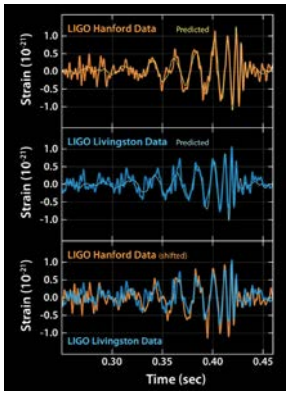
NSF: Astro 2020

Ralph Gaume
Saul Gonzalez
Vladimir Papitashvili



Outline

- NSF Goals for Astro2020
- Notional NSF Budgets: Construction and Operations
- Highlights of AST Response to Astro2010
- Highlights of AST Program Status
- PHY Perspective
- OPP Perspective
- Science, Big Ideas, Summary

NSF Goals for Astro2020

NSF Goals for Astro2020

- Astro2020 will be most effective if it is *aspirational, inspirational,* and *transformative.*

- Astro2020 will be most effective if it is based on *community consensus science priorities*.

- The agencies are the *customers*. Astro2020 will be conducted independently of the customer, but must provide *recommendations, clear priorities,* and *actionable advice* to the customer.

NSF Goals for Astro2020

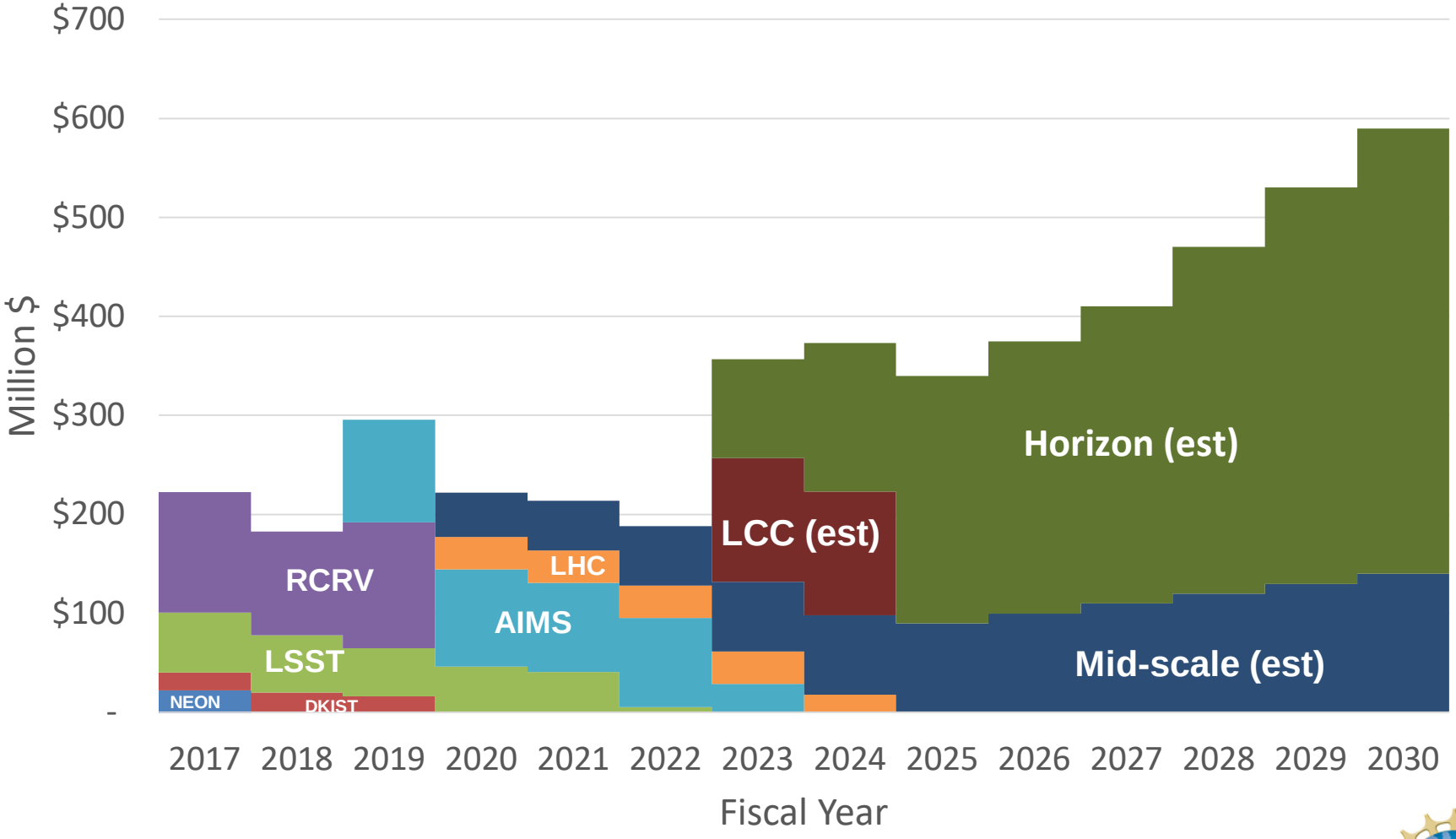
- NSF wants to know:
  - What are science priorities for next decade?
  - What projects address these priorities?
  - Which projects are ready to go now and later? When?
  - What are costs, risks, development needs of projects?
  - What is the priority order for these projects?
  - What budgets are needed to support the priorities, and are they realistic?

NSF Goals for Astro2020

- NSF wants to know (continued):
  - How does the current NSF portfolio address priorities?
  - What is the state of the profession?
    - Recommendations for the agencies.
  - Division specific:
    - AST: Decision rules for MSIP.
    - PHY: Welcome recommendations on promising Technology R&D for next gen. facilities
- Let NSF sweat implementation details.
  - One NSF Astronomy/Astrophysics program
- Provide clear priorities with explanatory decision rules leading to the priorities.

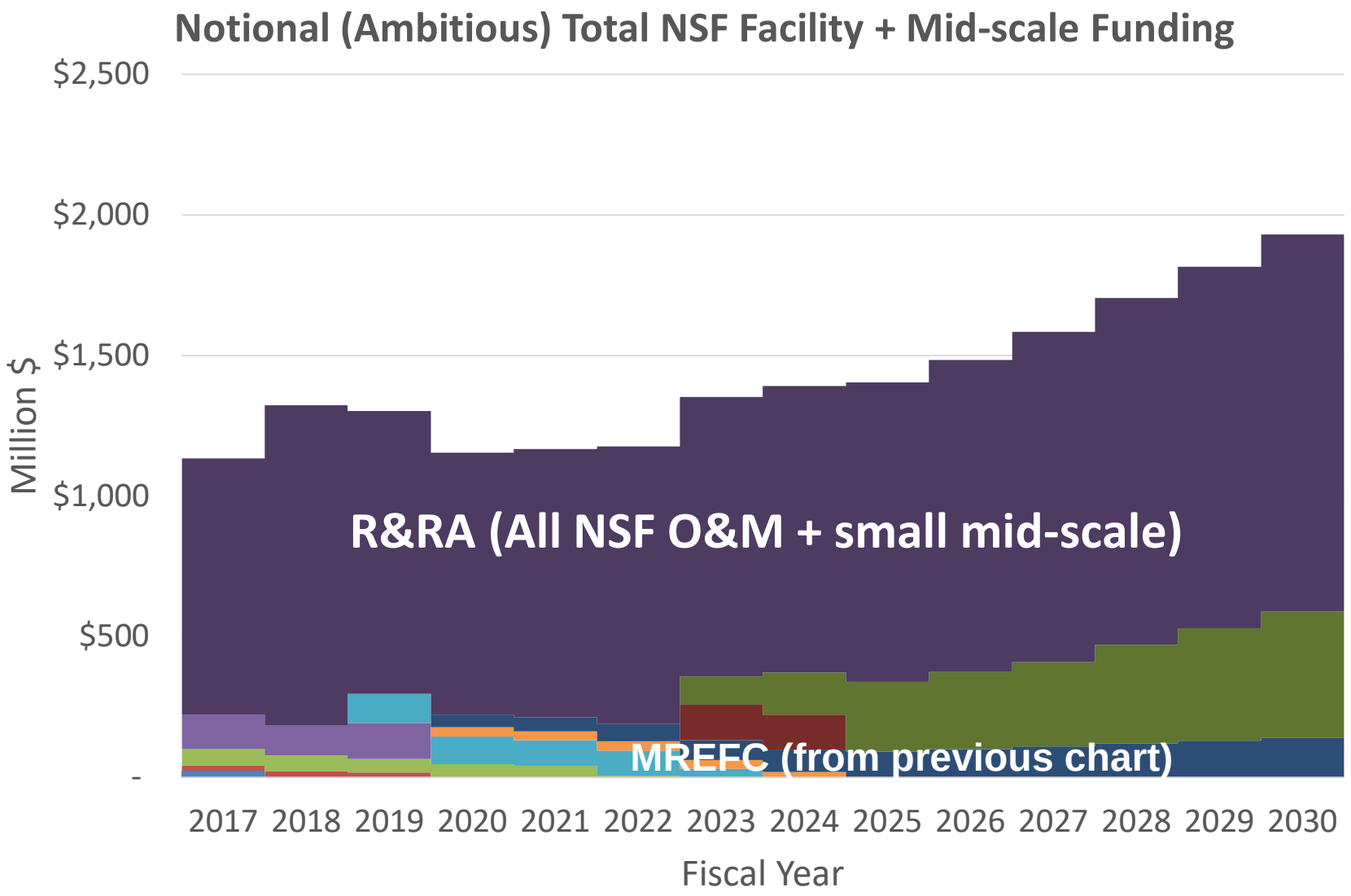
Notional NSF Budgets: Construction and Operations

