



NSF/AST Update for CAA

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NSF Division of Astronomical Sciences

March 24, 2021





CAA-suggested Agenda topics

- Significant new events
- Changes to programs/projects
- 1-2 slides on Decadal projects not yet in operations
- Summary of COVID -19 impacts and response to date
- Observatory operation, funded researchers, grants programs, projects
- Arecibo status and any future plans
- Update to Satellite Constellation Interference (I'll defer to Connie Walker)
- Budget outlook for last year and crystal balls for the future
- Address relevant policies & issues regarding working with international partners and China specifically



Science Highlights

2020 Nobel Prize in Physics



PRESS RELEASE

6 October 2020

The Nobel Prize in Physics 2020

The Royal Swedish Academy of Sciences has decided to award the Nobel Prize in Physics 2020 with one half to

and the other half jointly to

Roger Penrose

University of Oxford, UK

Reinhard Genzel

Max Planck Institute for Extraterrestrial Physics,
Garching, Germany and University of California,
Berkeley, USA

Andrea Ghez

University of California, Los Angeles, USA

“for the discovery that black hole formation is a robust prediction of the general theory of relativity”

“for the discovery of a supermassive compact object at the centre of our galaxy”

Black holes and the Milky Way’s darkest secret

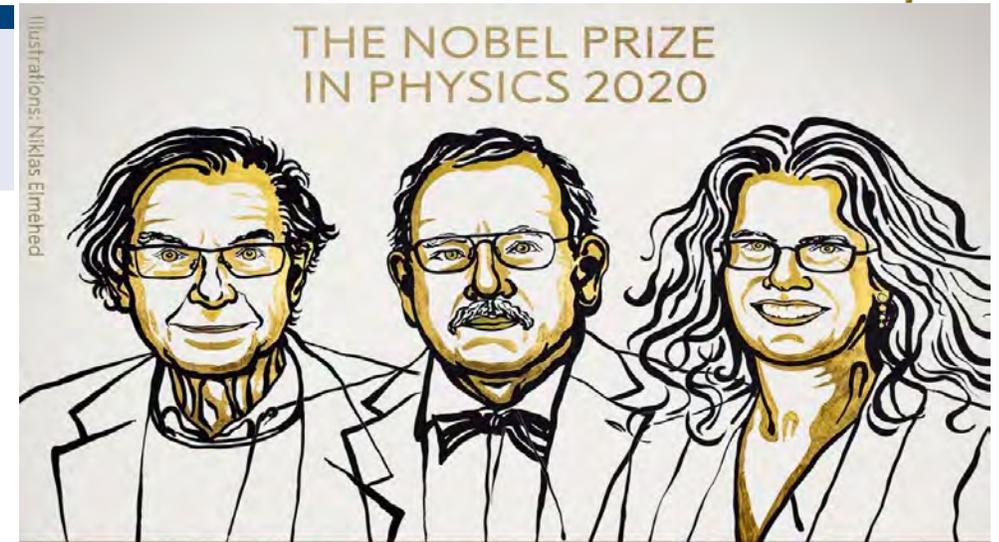
Three Laureates share this year’s Nobel Prize in Physics for their discoveries about one of the most exotic phenomena in the universe, the black hole. Roger Penrose showed that the general theory of relativity leads to the formation of black holes. Reinhard Genzel and Andrea Ghez discovered that an invisible and extremely heavy object governs the orbits of stars at the centre of our galaxy. A supermassive black hole is the only currently known explanation.

Roger Penrose used ingenious mathematical methods in his proof that black holes are a direct consequence of Albert Einstein’s general theory of relativity. Einstein did not himself believe that black holes really exist, these super-heavyweight monsters that capture everything that

dizzying speeds. Around four million solar masses are packed together in a region no larger than our solar system.

Using the world’s largest telescopes, Genzel and Ghez developed methods to see through the huge clouds of interstellar gas and dust to the centre of the Milky Way. Stretching the limits of technology, they refined new techniques to compensate for distortions caused by the Earth’s atmosphere, building unique instruments and committing themselves to long-term research. Their pioneering work has given us the most convincing evidence yet of a supermassive black hole at the centre of the Milky Way.

“The discoveries of this year’s Laureates have broken new ground in the study of compact and supermassive objects. But these exotic objects still pose many questions that



Roger Penrose: 6 NSF/MPS/DMS & 11 NSF/MPS/PHY awards 1984 – 2008

Reinhard Genzel: 8 AST awards 1982 – 1987

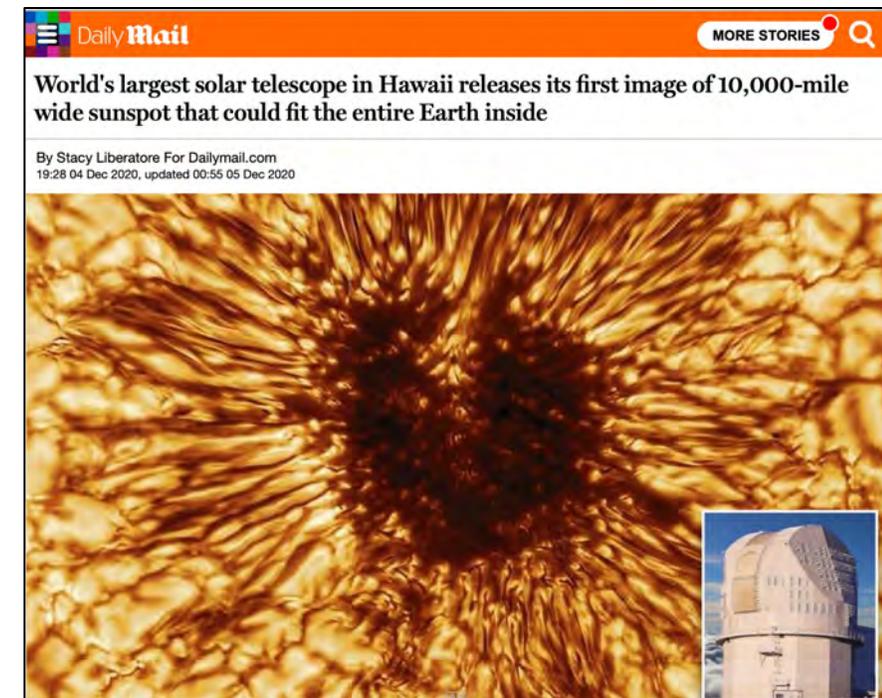
Andrea Ghez: 10 AST awards 1994 – 2019

Fed News Radio discussion with A. Ghez & G. Langston

Daniel K. Inouye Solar Telescope



- **March 17, 2020:** DKIST site construction halted
- **July 6, 2020:** Project transitioned to a phase 1b return-to-work that allows for two overlapping shifts of approximately 35 personnel per shift; ~60-70% efficient
- **June 22, 2020:** NSF Acting Director authorized \$9.4M in Management Reserve
- Primary activities: IT&C on Wavefront Correction System and 4 facility instruments (VBI, ViSP, DL-NIRSP, Cryo-NIRSP)
- Current Start of Operations milestone is May 2021, but expected to slip due to COVID-19 impacts
- Press Release – **Dec. 8, 2020**
 - Highest resolution image of a sunspot ever recorded
 - Diffraction-limited image taken earlier in the year (Jan. 28) with the context imager
 - Released in conjunction with DKIST overview journal paper: [Rimmele, T.R. et al., 2020, Sol Phys, 295, 172](#)



Vera C. Rubin Observatory



- Ramp up of construction activity on summit began as planned on September 28 under COVID protocols with excellent progress.
- Currently, work crew size about half pre-pandemic level.
- Critical path subsystem, Telescope Mount Assembly (TMA), restarted work.
- Top-end assembly installed on TMA: Spectacular milestone achievement!
- Expected: COVID delay at least one year with detailed replan this year.
- Pre-operations standing up Interim Data Facility in Google cloud, and US Data Facility to be managed by SLAC in coordination with AURA.
- Dome now substantially closed, protecting TMA.



National Solar Observatory

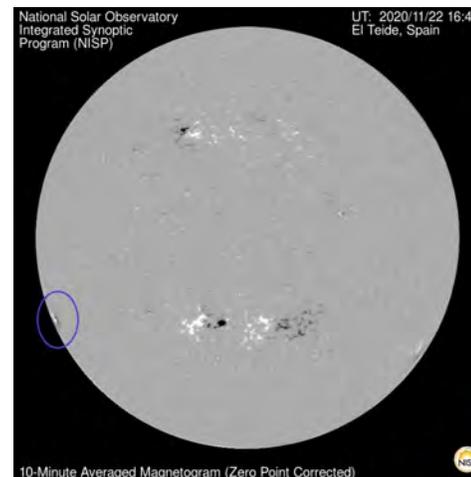


- NSO is preparing for DKIST Operations and Commissioning Phase
 - First round of observing proposals received and have been evaluated
- GONG and Dunn Solar Telescope are continuing to operate
 - GONG is renewing an IAA with NOAA/SWPC
- NSO to transfer Sac Peak relocatable Housing Units to White Sands Habitat for Humanity – first units should transfer in March 2021
- GONG measures complex “Thanksgiving Sunspot” on the far side of the sun before it can be seen on the Earth facing disk



Solar astronomers can now predict future sunspots. There should be a big one in a couple of days

The surface of the Sun is a turbulent dance of gravity, plasma, and magnetic fields. Much like the weather on Earth, its behavior can seem unpredictable, but there are patterns to be found when you look closely.



Monster sunspot AR2786 swings into better view

Posted by Eleanor Imster and Deborah Byrd in SPACE | SUN | TODAY'S IMAGE | November 29, 2020

The sun is becoming active again as it enters Solar Cycle 25. This week, scientists' predictions of sunspots were proven via photos from astronomers around the world. Giant sunspot AR2786 can be viewed with proper filters and may create strong flares that reach Earth.

Sharing is caring!

