IceCube-Gen 2

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University of Wisconsin-Madison

IOFG meeting
September 28, 2020

- Science
- Scope
- Project status
- Cost and schedule
- Project development

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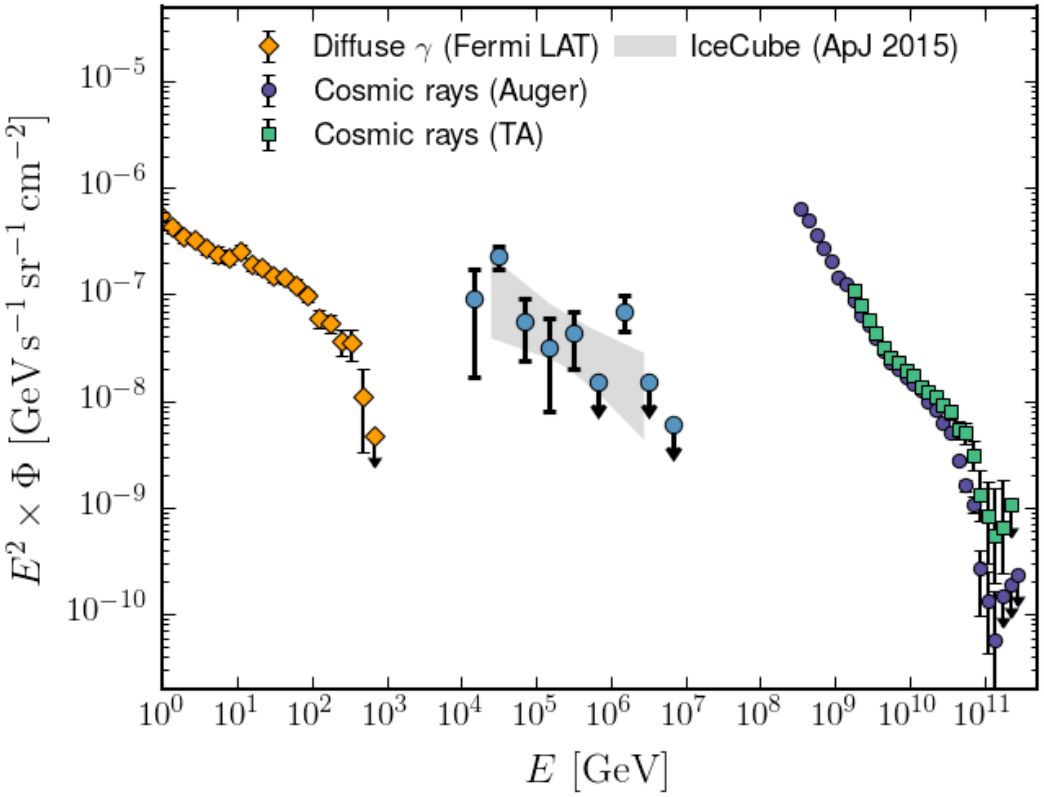
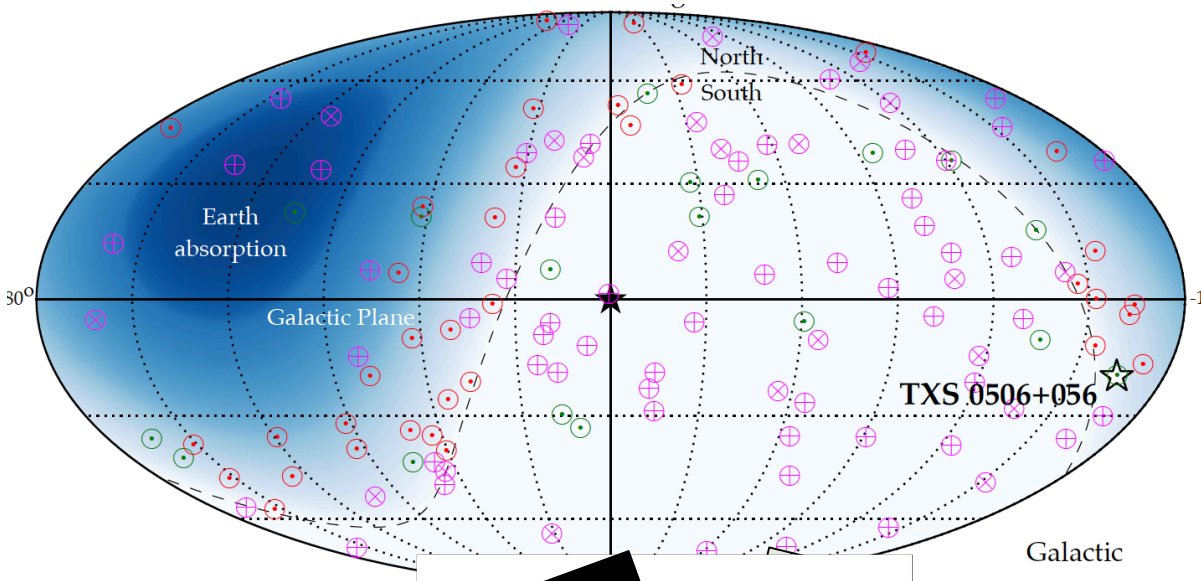
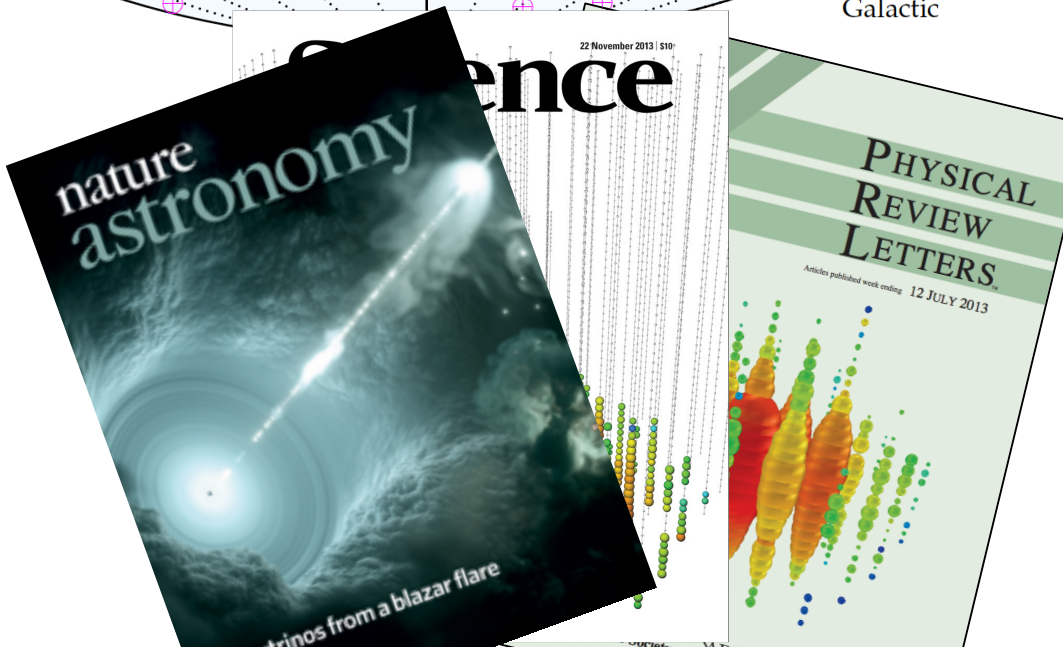
10 yrs of IceCube - a first view on the PeV Universe

