC

**Description and Objectives:** Measure polarization of the cosmic microwave background to test primordial inflation and quantum gravity

**Key Challenge/Innovation:** Fully cryogenic telescope and no-window liquid helium dewar improves mapping speed by factor of 10 to measure CMB signal on largest angular scales

**Approach:** Combine cryogenic telescopes with kilo-pixel detector arrays and fast signal modulation to map polarization on largest angular scales

**Development period:**
Funding initiated in FY09
Engineering flight FY17
Series of science flights begins 2018

**Key Collaborators:** Johns Hopkins University, NIST, University of British Columbia, Cardiff University

**Accomplishments/Milestones:**
Engineering flight 2017 (Ft Sumner, NM) follows series of campaigns when payload was flight-ready but not launched
Students to date: 2 post-doctoral students
6 graduate students
37 undergraduate students

**Application:** Advance technologies to TRL-6 for space mission
- Detectors (Transition-edge superconducting bolometers)
- Readout (Two-dimensional time-domain multiplexing)
- Cryogenics (Continuous adiabatic demagnetization refrigerator)
- Modulator (Variable-Delay Polarization Modulator)

Fully cryogenic system allows detector operation at space-like loading

# SuperBIT: Wide-field, sub-arcsecond Imaging from the Super Pressure Balloon

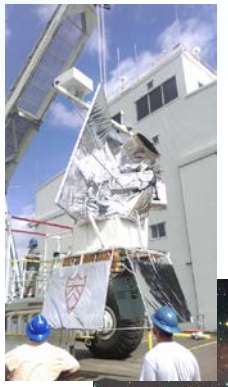
PI W. Jones, Princeton

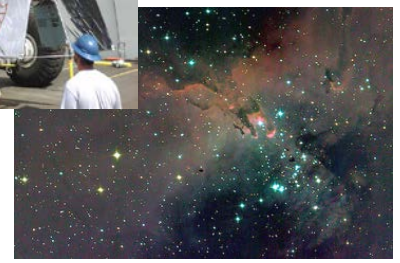
## Description and Objectives:

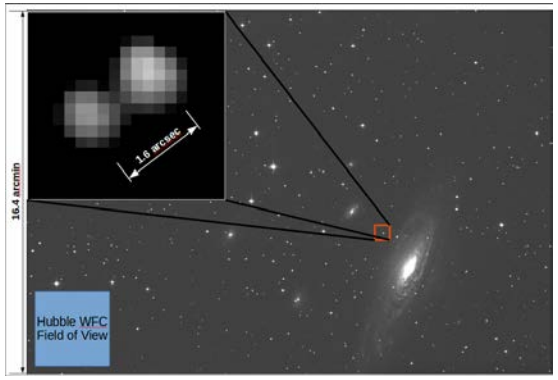
SuperBIT is a wide field, 250 milli-arcsec resolution imaging telescope designed to take advantage of the persistent near space environment provided by the Super Pressure Balloon platform.
The primary science goal is to produce lensing masses for a sample of hundreds of galaxy clusters, dramatically improving the mass-observable relations that are critical to understanding the cosmological matter distribution on large scales.

## Key Challenge/Innovation:

SuperBIT has demonstrated the ability to provide 80 mas pointing stability with field rotation for long (15 minute) exposures. Even with a ½ meter primary aperture, the large format camera and space-like environment enable survey speeds comparable to the Hubble ACS.








At left, SuperBIT prior to the 2018 flight. Below, an image of the Eagle Nebula (M16) obtained by SuperBIT 2016. Above, a single 5min exposure on NGC7335 from 2018, showing the FOV compared to HST, and sub-arsec resolution.

## Approach:

A three-axis pointing system provides ~2 arcsecond pointing stability and field rotation. A fast tip/tilt mirror, servoed by a guide camera and a suite of advanced fiber optic gyroscopes, provides image stabilization at the subarcsecond level. A 29 megapixel science camera and six filters between 250 and 900 nm provide a survey speed comparable to that of the Hubble ACS.

