Arecibo Observatory
Status Update

Arecibo Observatory 2018

AAAC
January 27, 2021

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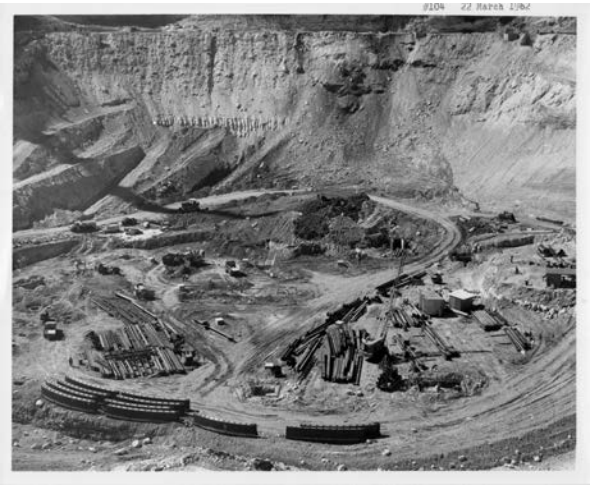
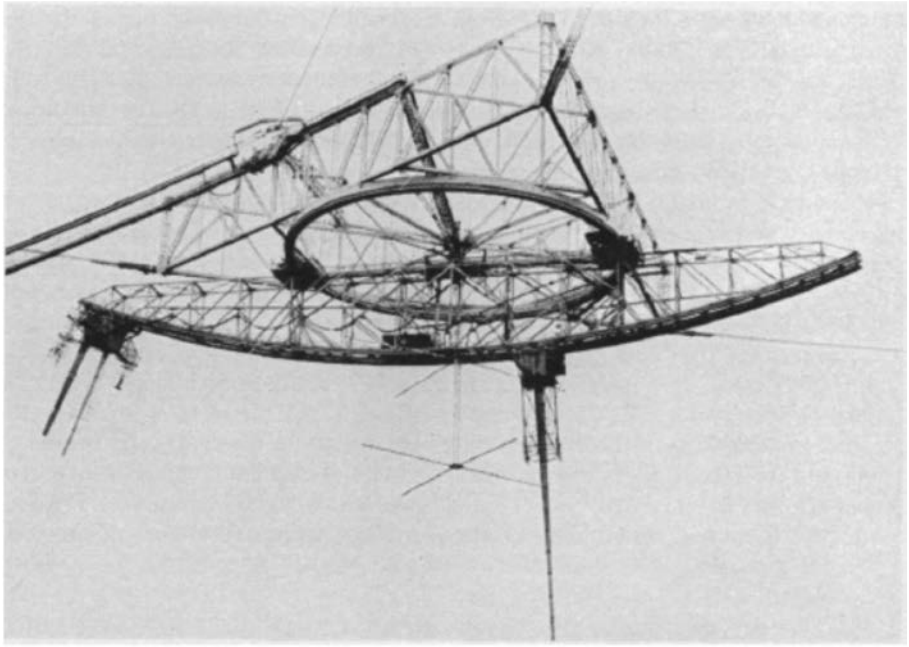
Main points

- 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)
- ***Observatory is not closed***

https://www.nsf.gov/news/special_reports/arecibo/

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

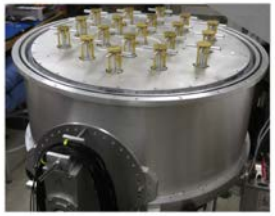
ALFA 7-beam cooled receiver installed at Arecibo – 2004 / *Picture courtesy of Steve Torchinsky (NAIC.edu)*

- 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

NANOGrav Physics Frontiers Center

GORDON AND BETTY MOORE FOUNDATION

September 2020:
NSF awards 762K supplement for Windows on the Universe Wideband receiver

