# IceCube-Gen2

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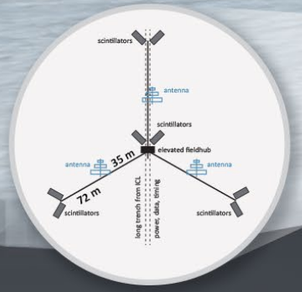
***for the IceCube-Gen2 Collaboration***

Photo: Yuya Makino

# IceCube GEN2 | DETECTORS

## SURFACE • RADIO • OPTICAL




**Cosmic Ray Surface Array**

An air shower array that sits on top of the optical array

One surface station installed above each optical string

**IceCube-Gen2 Optical Module**

4x the sensitivity of IceCube's modules

9,600 new optical modules in total to be deployed in the ice

80 modules on each string, spaced 17 meters apart

IceCube Laboratory

50 m

1370 m

2780 m

**IceCube-Gen2:** 120 new strings of optical modules

**IceCube:** 86 strings of optical modules

DeepCore

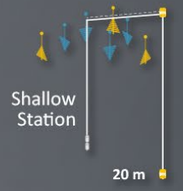
Antarctic bedrock

IceCube (1 km)

IceCube-Gen2 (5 km)

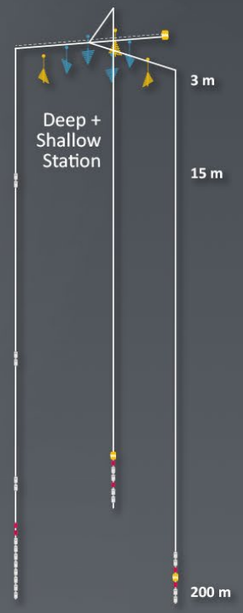
**Amundsen–Scott South Pole Station, Antarctica**

A National Science Foundation-managed research facility



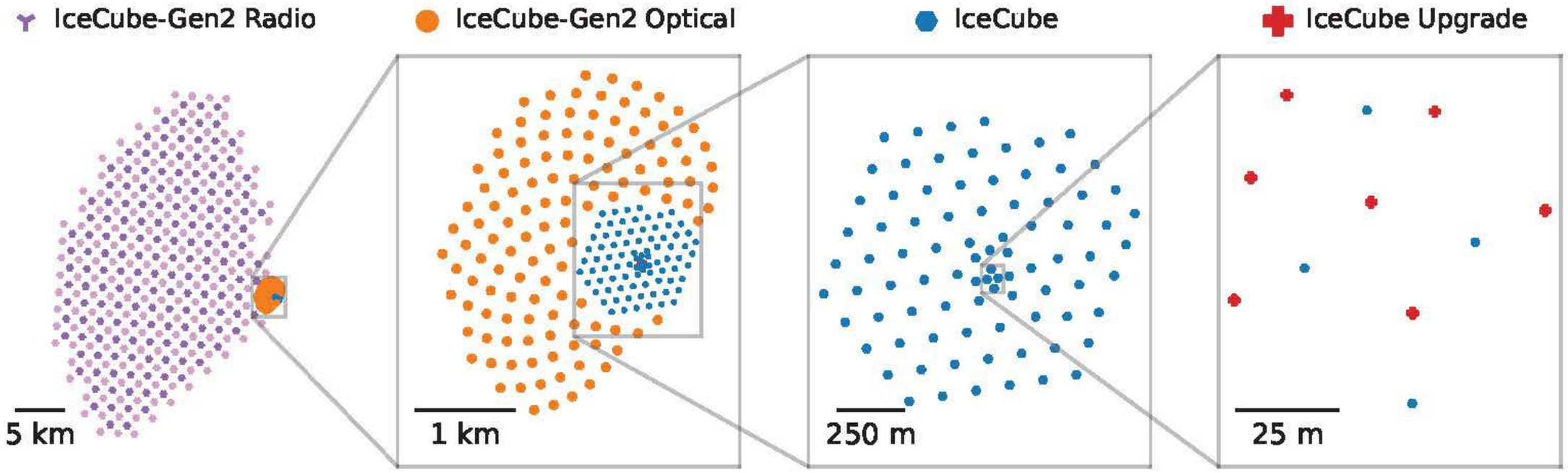

**Below-Ice Radio Array**

361 detector stations spread over an area of 500 km²



# IceCube-Gen2: extending the IceCube Neutrino Observatory

- Increasing the deep optical and surface arrays by eight-fold
- Large in-ice radio array for ultra high energy neutrinos




361 radio stations

120 new strings / 9600 optical modules
130 new surface stations

86 strings; 5160 optical modules
81 pairs of Surface detectors (IceTop tanks)