Multimessenger spectroscopy



First sky map of cosmic neutrinos





Some highlights:

2013: Discovery of cosmic PeV neutrino flux

2018: Evidence for Blazars as neutrino sources

2019: Observation of first tau neutrino

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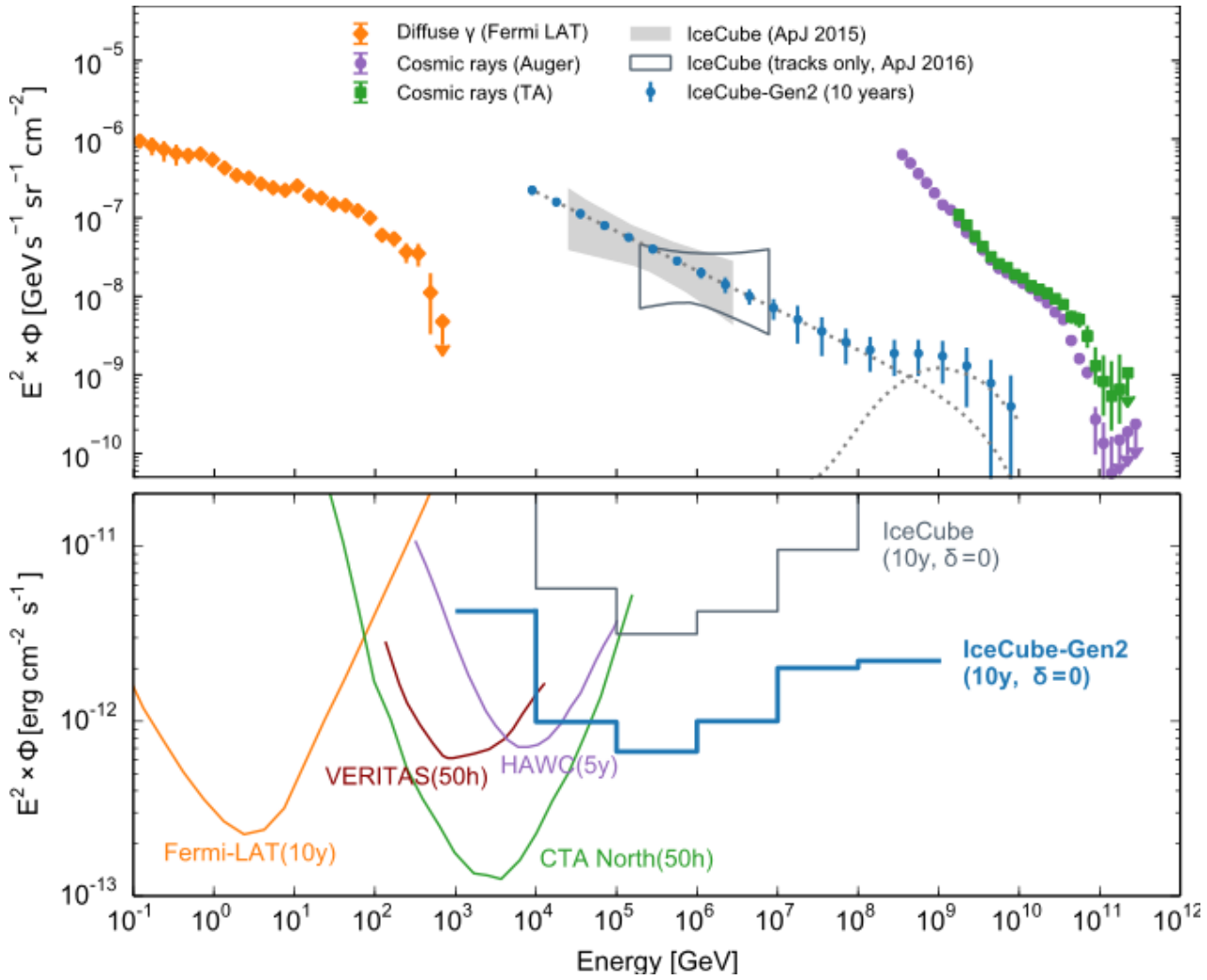
Scientific objectives

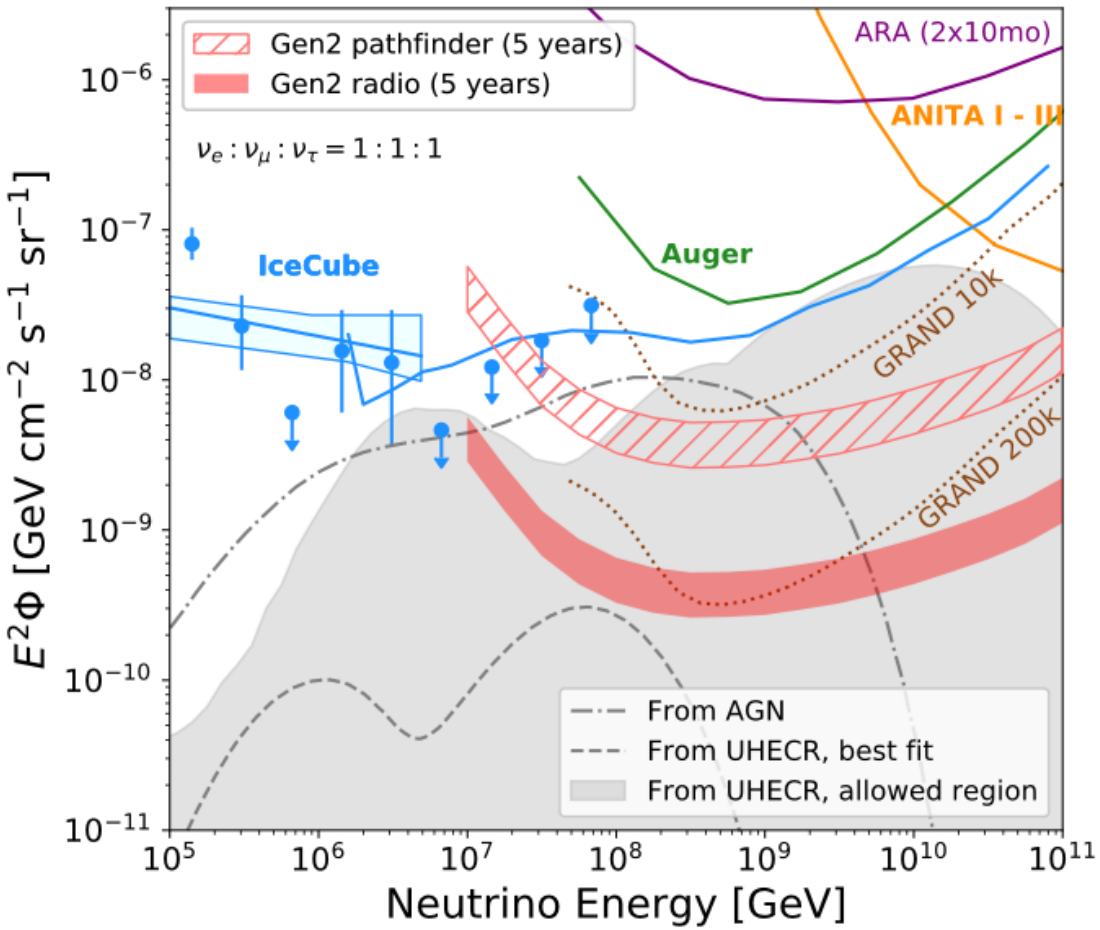
Understanding cosmic particle acceleration through multimessenger observation



