National Aeronautics and
Space Administration

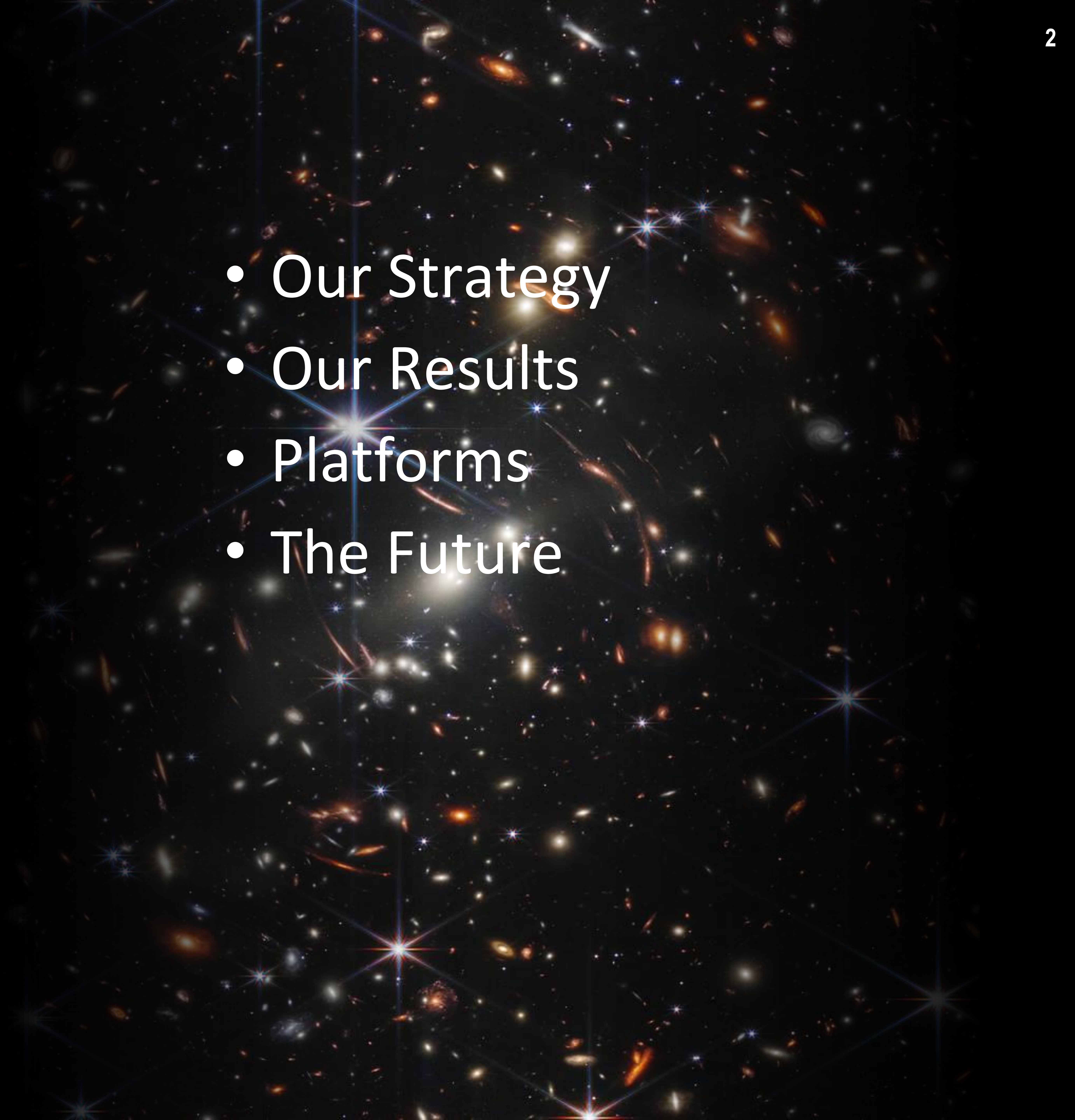
NASA Astrophysics Technology Platforms

Dr. Dominic Benford, Deputy Chief Technologist

Dr. Mario Perez, Chief Technologist

NASA's Astrophysics Division

Outline



- Our Strategy
- Our Results
- Platforms
- The Future

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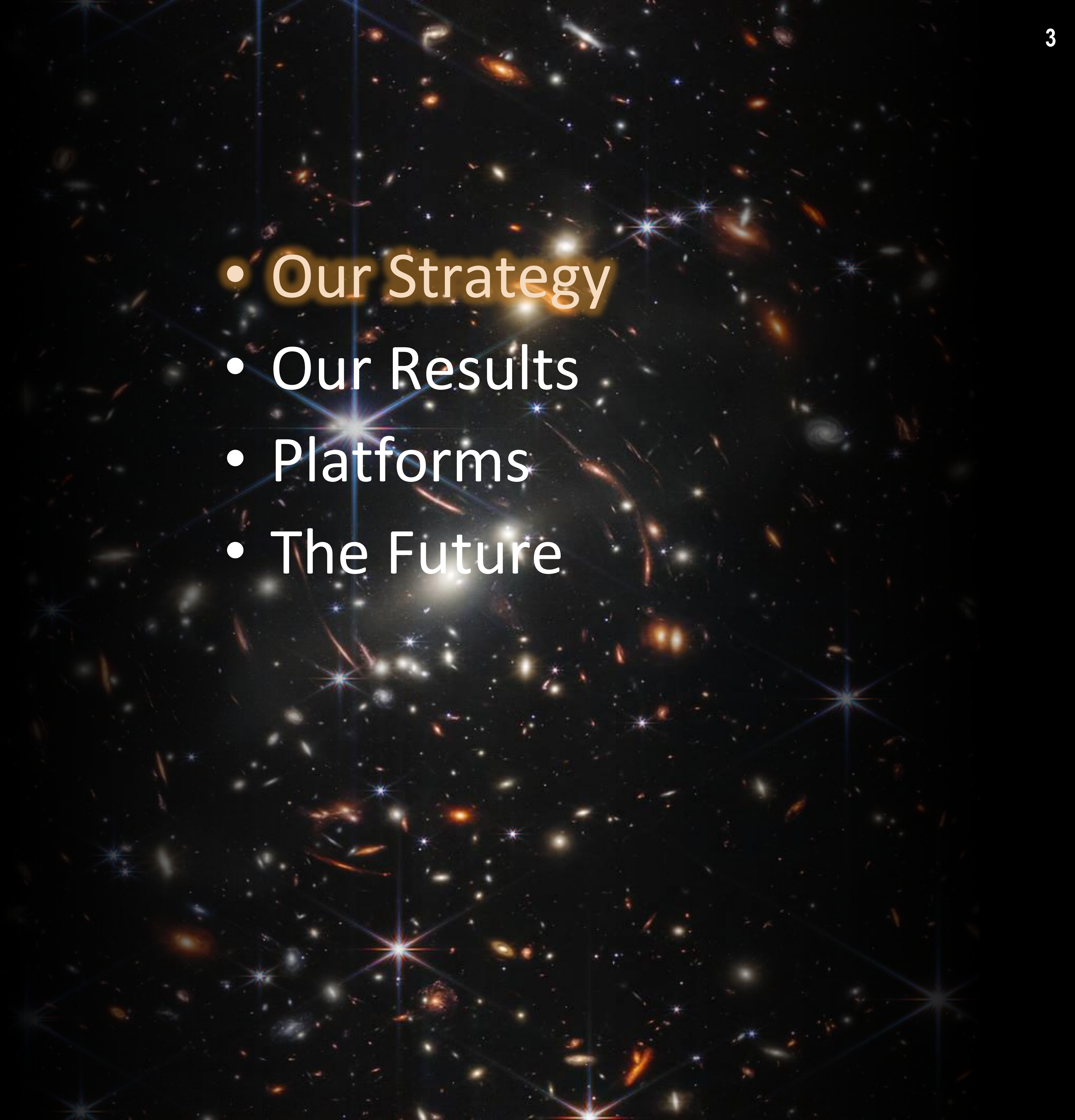
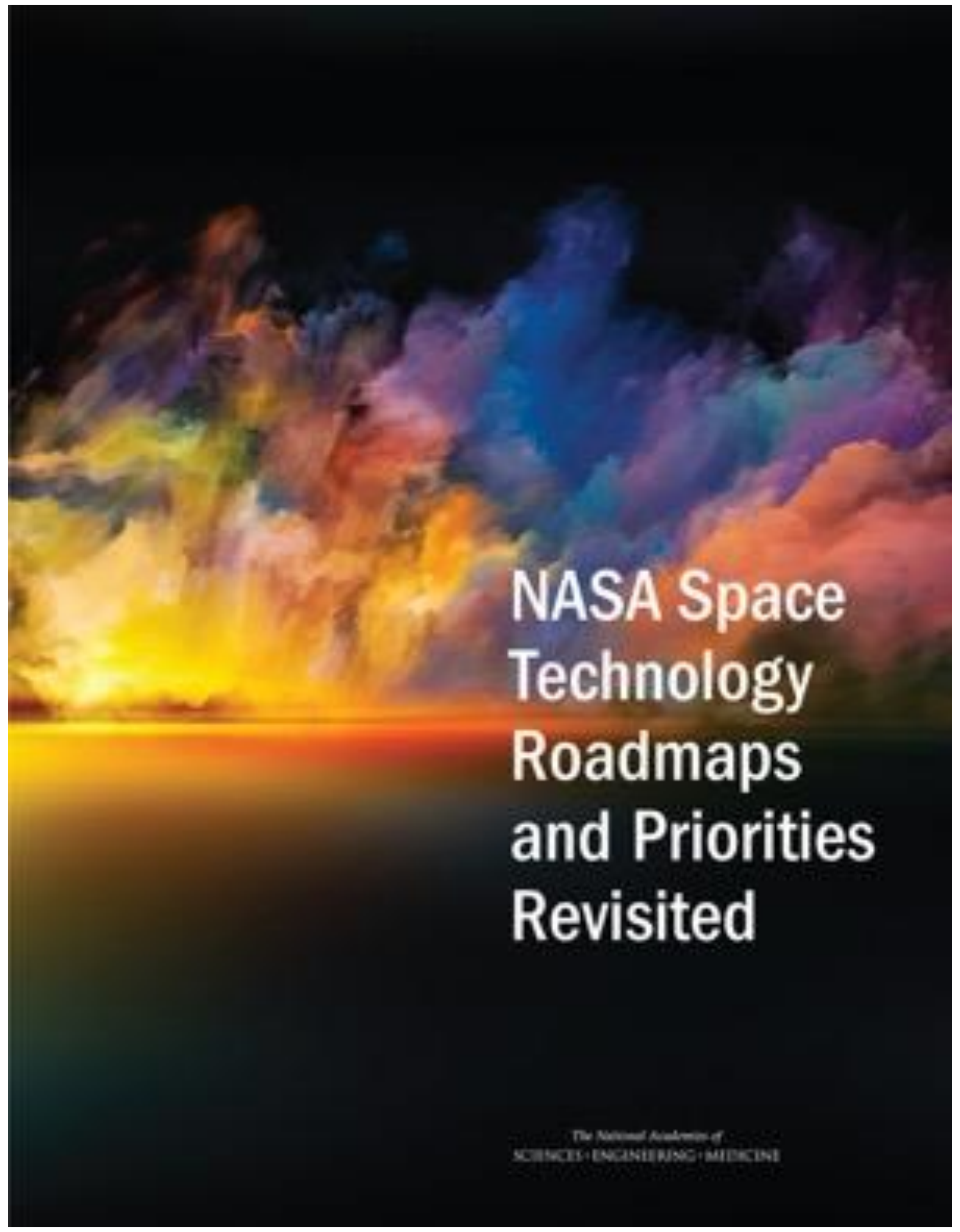



Astrophysics
Decadal Survey
Missions
1972
Decadal
Survey
Hubble
1982
Decadal
Survey
Chandra
1991
Decadal
Survey
Spitzer
2001
Decadal
Survey
Webb
2010
Decadal
Survey
Roman
2021
Decadal
Survey
Habitable
Worlds
Observato
and Astrophysics
for the 1970's
Reports of the Panels
Astronomy
and Astrophysics
for the 1980's
ASTRONOMY
AND
ASTROPHYSICS
Astronomy and Astrophysics
in the New Millennium
New Worlds,
New Horizons
in Astronomy and Astrophysics
Pathways to Discovery in
Astronomy and Astrophysics
for the 2020s


NASA Space Technology Roadmaps and Priorities Revisited
The National Academies of
SCIENCES · ENGINEERING · MEDICINE


2020
NASA
Technology
Taxonomy


Introduction
About
How to Participate
Supporting Materials
Shape the Future of Space Technology with NASA
Provide your valuable feedback on NASA-identified space technology shortfalls by May 13.
Register to Provide Feedback

Why and How We Invest in Technologies

- Astrophysics Division supports a wide range of technologies; everything that is unique to an astrophysics mission need should be fundable somewhere in our portfolio
- Mix both for specific, identified missions (ex: Habitable Worlds Observatory) and those yet to be identified (Explorers)
- Mix of selection mechanisms: primarily via open proposal opportunities but also via directed funding
- Mix of both low-Technology Readiness Level (TRL1-3) and maturation for space flight readiness (TRL4-6)

Technology Readiness Levels (TRL)

- TRL 1-3: demonstrate it works; realize performance
  - i.e. if you have a far-IR spectroscopy mission goal, your detector is probably TRL≤3 until it has achieved the pixel format, saturation power, and sensitivity required
- TRL 4-6: prove you can make it; prove it survives
  - i.e. then you prove you can make these repeatably and they survive vibrations, radiation, etc. for reasonable SWaP
- Definitions: NPR 7123.1D Appendix E

Astrophysics Research & Analysis Programs

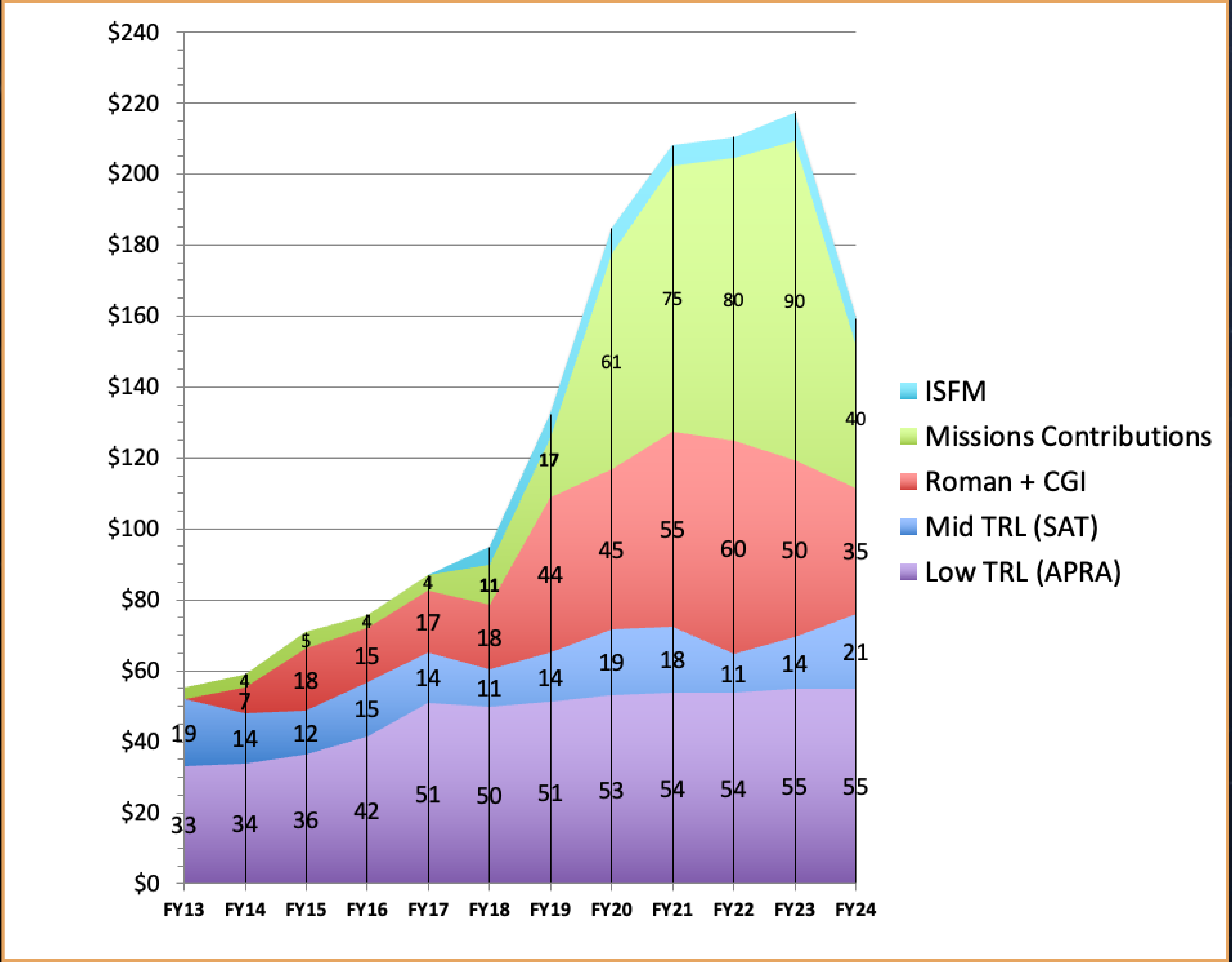
- D.3 *Astrophysics Research & Analysis* (APRA): Feb 21, 2025
- D.7 *Strategic Astrophysics Technology* (SAT): Feb 21, 2025
- D.8 *Roman Technology Fellowship* (RTF): Feb 21, 2025
- D.19 *Habitable Worlds Observatory* (HWO): Mar 4, 2025
- Other solicitations typically exclude technology development

Astrophysics Research & Analysis Programs

- D.3 *Astrophysics Research & Analysis* (APRA): Jan 30, 2025
  submissions in 2011-2022, 2024
- D.7 *Strategic Astrophysics Technology* (SAT): Jan 30, 2025
  submissions in 2011-2019, 2021-2022, 2024
- D.8 *Roman Technology Fellowship* (RTF): Jan 30, 2025
  submissions in 2011-12, 2014-2015, 2016- w/ APRA, 2021- w/ SAT
- D.19 *Habitable Worlds Observatory* (HWO): Feb 6, 2025
  D.19 in 2023 for *Critical Technologies for Large Telescopes*
- Other solicitations typically exclude technology development
  Exception: in 2018 & 2019, *System-Level Segmented Telescope Design*

Astrophysics Technology Investments

- At top: mission-driven
- At bottom: proposal-driven



SMD Requests to STMD

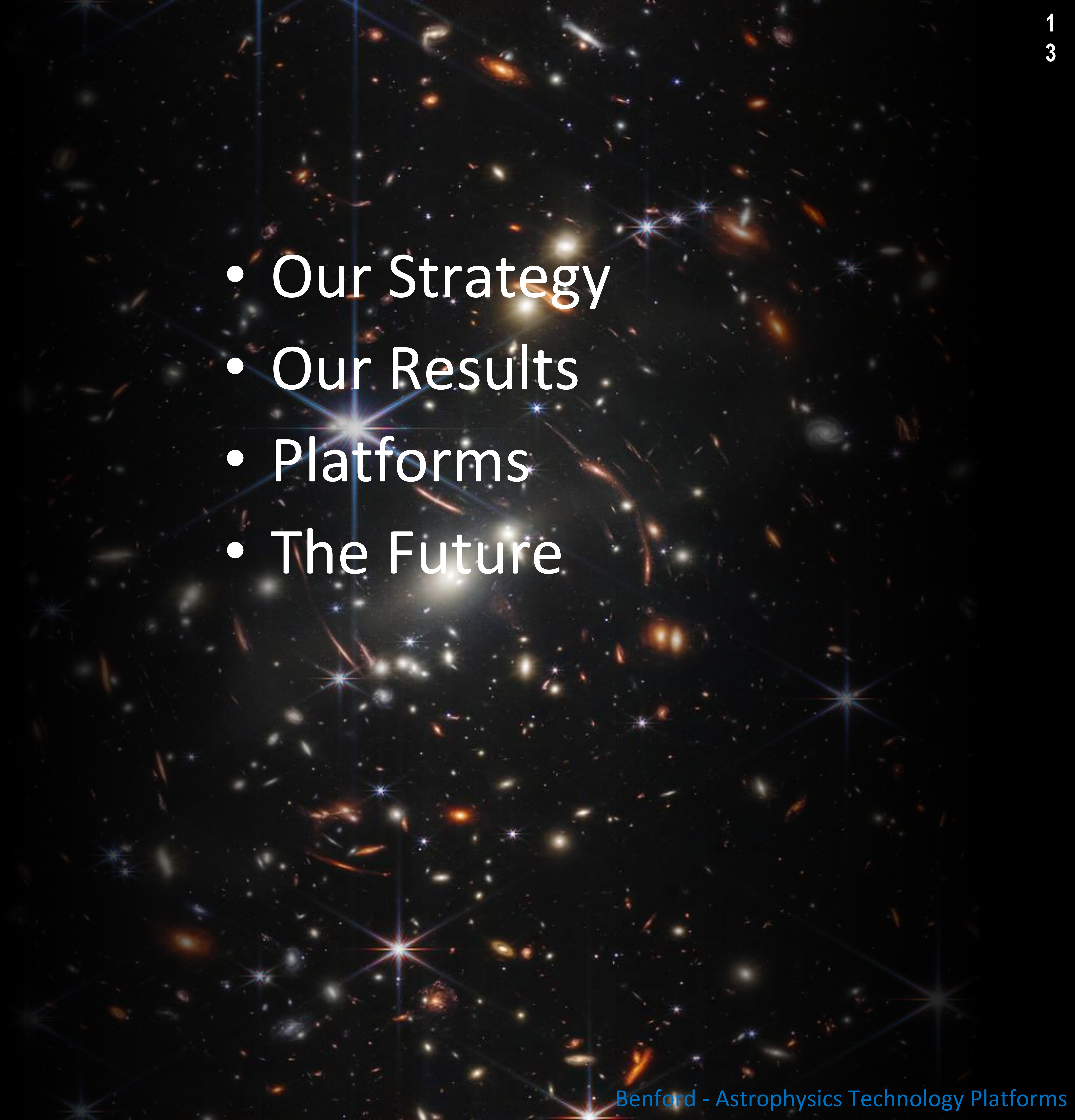
Technical Areas	SMD Requests for STMD Investments in FY25 – Proposed 10/2/24
TX01 Propulsion	Micro-thrusters (HPD, APD)
TX08 Sensors	**Quantum sensing component technology** (APD, BPS, ESD); **Low TRL improvements to photon detection, energy resolution & scaling to large low-SWaP arrays** (APD, PSD, HPD, ESD)
TX10 Autonomy	**AutoNav demo** (PSD, HPD, ESD, APD, ESSIO) *(increased priority)*
TX12 Structures	**Ultra-Stable Structures Tech Demo** ((*formerly Disturbance-Free Payload;* APD, ESD, BPS); **Micrometeoroid-robust deployable membranes and baffles** (APD, ESD)
TX14 Thermal	**Low-vibration cryogenic cooling for single photon detectors** (APD)

- **Bold Text: Highest priority**
- Regular Text: High priority
- Change from last year

If You Are A Technologist At A…

- NASA center
  - –Project or ISFM support; STMD
- Industry partner
  - –D.19 teams, future calls (RFP/RFI/etc.); STMD
- University
  - –Future ROSES solicitations; ST-REDDI
- International agency/institutions
  - –Grassroots international partnerships
- …Anywhere
  - –Standing Review Board, Independent Technology Review, Peer Reviewer

Outline



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Astrophysics by the NUMBERS

TECHNOLOGY DEVELOPMENT
~$160M Invested Annually

RESEARCH
~365 U.S. Science PIs Funded currently
~130 Individual Institutions Selected
~$145M Awarded Annually

SMALLSATS/CUBESATS
4 Science Missions Launched
4 Missions Complete
10 Science Missions in Development
8 Free-flying CubeSats
1 Supporting Technology Development Project
2 ISS-attached Science Missions

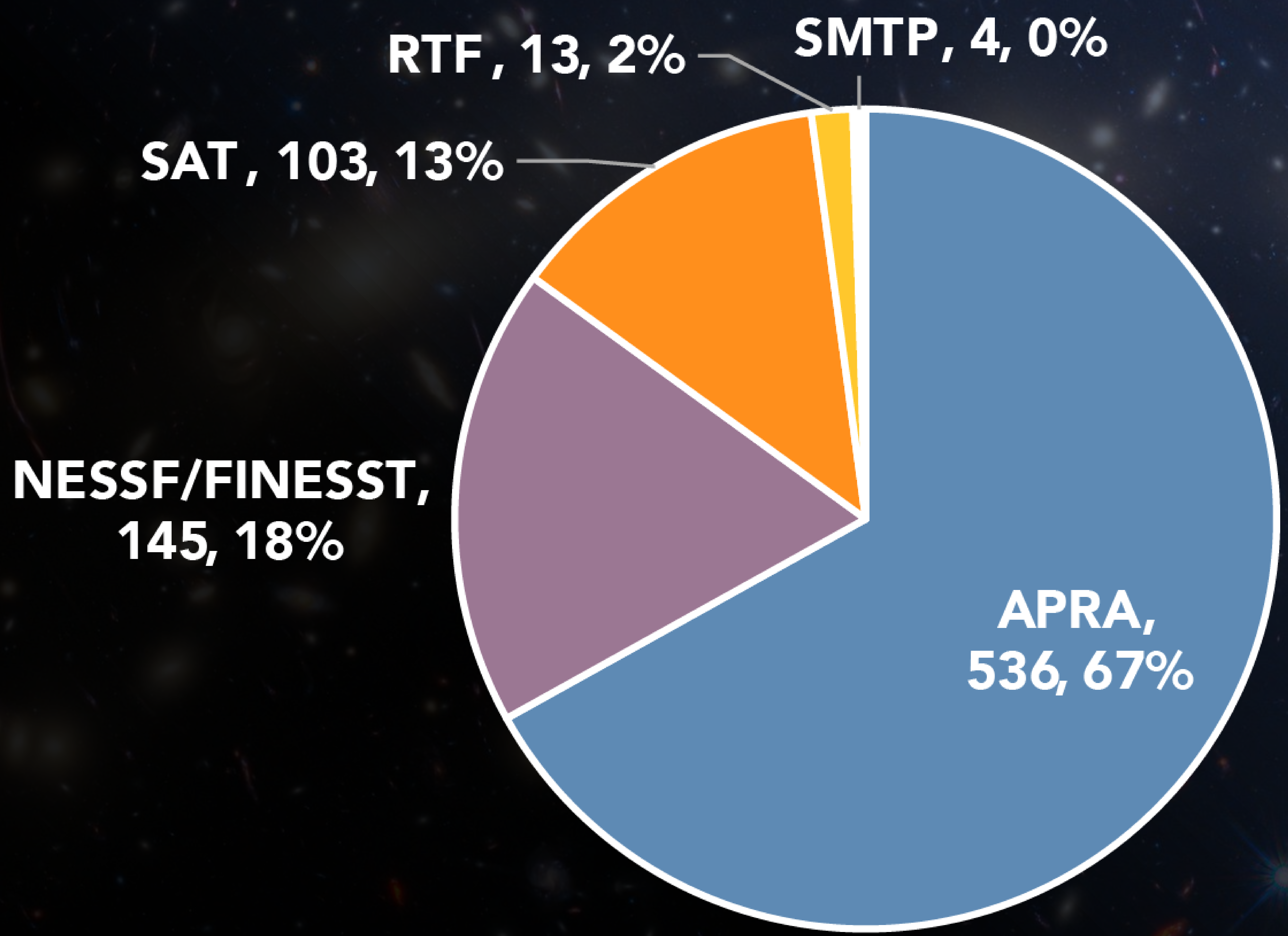
REFEREED PUBLICATIONS
>21,361 Hubble Publications (1991-Current)
>1,745 Webb Publications (July 2022-Current)
>10,091 Chandra Publications (1999-Current)