7 strings; 790 modules

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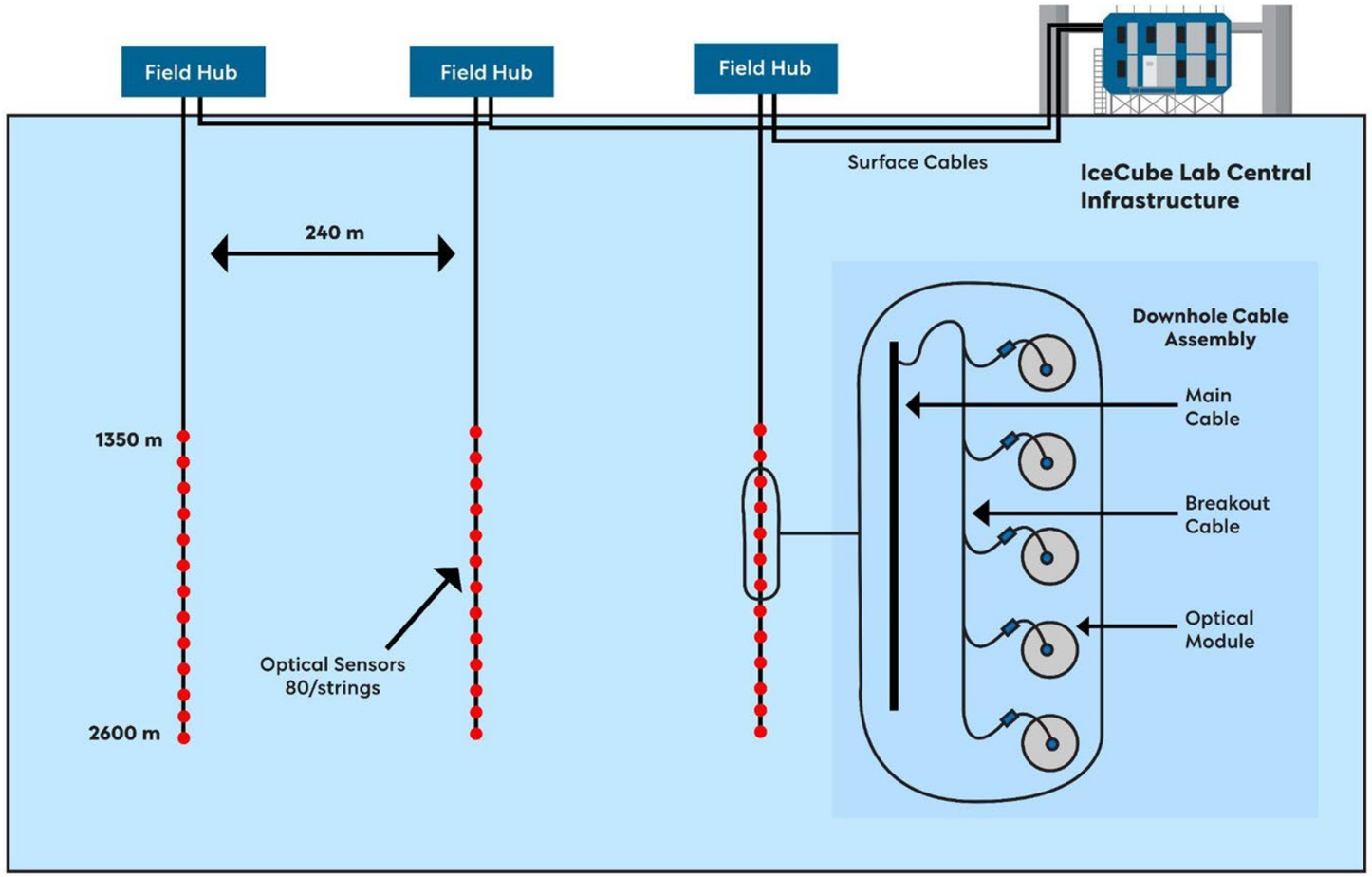
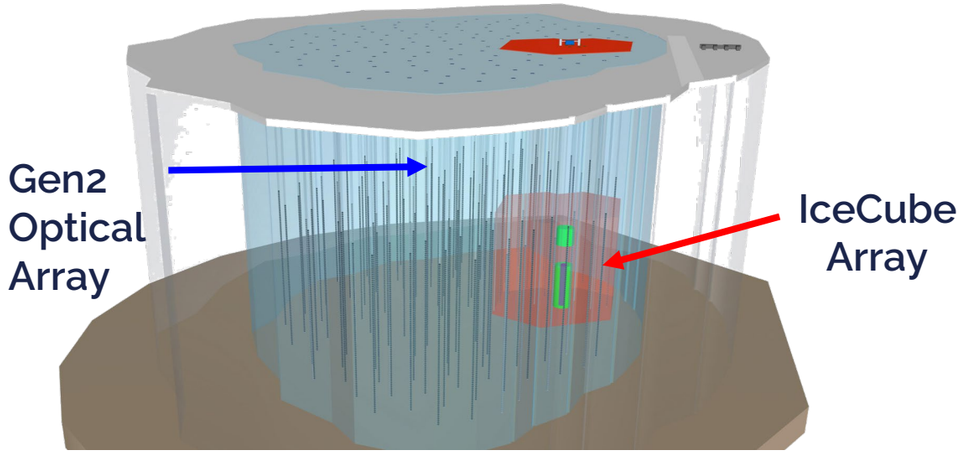
# Conceptual Design of the Optical Array




- 120 detector strings with 80 sensors each.
- 8 $km^3$ instrumented volume of ice
- Optimized for high energy events

# IceCube-Gen2 Optical Modules

The new design compared to IceCube optical modules has:

- 4 x sensitivity.
- Less power consumption.

Uses the module “footprint” of the Upgrade D-Egg (narrower module => smaller diameter drill hole, more time and fuel efficient drilling), and the multi-PMT concept of the Upgrade mDOMs.

Come in 2 flavors: 16 PMT / 18 PMT
6 of each type (12 in total) will be installed in the Upgrade this year allowing in-ice testing and calibration.

One design will be selected for building during the design phase of the detector. IceCube-Gen2 will install 9,600 optical modules

