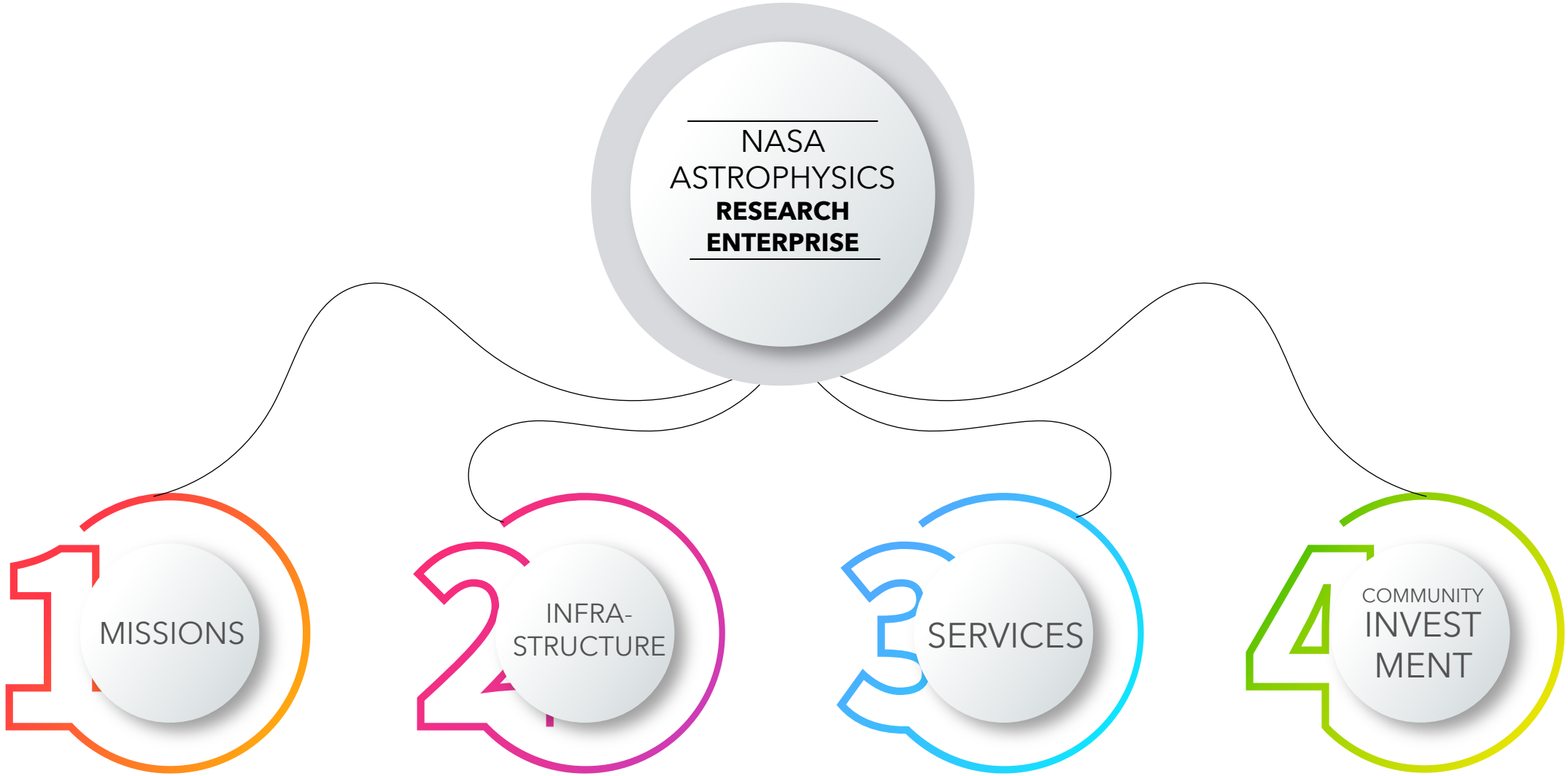
NASA Astrophysics

Astro2020: Panel On An Enabling Foundation for Research
National Academies Keck Center, Washington DC
October 22, 2019

Paul Hertz, Dan Evans, and Stefan Immler

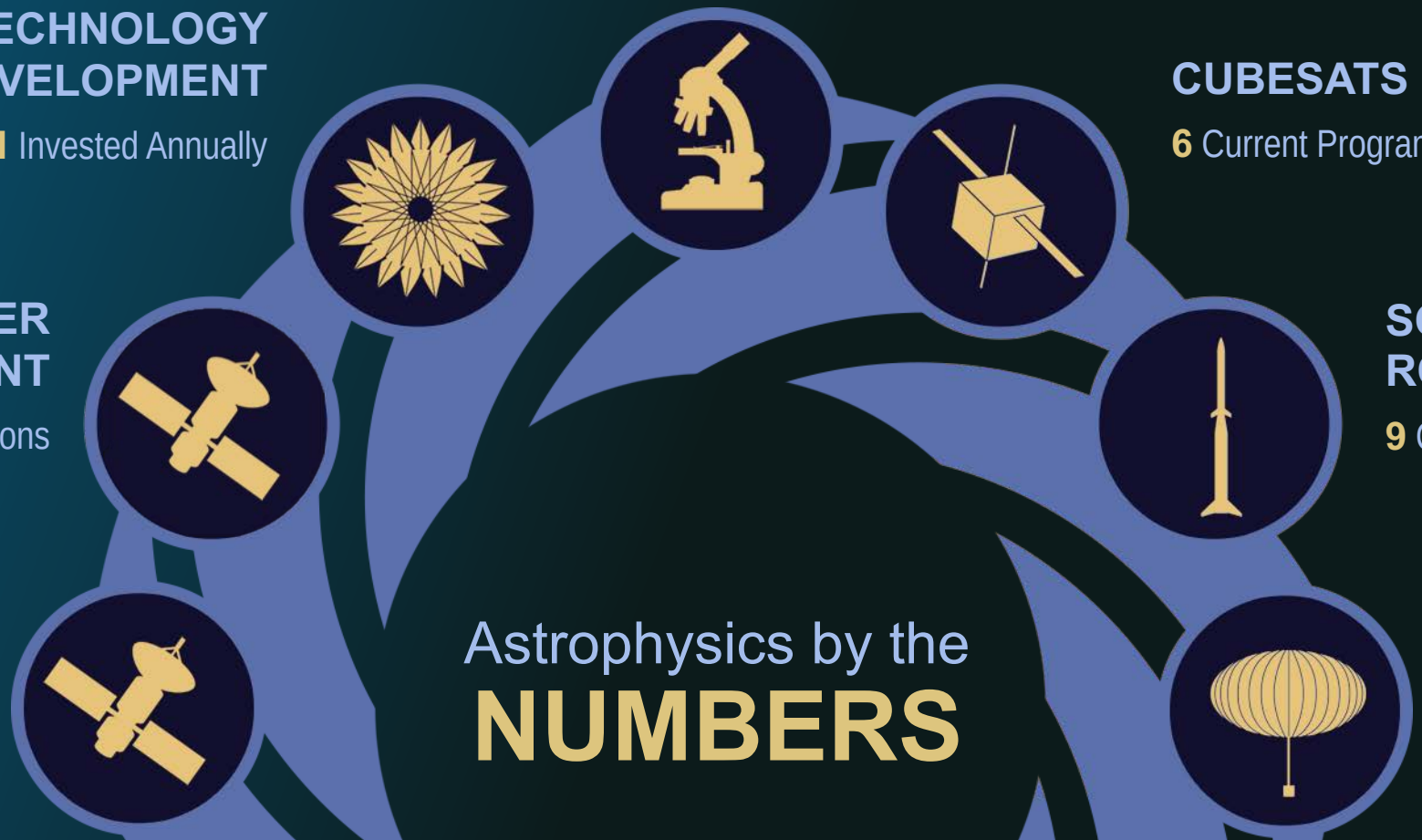
Astrophysics Division
Science Mission Directorate


NASA
ASTROPHYSICS
RESEARCH
ENTERPRISE
1
MISSIONS
2
INFRA-
STRUCTURE
3
SERVICES
4
COMMUNITY
INVEST
MENT
OPERATING,
UNDER DEVELOPMENT
LABORATORIES,
BEAMLINES, TEST
FACILITIES
ARCHIVES, BALLOONING,
COMPUTING
>$200M PER YEAR
VIA GO, FELLOWS, TECH,
AND R&A


OPEN
COMPETITION
COMMUNITY
GUIDANCE
EFFECTIVE
PARTNERSHIPS
BALANCED
PORTFOLIO
PRINCIPLES
OF NASA SCIENCE
INVESTMENT
OPEN
ACCESS
COMMUNITY
INVESTMENT
LESSONS
LEARNED
PUBLIC
COMMUNICATION