Completing the multi-wavelength view of the Universe

Scientific objectives

Revealing the sources and propagation of the highest energy particles in the universe



Probing source populations and composition of highest energy cosmic rays

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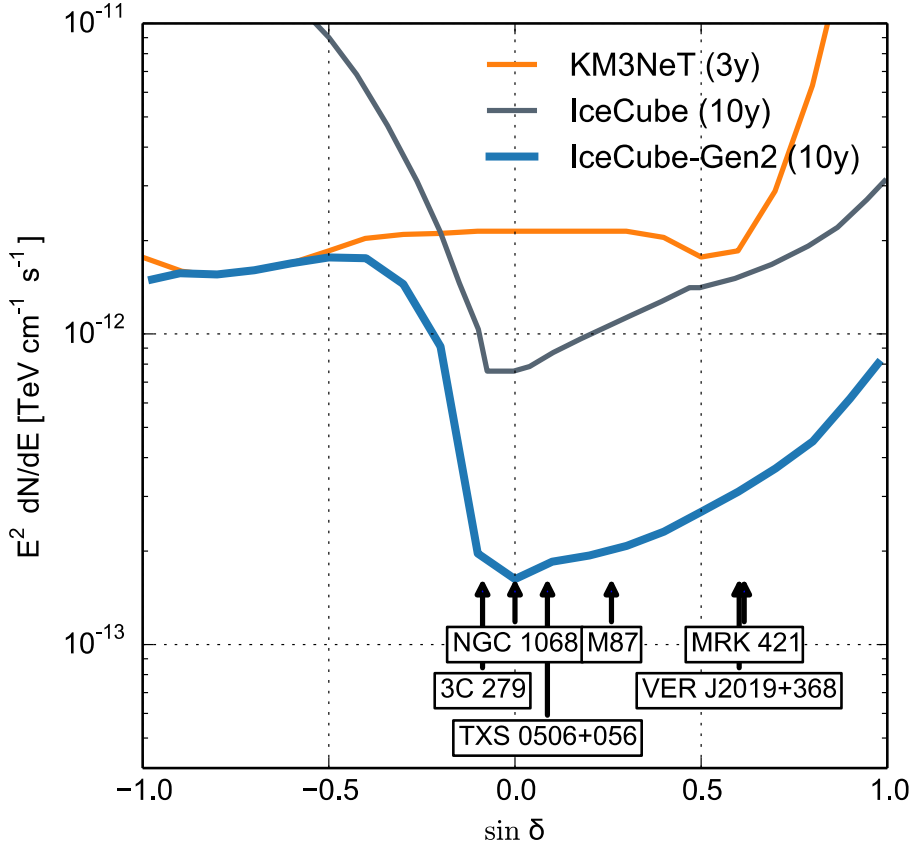
IceCube GEN2