NOIRLab: MSO and CSDC

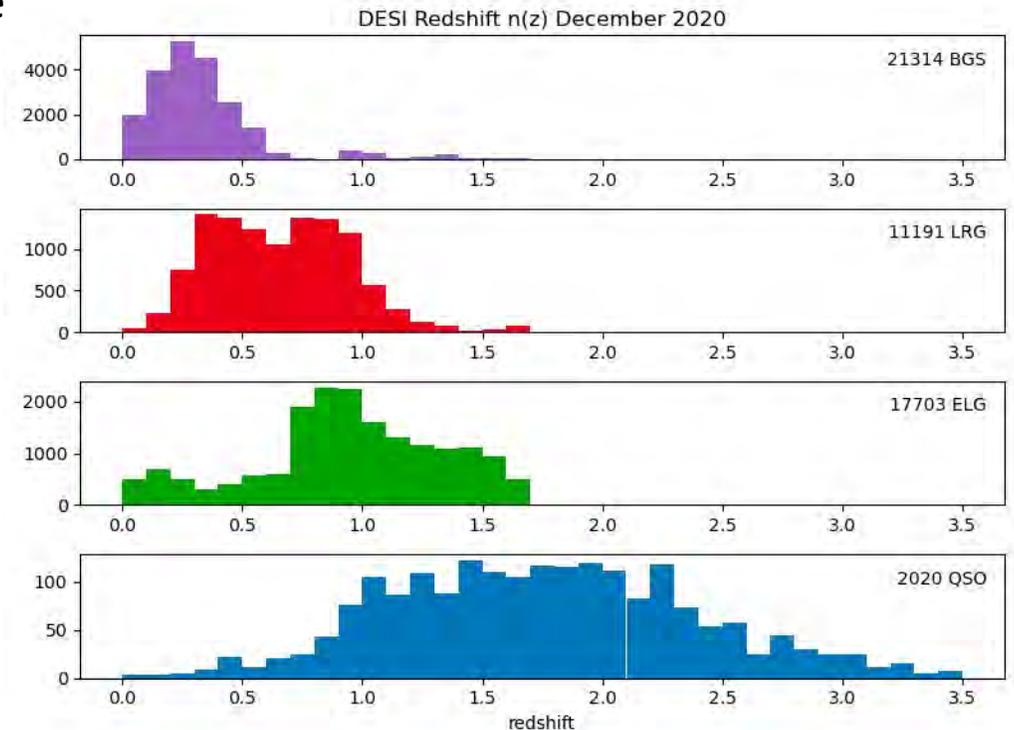


- Kitt Peak and Cerro Tololo Observatories operating since Sept./Oct. 2020
 1. Mayall: DESI preparing for start of 5-year Dark Energy Spectroscopic Survey in early 2021
 2. WIYN: NEID commissioning continues with shared risk observing available in 2021B
 3. SOAR: AEON-mode now provides queue-based observing with support for time domain alerts
 4. Blanco/CSDC: Dark Energy Survey (DES) DR2 release



NGC 474 (DECam)

DES: DR2 public release (Jan 2021) of images and object catalogs with data on almost *700 million* objects (DR2 processed by NCSA and hosted by CSDC/Astro Data Lab)



DESI: More than 50,000 redshifts measured (DESI Collaboration, December 2020)

International Gemini Observatory

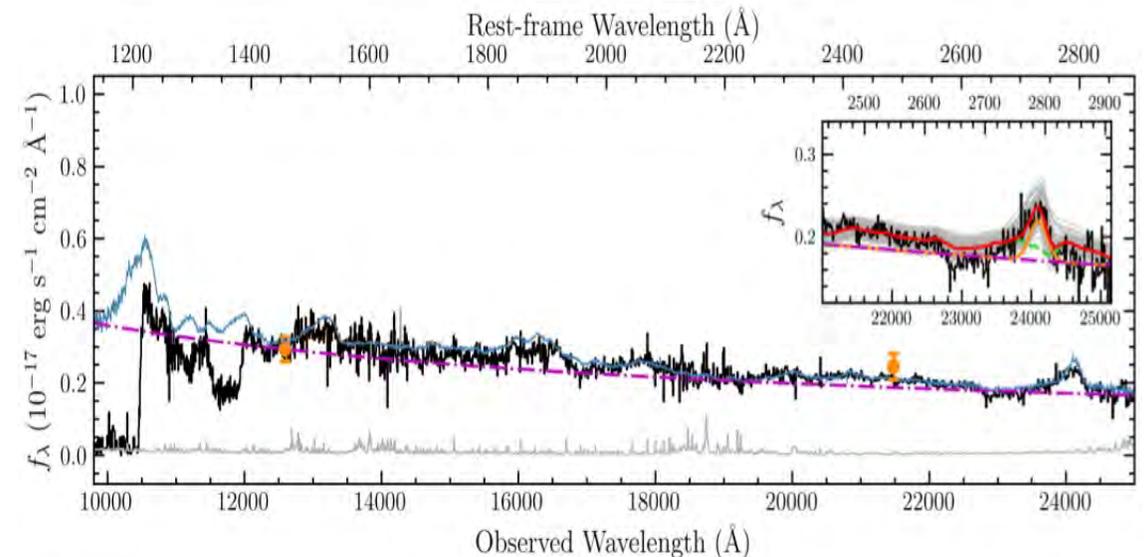


- **Current status:**

- Gemini-N has been conducting nighttime observations since May 19, 2020.
- Gemini-S returned to science on Oct 22, 2020.
- The Gemini offices in Hilo and La Serena are operating under mostly telework.
- Ongoing instrument development programs include:
 - GHOST (high-resolution spectroscopy),
 - SCORPIO (multi-channel time-domain imaging and spectroscopy, g, r, i, z, Y, J, H, and K_S)
 - GNAO (Gemini-N Adaptive Optics upgrade)

- **Science Highlight:**

- Wang+ (2021), *A Luminous Quasar at z = 7.642*.
- The Earliest Supermassive Black Hole detected in the Universe; 670 million years after Big Bang, $1.6 \times 10^9 M_{\odot}$.
- “The presence of such a massive black hole so early in the Universe’s history challenges theories of black hole formation”.



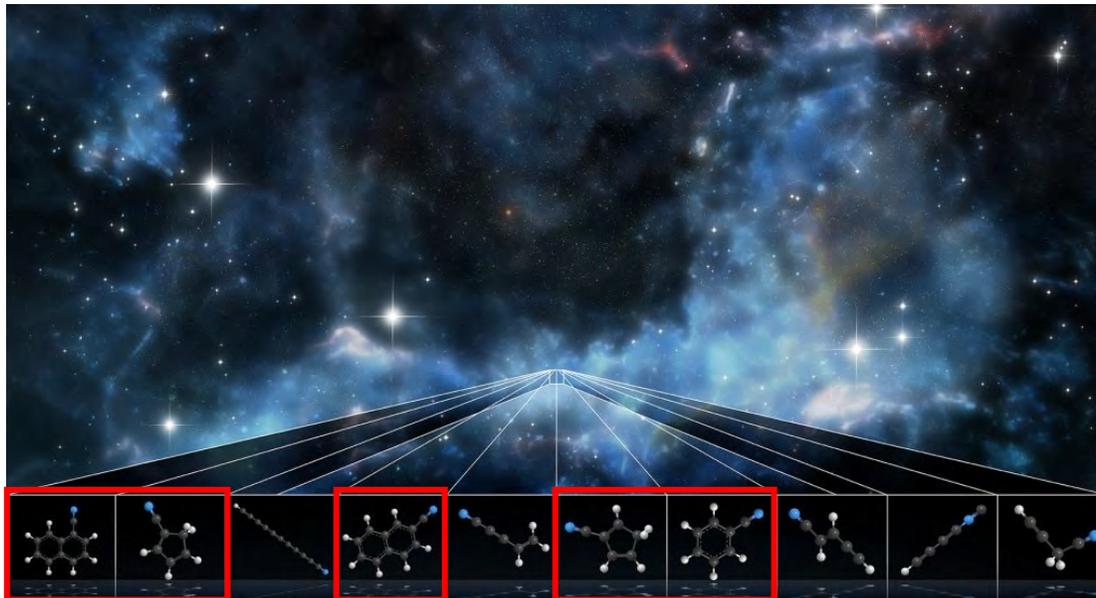
Green Bank Observatory



- Current Status

- Operational: Science operations continue with COVID-19 protocols in place and ~50% of the staff currently on-site; travel paused, on-site workshops/meetings canceled or made virtual
- Numerous “Community Zoom Updates” offered since spring 2020 have been well attended
- [Announcement in response to collapse of Arecibo](#) (sympathy, expression of support)

- Science Highlight



Complex molecules detected in the Taurus Molecular Cloud. Red boxes highlight aromatic rings and PAHs. Credit: J. Mallusky, GBO/AUI.

Using the GBT, astronomers detect Polycyclic Aromatic Hydrocarbons (PAHs) in a cold dark cloud

- Direct detection of *specific* polar aromatic rings and PAHs – largest molecules detected by radio astronomy
- Advances 30-year-old puzzle of bulk IR signatures *generically* assigned to PAHs
- Growth of molecular complexity in the ISM: evolution of carbon reservoir during early stages of star formation, possible "seeds" of interstellar dust

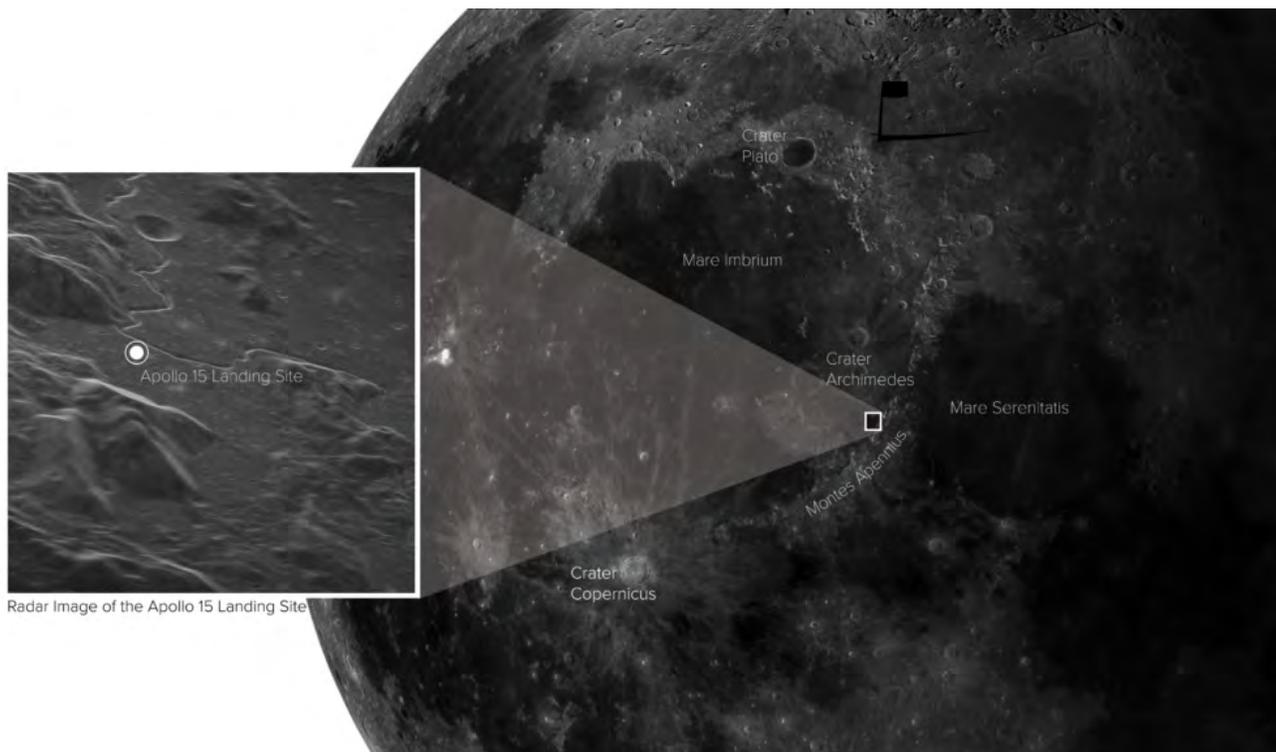
GOTHAM Large Project; PI: B. A. McGuire, MIT
McGuire et al. *Science*, 371, Issue 6535, pp 1265-1269. 19 March 2021
+6 papers in *Nature Astronomy* and *ApJ Letters* since January 2021
[Link to GBO release](#)