NASA’s Astrophysics Budget

Astrophysics by the NUMBERS



RESEARCH

>3,500 Proposals Received
>700 Proposals Awarded
~$200M Awarded Annually

TECHNOLOGY DEVELOPMENT

~$140M Invested Annually

CUBESATS

6 Current Programs

UNDER DEVELOPMENT

8 Missions

SOUNDING ROCKETS

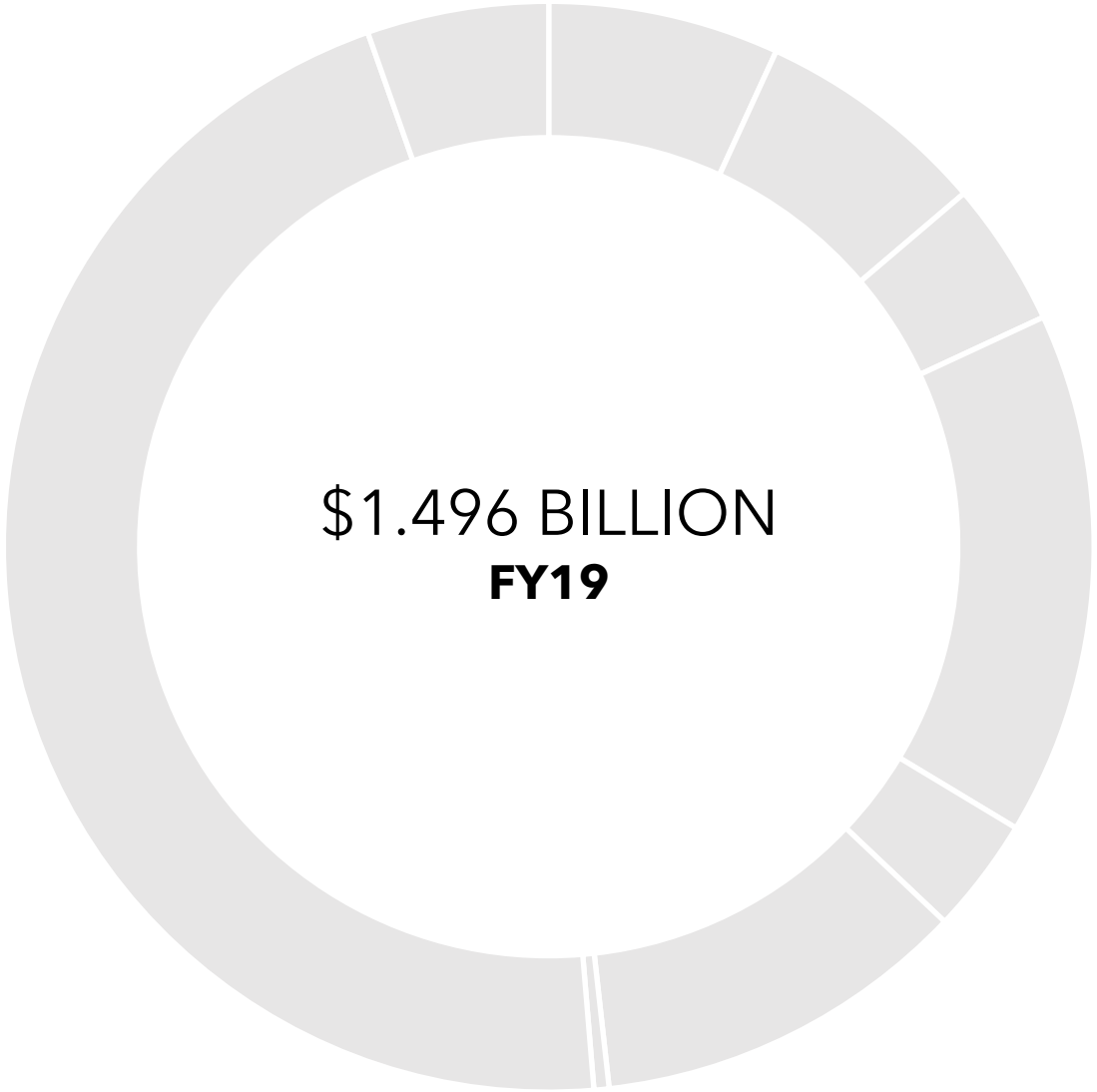
9 Current Programs

OPERATIONS

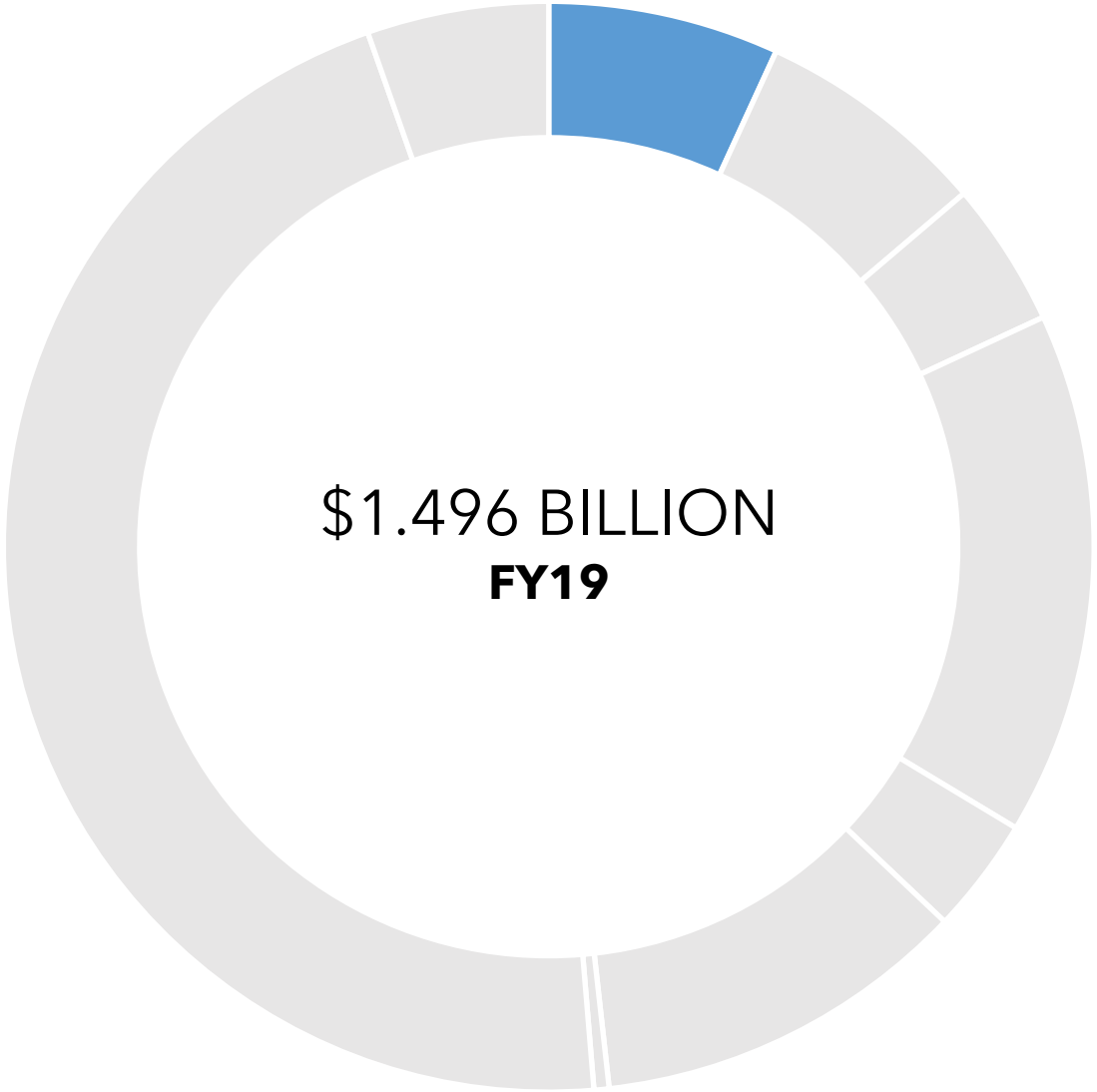
9 Missions

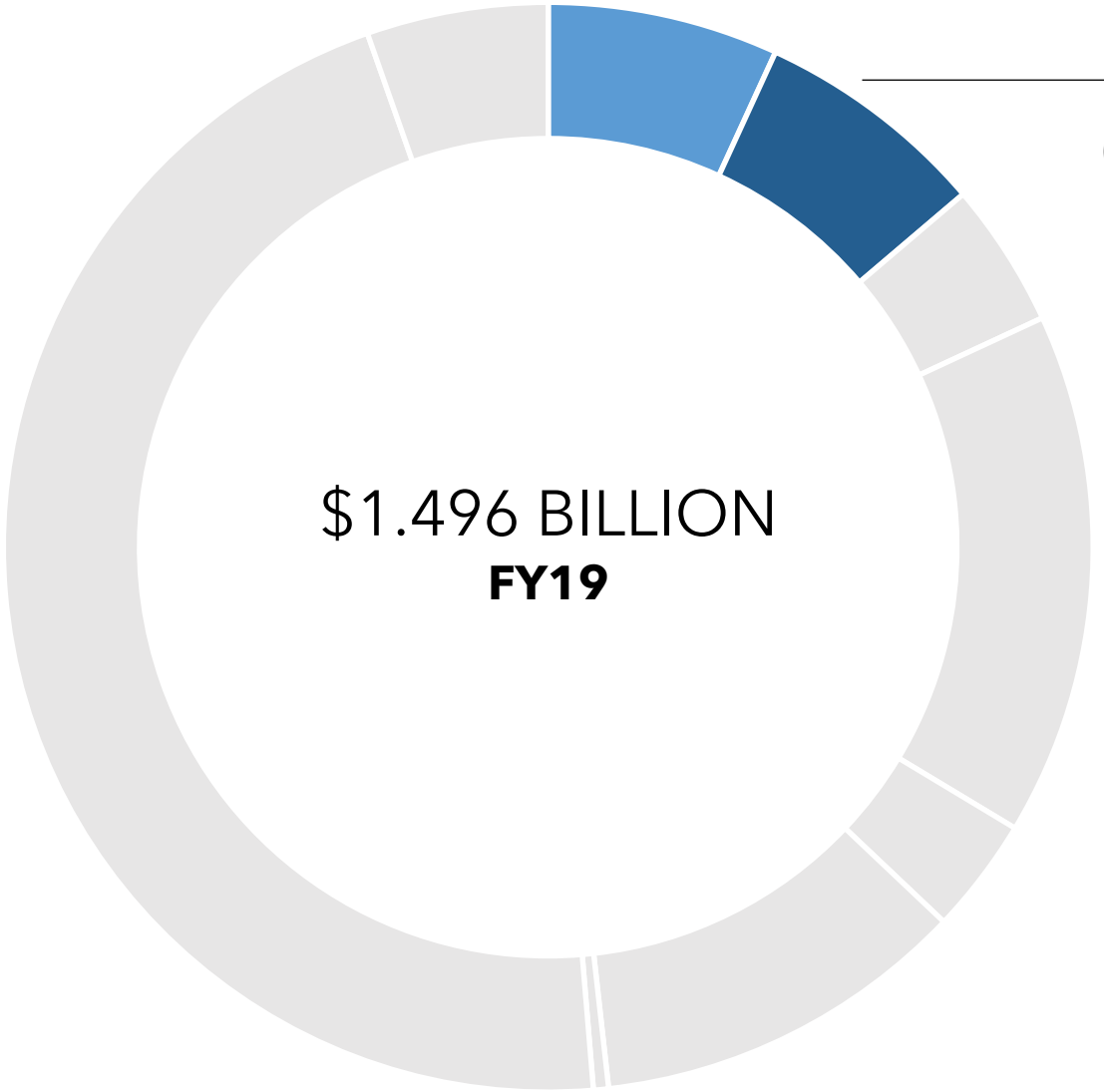
BALLOONS

3-6 Launches Per Year


$1.496 BILLION
FY19

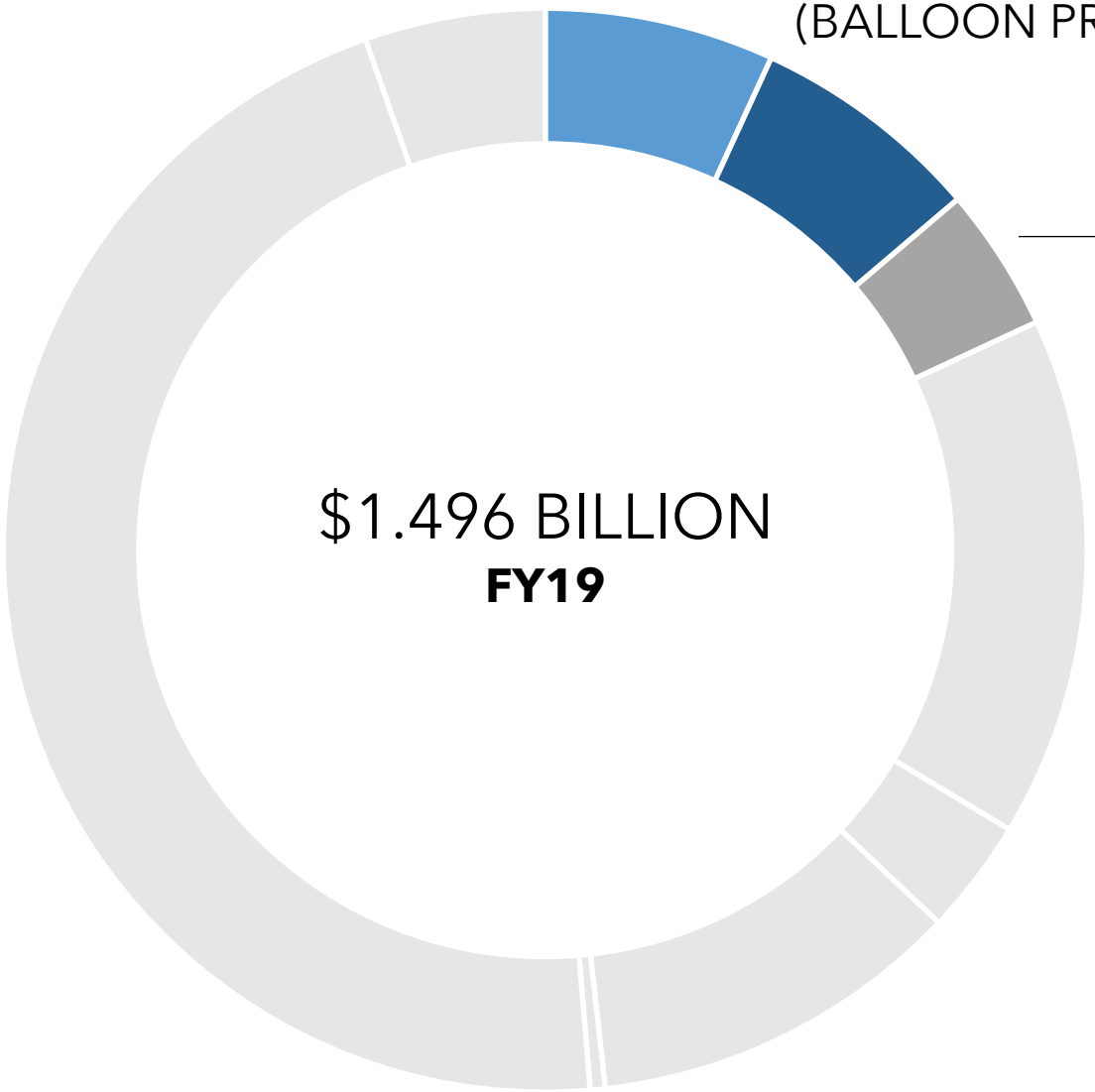
RESEARCH
(ADAP, APRA, ATP, ETC.)
7%

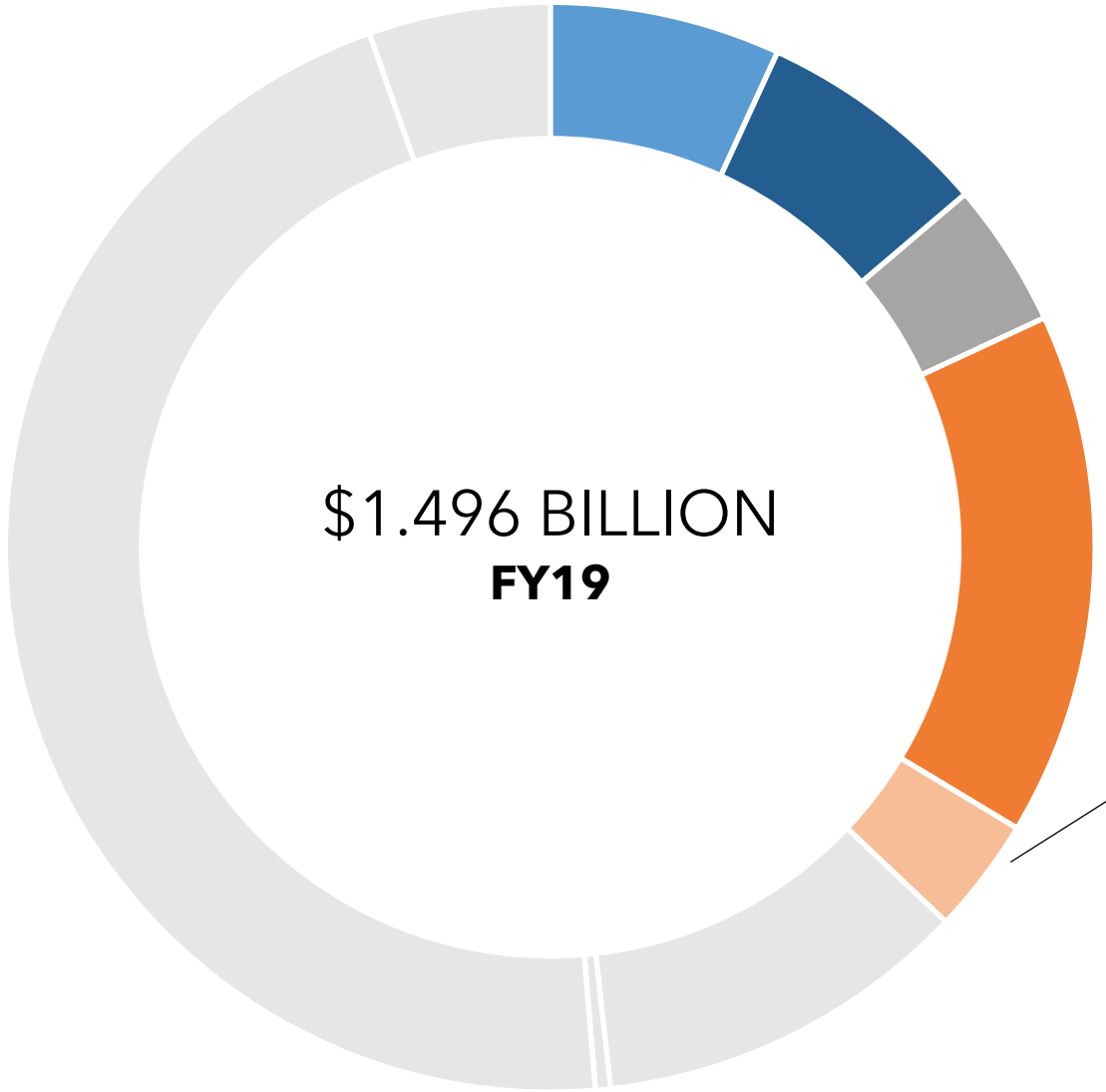


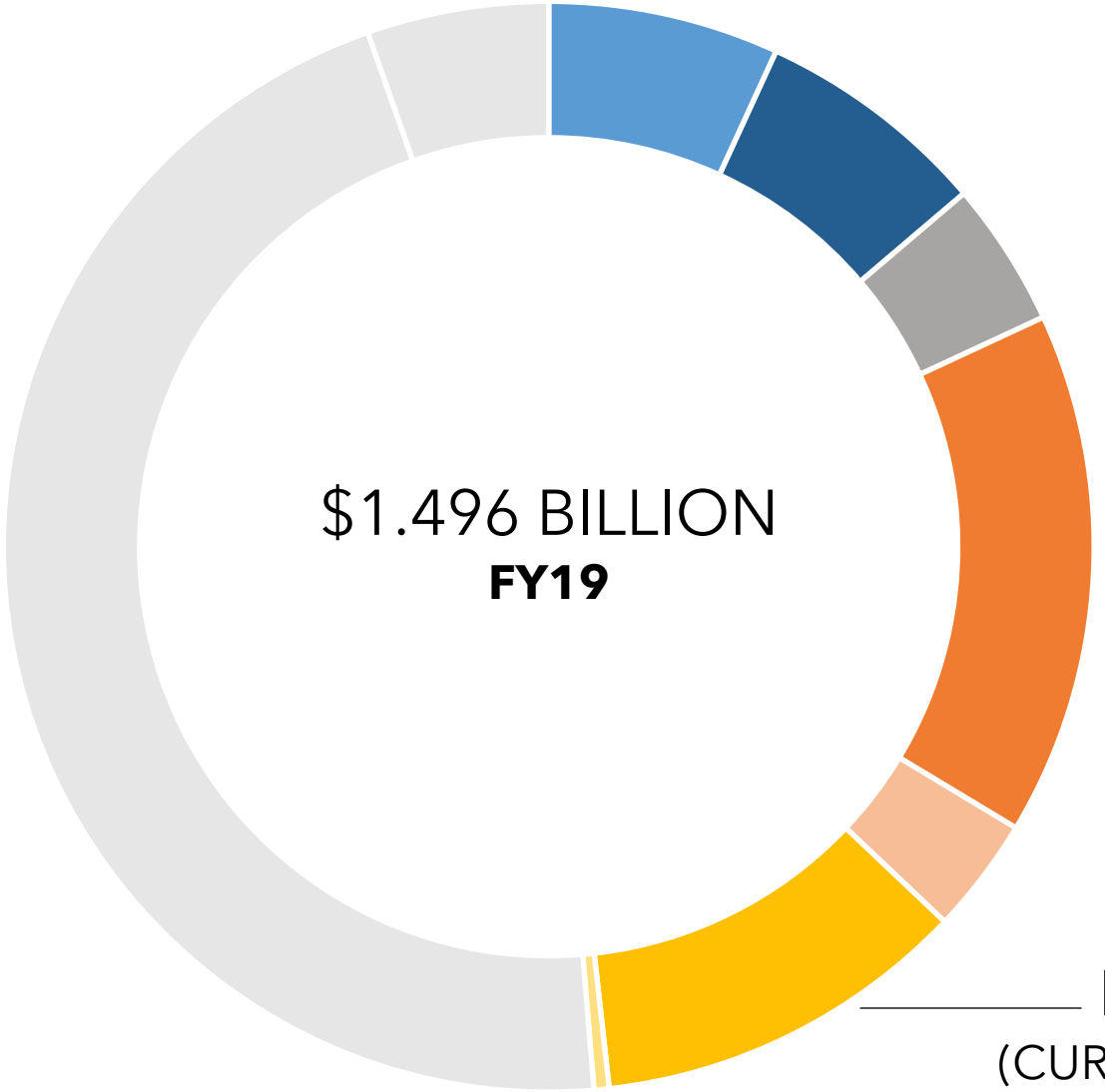


TECHNOLOGY
(SAT, ATHENA, LISA, ETC.)
7%

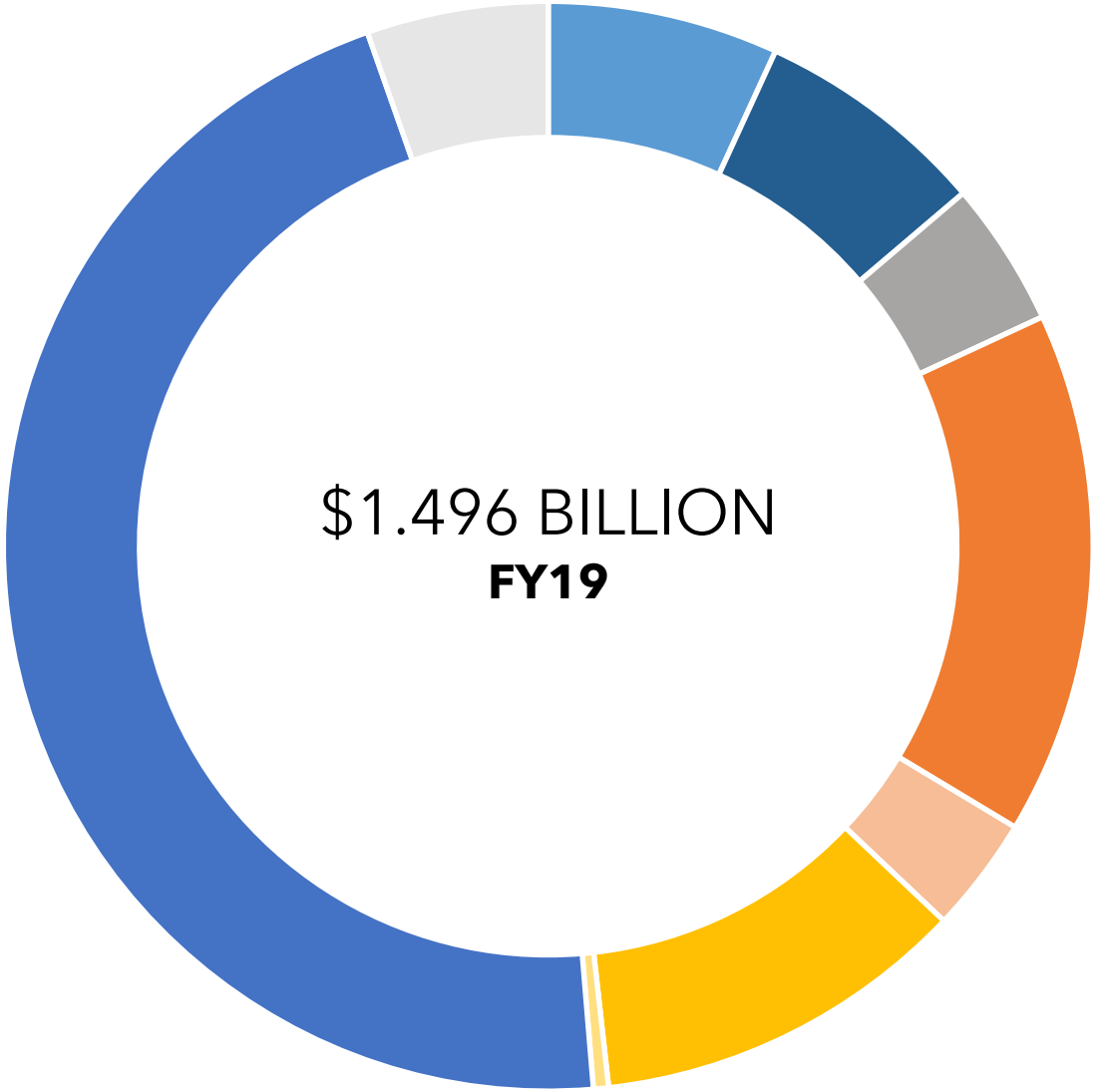
SERVICES & INFRASTUCTURE
(BALLOON PROGRAM, ARCHIVES, ETC.)
4%



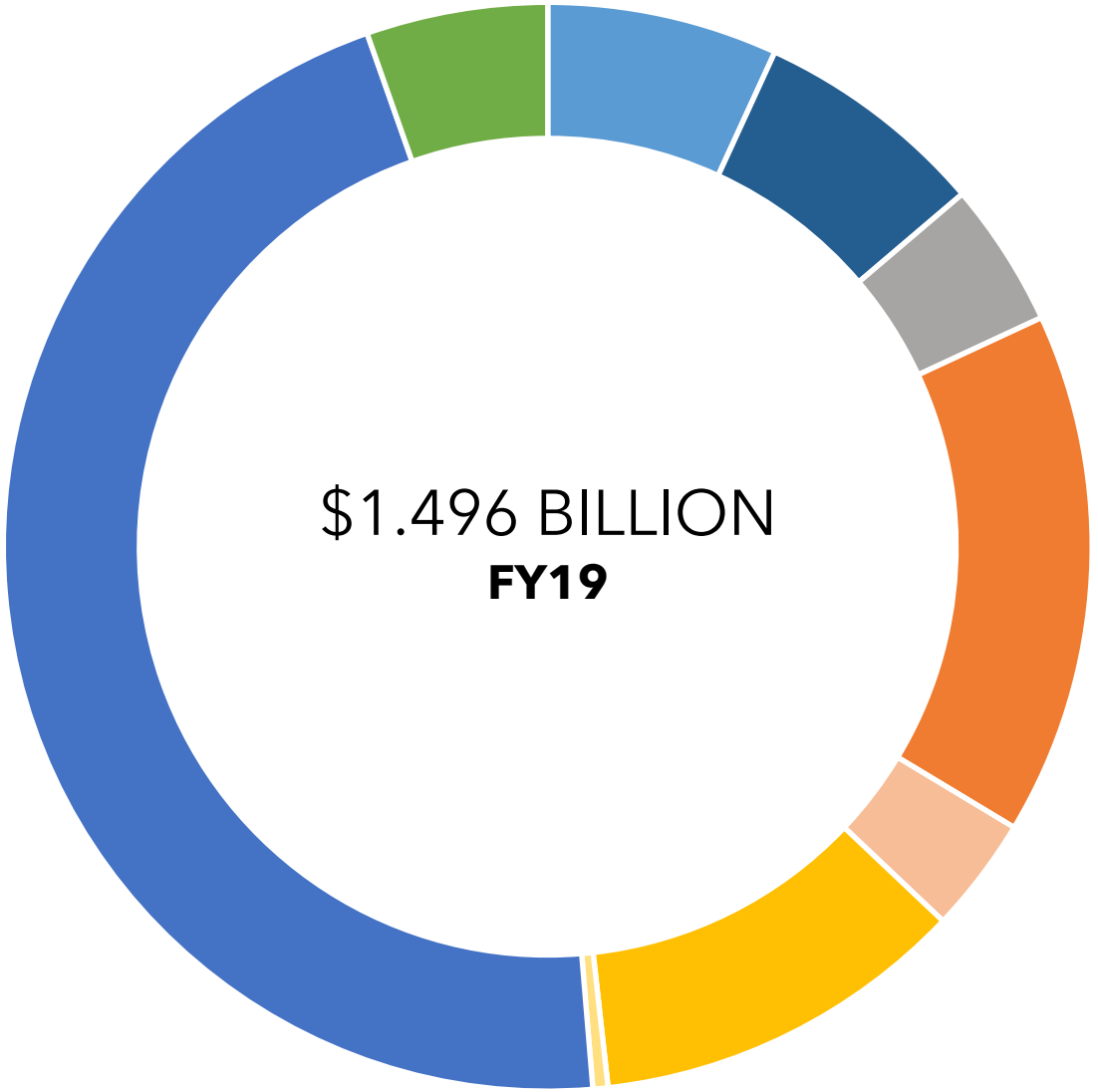

$1.496 BILLION
FY19
OP. MISSIONS
(INCL. GO PROGRAMS)
19%


$1.496 BILLION
FY19
EXPLORERS
(CURRENT AND FUTURE, INCL. GO)
11%

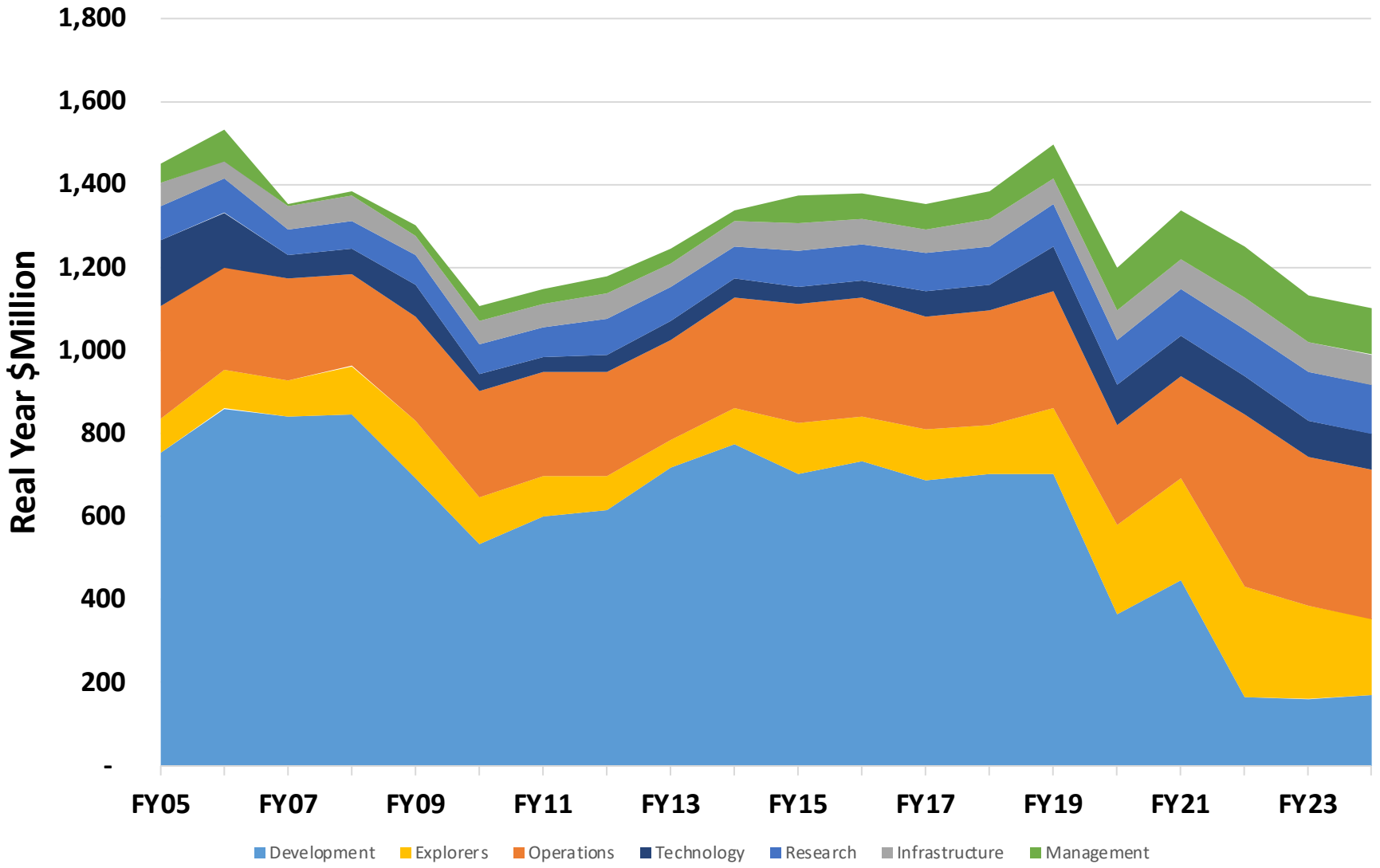
DEVELOPMENT
(WEBB, WFIRST)
46%



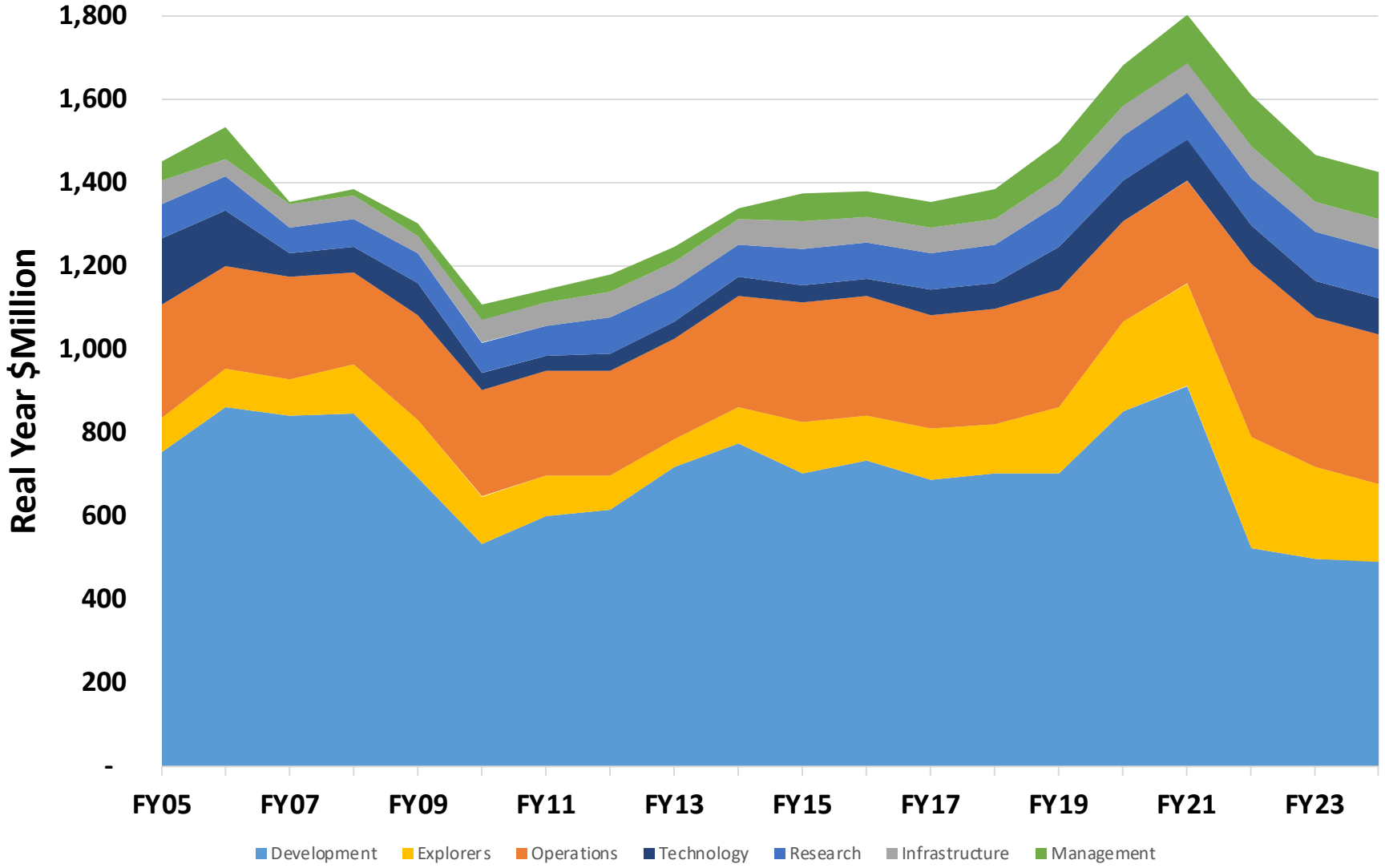
MANAGEMENT
INCL. STEM ACTIVATION
5%



Astrophysics Budget by Function
FY05-FY18 Actual, FY19 Op Plan, FY20-FY24 Request



Astrophysics Budget by Function
FY05-FY18 Actual, FY19 Op Plan, FY20-FY24 Request
+ WFIRST FY20-FY24



Astrophysics Research Programs

Astrophysics Research Elements

ROSES Programs

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) (cross-div)
