platforms for developing far-ir technology

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Far Infrared Next Generation Instrumentation Community Workshop

Credits (left to right):
Carl Ferkinhoff; NASA / Jeff Doughty;
BLAST / Mark Halpern; NASA/ Wallops;
Blue Origin BISA/ESA

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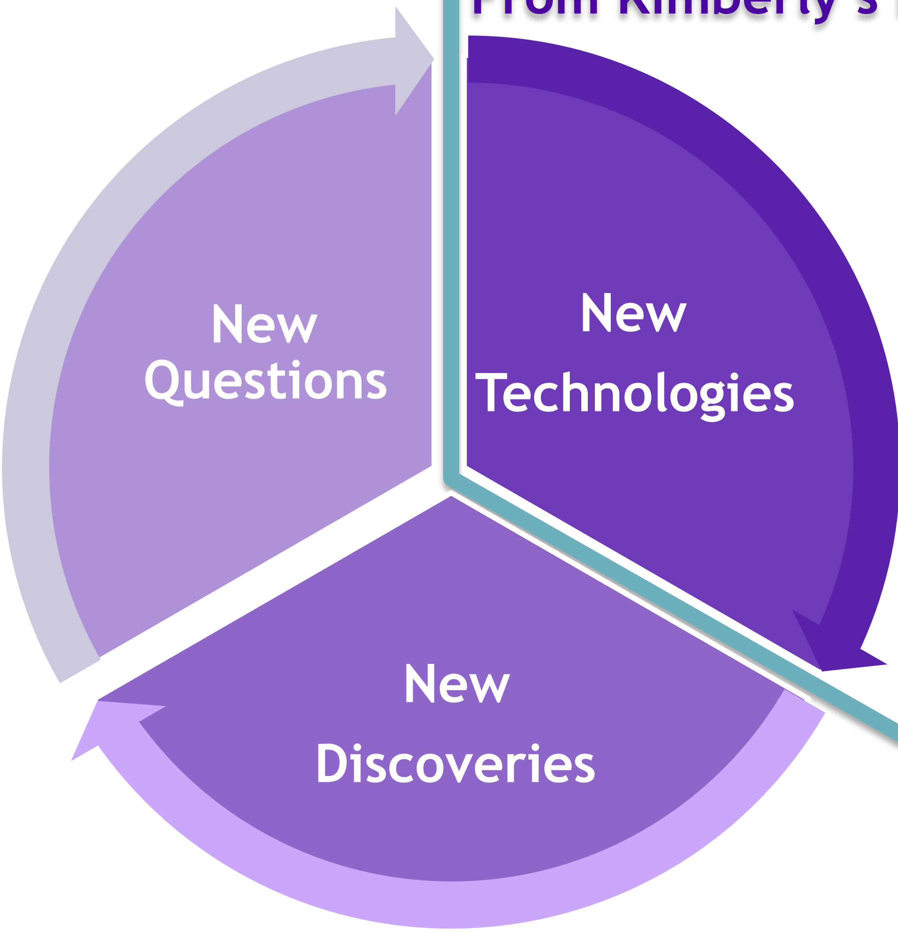
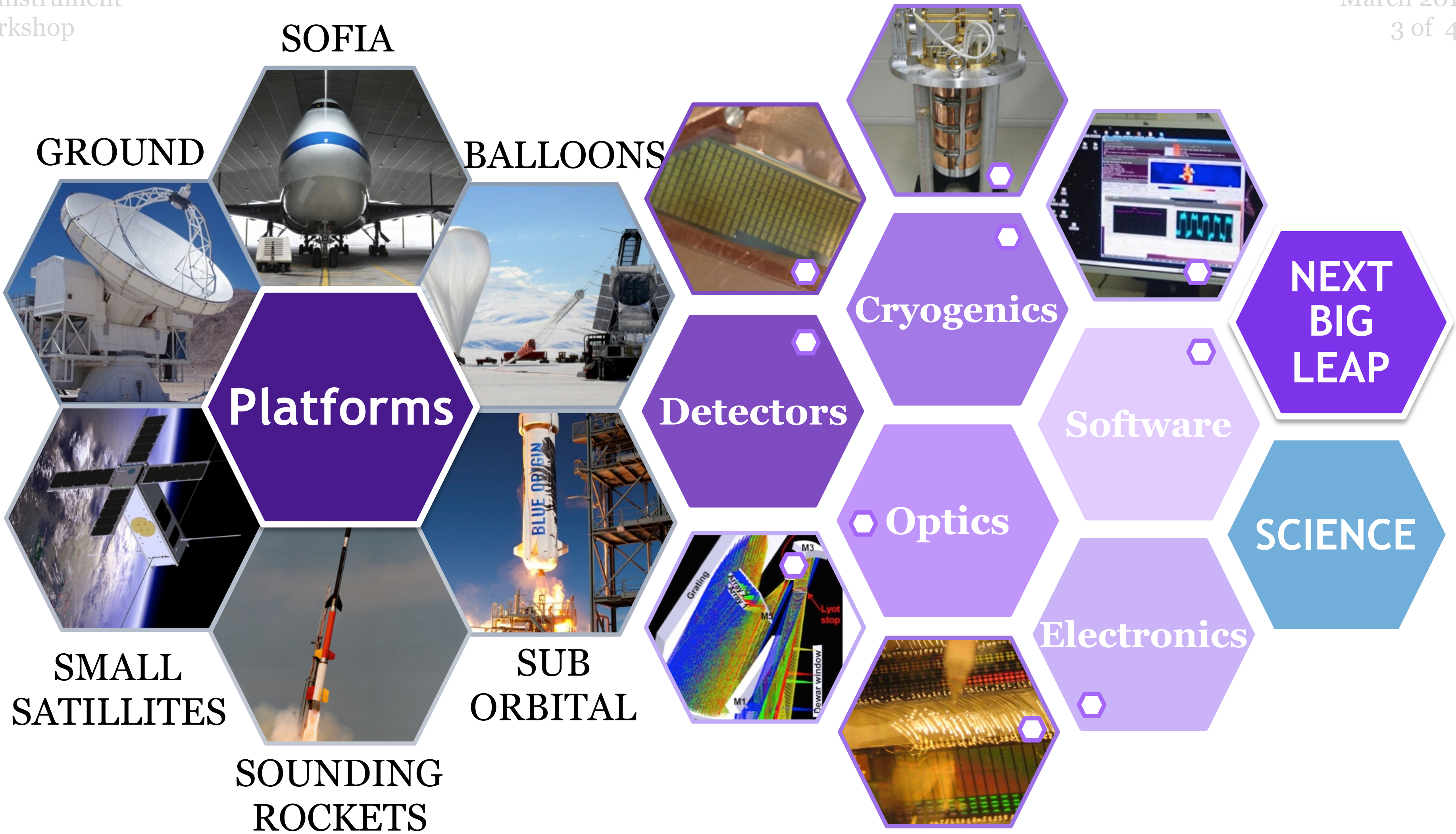


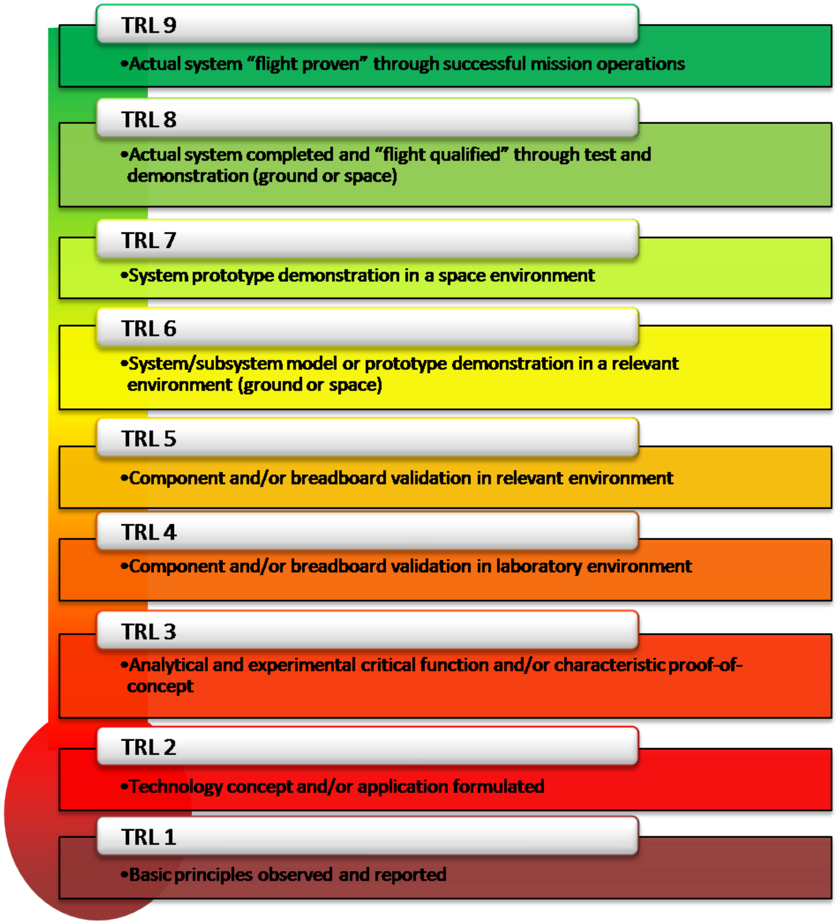
From Kimberly's Introduction:

How can we be better at utilizing our existing platforms, including SOFIA, balloon-based platforms, sounding rockets, and the emerging field of reusable suborbital vehicles?

How can we get our technology ready for ~~the next great far-IR leap?~~ something like Origins


SOFIA
GROUND
BALLOONS
Platforms
SMALL
SATILLITES
SOUNDING
ROCKETS
SUB
ORBITAL
BLUE ORIGIN
Detectors
Cryogenics
Software
Optics
Electronics
NEXT
BIG
LEAP
SCIENCE

Technology Readiness Level



How will we move through TRLs to prepare for the "next great leap" (NGL)?

Goals

1. **Summarize the various platforms for far-IR astronomy**
2. **Resource for future development, including relevant contact information**
3. **Spur ideas and discussion today**

Questions I Pondered . . .

- What is the ***critical technology*** needed for the NGL?
- What is the ***critical science*** needed for the NGL?
- Can we leverage ***disruptive technologies*** (additive manufacturing, open source) to do new & old things better? cheaper? More efficiently?
- How can we ***involve students*** (especially undergraduates) and primarily undergraduate institutions?

. . . .but don't answer.

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1. THE GROUND

Why include the ground?

Why should we include ground based instruments and platforms in our path to the NGL?

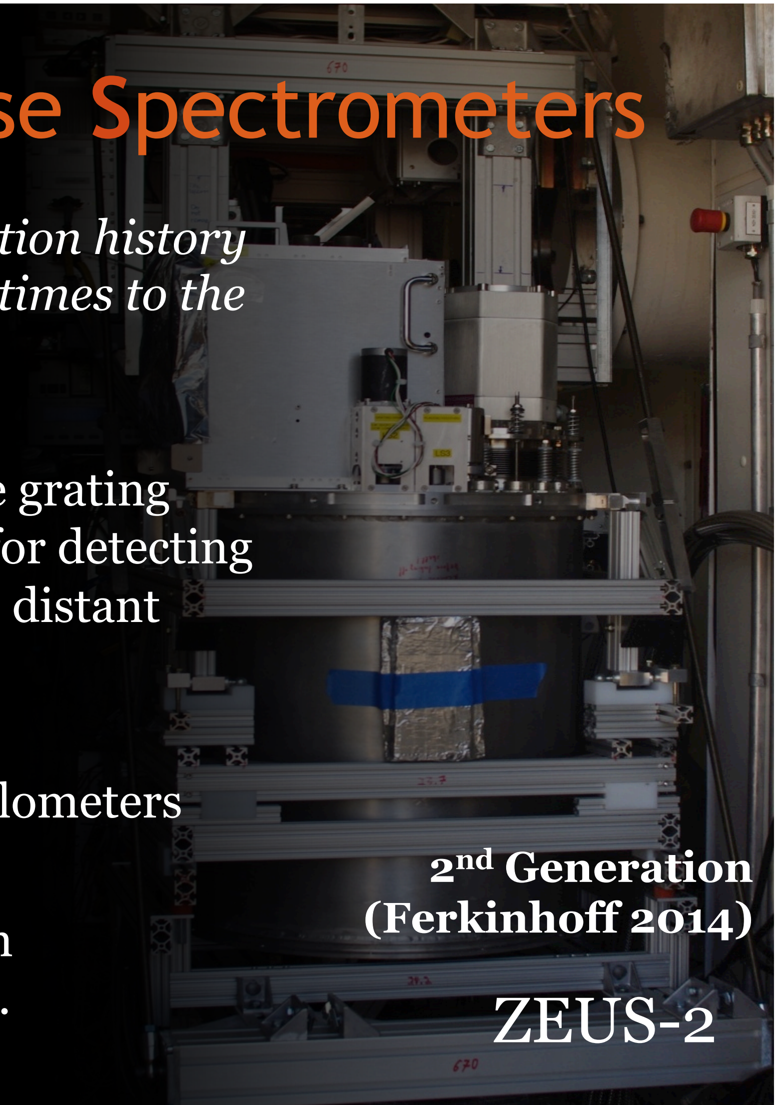
z(Redshift) & Early Universe Spectrometers

Goal: Study the star formation history of the Universe from early times to the current epoch.

Direct detection, echelle grating spectrometer(s) optimized for detecting the emission lines from distant galaxies.