Requirements for IceCube-Gen2

1. Increase the neutrino point source sensitivity at least 5 times over the current IceCube array
2. Enable multimessenger astronomy with individual, high-energy neutrinos
3. Collect 10 times more neutrinos per year than the current IceCube array in the energy range 100 TeV to 10 PeV
4. Expand energy range to beyond 10^{18} eV with sensitivity improved by two orders of magnitude
5. Enhanced sensitivity to neutrino flavors and the ability for flavor identification



Sensitivity to all realistic source populations (steady and transient) explaining the diffuse flux

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ICECUBE GEN2

Recent progress:

Submission to Decadal Survey on Astronomy and Astrophysics 2020

Important review process and definition of Gen2.
Still going on. Expect report in spring 2021.

White paper: IceCube-Gen2: The Window to the Extreme Universe
arxiv.org/abs/2008.04323

Science case developed in more detail. (Special thanks especially to Markus Ackermann)

Currently under way: Snowmass process. Strong presence of IceCube important.

IceCube
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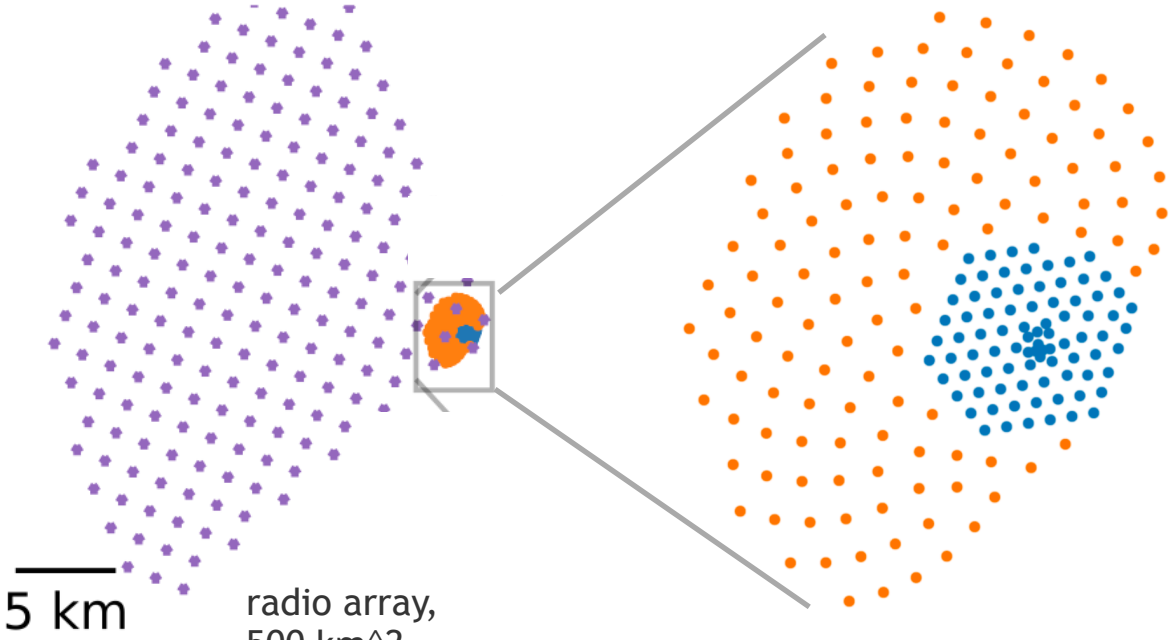
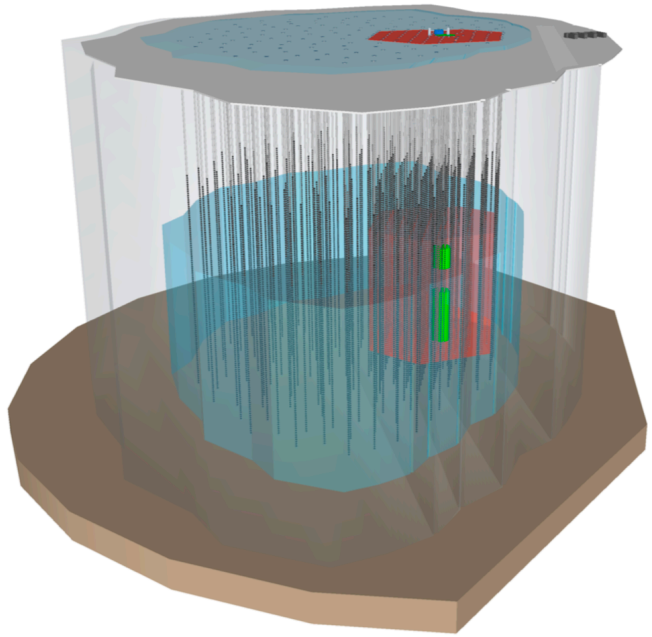
IceCube-Gen2: Scope