SOUNDING ROCKETS
19 Rockets Launched
7 In Development

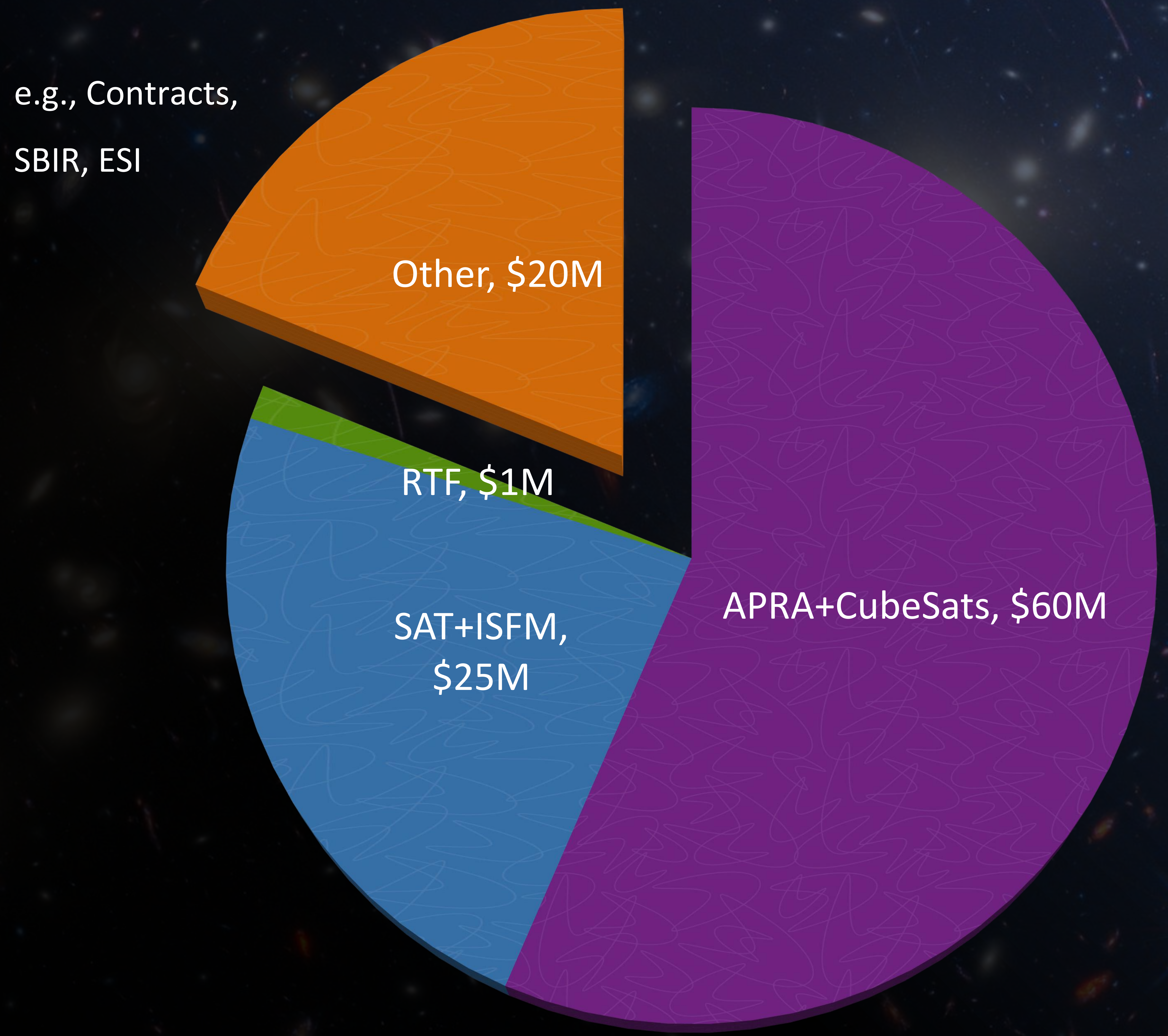
MISSION SUMMARY
15* Missions Operating
17* Missions in Development
2 Tech. Demos
*Including international partnerships

BALLOONS
32** Balloons Launched
***Includes APD, HPD, PSD, ESD, educational, & engineering missions*
21 in Development

Grant Selections, 2010-2020



Competed Funding ≈Now



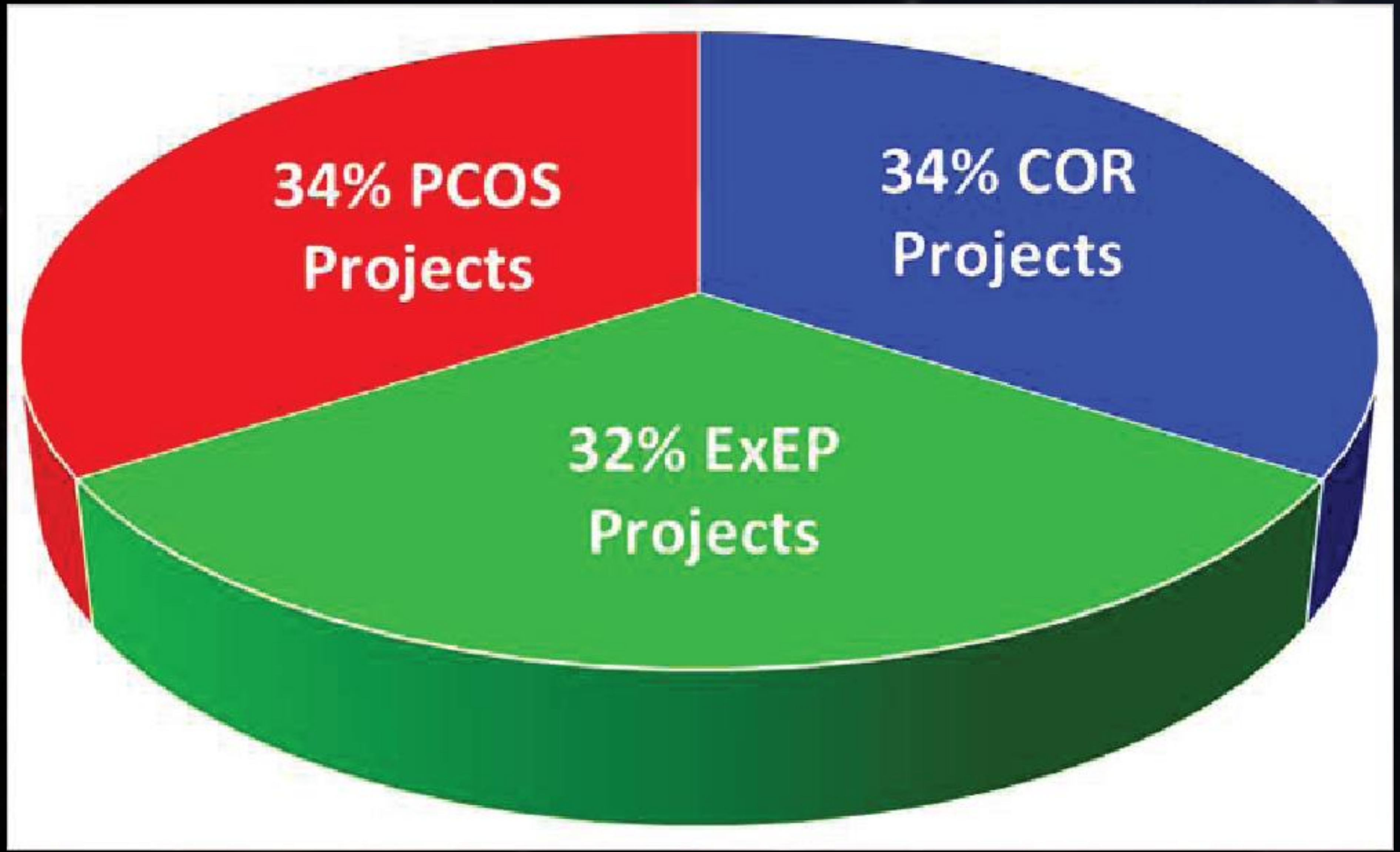
APRA+SAT Statistics

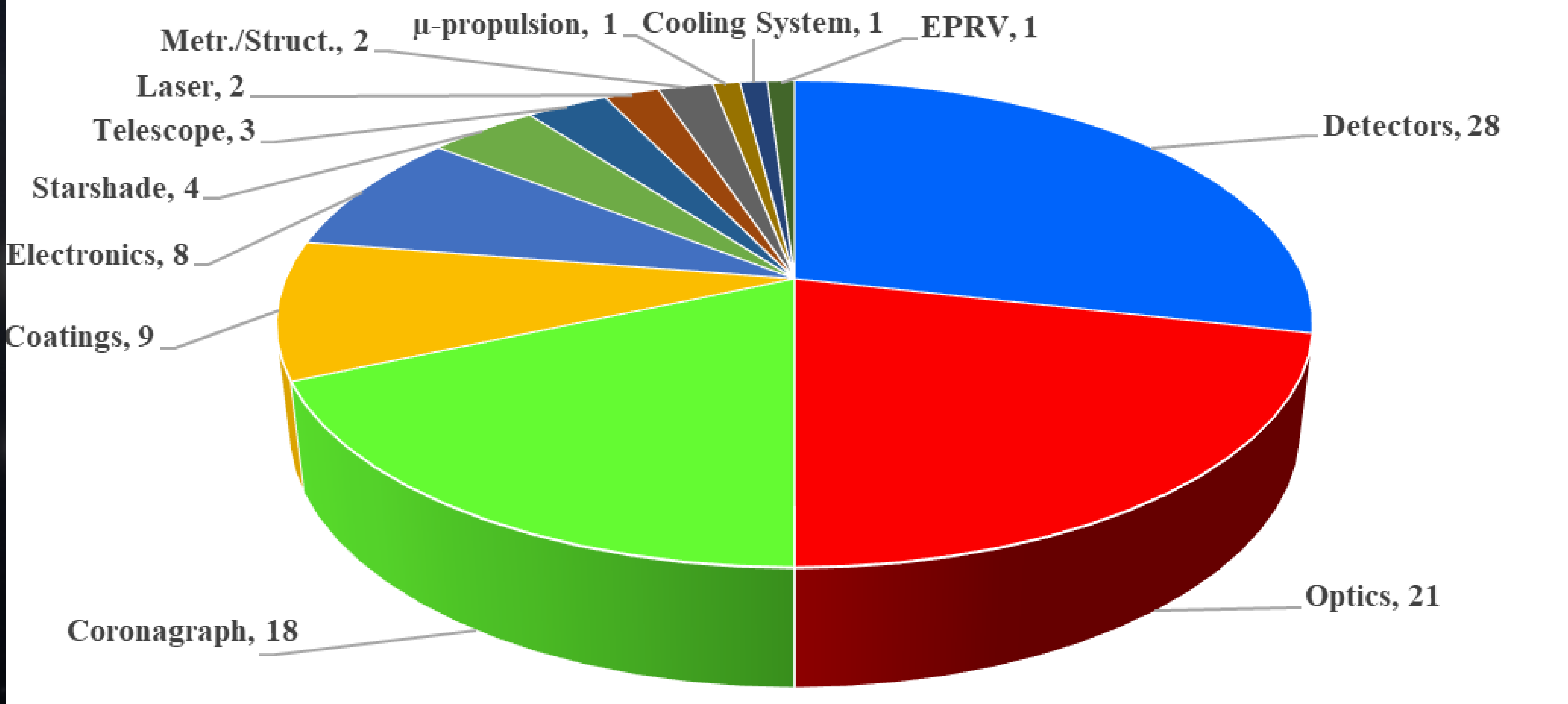
Year	Submitted		Funded	
	APRA	SAT	APRA	SAT
2015	151	29	60 (40%)	7 (24%)
2016	141	30	54 (38%)	8 (27%)
2017	169	25	52 (31%)	11 (44%)
2018	164	30	58 (35%)	12 (40%)
2020	170	–	45 (26%)	–
2021	155	40	57 (30%$)	16 (40%)
2022	147	37	38 (28%$)	13 (35%)
2023	163	41	40 (26%$)	12 (29%)

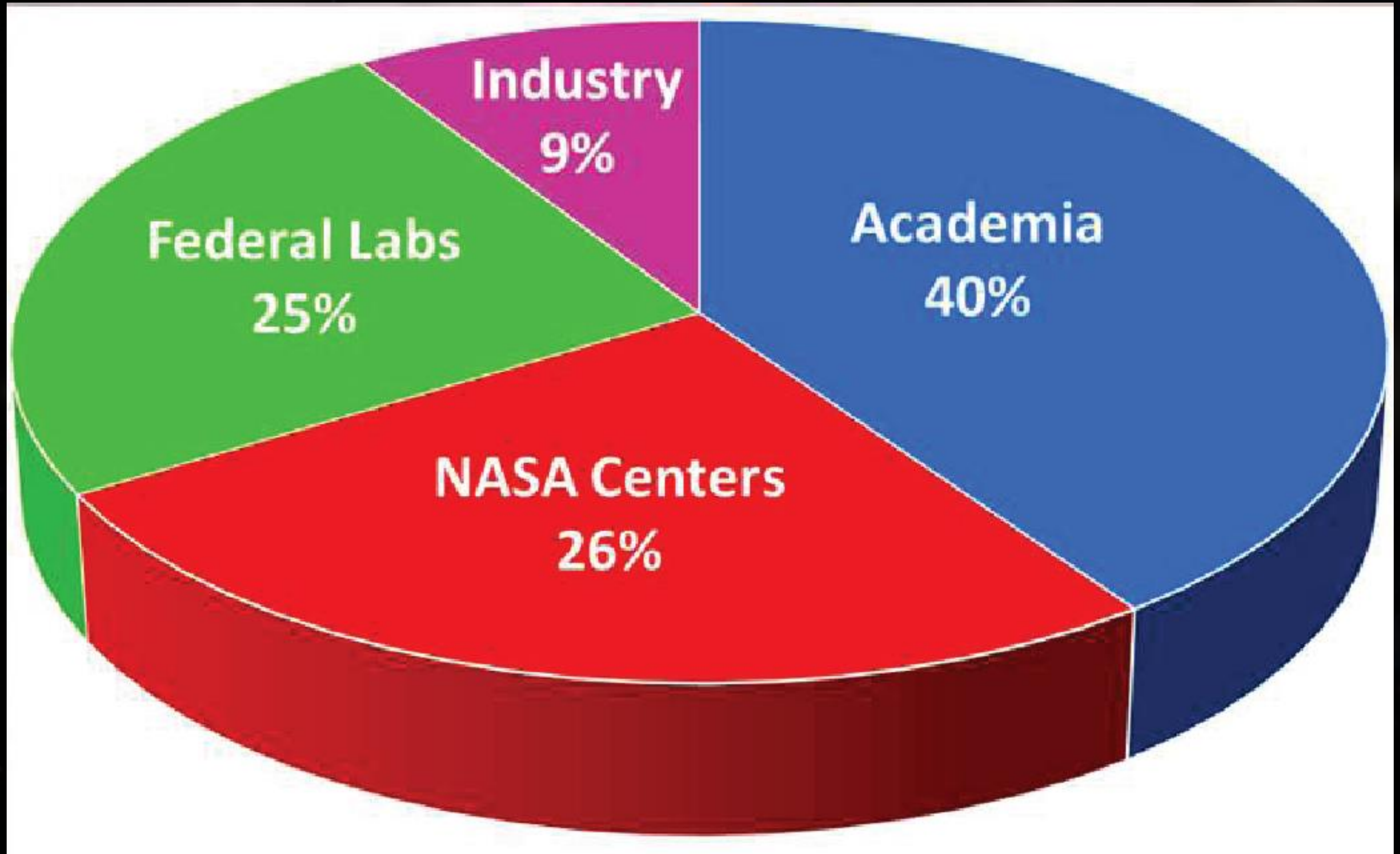
Oversubscription Rates (APRA+SAT, 2020-2023)

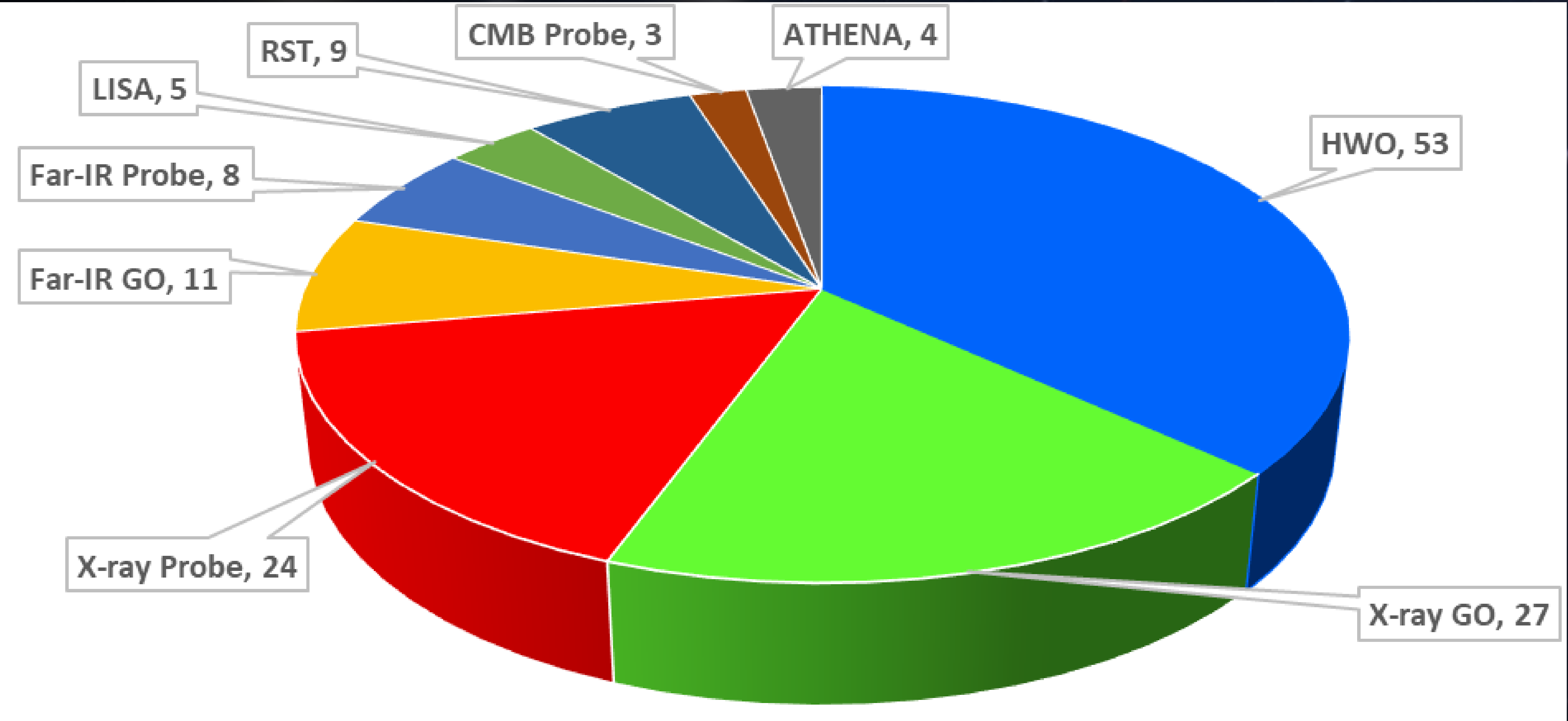
Discipline	# Proposals	Total Request ($M)	Avg. Request ($M)	Allocation – APRA	Oversubscription Rate – APRA
High Energy	143	279.6	2.0	72.3	3.5:1
UVOIR	293	610.4	2.1	65.5	6.3:1
Long Wavelength	173	378.3	2.2	59.9	5.7:1
Lab Astro	103	64.3	0.6	16.8	3.8:1
Particles	26	70.4	2.7	44.7	1.6:1
Fun Phys	4	9.1	2.3	3.2	2.8:1
Total	742	1412.1	1.9	262.4	4.4:1

Strategic Astrophysics Technology Projects





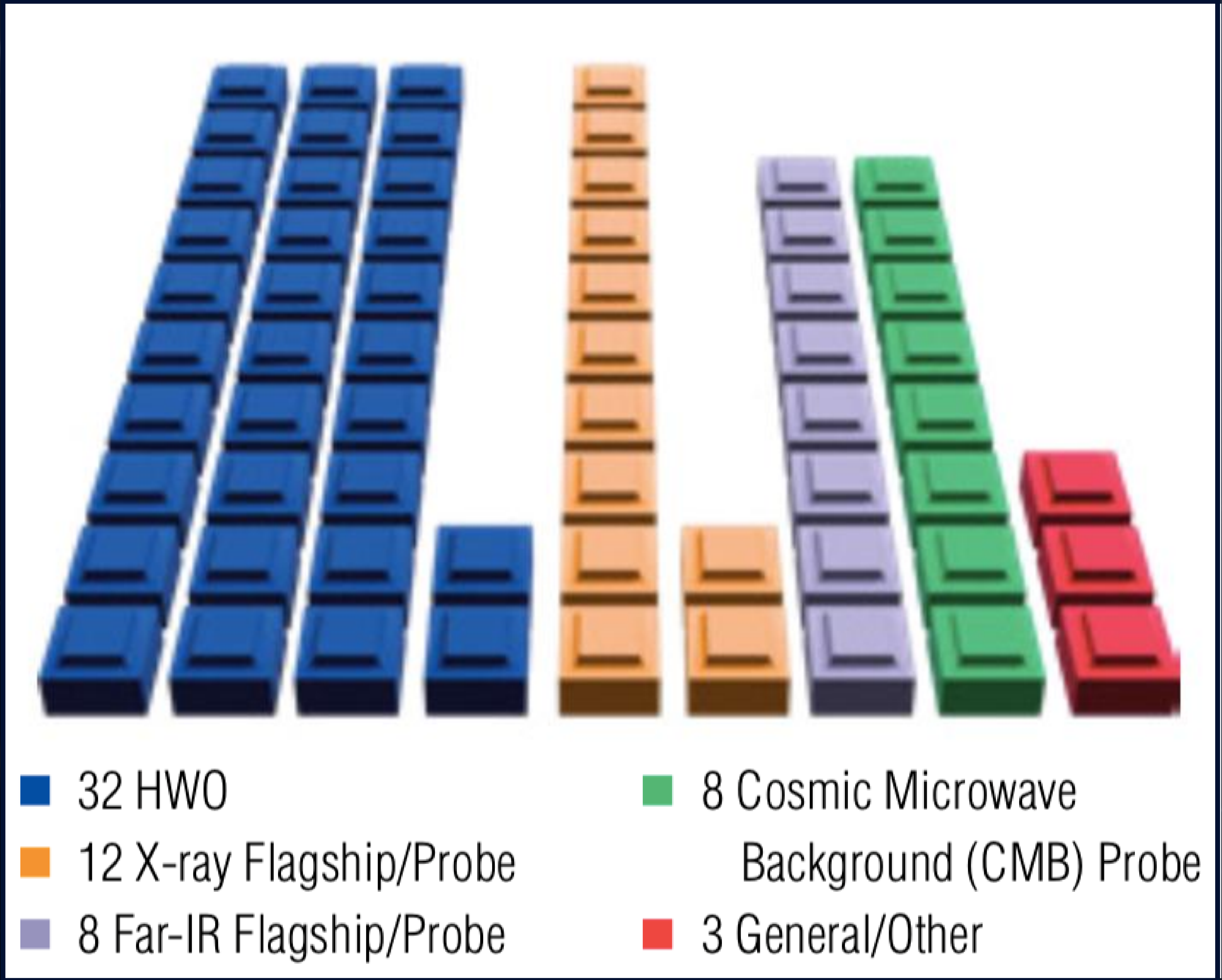




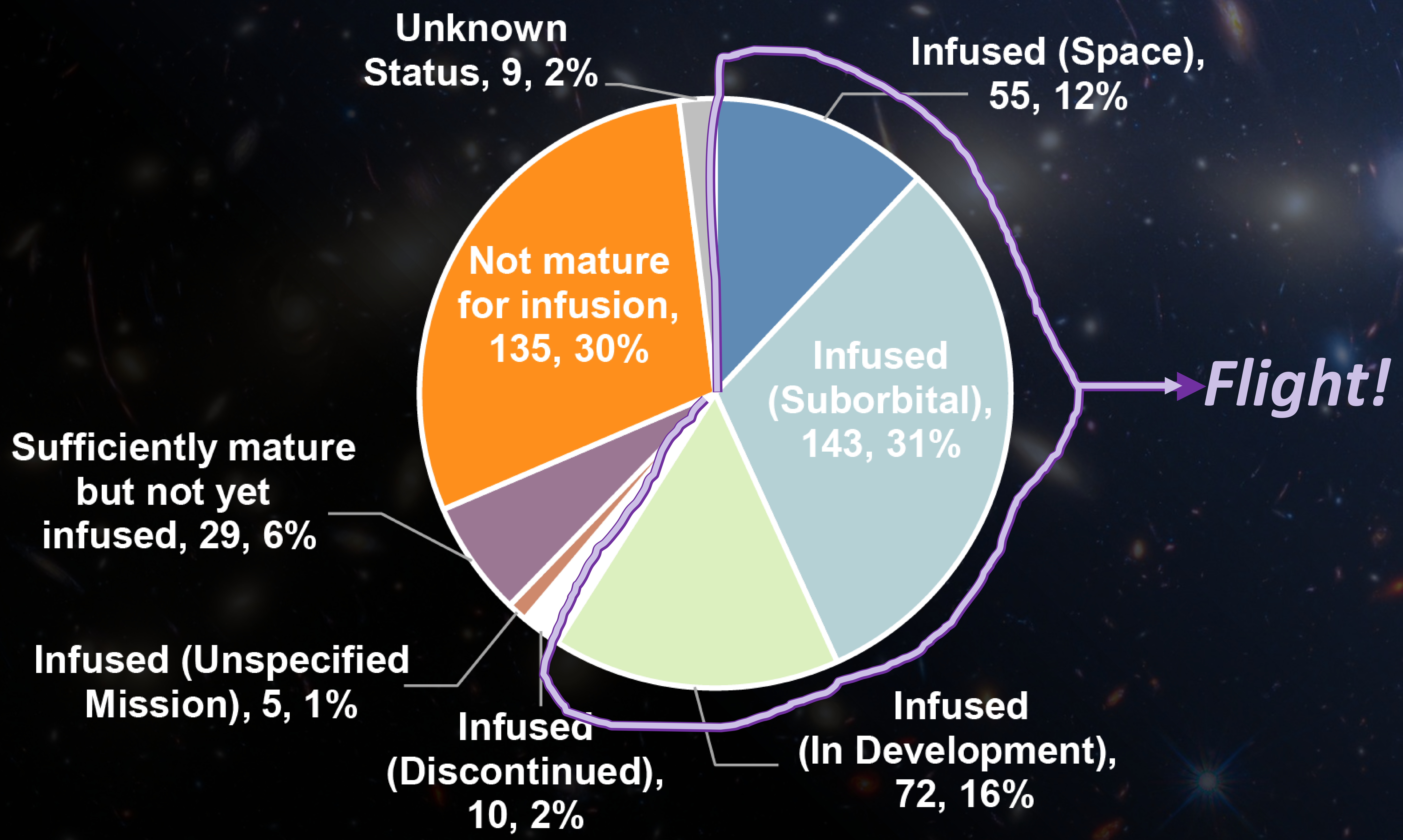
Pham et al. 2020, Proc. SPIE 11145107-1

Current Projects

53 active (41 SAT, 12 other)