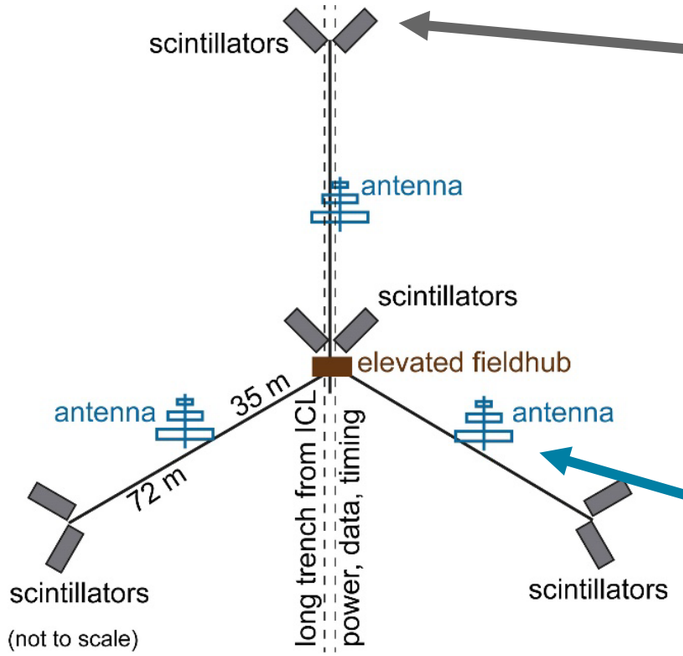
Prototype
Gen2 16-PMT Module

Prototype
Gen2 18-PMT Module

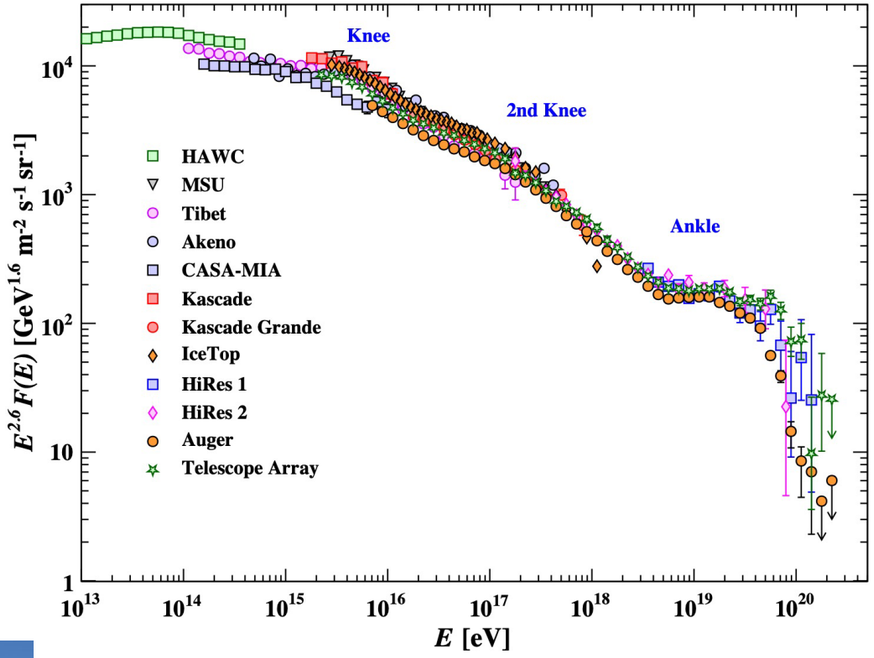
Photo credit: Yuya Makino/WIPAC

IceCube GEN2

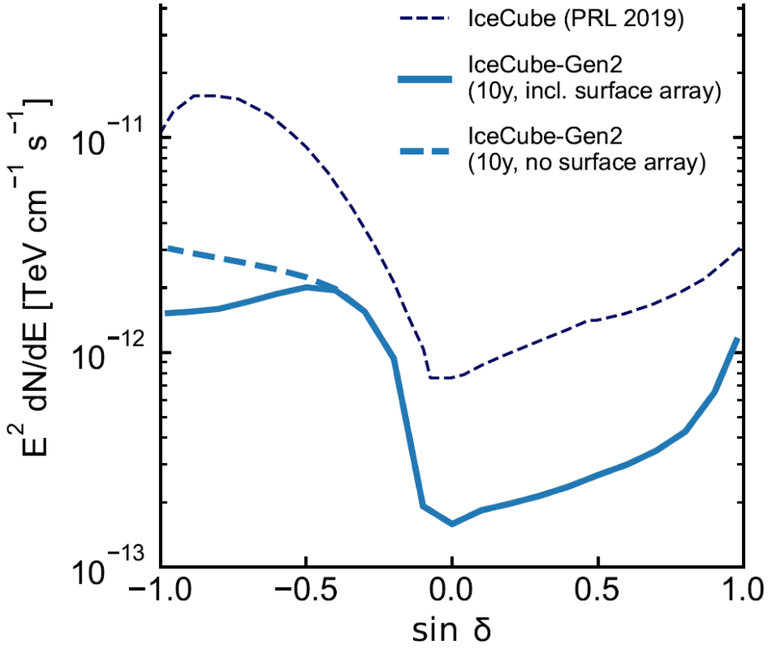
# Surface Array




Prototype station at South Pole




Each Surface Array station has 4 pairs of scintillators, 3 antenna



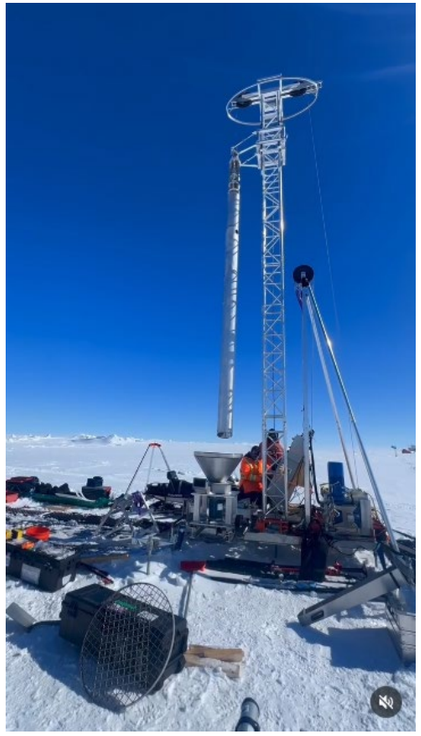
# Radio Detectors for Highest Energies

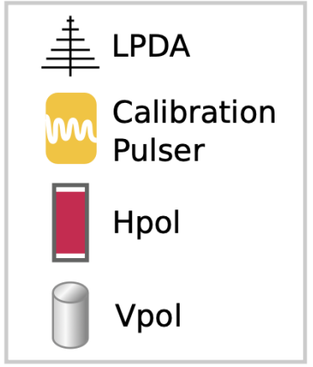
- 361 radio detector stations
- 1.6 x $10^3$ $km^3$ effective volume