- Roman Technology Fellowships (RTF)
- FINESST Graduate Student Research Awards

Data Analysis

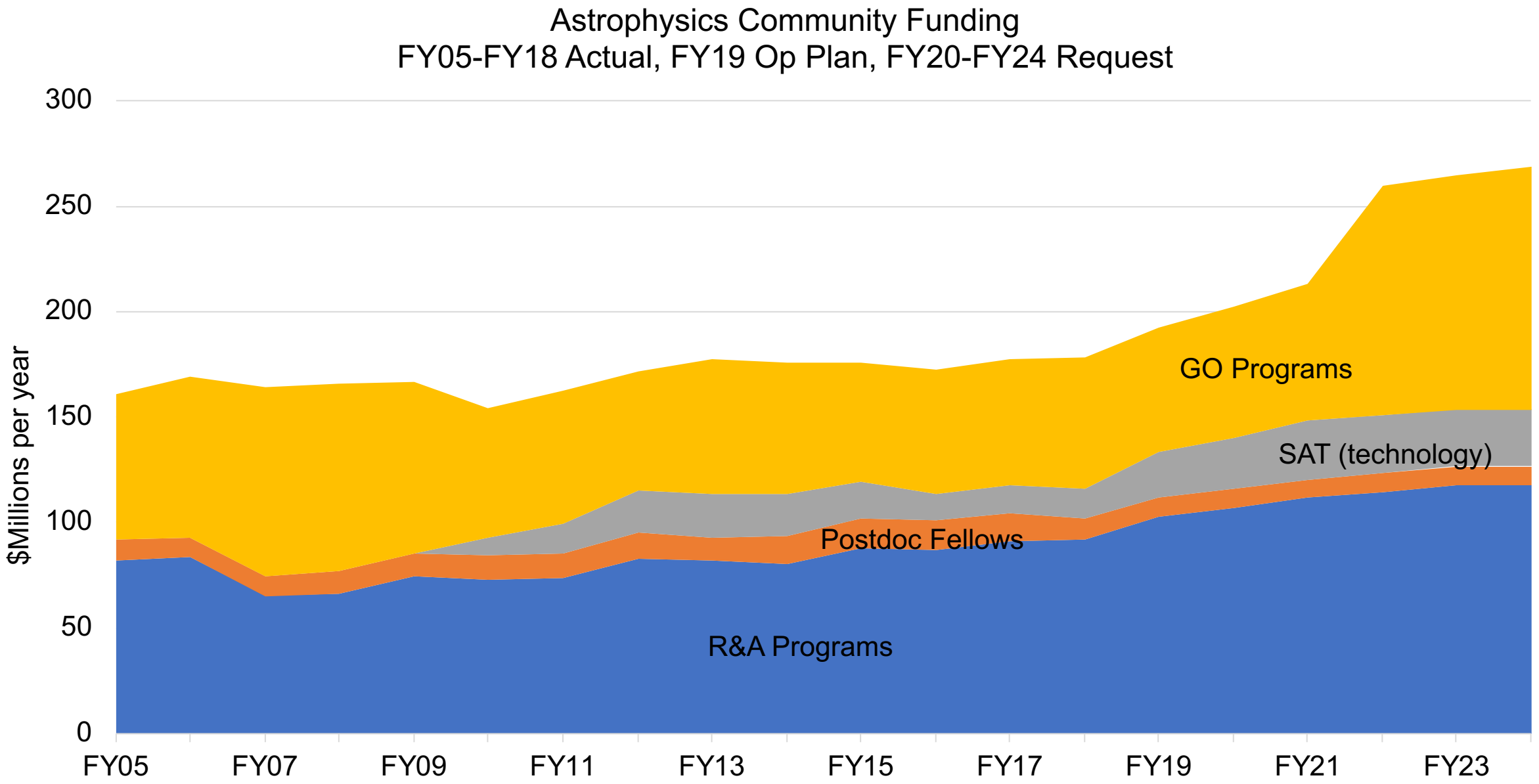
- Astrophysics Data Analysis (ADAP)
- GO/GI programs in ROSES for:
  - Fermi
  - Swift
  - NuSTAR
  - TESS
  - NICER

Mission Science and Instrumentation

- Sounding rocket, balloon, CubeSat, and ISS payloads solicited through APRA
- Astrophysics Science SmallSat Studies
- XRISM PV Phase GS
- WFIRST SWG (recompete)
- LISA Preparatory Science

Separately Solicited

- GO/GI/Archive/Theory programs for:
  - Chandra
  - Hubble
  - SOFIA
  - Webb
- NASA Hubble Fellowship Program
- NASA Postdoctoral Program


Astrophysics Community Funding
FY05-FY18 Actual, FY19 Op Plan, FY20-FY24 Request
$Millions per year
300
250
200
150
100
50
0
FY05
FY07
FY09
FY11
FY13
FY15
FY17
FY19
FY21
FY23
GO Programs
SAT (technology)
Postdoc Fellows
R&A Programs

Q. How Does NASA Estimate the Analysis Budget for our Missions in Phase E?

For some missions, NASA scaled up from existing programs (e.g. Hubble for Webb) based on the number of hours of available observing time.

For some missions, estimate how big a typical grant should be and calculate how many people will receive grants based on available observing time and typical exposure time. Mission Users' Committees provide valuable community input.

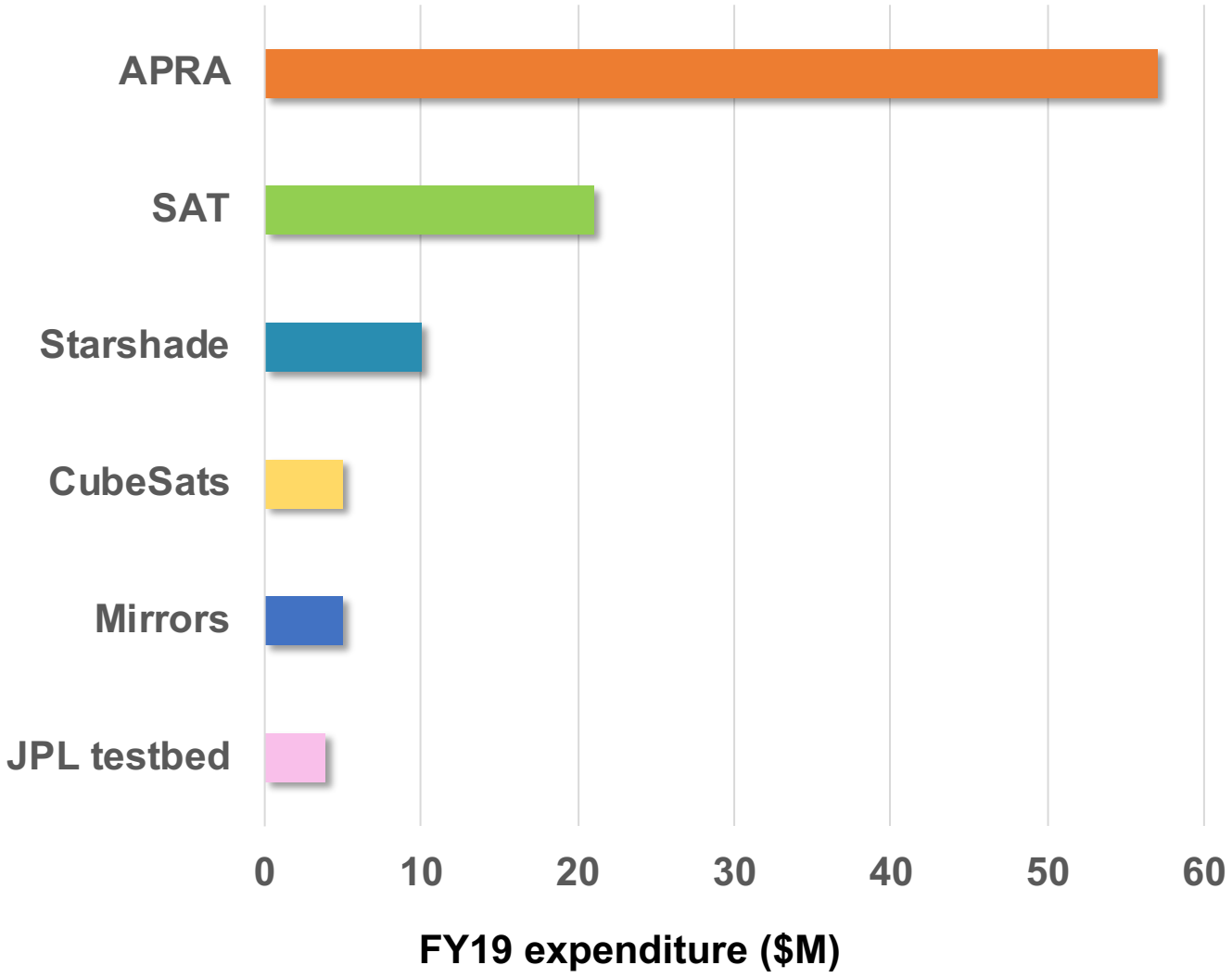
NASA periodically assesses GO program size via triennial Senior Reviews.