GBO Radar transmitter: Proof of Concept

- CRADA: GBO, NRAO, Raytheon Intelligence & Space
- 700 watt solid state transmitter on GBT
- 10 VLBA antennas used as receiving stations
- Imaged Apollo 15 landing site, 5m resolution, Nov. 2020
- Finalizing plans for 500-kilowatt transmitter

See <https://public.nrao.edu/news/successful-test-new-planetary-radar/> (January 28, 2021)



The Very Large Array (VLA)



Currently operating as usual

- Science operations have continued, uninterrupted; including observer support and array-configuration changes
- NRAO management devised Covid-19-safe practices for maintenance and operations
- The Visitor Center is closed

Data indicate how radio galaxies exist in the crowded environment of a cluster of galaxies

- The images (right) show jets interacting with gas in the cluster (being stopped, blown back, etc.)
- Images help understand the complex environment of clusters, the largest gravitationally-bound structures in the universe, and which harbor a variety of still poorly-understood phenomena



The Very Long Baseline Array (VLBA)

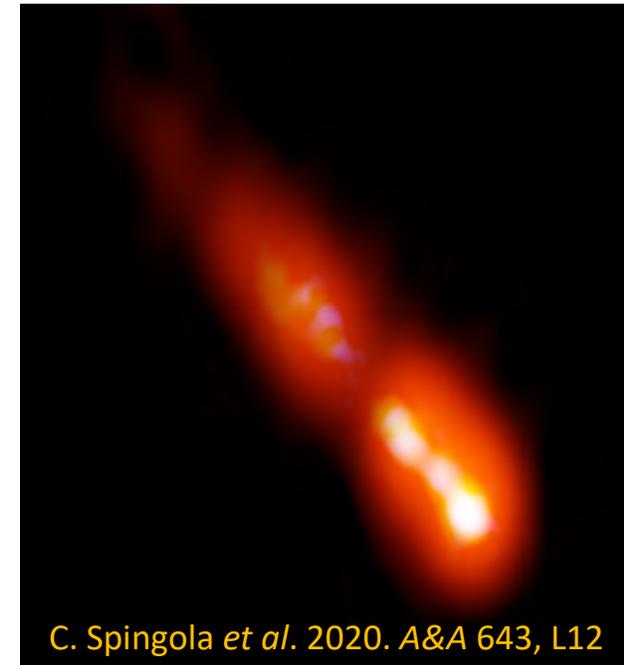


Currently operating as usual

- Science operations have continued, uninterrupted, at all 10 VLBA Stations across the continental USA, HI, and the US VI
- Hurricane Maria repairs have been completed at St. Croix, and all 10 stations are now connected via fiber

VLBA detected a relativistic jet from a radio-loud quasar at 12.8 Bly

- The 1,600 ly-long jet, powered by a supermassive black hole located at the lower right corner, moves outward to the upper left at $3/4$ the speed of light
- This is the brightest radio-emitting blazar seen at that distance
- The observation provides observational support for theoretical understanding of why these objects are so rare, especially in the early universe



The Atacama Large Millimeter/submillimeter Array (ALMA)

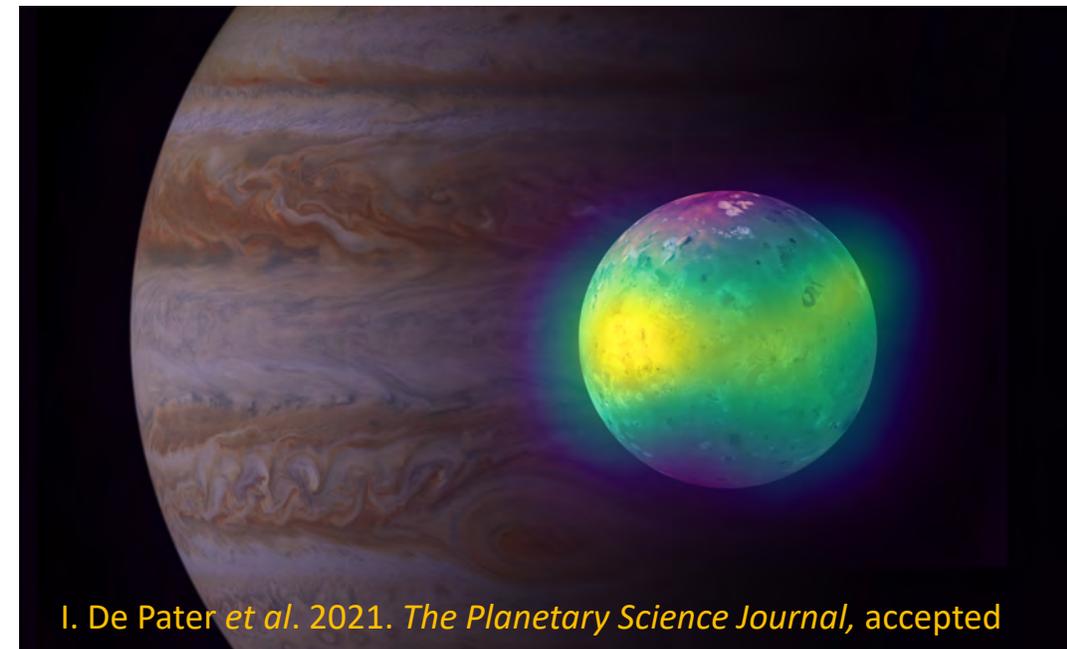


As of 17 Mar 2021, ALMA has returned to science ops!

- ALMA had been shut down for almost a year
- Start-up operations began in Oct 2020
- Safety of staff continues to be of paramount importance

ALMA shows for 1st time how Io's volcanoes impact its atmosphere

- Previously unknown which processes drive Io's atmosphere
- ALMA detected plumes of sulfur dioxide and sulfur monoxide from volcanoes, producing 30-50% of atmosphere



I. De Pater et al. 2021. The Planetary Science Journal, accepted

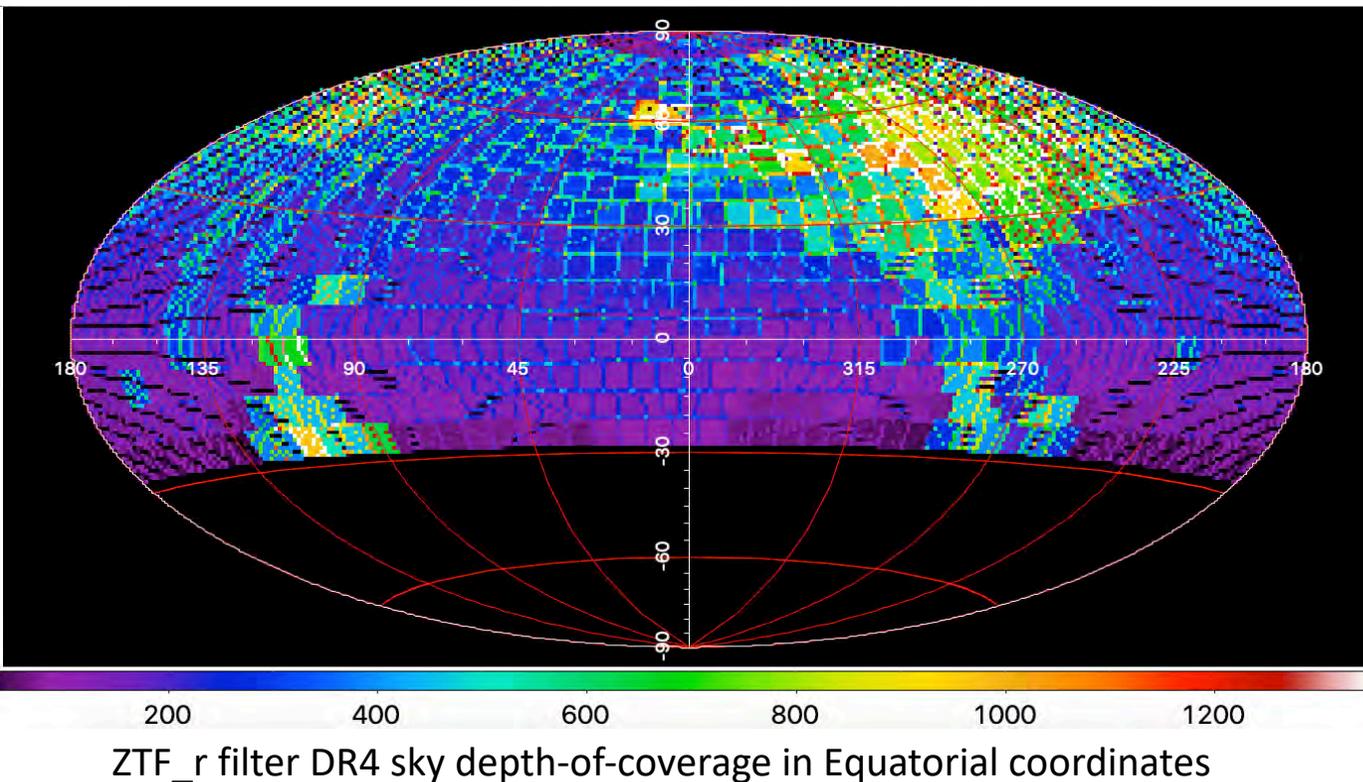
Mid-Scale Activity



- Current Status

- Approximately two dozen mid-scale projects supported in AST by the MSIP and MSRI programs are adjusting for the pandemic impact and the loss of Arecibo. Meanwhile, science continues.

- Science Highlight



The Zwicky Transient Facility (ZTF) and IPAC at CalTech announced the fourth ZTF Public Data Release on December 9th, 2020. Now available to everyone are ~18.5 million single-exposure images, ~144,000 co-added images, source catalog files containing ~296 billion sources, and ~2.7 billion light-curves.

See <https://www.ztf.caltech.edu/page/dr4> and <https://irsa.ipac.caltech.edu/Missions/ztf.html>



COVID, International Partners

Additional COVID Impacts/Response



- March 16, 2020 NSF implemented 100% telework posture
- NSF employees can now access building, but vast majority still telework
- Anticipated to remain in liberal telework posture for (at least) the next few months
- Minimal work-related travel
- All NSF meetings/panels 100% video conference
- On-going discussions regarding post-COVID hybrid work-place
- NSF is will be providing COVID relief in FY 2021
 - \$600M provided as part of \$1.9T American Rescue Plan Act of 2021





International Partners

- AST has existing strong International Partnerships
 - Gemini: US, Canada, Argentina, Brazil, Korea, Chile
 - ALMA: NA (Canada, US, Taiwan), ESO (16 member states), East Asia (Japan, Taiwan, Korea)
 - NSF FFRDCs have International Partnerships, e.g. NRAO/AUI and SHAO/CAS
- NSF has established the position of Chief of Research Security Strategy and Policy (Rebecca Keiser)
- NSF commissioned JASON report: *Fundamental Research Security*
 - See NSF web page on Protecting Research and Facilitating Collaboration https://nsf.gov/news/special_reports/jasonsecurity/





Personnel

NSF Office of the Director



- France Córdoba ended a 6-year term as NSF Director March 31, 2020.
- Kelvin Droegemeier was named Acting NSF Director on April 1 and served until June 23. Current Director of OSTP and former member of the National Science Board.
- Sethuraman Panchanathan was nominated by the President to be 15th NSF Director on 07 Jan. 2020 and took office on June 23.