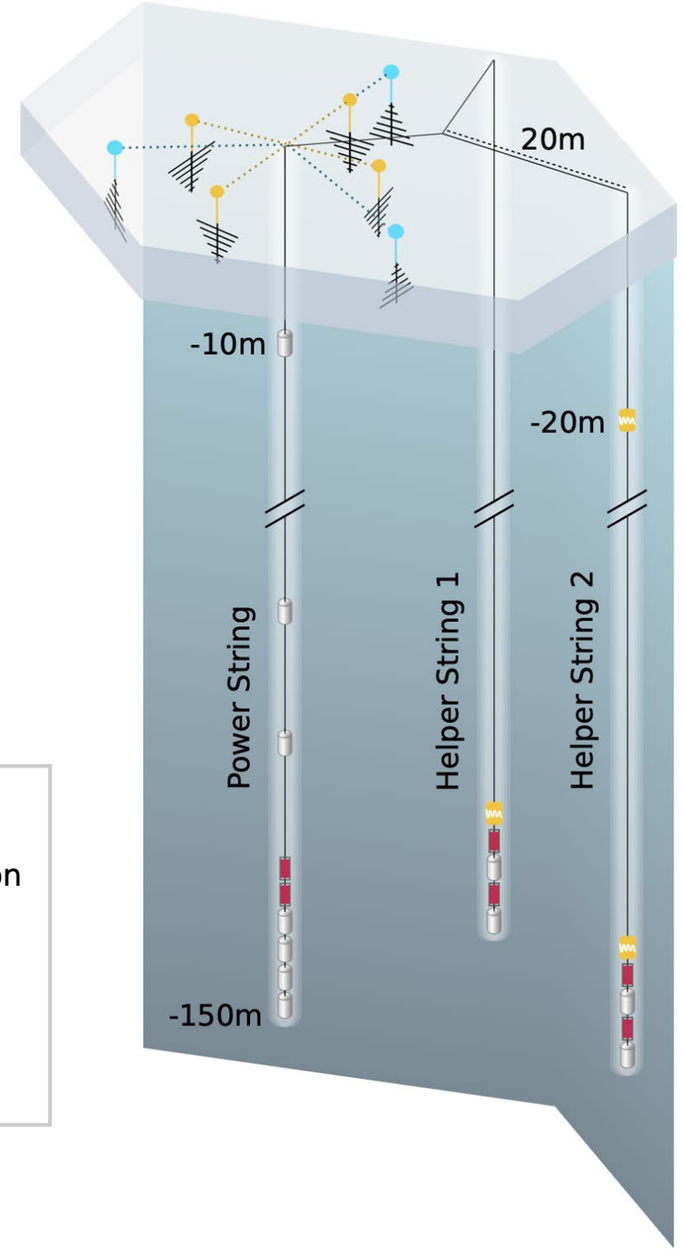
South Pole ice is extremely transparent to radio waves (attenuation length > 1.5 km).

Technology has been successfully tested at the South Pole (ARA) and in Greenland (RNO-G).