Q. How much theory is supported in programs more directly associated with missions in addition to ATP and TCAN?

$15M	$750k	$500k	$1M
ATP+TCAN (AVERAGE OF FY18 AND FY19)	**CHANDRA THEORY** (APPROX. PER YEAR)	**FERMI THEORY** (APPROX. PER YEAR)	**HUBBLE THEORY** (APPROX. PER YEAR)

In addition, several NASA Fellowship programs support theory work.

Q. Outside the missions, how much funding is available for low-TRL technology development? Answer: $102M in FY19.



APRA — $57M, covers TRL 1-9.

SAT — $21M, competed and directed. COR = 9M; PCOS = $7M; ExEP = $5M. Covers TRL 3-6.

STAR SHADE — $10M, NASA-directed investment.

CUBE SATS — $5M average annual investment.

MIRRORS — $5M, segmented mirror ROSES solicitation.

JPL TESTBED — $4M, JPL high-contrast imaging testbed.

NASA also invests $35M in tech. development for Athena and LISA.

Astrophysics Suborbital Programs

NASA's Astrophysics Balloon Program

Balloons provide low-cost, quick response, near space access for:

- Conducting cutting-edge research
- Developing technologies to enable future spacecraft science missions
- Advancing lighter-than-air platform technologies
- Enabling hands-on training of the next generation of scientists and engineers
- Now offering super-pressure balloons as a new capability

COSI launch from Wanaka, NZ on a Super-Pressure Balloon on 17 May, 2016.

Most recently successfully launched all 8 large payloads during the Ft. Sumner, NM Campaign.

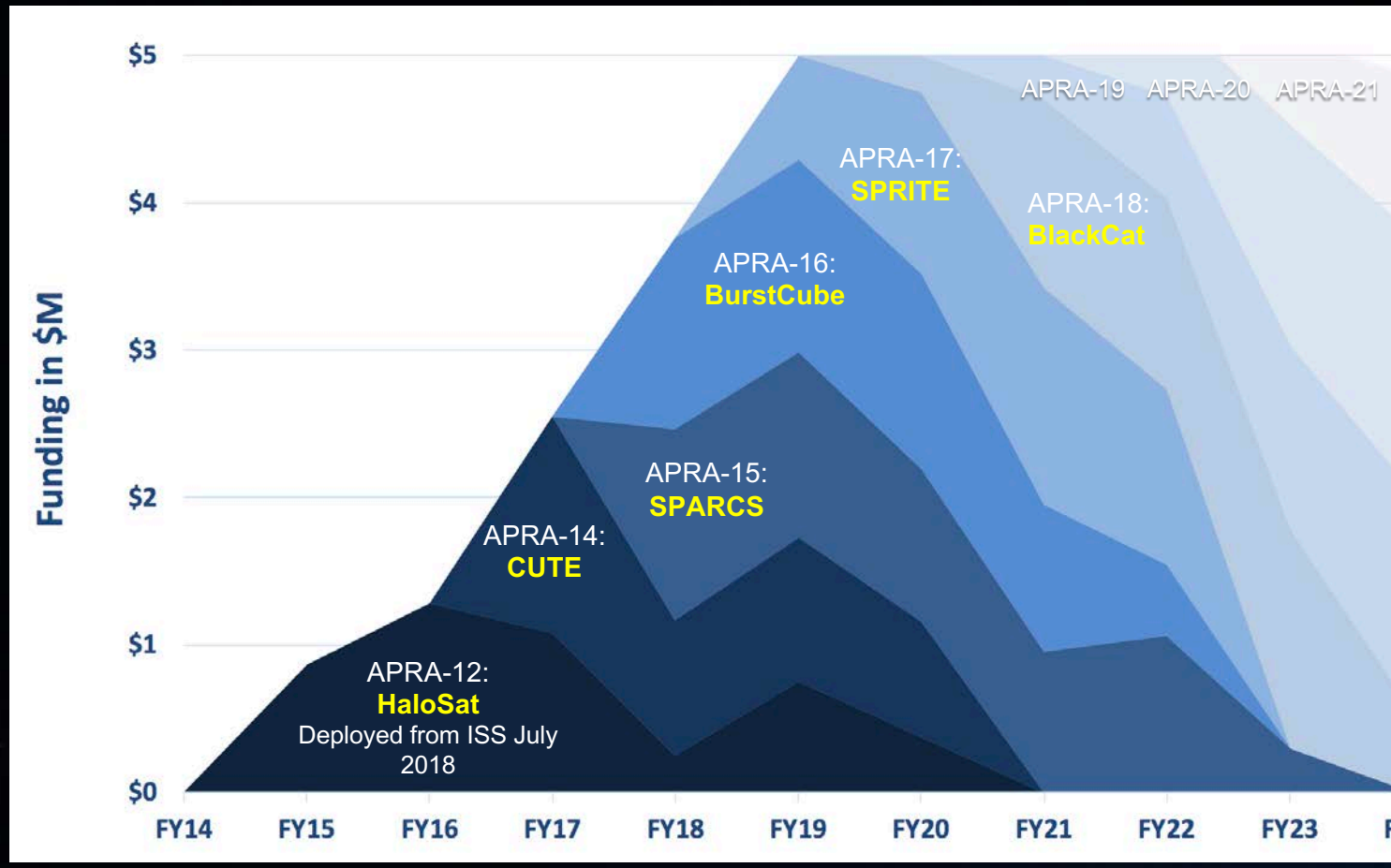
Super-Pressure Balloon Flights from Wanaka, NZ enable multi-day (night) astrophysics observation in the Southern Hemisphere.

3-6	~3	>300	>40
LAUNCHES PER YEAR	**CAMPAIGNS PER YEAR**	**STUDENTS PER YEAR**	**INSTITUTIONS PER YEAR**

NASA's Astrophysics CubeSat Initiative

The Astrophysics Division is investing approximately $5M per year in a new CubeSat initiative.

HaloSat, our first CubeSat, is in orbit and is producing excellent data.



Launch:

NASA's Astrophysics Sounding Rocket Program

Objective:

Enable discovery through frequent sub-orbital flight opportunities for NASA scientific, technology development, and educational investigation.

- Astrophysics has 3-5 Sounding Rocket launches per year.
- The next southern hemisphere campaign from Australia is currently scheduled for July 2020.

MISSION	PI	PROJECT	RANGE	DATE (ET)	DISCIPLINE
36.323 UG	FRANCE	CHESS	WSMR	2017-06-27	UV/OPTICAL
36.311 UG	GREEN	DEUCE	WSMR	2017-10-30	UV/OPTICAL
36.329 UH	GALEAZZI	DXL	PFRR	2018-01-19	HIGH ENERGY
36.330 UH	MCENTAFFER	WRX-R	KWAJ	2018-04-04	HIGH ENERGY
36.333 UG	FRANCE	CHESS	KWAJ	2018-04-16	UV/OPTICAL
36.245 UH	FIGUEROA	MICRO-X	WSMR	2018-07-22	HIGH ENERGY
36.331 UG	GREEN	DEUCE	WSMR	2018-12-18	UV/OPTICAL
36.346 UG	FRANCE	SISTINE	WSMR	2019-08-11	UV/OPTICAL
36.343 GG	NUTH	DUST	WSMR	2019-10-07	LAB ASTRO
36.352 UG	MCCANDLISS	FORTIS	WSMR	2019-10-27	UV/OPTICAL
36.245 UH	FIGUEROA	MICRO-X	WSMR	2020-03 TBC	HIGH ENERGY
36.281 UG	ZEMCOV	CIBER-2	WSMR	2020-02-02	UV/OPTICAL
36.339 UG	FRANCE	SISTINE	AUS	~2020-07-01	UV/OPTICAL
36.347 UH	MCCAMMON	XQC	AUS	~2020-07-01	HIGH ENERGY
36.350 UG	GREEN	DEUCE	AUS	~2020-07-01	UV/OPTICAL

NASA's View of a Balanced Program

What is a Balanced Program?

Balanced across multiple goals and priorities

- Addresses science (Decadal Survey) goals and priorities
- Addresses National goals and priorities

Balanced through time

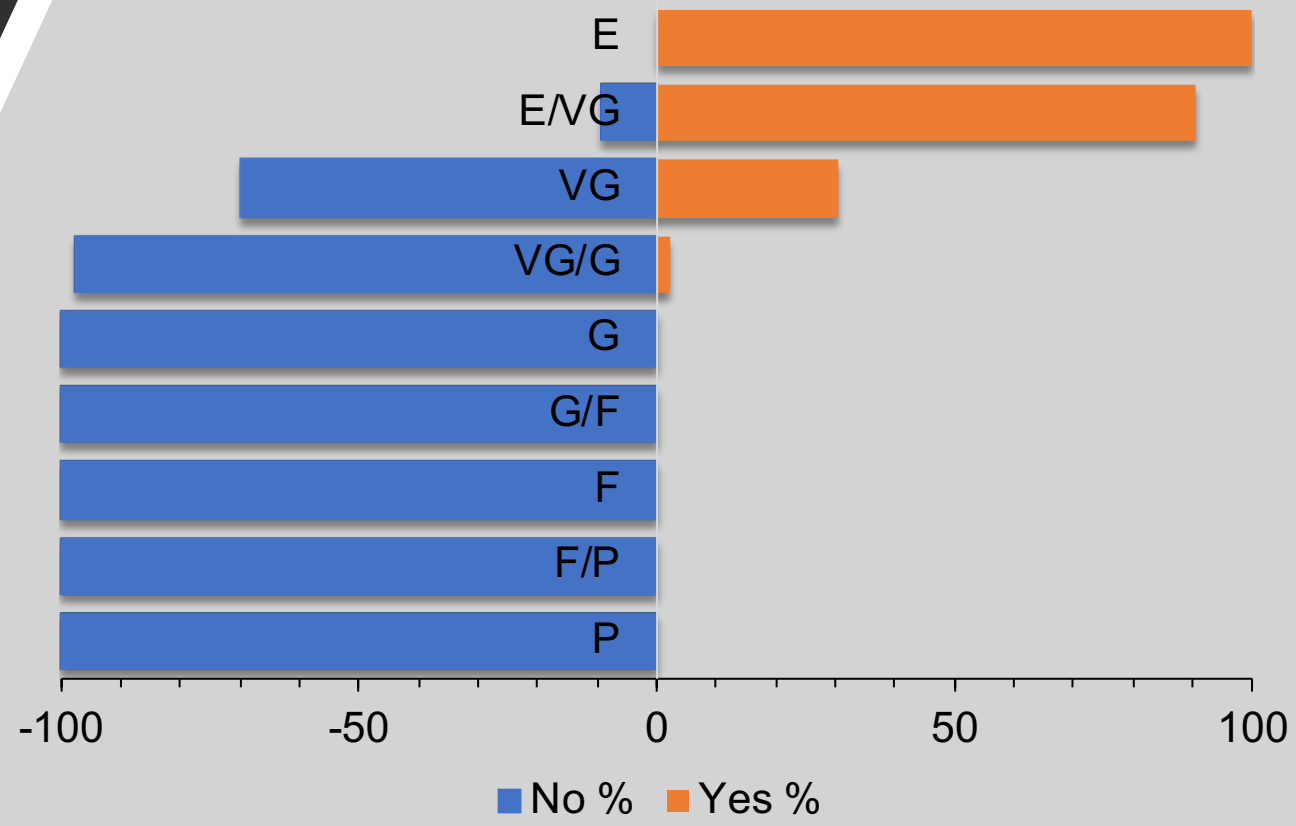
- Yields science discoveries today
- Enables science discoveries tomorrow
- Is sustainable: maintains necessary National capabilities

Balanced among:

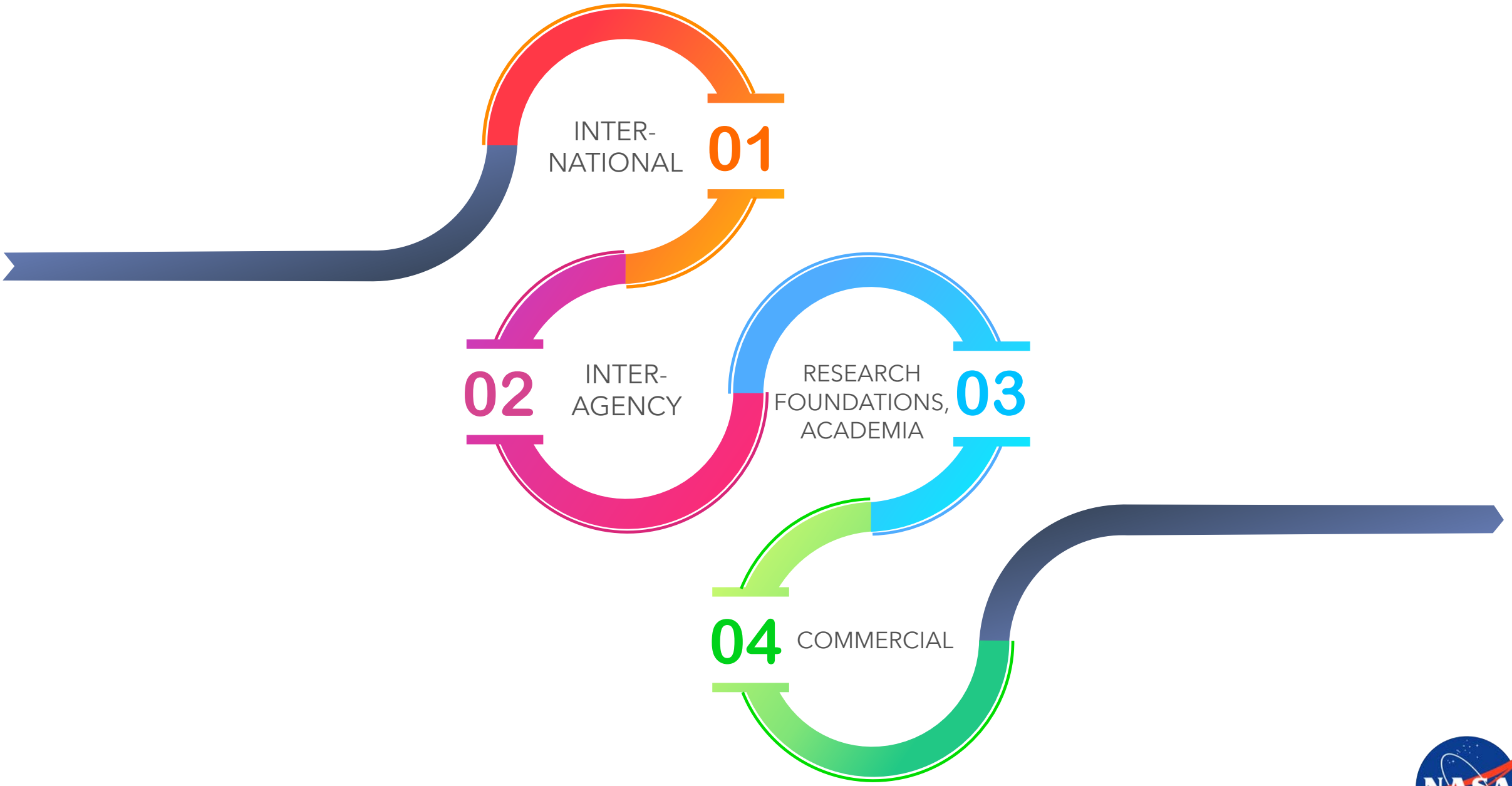
- Missions
- Research infrastructure
- Community investment

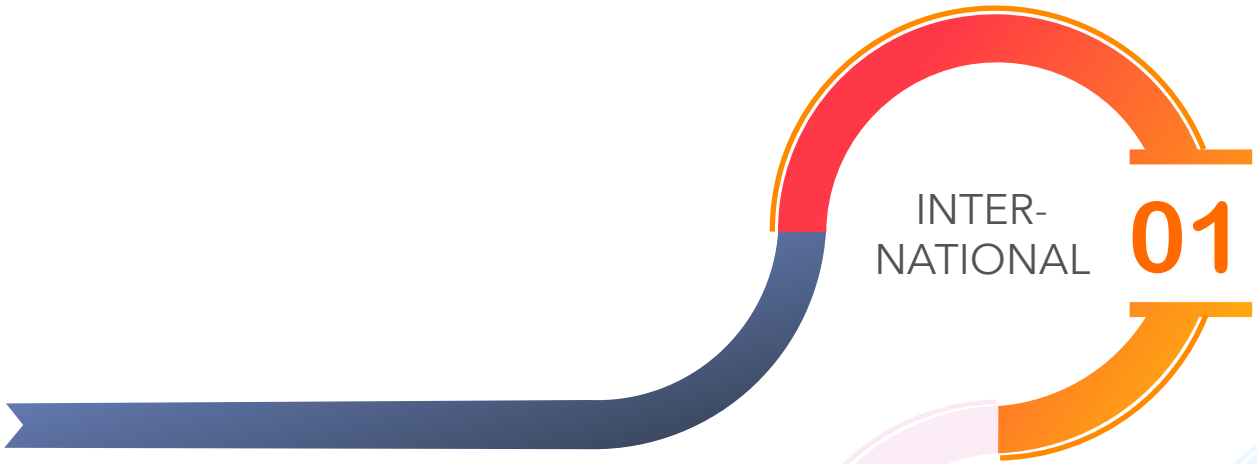
What Are Indicators of a Balanced Program?