Directorate for Mathematical and Physical Sciences (MPS)



- Anne Kinney, Assistant Director (AD) for MPS, left NSF May 1, to become the GSFC Deputy Director in May 2020.
- Sean Jones, was appointed AD for MPS on Sept. 29.
- Tie Luo, was appointed Deputy AD for MPS on Jan. 17, 2021.



Division of Astronomical Sciences (AST)



Management Team



Ralph Gaume
Division Director



James Neff
Deputy Division Director



Craig McClure
Program Support Manager



Donna O'Malley
Financial & Operations Specialist

Administration



Elizabeth Pentecost
Project Administrator



Matthew Viau
Program Analyst



Allison Farrow
Program Analyst



Renee Adonteng
Program Analyst

Individual Investigator Programs (IIP)



Hans Krimm
Program Director

IIP Coordinator; Lead: Stellar Astro.



Nigel Sharp
Program Director

Lead: Extragalactic & Cosmology; cross-NSF programs



Glen Langston
Program Director

Lead: Galactic Astronomy



Harshal Gupta
Program Director

Lead: Postdoctoral Fellowships; Lab Astro



Luke Sollitt
Program Director

Lead: Planetary Astronomy



Sarah Higdon
Program Director

Lead: CAREER; AAG



Zoran Ninkov
Program Director

Lead: Advanced Technology & Instrumentation; AAG



Marc Seigar
Program Director

Lead: REU; AAG



James Higdon
Program Director

AAG; SAA, EXC

Facilities, Mid-Scale, & MREFC Projects



Nigel Sharp
Program Director

MSIP; MSRI



David Boboltz
Program Director

DKIST



Christopher Davis
Program Director

NOIRLab



Edward Ajhar
Program Director

Vera C. Rubin Observatory



Joe Pesce
Program Director

NRAO; ALMA



Harshal Gupta
Program Director

GBO



Ashley VanderLey
Program Director

Arecibo



Martin Still
Program Director

Gemini



Carrie Black
Program Director

NSO



Alison Peck
Program Director

Arecibo



Ashley VanderLey
Program Director



Jonathan Williams
Program Director



David Morris
AAAS Fellow

ESM



New positions in AST

- AST Senior Advisor for Facilities (closed, interviews completed)
- AST Division Director
 - Opened January 15th 2021
 - Closes April 16th 2021
 - Suggested Candidates? Email Sean Jones (sjones@nsf.gov), Tie Luo (tluo@nsf.gov), & Ralph Gaume (rgaume@nsf.gov)
- AST Jobs Announcements recently closed:
 - AST Grants support: hired as VSEE, Fed. Temp., or IPA
 - AST Facilities: hired as permanent, Rubin Observatory support
 - AST Grants support: hired as permanent Fed. Employee



Programs

AST Division Programs



Individual Investigators
(Lead: Hans Krimm)

Mid-scale
(Lead: Nigel Sharp)

Facilities

MREFC

Research

AAG

MSIP

NRAO

CAREER

MSRI

ALMA

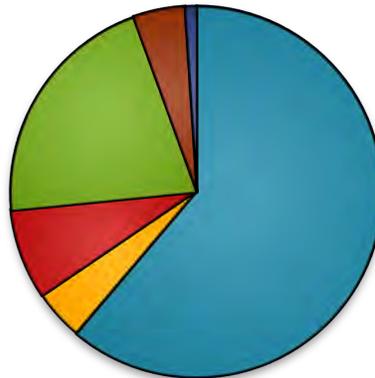
AAPF

GBO

Arecibo

**Technology/
Instrumentation**

ATI



NSO

DKIST

MRI

NOIR Lab

Rubin

**Education and
Special Programs**

REU

Gemini N & S

ESP

MidScale Obs

FY 2021 Programs and Deadlines



Acronym	Program Name	Deadline	Program Lead
CAREER*	Faculty Early Career Development Program	27 Jul 20	S. Higdon
REU Sites*	Research Experiences for Undergraduates	28 Aug 20	Seigar
AAPF	Astronomy & Astrophysics Postdoctoral Fellowships	15 Oct 20	Gupta
AAG	Astronomy & Astrophysics Research Grants	16 Nov 20	Sharp (EXC), Langston (GAL), Krimm (SAA), Sollitt (PLA)
ATI	Advanced Technology and Instrumentation	16 Nov 20	Ninkov
MRI*	Major Research Infrastructure	19 Jan 21	Ninkov
MSRI-2*	Mid-scale Research Infrastructure-2	LOI: 03 Feb 21 Pre: 05 Mar 21 Full: 20 Sept 21(if invited)	Sharp
MSRI-1*	Mid-scale Research Infrastructure-1	Pre: 07 Jan 21, 23 Apr 21 (if invited)	Sharp

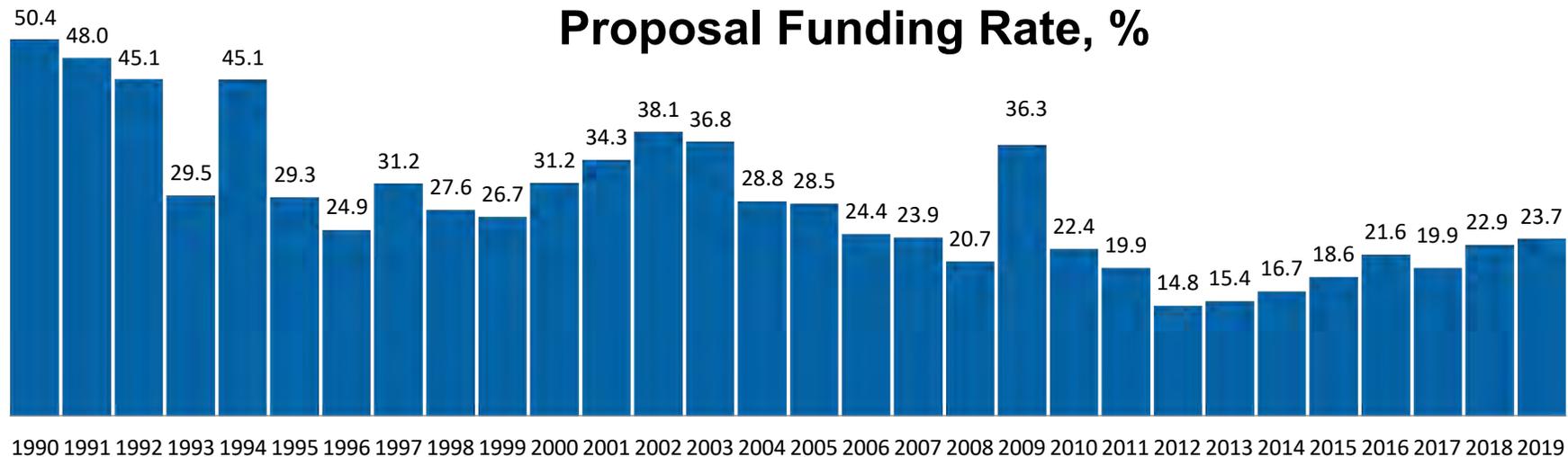
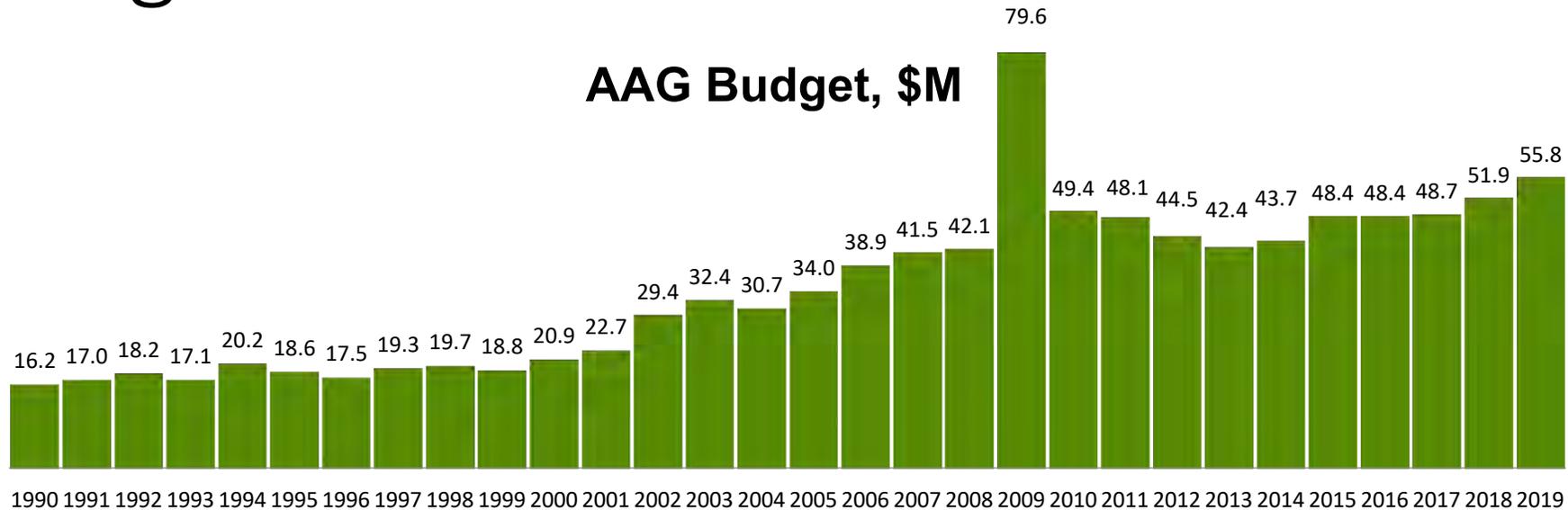
* NSF-wide solicitations



Budget: FY 2020



AAG program stats



2020:
Between
2018 and
2019 levels

MPS funding stats for FY 2020

Overall FY 2020 MPS funding rate: 28%

Division	Funding Rate	Actions	Awards
AST	24%	850	203
CHE	36%	1322	473
DMR	22%	1902	427
DMS	27%	2718	733
OMA	13%	8	1
PHY	39%	760	294