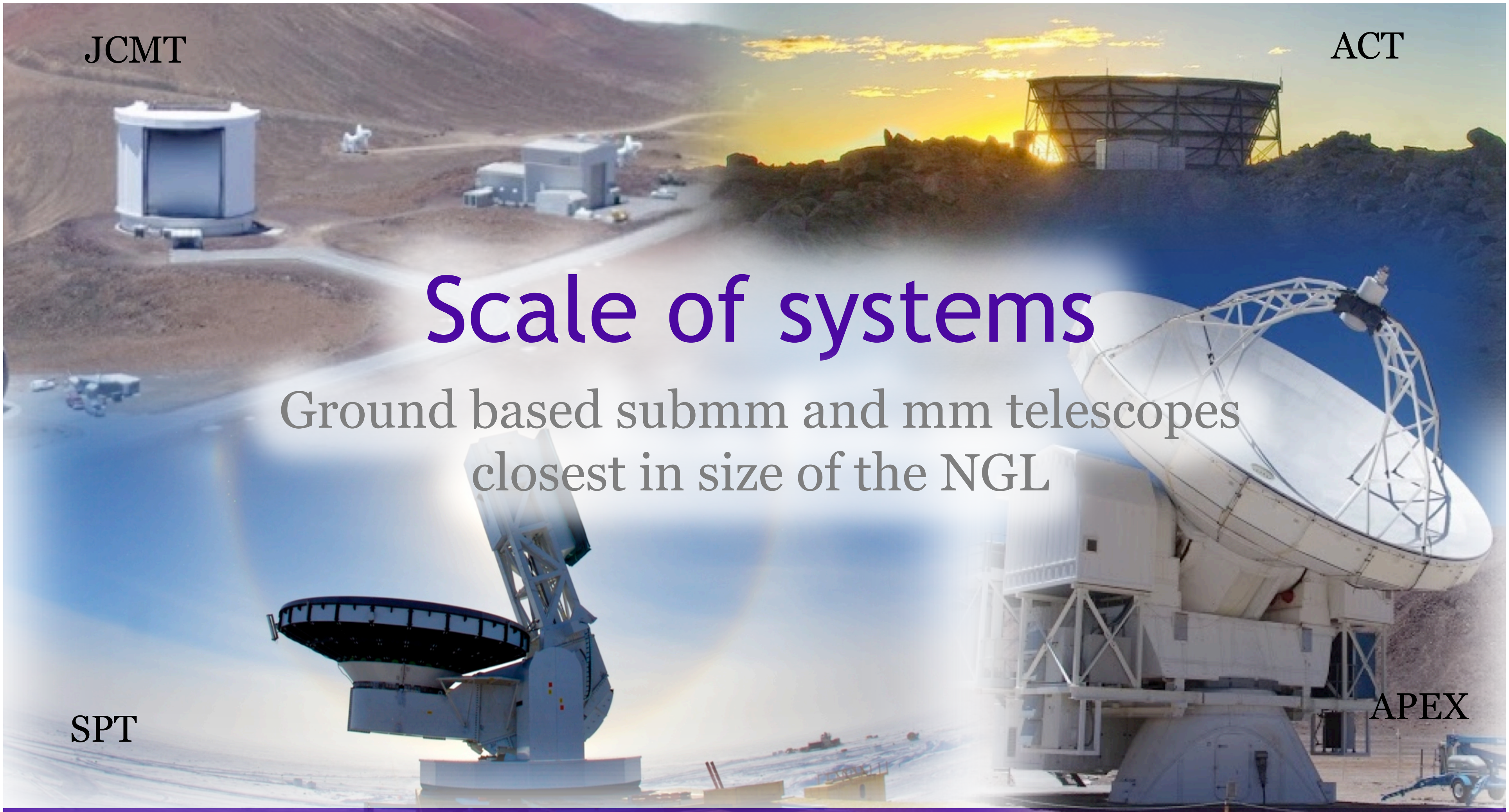
ZEUS-2 features TES bolometers

Detect light from ~200 to 645 µm.



Scale of systems

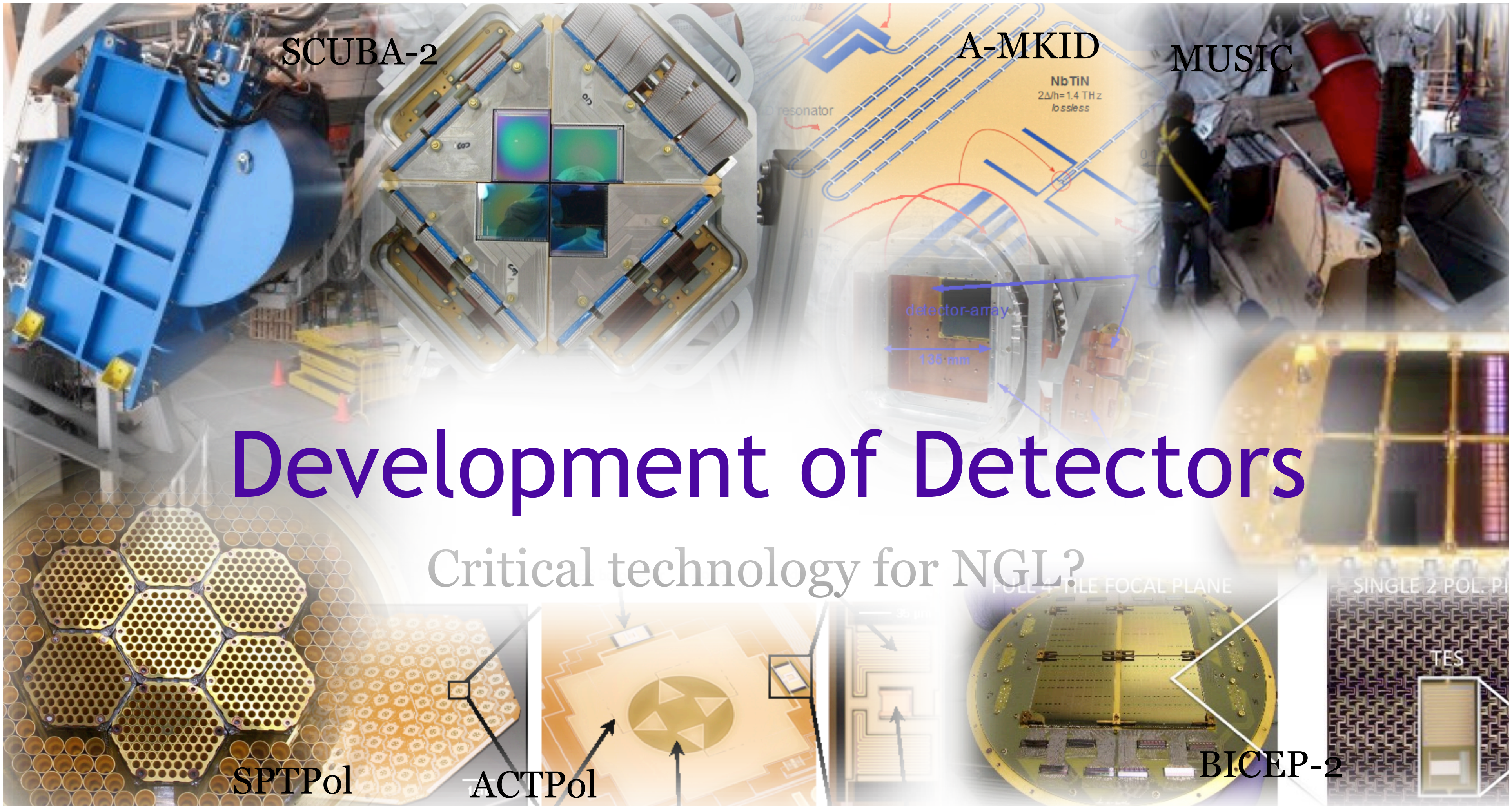
Ground based submm and mm telescopes closest in size of the NGL



Credit: Carl Ferkinhoff;
SPT/Jeff McMahon

Development of Detectors

Critical technology for NGL?



Credits: http://www.eaobservatory.org; A-MKID/MPIfR; https://scuba2.wordpress.com; Golwala et al. 2013; BICEP2/CfA; Thornton et al. 2016; Henning et al 2012;

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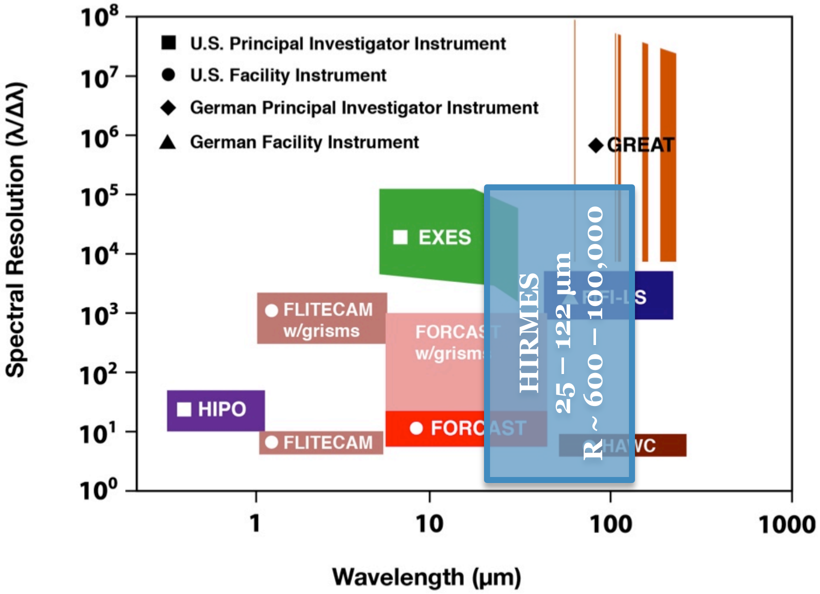
2. SOFIA

SOFIA

See talk by Hal Yorke



Aircraft Model: Boeing 747SP (Special Performance)

Proposed Mission Lifetime: 20 years

Telescope Diameter: 2.5 meters (100 inches)

Wavelength Range: 0.3-1,000 microns

Instruments: Seven First-Generation Instruments include cameras, spectrometers and a high-speed photometer

Observing Altitude: 37,000 – 45,000 ft (11,300 – 13,700 meters)