Optical Array of 120 strings with 100 sensors each
Surface array: for cosmic rays and veto
Radio Array: 500 km^2 for neutrino detection above 10 PeV



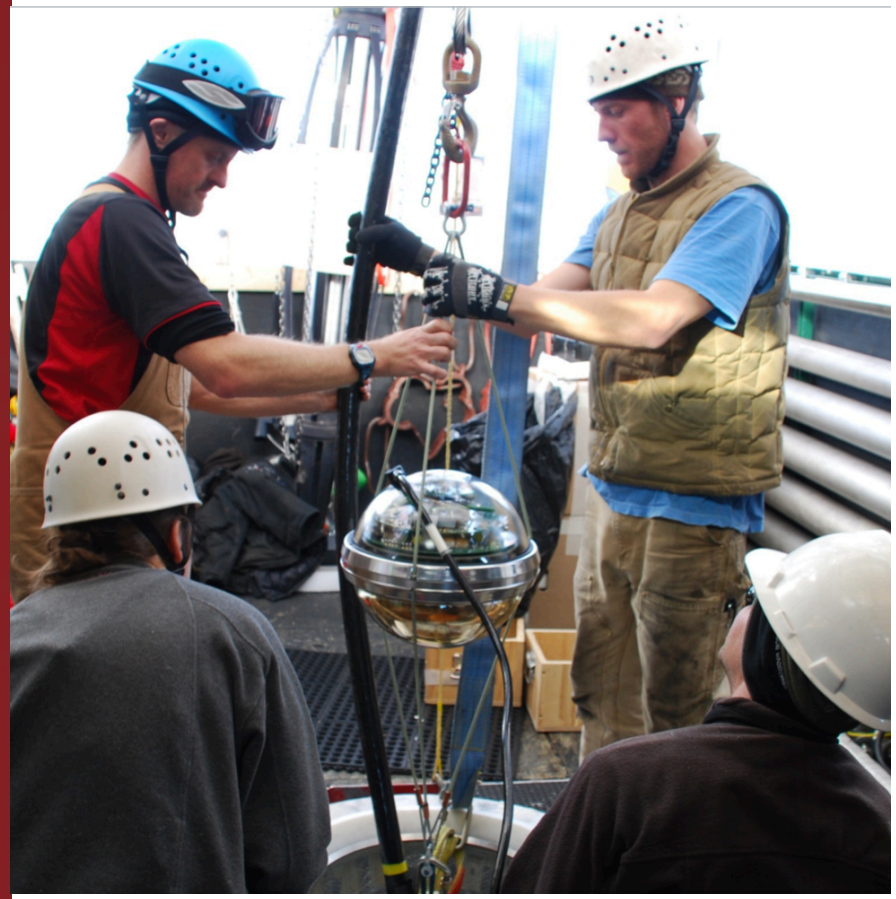


Artist's conception
120 strings at 240 m spacing

IceCube GEN2

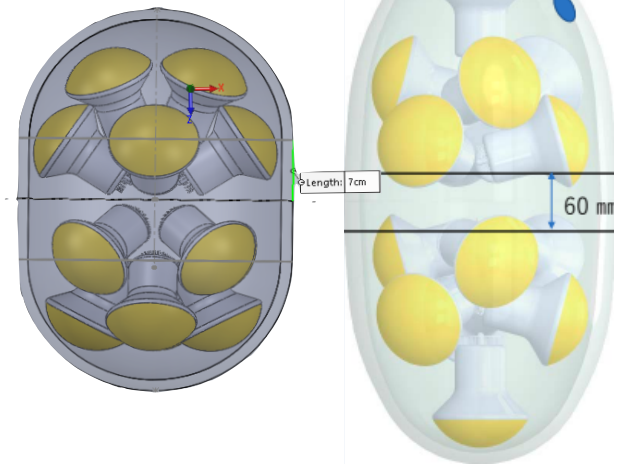
Advances in optical sensors

Building on understood technologies.