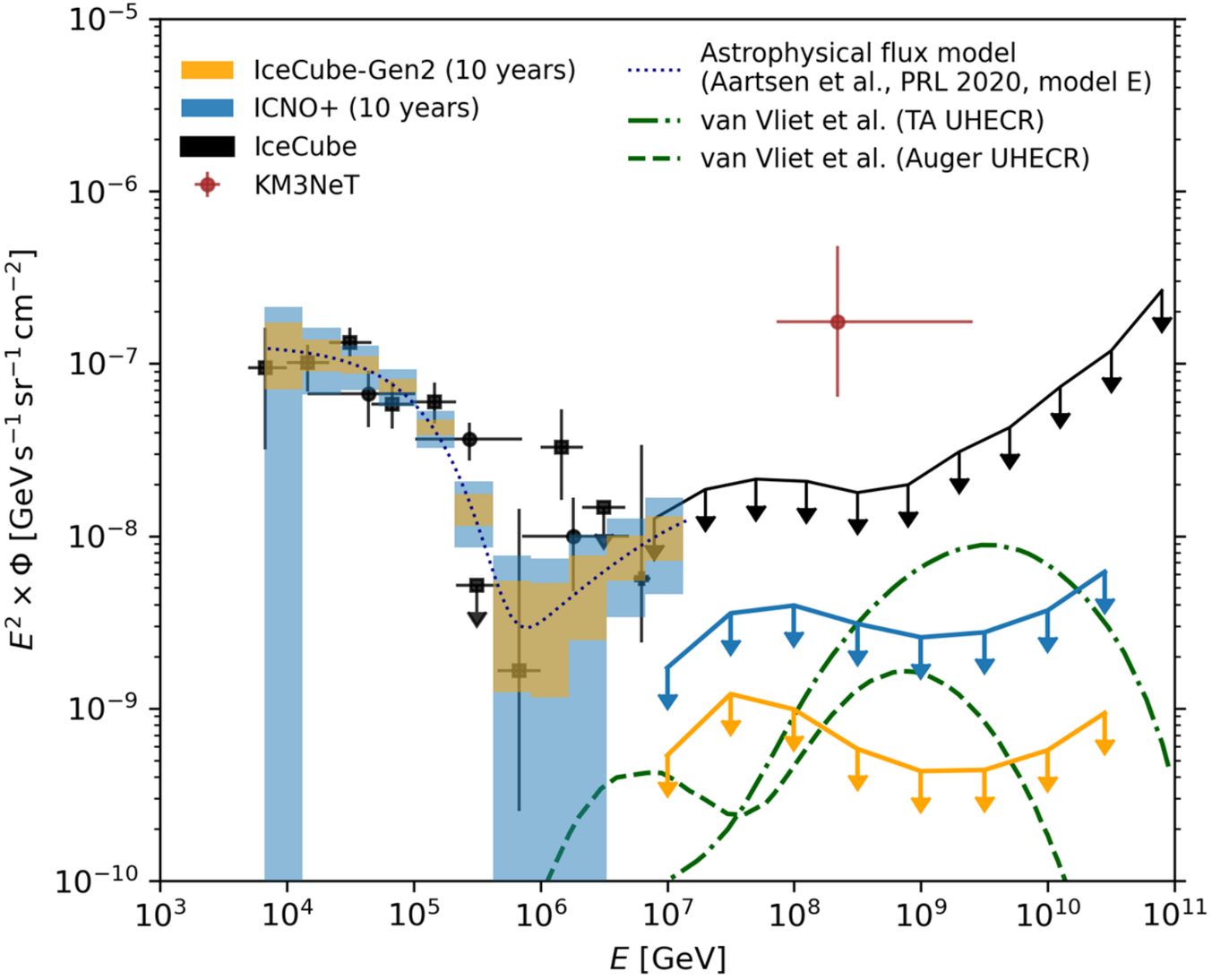
RNO-G Radio Station

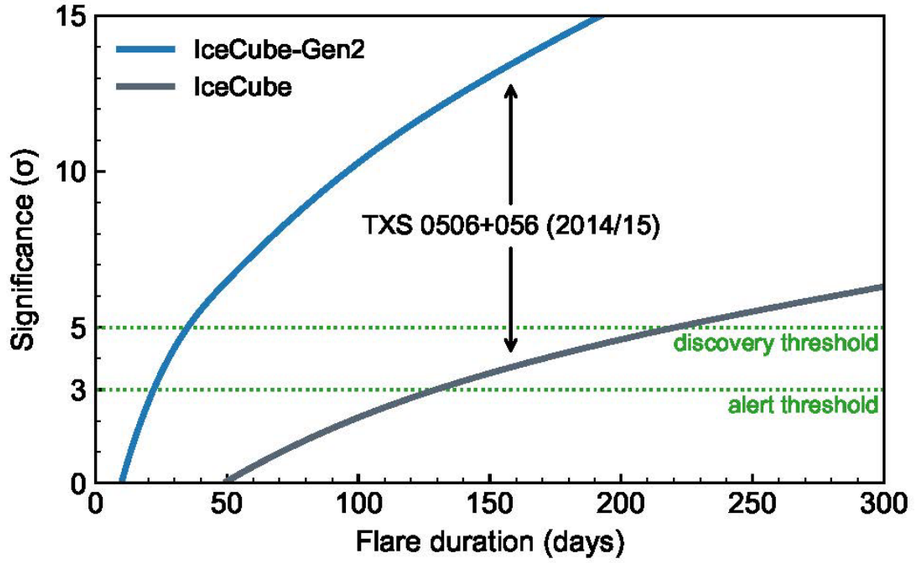


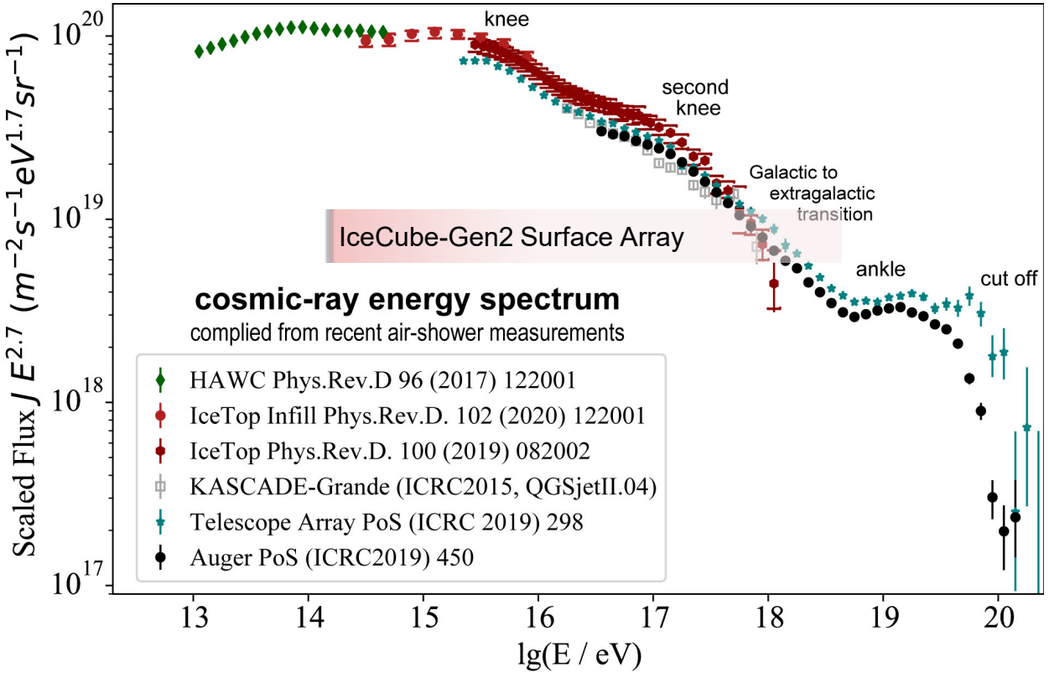


# Putting it all together

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# Large International Collaboration