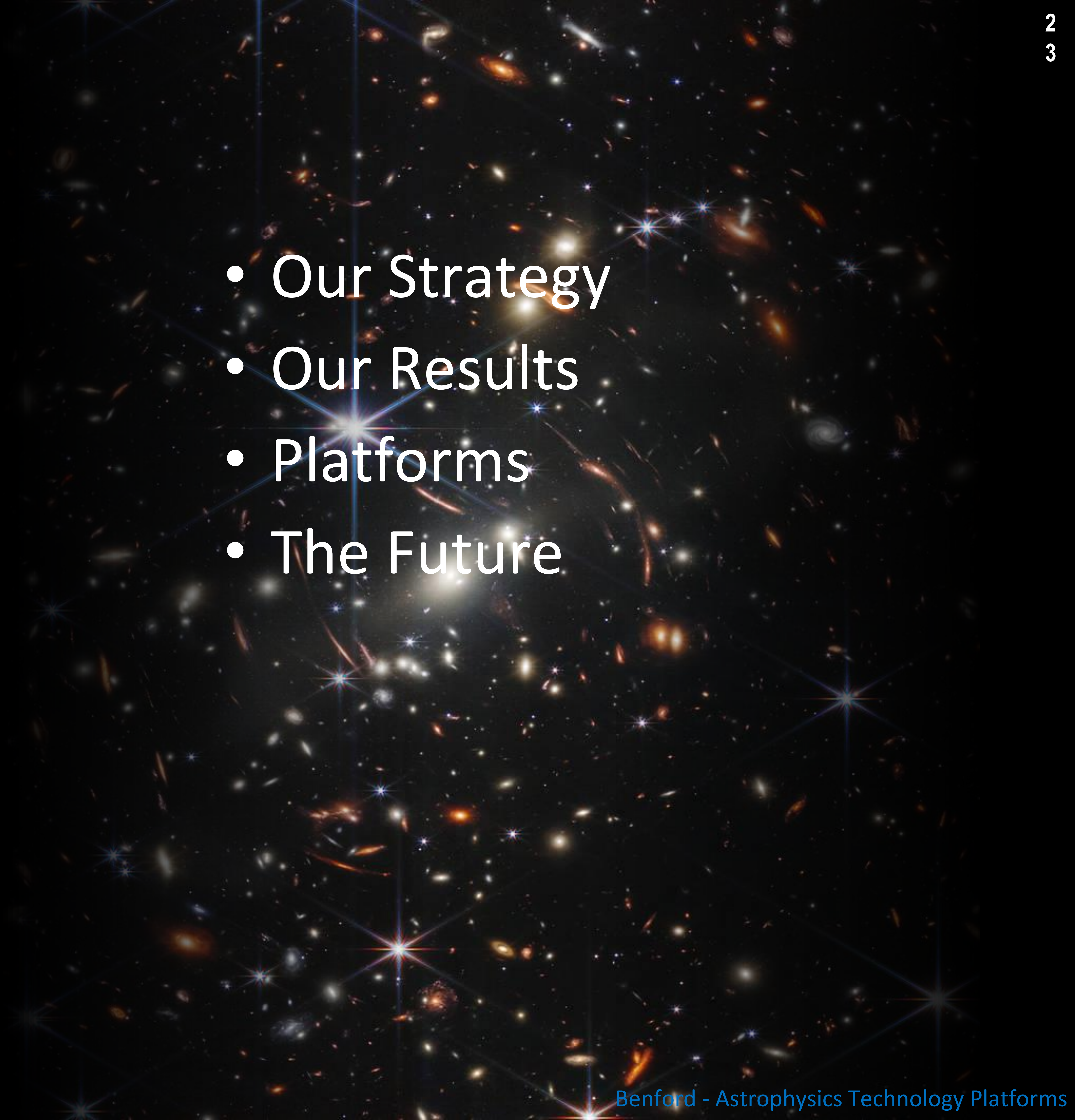


Infusion Status, 2010-2020



Hayhurst, Aerospace Crop. OTR 2022-00559

Outline



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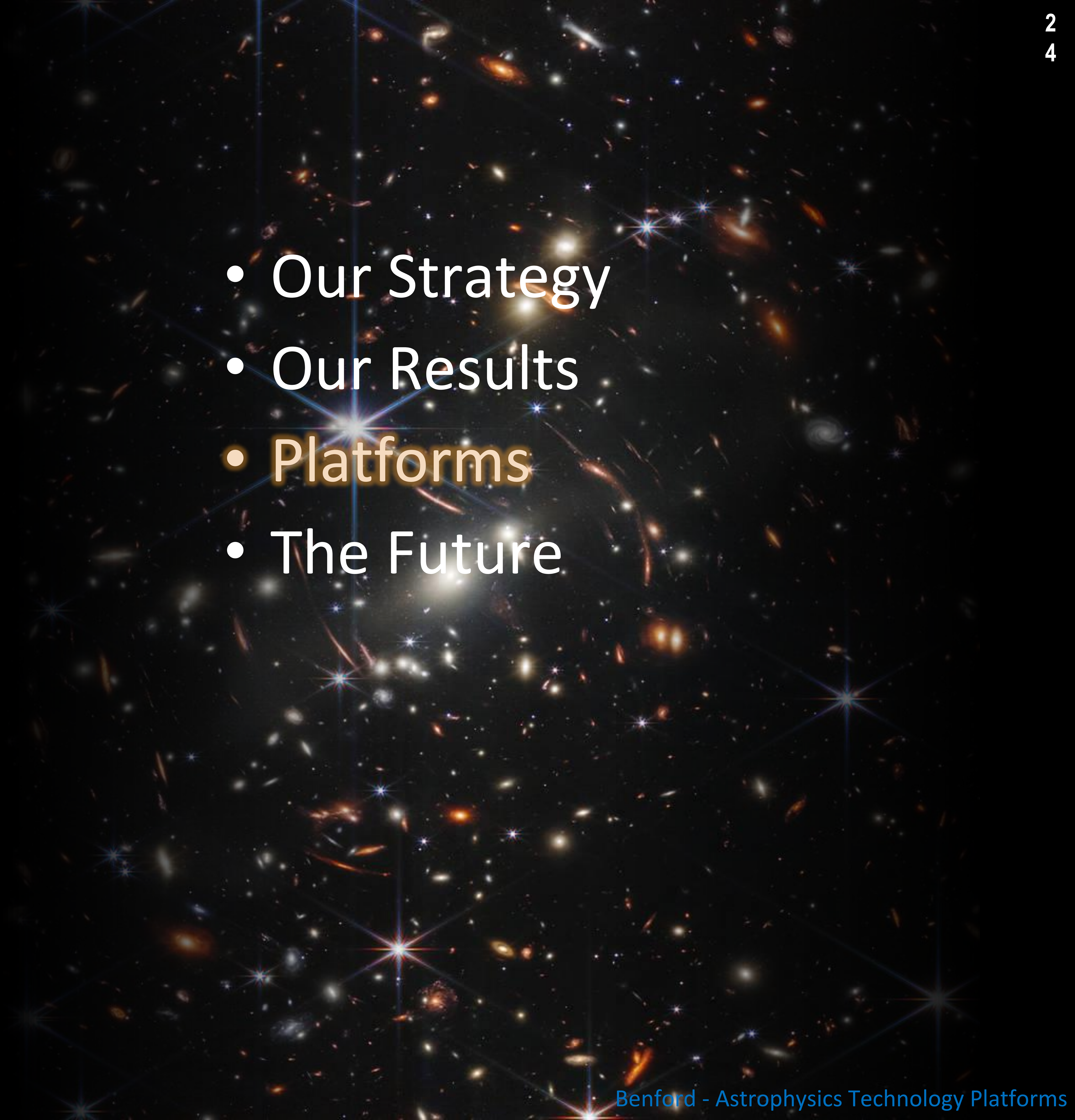

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Elements to Consider for Flight Test

- A high-level overview of the technology
  - Communicating what your technology is designed to do
- The technology's relevance to key NASA shortfalls
  - Enabling of high value mission – adoption likely if mature enough
- The current technology readiness level (TRL), including:
  - Has a benchtop unit or prototype been developed?
  - What type of testing have you performed to date?
- The environment in which the technology will ultimately be used
  - Consider the key characteristics of this environment
- How the findings from testing in a relevant environment will be used
  - How will the data you collect impact your technology development plan?
- Optimal timing for testing in a relevant environment
  - Technology developed enough to benefit from testing, not too late to incorporate learning
  - Can some components or subsystems be tested separately?
  - What are the biggest risks on the path to flight?

Platforms for Technology Maturation

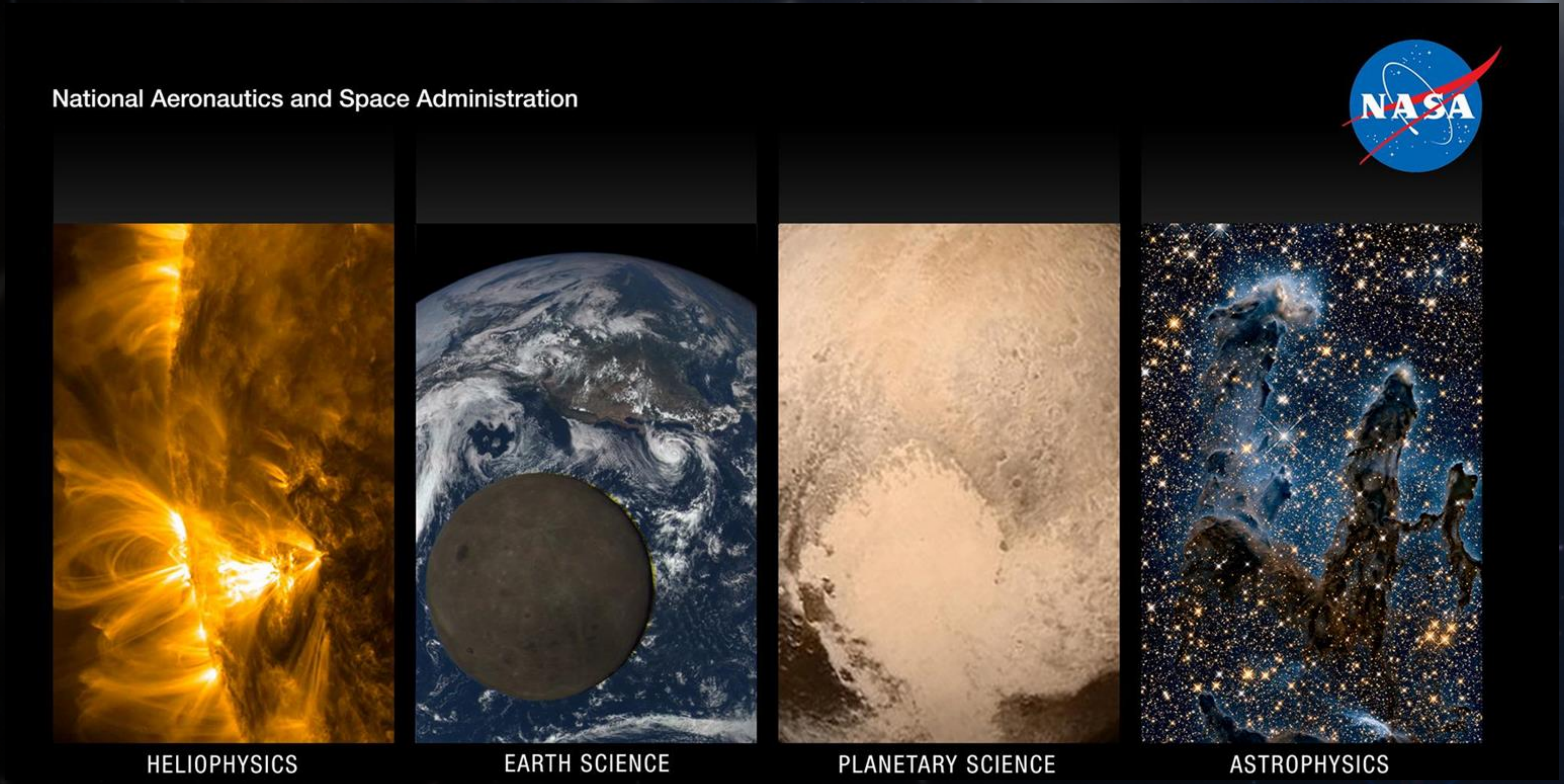
- Laboratories – proposers' own or NASA-provided (e.g. HCIT at JPL, ultrastability testbeds at Goddard, X-ray optics at Marshall)
- Ground-based telescopes – NASA doesn't control access & only works for a subset of technologies
- Balloons – more on this
- Sounding Rockets – more on this
- ISS-attached payloads (or other, potentially) – more on this
- CubeSats – more on this
- Spacecraft-as-a-Service – not much more on this

Technology Maturation Platforms

Platform	Balloon	Sounding Rocket	CubeSat	Hosted Payload
Environment	Air; gravity	Vacuum	Vacuum	Vacuum
Payload	Large	Moderate	Tiny	Small
Radiation	Minor	Minor	Space	Space
Time	Days	Minutes	Months+	Months+
Effort	PI responsibility; some standards	PI responsibility; many standards	PI responsibility; substantial COTS	PI mostly responsible; substantial existing

Why Balloon Payloads at NASA?

Balloons have provided fundamental discoveries of our Earth, the Sun, the solar system, and the universe, and have also played an important role in developing and validating space technologies as well as train future leaders of the field.



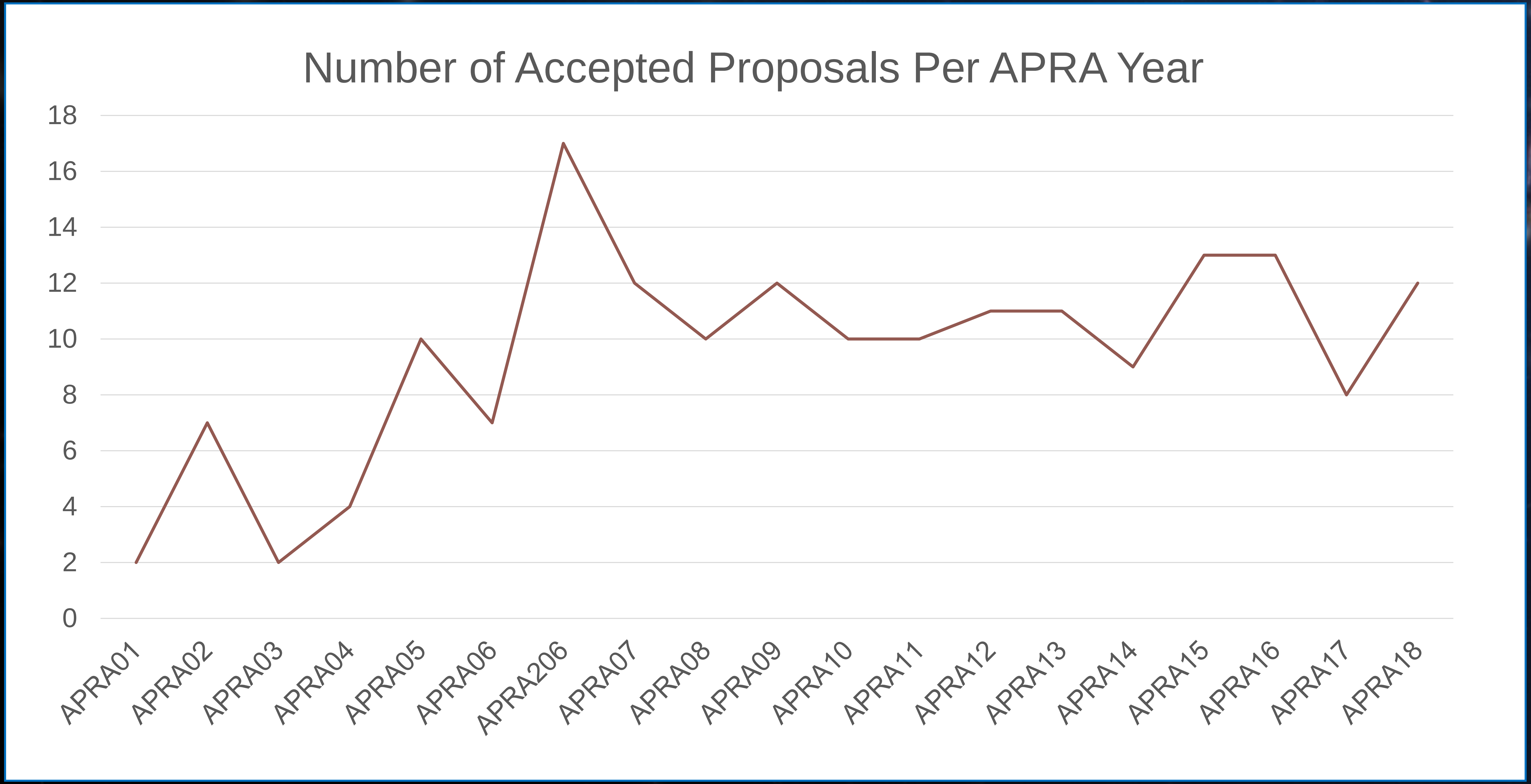
About **Half** of the suborbital PI are first-time suborbital PIs.

Balloon Launch Facilities Worldwide (NASA, non-NASA)

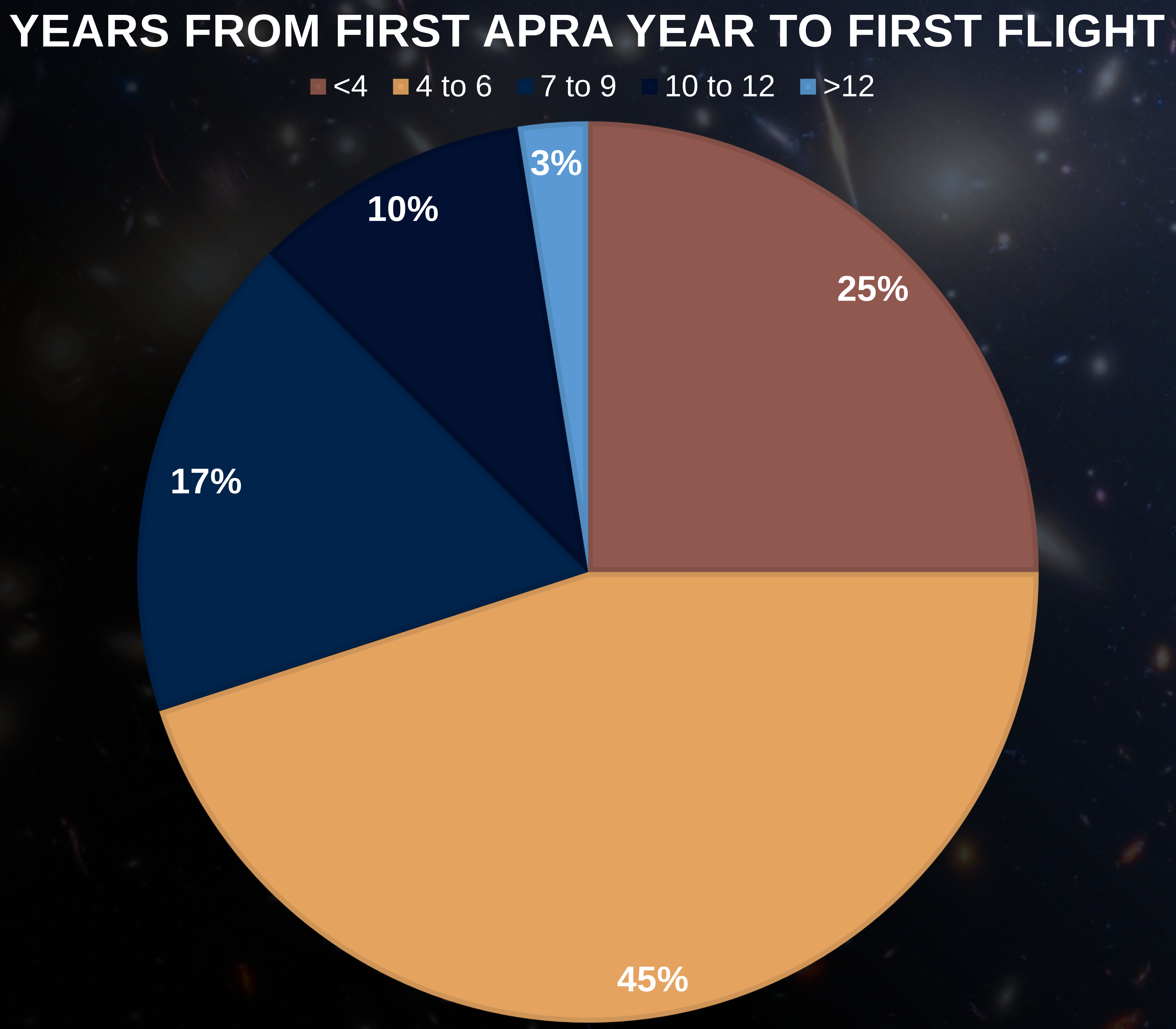
- Each launch site has unique characteristics for science.
- Some sites are shared by nations. For example:
  - NASA site in Alice Springs is used by Japan and France
  - Swedish site at Esrange used by France, Italy, US.
- Balloon missions are usually multi-institutional partnerships with different nations contributing technology and science. International contributions are often partnering with the PI not NASA.