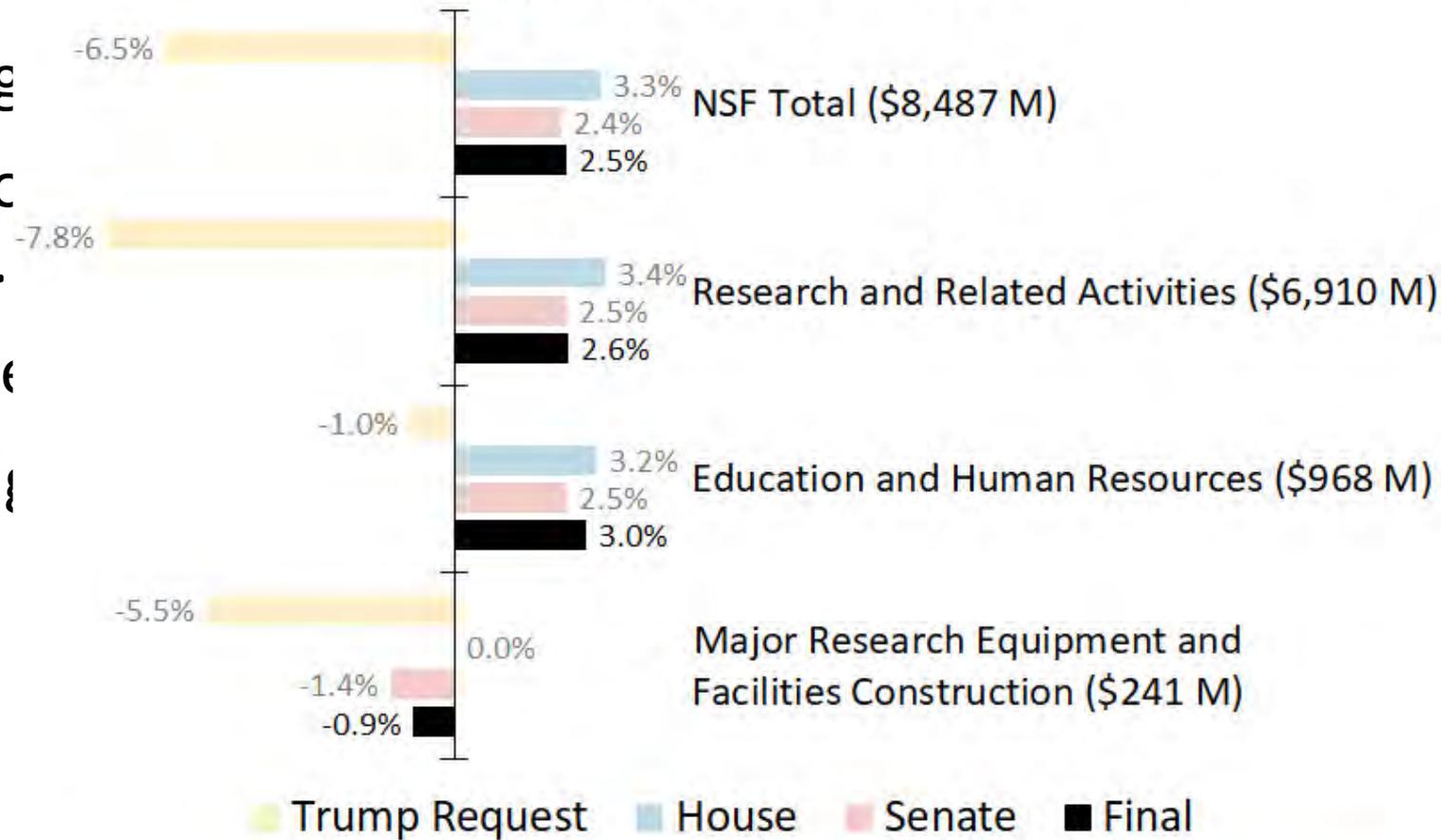
Budget: FY 2021

FY21 Appropriations: National Science Foundation



\$ in () are the FY21 amounts

- Continuing
- Enacted Fc
\$6,910M).
- MREFC line
- AST/AAG (





Budget: FY 2021
AST-related
report language

House report language (RG synopsis)



- Allocate no less than FY 2020 levels to existing research infrastructure. *The Committee instructs NSF to sustain support for programs and scientific facilities funded by the Astronomical Sciences Division at no less than fiscal year 2020 levels to maintain full scientific and educational operations.*
- Keep Committee informed of O&M partner cost-sharing. Divestment of facilities proposed as part of future NSF budget request.
- Support existing astronomical facilities through WoU-MMA Big Idea.
- Astro 2020: Supports preliminary investments in emerging priority facilities, *such as the next generation Very Large Array and the Extremely Large Telescopes.* Committee encourages NSF to continue providing preparatory funding over the coming year.
- Continue to partner with academic institutions to operate Dunn Solar Telescope.
- Within 90 days report to Committee on implementation of Facility Operation Transition pilot program.
- Rubin Obs: recommend funding at requested level.
- Mid-Scale Research Infrastructure: Funded at requested level.
- Infrastructure Planning: *The Committee encourages NSF to develop a comprehensive and prioritized list of large-scale facilities requested by NSF-supported science disciplines.*

Senate report language (RG synopsis)



- Committee expects NSF to continue support for astronomy facilities and instrumentation while preparing for facility upgrades and Astro 2020. Explore partnership when feasible, including for next generation optical and infrared telescopes.
- DKIST: supports at request, encourages NSF support for ancillary partnerships that have made construction successful.
- Continue working with NSO and academic community to operate Dunn Solar Telescope.
- Fully fund Facility Operation Transition activity.
- Supports investment in the Spectrum Innovation Initiative to realize goals without negatively impacting radio astronomy.
- Green Bank Observatory: Committee encourages development of multi-agency management plans for GBO.
- Rubin Observatory: support at request level.
- Mid-Scale Research Infrastructure: support at \$10M above request level.
- Infrastructure planning: Understand the impact of extended construction shutdowns and continue planning and budgeting for next generation of major facilities

Omnibus language (RG synopsis)



- Maintain Core Research (including astronomy facilities) at no less than FY 2020 level.
- Support DKIST budget at request level and ancillary academic partnerships.
- Support Facility Operation Transition at budget request level.
- Support Spectrum Innovation Initiative.
- Green Bank Observatory: Supports NSF effort to develop multi-agency plans. Funding at no less than request level.
- Rubin Observatory: funded at the requested level
- Mid-scale Research Infrastructure funded at \$76.25M. Encouraged to award at least one mid-scale research infrastructure led by an institution in an EPSCoR State.
- Infrastructure Planning: Include in annual budget request to Congress plans for construction, repair, & upgrades to national research facilities. *In lieu of House language regarding infrastructure planning, NSF and the Board are encouraged to engage in robust planning for and investments in the next generation of world class facilities, including any projects recommended by the upcoming Astrophysics decadal survey.*



Omnibus language

Arecibo Observatory (AO) - The significant loss caused by the collapse of the 305-meter radio telescope at the Arecibo Observatory in Arecibo, Puerto Rico, is devastating. During its 57 years in operation, the telescope was an integral part of U.S. capabilities to advance scientific research and served as an iconic, beloved site for the residents of Puerto Rico and the scientific community. With this in mind and keeping safety as the number one priority, NSF is directed to report to the Committees within 60 days of enactment of this Act on the causes and extent of the damage, the plan to remove debris in a safe and environmentally sound way, the preservation of the associated AO facilities and surrounding areas, and the process for determining whether to establish comparable technology at the site, along with any associated cost estimates. NSF shall keep the Committees informed of any other activities related to this facility.



Arecibo Observatory

Status Update



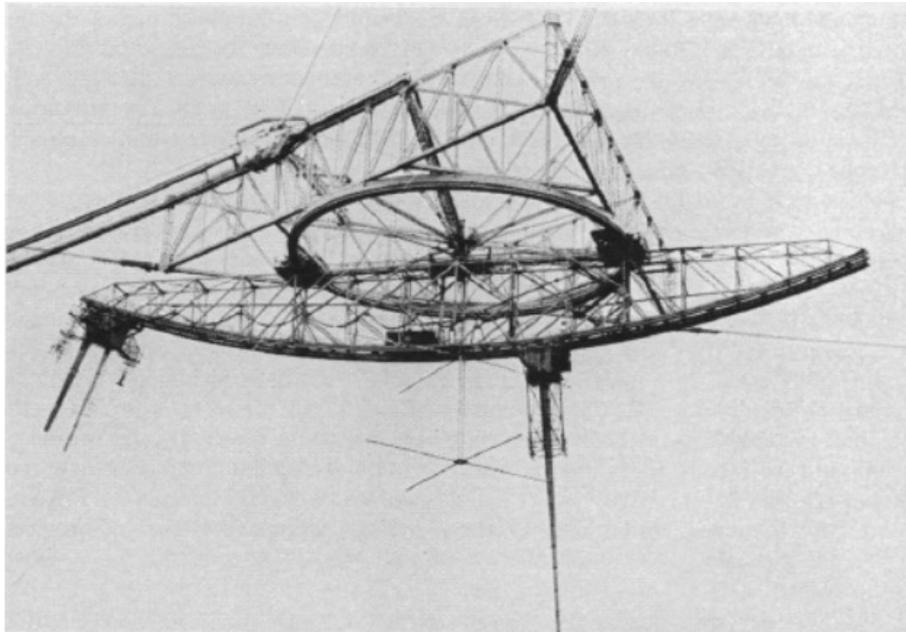
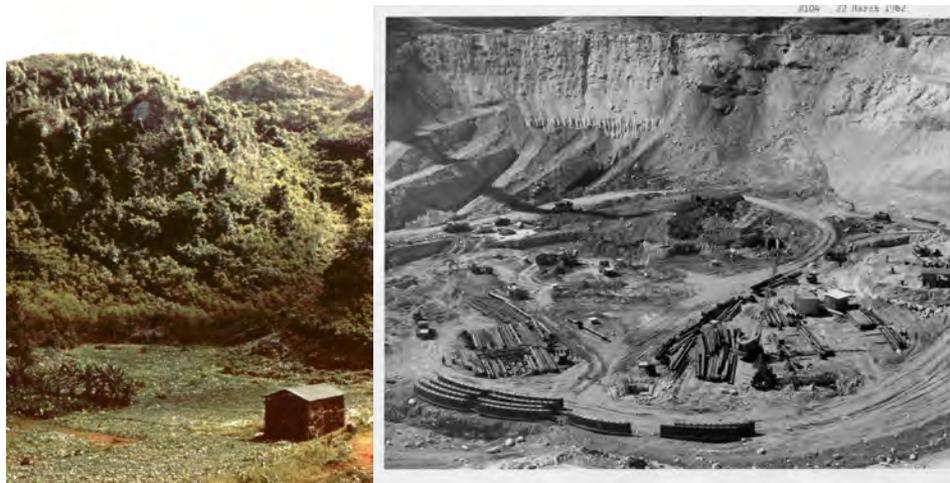


Main points

- Key Dates: August 10, November 6, December 1
- We are grateful that safety zones were adequate and ***nobody was physically hurt***
- NSF had every intention of ***repairing facility and continuing science*** prior to November 6th
- ***NSF authorized use of O&M funds immediately in August*** / failures had nothing to do with planned Hurricane repairs
- ***Safety was consistently prioritized*** (after August and November unexpected failures)
- ***Observatory is not closed***



Short History



- Developed as ionospheric radar by W. E. Gordon in 1958
- Built June 1960 - August 1963 with funds from the AF until 1969
- Transfer to NSF and managed by Cornell until 2011
- Gregorian upgrade in the 1990s
- SRI from 2011 to 2018
- UCF from 2018 to present
 - Significant partnership with NASA for planetary radar
 - Private partnerships for some instrumentation and Education & Public Outreach



Legacy of Scientific Discovery



ALFA 7-beam cooled receiver installed at Arecibo – 2004 / *Picture courtesy of Steve Torchinsky (NAIC.edu)*

- 1992 - Arecibo discovered the **first ever exoplanet**: In subsequent observations, an entire planetary system was found around the pulsar PSR 1257+12.
- 1994 - Arecibo mapped the **distribution of polar ice on Mercury**.
- 2008 - Astronomers use Arecibo to **detect for the first time, methanimine and hydrogen cyanide molecules** -- two organic molecules that are key ingredients in forming amino acids -- in a galaxy 250 million light-years away.
- 2016 - Arecibo discovered the **first-ever repeating fast radio burst**. Repeating fast radio bursts are millisecond-duration radio pulses that appear to be extragalactic. The repeater demonstrates that its source survives the bursts and rules out a class of models requiring catastrophic explosions.