Notional (Ambitious) Future NSF MREFC Account Profile



NSF Operations and Maintenance

- NSB: Study of O & M costs for NSF Facilities May 2018
- Recommendation 1: *NSB and the NSF Director should continue to enhance agency-level ownership of the facility portfolio through processes that elevate strategic and budgetary decision-making.*
  - *…a scientifically robust Foundation-wide strategy that is both transparent and fiscally responsible is critical.*
  - *Planning horizons that are longer than the current 5-year projections required by statute could inform this strategy. The Department of Energy's Office of Science has found notable success using a 10-year planning model.*
  - *While NSB does not believe that it is necessary to establish a central O&M account at this time, greater flexibility in use of the MREFC account would enhance visibility and agency-level ownership.*


Notional (Ambitious) Total NSF Facility + Mid-scale Funding
$2,500
$2,000
$1,500
$1,000
$500
-
Million $
R&RA (All NSF O&M + small mid-scale)
MREFC (from previous chart)
2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030
Fiscal Year

Highlights of NSF Response to Astro2010

Astro2010: Recommendations for new large projects

- Priority 1: LSST
  - In construction phase, operations ramp began in FY 2019, beginning 10-yr survey in FY2023.

LSST Current Construction Site

On budget and on schedule for full operations in FY 2023.

Astro2010: Recommendations for new large projects

- Priority 1: LSST
  - In construction phase, operations ramp began in FY 2019, beginning operations in FY2023.

- Priority 2: Initiate MSIP, reach annual budget of $40M/yr
  - Constrained budget and priority choices led to $15-$20M/yr in alternate year solicitations during mid-decade
  - FY 18 appropriation allowed $25M/yr
  - MSRI-1 and 2 hold the potential for further AST support
  - MSIP will be continued as well as MSRI, potential for MSRI to replace MSIP in future years. Decision rules for MSIP?

- Other large project priorities not addressed due to budgetary constraints. (CTA team was instructed to apply to MSIP.)

Astro2010: Medium project and other

- Medium Project:
  - CCAT → a wide field-of-view 25m telescope to be constructed near ALMA.
  - Astro2020 estimated total construction cost at $140M.
  - Astro2020 recommended NSF share of construction $37M.
  - Astro2020 recommended $7.5M/year NSF share of operations.
  - Funding was insufficient for to address CCAT, CCAT team instructed to apply to MSIP.
- Other:
  - Conduct mid-decadal progress study on Astro2010 recommendations. NWNH: A Midterm Assessment.
  - Conduct Senior Review of AST portfolio prior to mid-decadal. AST Portfolio Review (2012).

Astro2010: Recommendations for AST core program

- ATI – 50% increase over $10M/yr.
  - Budgetary limitations reduced to ~$8M every other year.
- AAG – increase to $54M/yr.
  - Dipped to $42M in FY13, recovered to $51M in FY18.
- Gemini augmentation - gain increased share for slight increase in budget.
  - That was essentially the outcome of the UK withdrawal.
- TSIP – increase from $2-3M/yr to $5M/yr.
  - TSIP program discontinued; subsumed in MSIP as recommended by Portfolio Review.
- Theory and Computation Networks – fund at $2.5M/yr.
  - Joint solicitation with NASA, one round funded, then folded into AAG due to funding constraints.
  - Several programs jointly funded with CISE.
  - HDR Big Idea is latest agency-level commitment.

Highlights of AST Program Status

AST Division Programs

Individual Investigators

Mid-scale

Facilities

AAG

* CAREER

AAPF

ATI

* MRI

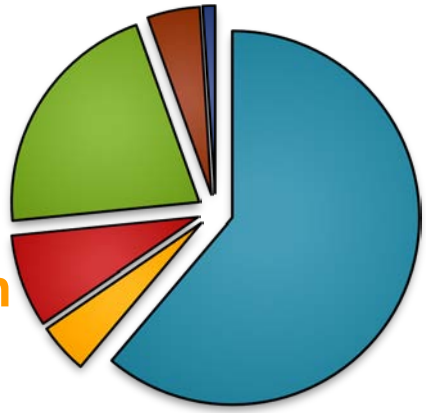
* REU

Research

Technology/ Instrumentation

Education and Special Programs

MSIP



ALMA

NRAO

Gemini

NOAO

LSST

Arecibo

NSO

GBO

* NSF Wide

NSF and AST Support for Workforce

- NSF has provided leadership in ensuring the research and learning environments its supports are free from harassment.
  - Awardee organizations must notify NSF of findings, determinations, admin leave and/or action for funded PIs and CoPIs.

- NSF recognizes the need to promote a diverse and inclusive workforce in our quest to promote the progress of science.

- NSF and AST: AAPF, CAREER, INCLUDES, RUI, REU sites, GRFP, HBCU, EPSCoR, Educ. and Special Pgms, facility awardee's programs

Forefront Facilities

- Radio-Millimeter-Submillimeter
  - Atacama Large Millimeter-Submillimeter Array
  - Jansky Very Large Array
  - Very Long Baseline Array
  - Green Bank Observatory
  - Arecibo Observatory
- Optical/Infrared
  - Gemini 8-m North and South (+Subaru exchange)
  - Blanco 4-m
  - SOAR 4.2-m
  - WIYN 3.5-m
  - Community access to SMARTS, LBT, CHARA, LCO, AAT
- Solar
  - GONG, SOLIS, DKIST

DKIST Telescope

- Telescope optics in place, M1 & M2 aligned.
- Current challenges largely with instrument completion and delivery, as well as data policy.
- Commissioning of thermal control loops also a significant task.
- Still on schedule and within budget contingency.