- Program balance within Astrophysics has been endorsed by numerous Decadal Surveys, as well as the last mid-term assessment
- Current success rate of ~22% allows us to fund the most compelling investigations
- NASA changes the Astrophysics program balance in response to Decadal Surveys (example: increasing the R&A program budget within a flat or decreasing top line)

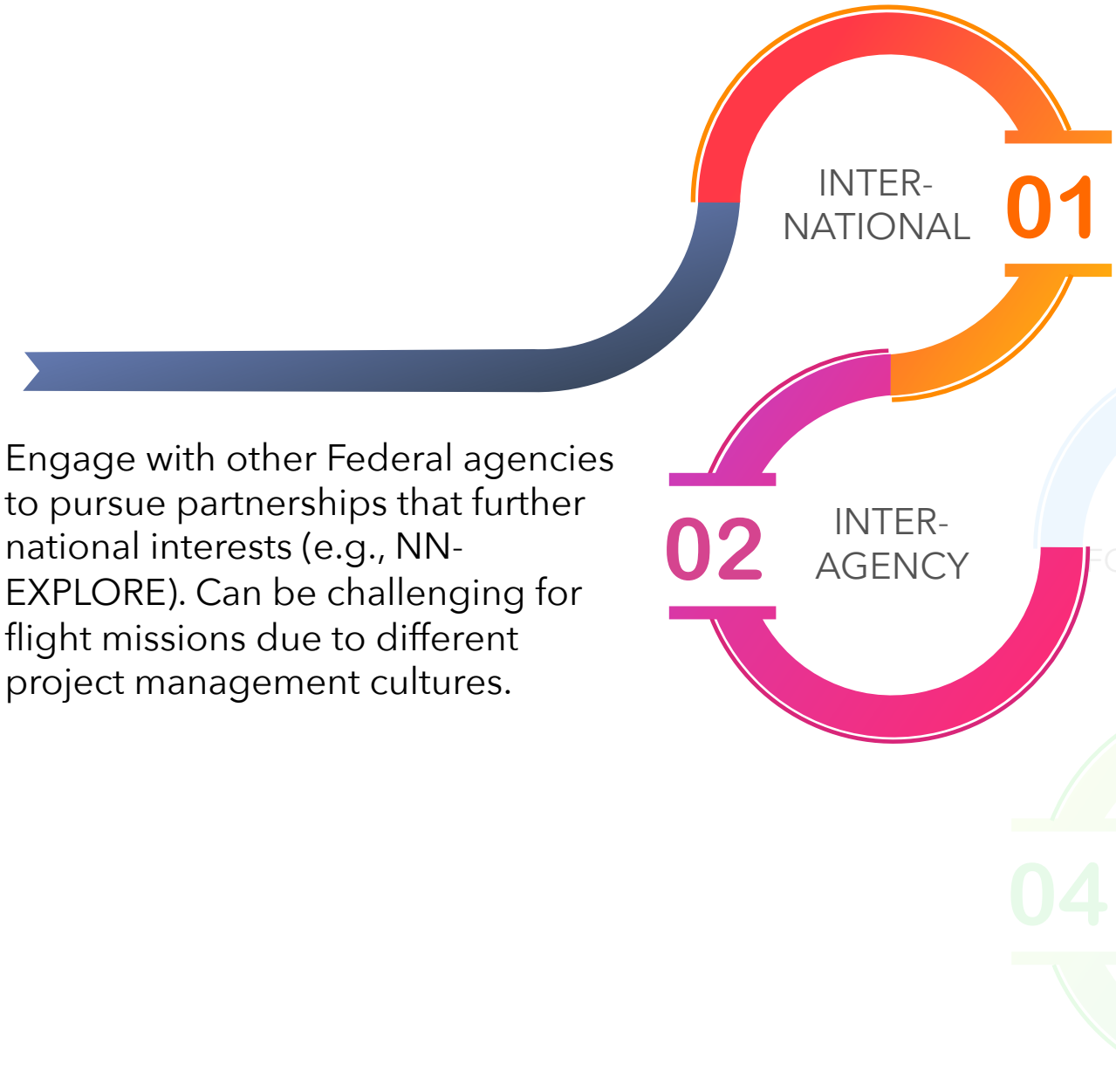


Partnerships

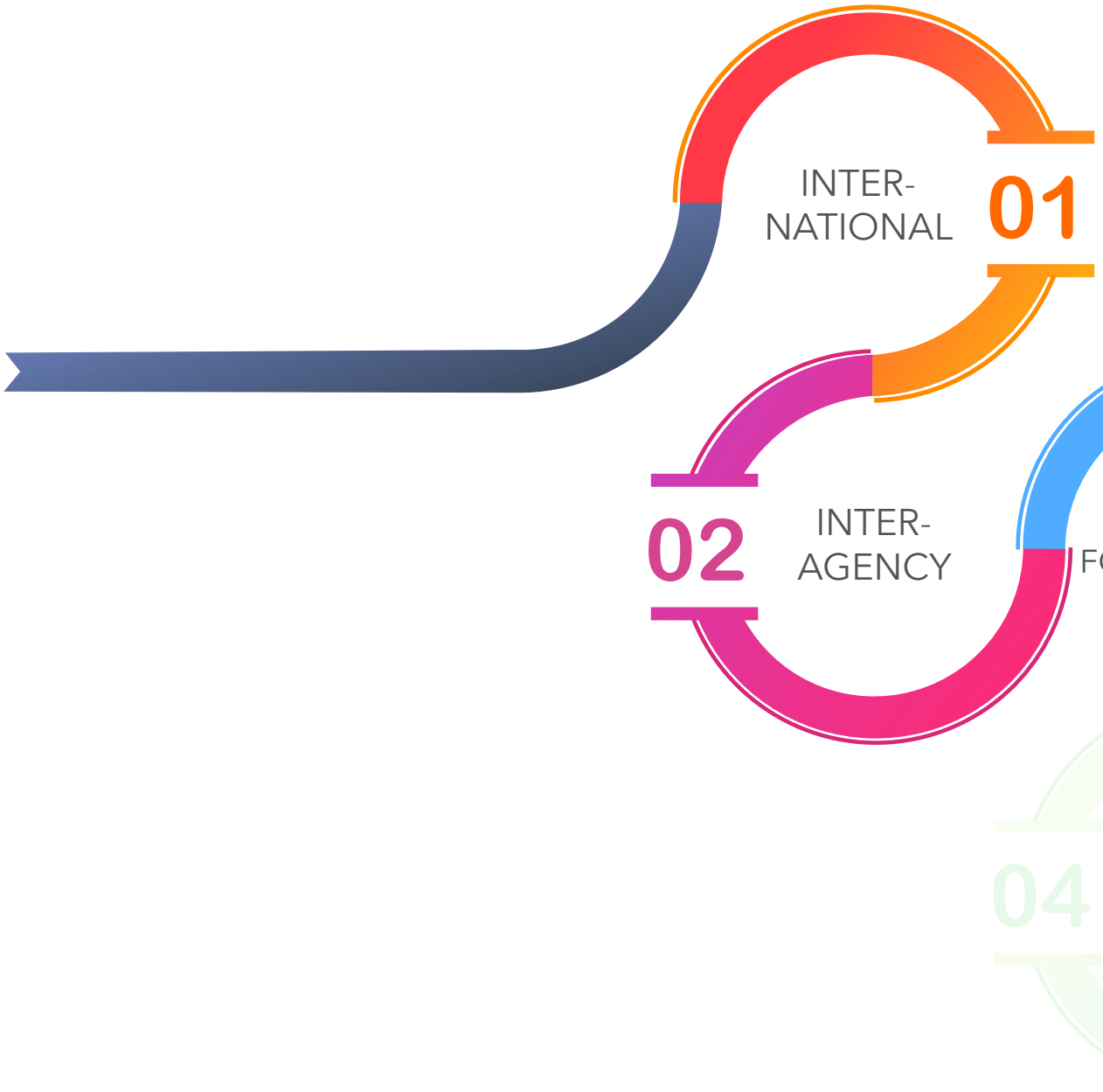

INTER-
NATIONAL
01
02
INTER-
AGENCY
RESEARCH
FOUNDATIONS,
ACADEMIA
03
04
COMMERCIAL



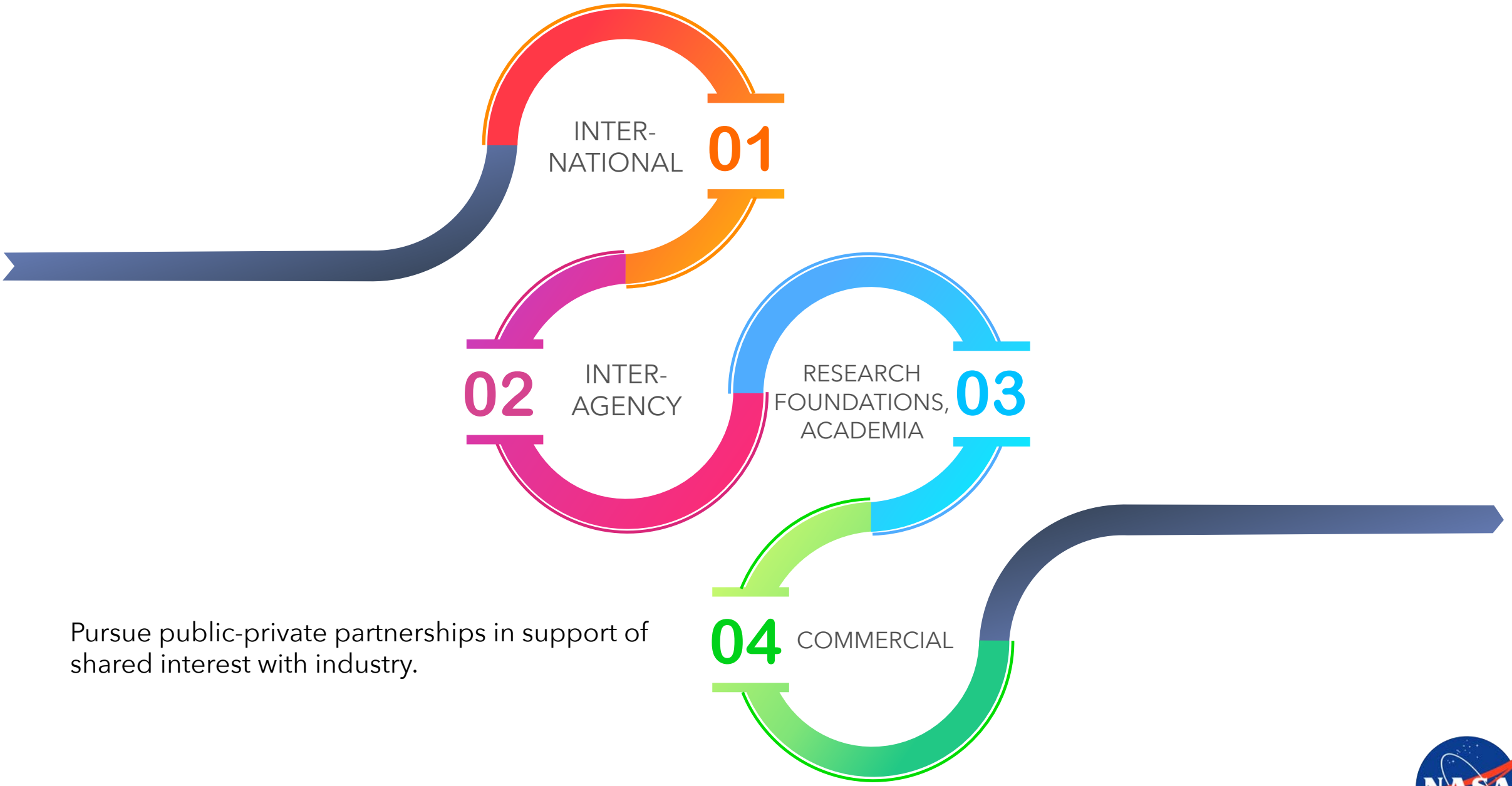
Excellent means of global engagement.
Based on mutual scientific goals.
Better for the worldwide astronomical community.
Can make missions more affordable.
No exchange of funds.



Engage with other Federal agencies to pursue partnerships that further national interests (e.g., NN-EXPLORE). Can be challenging for flight missions due to different project management cultures.

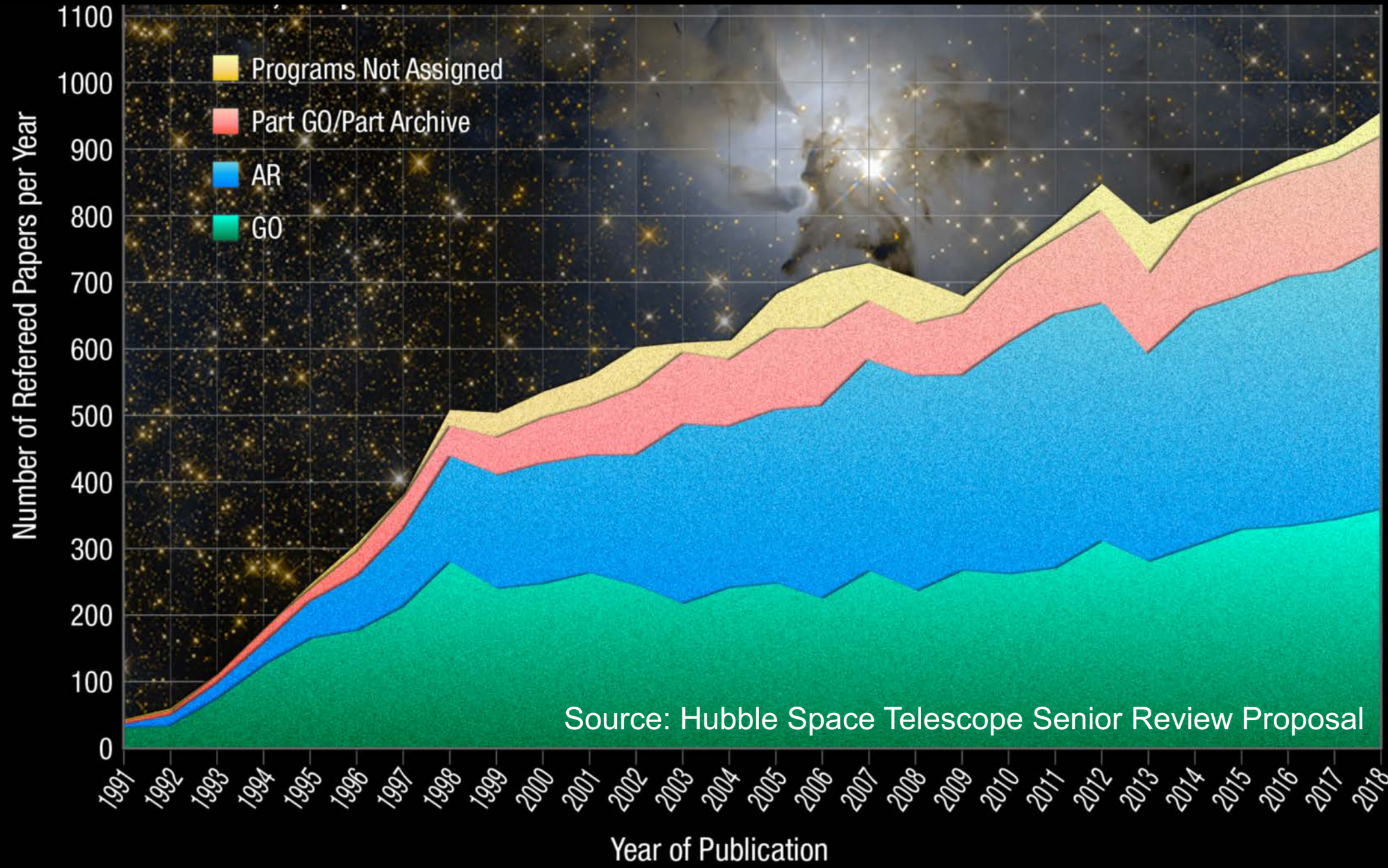


Provide opportunities for research institutions, including academia and non-profits, to contribute to NASA Science's mission. Astrophysics has signed multiple SAAs.



Pursue public-private partnerships in support of shared interest with industry.