## Key Collaborators

- C. Barth Netterfield (U. Toronto)
- Richard Massey (Durham)
- Jason Rhodes (JPL)

## Accomplishments and Next Milestones:

- Successful test flights in 2016 & 2018
- Student led program (5 GS, 3 UG and 1 post-doc)
- Demonstrated 80 mas pointing stability with 300s integrations
- Demonstrated survey speeds near ó that of Hubble ACS
- Identified & implemented areas of improvement, including fiber optic gyros and guide camera upgrades
- Design study for an improved SiC three-mirror anastigmat telescope
- Upgrading ½ meter telescope for SPB science flight

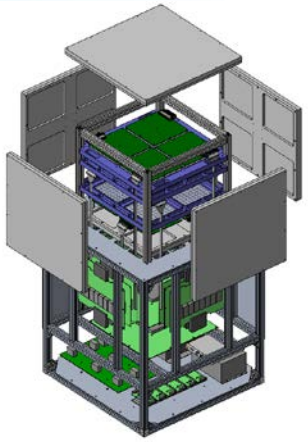
## Current Award Period:

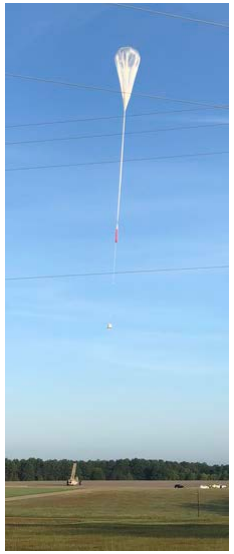
- Jan 2016 - Jan 2021

# Advanced Scintillator Compton Telescope (ASCOT)

**Description and Objectives:** ASCOT is a prototype Compton telescope designed to operate in the MeV gamma-ray band. The objective of the ASCOT project is to demonstrate new detector technology in a near-space environment by imaging the Crab Nebula at energies of ~0.3 – 2 MeV

**Key Challenge/Innovation:** ASCOT uses modern fast scintillator detectors (p-terphenyl as scatterer and $CeBr_3$ as calorimeter) read out by silicon photomultipliers (SiPMs). This enables time-of-flight background rejection in an efficient, compact instrument with good energy resolution.





**Approach:**
Prototype development and demonstration via balloon flight to raise TRL to 6/7

**Development period:**
APRA-13 selection; instrument & payload development 3/15 – 5/18; launched 7/5/18

**Key Collaborators:**
- ASCOT developed solely by the University of New Hampshire
- Collaborators at University College Dublin flew a piggyback payload, the Gamma-ray Module Demonstrator (GMoDem)

**Accomplishments/Milestones:**
- ASCOT balloon payload successfully flown
- Instrument operated nominally during five hours at float (122,000 feet)
- Project has supported one graduate student and one undergraduate student
- Three SPIE proceedings papers to date; expect 1 – 2 science publications in coming year

**Application:**
Scintillator/SiPM detector technology applicable to astrophysics, heliophysics, and planetary science for compact, low-mass gamma-ray and neutron instruments (e.g., CubeSats, SmallSats, landers)