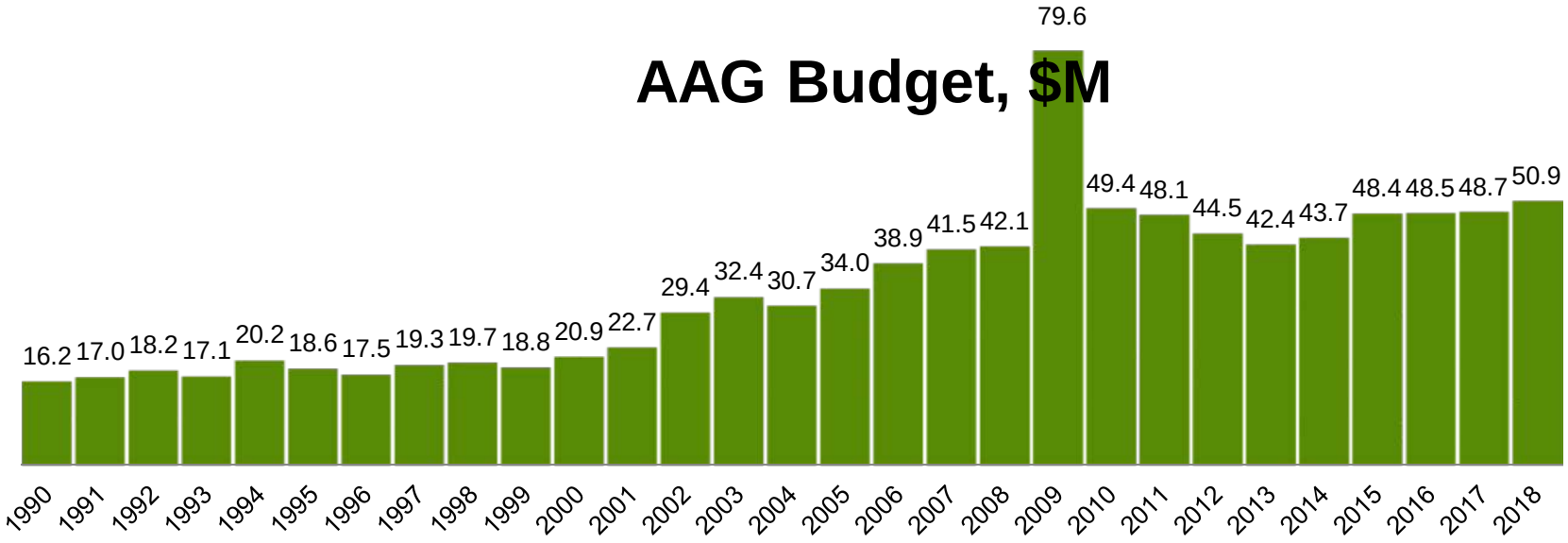
AST Facility Transition Summary

Telescope	Status
KPNO 2.1m	Caltech-led consortium operating for FY 2016-2020.
Mayall 4m	DESI; NSF to DOE; NSF/DOE MOA for operations .
WIYN 3.5m	NOAO share to NASA-NSF Exoplanet Observational Research Program; NSF/NASA MOU in place; NASA instrument under development.
GBO	Separation from NRAO in FY 2017; Collaborations in place for operations; MOA for new partner; more new partners desired.
LBO/VLBA	Reintegrated into NRAO; MOA with US Navy in place for 50%.
McMath-Pierce	Funding for utilization as science outreach center.
GONG/SOLIS	GONG refurbishment; Interagency Agreement with NOAA signed to share GONG operations costs. SOLIS moved from Kitt Peak to Big Bear.
Sacramento Pk.	Initial NSF and State funding for consortium led by NMSU; NSO to provide continuing site support; NSB approval for ROD.
Arecibo	UCF new operator, plans to increase funding share from UCF partners; hurricane recovery funding being deployed; staffing challenges.
SOAR	AAAC subcommittee recommended continuing renewal

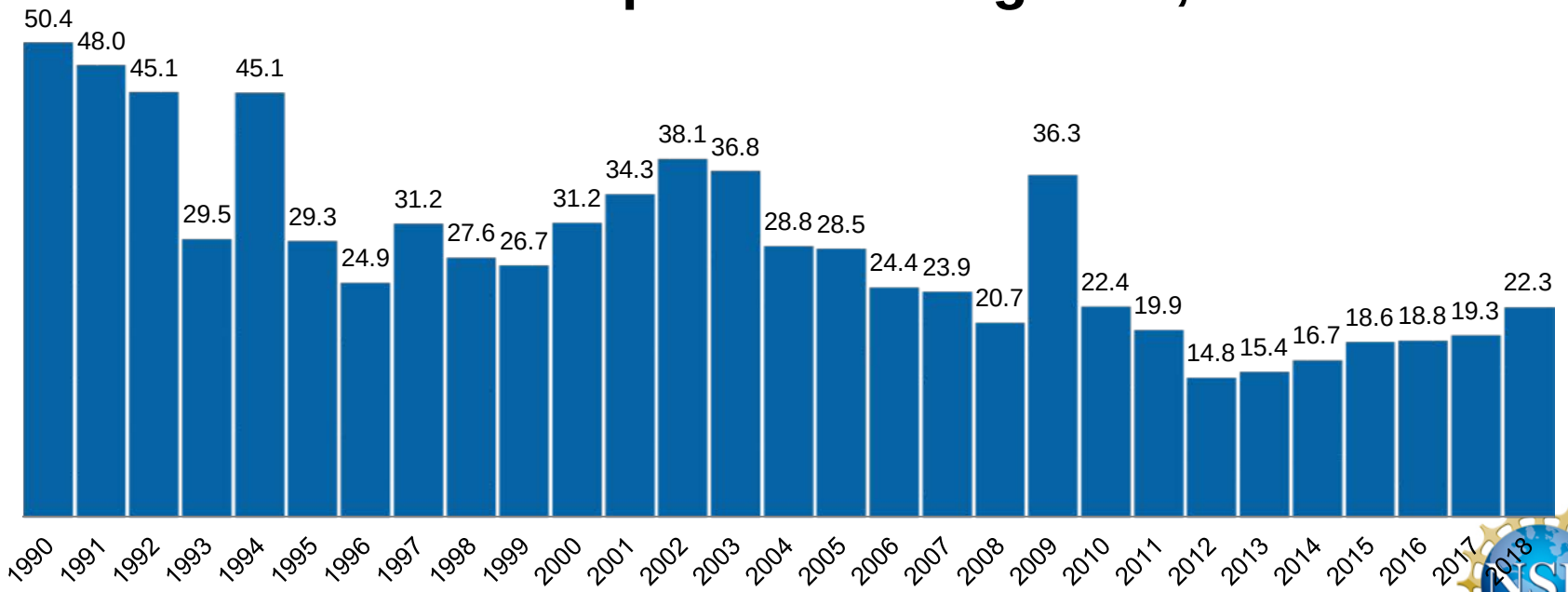
FY 2018 Budget (AST)

- Very good outcome in the end for AST – total $307M, compared to FY17 actual of $252M.
- Much of the increase went to one-time specific projects (some dependent on FY19 availability of funds to complete):
  - MSIP, for total funding close to aspirations in NWNH
  - Multi-messenger astrophysics grants
  - Major upgrade to Gemini N Adaptive Optics system in service of time domain follow-up, stellar populations studies
  - Early funding of DKIST operations for timely completion of data center, supplement for Level 2 data products.
  - Initial funding of LSST operations ramp for three years.

AAG Budget, $M

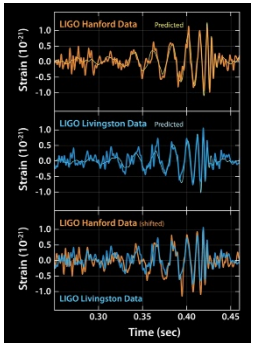


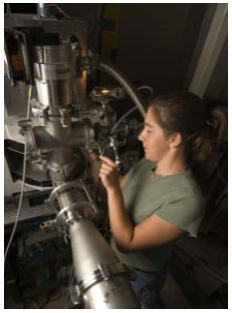
Proposal Funding Rate, %

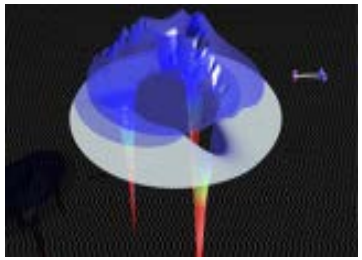


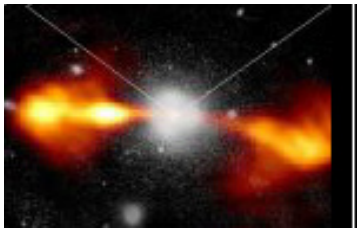
NSF FY 2019 Budget

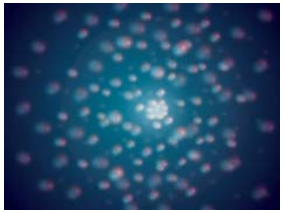
- Enacted appropriation increases R&RA by 3%.
- MREFC line re-incorporates Antarctic infrastructure; DKIST (final year, Ops begin June 2020) and LSST at requested levels.
- NSF's bill was not under consideration for passage before the end of FY 18, so operations after October 1, 2018 were under a Continuing Resolution until Dec 21st.
- Major 35-day shutdown challenge for NSF was maintaining flow of funds to facilities awardees, particularly those with Chilean labor contracts. OMB allowed cash draws for previously allocated funding, unlike the 2013 shutdown.
- FY 20 President's Budget Request public last winter. Now preparing FY 2021 PBR for release in early CY 2020.
- FY 2019 Directorate and Divisional allocations being executed (spend plan approved by Congress in June 2019). FY 2019 is not yet over, so will not discuss details of FY 2019 budget.