Astrophysics Archives

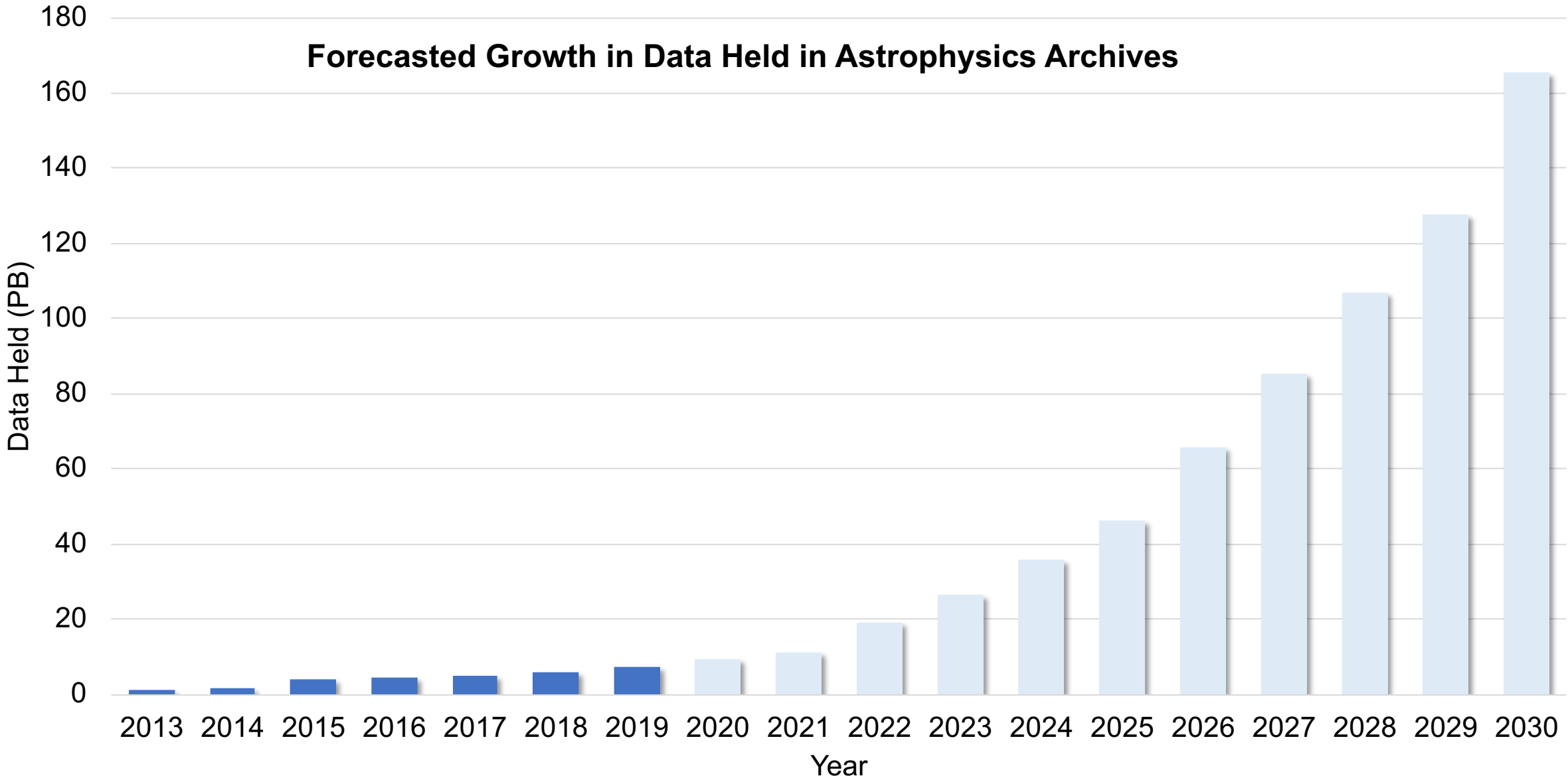

Programs Not Assigned
Part GO/Part Archive
AR
GO
Number of Refereed Papers per Year
0
100
200
300
400
500
600
700
800
900
1000
1100
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year of Publication
Source: Hubble Space Telescope Senior Review Proposal

Astrophysics Archives

Archiving and data handling are integral parts of NASA's Astrophysics missions

NASA invests approximately $20M per year in Astrophysics archives (HEASARC/LAMBDA, MAST, NED, IRSA, ADS, NEA)

NASA additionally invests in rapid alerts (GCN)


Forecasted Growth in Data Held in Astrophysics Archives
Data Held (PB)
180
160
140
120
100
80
60
40
20
0
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
Year

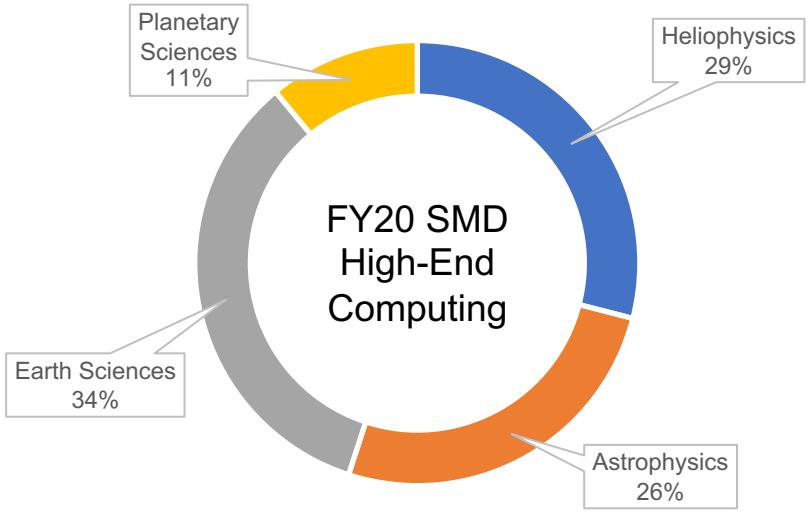
Future of Astrophysics Archives

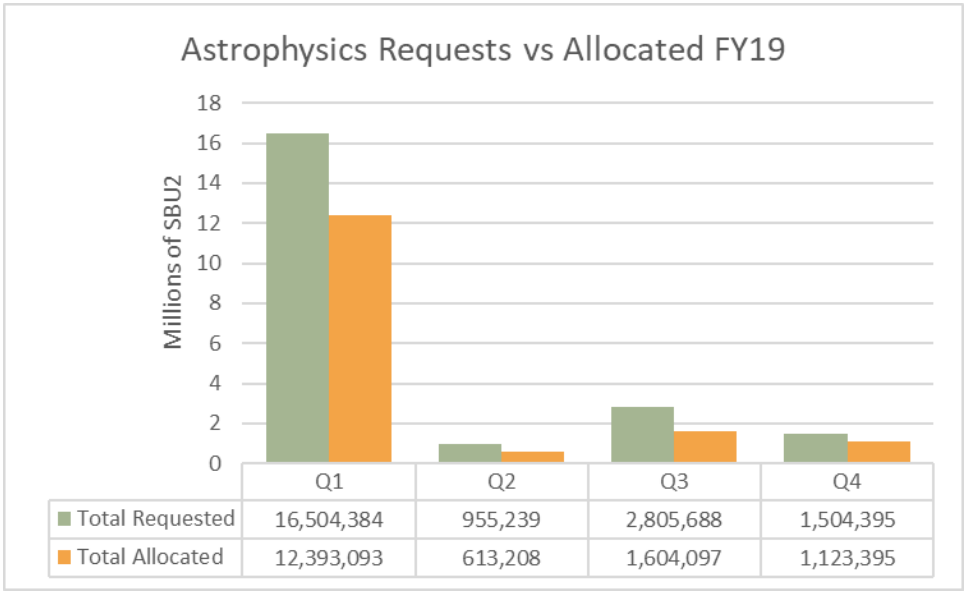
NASA is studying the evolution of the Astrophysics Archives and we are looking for input from the Decadal Survey on what should be done, with the understanding that the funding comes from the “Decadal Survey wedge.”

- Data sets will soon become too large for scientists to download; it will become more efficient for researchers to bring their analysis code to the data.
- MAST and IPAC have performed test cases using the cloud.
- WFIRST will likely be the tipping point.

Data Science and Supercomputing

Q. What Fraction of Agency Supercomputing Resources Goes To Astrophysics?





	Q1	Q2	Q3	Q4
Total Requested	16,504,384	955,239	2,805,688	1,504,395
Total Allocated	12,393,093	613,208	1,604,097	1,123,395

Q. Is There Any Concern That This Time Allocation Could Disappear if Center Priorities Change?

No. SMD, rather than a NASA Center, manages the supercomputing capability on behalf of the agency. Each Mission Directorate has its own allocation; SMD further divides its allocation per division.

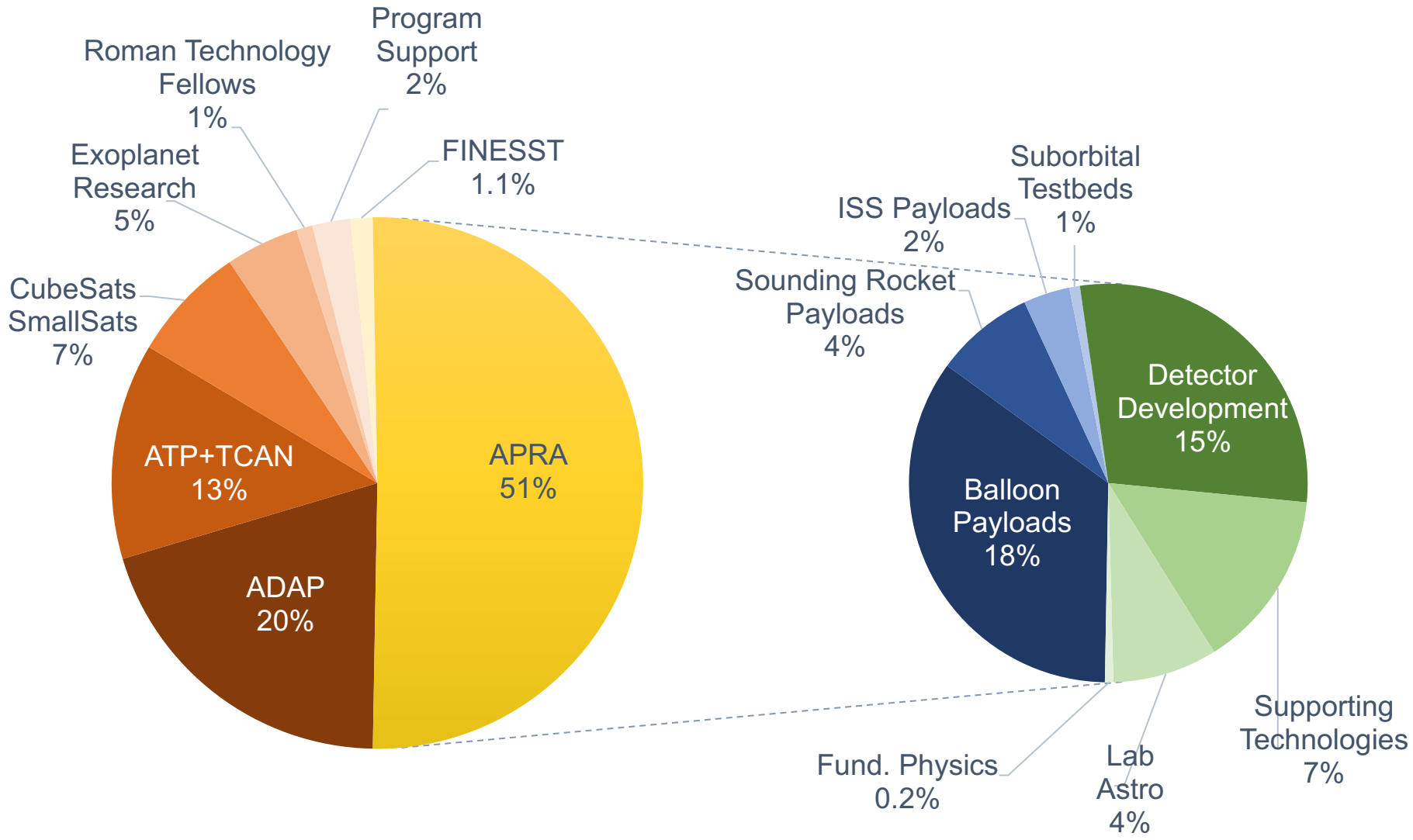
Q. Does NASA Astrophysics Have A Machine Learning Initiative?

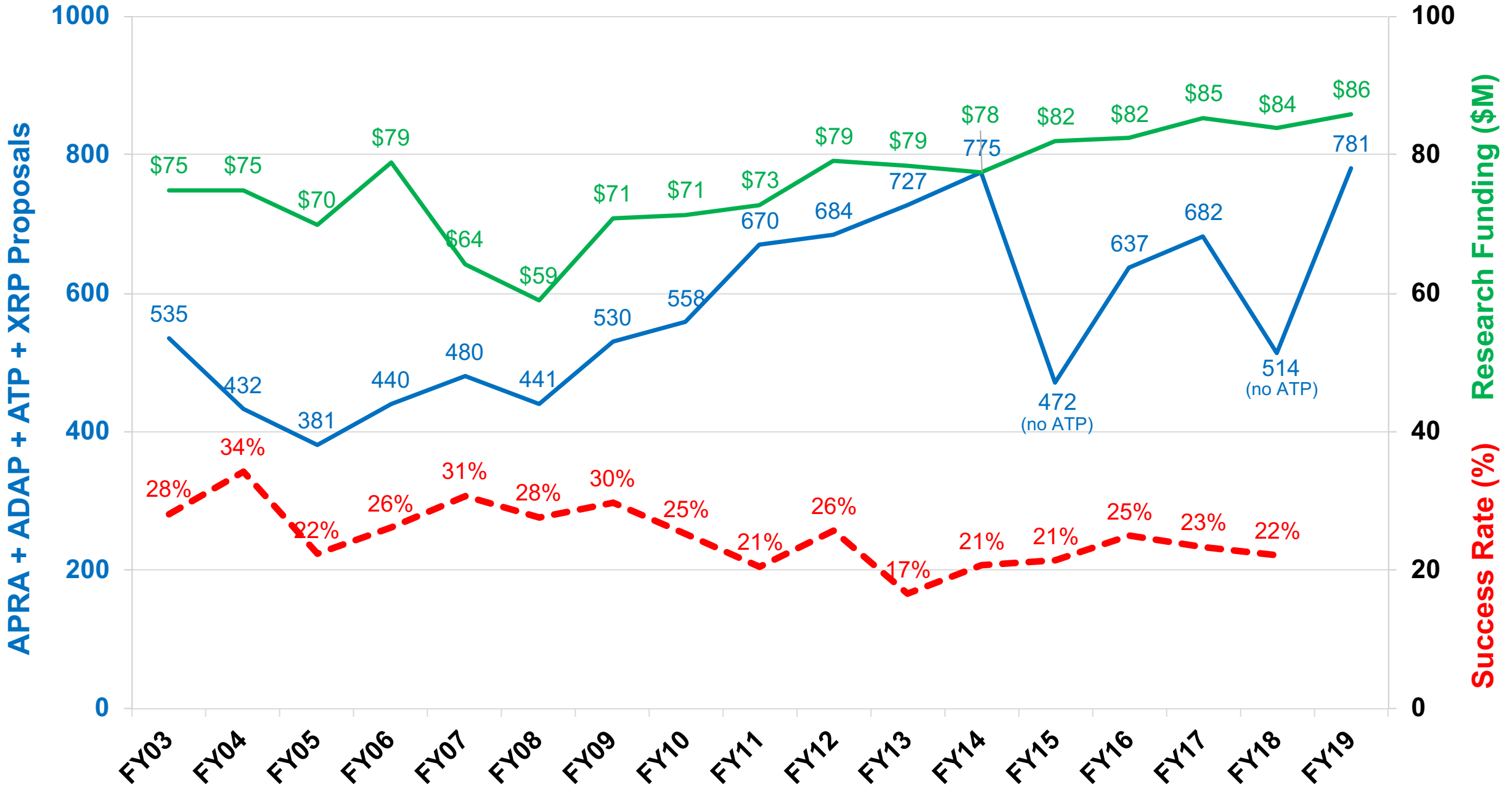
- Our support for data science, including machine learning, is embedded in all of our Research and GO programs; it is not a separate program
- Philosophically, NASA Astrophysics is concerned about balkanization; we have three broad programs (ADAP, APRA, and ATP), which allows us to be flexible with new trends in data science


NASA
EXPLORE
with us

Backup

FY19 R&A Elements
(excludes GO Programs and SAT)




APRA + ADAP + ATP + XRP Proposals
Research Funding ($M)
Success Rate (%)
1000
800
600
400
200
0
100
80
60
40
20
0
FY03
FY04
FY05
FY06
FY07
FY08
FY09
FY10
FY11
FY12
FY13
FY14
FY15
FY16
FY17
FY18
FY19
$75
$75
$70
$79
$64
$59
$71
$71
$73
$79
$79
$78
$82
$82
$85
$84
$86
535
432
381
440
480
441
530
558
670
684
727
775
472
(no ATP)
637
682
514
(no ATP)
781
28%
34%
22%
26%
31%
28%
30%
25%
21%
26%
17%
21%
21%
25%
23%
22%

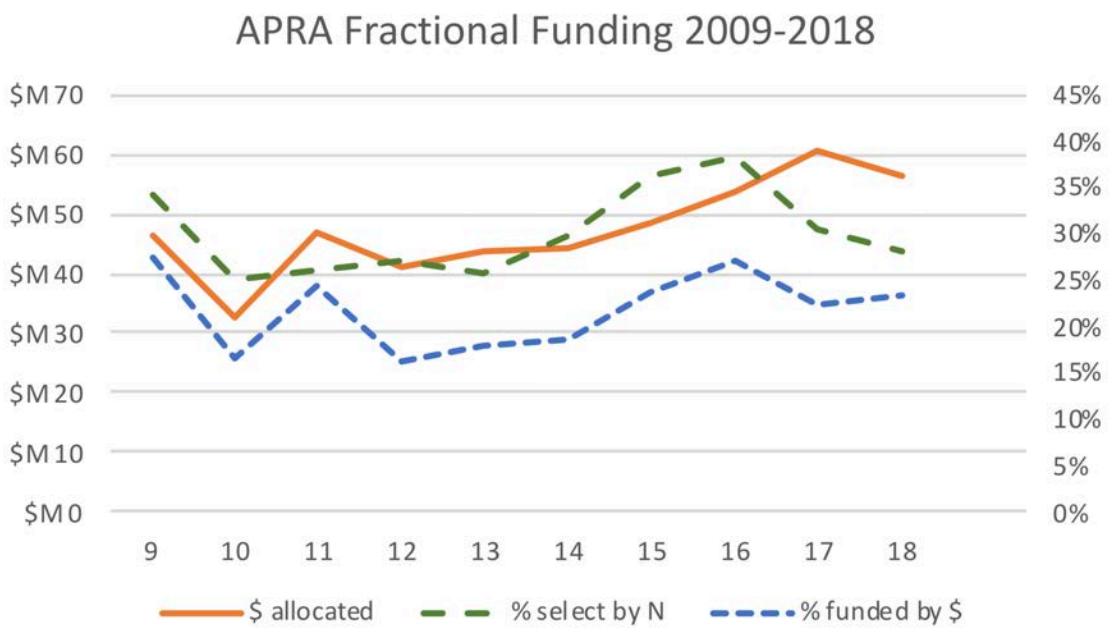


Figure 1. Spending (orange) in each selection year along with selection rates by number (green) and funding (blue). This shows the trend of increasing funding but the selection rates do not appreciably change.