IceCube Upgrade

IceCube-Gen2



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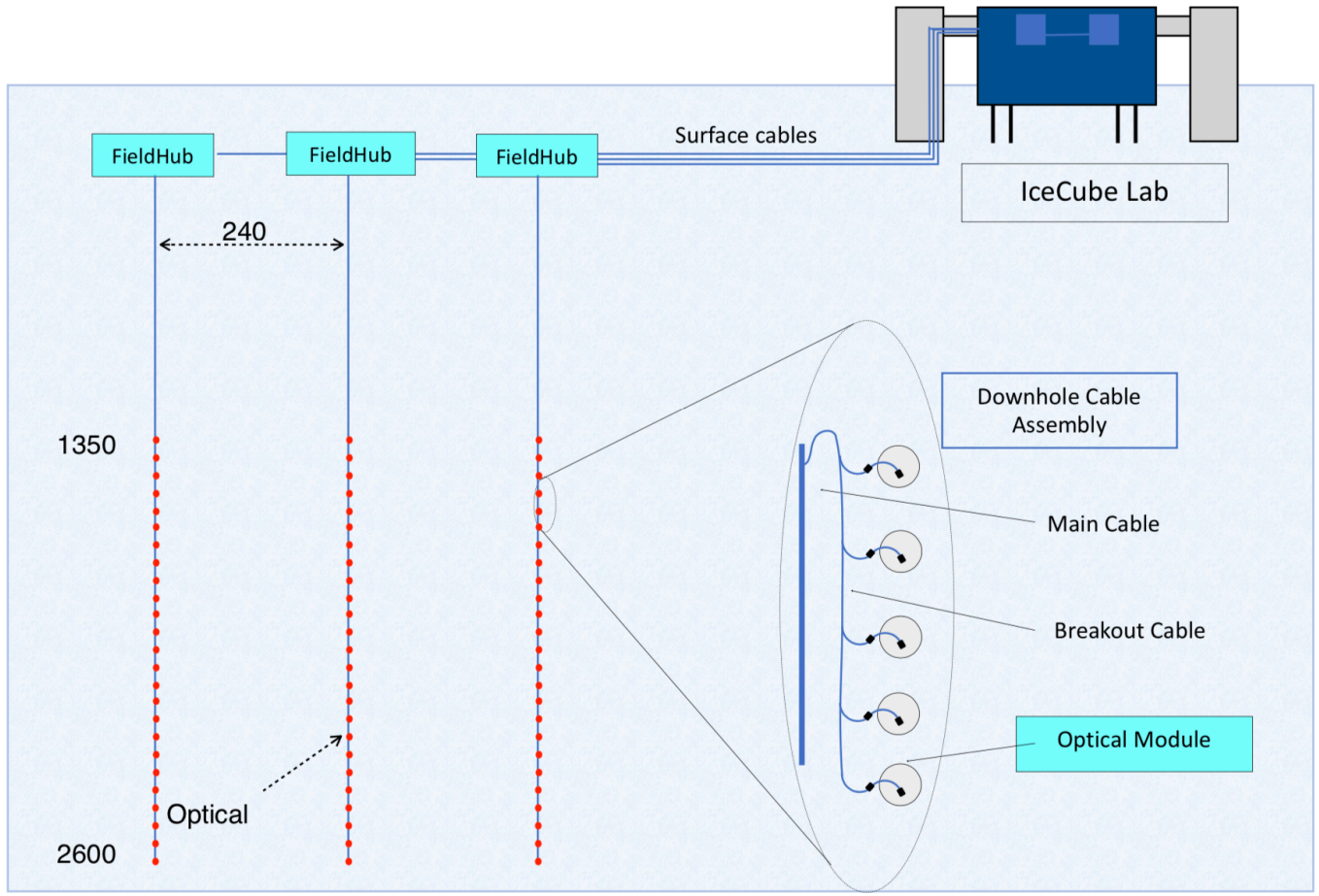
IceCube GEN2

Power and communications architecture

A safe strategy with room for optimizations and cost savings.

- Reference design
  - Adiabatically evolved from IceCube: copper for power and comms, use field hub to switch comms from copper to fiber.
  - Less copper needed (1/2)
- R&D for alternate approach:
  - Optical fiber all the way to deep ice. Locally switch to comms on copper.