Planned Upgrades



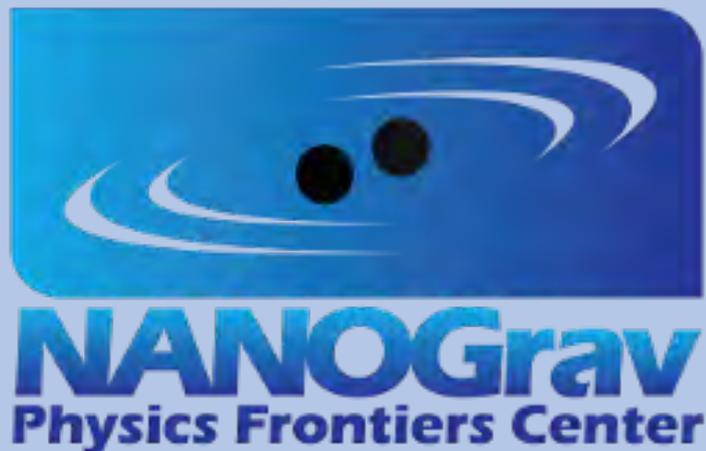
ALPACA = AO40

- **A**dvanced **L**-Band **P**hased **A**rray **C**amera for **A**recibo (**ALPACA**)
- 40 beam feed being developed for Arecibo (“AO40”)
- L-band is good frequency for pulsars
- Being developed by BYU, Cornell, and Arecibo
- Enables both post correlation beamforming (PCB) and real-time adaptive null forming RFI mitigation



19 beam PAF successfully tested

June 2018:
NSF awards \$5.8M for ALPACA



GORDON AND BETTY
MOORE
FOUNDATION

September 2020:
NSF awards \$762k
supplement for
Windows on the
Universe Wideband
receiver



Significant events 2018 – 2020

- **Hurricane Repairs:** \$14.3M appropriation
- **Earthquakes:** 2019 - 2020
- **Auxiliary cable failure** – August 10
 - Planned stabilization (September)
 - Design for full repair (Proposal submitted in October)
- **Main Cable failure** – November 6
- **NSF announces decision to start planning decommissioning** – November 19th
- Collapse** – December 1st



Unexpected. NSF places emphasis on safety and understanding structural stability in stabilization and work plans moving forward.



Tower 4 /
Aux North Cable Failure
Main Cable Failure

Tower 8 /
Spliced main cable replacement
planned as part of Hurricane award

Tower 12 /
Visitor's Center
Backstay with ~2 inch
slippage

Gregorian: 1990s upgrade

39 total cables
12 auxiliary cables
27 main cables



Hurricane Repairs

**Hurricanes Irma & Maria –
significant damage Fall 2017
winds in excess of 100 mph**

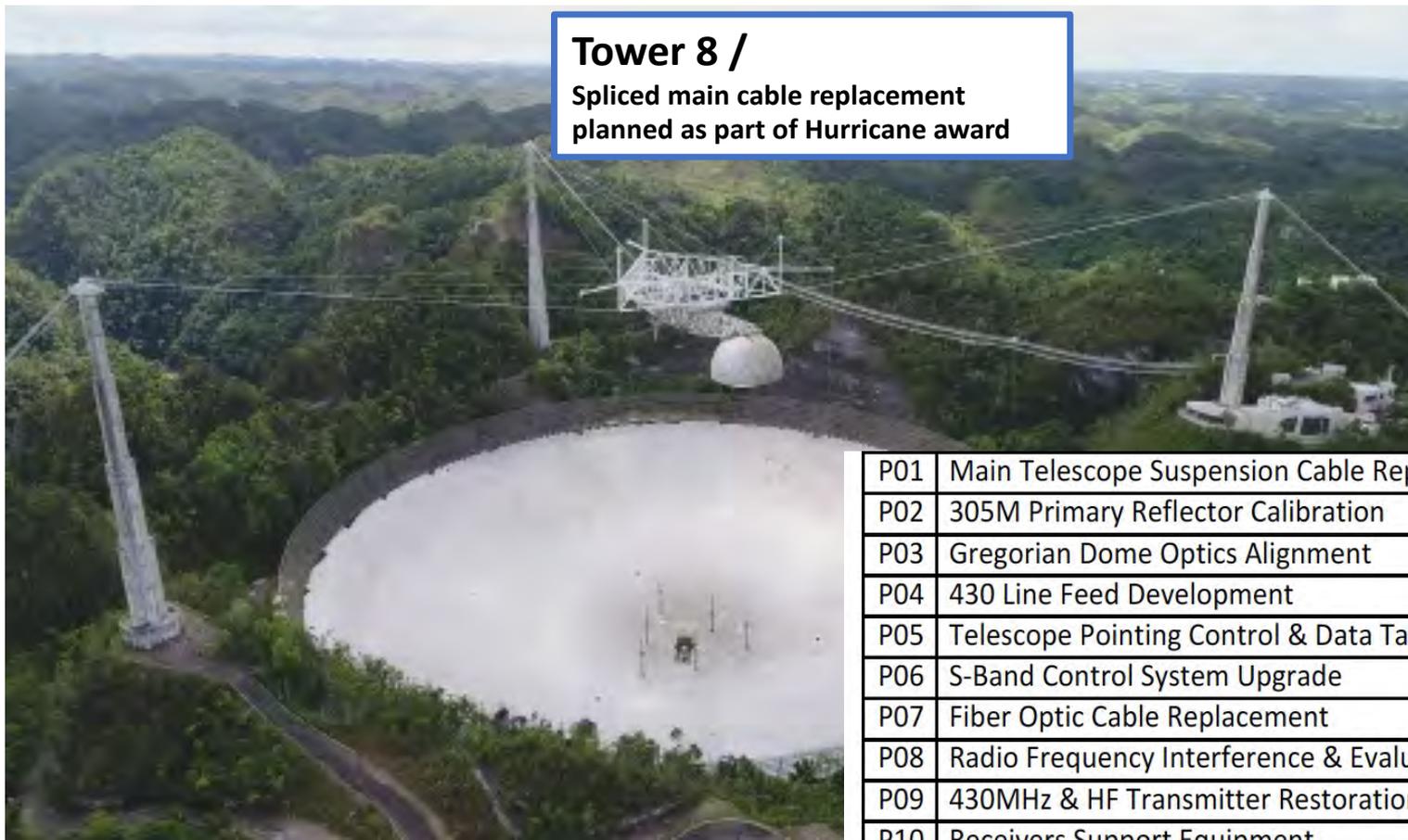


2M awarded Summer 2018 / completed:

- Generator rewinding
- Debris cleanup & Building repairs
- Electrical restoration
- Catwalk repair / Cable Car wheels replaced
- Procurement of material handler, three vehicles, water pump
- Cable replacement analysis and design



12.3M awarded summer 2019 (timeline thru FY23)



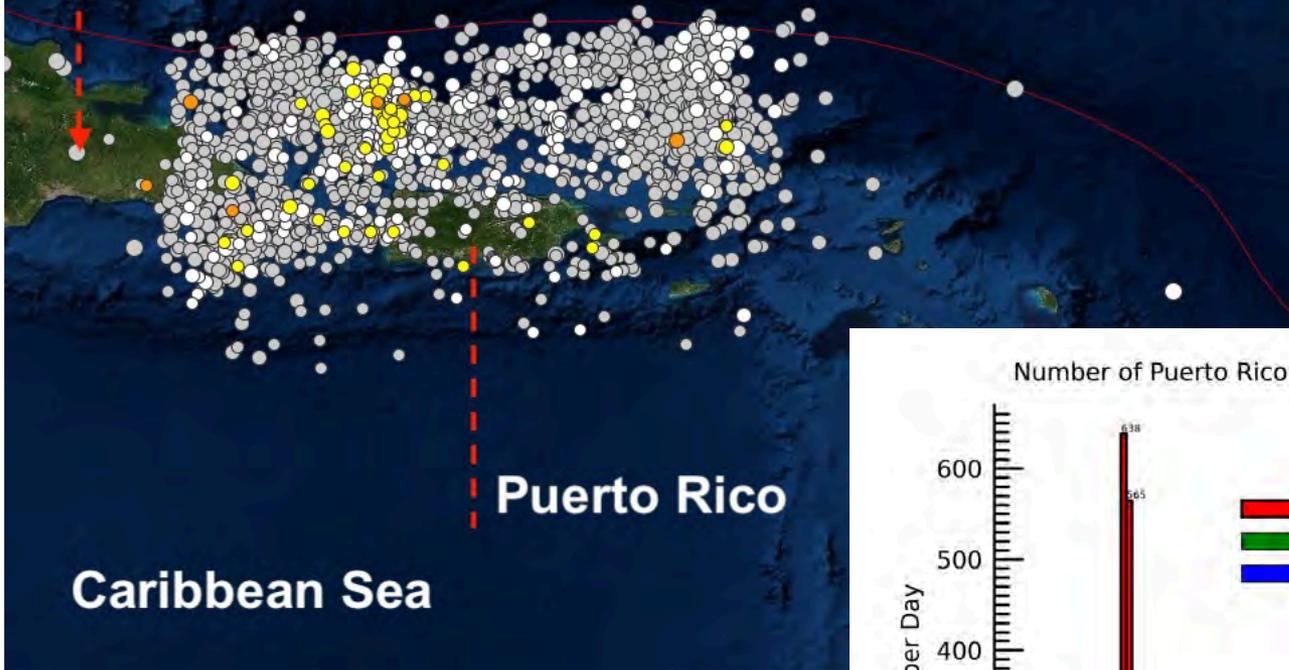
Tower 8 /
Spliced main cable replacement
planned as part of Hurricane award