# NASA/CU 36.323 UG: CHESS-4. Measuring the Temperature of the Milky Way

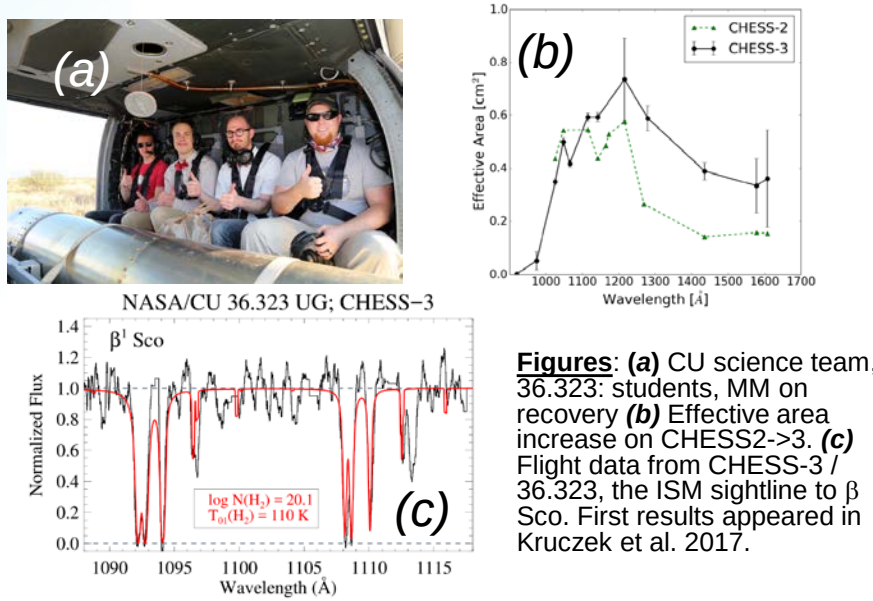
ASTROPHYSICS

## Description and Objectives:

- Fabrication and laboratory testing of critical path technologies for future NASA UV/vis astrophysics missions
- Flight-testing of key technologies in operational space environment – raising TRL of flight technologies to TRL6-7
- Science, education, and training the next generation of scientists and engineers who will lead future NASA missions

## Key Challenge/Innovation:

- Diffraction gratings for high-resolution UV spectrographs
- UV/vis detector technology demonstration in space environment: larger formats, higher dynamic range, lower background equivalent flux
- High-reflectivity optical coatings with high wavefront control




**Figures**: ***(a)*** CU science team, 36.323: students, MM on recovery ***(b)*** Effective area increase on CHESS2->3. ***(c)*** Flight data from CHESS-3 / 36.323, the ISM sightline to β Sco. First results appeared in Kruczek et al. 2017.

## Approach:

- Design rocket-borne spectrographs and telescopes
- Work with collaborators and vendors on specifications and fabrication procedures for key technologies
- Component-level efficiency and environmental testing
- End-to-end payload development and launch
- Scientific and technical analysis, student training, and publication of results

## Key Collaborators:

- Oswald Siegmund & John Vallerga – UC Berkeley
- Shouleh Nikzad – JPL
- Manuel Quijada - GSFC
- Aki Roberge (GSFC), Jason Tumlinson (STScI), Ed Jenkins (Princeton) – Science and large mission application

## Development Period:

- 06/01/2016 – 05/31/2020

## Accomplishments and Next Milestones:

•Successfully launched CHESS-3 (June 2017), published results from the mission (Kruczek et al. 2017, 2018), and recently published an overview paper on science and technology from CU program (France et al. 2016a,b)
•Graduate and undergraduate students took lead roles on CHESS-3, graduated Ph.D. student who joined Martin group at Caltech
•Component development and instrument design for LUVOIR LUMOS instrument (design based on CU rocket payloads)
• Received and tested UV-optimized CCD from ASU/JPL.

## Application:

- All UVOIR missions requiring high spectral resolution, high-sensitivity, and low background equivalent flux [for both imaging and spectroscopy]
- Flagship (LUVOIR Surveyor); Lifecycle of Baryons Probe; IGM spectral imaging and supernovae Explorer missions
- CU rocket team leading LUVOIR spectrograph study

***TRLin = 3*** ***TRLcurrent = 4 (coatings), 7 (XS MCP)*** ***TRLtarget = 6-7***

***Grad Students = 4*** ***Undergrad Students = 6*** ***Publications = 8***

# University of Colorado UV Rocket Program
# Dual channel Extreme Ultraviolet Continuum Experiment (DEUCE)

PI: James Green/University of Colorado/CASA

## Description and Objectives:

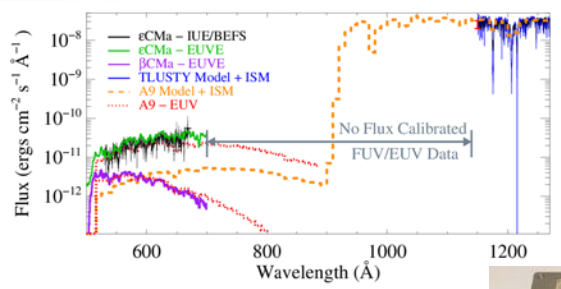
**Science**: Directly measure the ionizing radiation from local hot B stars to determine if B stars (as opposed to O stars) are viable candidates for providing the ionizing radiation to the modern intergalactic medium.