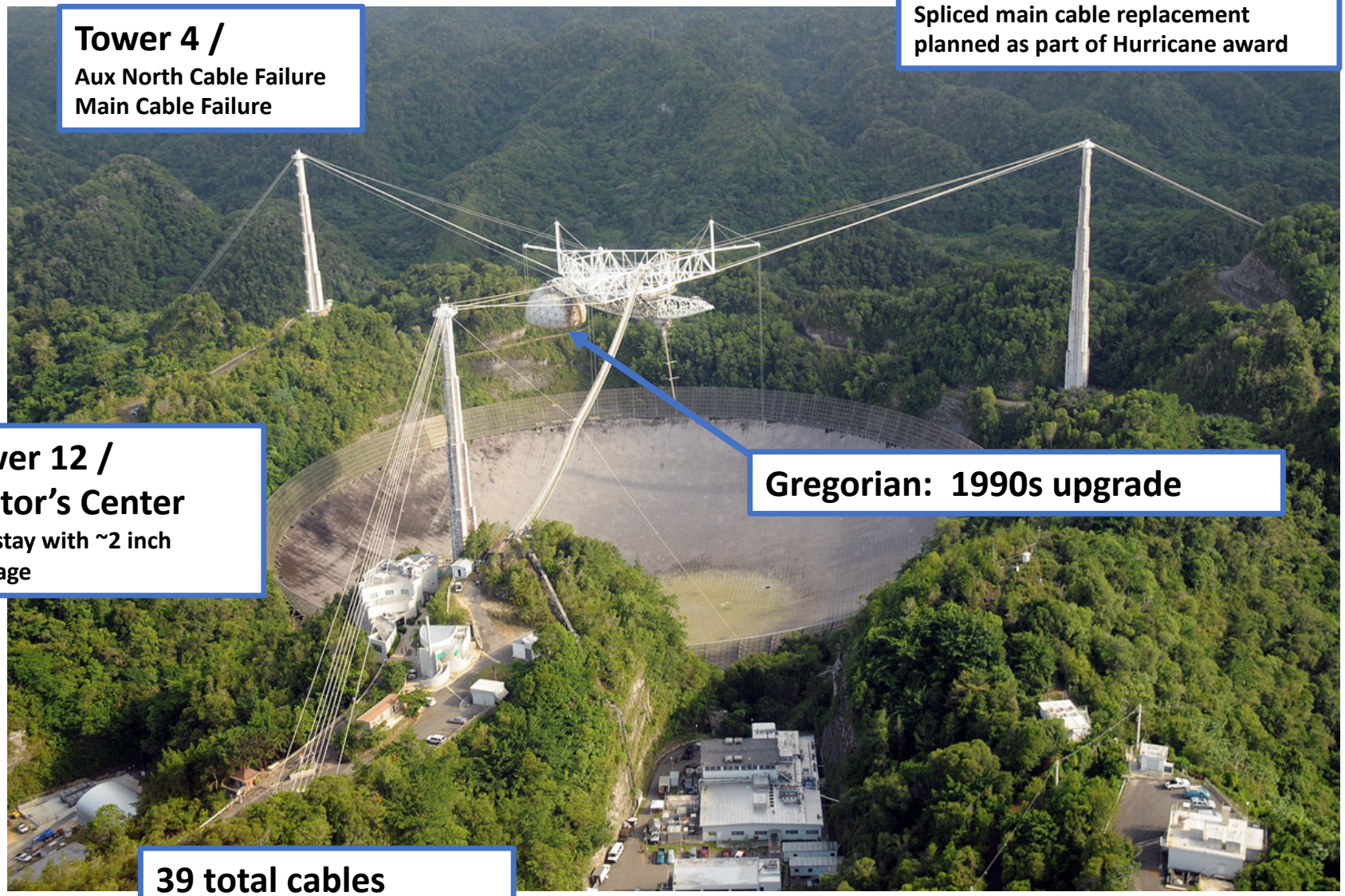

EARTH
FROM SPACE

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

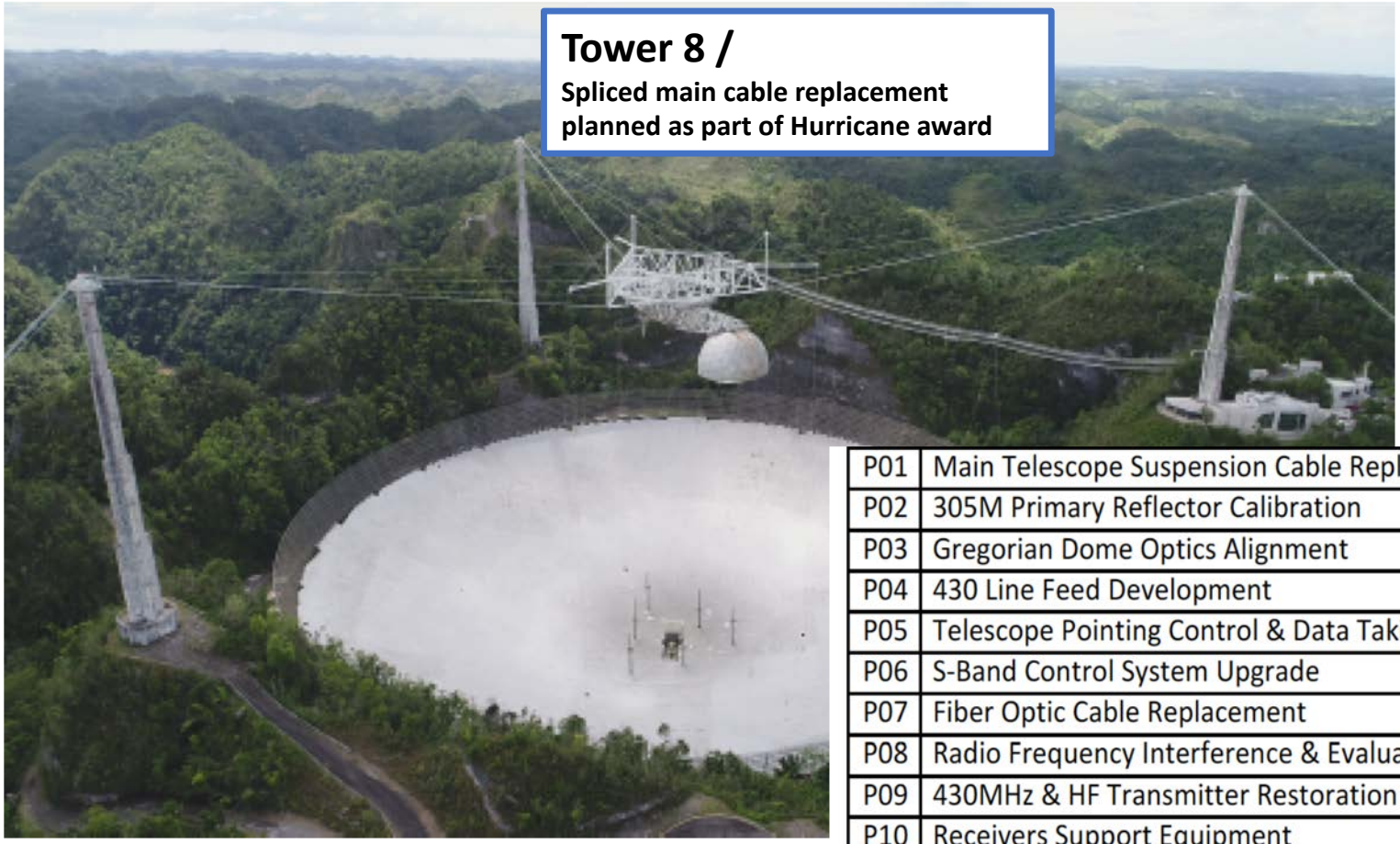
Hurricane Repairs