A Decade of Statistics

- Approximately APRA-09 through APRA-18
- ~200 Suborbital proposals submitted
- 21 Projects funded

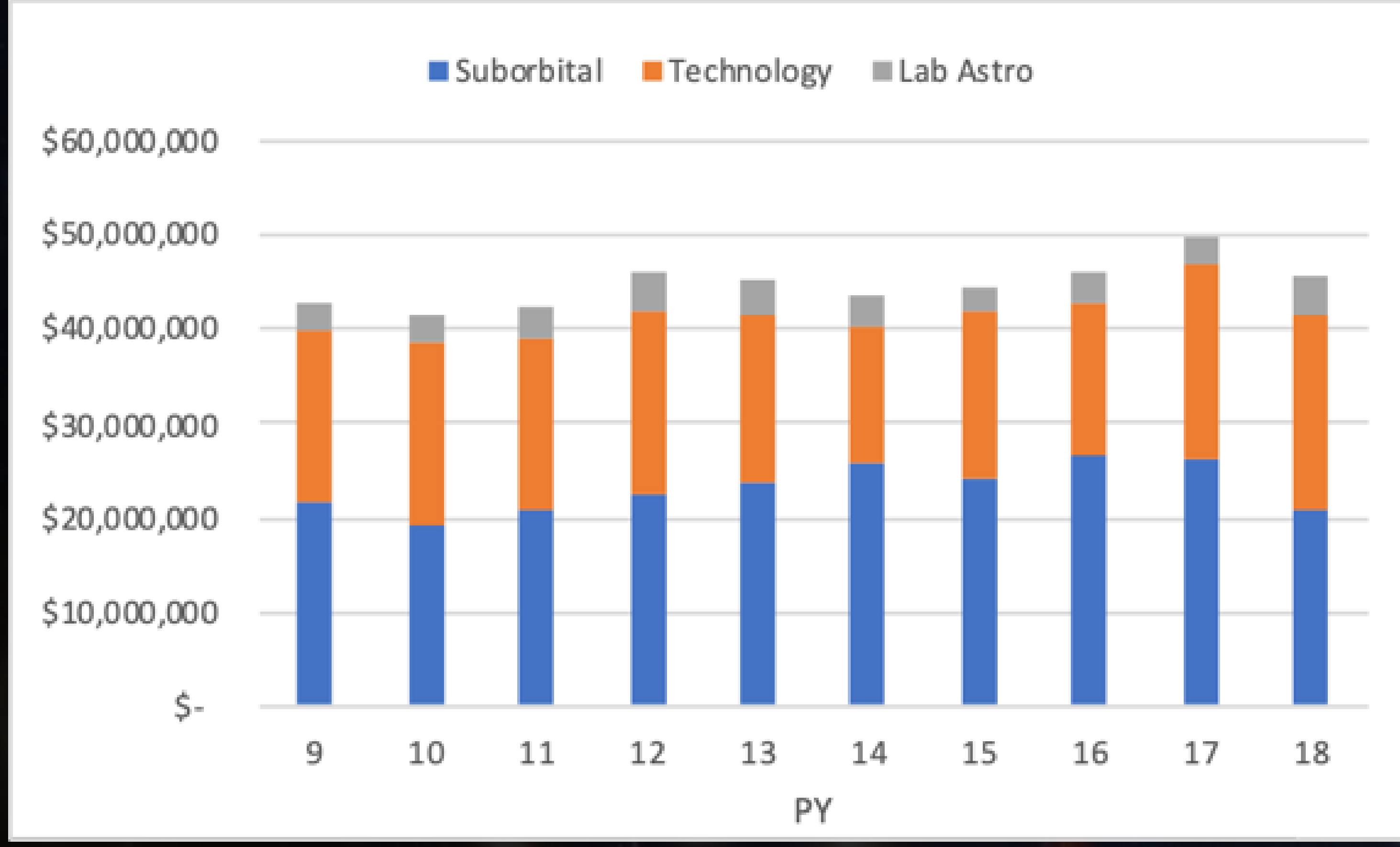


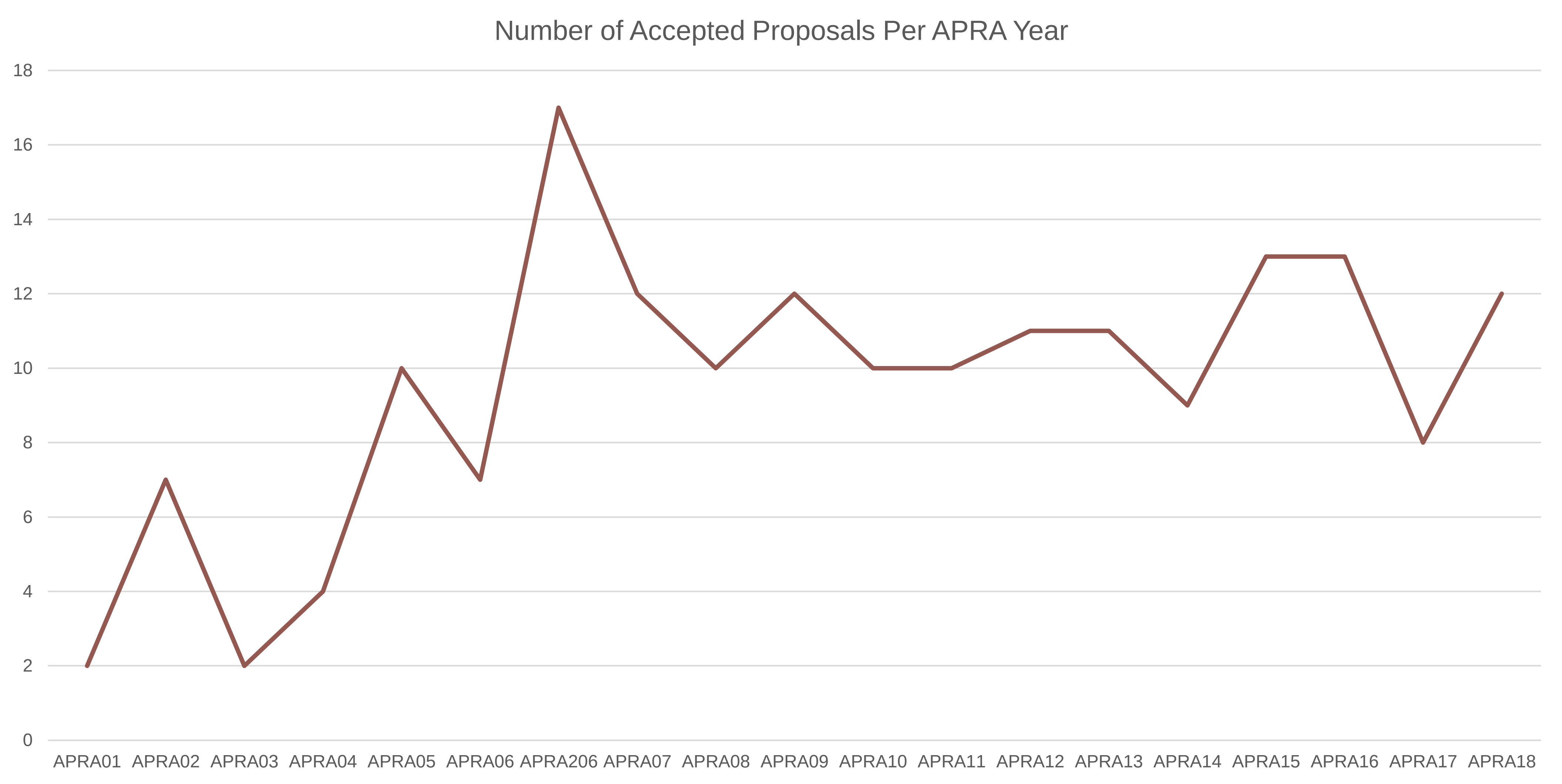
How Long to Get To Flight?



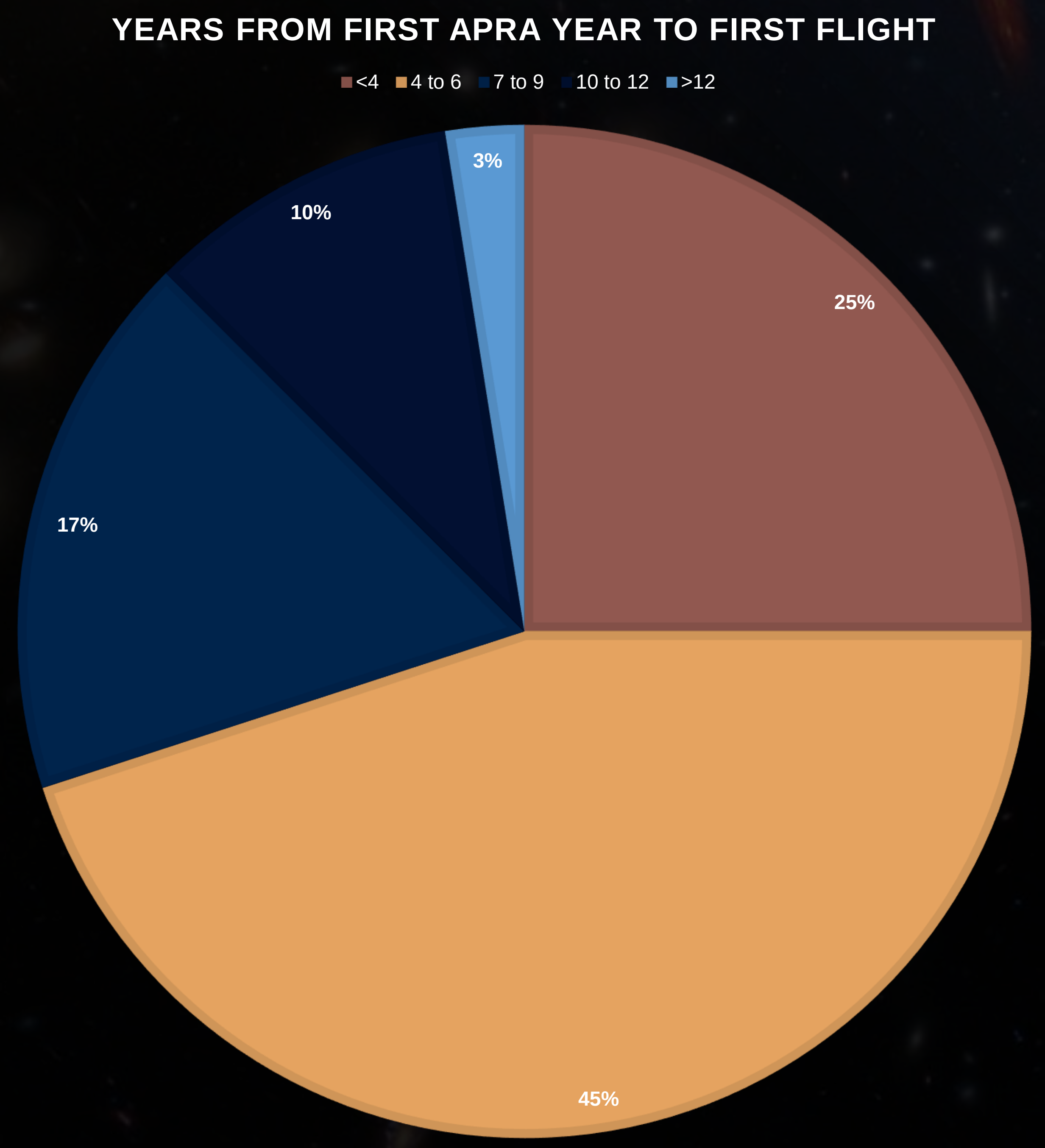
Balloon Flight Rate Decreasing: Better vs. Faster?

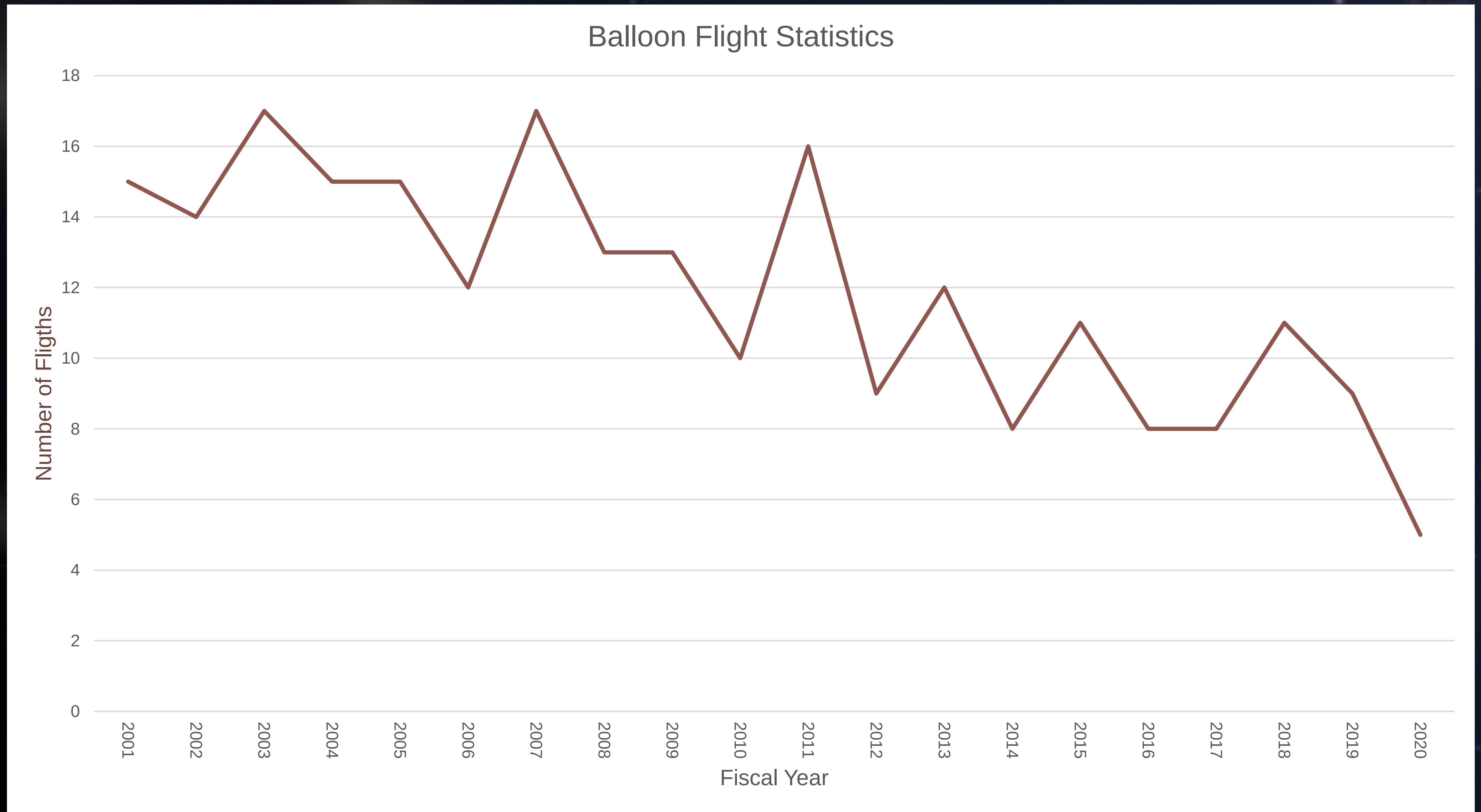
- Selected:





- Flown:





Wiser & Benford, AAS #237 – 432.04

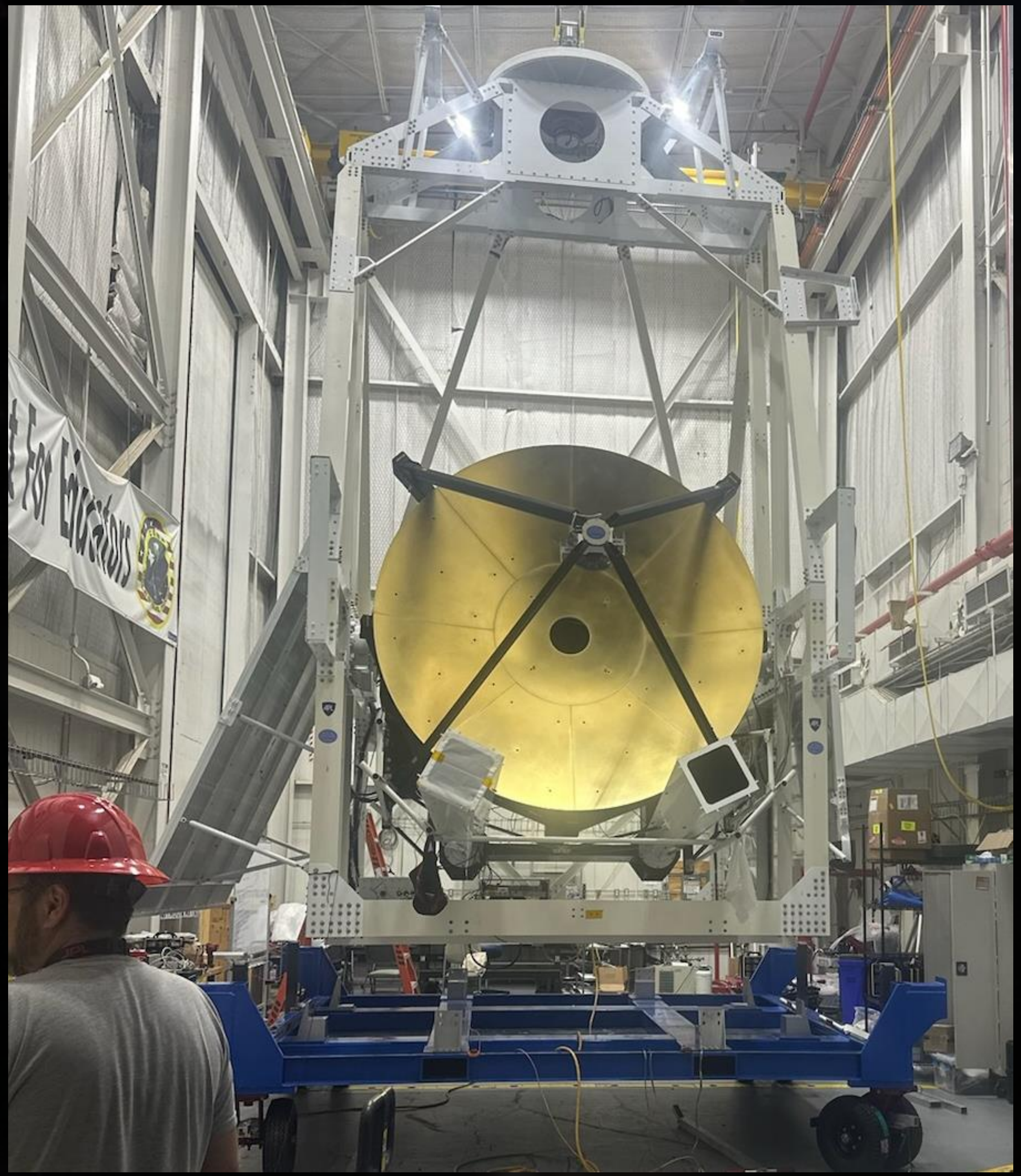
Suborbital Projects

- **Balloons:**
- PICTURE – launched from Ft. Sumner 2022, in data analysis
- Spider – launched from McMurdo 22/23 season, in data analysis
- SuperBIT – launched from Wanaka 2023, in data analysis
- HELIX – launched from Sweden 2024, in data analysis
- FIREBALL2 – launch from Ft. Sumner 2024
- THAI-SPICE – launch from Ft. Sumner 2024
- EXCITE – launch from Ft. Sumner 2024
- EXCLAIM – first launch 2024
- ASTHROS – launch from McMurdo 24/25 season
- GAPS – launch from McMurdo 24/25 season
- TIM (Terahertz Intensity Mapper) – launch from Ft. Sumner 2025
- ADAPT – launch from McMurdo 25/26 season
- GRAMS – first launch 2026
- PBR – launch from Wanaka 2027
- TAURUS – launch from Wanaka 2027

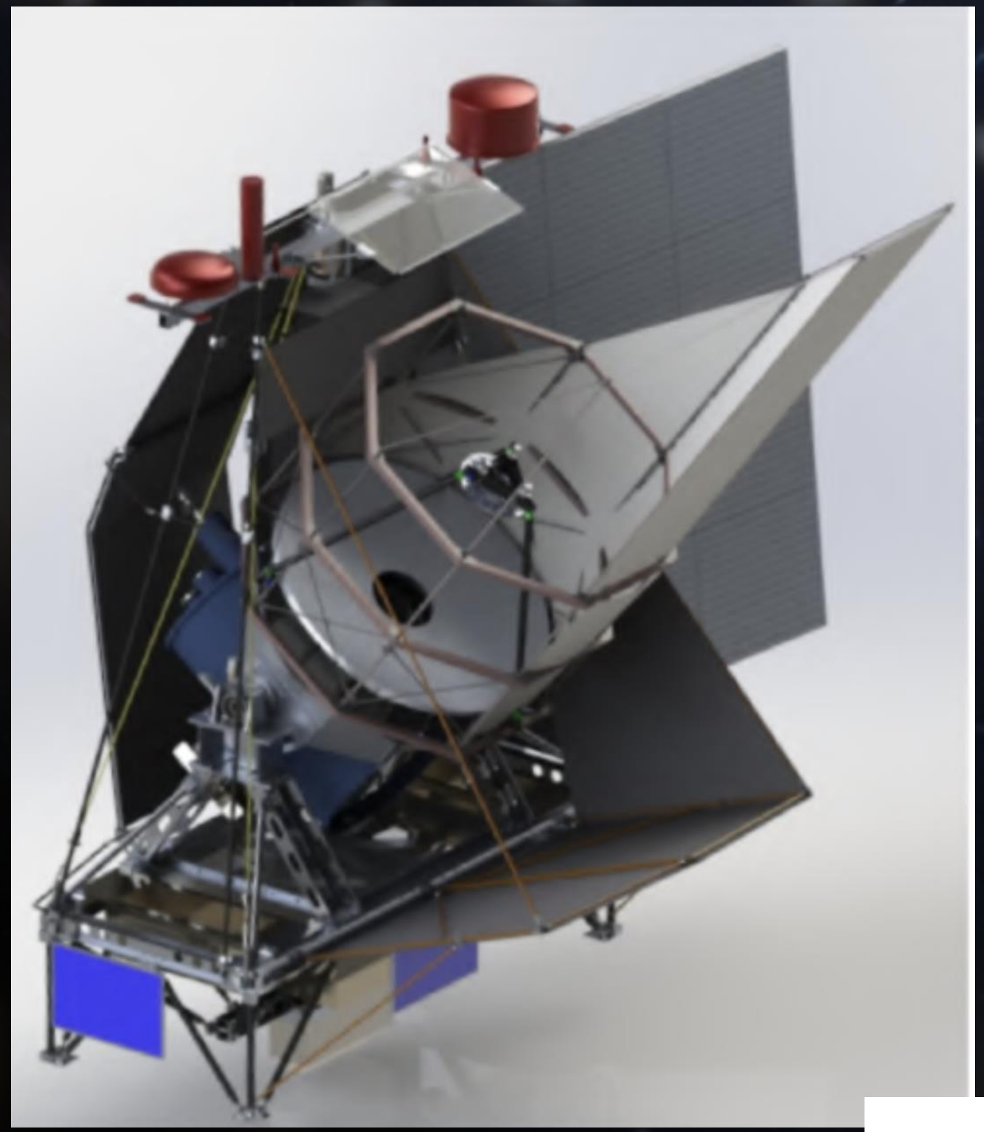
- **Sounding Rockets:**
- CHESS/SISTINE – launched from Northern Territories 2022, in data analysis
- DEUCE/INFUSE – launched from White Sands 2023, in data analysis
- FORTIS – launched from White Sands 2023, in data analysis
- CIBER – launched from White Sands 2024, in data analysis
- SHIMCO – launch 2026

APRA IR Balloons

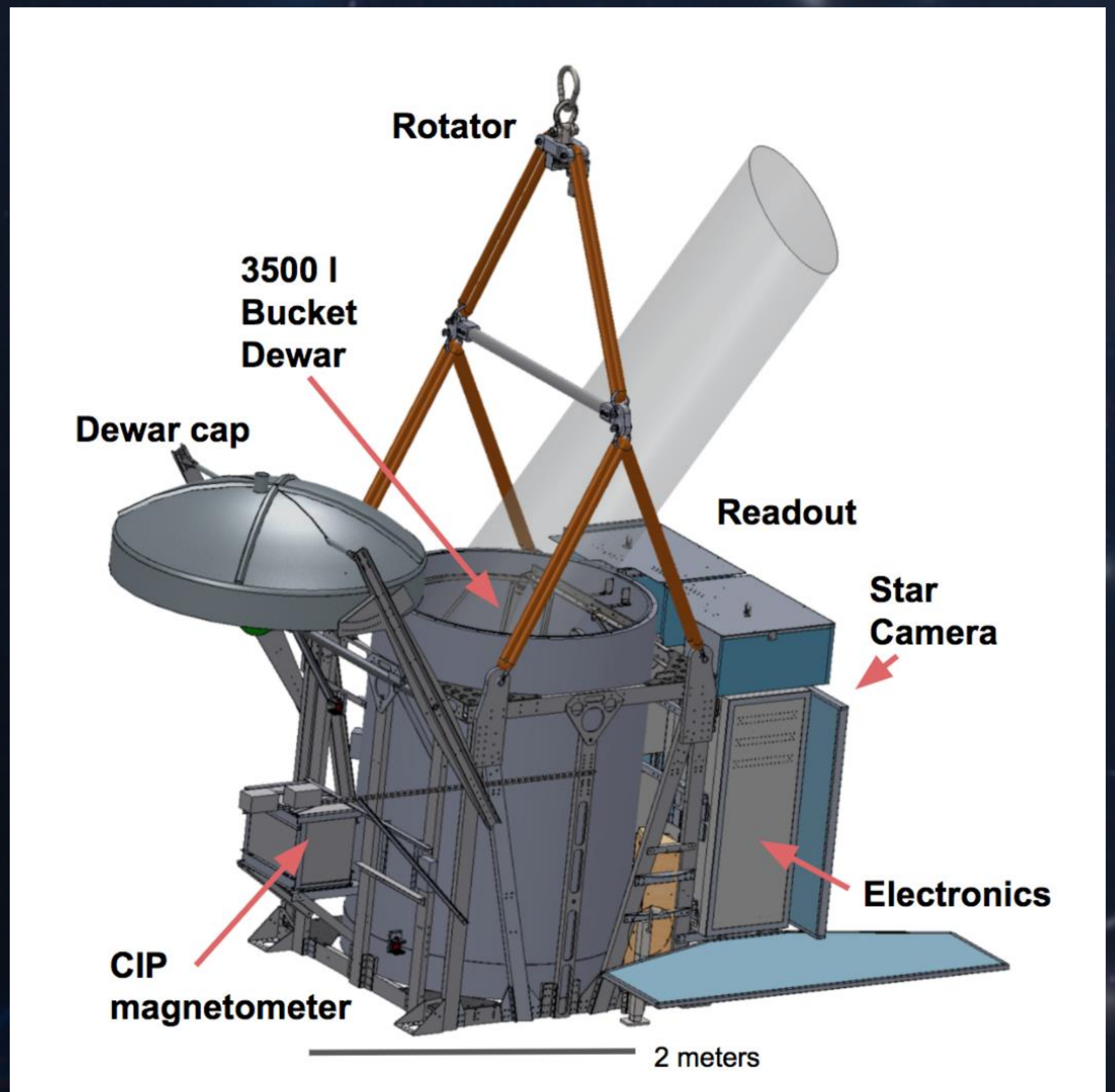
ASTHROS: PI Jorge Pineda, JPL,
Launch 24/25 McMurdo
mapping MW star forming regions with [NII] 122um (2.675 THz) and 205um (1.461 THz).