P01	Main Telescope Suspension Cable Replacement
P02	305M Primary Reflector Calibration
P03	Gregorian Dome Optics Alignment
P04	430 Line Feed Development
P05	Telescope Pointing Control & Data Taking
P06	S-Band Control System Upgrade
P07	Fiber Optic Cable Replacement
P08	Radio Frequency Interference & Evaluation
P09	430MHz & HF Transmitter Restoration
P10	Receivers Support Equipment
P11	Erosion Control
P12	Reference Antenna 12m
P13	Other Site Repairs
P14	Storage & Transmitter Lab



Dominican Republic

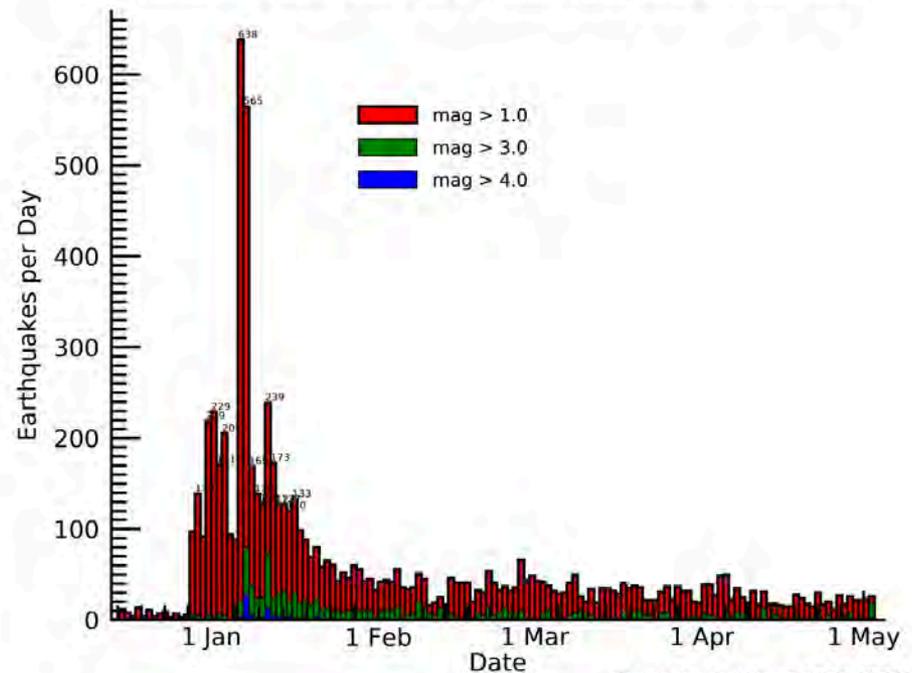
3,068 quakes of mag 2.5 or higher recorded here in 2019



Puerto Rico

Caribbean Sea

Number of Puerto Rico Earthquakes (Dec 2019 to May 2020)

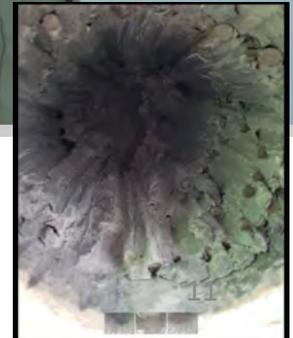


phl.upr.edu, Sat May 2 19:35:49 2020

Cable/socket failure (August 10, 2020; 3 am)

Cable that slipped out

Failed socket





Teams in place - UCF

- **Wiss, Janney, Elstner Associates, Inc.**
 - lead forensic evaluation
 - establish safe working conditions
 - Work with NASA Kennedy lab for forensic evaluation
- **Thornton Tomasetti**
 - structural analysis and modeling of tower/cables
 - Engineer of Record
- **WSP (acquired Louis Berger)**
 - project management; historical perspective



Teams in place - NSF

- **Safety experts (GEO/OPP)**
- **US Army Corp of Engineers**
 - Assist NSF in the review of engineering and design plans
- **Forensic Engineer Consulting**
 - Assist NSF in review of contracts established with the lead AE firm, structural analysis, and forensic evaluation



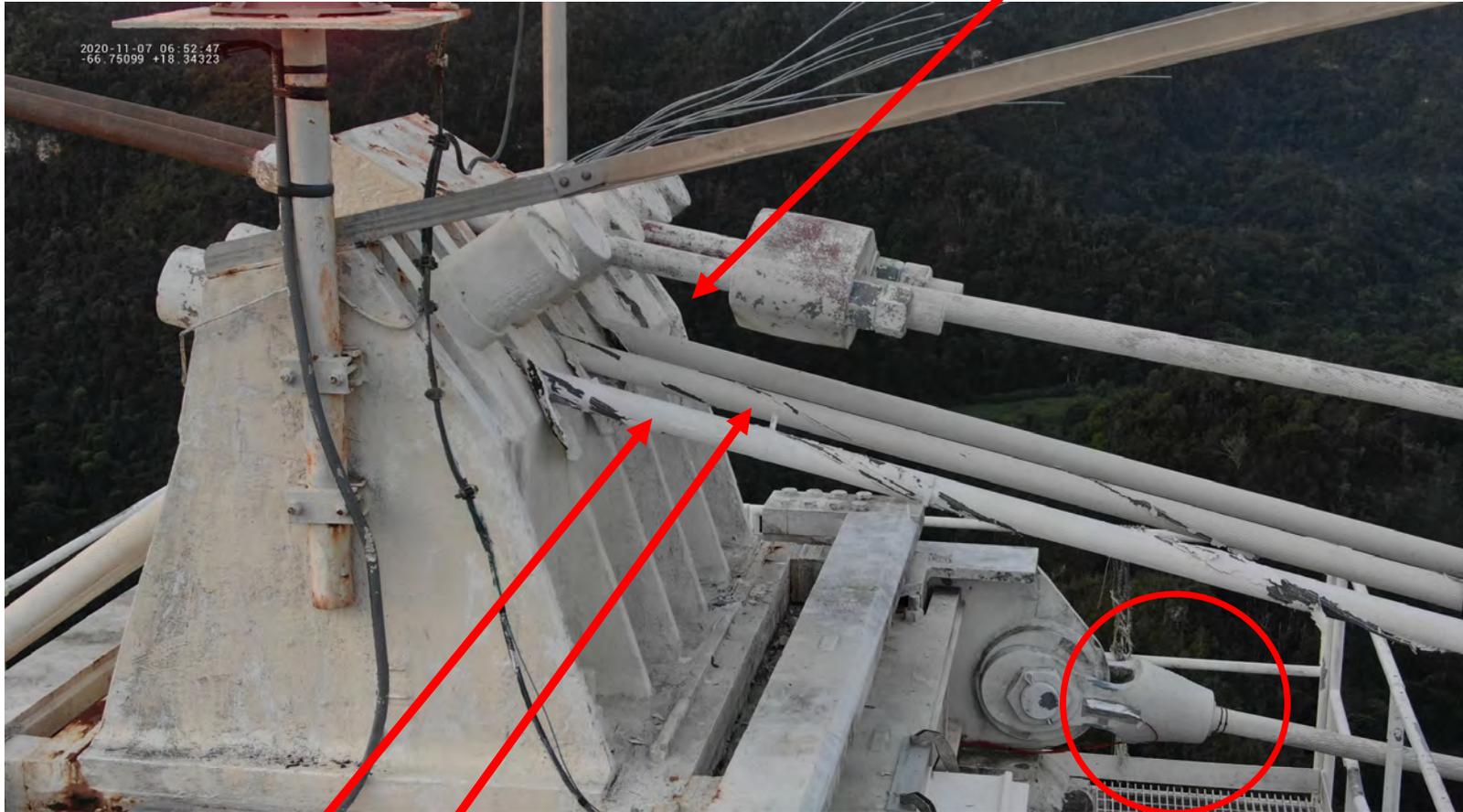
Stabilization Plan

- Structural modeling and safety zones identified; **September**
- Socket removed & sent to NASA Kennedy lab for forensics; **early October**
- Emergency stabilization plans approved; **end of September**
 - Two auxiliary cables and two temporary cables ordered; **early December installation expected**
- Oct 19 – emergency repair proposal for stabilization submitted
 - NSF asked UCF to include all costs incurred since Aug 10th failure, forensic evaluation, engineering analysis, designs for immediate stabilization, and evaluation leading to the designs for a full repair.
- Oct 19 – 23: Review by NSF, Engineering consultant, USACE
- Increased monitoring
 - Strain gauges installed
 - Tilt meters installed
 - Acoustic monitors ordered

6 November 2020 Failure



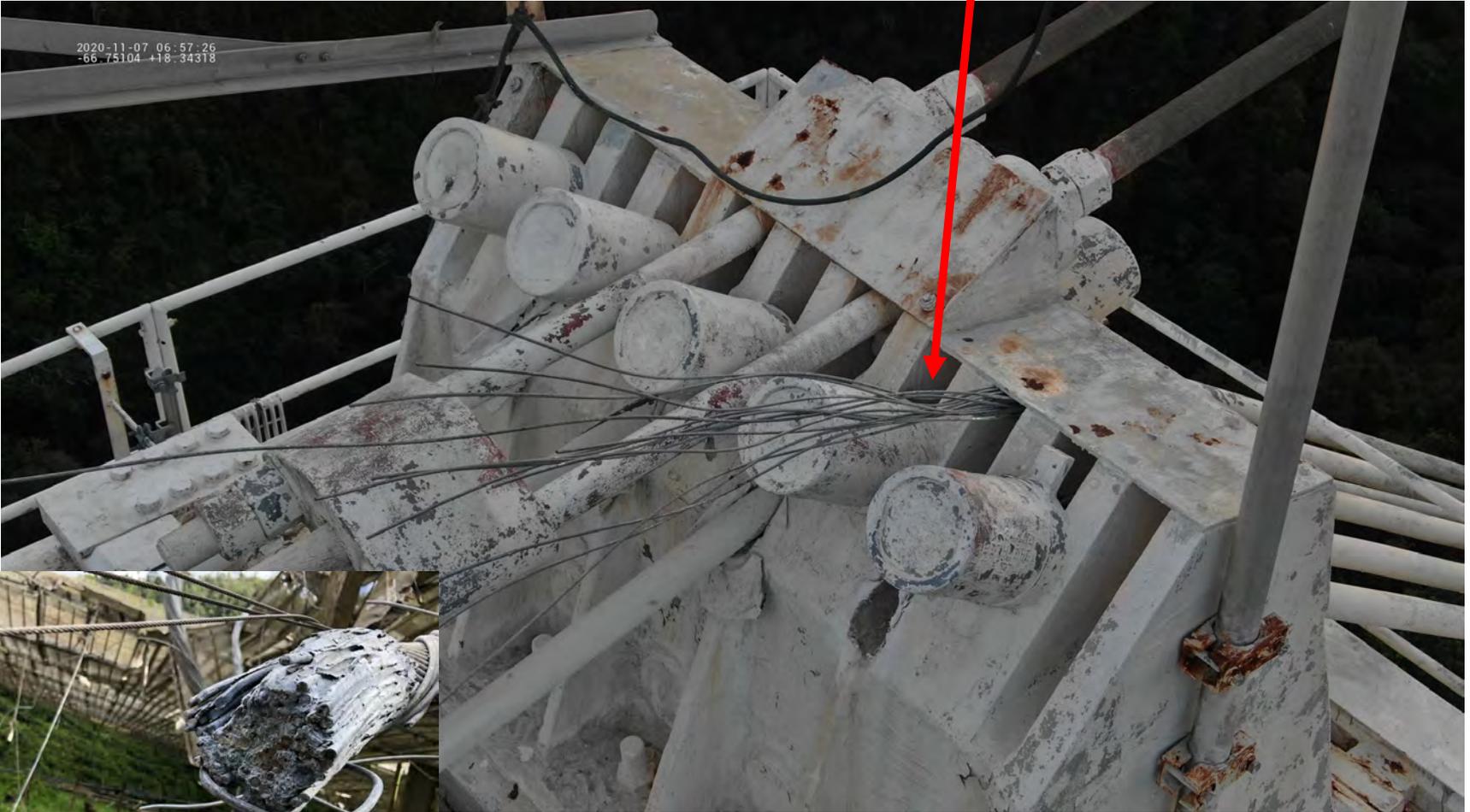
Failed main cable



New broken wires on M4-1 (4)
and M4-2 (2)