FIR Instruments: In active use

SOFIA

Harold Yorke
Director of SOFIA Science
Mission Operations
hyorke@sofia.usra.edu

Kimberly Ennico Smith
Project Scientist
kimberly.ennico@nasa.gov

- https://www.sofia.usra.edu/
  - For Documents & Details: https://www.sofia.usra.edu/science/publications
- @SOFIAtelescope
- SOFIA Next Gen Instrument Call
  - See ROSES-2017

platforms for developing far-ir technology

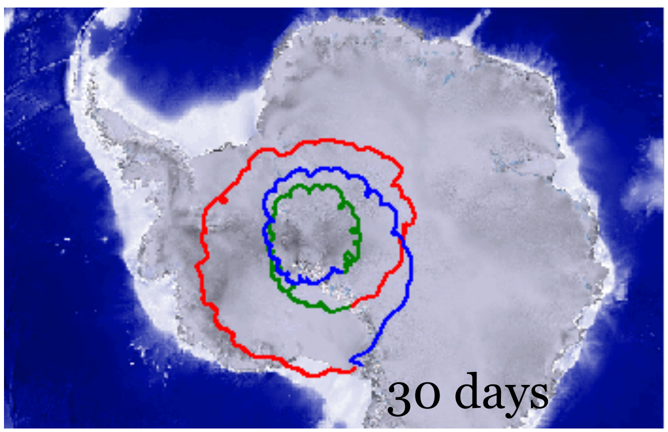
3. BALLOONS

Balloons

See talk by Chris Walker

- 10 – 15 flights per year
- Near space access
- Up to 6,000 lbs

FIR Instruments:
In active use



Balloon Type	Zero Pressure (ZP)	ZP	Super Pressure (SP)
Mission Type	Conventional	LDB	ULDB
Duration	2 hours to 3 days	Typical 7-15 days Up to 55+ days	Up to 100 days
Science Payload Weight	Up to 2,721 kg (Up to 6,000 lbs)	Up to 2,721 kg (Up to 6,000 lbs)	18.8 MCF* – 907 kg (2000 lbs) 26 MCF – 454 kg (1000 lbs)
Typical Float Altitude	29.2 to 38.7 km (96 to 127 kft)	36.5 to 38.7 km (120 to 127 kft)	18.8 MCF – up to 34 km (~110 kft) 26 MCF – up to 36 km (~117 kft)
Support Package	Consolidated Instrumentation Package (CIP) ● Line of Sight (LOS) ● Up to 1 Mbps direct return	Support Instrumentation Package (SIP) ● Over The Horizon (OTH) ● 6 kbps TDRSS downlink ● 100 kbps option with TDRSS or Iridium	
	Micro Instrumentation Package (MIP) ● Stand alone package for small payload support ● LOS and OTH TM & Command (Iridium) 255 byte/min packets ● Up to 1 Mbps LOS option System without batteries ~20 lbs (9 kg) * MCF – Million Cubic Feet		

BLAST

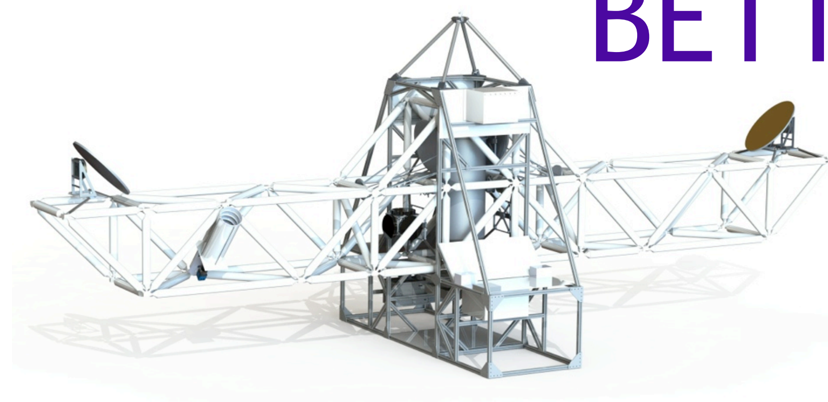
- **B**alloon-borne **L**arge **A**perture **S**ubmillimeter **T**elescope
- 250, 350 , 450 micron
- Thermistor sensed, spider web bolometers
- Pathfinder for Herschel/SPIRE
- http://blastexperiment.info

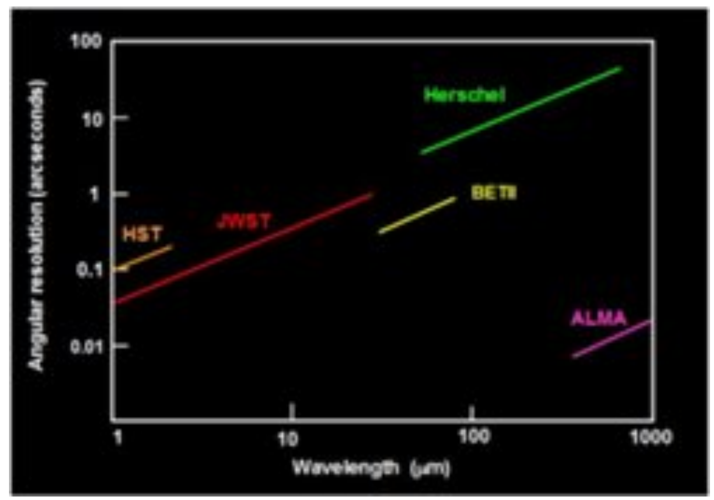
Example of demonstrating technology while achieving excellent science

BETTII

- **B**alloon **E**xperimental **T**win **T**elescope for **I**nfrared **I**nterferometry.
- 8-meter baseline balloon-borne interferometer
- two FIR bands (30-50 µm and 60-90 µm)
- Fly in 2017

Example of demonstrating technology while achieving excellent science





Balloons

NASA Scientific Balloon Program

- Manages program
- https://sites.wff.nasa.gov/code820/index.html

Debora Fairbrother
Balloon Program Office Chief
(757) 824-1453
debora.a.fairbrother@nasa.gov

Columbia Scientific Balloon Facility (Orbital ATK)

- Palestine, Texas,
- program management, mission planning, engineering services and field operations
- https://www.csbf.nasa.gov/
  - See "Documents" for flight application information

General Contact Information
903-729-0271

Dwayne Orr, Site Manager
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Bryan Stilwell, Electronic Systems Manager bryan.d.stilwell@nasa.gov
Hugo Franco, Operations Manager
hugo.franco@nasa.gov

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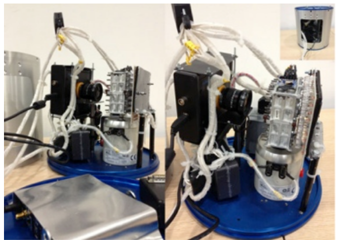
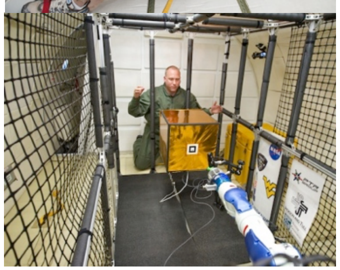
5. SUBORBITAL