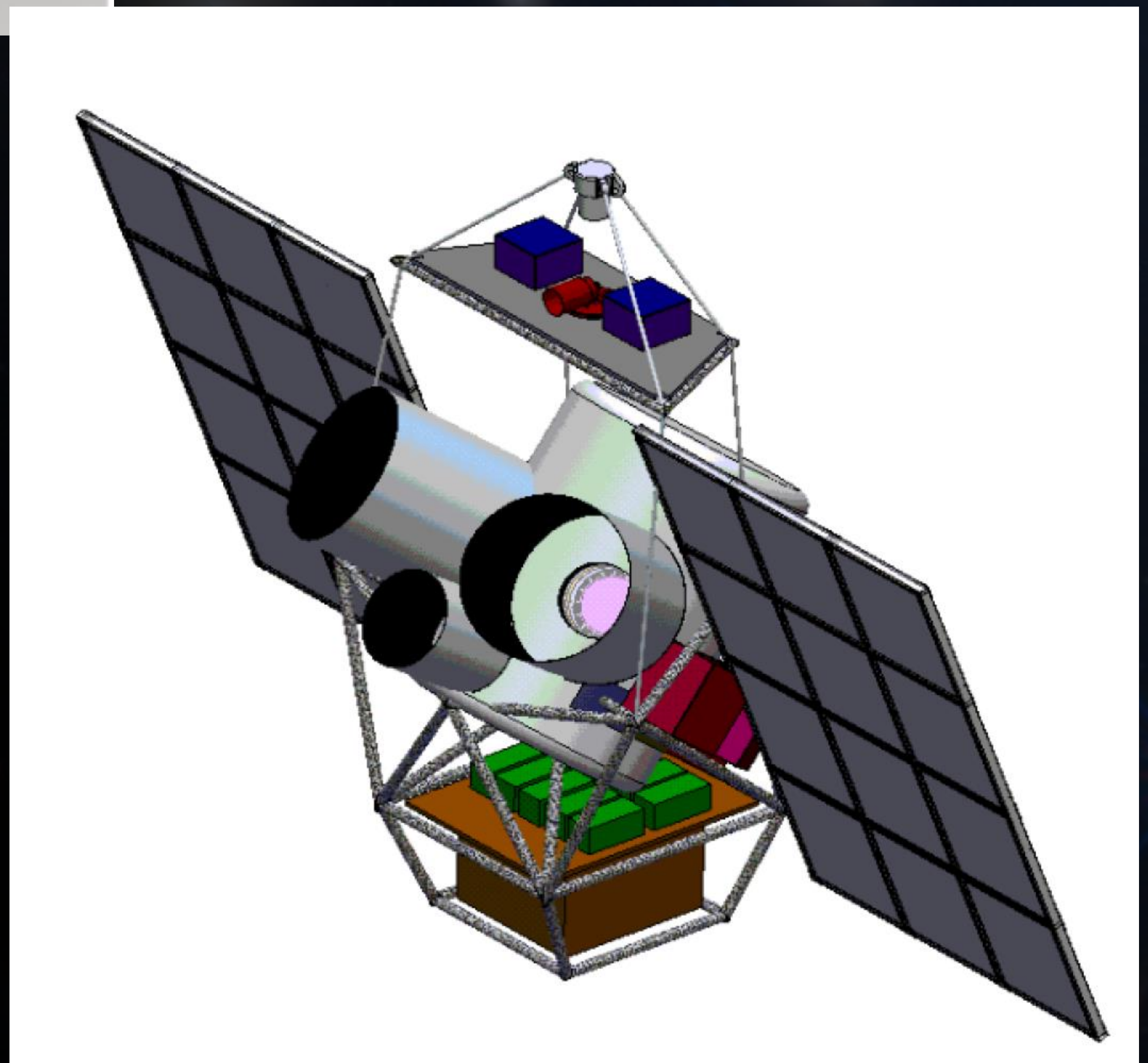
TIM (Terahertz Intensity Mapper): PI Joaquin Vieira. U Illinois,
Ft Sumner 24/25, McMurdo 26/27



SPIDER: PI Jeff Filippini, U Illinois,
CMB B-mode probe with 94 and 150 GHZ (McMurdo 13/14) 280 GHZ (McMurdo 22/23).



EXCLAIM: PI Eric Switzer, GSFC, mapping C
in star forming 0 < z < 3.5). First launch Ft Sumner CY24



TAURUS: PI Steven Benton, Princeton,
SPB Dust Polarization Experiment.
Launch Wanaka FY27.

APRA UVOIR Sounding Rockets

Australia launch July 2022:
SISTINE, DEUCE, and DLX,
ELA launch, Northern Territories

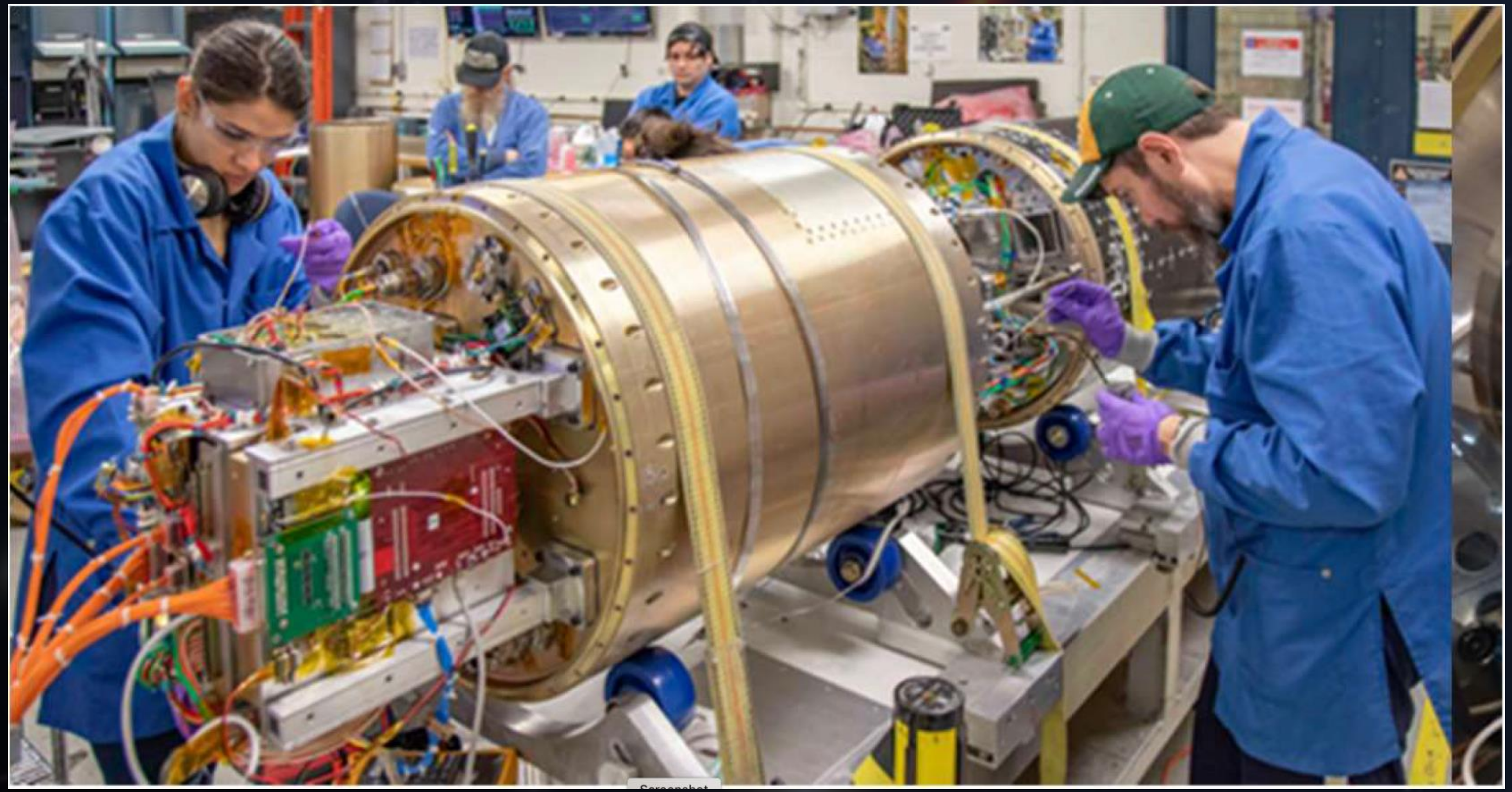
DEUCE/INFUSE: PI Brian Fleming CU, B-star EUV flux cal and next gen EUV spectrograph, launch, WSMR 12/2018, WSMR 10/2020, ELA 6/2022, WSMR 10/2023

FORTIS: PI McCandliss JHU, Far-UV Off Rowland-circle Telescope for
Imaging and Spectroscopy.
Launch WSMR 10/2019, 2/2024

CHESS/SISTINE: PI K. France CU, next gen UV coatings/gratings/MCP, launch
Kwajalein Atoll April 2018, WSMR Nov 2021, ELA July 2022

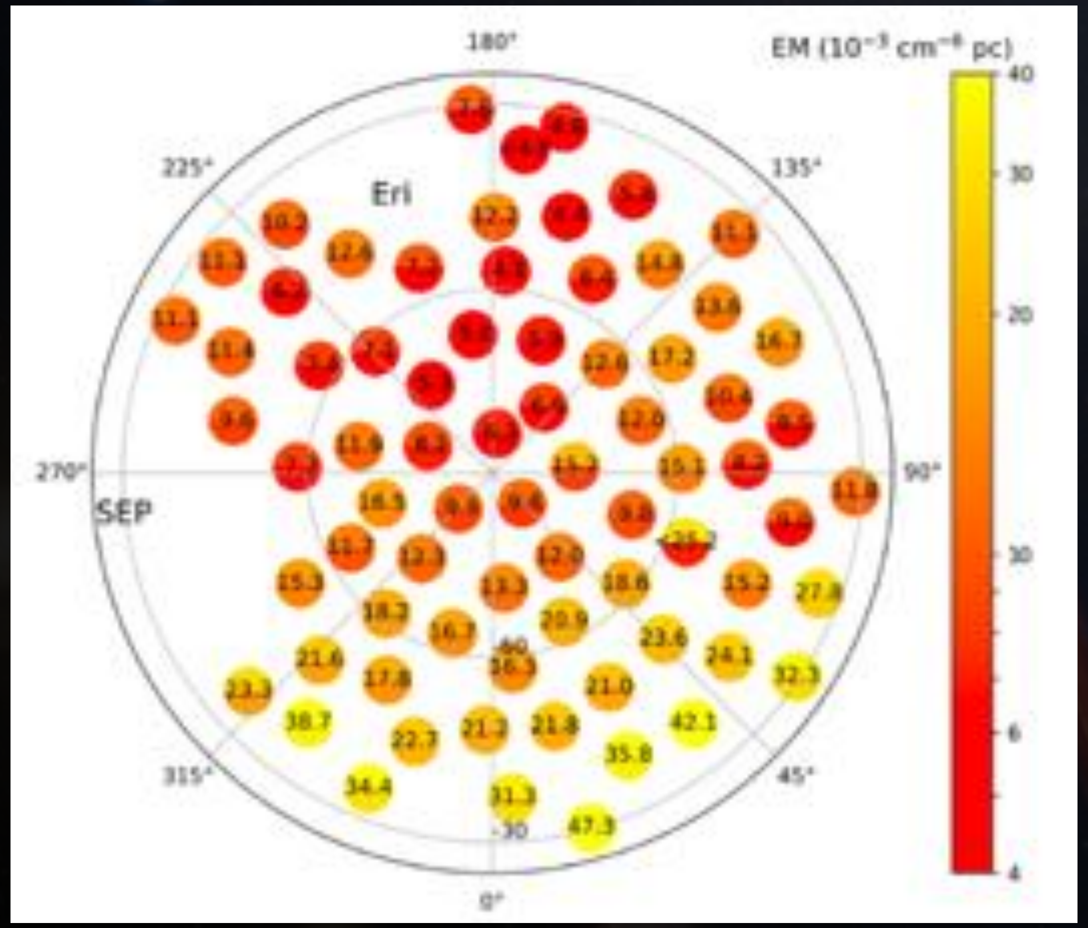
CIBER: PI Michael Zemcov RIT, Cosmic IR BG Experiment,
Launch 2013 WFF, WSMR 2021/2023/2024

SHIMCO: PI: Corliss, U of AZ, high R spectroscopy of H2 in Orion molecular cloud, LRD early 2026

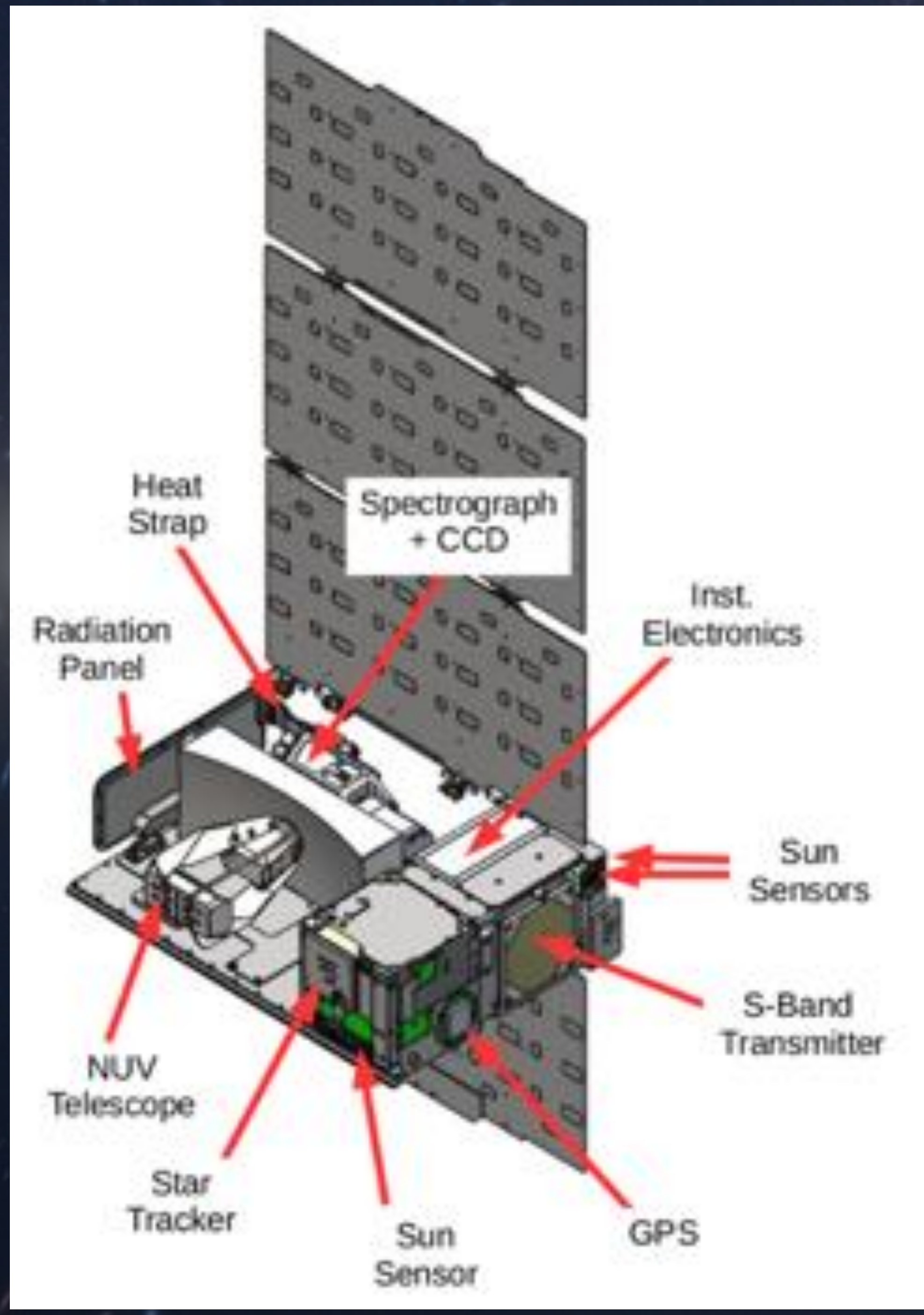


Astrophysics CubeSats (1 of 2)

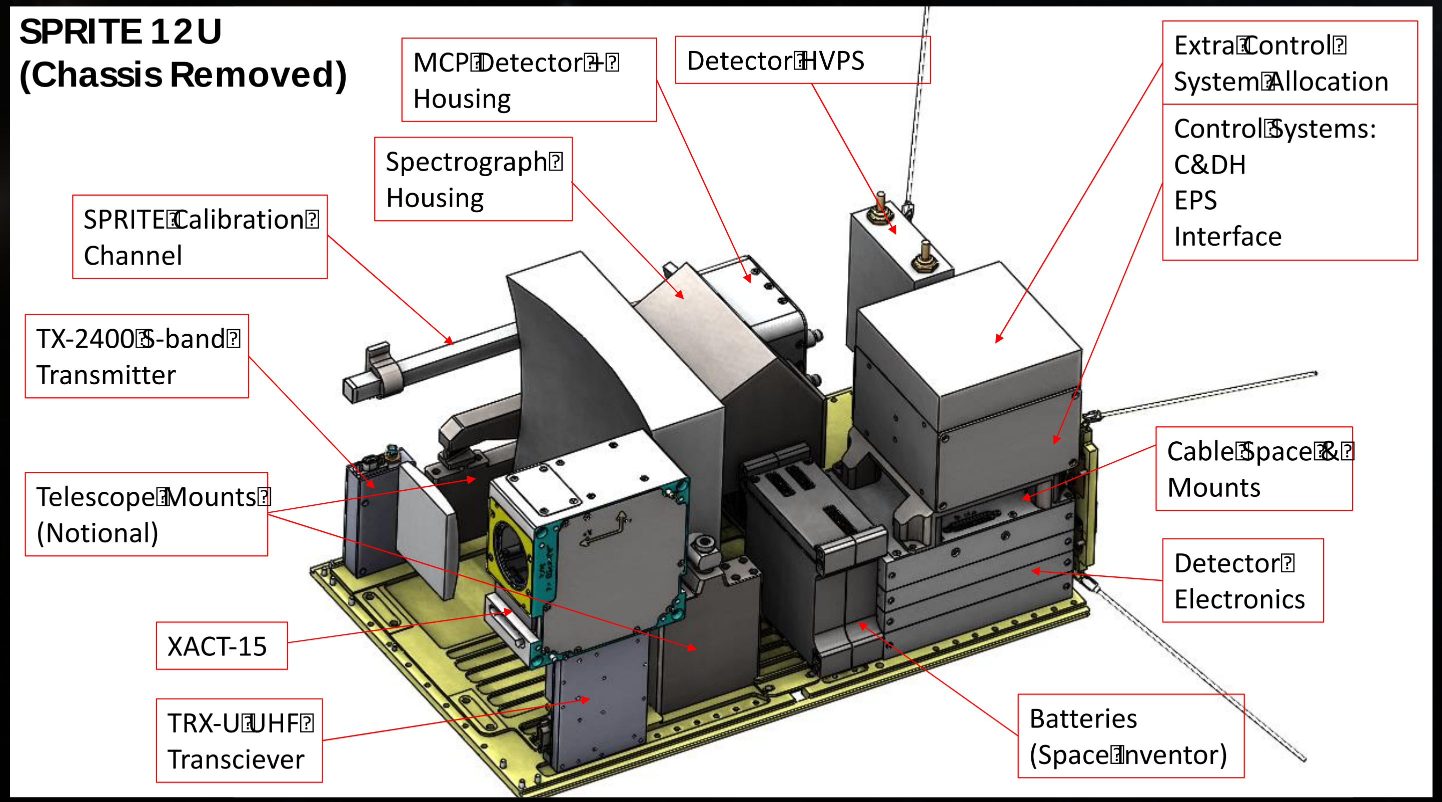
HaloSat
PI Phil Kaaret, U of Iowa, launch 5/2018, reentry 2/2021, OIV line in galactic halo, found unexpected structure of halo

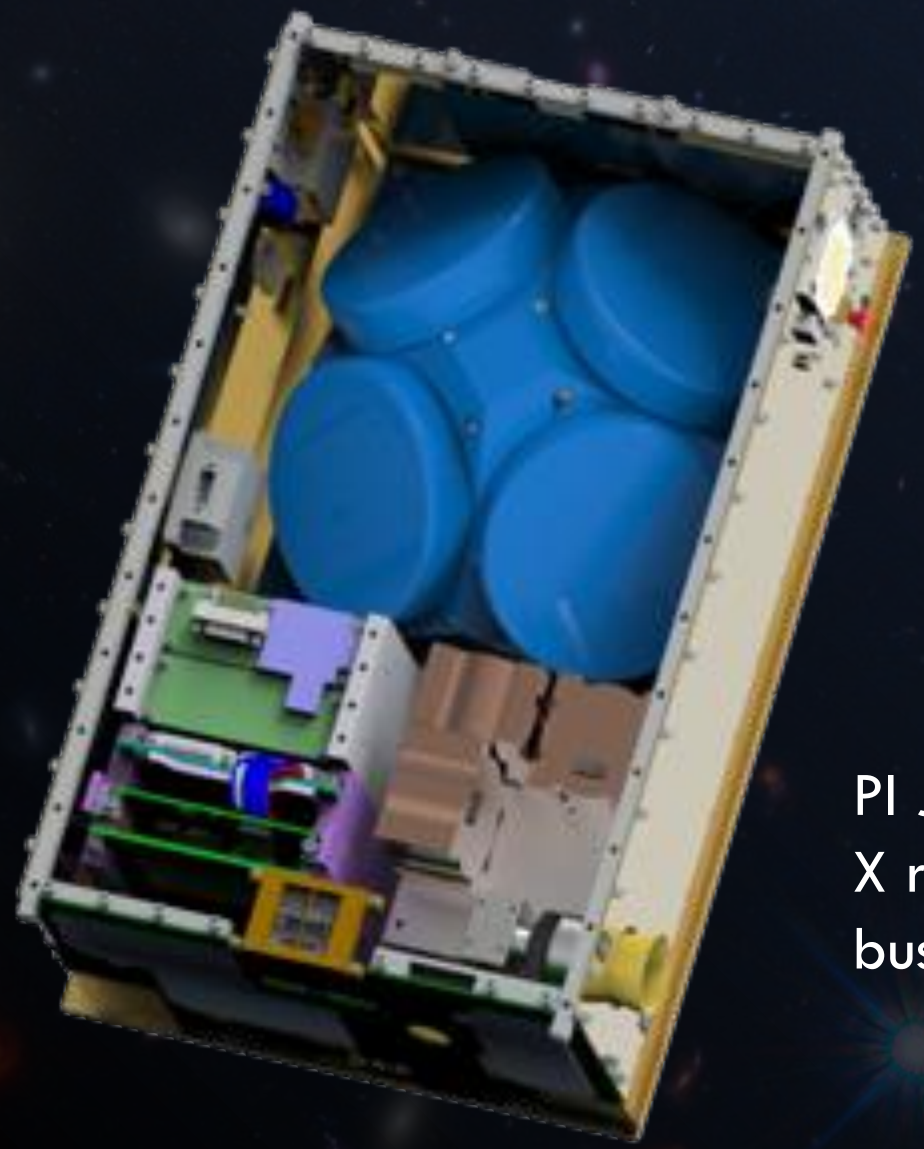


CUTE
PI Kevin France, U CO,
launched 7/2021,
in operation,
UV imaging of hot Jupiter ablation



SPRITE (Jul 2024)
PI Brian Fleming, U CO, First Astrophysics 12U, UV spectra of ionizing radiation from star forming galaxies, bus in house, launch 2024, Space-X Transporter



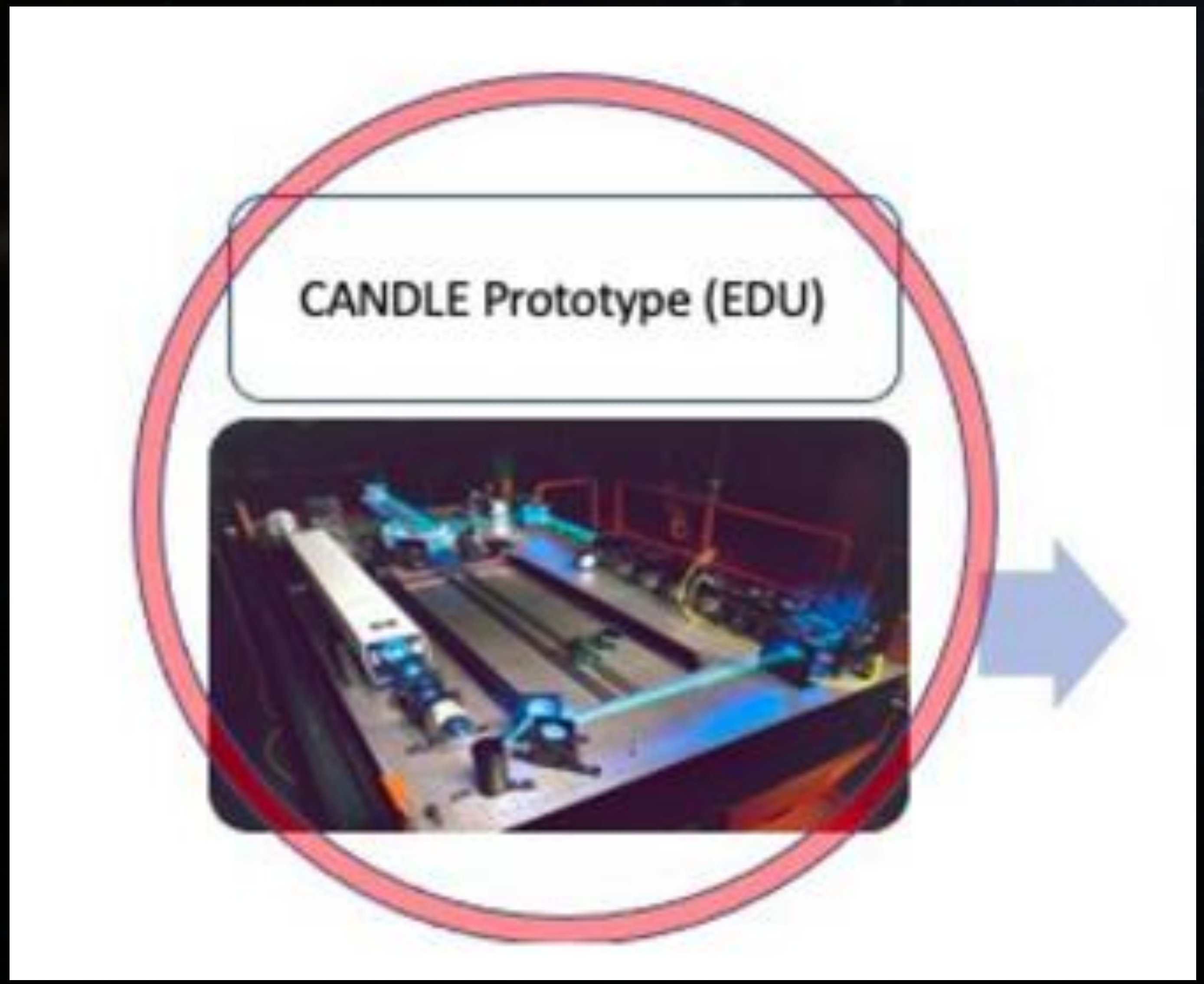


BurstCube (Feb 2024)
PI Jeremy Perkin, GSFC, launch 2/2024 Space-X resupply, GRB monitor with TDRSS link, GSFC bus