Hurricanes Irma & Maria – significant damage Fall 2017 winds in excess of 200 mph

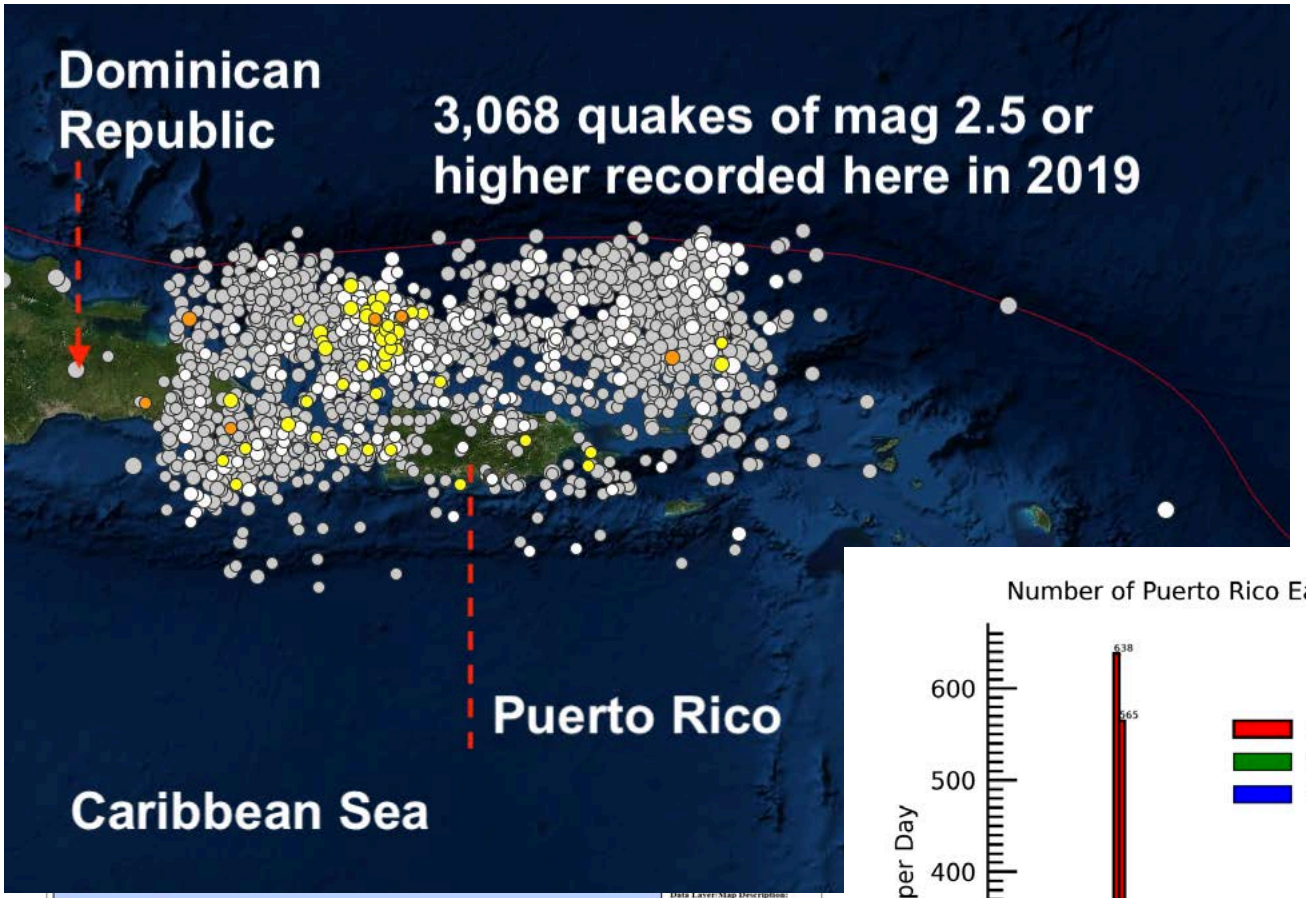
2M awarded Summer 2018 / completed:

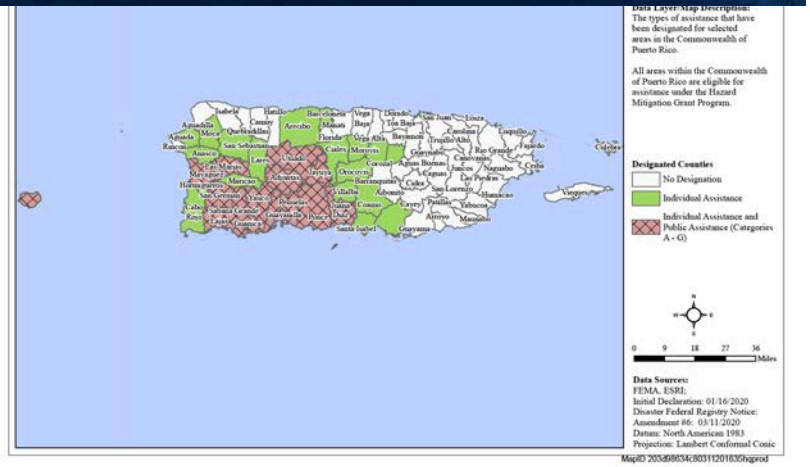
- Generator rewinding
- Debris cleanup & Building repairs
- Electrical restoration
- Catwalk repair / Cable Car wheels replaced
- Procurement of material handler, three vehicles, water pump
- Cable replacement analysis and design

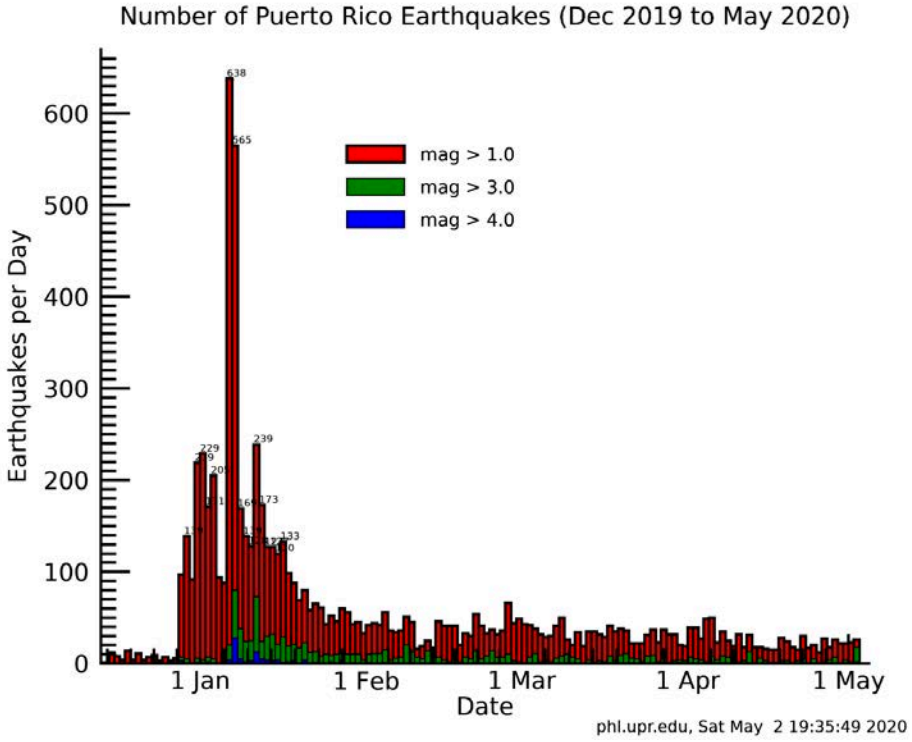
12.3M awarded summer 2019 (timeline thru FY23)