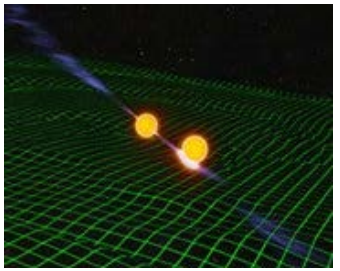


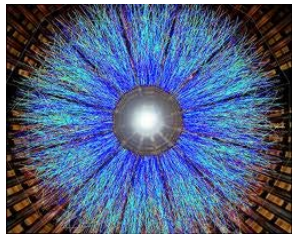


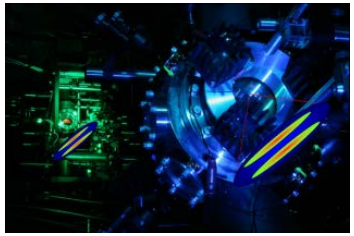


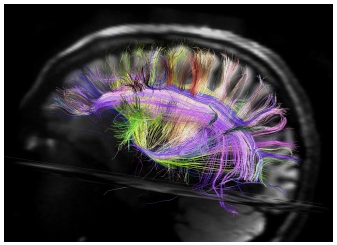


NSF Division of Physics Perspective

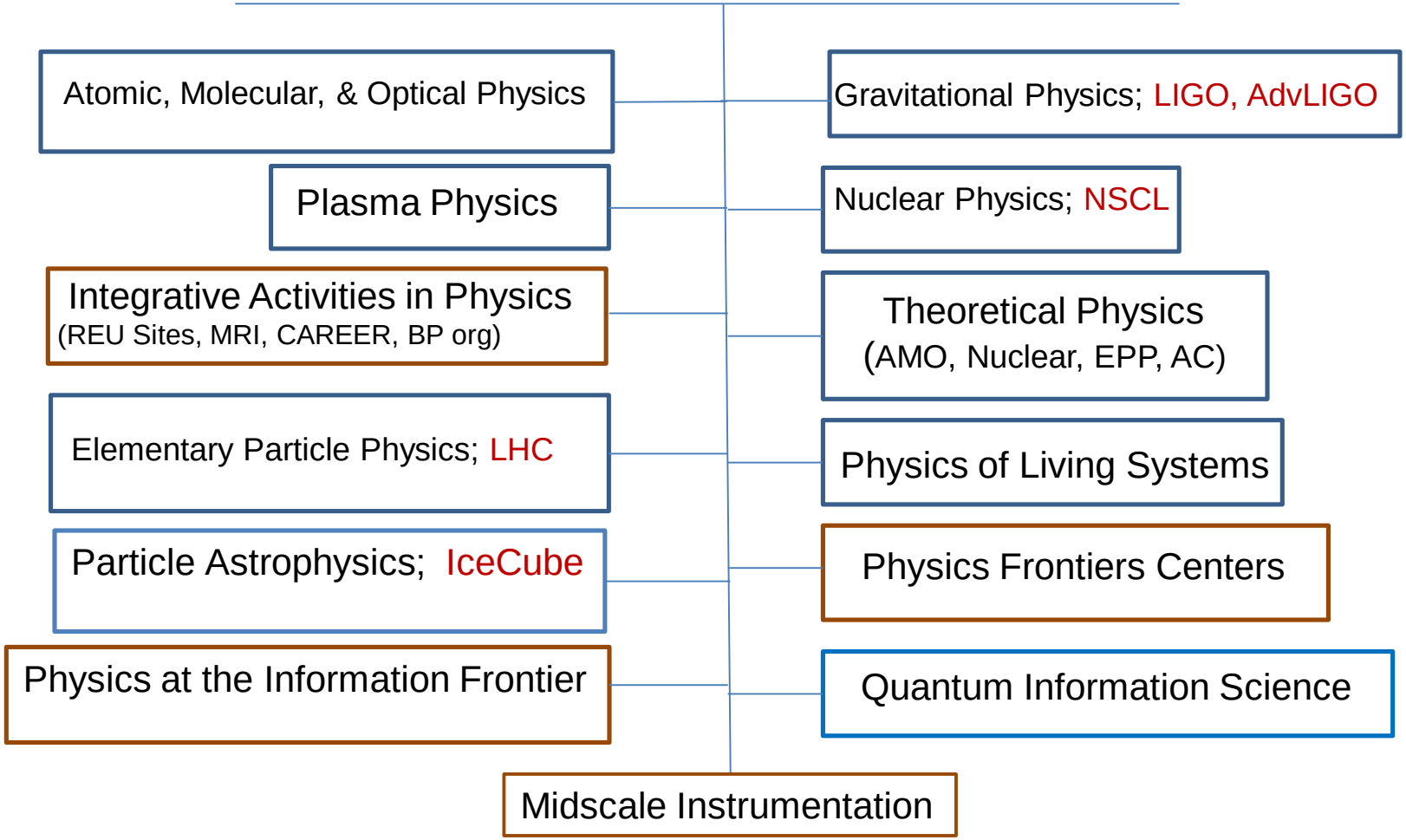




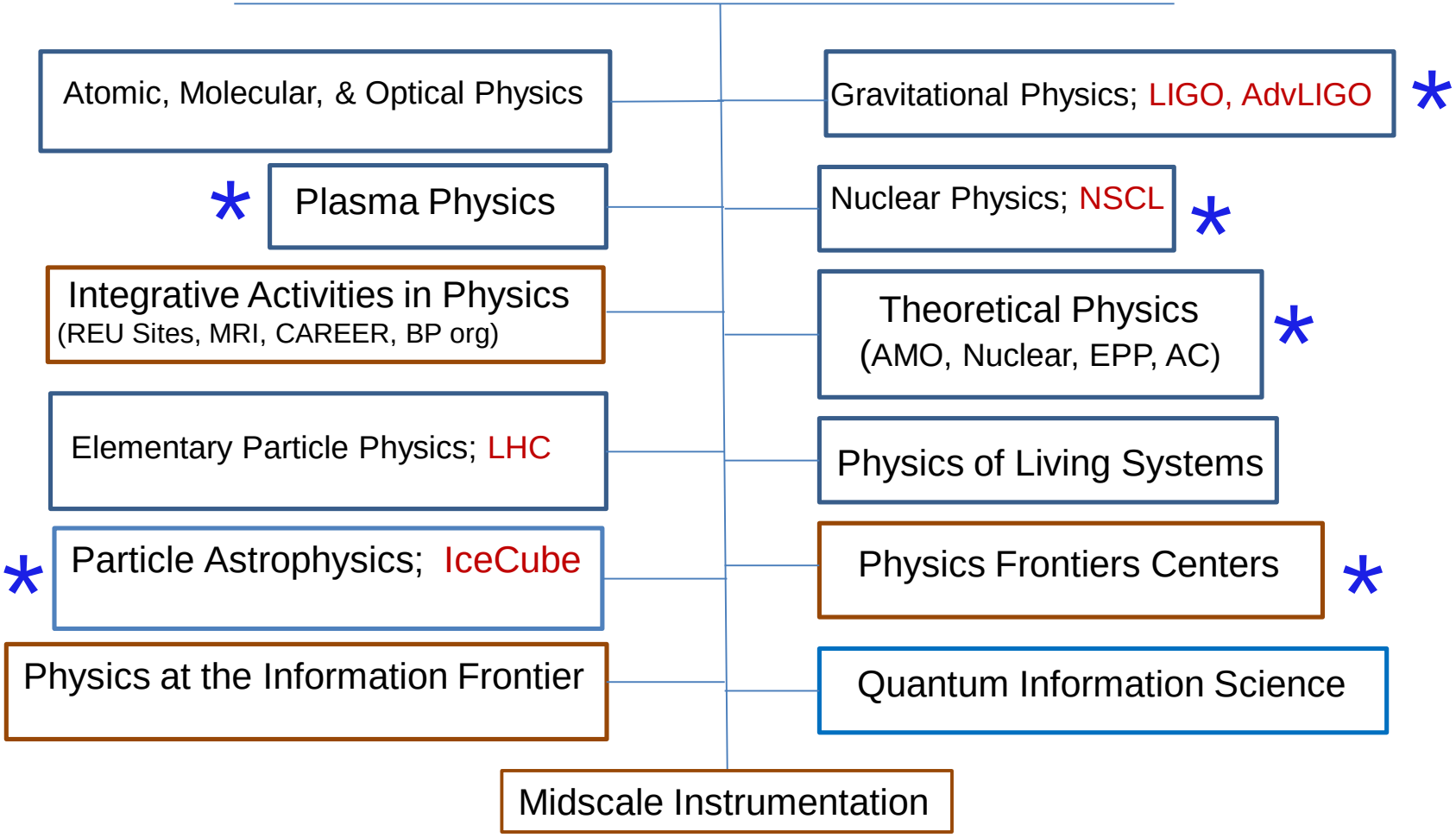




Division of Physics –2019 - Programs



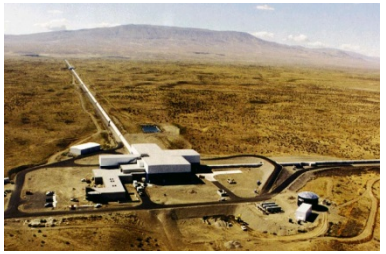
Division of Physics –2019 - Programs

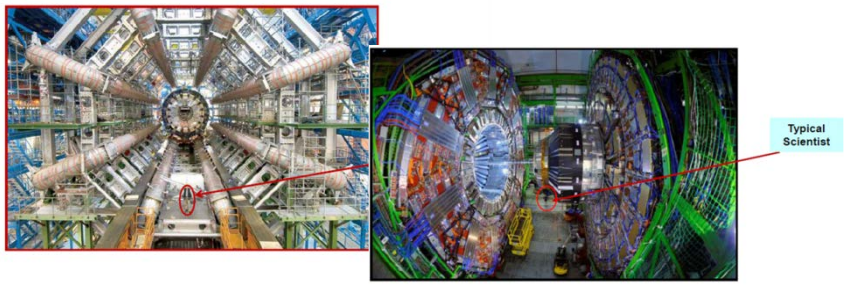


* Program with relevance to Astro2020

Facilities in the Physics Division

Laser Interferometer Gravitational Wave Observatory (LIGO)