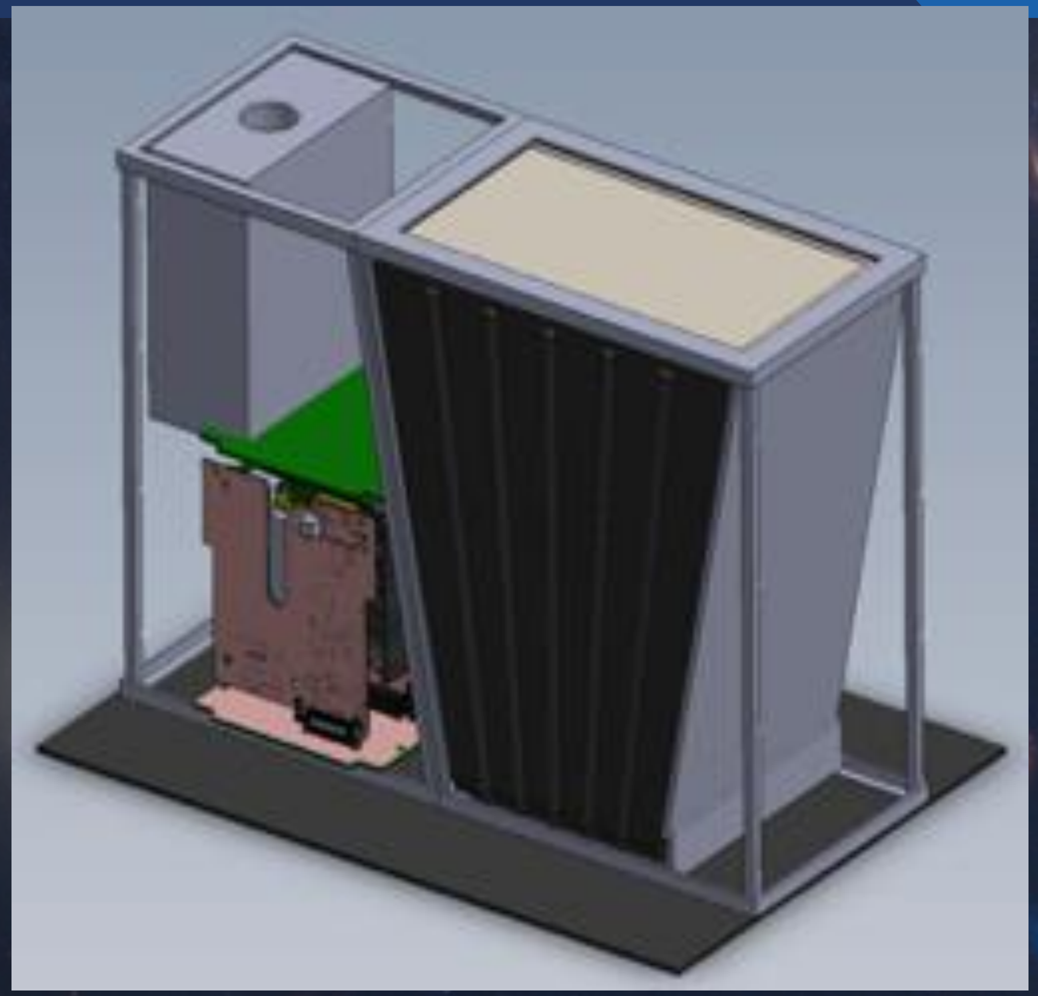
Astrophysics CubeSats (2 of 2)

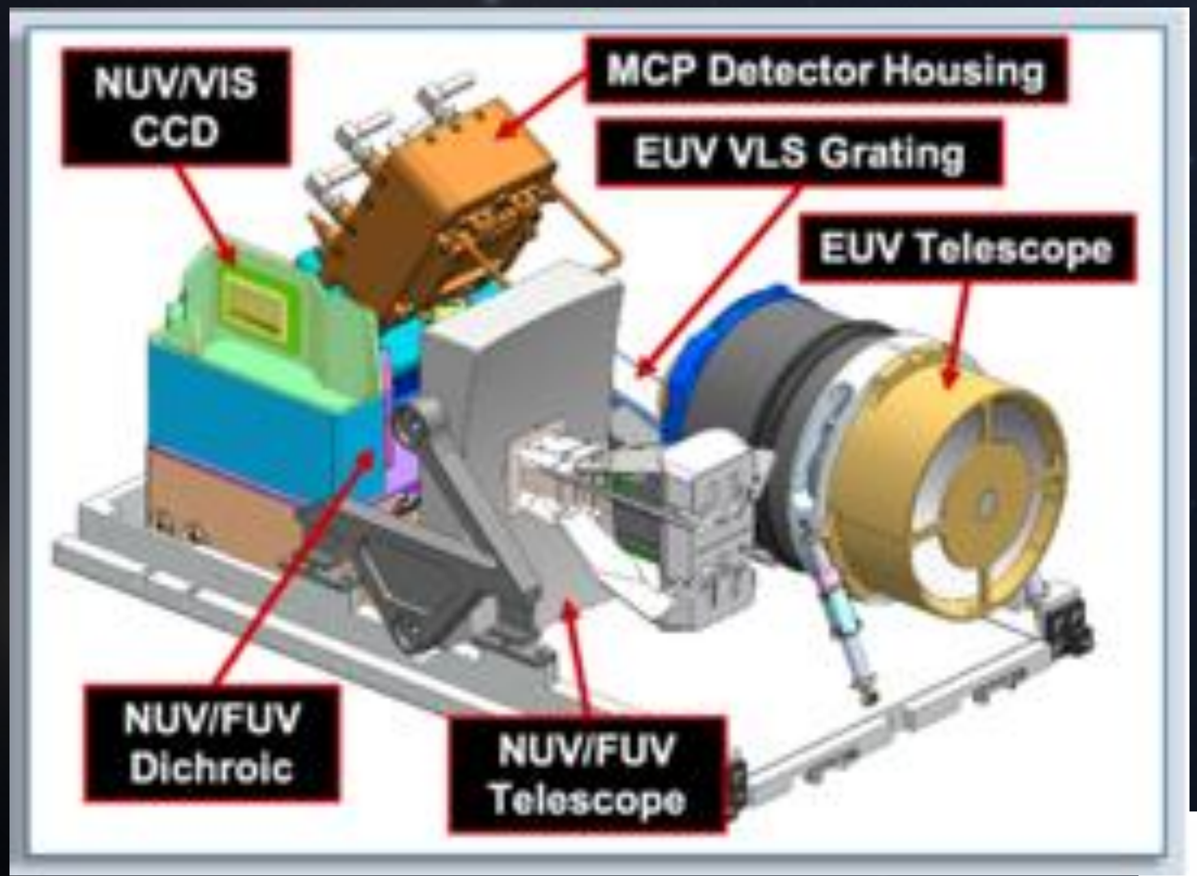
SPARCS (Apr 2025)
PI Evgenya Shkolnik, ASU, launch NET 7/2024, two UV band monitoring of M-star flares to investigate planetary habitability effects, BCT bus

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



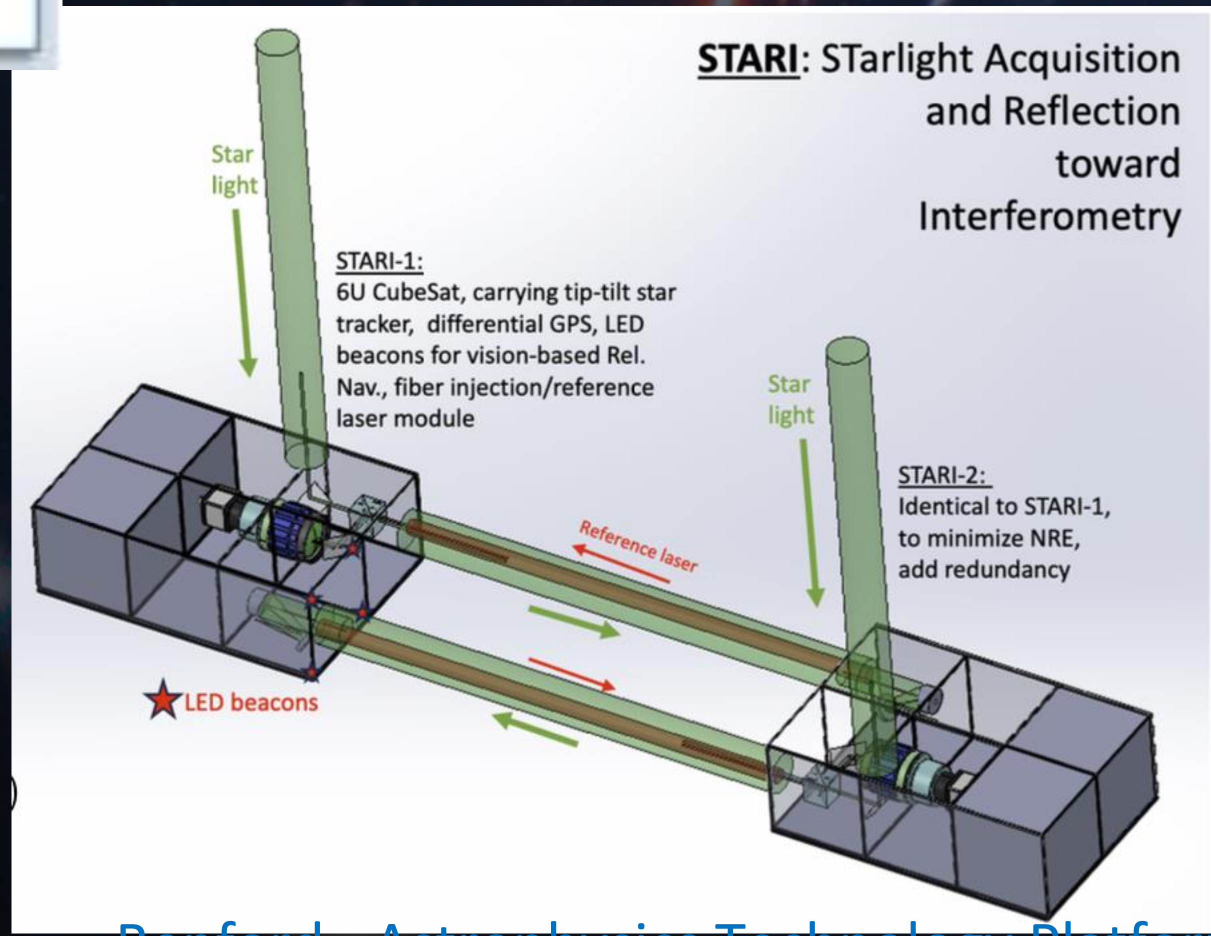
BlackCat (Sep 2025)
PI Abe Falcone, PSU,
launch NET 8/2024,
2-20 KeV wide FOV localization of X-ray transients, real-time 'cell phone' downlink, NanoAvionics bus





MANTIS
PI Briana Indahl, U CO,
launch 01/2028, EUV-NUV stellar flux on ExoPlanet habitability, bus in house

STARI
PI John Monnier, UMich
Validatig formation flying interferometer; inform systems engineering



Commercial Flight Opportunities Contracts

Suborbital Rocket-Powered Vehicles

Credits: Virgin Galactic

- Astrobotic
- Blue Origin
- Rocket Lab USA Inc.
- Virgin Galactic

High-Altitude Balloons

Credits: World View Enterprises

- Aerostar International LLC (acquired Near Space Corporation)
- Angstrom Designs
- World View Enterprises

Parabolic Flights

Credits: University of California, Berkeley

- Zero Gravity Corp.

Orbital Platforms Hosting Payloads

Credits: Varda

- Astro Digital
- Loft Federal
- Momentus Space
- Rocket Lab USA Inc.
- Space Exploration Technologies (SpaceX)
- Spire Global
- Tyvak Nano-Satellite Systems (Terran Orbital)
- Varda Space Industries

Links to payload users guides (PUGs) available on Flight Opportunities website

Hosted orbital services via flight opportunities idiq4

Hosted Orbital Payload Definition

- Payload is integrated on to provider's vehicle and remains attached throughout mission
- Integration, launch, and mission management included in hosting service
- Researchers can focus on technology, instrument, or experiment development rather than spacecraft development or mission planning

Provider Qualifications

- Successful flight of a 2U, 2kg payload with one orbit of Earth
- Opportunity for on-ramps of new capabilities

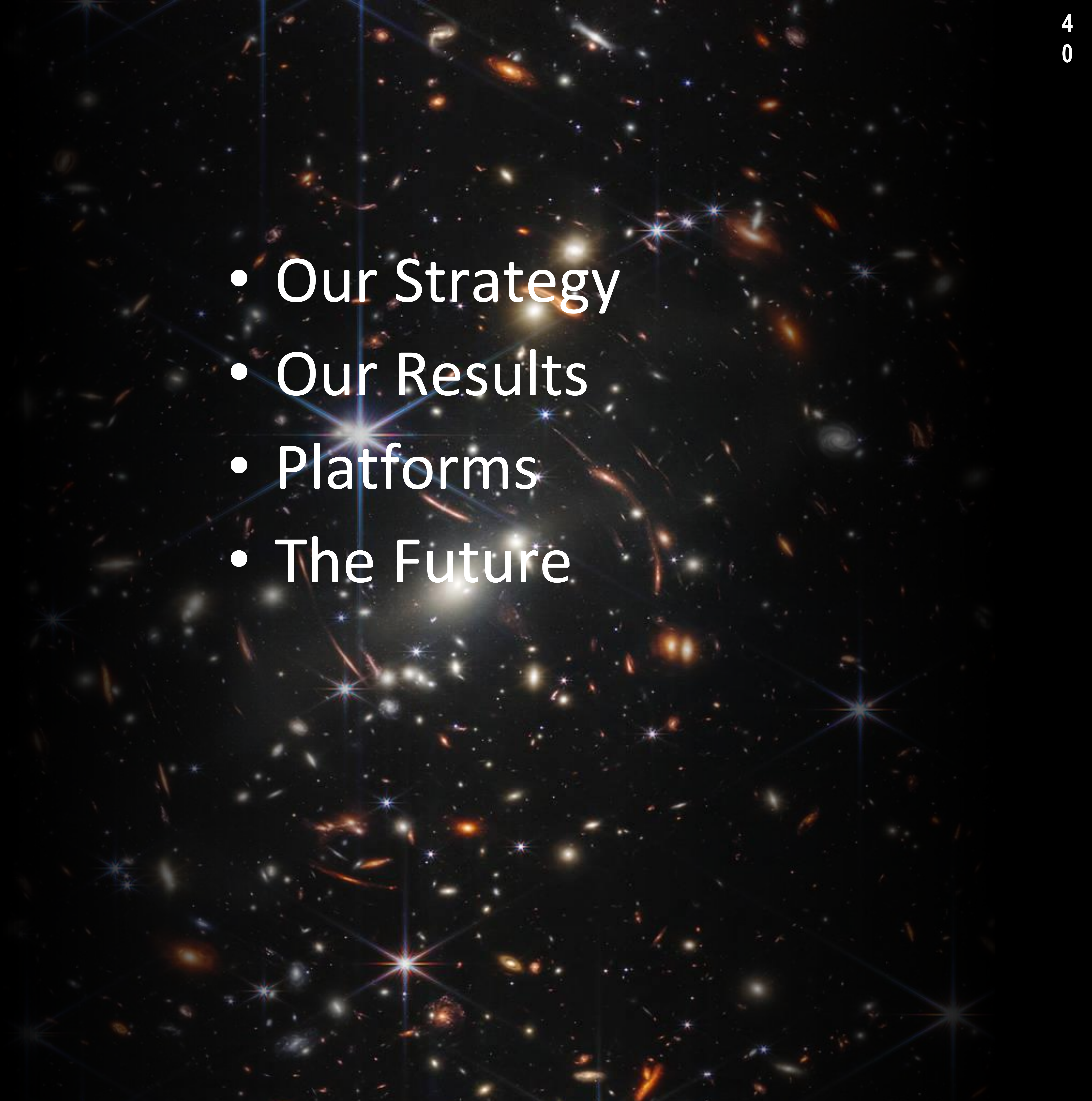
Structure of Proposed Services

- Each provider proposed their own standard services
- Non-standard rates cover unique requirements or evolving capabilities

Wide Variety of Commercial Services

- Slots on small spacecraft (e.g., ESPA buses) designed for multi-payload / multi-customer hosting
- Hosting on a CubeSat designed for a specific payload
- Space-available options on vehicles conducting other commercial missions
- "Virtual" hosting of software payloads leveraging provider assets
- Space in or on capsules that return to Earth
- Test articles attached to rocket upper stages

Outline



- Our Strategy
- Our Results
- Platforms
- The Future

Outline

- Our Strategy
- Our Results
- Platforms
- The Future

Main Takeaways

- **Funding stable but there are some key challenges ahead:**
  - No defined space mission motivating certain technologies (particles, gamma-rays)
  - What technology is the one that will allow us to make that next quantum leap?
    - Detectors, Cryogenics, Telescopes, Electronics, On-board Data Processing?

- **Balloons & Sounding Rockets - many opportunities and challenges here:**
  - For some technologies, may be best way of accessing relevant environment at scale
  - Time to launch (and therefore) typical cost of typical balloons increasing
  - Lots of effort for tech demo purpose

- **Hosted Payloads - untested opportunities**
  - For some technologies, may be best way of accessing relevant environment
  - Time to launch and cost may be lower threshold
  - New opportunity for Astrophysics?

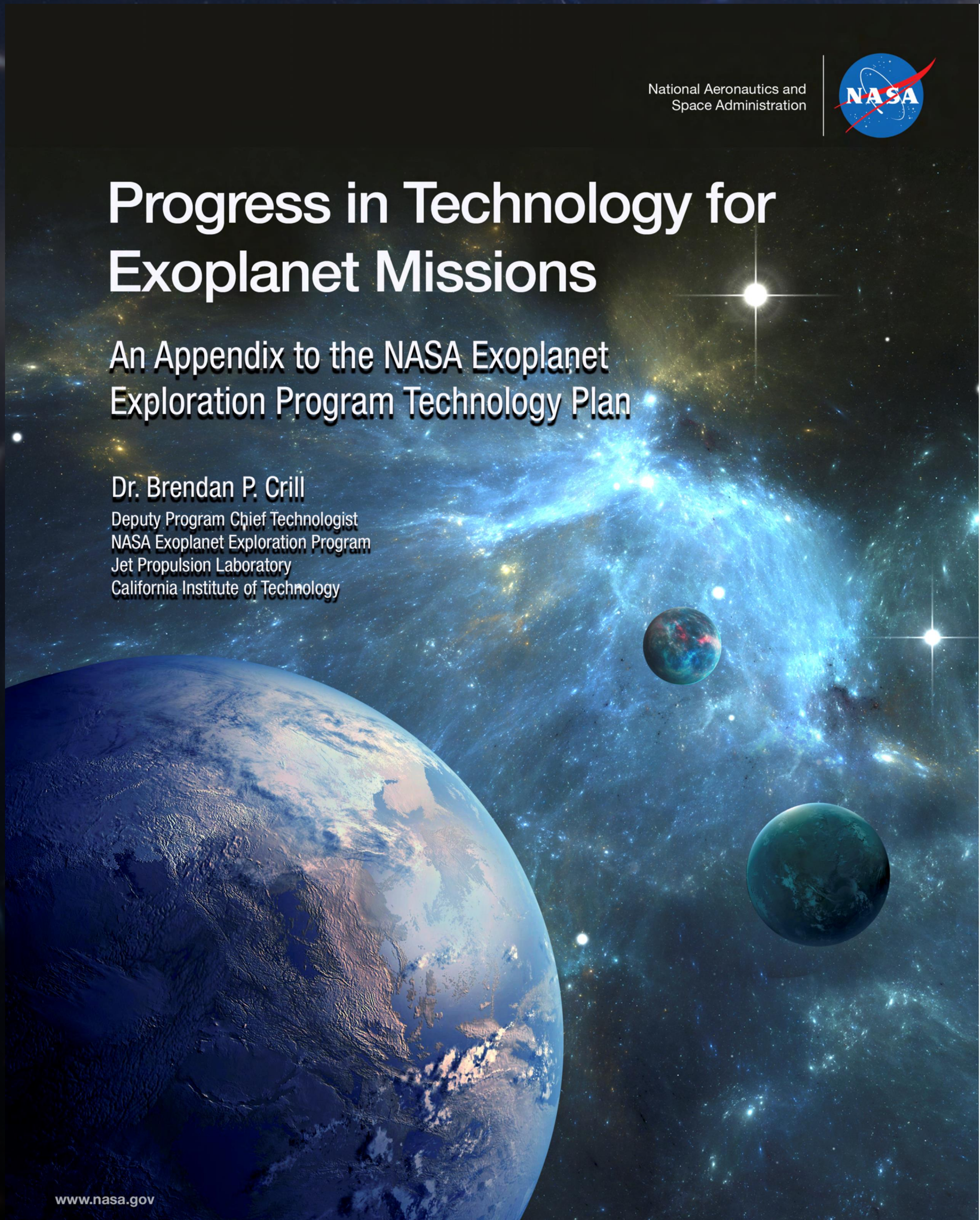
Sources of Funding

- **Astrophysics:**
  - APRA, SAT
  - Pioneers
- **Science Mission Directorate:**
  - Also ROSES; tech for Helio, Planetary, Earth science, and BPS
- **Space Technology Mission Directorate:**
  - Not ROSES. ST-REDDI = Research, Development, Demonstration, and Infusion
  - Early Stage Innovations
  - Early Career Faculty
  - NASA Innovative Advanced Concepts
  - Small Business Innovation Research / Small Business Technology Transfer
  - NASA Space Technology Graduate Research Opportunities

Thank You!

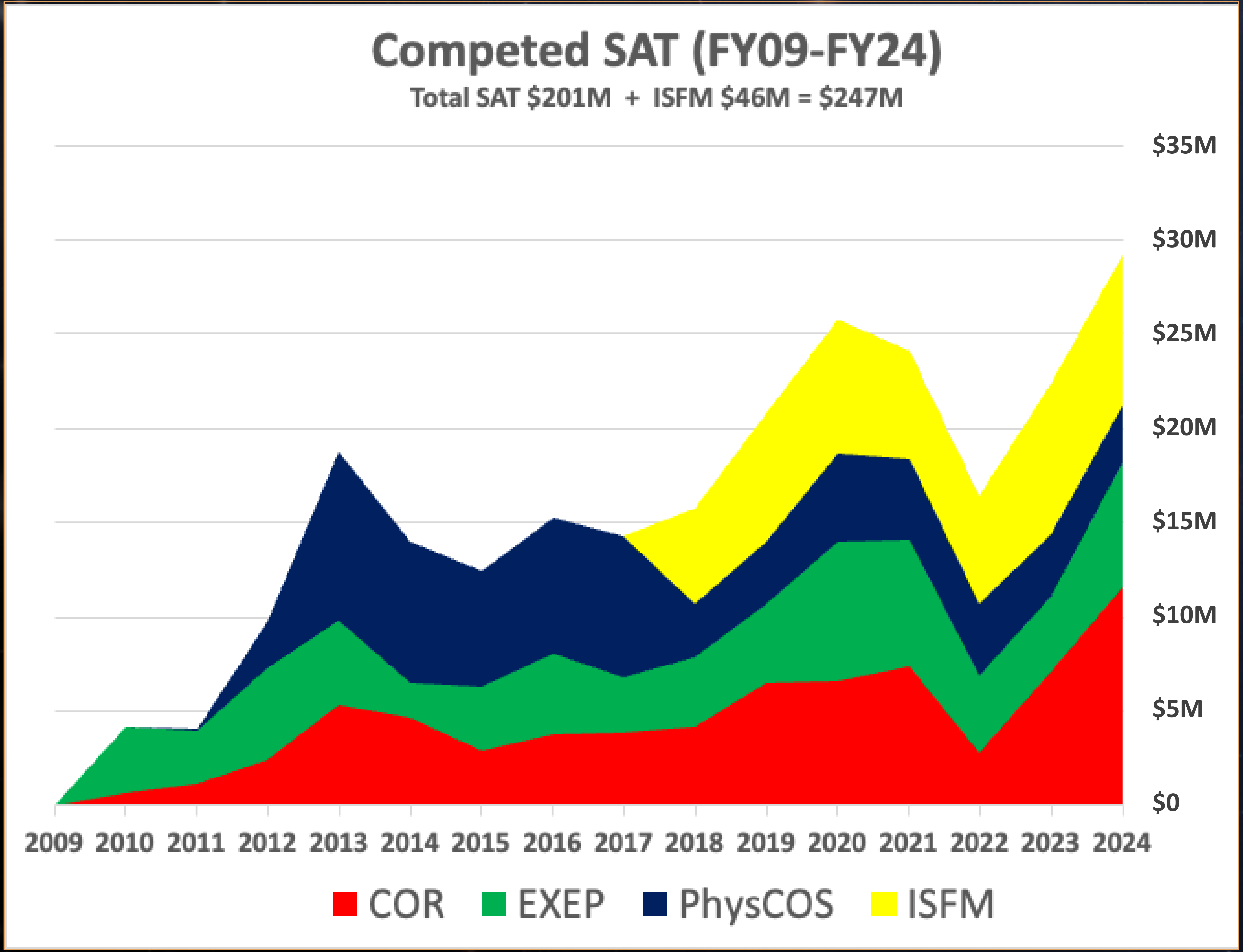
Additional Slides


National Aeronautics and Space Adminstration
NASA
Astrophysics Technology Update 2024
Astrophysics Division
Science Mission Directorate


National Aeronautics and Space Administration
NASA
Progress in Technology for Exoplanet Missions
An Appendix to the NASA Exoplanet Exploration Program Technology Plan
Dr. Brendan P. Crill
Deputy Program Chief Technologist
NASA Exoplanet Exploration Program
Jet Propulsion Laboratory
California Institute of Technology
www.nasa.gov

Technology Maturation Investments

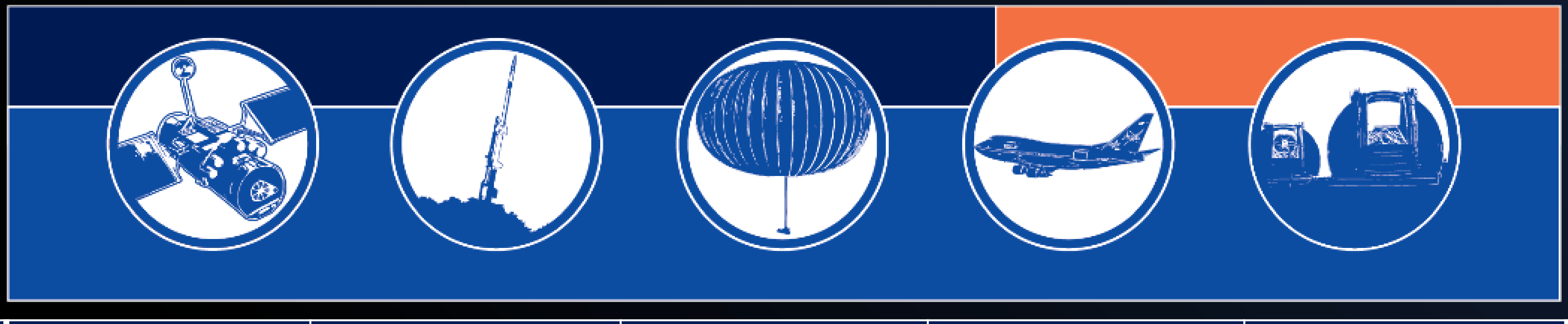
- Total for proposing ≈ constant
- In-scope missions have evolved
- Increasing recently