Flight Opportunities

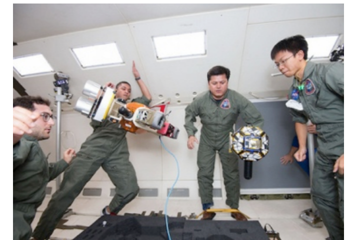
NASA Flight Opportunities Program

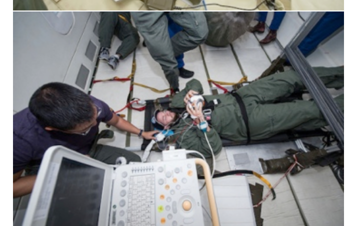
Flight Testing Opportunities

Adapted from

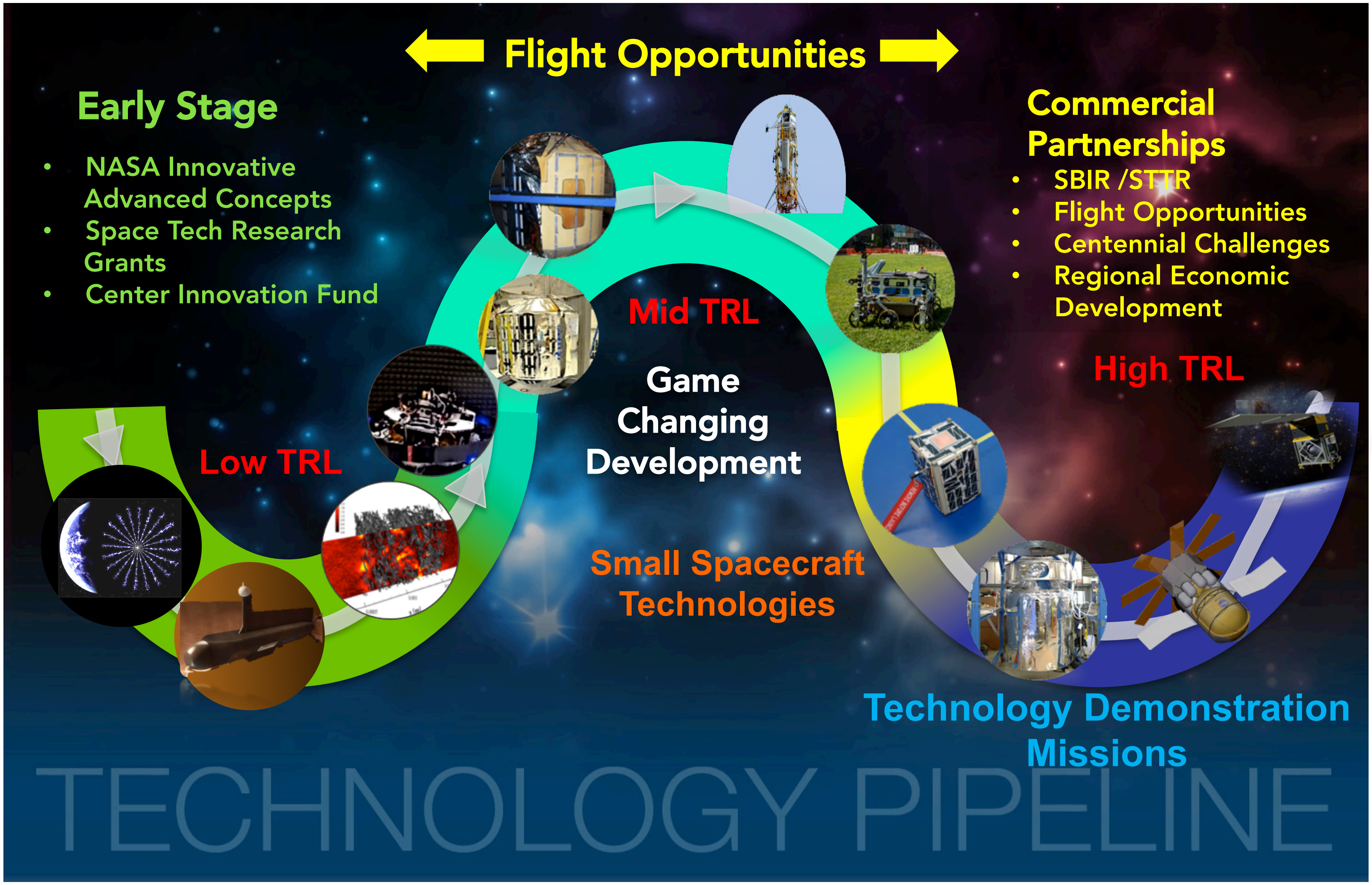
Technology Manager – Stephan Ord

FIR Instruments: none




Space Technology Mission Directorate Pipeline



Flight Opportunities Overview

Space Technology Mission Directorate (STMD) Goals:

1. Develop cross-cutting technologies for future human & robotic space exploration missions
2. Stimulate growth in U.S. aerospace industry - new revolutionary technological capabilities that create or expand markets, products, and services
3. Harness innovation and entrepreneurship through partnerships with universities, small businesses, emerging commercial entities, and other industries and government agencies

Flight Opportunities Goals:

1. **Mature technologies for future space missions**
2. **Develop suborbital and small launch vehicles**

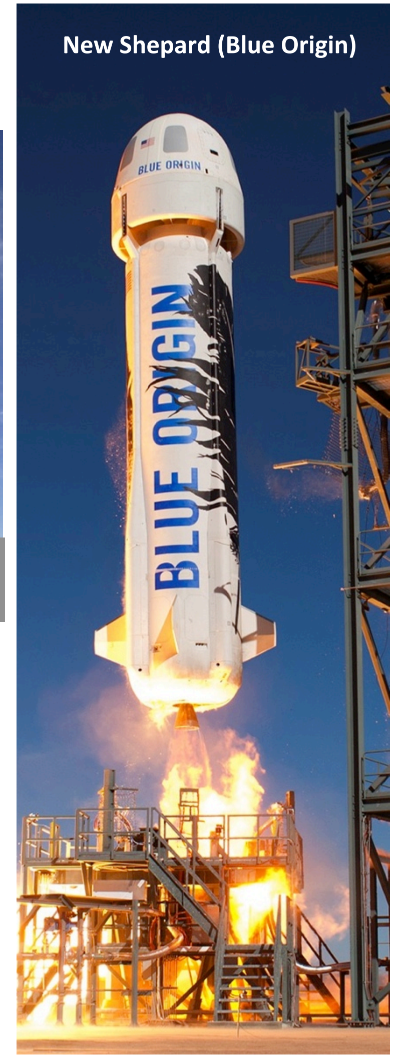
Reduce Risk, Reduce Cost, Improve Performance, Advance Capabilities

Typical Flight Platforms

Parabolic Flight Vehicle

G-Force One (Zero G Corporation)


SpaceLoft™ XL (UP Aerospace)



New Shepard (Blue Origin)

Suborbital Reusable Launch Vehicles (sRLV)

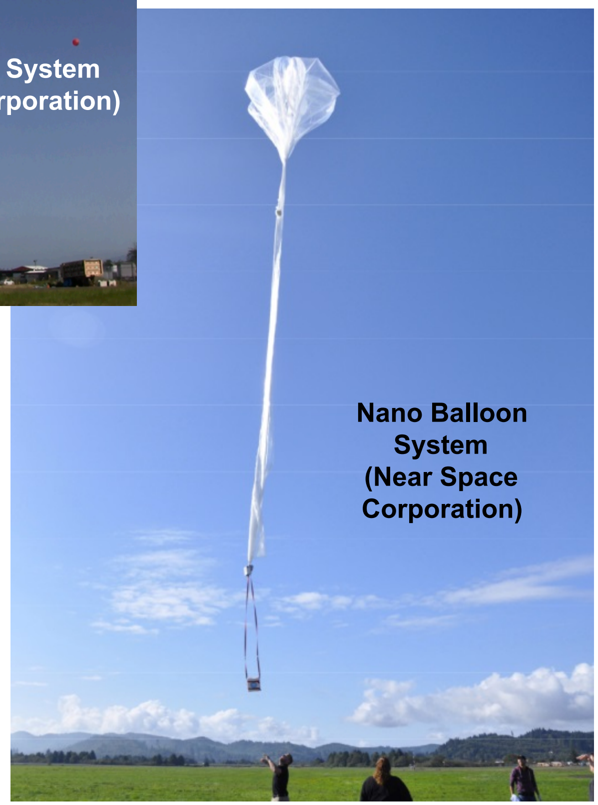

Xombie (Masten Space Systems)


SARGE (EXOS Aerospace)