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


Data Layer Map Description:
The types of assistance that have been designated for selected areas in the Commonwealth of Puerto Rico.
All areas within the Commonwealth of Puerto Rico are eligible for assistance under the Hazard Mitigation Grant Program.
Designated Counties
No Designation
Individual Assistance
Individual Assistance and Public Assistance (Categories A - G)
Data Sources:
FEMA, ESRI;
Initial Declaration: 01/16/2020
Disaster Federal Registry Notice:
Amendment #6: 03/11/2020
Datum: North American 1983
Projection: Lambert Conformal Conic


Number of Puerto Rico Earthquakes (Dec 2019 to May 2020)
Earthquakes per Day
0
100
200
300
400
500
600
mag > 1.0
mag > 3.0
mag > 4.0
638
665
239
229
1 Jan
1 Feb
1 Mar
1 Apr
1 May
Date
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

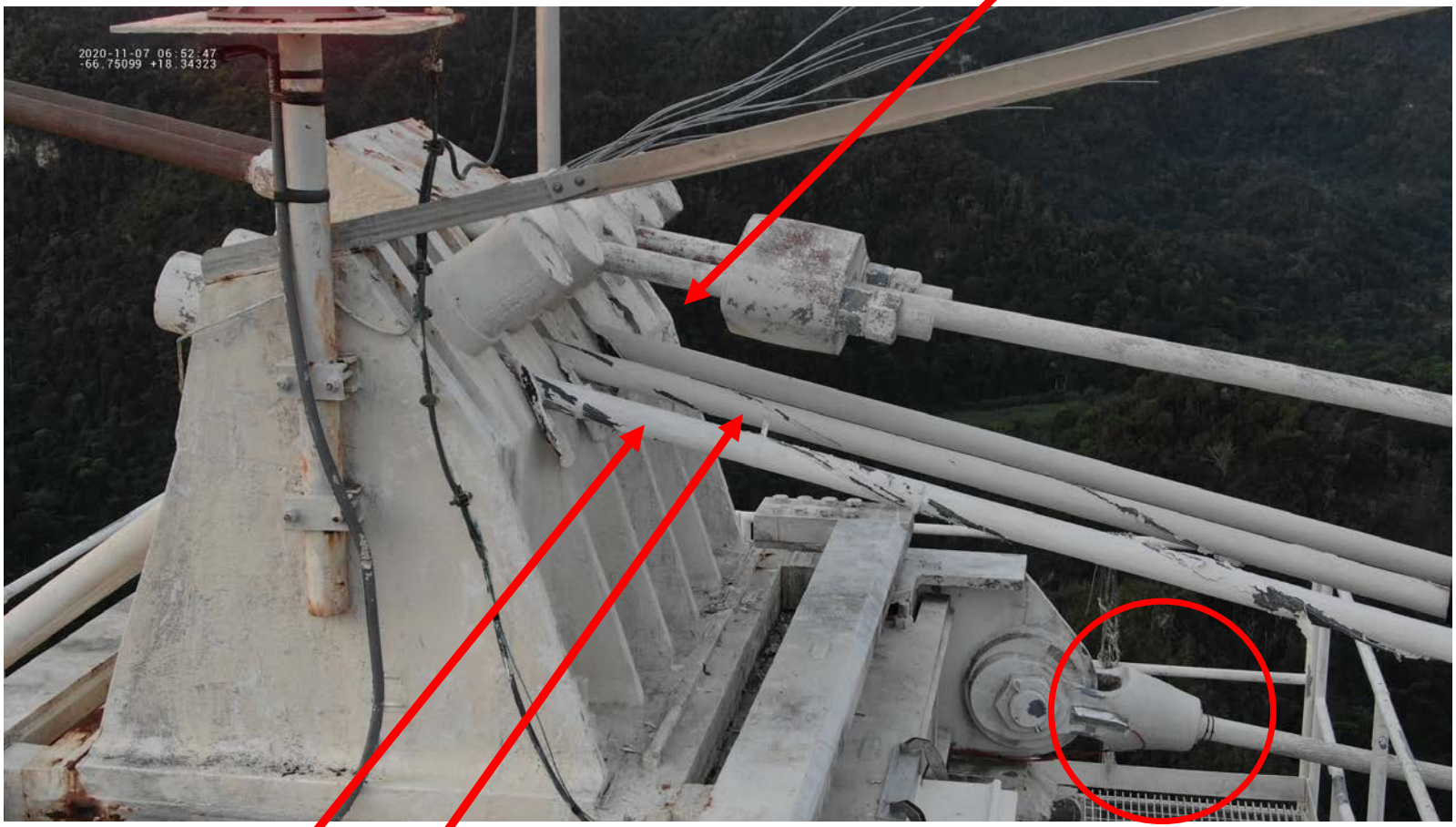
- **Safety experts (GEO/OPP)**
- **US Army Corp of Engineers**
  - Assist NSF in the review of engineering and design plans
- **Forensic Engineer Consulting**
  - Assist NSF in review of contracts established with the lead AE firm, structural analysis, and forensic evaluation