ATLAS and CMS Detectors at Large Hadron Collider (LHC)

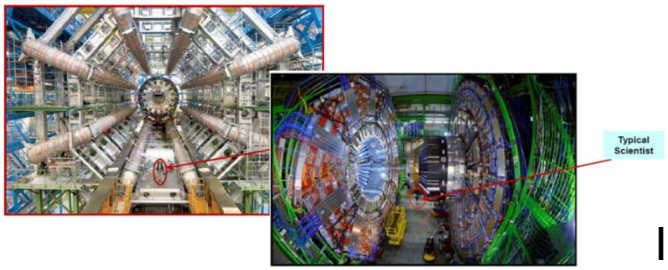
National Superconducting Cyclotron Laboratory (NSCL)

IceCube (joint with OPP)

Current Status of PHY Facilities

LIGO

O3 Run Started April 1; A+ Upgrade underway



LHC

Planning for MREFC High-Luminosity Upgrade Underway ($150 M);
IRIS Award to Address Computational Challenges

NSCL

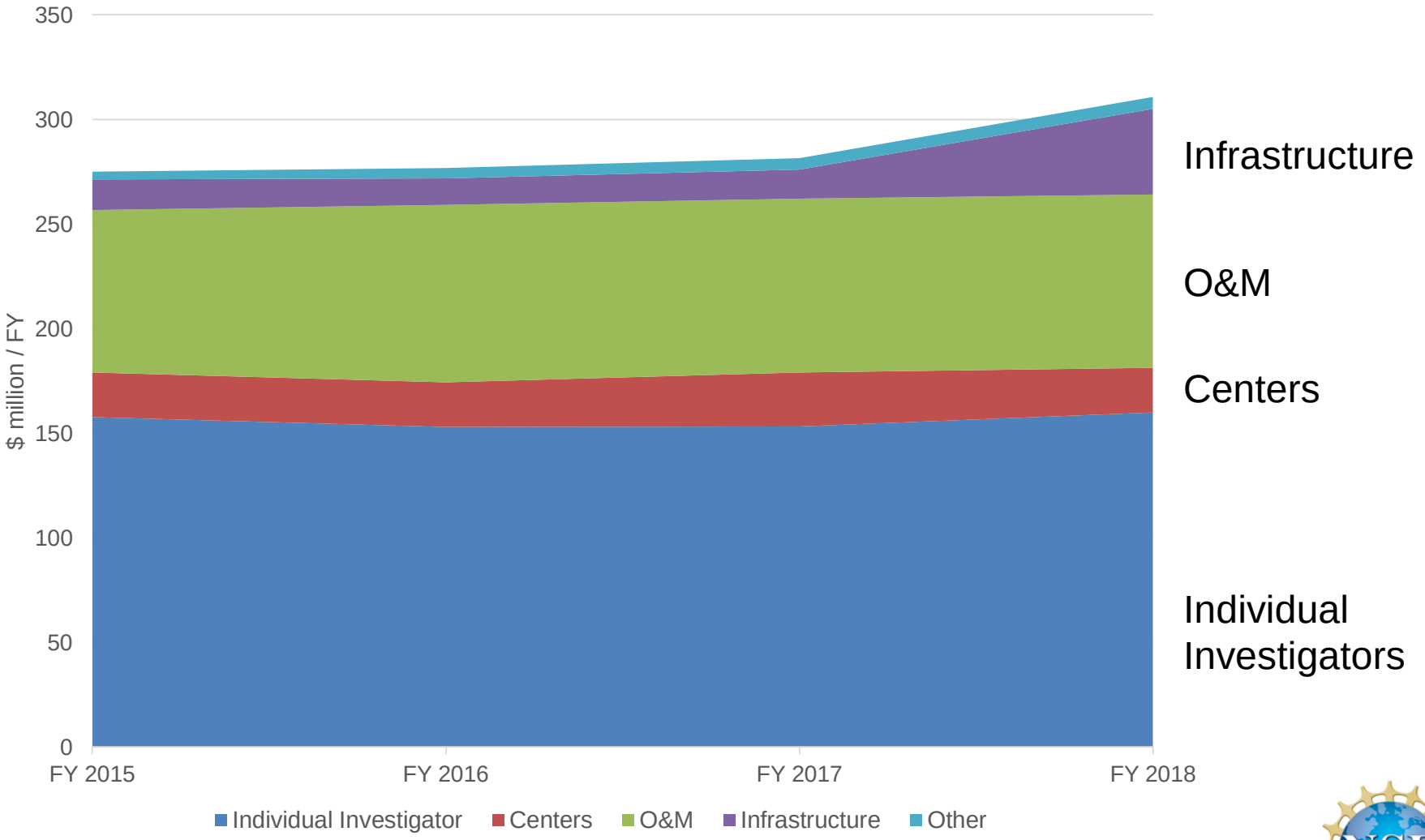
Transfer to FRIB (DOE) in 2021 Progressing Smoothly

IceCube

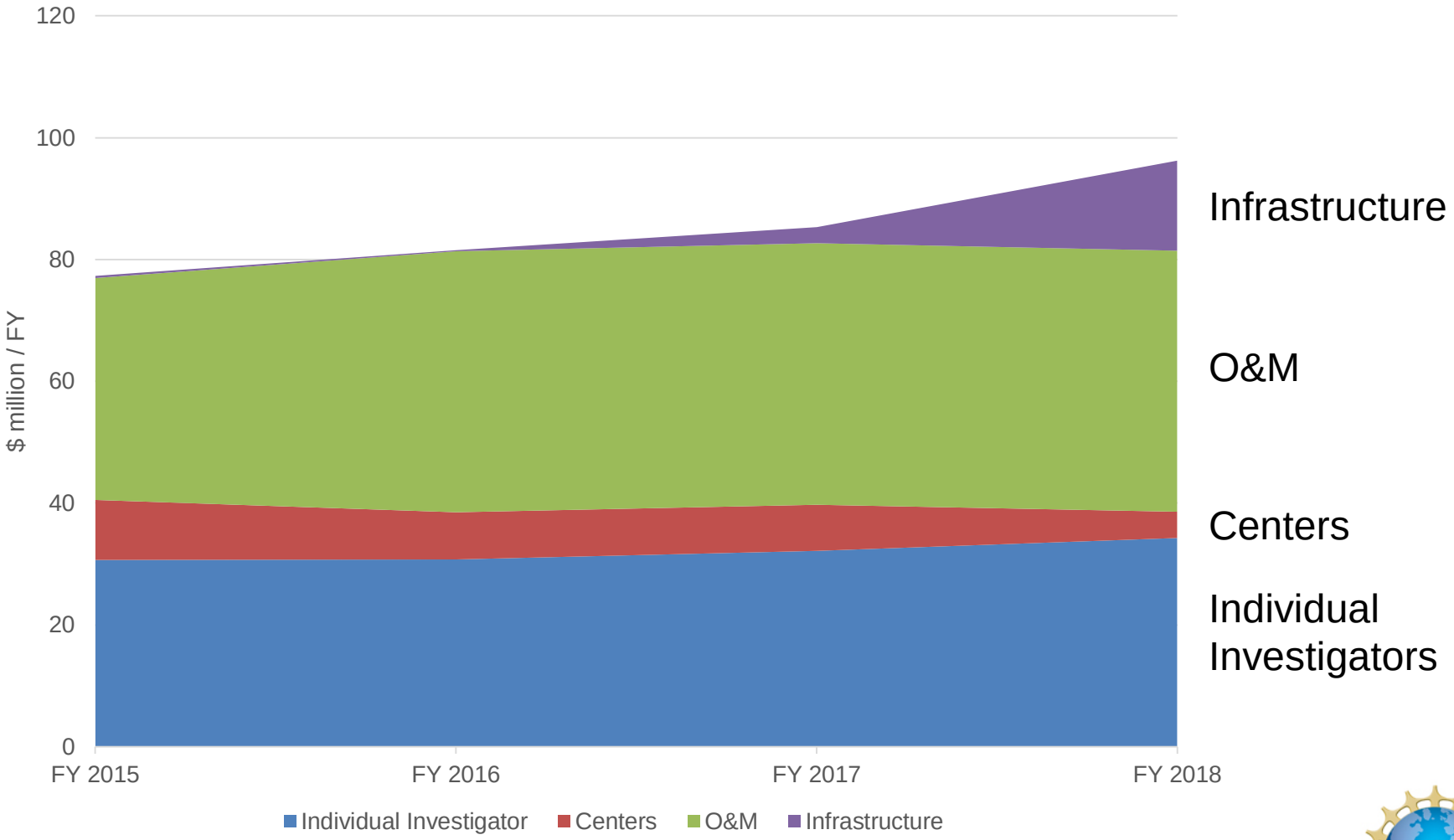
Upgrade Underway (joint with OPP)