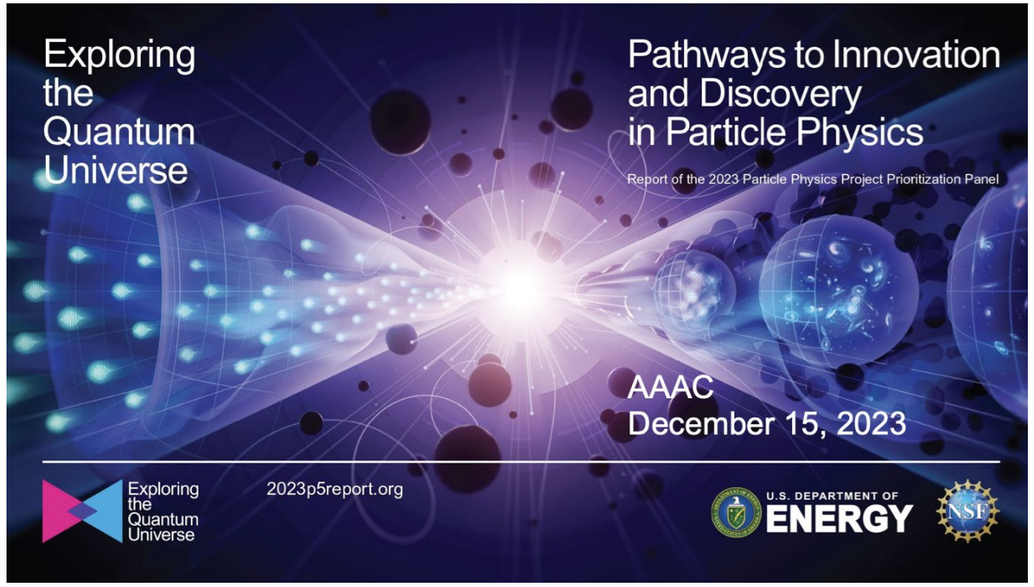

**IceCube-Gen2 Collaboration:**

More than 400 scientists from 63 institutions in 15 countries.
https://icecube-gen2.wisc.edu/

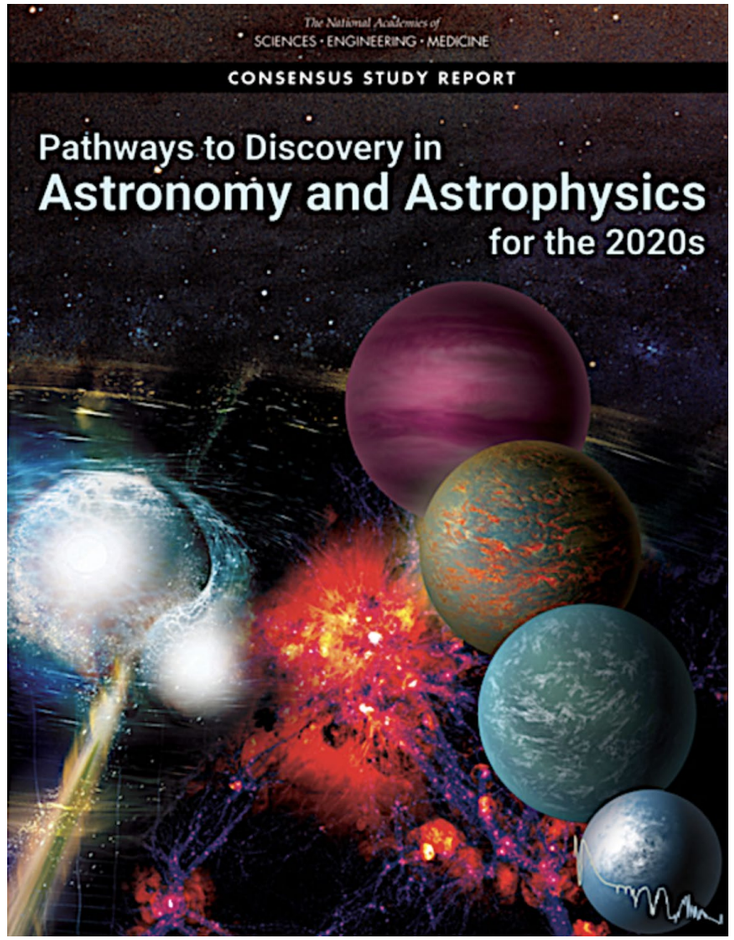
# Strong Community Support in the US

IceCube has been received endorsements from major reviews and roadmap processes.

**The Report of the 2023 Particle Physics Project Prioritization Panel (P5 panel)**:
Ranked among the top 5 particle physics projects in the US.
Recommendation: IceCube-Gen2 without reduction in scope.



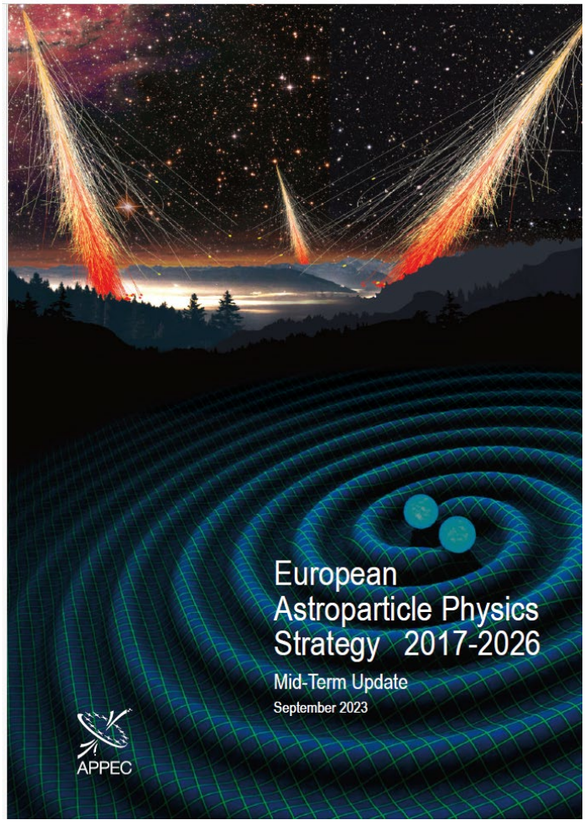

**US Decadal Survey on Astronomy and Astrophysics 2020**




Strong endorsement of IceCube-Gen2.