Not Our (Astrophysics) Solicitations

- Overall technology needs: https://www.spacetechpriorities.org/
- Earth, Planetary, Heliophysics, Biological/Physical: all ROSES
- Space Technology Mission Directorate (STMD) REDDI:
  - Early Stage Innovations: June 6, 2024
  - NASA Innovative Advanced Concepts (NIAC): July 1, 2024
  - NASA SBIR Ignite: July 30, 2024
  - Early Career Faculty: July 15, 2024 / October 24, 2024
  - NASA Space Tech Grad. Research Opprts. (NSTGRO): Nov 1, 2024
  - NASA SBIR/STTR: to be released Jan 2025
- Dual Use Technologies (esp. from Marshall) – annual call

From Technology Maturation to Infusion
January 2009 - October 2024



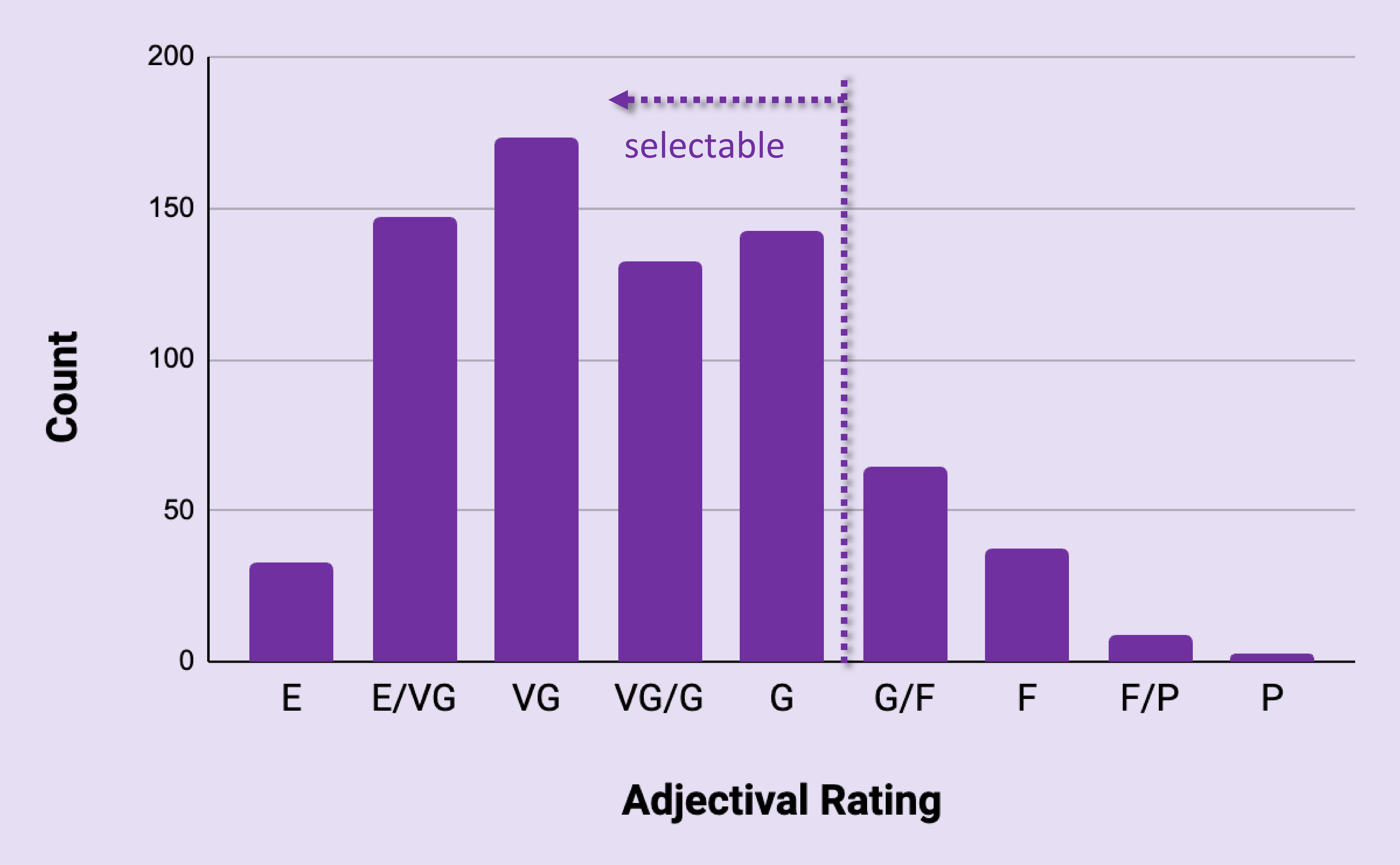
		Space	Rocket	Balloon	Airborne	Ground	Total
Infused	Implemented [1]	19	25	12	3	43	102
	Upcoming [2]	31	13	9	1	6	60
Infused Subtotal		50	38	21	4	49	162
Potential	Concepts [3]	**62**	-	-	-	-	**62**
	Ready [4]	**3**	-	-	-	-	**3**
Potential Subtotal		**65**	-	-	-	-	**65**
Infused/Infusable Total		**115**	**38**	**19**	**4**	**49**	**225**

Flown, deployed, or implemented

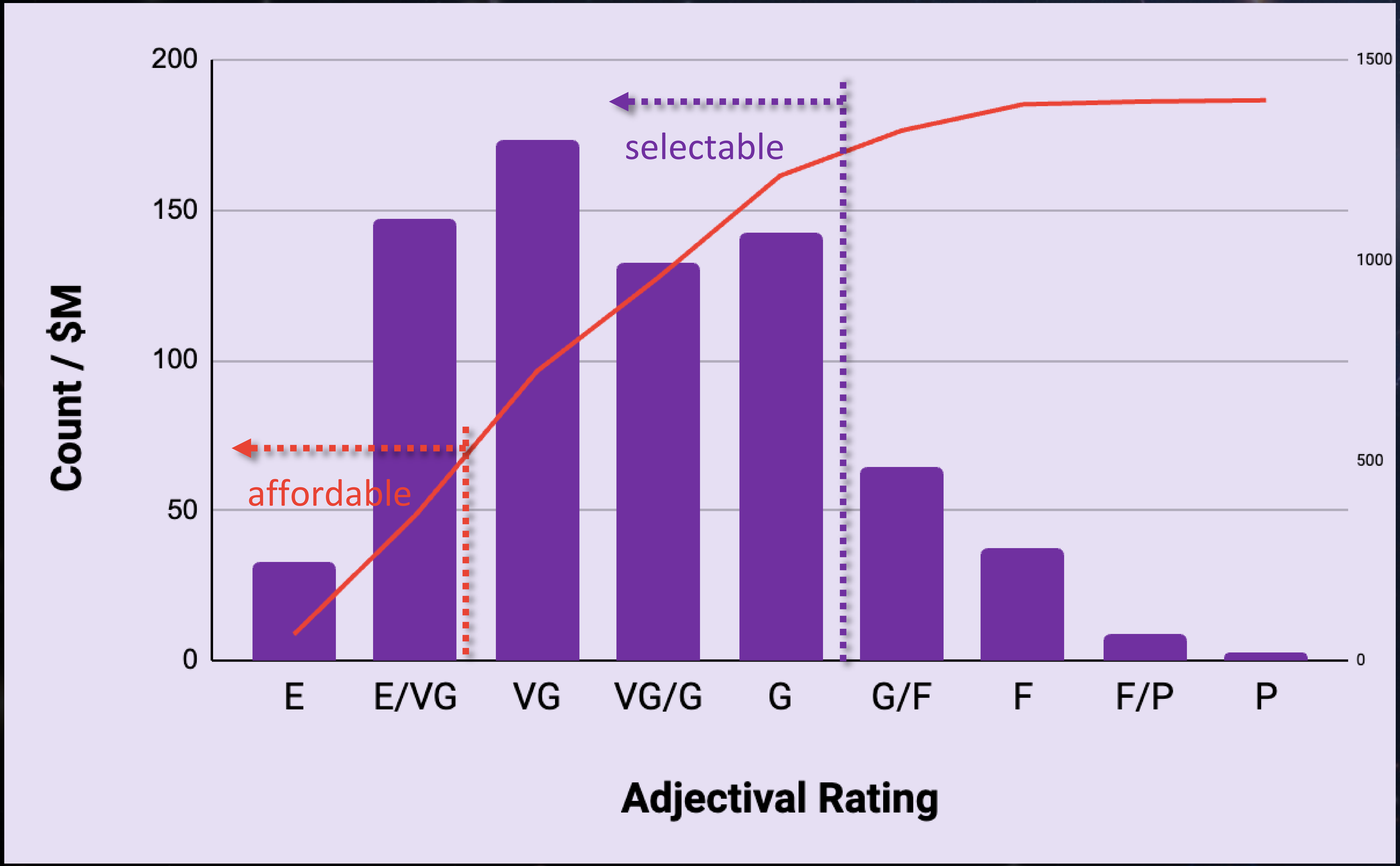
Baselined or in progress

Credit: Opher Ganel &
PhysCOS-COR technologists

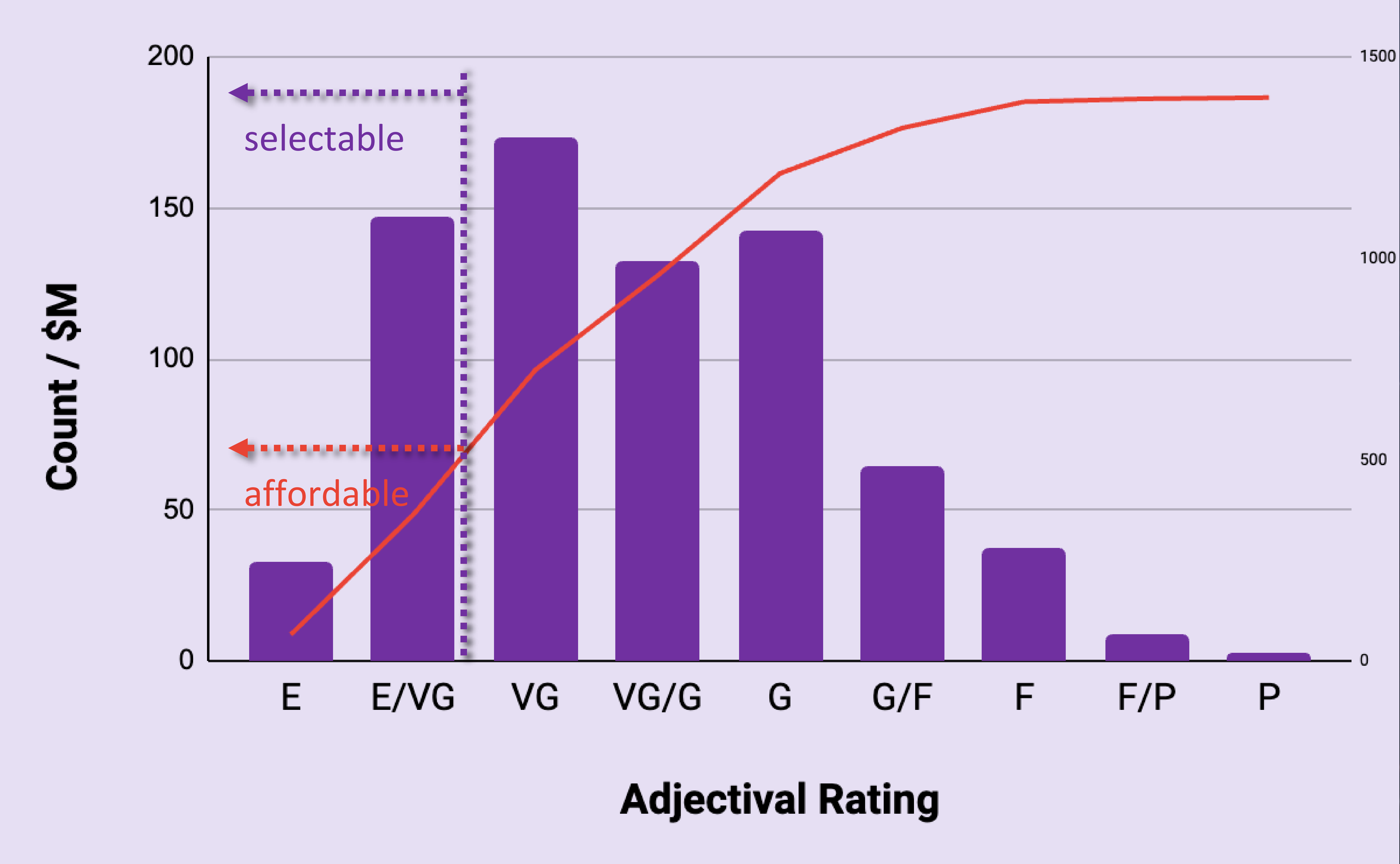
Ratings (APRA+SAT) 2020-2023



Ratings (APRA+SAT) 2020-2023



Ratings (APRA+SAT) 2020-2023



Evaluation Criteria

- APRA-22

APRA-23

2.7 Evaluation Criteria

All proposals with be evaluated for Intrinsic Merit, Cost, and Relevance, as defined in Appendix D of the *NASA Guidebook for Proposers* and consistent with Section VI(a) of the *ROSES-2021 Summary of Solicitation* and D.1 the Astrophysics Research Overview (e.g., see Section 1.1 regarding the new requirement for Data Management Plans and Archiving). In addition, for suborbital and suborbital-class investigations (as noted in Section 1.2.1), the evaluation of intrinsic merit will include the degree to which it advances the technology readiness level of a detector or supporting technology, and secondarily the degree to which it advances the readiness of early-career researchers or graduate students to assume roles in advancing NASA's strategic objectives. **Note that the TRL claimed in the cover sheet is for tracking purposes only, and reviewers are not asked to assess whether that datum is valid. [updated September 24, 2021]**. Finally, requests for upgrades to and/or replacement of laboratory equipment are subject to the evaluation factors mentioned in Section 1.2.4.

2.9 Evaluation Criteria

All proposals with be evaluated for Intrinsic Merit, Cost, and Relevance, as defined in Appendix D of the *NASA Guidebook for Proposers* and consistent with Section V(a) of the *ROSES-2023 Summary of Solicitation* with the following modifications:

The assessment of the "Open Science and Data Management Plans" is part of the evaluation of Merit.

For Suborbital and CubeSat Investigations, the evaluation of Merit also includes the degree to which it advances the technology readiness level of a detector or supporting technology and, equally, the degree to which it advances the readiness of early-career researchers or graduate students to assume leadership roles on future NASA space flight missions.

Investigators must identify, in response to the question on the NSPIRES cover pages, which of these three is the main focus of the proposal: science investigations, technology development, or training of early-career scientists and engineers. During evaluation, a proposal found to be significantly lacking in its main focus would likely be assessed a major weakness, whereas for the other two foci shortcomings would more likely (but not necessarily) be minor weaknesses.

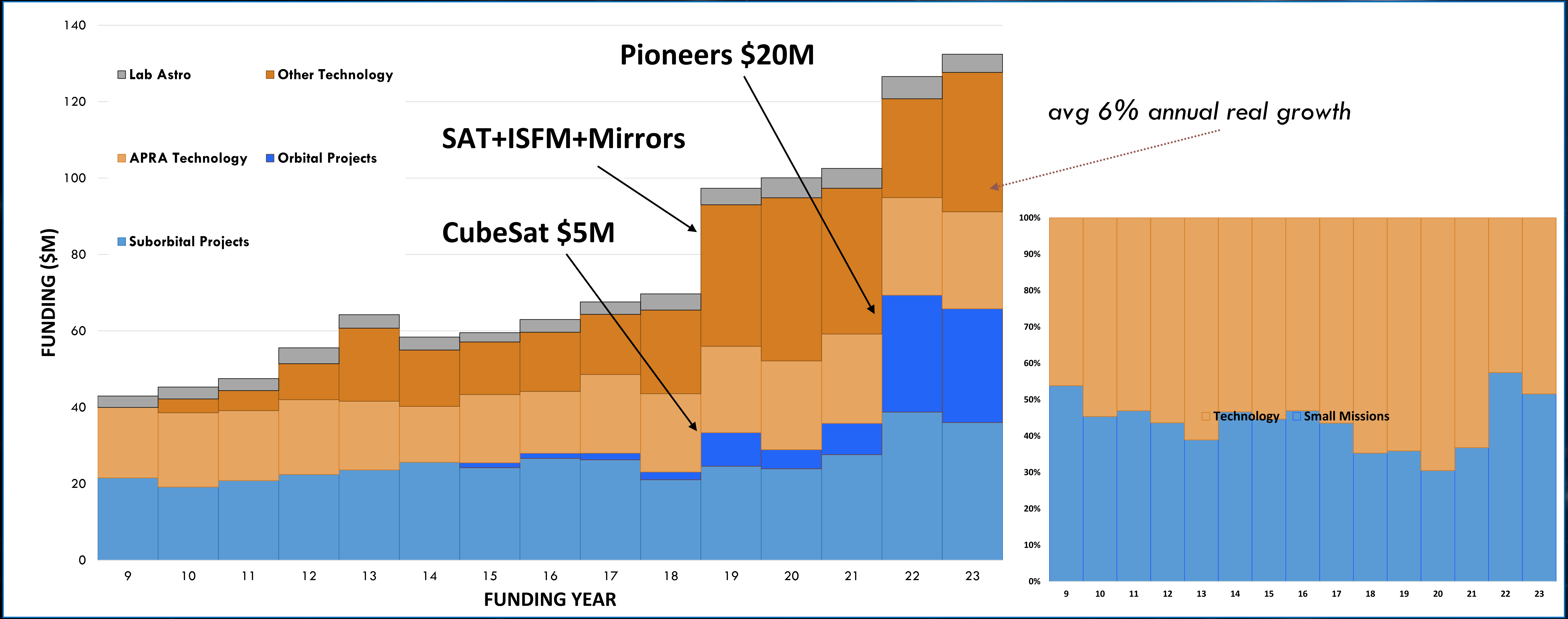
The assessment of the inclusion plan will not be part of the grade for the proposal nor have any bearing on selection.

Note that the TRL claimed in the cover sheet is for tracking purposes only, and reviewers are not asked to assess whether that datum is valid.

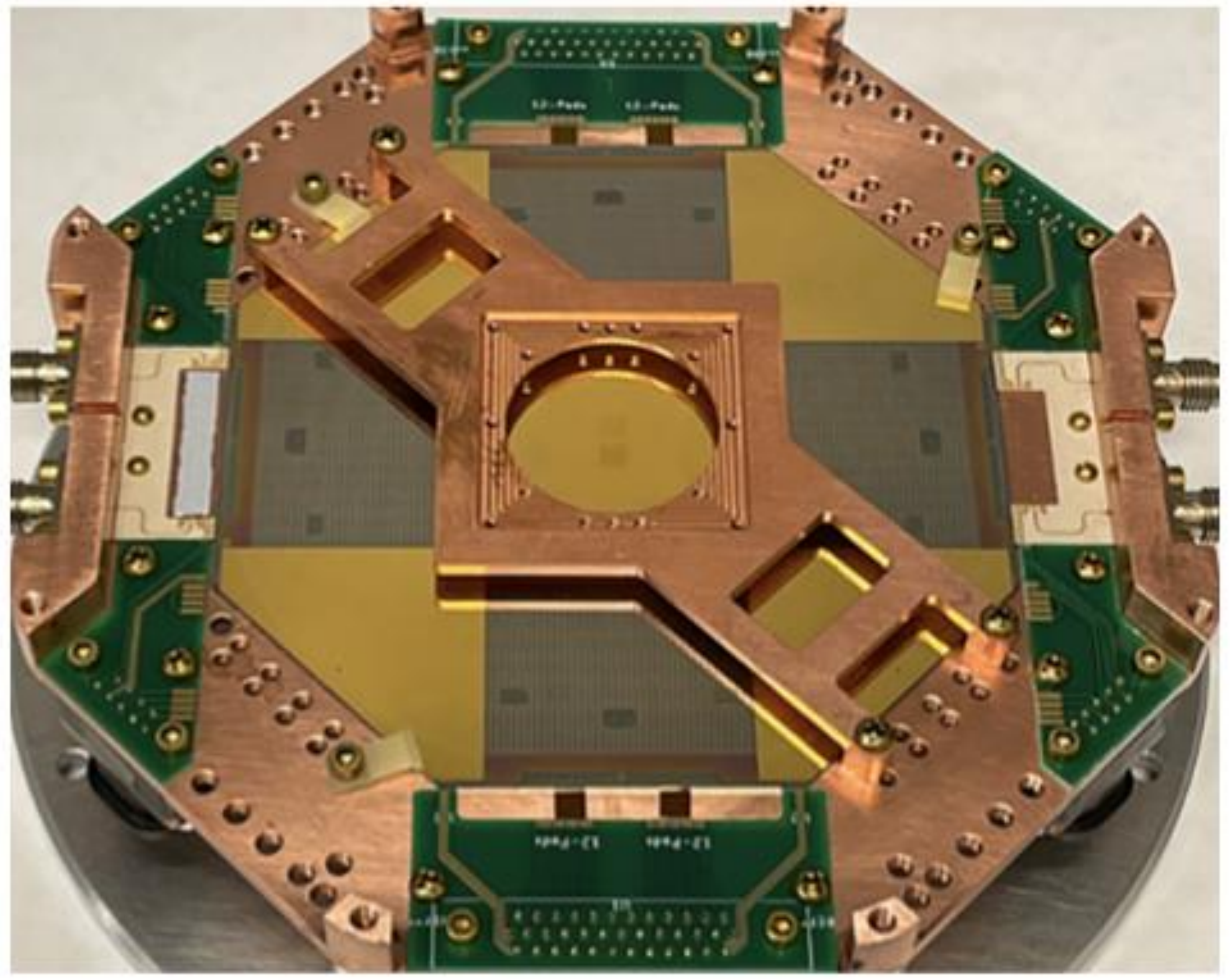
Finally, requests for upgrades to and/or replacement of laboratory equipment are subject to the evaluation factors mentioned in Section 1.2.4.

Tech Dev & Small Mission Balance

- APRA (tech, lab astro, suborbital-class, CubeSats) + Pioneers + SAT, RTF, ISFM, Mirrors

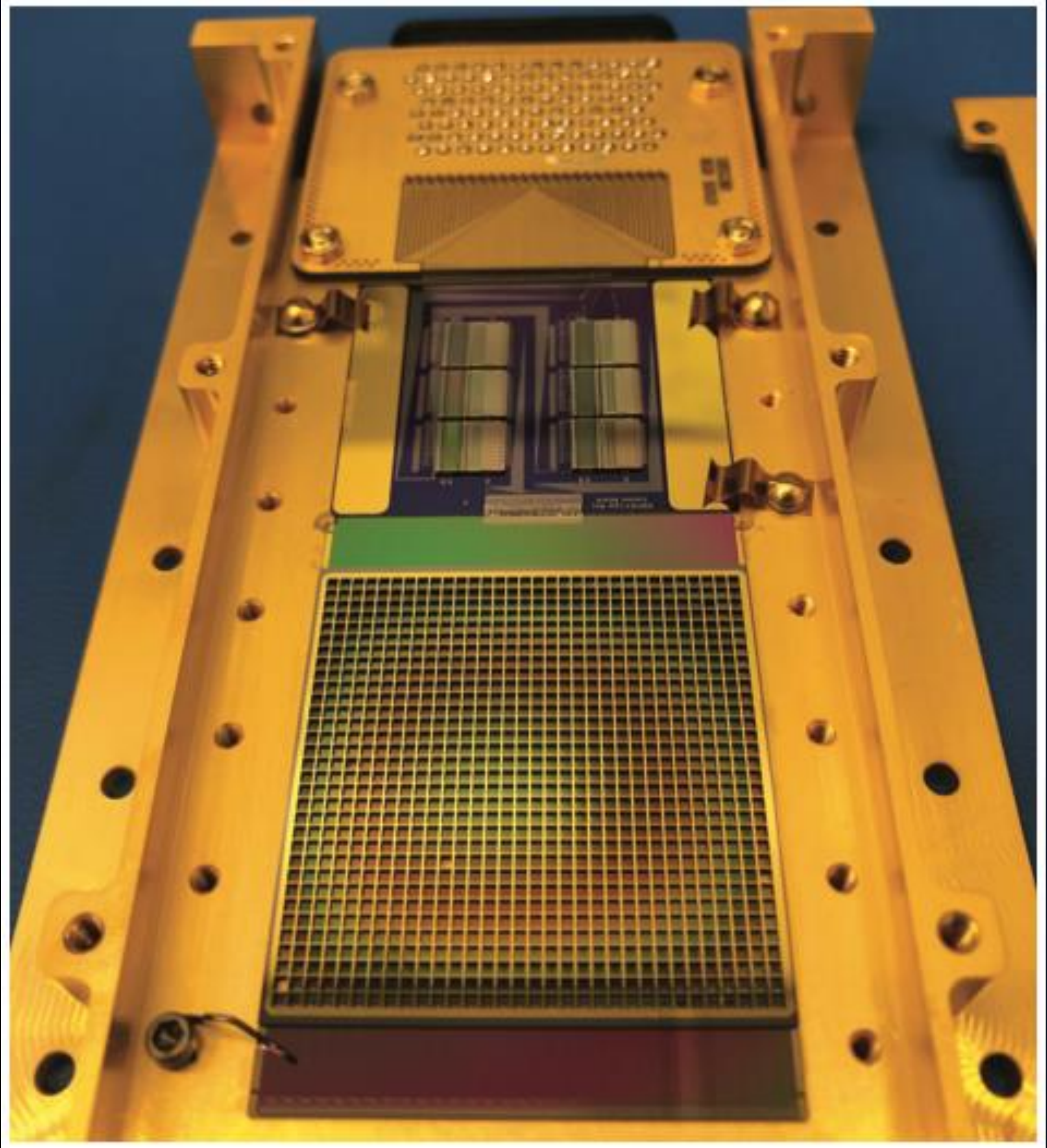


Several ongoing technology maturation projects for X-Ray and Far-IR



Prototype 100,000-pixel MMC array developed via collaboration between GSFC and MIT/LL. Image credit: Wonsik Yook