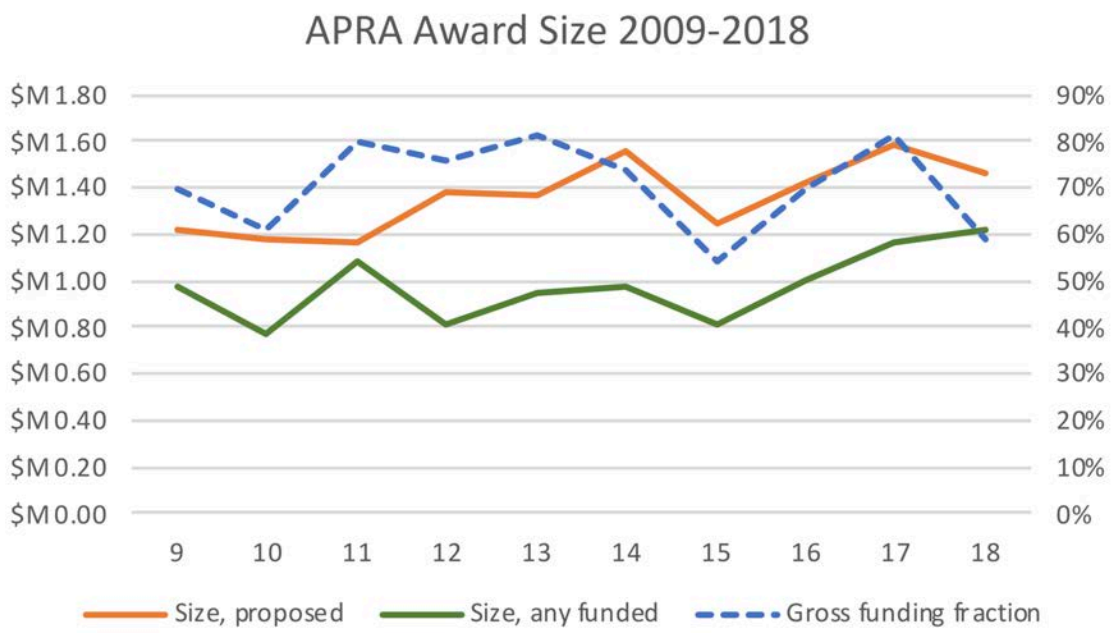
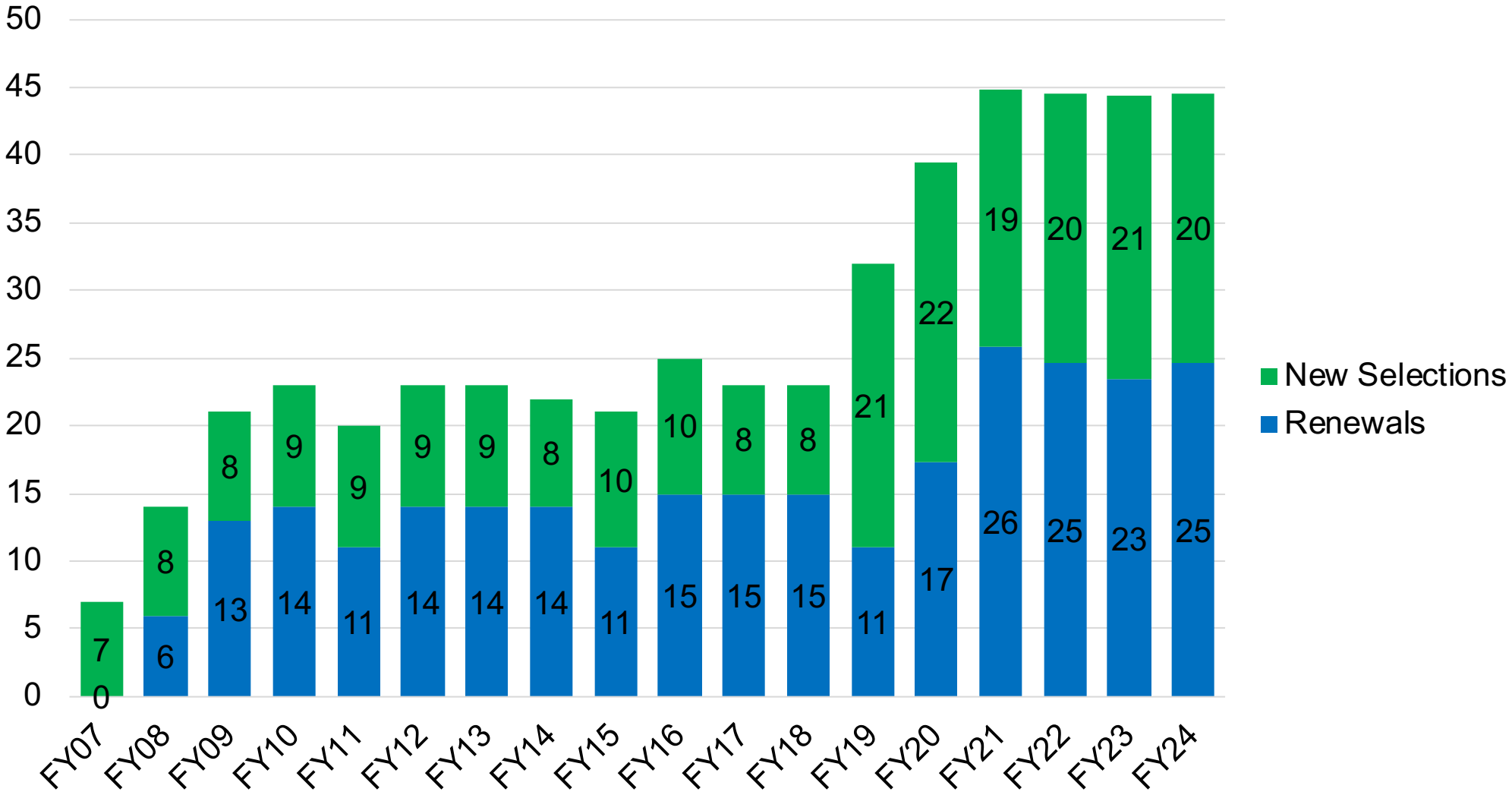
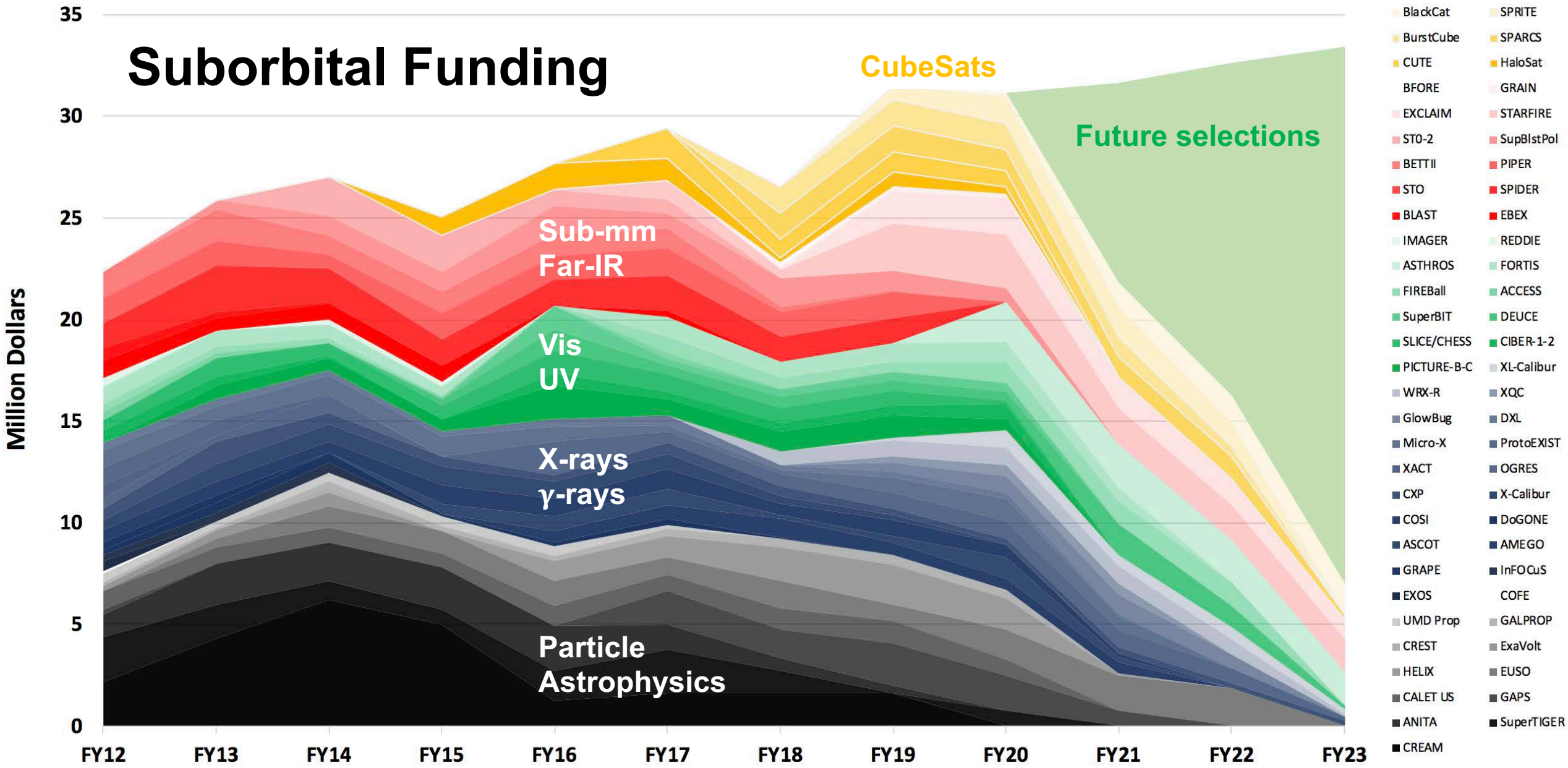


Figure 2. Average proposed (orange) and awarded (green) size of grants in each selection year. This shows a slight increase in the size of proposed investigations, but also a similar increase in the size of awards. The fraction of each award's request that we fund has been roughly constant, at ~70%.

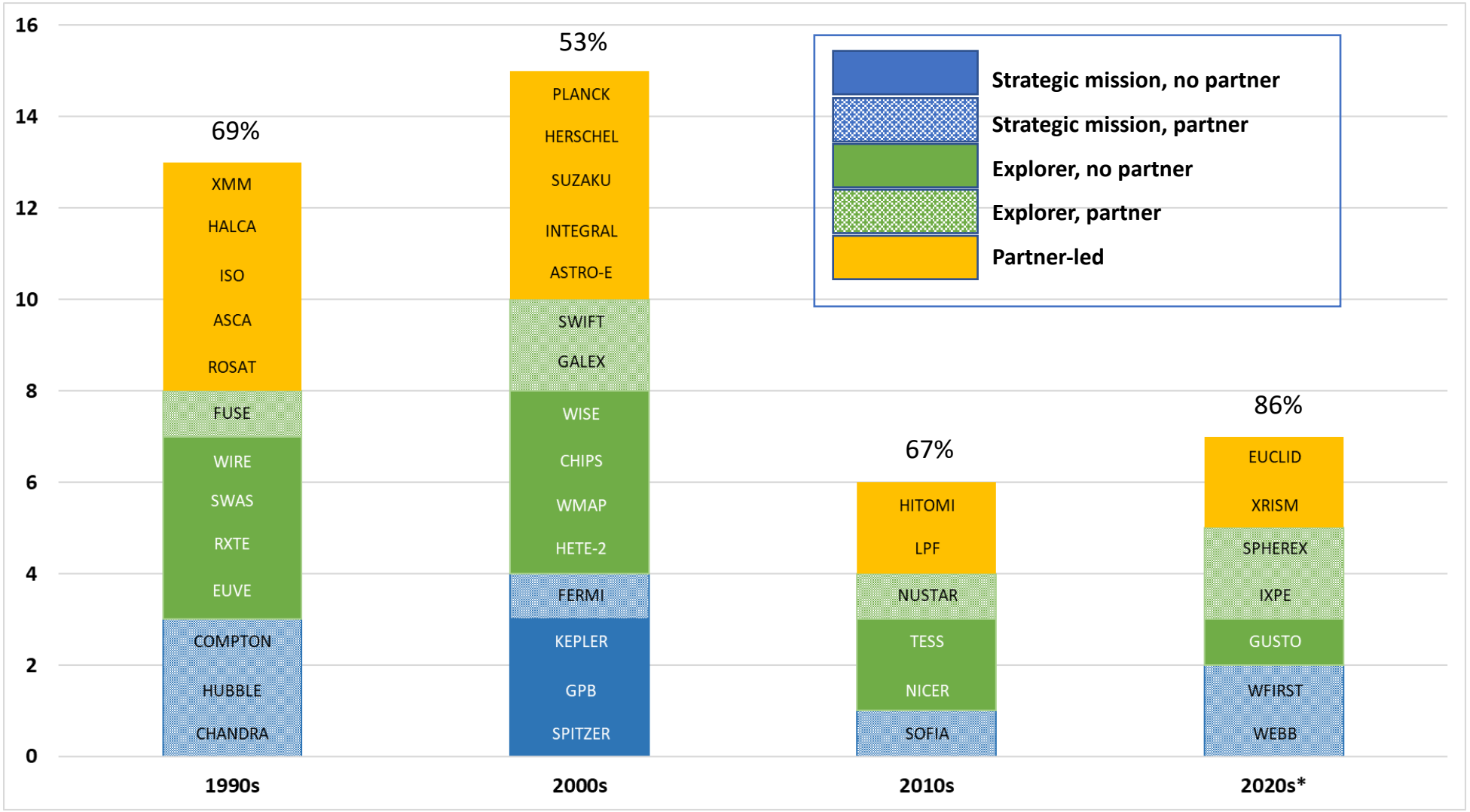
Growth in FINESST Funding



Suborbital Funding

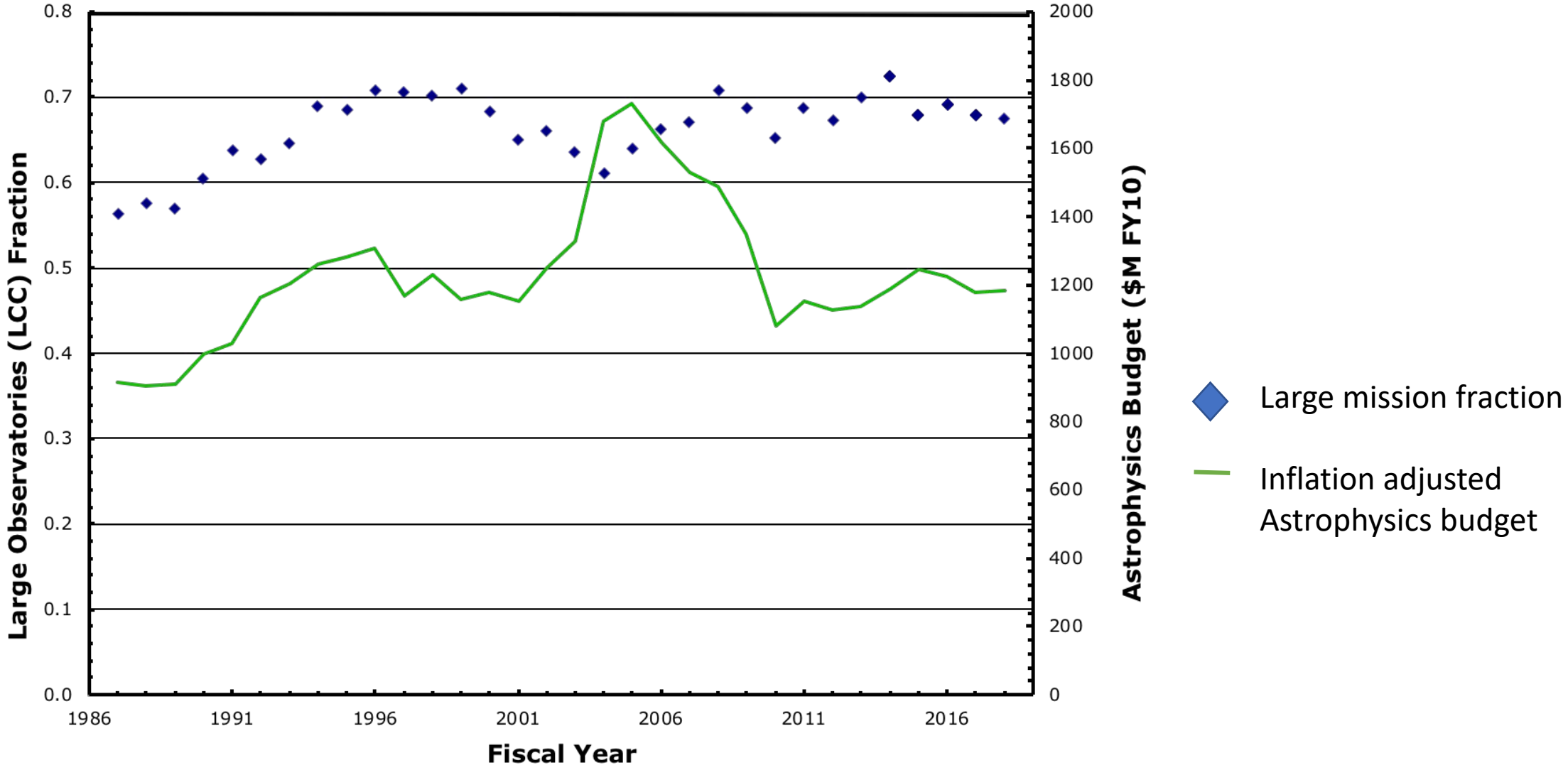


History of International Partnerships



* through WFIRST (2025)
* does not include unselected SMEX and MO missions

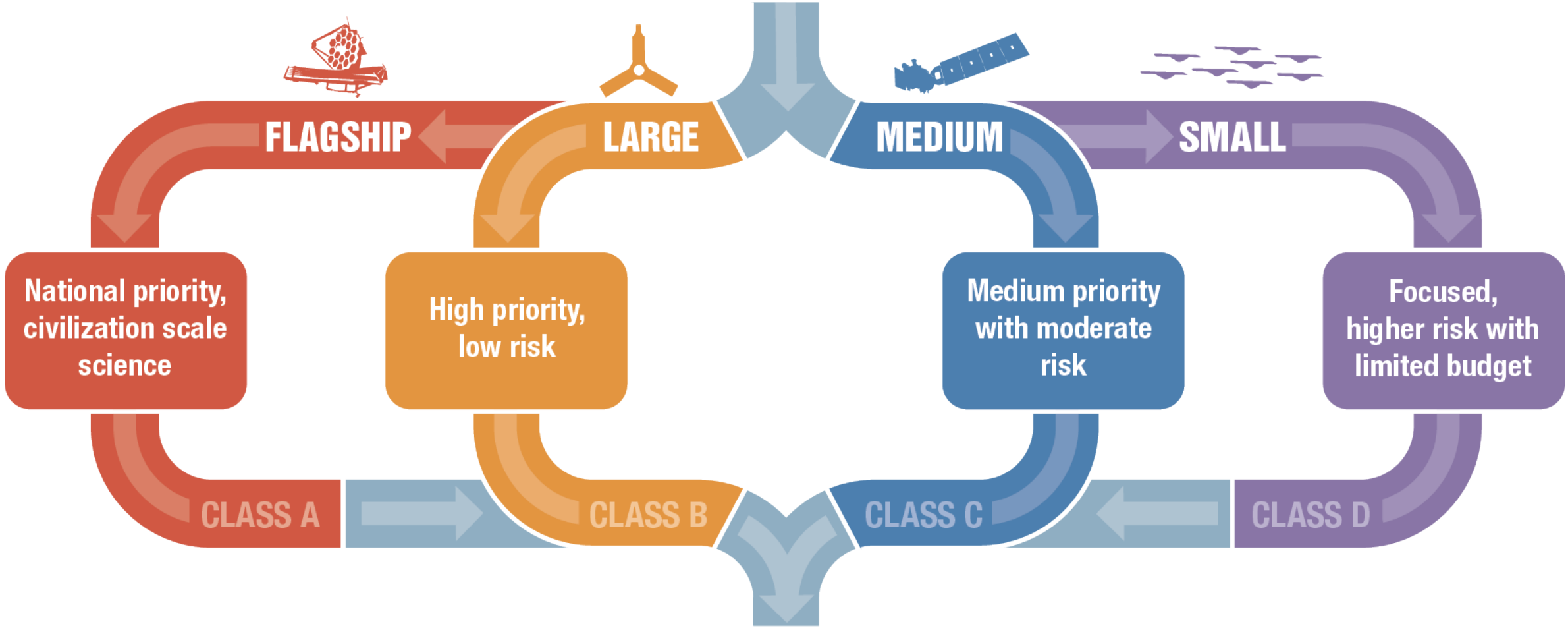
Flagship Fraction of Astrophysics Budget