# … and Internationally

**European Astroparticle Physics Strategy 2017 – 2026 (APPEC roadmap)**
"APPEC strongly supports the construction of the IceCube Upgrade, and the ambition to build IceCube-Gen2 in the following decade."





Selected to final road map for large infrastructure in **Germany (FIS)** 2025, with 75M Euro allocated for IceCube-Gen2.


**Japan:** IceCube-Gen2 is included in the Japanese MEXT roadmap 2023, with a projected contribution of ~5 billion yen from Japan.”.

# Current Status

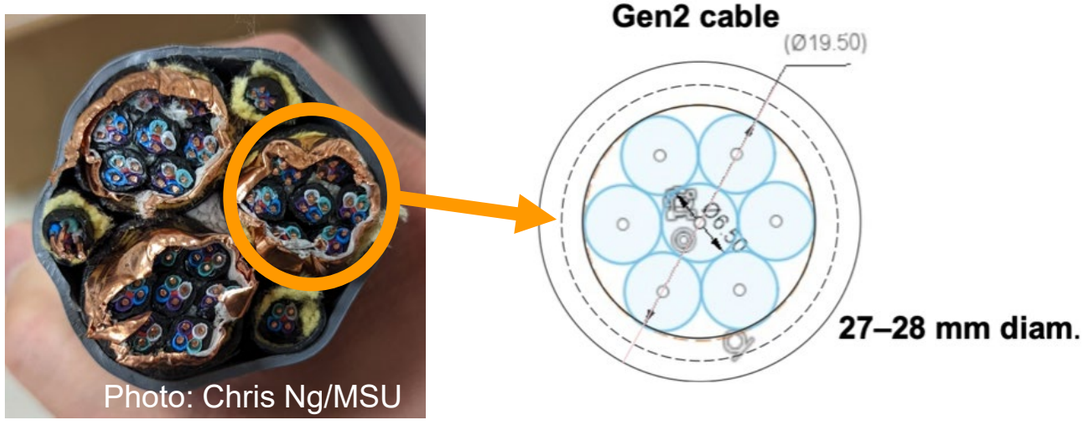
- Embarking on a 2-3 year design plan
  - Complete optical array design, including optical modules, readout, cables
  - Refine radio array electronics; continue to monitor progress in Greenland
    - Plan to complete a site study to determine if IceCube-Gen2 radio array could be installed in Greenland
      - Many challenges: infrastructure, ice quality
  - Review results from prototype surface array stations; finalize designs as needed
  - Redesign the hot water drill to support larger inter-string distances of IceCube-Gen2; replace and upgrade obsolete equipment; improve fuel efficiency
  - Review and refine logistical needs; work with NSF to build a supportable model in terms of cargo, personnel, fuel, etc.

# Near term goals

## Optical Strings

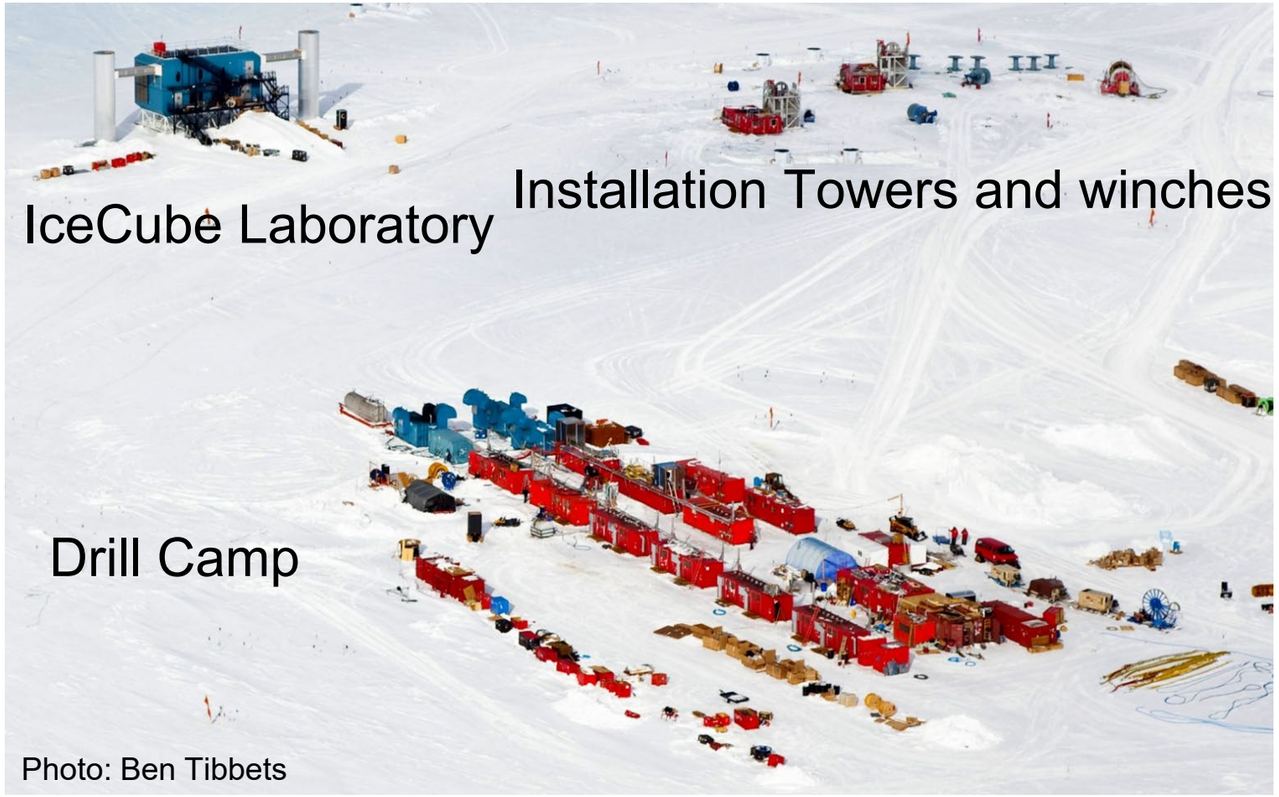
- Deploy optical module prototypes during the upcoming South Pole field season
  - Will review efficiency / reliability / calibrations in situ
- Complete the optical module mechanical and electrical design and configuration
- Build, test, and document O(100) modules across two build sites (Japan / UW–Madison+Chang Mai University)
  - Design uniform build procedures, fixtures, and techniques that can be shared across build sites
  - Develop comprehensive testing suites and calibrations
- Prototype and test main downhole cable
  - Can reduce size by a factor of 3