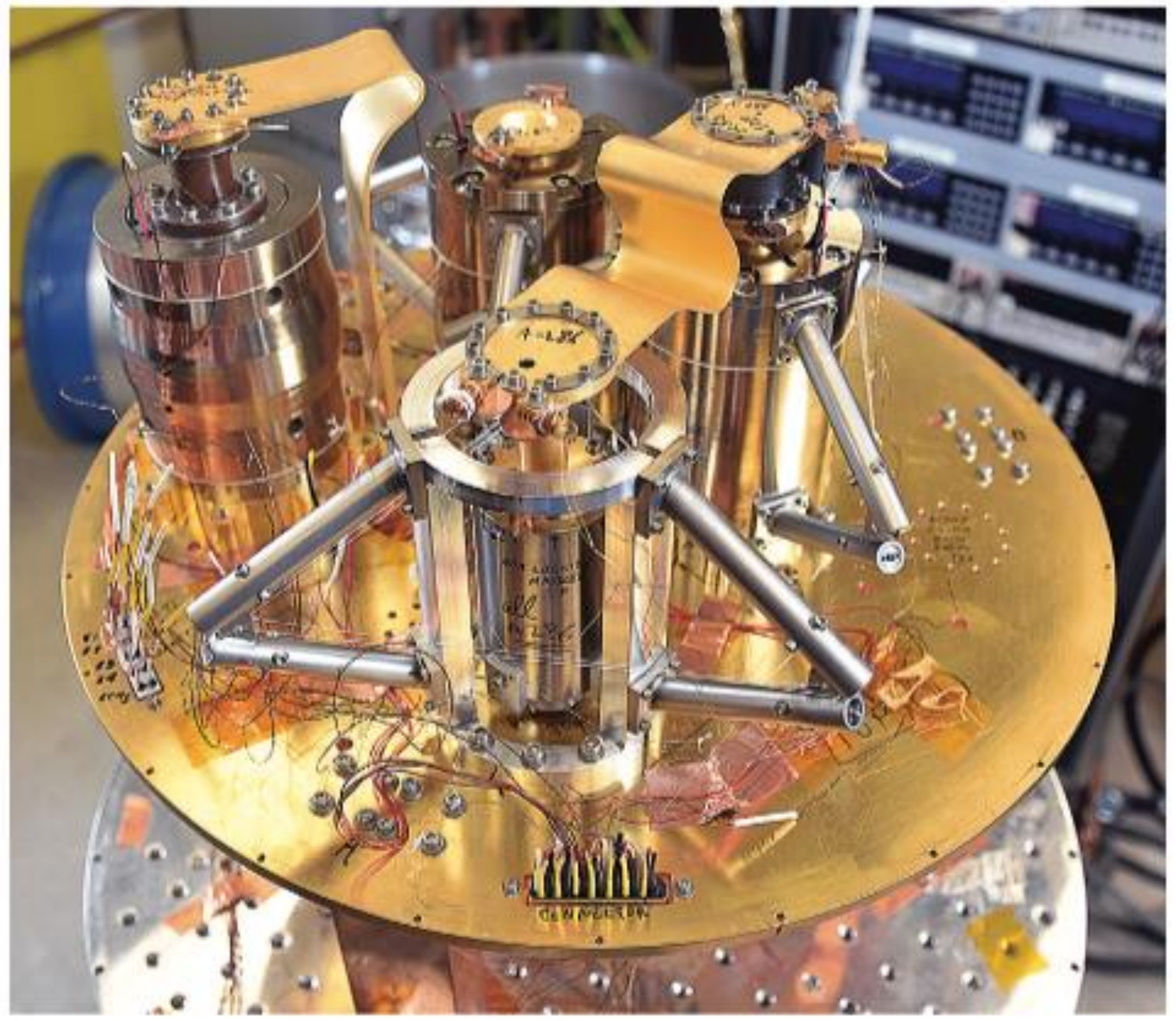
New X-ray Detectors to View the High-Energy Universe



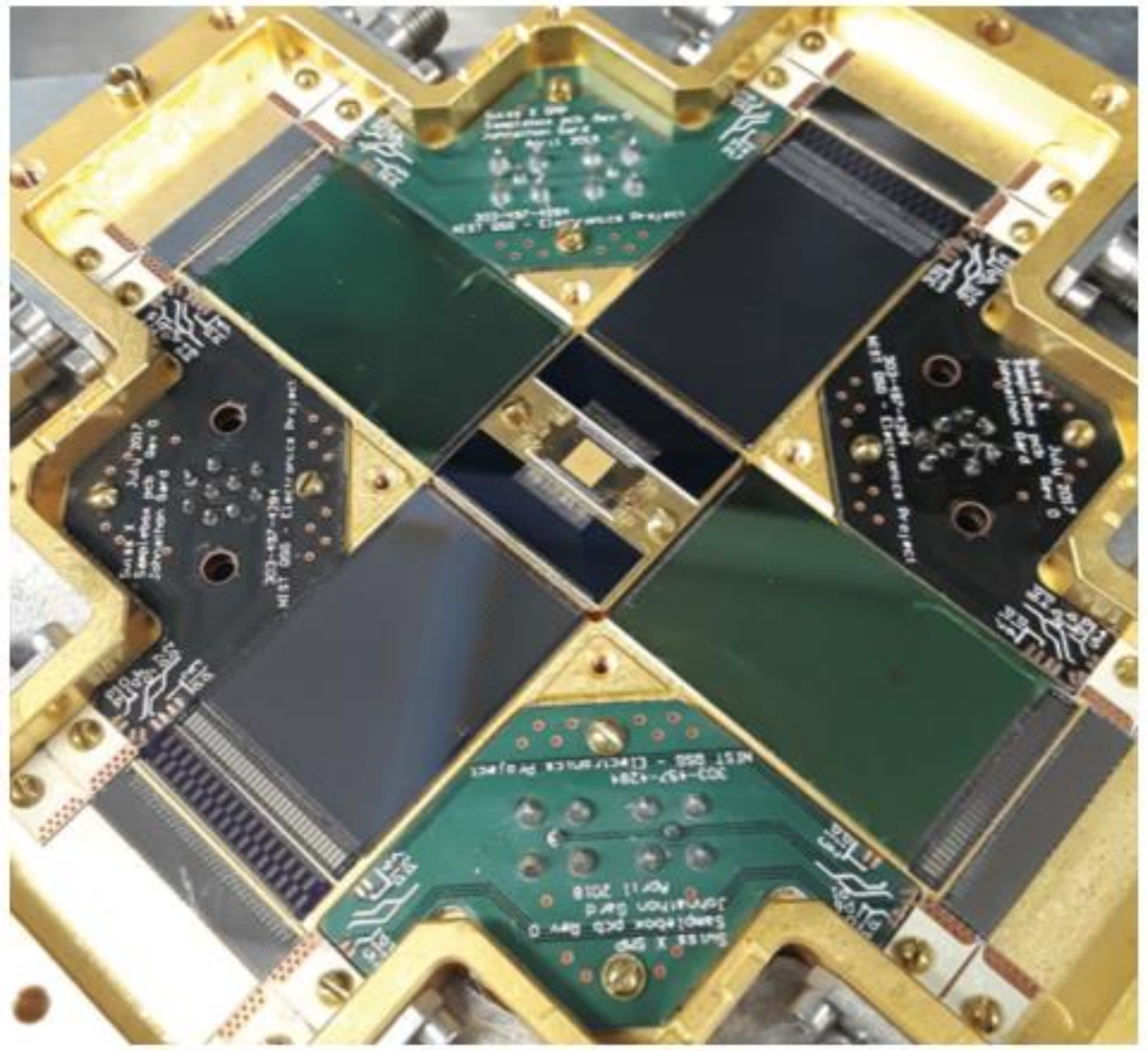
The interface between a "Double Stack" detector (bottom component) and cryogenic readout SQUID multiplexers (above the detector). Image credit: Felipe A. Colazo Petit

Large Superconducting Sensor Arrays Enabling Far-IR Observatories

CADR: Enabling Ultra-Low-Noise Detectors



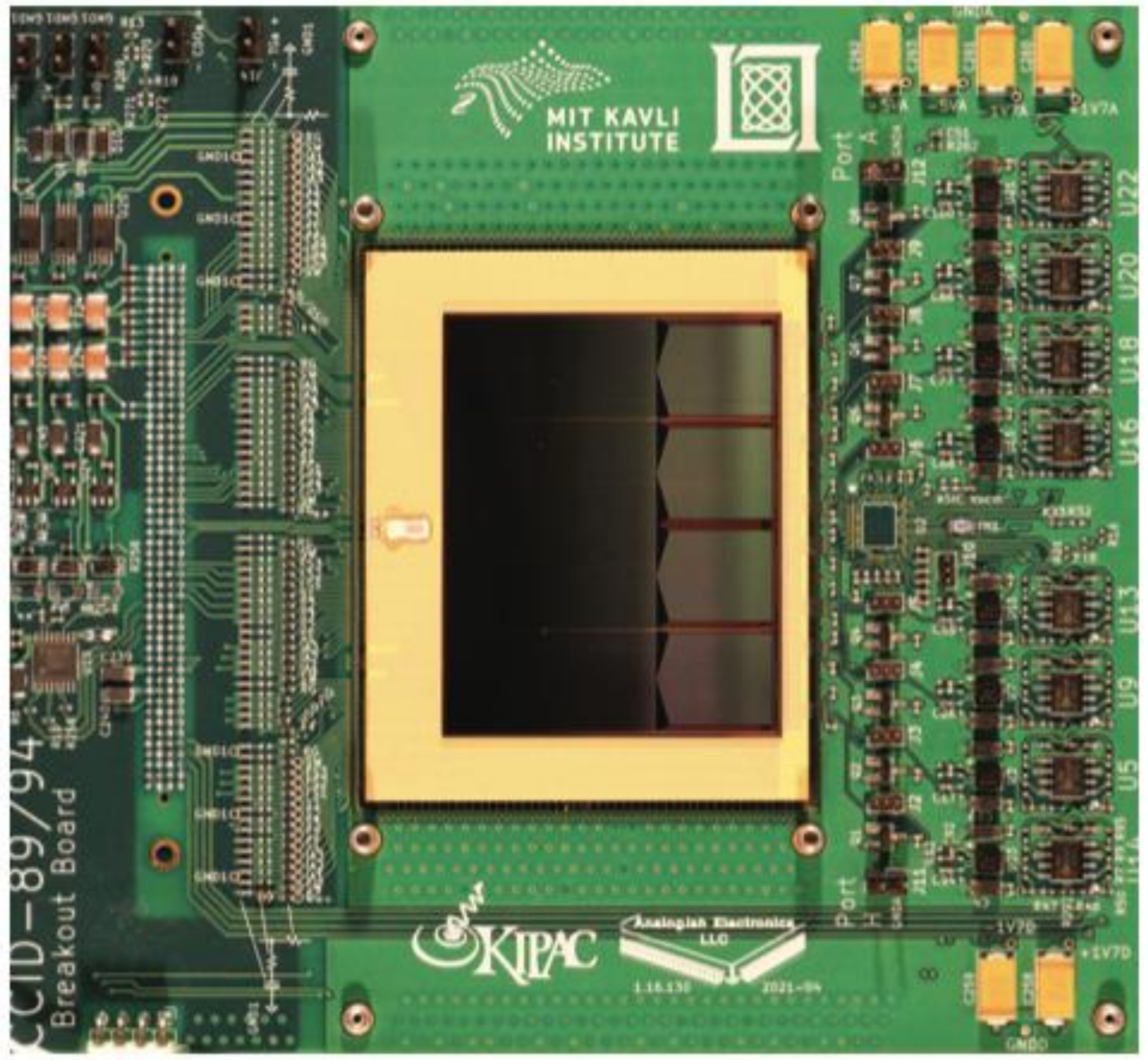
A four-stage 0.05 K to 4 K CADR installed in a cryogenic test facility. Image credit: Herbert Eaton



Microwave SQUID multiplexers (outermost chips) integrated with hydra TES array (innermost chip) fabricated by GSFC. Image credit: Kelsey Morgan

Microwave SQUID Multiplexing Enables Large X-ray Detector Arrays

Fast, Low-noise X-ray Sensors for Investigating Supermassive Black Holes



Advanced 2-megapixel X-ray image sensor (dark brown rectangle surrounded by gold frame) mounted on a test board (green). Image credit: David Volfson

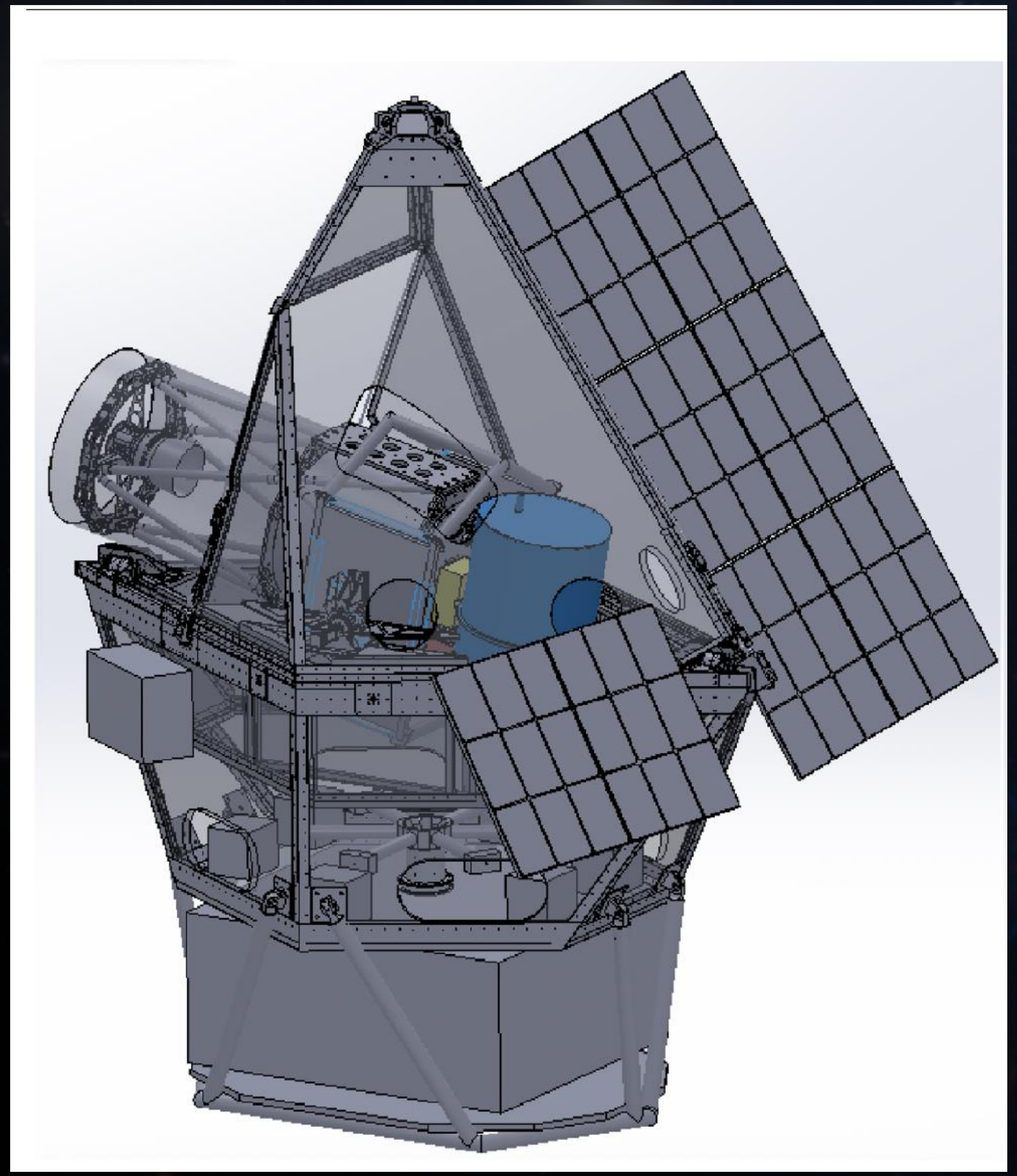
APRA UVOIR Balloons

FireBall: PI Chris Martin Cal Tech, Launch 9/2018, 9/2024 Ft Sumner, UV MOS, d-doped EMCCD, French gondola, galaxy evolution, ICM/GCM emission

PICTURE: PI Supriya Chakrabarti / Chris Mendillo, Launch 9/2020,9/2022 Ft Sumner, VV/EMCCD coronagraph testbed, eps Eri

SuperBIT: PI Bill Jones, Princeton, Launch 3x 2016-2019, April 2023 NZ. Optical diffraction limited imaging with 0.5m -> 1.5m telescope. Omega Nebula 2018

THAI-SPICE, PI Eliot Young, SWRI CO, Launch ¼ scale 9/2019, Full Scale 9/2024, Ft Sumner, **T**estbed for **H**igh-**A**cuity **I**maging, **S**table **P**hotometry and **I**mage-motion **C**ompensation **E**xperiment

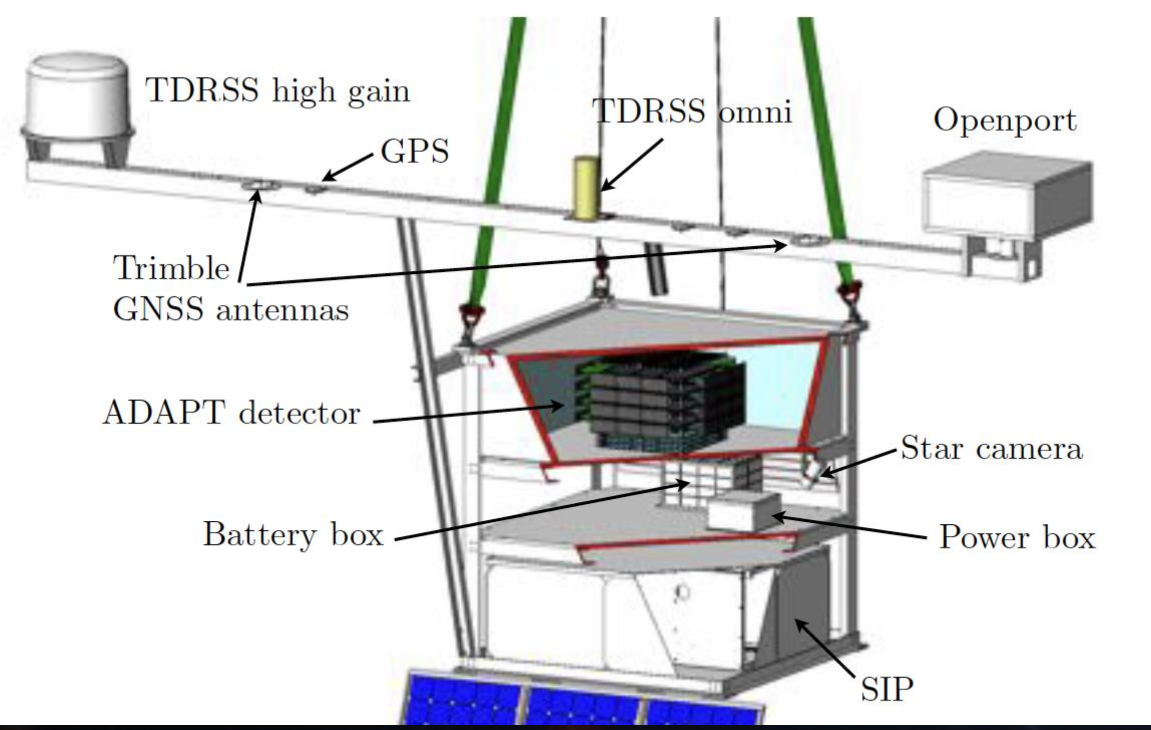


EXCITE: PI Peter Nagler GSFC, 0.5m telescope, Launch 9/2024 Ft Sumner, then NZ 1-4m spectra of hot Jupiters over full orbit

APRA PA Balloons

GAPS **(General Antiparticle Spectrometer):**
PI Chuck Hailey, Columbia,
Launch 24/25 McMurdo
Search for Antimatter via annelation x-ray emission.

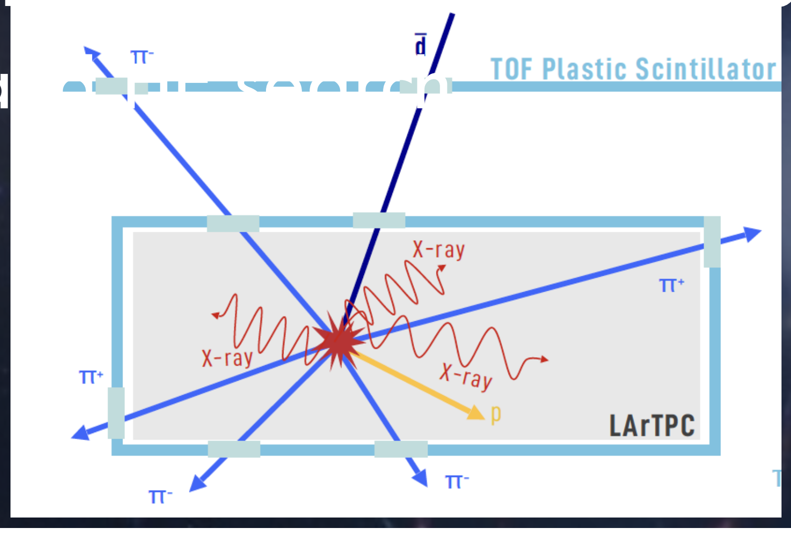
ADAPT **(Antarctic Demonstrator for the Advanced Particle-Astrophysics Telescope):**
PI James Buckley, WUSTL
Launch McMurdo 25/26



HELIX **(High Energy Light Isotope eXperiment):**
PI Scott Wakely, U Chicago
Cosmic Ray light element/isotopic composition with super conducing magnetic rigidity spectrometer.
Launched FY24 Sweden

GRAMS

PI Tsuguo Aramaki, Northeast U
Launch FY26, first commercial balloon launch in ROSES
Liquid Argon detector for antimatter
a



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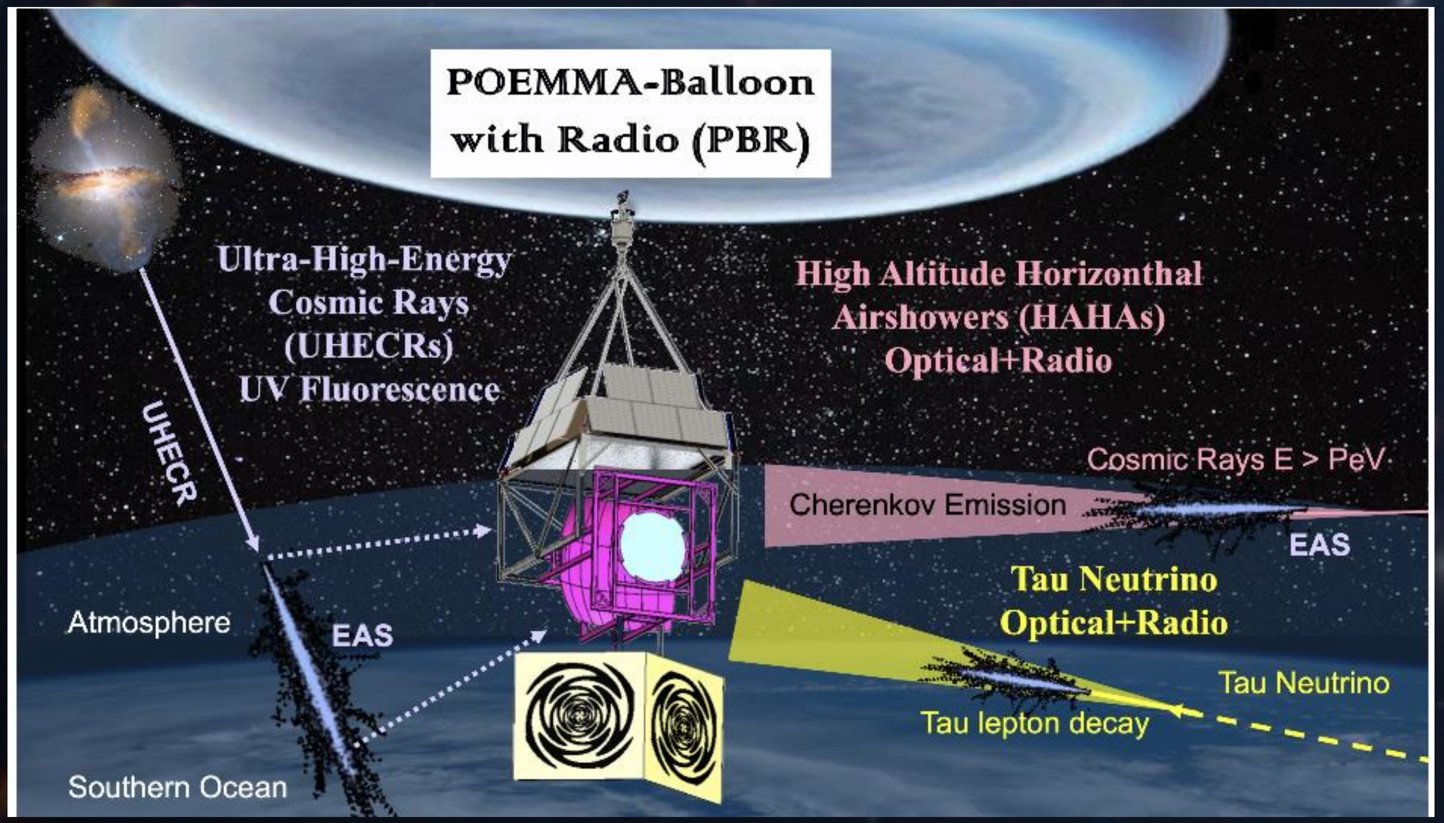
Launch 26/27 Wanaka



PUEO: PI Abby Vieregg, U Chicago started as an APRA PA award before successfully transitioning to the Pioneer Program.

Lots of launches coming up!

- ***C:*** BurstCube, Space-X ISS resupply, 3/21/2024 Launched; , 4/18/2024 Deployed
- ***C:*** SPARCS, March 2025, launch not yet identified
- ***C:*** BlackCat, July 2025, launch not yet identified.
- ***C:*** SPRITE, Space-X rideshare with ESD, April 2025
- ***P:*** Pandora, LRD 9/2025
- ***P:*** ASPERA, LRD 2/2026
- ***P:*** TIGERISS, LRD 10/2026
- ***P:*** PUEO, LRD 12/2026
- ***P:*** StarBurst, LRD 1/2027
- ***P:*** Landolt, launch NET 2027
- ***C:*** MANTIS, launch NET 2028
- ***P:*** POEMM, launch NET 2029

- ***C: CubeSat*** ***P: Pioneer***

Unanswered Questions

- *How to prioritize "balance" of the investment into 'pure' technology development, mission technology development (SAT, directed), and suborbital/small missions?*
  - *Metrics for appropriate balance between tech dev + small missions?*
  - *Should balance depend on strategic missions? Science area / Field?*
- Balance in use of Suborbital and Small Missions for supporting early career researchers vs. doing science
- Pressure for bigger projects vs. more projects
  - Balloons: *bigger vs. faster?*
  - CubeSats: *sustainability?*
- Balance in use of small missions for science vs. *tech dev?*