Aux South – no
observed change

Failed main cable wires



2020-11-07 06:57:26
-66.75104 +18.34318



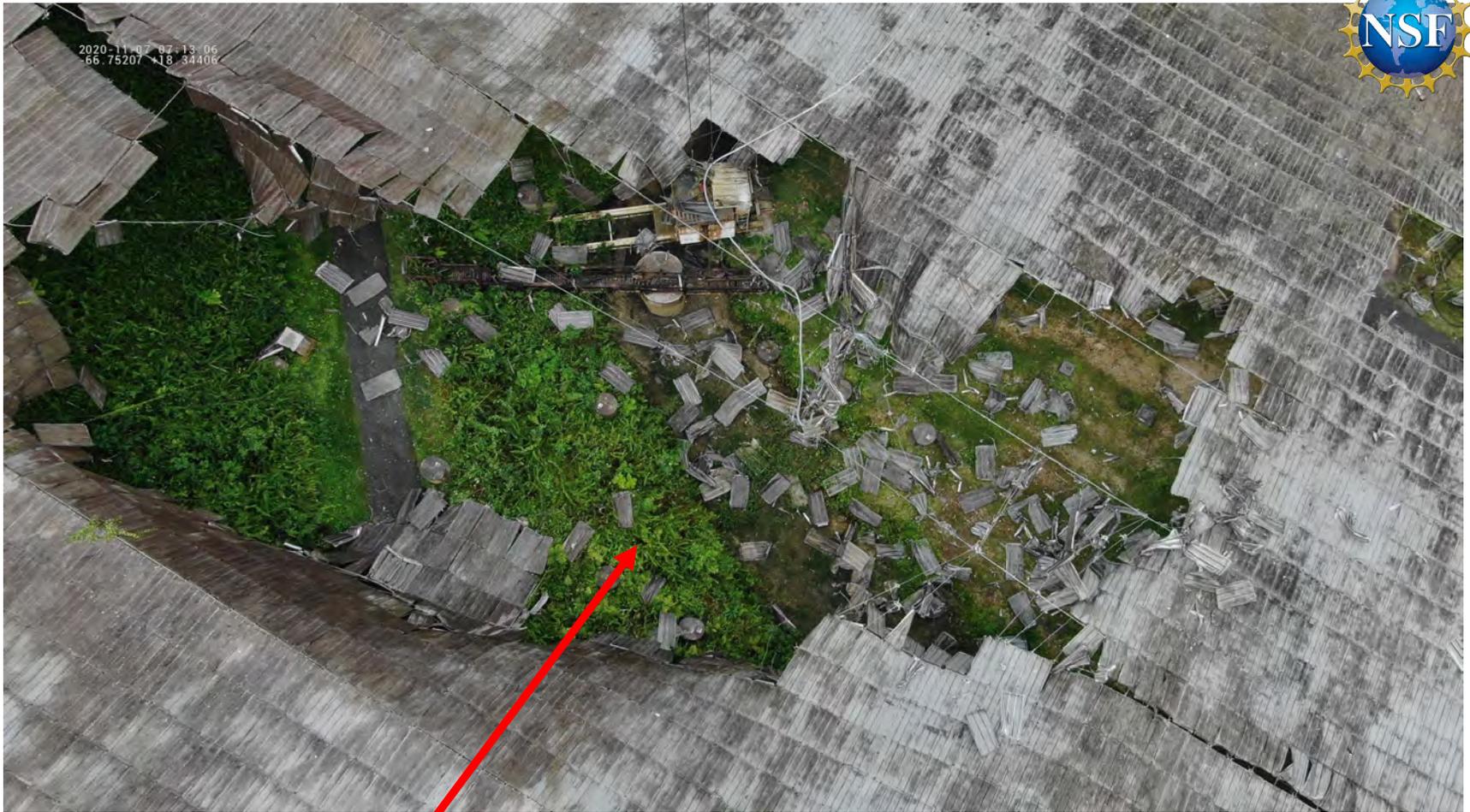


Back side of failed main cable; each cable has ~160 wire strands

Failed main cable wires



New broken wires on M4-1 (4)
and M4-2 (2)



Main cable swung into the same hole in the reflector created by the failed auxiliary cable, slightly enlarging the hole and damaging one of the main cables underneath that helps retain the reflector's shape



Main Cable M4-4 Failure Details

- **Tower 4 is where the auxiliary cable failure occurred** 10 August 2020; 4 of 6 cables remaining between tower and platform
- **Cable failed below its expected capacity** making it impossible for engineers to determine stability of structure (cable failed below 60% its expected capacity)
- **Engineers identify in official report that another cable failure at Tower 4 would likely be catastrophic;** failure at other towers may be absorbed by structure, but would increase loading on the cables at Tower 4
- **Thornton Tomasetti and WSP recommend planning a controlled demolition**
 - see: https://www.nsf.gov/news/special_reports/arecibo/



Steps after November failure

- Increase Monitoring
 - Strain gauges
 - Drone inspections every two hours
- Materials
 - NSF approved expedited shipment of cables from two suppliers
- Load reduction/transfer strategies (WJE)
- Determine new “keep out” zones
 - Work may proceed in these zones only with adequate work/safety plans

Restricted Safety Zones

Tower 12 anchorage

Arecibo Observatory

450.00 ft

62

Tower 8 anchorage

710.00 ft

500.00 ft

Failed Auxiliary Main Cable

Failed Main Cable

Tower 4 anchorage

480.00 ft

Google Earth

Image © 2020 Maxar Technologies
2020 Google

1000 ft





Potential Conditions contributing to failure

Disclaimer: Analysis is ongoing and we don't know the total or relative contribution of each

- Significant damage after Hurricane Maria in 2017
- Thousands of Earthquakes since December 2019
- Puerto Rican weather/humidity
- Age / material degradation / maintenance



Final points

- We are grateful that safety zones were adequate and ***nobody was physically hurt***
- NSF had ***every intention of repairing facility and continuing science*** prior to November 6th
- NSF ***authorized use of O&M funds immediately*** in August / failures had nothing to do with planned Hurricane repairs
- ***Safety was consistently prioritized (after August and November unexpected failures)***

Final points

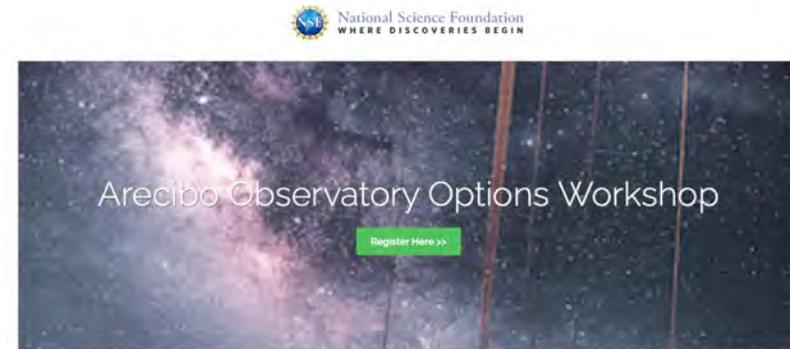
- Observatory is not closed
 - 12 meter telescope repairs authorized; observations have begun
 - LIDAR facility is operational (and remote Culebra site)
 - Visitor's center had very limited damage; still closed during cleanup (also impacted by COVID)





Where do we go from here?

- NSF prioritizing safety and environmental issues in cleanup
- Cleanup decisions will be made recognizing scientific and historical importance
- Forensic evaluation ongoing
- NSF Arecibo Updates Web page:
 - https://www.nsf.gov/news/special_reports/arecibo/index.jsp
- NSF Arecibo DCL
 - Explore Novel Ideas for Future Scientific Educational & Cultural activities
 - <https://www.nsf.gov/pubs/2021/nsf21055/nsf21055.jsp>
- NSF Arecibo Observatory Options Workshop
 - Kickoff April 2
 - Sessions in June



Arecibo Observatory Options Workshop

An Interactive Workshop to Explore Novel Ideas for Future Scientific, Educational, and Cultural Activities with the Arecibo Observatory

Overview

The National Science Foundation (NSF) is keenly interested in exploring novel ideas for future scientific, educational, and cultural activities at the Arecibo Observatory following the collapse of the 305-meter telescope platform. In order to explore the broadest range of options possible, we will hold a workshop focused on finding actionable and innovative ways to support, broaden, and strengthen the radio science community across Puerto Rico and to create or enhance the opportunities for scientific, educational and cultural activities and public outreach at the Arecibo Observatory. All are welcome, and participants at universities, colleges, and non-academic organizations, such as museums (etc.), in Puerto Rico are particularly encouraged to contribute.

The goal of the workshop is to assemble a diverse, multidisciplinary group of researchers, engineers, and educators who will develop ideas and provide input for expanding the breadth and depth of radio science in Puerto Rico, as well as facilitate the generation of innovative design ideas for the Arecibo Observatory for the short (1-3 years), medium (3-10 years), or long term (10+ years). The broad theme of this activity is a multifaceted approach supporting any or all of the following next generation science in astronomy, atmospheric and geospace sciences, planetary radar or related fields; inclusive educational and cultural programs; and robust radio science programs, including engineering, instrumentation and radio frequency interference (RFI) mitigation.

This workshop does not offer any direct funding opportunities, and no selection process will take place during the workshop. The aim of this workshop is to provide participants with the tools needed to produce a clear and collaborative proposal which may subsequently be submitted to the NSF or other funding organizations. All proposals for future activities at Arecibo, whether developed through this workshop or independently, will be reviewed following the formal proposal review process in place at the agency that receives them.

Key Dates (subject to change)

- Overview and Workshop Plan 04/02/2021
- Workshop Application Deadline 05/03/2021
- Workshop Invitations Sent Out 05/21/2021
- Workshop Registration Deadline 05/28/2021
- Virtual Workshop Sessions: 05/04/2021- 6/28/2021 (see schedule below)