Upgrade: Optical module production at DESY, Zeuthen




Main (downhole) cable: New trigger/data acquisition architecture could allow a factor 3 reduction in cable size (cost, weight, and volume!).

# Near term goals: Drilling




A photo of the “drill camp” (source of pressurized hot water for the drill). Drill camp comprises ~ 40 buildings.

| | IceCube | IceCube Upgrade | IceCube-Gen2 |
|---|---|---|---|
| Hole Depth (meters) | 2,450 | 2,600 | 2,690 |
| Hole Diameter (centimeters) | 45 | 52 | 45 |
| Hole Lifetime (hours) | 37 | 45-55 | 36 |
| Hole Spacing (meters) | 125 | 22 | 240 |
| Number of Holes | 86 | 7 | 120 |
| Number of Field Seasons | 7 | 1 | 9 |
| Optical Modules/hole | 60 | 112-115 | 80 |

**Deep hot water drilling (> 1.6 miles!) at the South Pole is a unique capability of IceCube.**

- The end of life for many elements is at hand.
- Need to develop/streamline drill and installation towers to support larger inter-hole spacing; update mechanicals and control systems.

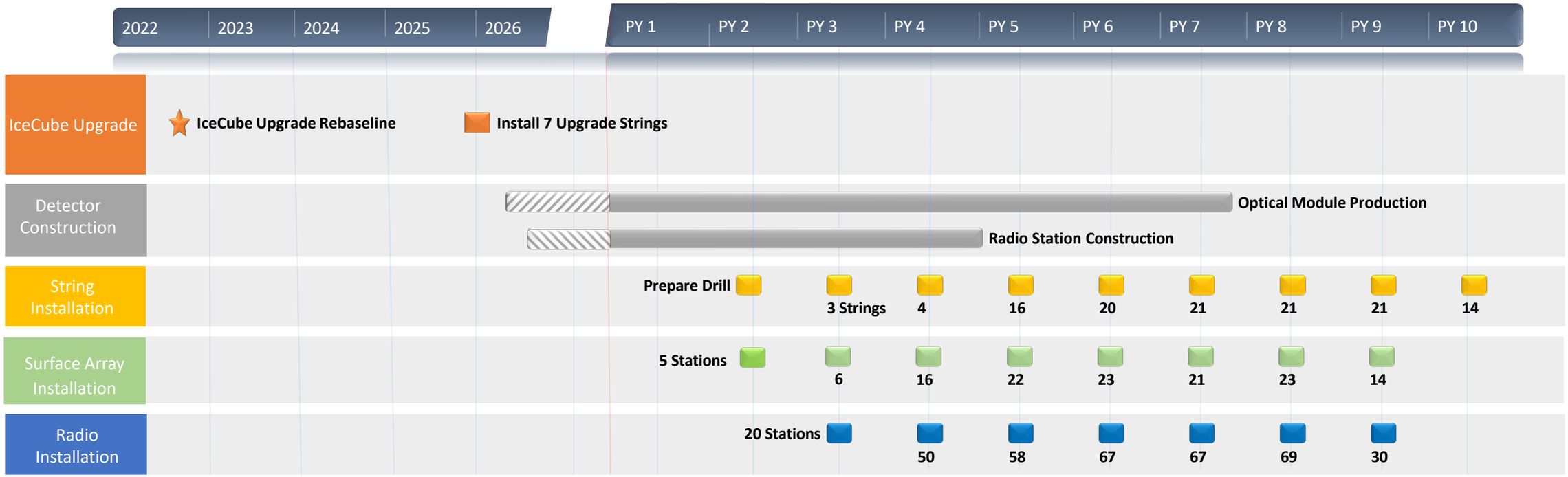
# Logistics

- Minimizing dependence on logistical support is a major goal of the program.
- Logistical support will play an important role. LC-130 flights (used for moving people and cargo) have been reduced by factor of ~5 since IceCube was installed.
- However, overland transport (SPoT) has been established and, if expanded, could allow us to reduce our dependence on flights by about a factor of 5.
- We plan to work with NSF/Antarctic Contractor to develop model for supporting logistics

Photo: Geoffrey Chen, SPT/NSF

Photo: Albrecht Karle

# Schedule




- 3 volume Technical Design Report completed June, 2024
- Spend the next 2-3 years completing designs
- Once project starts, will take 10 years to complete the full array
  - Will be taking data as the array is installed; could have 25 strings installed within 5 years of startup

# Summary

- The IceCube-Gen2 Collaboration has been designing a detector that would provide an order of magnitude greater sensitivity to high- and ultra-high-energy neutrinos.
- This project has been enthusiastically endorsed by the P5 and Astro2020 panels, and has already been included in the strategic roadmaps of the German and Japanese funding agencies.
- We have prototype optical and surface array devices that will be completed and installed at the South Pole in the upcoming South Pole field season.
- A radio array is being built in Greenland: we plan to use experience gained from the development, installation, and commissioning RNO-G to guide the design of the radio array for IceCube-Gen2.
- We plan to complete designs of the detector in the next 2-3 years and will be ready to construct, test, and install the detector.