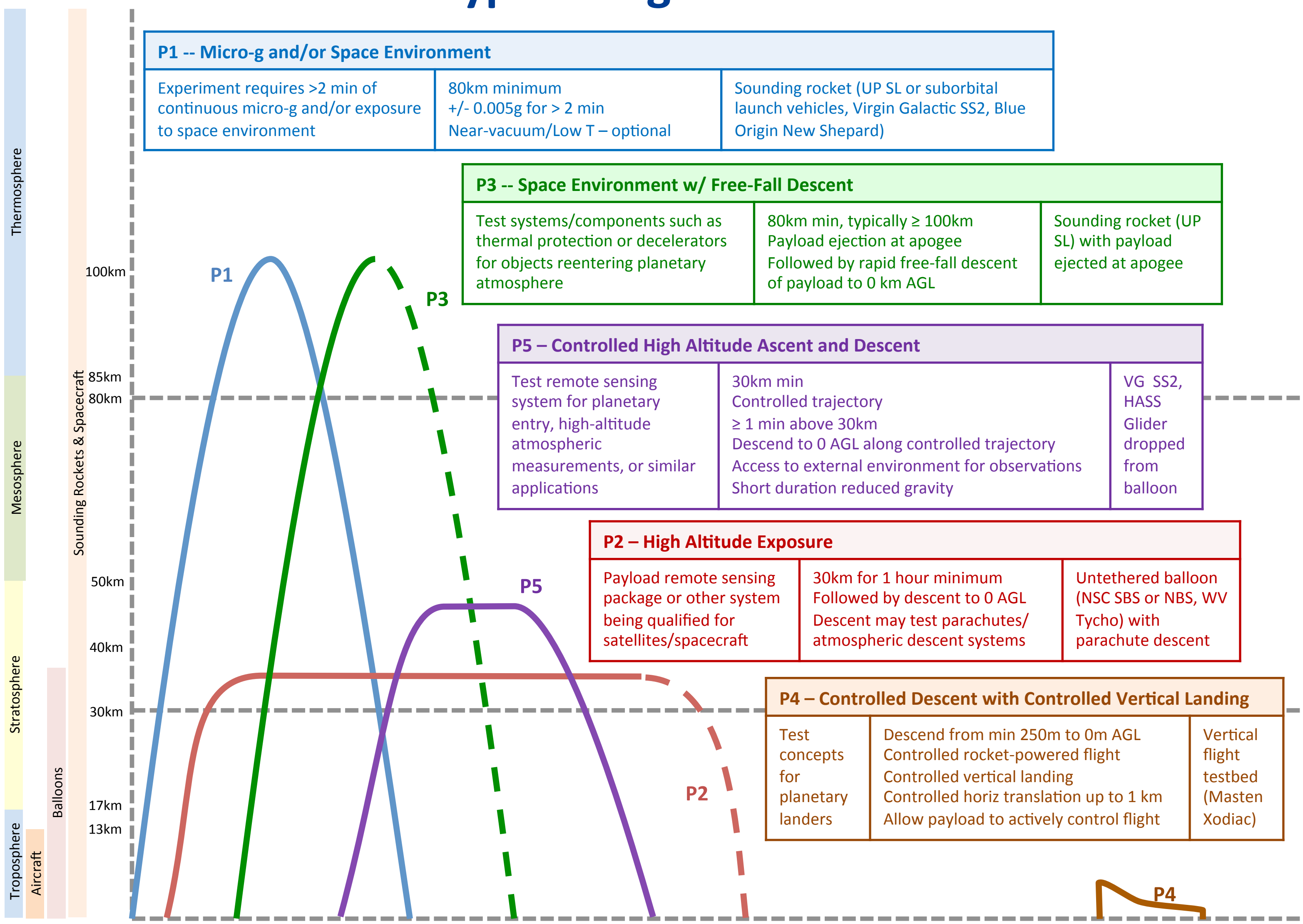
SpaceShip Two (Virgin Galactic)

Typical Flight Platforms

High-Altitude Balloons



Typical Flight Profiles



Flight Opportunities Call/Solicitation Overview

Paths for Flying Technologies

External

SpaceTech-REDDI NRA Appendix F1 Solicitation
(Use Any Qualified Flight Vehicle)

Universities
Private Entities (for-profit)
Private Entities (non-profit)
FFRDCs (except JPL)
Foreign Entities
w/ Lead U.S. Partner

Flight Opportunities Program

Internal

NASA Internal Call
(Use IDIQ-2 Contract Flight Vehicles)

NASA Researchers
STMD Programs
(e.g. GCD, NRA, CIF, SBIR, SST)
Other Mission Directorates
(e.g. ROSES, HOPE, USIP, HERO)
Other Government Agencies
(e.g. FAA)
NASA JPL

NASA MISSE Call

NASA Researchers

Call/Solicitation Overview (non-MISSE)

Eligibility
- TRL 4 at time of submission - hardware should already have been bench tested
- U.S. entities (for-profit & non-profit)
- Foreign entities when in partnership with a U.S. entity – U.S. entity must be lead

Key Dates
- External Calls (REDDI Appendix F1) – 2 per year (one coming soon)
- Internal Calls (NASA Internal Call for Payloads) – 4 per year

REDDI F1 Award Details
- Awards up to $300K
  - Max $250K for allowable flight costs (flight costs + indirect costs related to flight cost only)
  - Max $50K for other costs (indirect costs, travel, labor, materials to build flight hardware)
  - Max amounts include any indirect costs if applicable
  - Researchers contract directly with Flight Providers for flights

NASA Internal Call Award Details
- FO provides flight from flight providers currently on contract with FO
- Max $50K for other costs (no Civil Service travel or labor)

Call/Solicitation Overview (non-MISSE)

REDDI Appendix F1 Topics

- **Topic 1: Demonstration of Space Technology Payloads**
  - Technologies that address one or more needs described in Space Technology Roadmaps (STRs) , National Research Council (NRC) recommendations, Strategic Space Technology Investment Plan (SSTIP), and STMD focus areas
- **Topic 2: Demonstration of Vehicle Capability Enhancements and Onboard Research Facilities for Payload Accommodation**
  - Demonstration of new or enhanced onboard facilities for commercial suborbital reusable launch vehicles, reduced gravity aircraft, and high altitude balloons that will improve or enable use of vehicles for science research and/or technology flight test applications

NASA Internal Call for Payloads Applicability

- The NASA Internal Payload request is applicable to NASA internal and NASA funded technology development activities seeking maturation advancement from Technology Readiness Level (TRL) 4

Flight Opportunities Impacts

Jet Propulsion Laboratory
California Institute of Technology

Gecko Grippers

A novel approach to grappling non-cooperative objects in microgravity

	Achievement	Outcome
2014	Parabolic flight test	Demonstrated grappling ability
2015	Parabolic flight test	Demonstrated mobility and free-floating grappling
2016	Deployment to ISS	Longer duration testing in microgravity

Testing helped researchers adjust design and demonstrate functionality in a realistic operational environment

Additive Manufacturing Facility (AMF)

MADE IN SPACE

Enabling production of critical components in micro-gravity

	Achievement	Outcome
2011	Parabolic flight test	Technology optimization for microgravity
2013	SBIR Phase 3	Develop printer for ISS
2013	Parabolic flight test	Demonstrated effectiveness
2014	Deployment to ISS	Zero-Gravity 3D experimental printer operated successfully
2016	Deployment to ISS	AMF deployed as a permanent manufacturing facility on ISS

In-flight observations enabled hardware/ software modifications and rapid optimization for operation in microgravity

Flight Opportunities Contact Info

If you would like to get started . . .

Flight Opportunities Contact:

Stephan Ord – Flight Opportunities Technology Manager

650-604-5876

email
sord@nasa.gov

NASA FO Website
nasa.gov/flightopportunities

FO Technologies
flightopportunities.nasa.gov/technologies/

Newsletter & Signup
www.nasa.gov/directorates/spacetech/flightopportunities/newsletter

Outlook for Far-IR

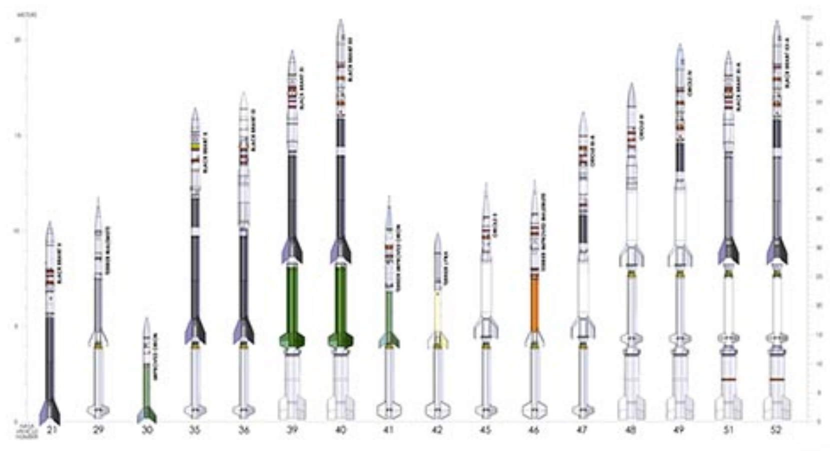
- Flights can be "inexpensive", **possible that $250K can cover multiple flights**
- Most project would fall under "**Topic 1 - Demonstration of Space Technology Payloads**"
- **No cryogenic missions to date**, though tests of cryogenic components in micro-g
  - **One would talk with flight providers to discuss capabilities**
  - "Topic 2 - Demonstration of Vehicle Capability Enhancements and Onboard Research Facilities for Payload Accommodation**" proposal to develop cryo capability**

platforms for developing far-ir technology

5. SOUNDING ROCKETS

Sounding Rockets

- 16 different sounding rocket vehicles
- 20 – 30 flights per year
- Altitudes from 100 to 1400 km
  - Significantly higher than offered through Flight Opportunities
- Payloads up to 1500 pounds