Photos courtesy of facilities, resp.

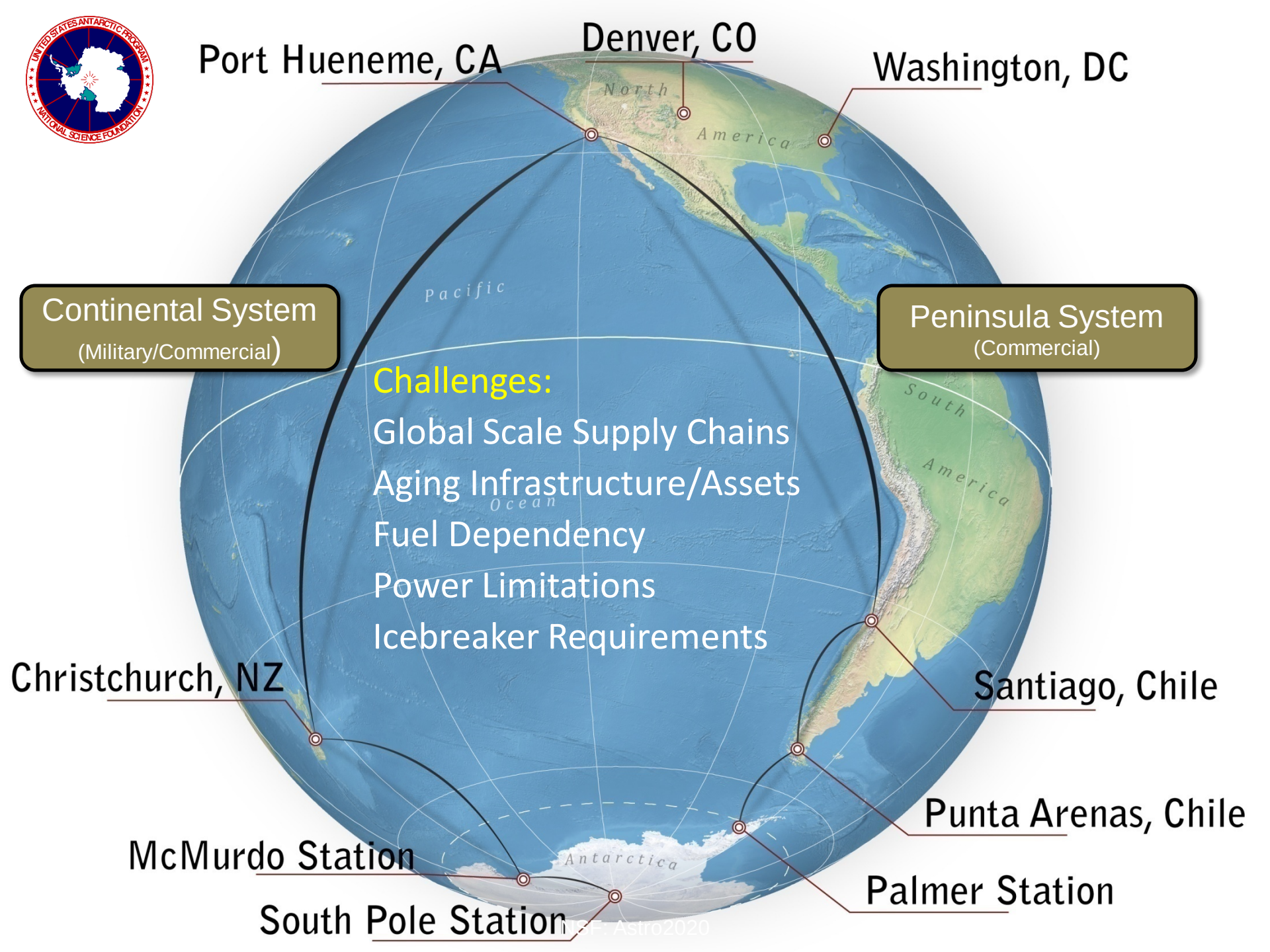
Physics Division Budgets



Astrophysics-related Programs in PHY



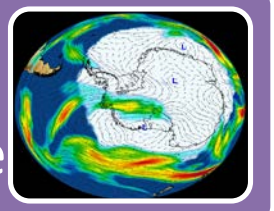
U.S. Antarctic Program

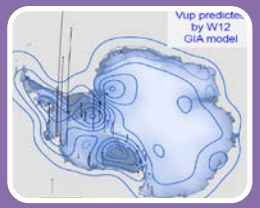

Port Hueneme, CA
Denver, CO
Washington, DC
Continental System
(Military/Commercial)
Peninsula System
(Commercial)
Challenges:
Global Scale Supply Chains
Aging Infrastructure/Assets
Fuel Dependency
Power Limitations
Icebreaker Requirements
Christchurch, NZ
Santiago, Chile
Punta Arenas, Chile
McMurdo Station
Palmer Station
South Pole Station
North America
South America
Pacific Ocean
Antarctica