Stabilization Plan

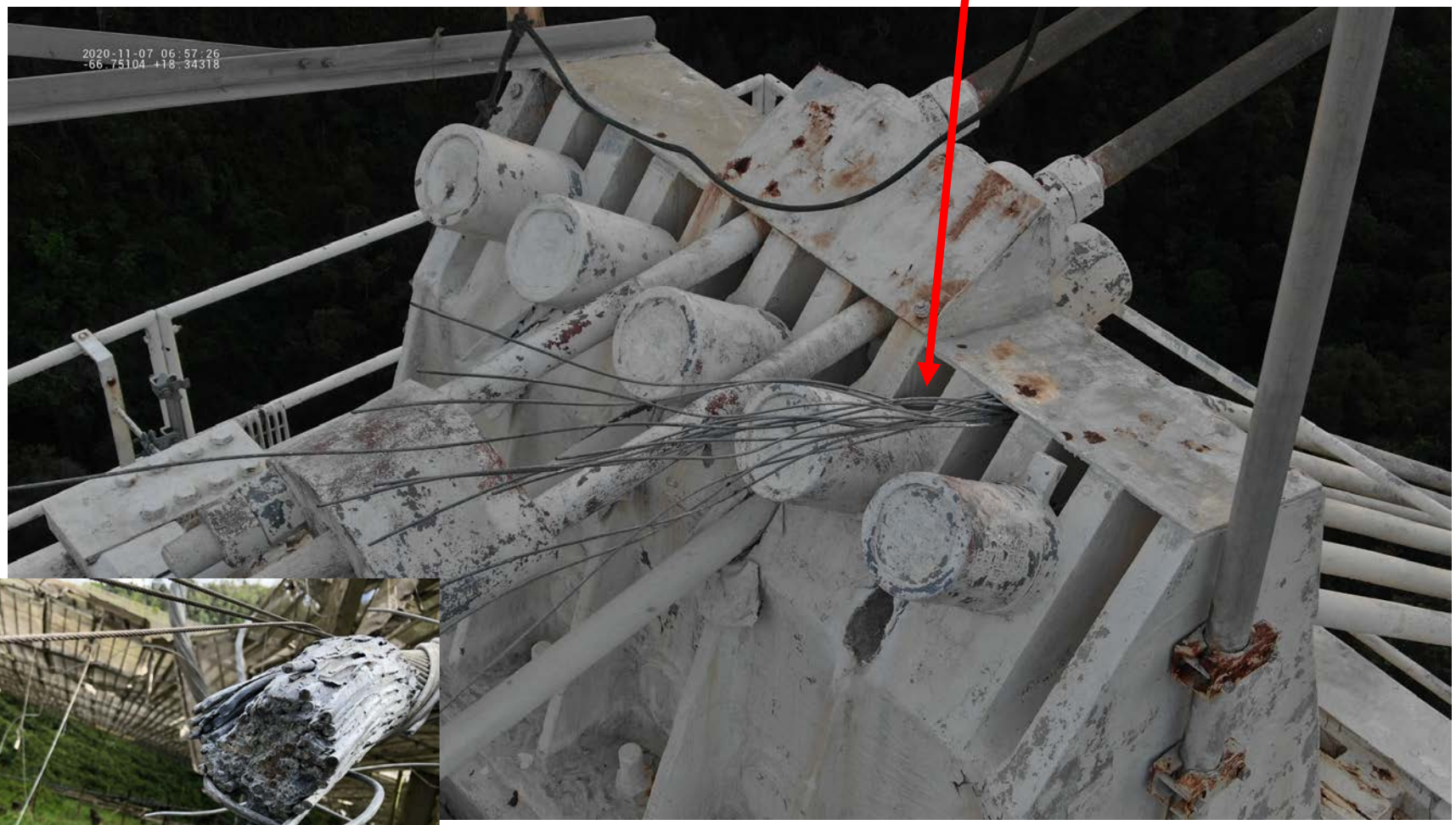
- Structural modeling and safety zones identified; ***September***
- Socket removed & sent to NASA Kennedy lab for forensics; ***early October***
- Emergency stabilization plans approved; ***end of September***
  - Two auxiliary cables and two temporary cables ordered; ***early December installation 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 wires