FIR Instruments:
In active use in the near-IR
Historial use at far-IR

1966 – first IR rocket instrument

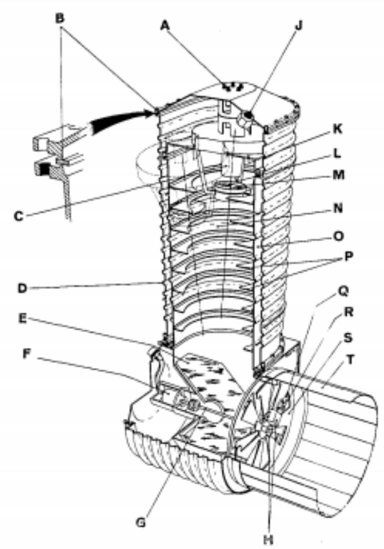


Fig. 2. Isometric drawing of the telescope. A. Electrical feed-through. B. Vacuum seal. C. Conical baffle. D. Strengthening convolution. E. 45° mirror. F. Motor. G. Stainless steel shaft. H. Magnetic reference pickup. J. Liquid N_2 fill port. K. Primary mirror. L. Detector. M. Secondary mirror. N. Vacuum. O. Liquid N_2 region. P. Blackened stops. Q. Chopper. R. Calibration light. S. Stator. T. Be–Cu pop-out baffles.

A Liquid Nitrogen Cooled, Rocket Borne, Infrared Telescope

Martin Harwit, D. P. McNutt, K. Shivanandan and B. J. Zajac

We have constructed a liquid nitrogen cooled telescope that was flown in an Aerobee 150 rocket. The telescope allows measurement of absolute ir signal strengths from astronomical objects in the wavelength range out to about 7.5 μ. In contrast to ground-based telescopes, it can observe diffuse as well as discrete astronomical sources.

- LN Cooled operating at 5 -7 micron
- Martin Harwit describes *"pioneering rocket astronomy was not a happy venture“*.
  - On initial flight, a six hour flight delay caused all the LN, which only lasts 6 hours, to boil off.

1968 – LHe Rocket Telescope

Rocket-Borne Liquid Helium Cooled Telescope

Martin Harwit, J. R. Houck, and K. Fuhrmann

We describe a rocket-borne telescope in which all components in or near the detector's field of view are cooled to liquid helium temperature. The system uses ir detectors to make photometric observations of the night sky in the 5-μ to ~1.6 mm spectral range. A description of the detectors and their calibration is given. On 29 February 1968, the telescope was successfully flown to an altitude of 170 km on an Aerobee 150 sounding rocket.

- 5 to 120 micron and 400 micron to 1.2 mm

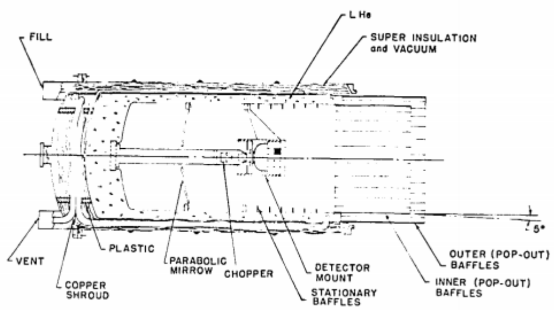
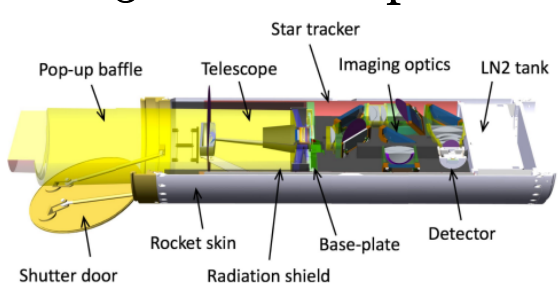


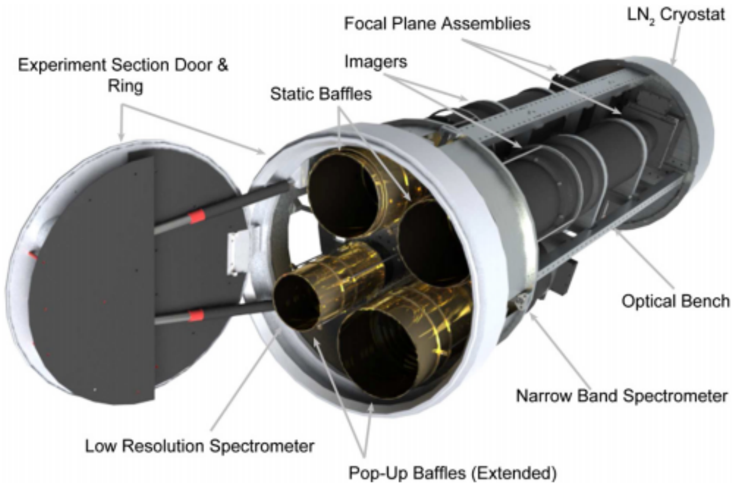
Fig. 1. A cross section of the liquid helium cooled telescope is shown. The primary mirror has a diameter of 18 cm and a focal ratio of 0.9.

This cryogenically cooled telescope vacuum housing was constructed by Sulfrian Cryogenics of Rahway, New Jersey. Even after the telescope had been recovered, following flight, the cryogenics worked properly after we brushed the desert sand out of the system.

CIBER

- Cosmic Infrared Background Experiment
- Study the near-IR background light
- Cooled with LN
- CIBER-2 schedule for launch in August 2017
  - 28.5 cm telescope





Sounding Rockets

Sounding Rocket Program Office

- Wallops Flight Facility
  - https://sites.wff.nasa.gov/code810/

Philip J. Eberspeaker
Chief, Sounding Rockets Program Office
Ph: 757-824-2202
Email: Philip.J.Eberspeaker@nasa.gov

Libby West
SRPO Projects Manager
Ph: 757-824-2440
Email: Libby.West@nasa.gov

Resources

- Sounding Rockets User Handbook
  - https://sites.wff.nasa.gov/code810/files/SRHB.pdf
- Capabilities
  - Routine use of cryogenic cooling of payloads
    - Both LN and LHe
    - At least one recent use of sub-Kelvin cooling (~0.1K)
  - Celestial ACS provides sub arc-second pointing
  - Observing Times: Currently > 10 mins
    - 2 year goal: 10 – 15 minutes
    - 5 year goal: up to 30 mins

platforms for developing far-ir technology

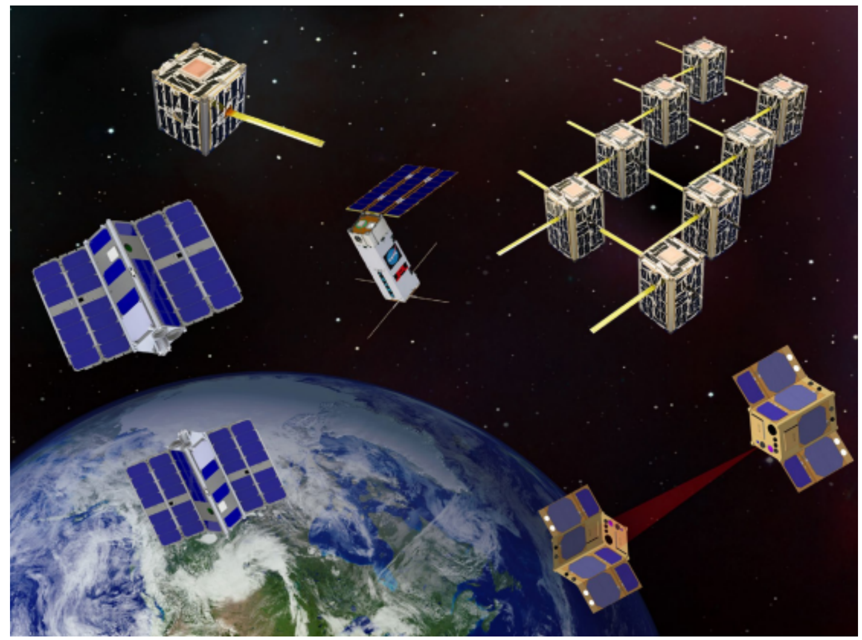
6. SMALL SATELLITES

Small Satellites

- Mass less than 180 kg
  - Minisatellite, 100 kilograms or higher
  - Microsatellite, 10-100 kilograms
  - Nanosatellite, 1-10 kilograms
  - Picosatellite, 0.01-1 kilograms
  - Femtosatellite, 0.001-0.01 kilograms