NSF/Office of Polar Programs
Antarctic Sciences and Logistics

Ocean

Atmosphere





Earth sciences

Integrated System Science

Glaciology

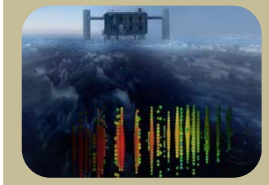
Organisms and Ecosystems

Annual budget

Astrophysics $9.0M

& Geospace $2.5M

Instrumentation and Facilities



Infrastructure and Logistical Support

~$4 per each science dollar

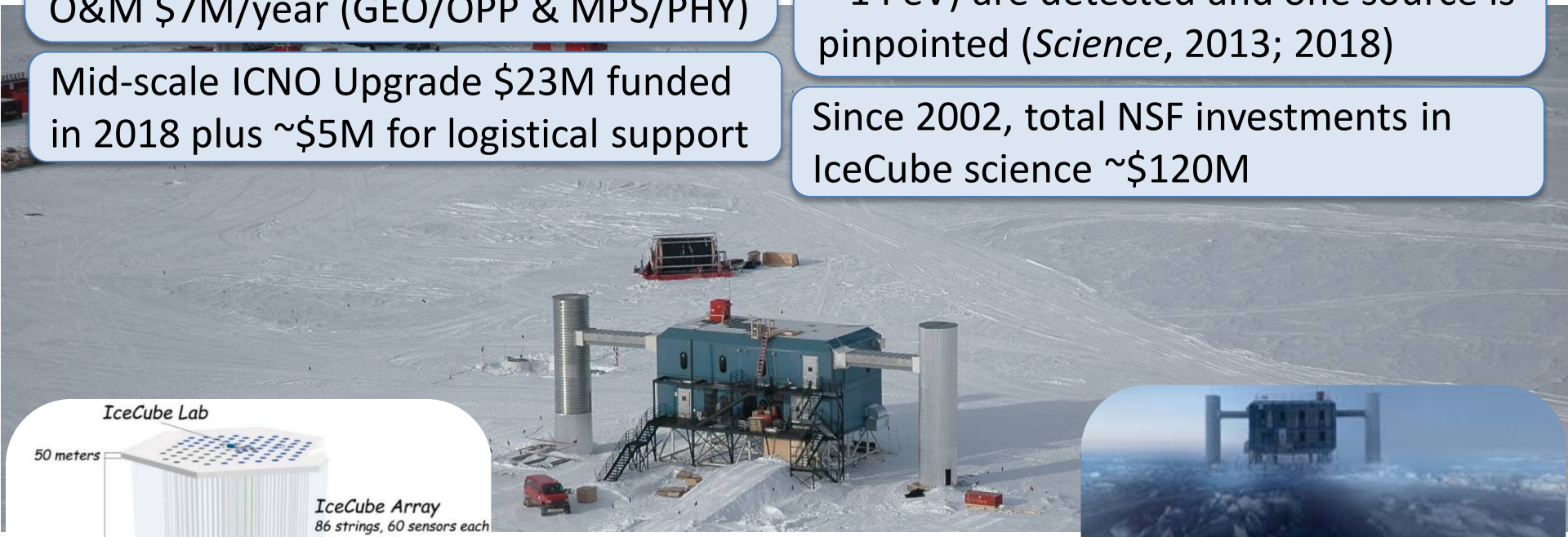
Neutrino Astrophysics at South Pole

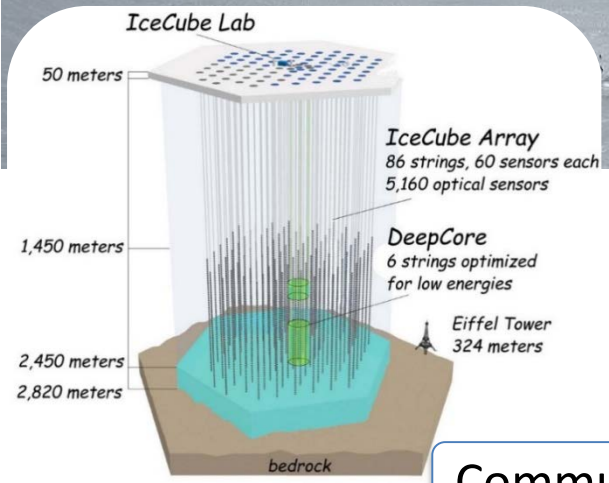
IceCube Neutrino Observatory ($272M, NSF/MREFC project, 2002-2010)
O&M $7M/year (GEO/OPP & MPS/PHY)

Mid-scale ICNO Upgrade $23M funded in 2018 plus ~$5M for logistical support

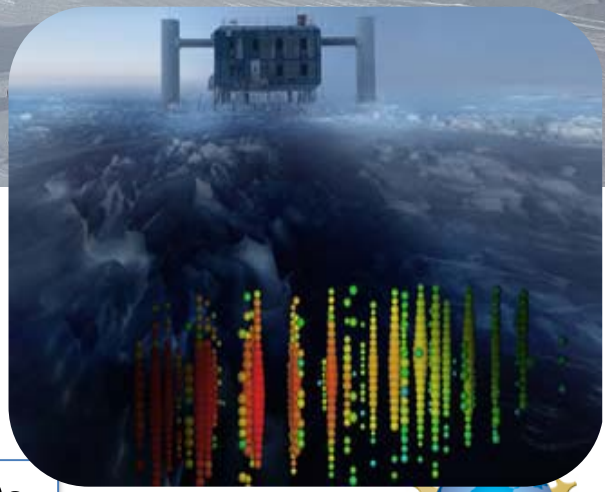
High-energy cosmic neutrinos (100 TeV – 1 PeV) are detected and one source is pinpointed (*Science*, 2013; 2018)

Since 2002, total NSF investments in IceCube science ~$120M





A New Windows on the Universe
Multimessenger Astrophysics



Community plans IceCube Gen2 in 2020s

Cosmology and CMB Research at South Pole

10m South Pole sub-mm Telescope:
Origin and Early History of the Universe
CMB *E* & *B* modes polarization

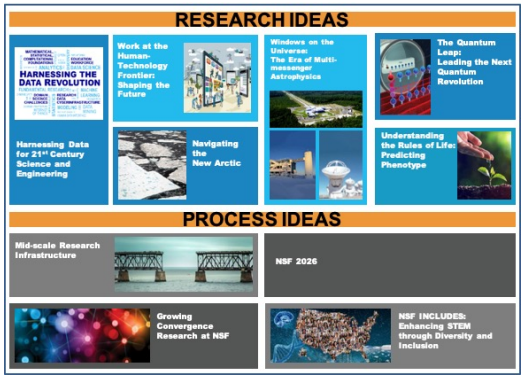
BICEP small aperture telescopes:
Imprints of Primordial Gravitational Waves in CMB polarization

Since 2002, total NSF investments in Antarctic Cosmology ~$100M

A workhorse of the Antarctic: LC-130

All cargo to South Pole is delivered by this aircraft!

Community plans CMB-S4 program in 2020s



Science, Big Ideas, Summary

NSF's 10 "Big Ideas" for Future Investment

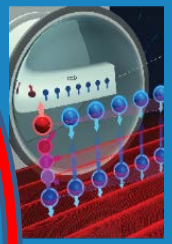
RESEARCH IDEAS

Harnessing Data for 21st Century Science and Engineering

Work at the Human-Technology Frontier: Shaping the Future

Navigating the New Arctic

Windows on the Universe: The Era of Multi-messenger Astrophysics



The Quantum Leap: Leading the Next Quantum Revolution

Understanding the Rules of Life: Predicting Phenotype

PROCESS IDEAS

Mid-scale Research Infrastructure

NSF 2026

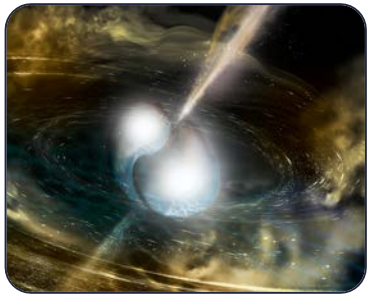
Growing Convergen... Research at NSF

NSF INCLUDES: Enhancing STEM through Diversity and Inclusion

The Era of Multi-MessengerAstrophysics (MMA)

Electromagnetic Waves | High-energy Particles | Gravitational Waves

Goal: To build the capabilities and accelerate the **synergy** and **interoperability** of the three messengers, realizing integrated, multi-messenger explorations of the universe

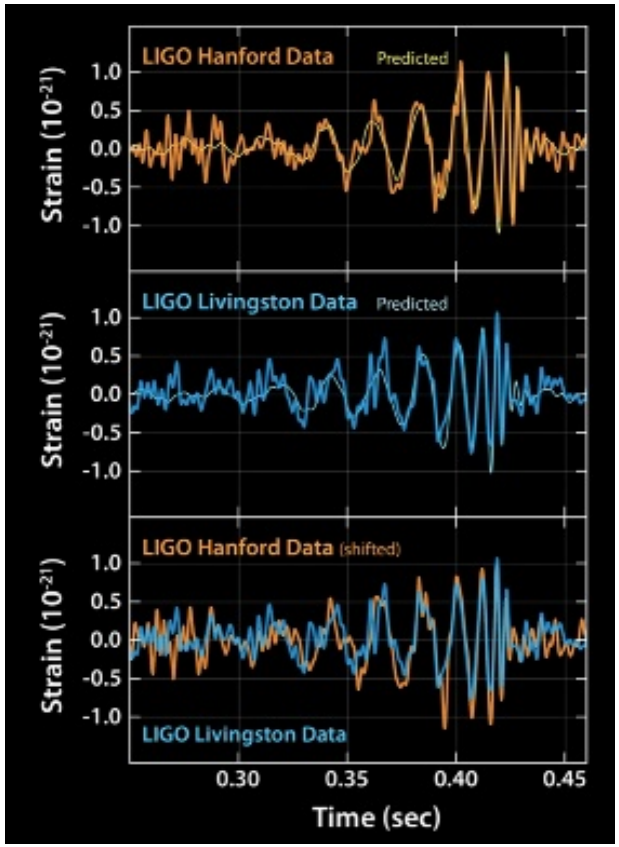


Artist's illustration of binary neutron star merger

Focus Areas:

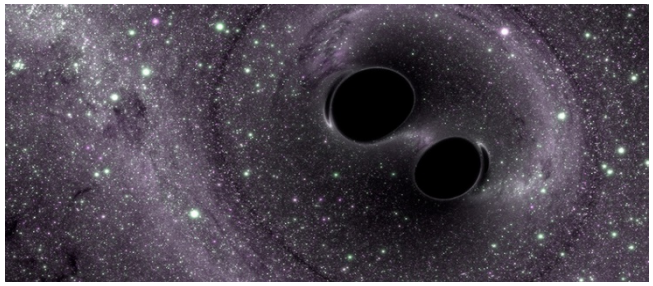
- Enhancing and accelerating the theoretical, computational, and observational activities within the scientific community
- Building dedicated midscale experiments and instrumentation
- Exploiting current facilities and developing the next generation of observatories

Highlight: LIGO



September 14, 2015 at 5:51 a.m. Eastern Daylight Time

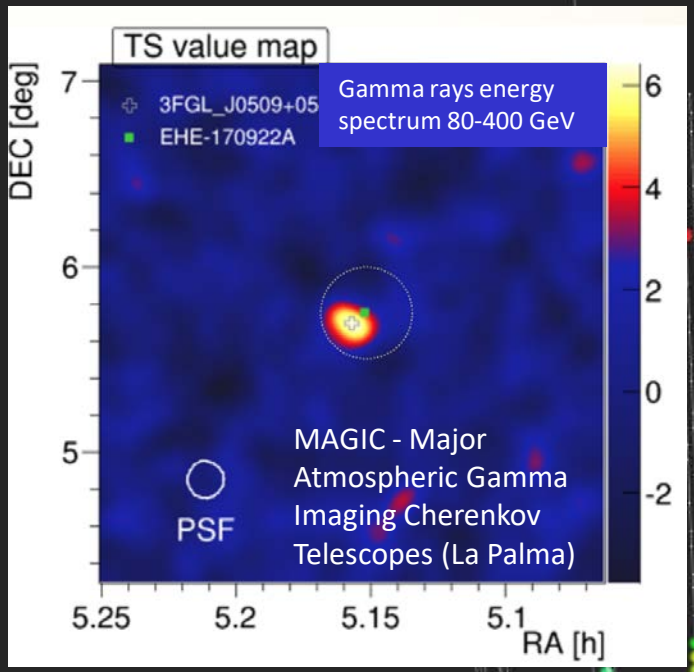
First Direct detection of Gravitational Waves



(B. P. Abbott et al. (LIGO and Virgo Scientific Collaborations, Phys. Rev. Lett. 116, 061102 (2016))

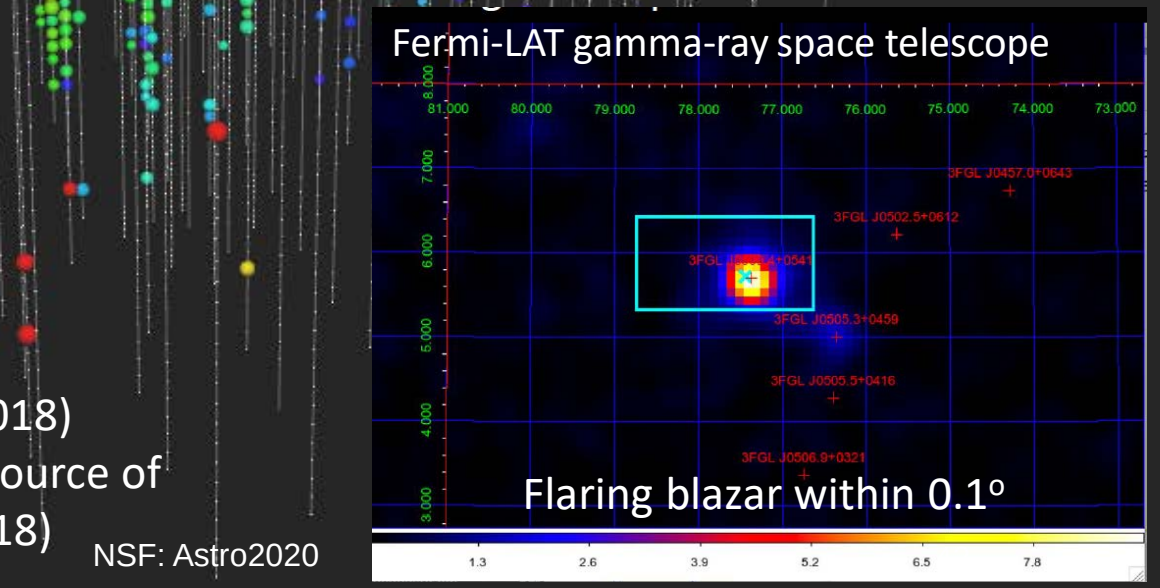
"LIGO scientists estimate that the black holes for this event were about 29 and 36 times the mass of the sun, and the event took place 1.3 billion years ago. About 3 times the mass of the sun was converted into gravitational waves in a fraction of a second" [Press Release]

2017 Nobel Prize



IceCube 170922
290 TeV

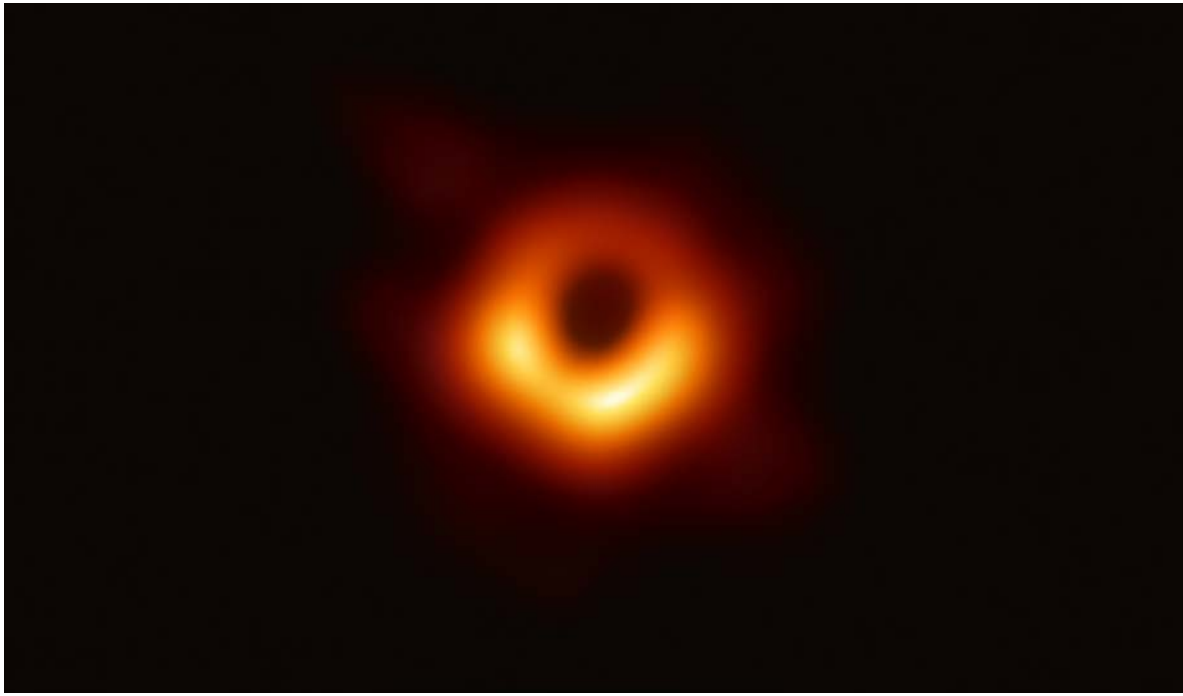
4 in Top 10 stories of 2018 by http://www.sciencenews.org



NSF Press Release 18-050 (July 12, 2018)
Neutrino observation points to one source of high-energy cosmic rays (*Science*, 2018)

Image of M87 from Event Horizon Telescope

- Doeleman et al. team with 8 telescope VLBI at 1.3 mm.
- Black hole shadow with inferred angular gravitational radius of $3.4 \pm 0.4 \mu as$.
- Assumed distance yields $M=(6.5 \pm 0.7) \times 10^9 M_\odot$
- Crescent brightness distribution consistent with Kerr Black Hole.



- NSF (AST) invested some $28M in EHT research over the last two decades, including hardware and algorithm development as well as theoretical modeling (PIRE grant for international collaboration).
- ALMA observations were critical for closing phase; South Pole telescope provided critical baselines.

Summary

- Astro2020 will be most effective if it is *aspirational, inspirational,* and *transformative.*
- Astro2020 will be most effective if it is based on *community consensus science priorities*.
- Let NSF sweat implementation details.
- Provide clear priorities with explanatory decision rules leading to the priorities.