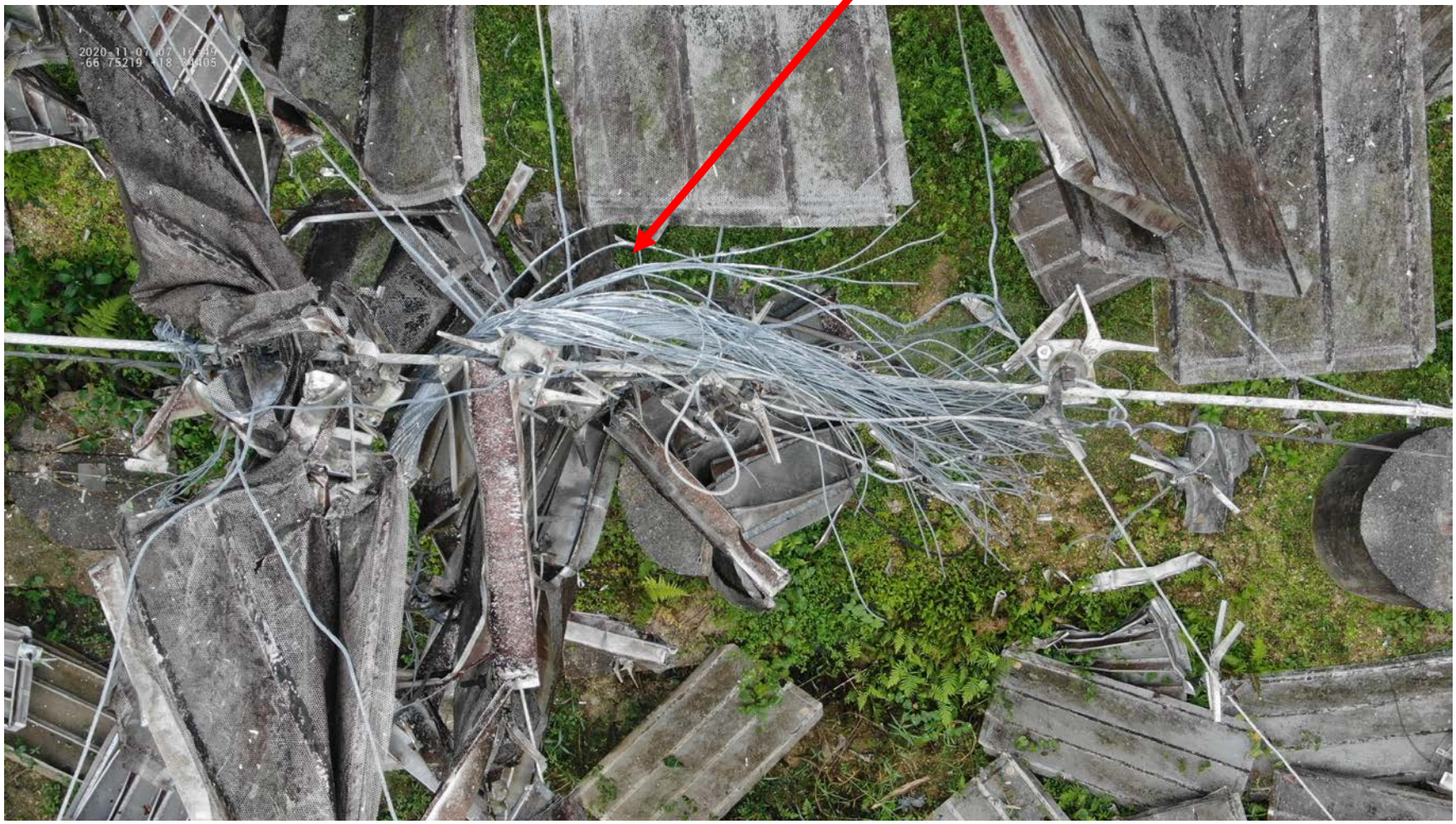


Back side of failed main cable; each cable has ~160 wire strands

Failed main cable wires

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

Failed main cable; end that broke from Tower 4



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

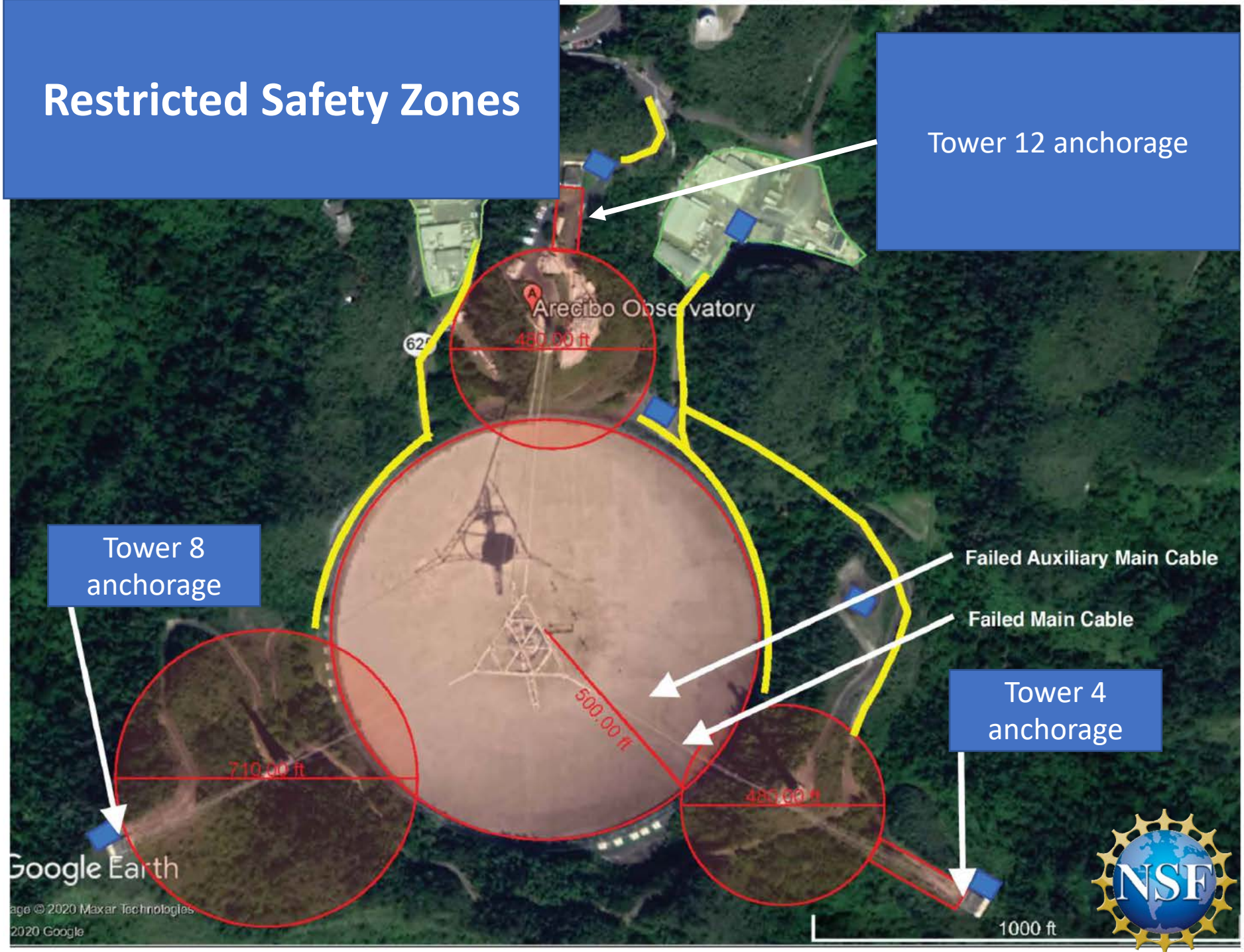
Main Cable M4-4 Failure Details

- **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



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
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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 plans to utilize community input on scientific ideas moving forward.

The heart and soul of Arecibo Observatory is not the telescope, but ***the people*** who live by William E. Gordon's words:

"If you dream, have big dreams."

NSF looks forward to a bright scientific future with many new discoveries to come from the Arecibo Observatory.

Arecibo staff photo; January 2020 Image Credit: NAIC