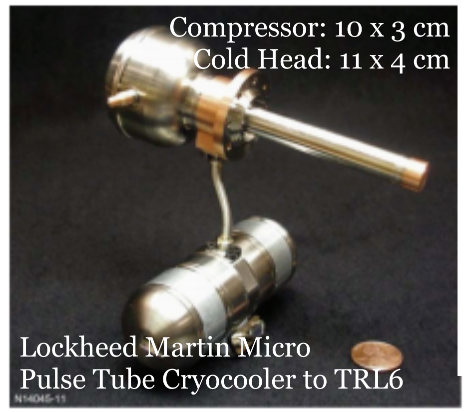
- CubSat: a popular type
  - One CubeSat unit (1U) has dimensions of 10 by 10 by 11 centimeters, < 1.5 kg
  - Cubesats have been built in 1U, 1.5U, 2U, 3U and 6U sizes. 12U has been proposed
  - Utilize & develop "off the shelf" components
  - Piggy-back launch

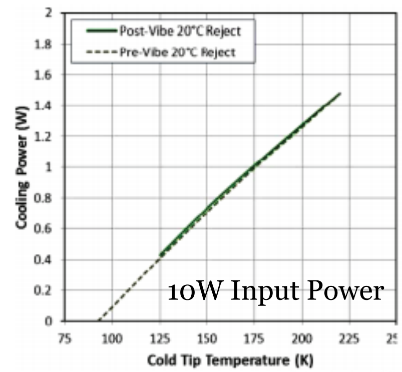
FIR Instruments: none



Small Satellites (Cubsat)

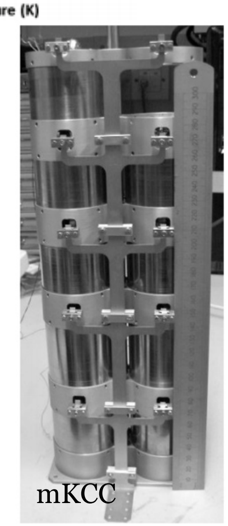
- Power:
  - Deployable arrays
  - 1U: few Watts,
  - 3U: 20w
  - 6U: up to 100W
- Cryogenics
  - Not been demonstrated on CubSat (anything smaller than 50 kg)
  - Not prohibited
  - Active Development





Micro milliKelvin Cooler Array
Ian Hepburn, UCL

- Continuous ADR
- 100 mK with 0.3 uW cooling, at 4 K base temp
- 3 x 2 x 5 cm
- Based on large mKCC design



Do Small Sats have a role in the far-IR?

http://cryocooler.org/proceedings/paper-flies/C18papers/007.pdf
http://gtr.rcuk.ac.uk/projects?ref=EP%2FL010720%2F1
Bartlett et al 2012, SPIE

Small Satellites

NASA Programs

- Small Spacecraft Technology Program
  - Develop & Demontrate new capabilities for small satellites and demonstrate technology for large space craft
- CubSat Launch Initiative
  - Provide launch access to CubSat Missions

Bruce D. Yost
Director, Small Spacecraft Systems Virtual Institute
Small Spacecraft Technology Program Manager
NASA Ames Research Center
Bruce.D.Yost@nasa.gov

- NASA Small Satellite Mission Pages:
  - https://www.nasa.gov/mission_pages/smallsats
- Small Spacecraft Virtual Institute
  - https://www.nasa.gov/smallsat-institute
  - Opportunities:
    - **STMD: Space Technology Announcement of Collaborative Opportunity (ACO)**
      Preliminary Proposals Due March 15, 2017
      Full Proposals Due May 31, 2017

      STMD: Small Spacecraft Technology Program SmallSat Technology Partnerships Solicitation – Coming Soon!
    - **SMD Advanced Component Technology (ACT)**
      Notice of Intent Due April 19, 2017
      Full Proposals Due June 19, 2017
- CubSat: http://www.cubesat.org/

Questions I Pondered

- What is the ***critical technology*** needed for the NGL?
- What is the ***critical science*** needed for the NGL?
- Can we leverage ***disruptive technologies*** (additive manufacturing, open source) to do new & old things better? cheaper? More efficiently?
- How can we ***involve students*** (especially undergraduates) and primarily undergraduate institutions.

Next

- Part 1 - Our Future: Are there specific areas that we need to see emphasized in future Far-IR (ROSES, etc.) calls?
- Part 2 - Shaping the Next Generation What do you want your SOFIA Observatory to achieve next? Upcoming ROSES opportunity
- Part 3 - Shaping access above 80,000 feet (24 km)

platforms for developing far-ir technology

QUESTIONS?

Credits (left to right):
Carl Ferkinhoff; NASA / Jeff Doughty;
BLAST / Mark Halpern; NASA/ Wallops;
Blue Origin BISA/ESA

Carl Ferkinhoff
Assistant Professor of Physics
Winona State University
cferkinhoff@winona.edu

Far Infrared Next Generation Instrumentation Community Workshop

WINONA STATE UNIVERSITY

REDDI F1 - Evaluation Criteria Overview

REDDI F1 Evaluation Criteria (from 2016 F1(B) solicitation)

- **Criterion 1 - Relevance to U.S. Space Exploration and Utilization (40%)**
  - Alignment
  - Comparison to State of the Art
  - Infusion Potential

Important for STMD investment decision

- **Criterion 2 - Technical Approach (35%)**
  - TRL Assessment
  - Technology Development Plan
    - Includes degree of support/funding provided to date by other sponsors
    - Demonstrate flight test is required
  - Flight Test Plan
  - Qualifications and Capabilities
- **Criterion 3 - Cost, Value, and Schedule (25%)**
  - Cost – i.e. test plan makes optimal use of flight(s))
  - Value
    - Technology reduces mission and life-cycle costs, increases safety, or reduces risk, etc.
    - Potential to benefit more than one customer or mission type
    - Extent of cost-sharing provided by proposer
  - Schedule

NASA Internal Call - Evaluation Criteria Overview

NASA Internal Call Evaluation Criteria

- **Criterion 1 - NASA Mission Directorate Support**
  - Letters of support from a NASA Mission Directorate
- **Criterion 2 - Relevance to U.S. Space Exploration and Utilization**
  - Alignment with NASA strategic investment plans, Space Technology Roadmaps, Strategic Thrust Areas
- **Criterion 3 – Comparison to State of the Art and Requirement for Flight**
  - Extent that technology is revolutionary, disruptive, transformational
  - Mission enabling capability or substantial improvement relative to state-of-the-art
  - Compelling case for flying payload vs. ground testing
- **Criterion 4 – Past Performance**
  - Initial selection manager input on team's development performance
  - Previous flight test activities

Important Things to Communicate

Technology Need

- Describe current state of the art
- Describe need for improvement
- Describe how your technology will advance the state of the art
- What will I now be able to do?

Technology Concept

- Describe your technology – how does your technology work
- If the technical review panels don't understand how your technology works, it's difficult to evaluate

Flight Test Plan

- **REDDI F1** - Make sure that you have worked out the flight test with the flight provider – minimum number of parabolas, minimum altitude, etc.
- **NASA Internal Call** – Identify type of flight required per the call – our campaign managers will work with you to determine the best flight provider