Building Excellence

- Excellent teams bring diverse opinions and perspectives
- SMD is supporting early-career scientists to build careers working with NASA
- SMD is encouraging development of future leaders, including the next generation of mission principal investigators, through targeted outreach and hands-on opportunities
- We are attracting and retaining talent by promoting a culture that actively encourages diversity and inclusion and removes barriers to participation

BALANCED MISSION PORTFOLIO



GREAT SCIENCE

Astrophysics Division Statistics within the High-End Computing Program

Current HECC Capability

HECC Hardware Assets

5 Compute Clusters

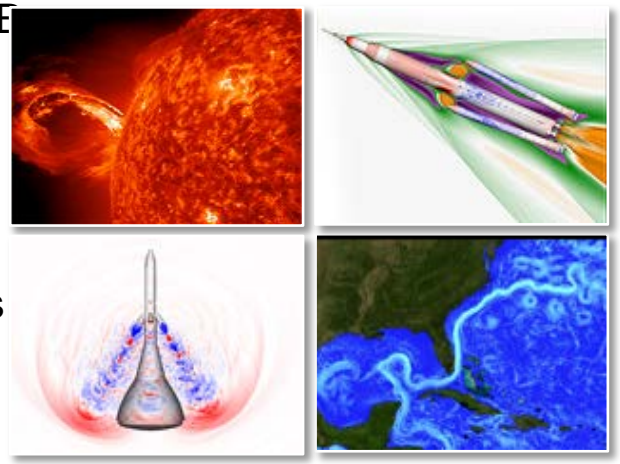
- Pleiades 158 ½ Racks / 11,215 nodes / 7.85 PF / 8,222 SBU/hr
- Electra 24 Racks / 3,422 nodes / 8.32 PF / 4,815 SBU/hr
- Aitken 4 E-Cells / 1,152 nodes / 3.69 PF / 2,290 SBU/hr
- Merope 56 ½ Racks / 1,792 nodes / 252 TF / 520 SBU/hr
- Endeavour 3 Racks / 2 nodes / 32 TF / 44 SBU/hr

1 Visualization Cluster 245 million pixel display / 128 node / 703 TF

10 Lustre File Systems 46.0 PB

6 NFS File Systems 1.5 PB

Archive System 1,000 PB



D-Wave 2000Q quantum system

- Whistler processor with 2031 qubits

NAS Facility Extension

- A one-acre site with 30 MW power to house HPC systems in modules.

HECC Services

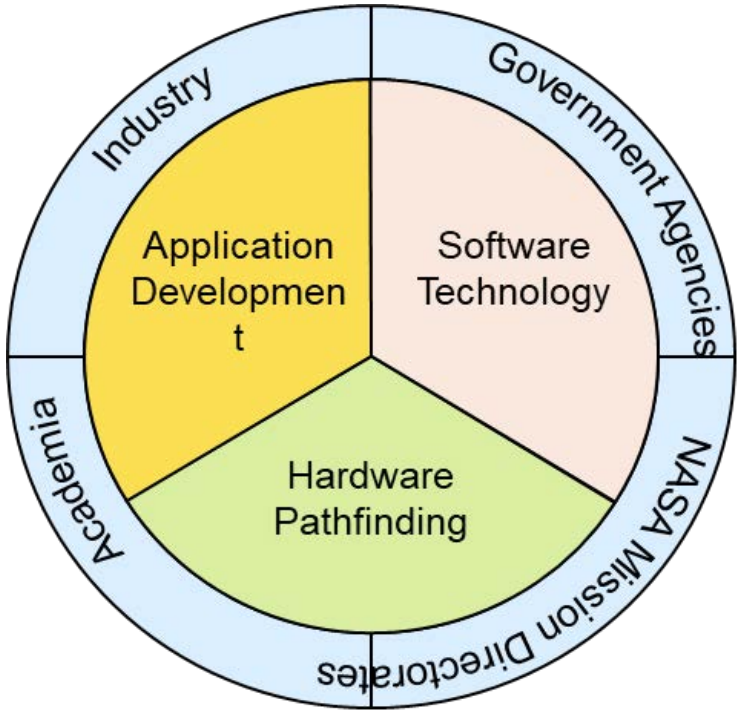
HECC provides a suite of complimentary services to the user community to enhance the scientific and engineering results obtained from the hardware assets.

- Systems: Customized solutions including compute and storage solutions to meet specific project or mission requirements. Cloud access for immediate or non-standard computing.
- Application Performance and Productivity: Software solutions provided to research/engineering teams to better exploit installed systems.
- Visualization and Data Analysis: Custom visualization during traditional post-processing or concurrent during simulation to understand complex interactions of data.
- Networks: End-to-end network performance enhancements for user communities throughout the world.
- Data Analytics: Exploitation of data sets through neural nets and emerging new techniques.
- Machine Learning: Custom environments to enable learning through advanced data techniques.
- Custom Data Gateways: Custom data portals to support diverse programs and projects.

Preparing for the Future

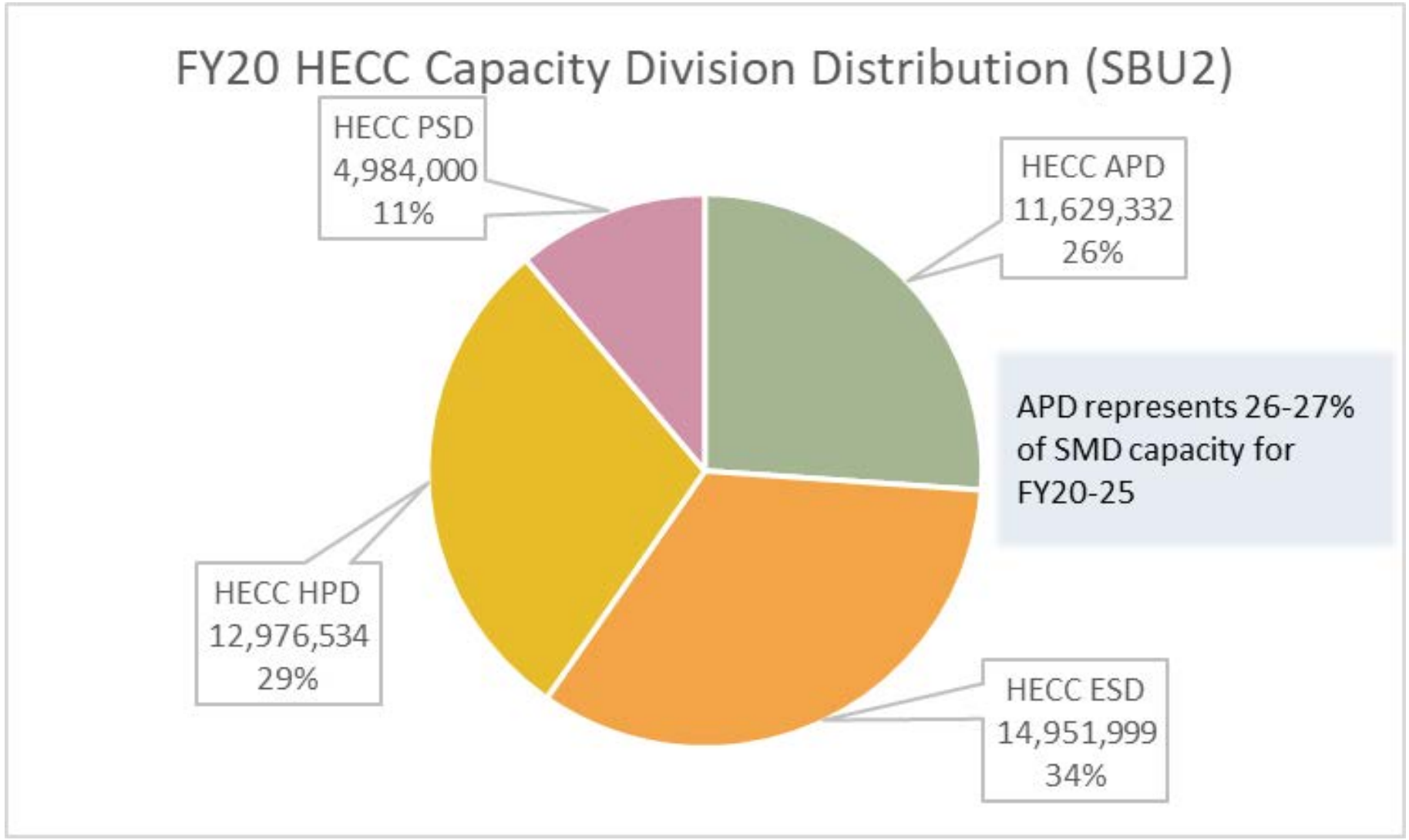
- New algorithms to match hardware realities.
- Mixed precision and machine learning/AI in computation.
- New methods in visualization and data analytics.
- Application enhancements to exploit I/O advancements.
- Fault resilience.
- Performance optimization.

- Examine requirements.
- Develop necessary benchmarks.
- Assess I/O approaches.
- Develop models to predict performance.
- Make recommendations for pathfinding systems.

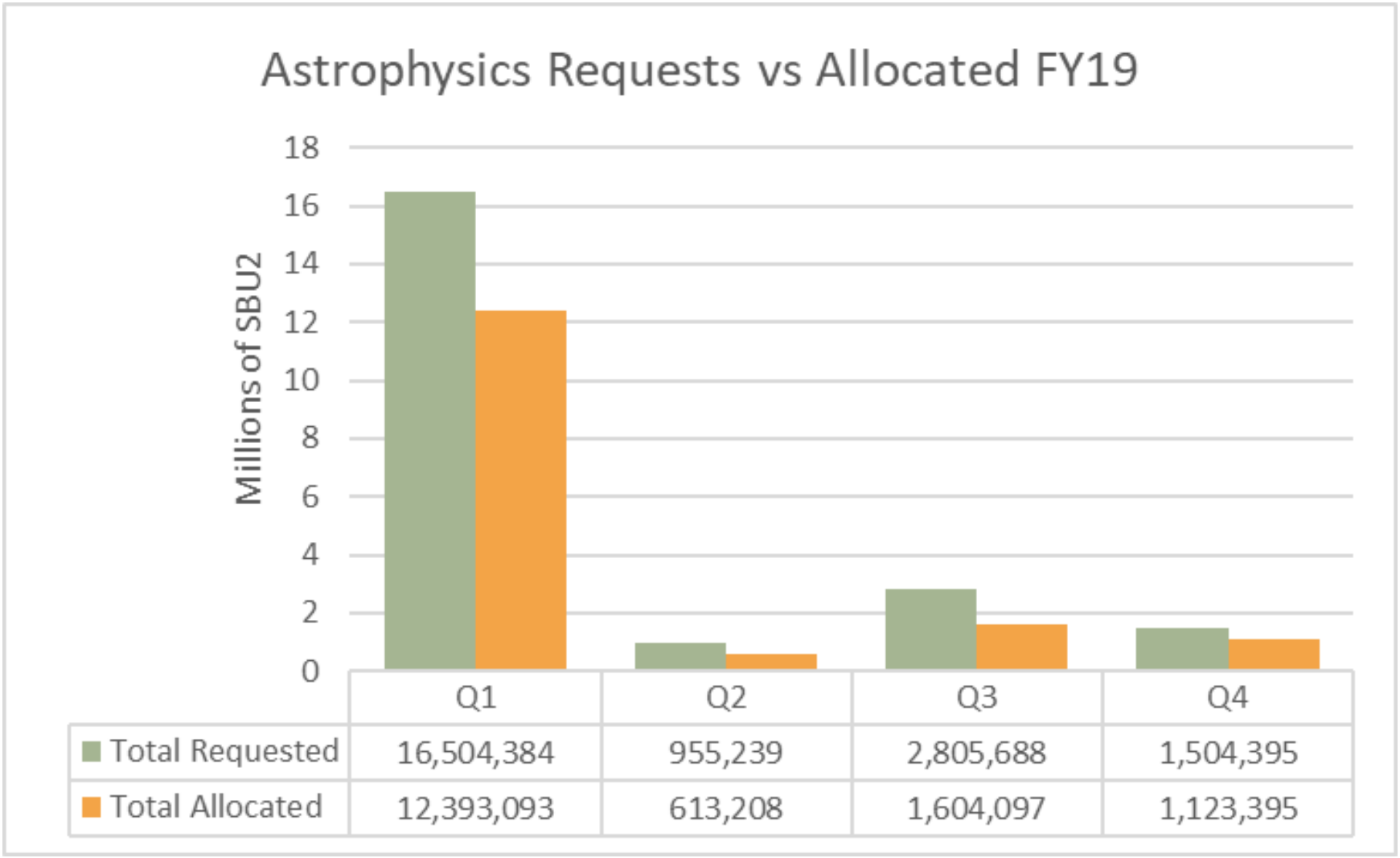


- Research and develop programming approaches, for accelerated and non-accelerated architectures.
- Optimize and port techniques/tools.
- Optimize and port techniques/tools for visualization, data analytics, AI, and machine learning.
- Research and develop efficient math libraries.
- New file system software technologies.
- Research and develop machine learning techniques for problem solving and system error tracking/prediction.
- Evaluate software packaging technology, such as containers.

FY20 SMD HECC Resource Distribution

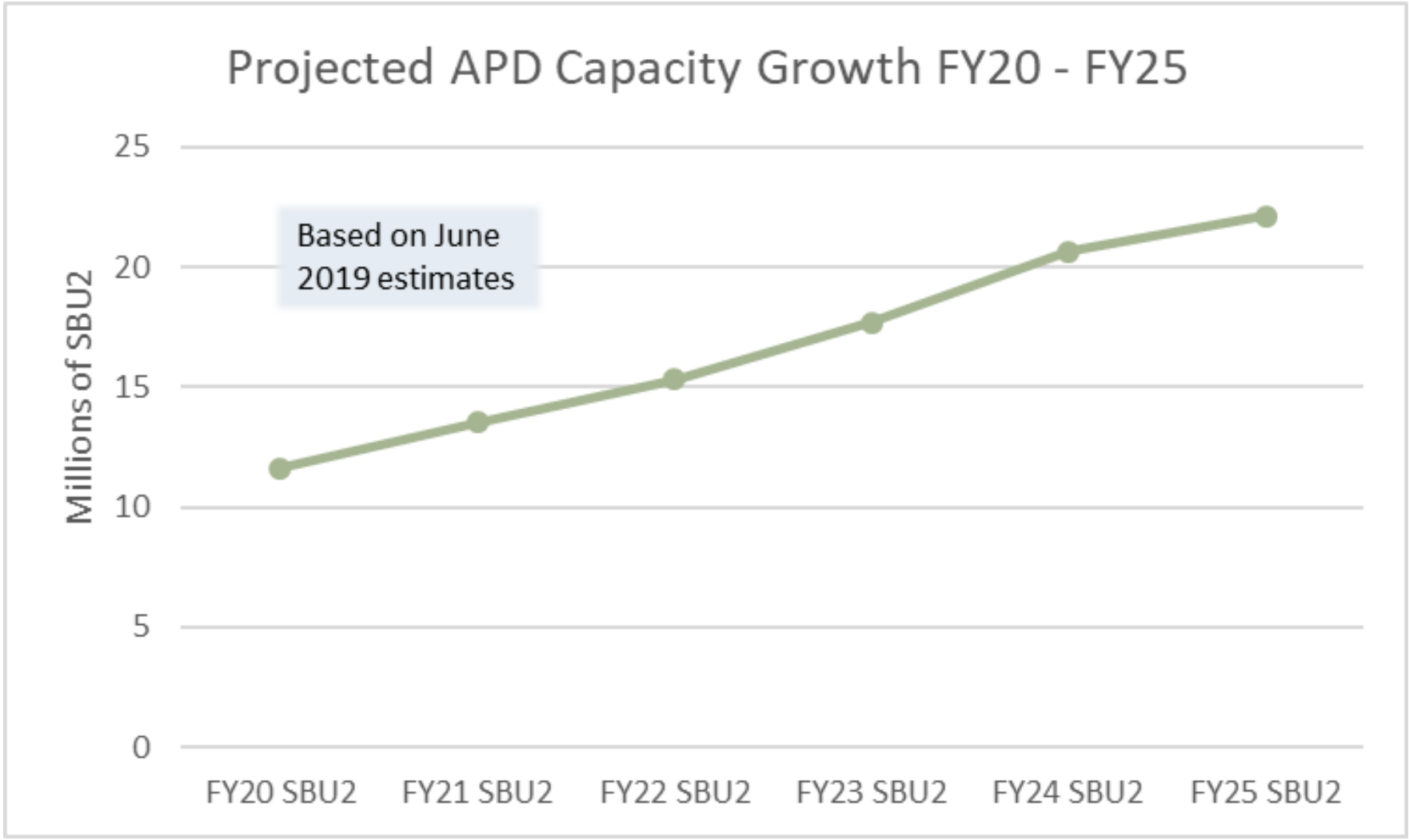


FY19 Astrophysics Requests vs Allocated



	Q1	Q2	Q3	Q4
Total Requested	16,504,384	955,239	2,805,688	1,504,395
Total Allocated	12,393,093	613,208	1,604,097	1,123,395

Projected APD Capacity Growth



ROSES Requests by Solicitation (91M SBU2)