**Technology**: Incorporating a large format (200 X 200 mm) microchannel plate detector utilizing boro-silicate plates. This will be the first flight verification of this glass and this size MCP detector.

**Training**: Graduate student involvement (Nicholas Erickson) for the Ph.D. and 5 undergraduates supporting the lab effort.

## Key Challenge/Innovation:

Large format MCP can enable wide field imaging / multi-object spectroscopy on the next large aperture UV capable probe/surveyor.




**Above**: Flux discrepancy between models and data, also showing the data gap between 700 and 1150 Å.

**Right**: 200 X 200 mm lab prototype MCP

## Approach:

- Diamond turned razing incidence Wolter II telescope feeding normal incidence Rowland circle spectrograph utilizing SiC coated holographically ruled grating
- Component-level efficiency and environmental testing
- End-to-end payload development and launch
- Scientific and technical analysis, student training, and publication of results

## Key Collaborators:

- Oswald Siegmund – Sensor Sciences – Detector
- Horiba JY – grating production
- GSFC – Grating coating

## Development Period:

- April, 2015 – October, 2017
- First launch in October 2017

## Accomplishments and Next Milestones:

- Payload fully assembled and tested
- Launch in October 2017, had a failure in the attitude control system and did not acquire the target
- Next launch is scheduled for early December, 2018
- Re-flights from WSMR on missed target and from Australia in 2020 to observe Alpha Cen have been proposed. Awaiting NASA decision.

## Application:

- All UVOIR missions requiring large fields of view or multi-object spectroscopy in the far ultraviolet
- Flagship (LUVOIR Surveyor, HABEX); Lifecycle of Baryons Probe; IGM spectral imaging Explorer missions

*Detector TRL development:* *TRLin* = ***3*** *TRLtarget* = ***6/7 (post flight)***

# NASA/CU 36.333 UG: CHESS-4. Enabling Water Recovery for Future Science Missions

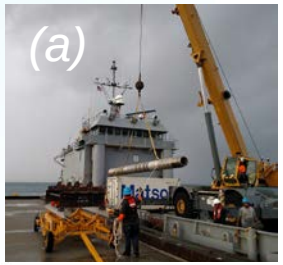
ASTROPHYSICS

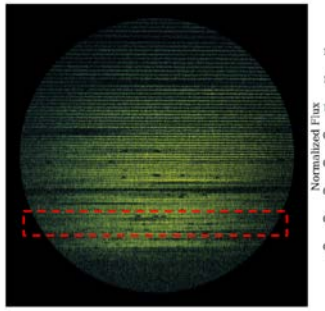
## Description and Objectives:

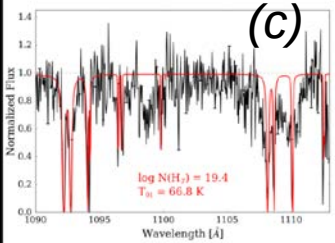
- Develop water recovery system that enables launch opportunities for astrophysics missions from southern ranges
- Design, fabricate, and flight test shaped echelle grating to enhance resolution of spectrographs on future missions
- Science, education, and training the next generation of scientists and engineers who will lead future NASA missions

## Key Challenge/Innovation:

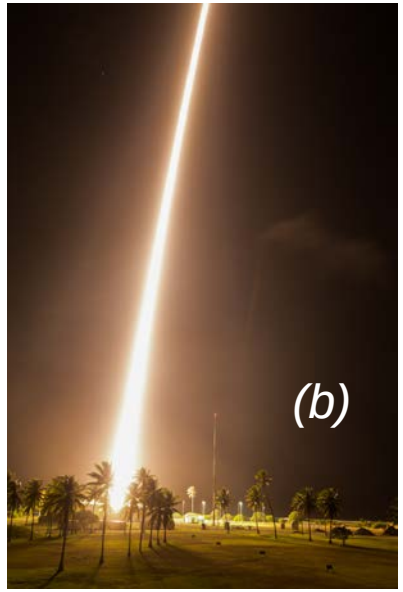
- Diffraction gratings for high-resolution UV spectrographs
- UV/vis detector technology demonstration in space environment: larger formats, higher dynamic range, lower background equivalent flux
- High-reflectivity optical coatings with high wavefront control






**Figures**: **(*a*)** First water recovery of 17" astrophysics payload ***(b)*** CHESS-4 launch from RTS/Kwajalein ***(c)*** Flight data from CHESS-4 / 36.333, the ISM sightline to γ Ara. First results appeared in Kruczek et al. 2018.




## Approach:

- Design rocket-borne spectrographs and telescopes
- Work with collaborators and vendors on specifications and fabrication procedures for key technologies
- Component-level efficiency and environmental testing
- End-to-end payload development and launch
- Scientific and technical analysis, student training, and publication of results

## Key Collaborators:

- Oswald Siegmund & John Vallerga – UC Berkeley
- Shouleh Nikzad – JPL
- Manuel Quijada - GSFC
- Aki Roberge (GSFC), Jason Tumlinson (STScI), Ed Jenkins (Princeton) – Science and large mission application

## Development Period:

- 06/01/2016 – 05/31/2020

*TRLin = **3*** *TRLcurrent = **7** (water recovery)* *TRLtarget = **7***

## Accomplishments and Next Milestones:

•Successfully launched CHESS-4 (April 2018), published results from the mission (Kruczek et al. 2018)
•Graduate and undergraduate students took lead roles on CHESS-4, Ph.D. student graduating Dec 2018.
•Component development and instrument design for LUVOIR LUMOS instrument (design based on CU rocket payloads)
•Demonstrated first test of shaped echelle gratings to increase spectral res
•Designed and ordered all long-lead items (telescope mirrors, diffraction grating, detector) for new SISTINE payload (2019 first flight)

## Application:

- All UVOIR missions requiring high spectral resolution, high-sensitivity, and low background equivalent flux [for both imaging and spectroscopy]
- Flagship (LUVOIR Surveyor); Lifecycle of Baryons Probe; IGM spectral imaging and supernovae Explorer missions
- CU rocket team leading LUVOIR spectrograph study

*Grad Students = **4*** *Undergrad Students = **6*** *Publications = **8***

# Water Recovery X-ray rocket (WRX) 36.330
# PI R McEntaffer, PSU

**Description and Objectives:**
The Water Recovery X-ray rocket (WRX) payload (36.330) intended to test key X-ray technologies such as reflection gratings and hybrid CMOS detectors while also proving water recovery technologies for suborbital rockets. The science target for the mission is the Vela supernova remnant.

**Key Challenge/Innovation:**
Diffusive X-ray spectroscopy with reflection gratings and hybrid CMOS detectors, water recovery

A happy science team in the control room after launch

**Approach:**
Suborbital rocket launch from Roi-Namur, Kwajalein

**Development period:**
15 months from award (partially funded 12 month award) to launch. Payload will relaunch during the Australia mission in 2020.

**Key Collaborators:**
Abe Falcone, PSU: hybrid CMOS detector lead

**Accomplishments/Milestones:**
Flight qualification of reflection gratings, hybrid CMOS detectors, and water recovery technologies
4 graduate students and 4 undergrads trained. Four publications in prep (project instrumentation overview, grating test results, grating alignment results, optical design), multiple SPIE papers/presentations

**Application:**
Payload will refly in Australia. Reflection gratings will fly in 3 upcoming suborbital missions. Gratings and hybrid CMOS detectors studied for future NASA missions.