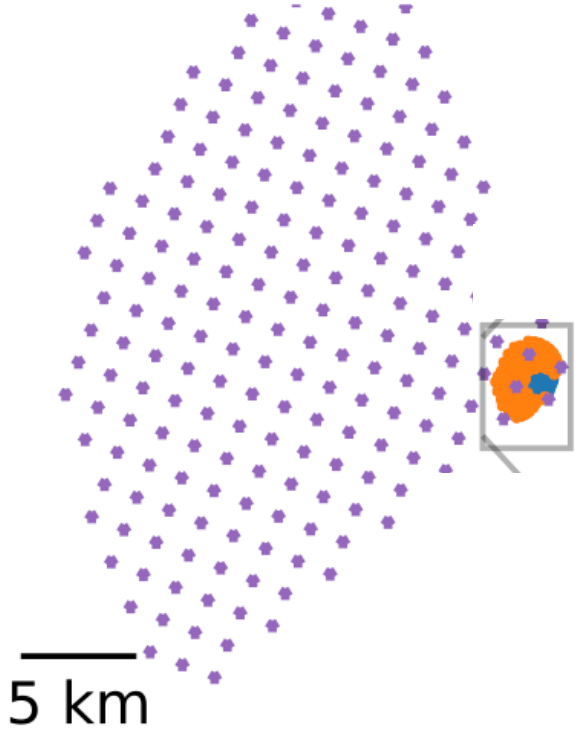
IceCube GEN2

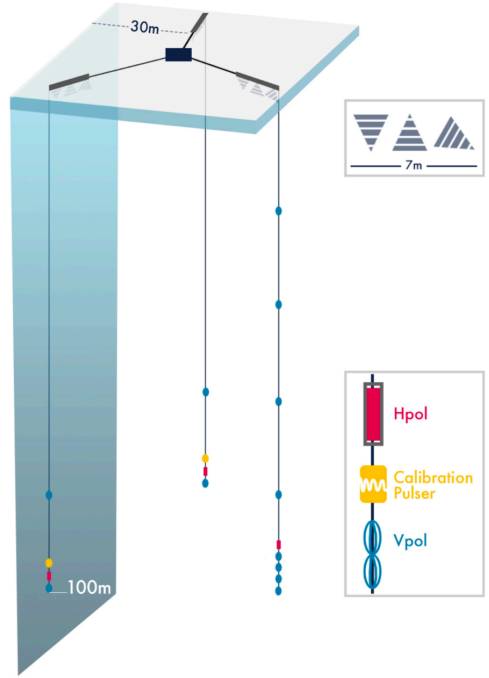
The Gen2 radio array

A highly transformative addition.

Design under review.
Task Force assigned to advance and detail the conceptual design.

A large array with distances of more than 10 km from South Pole.





IceCube GEN2

IceCube infrastructure

Cost advantages of Gen2 compared to Gen1

IceCube exists and is running.

—> Gen2 can be essentially integrated into Gen1.

—> Significant savings in design effort eg for DAQ and data systems.

—> Benefit of established IceCube Maintenance and Operations that will provide an existing host environment.

There is still effort (and budget) needed, but it is different from starting from scratch.

- An interesting detail: fractional cost in optical sensors of total project cost:
  - IceCube: 11%
  - IceCube-Gen2: 23% (cathode area more than 4 times larger)
- Possible due to huge head-start on system design, drilling, data systems, data acquisition design, commissioning and calibration, and existing operations structure.

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IceCube GEN2

EHWD-Gen1

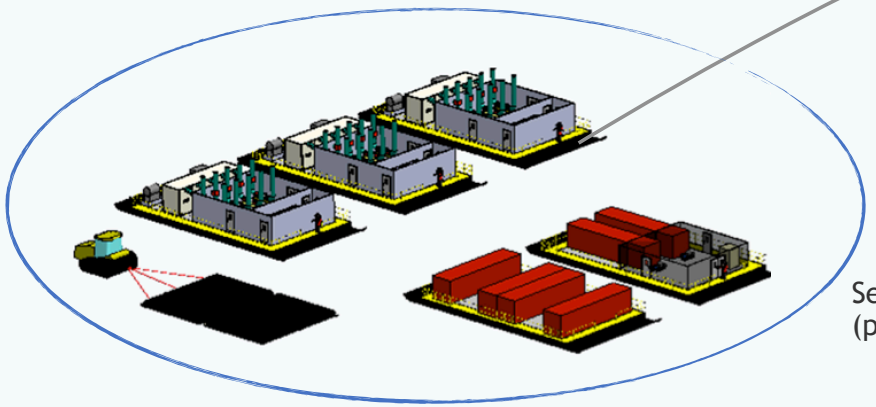
Hose reel

Mobile drill/deployment towers

EHWD heating plant: stationary
—> Gen2: mobile

Gen2 hot water drill: significant advances.

- Evolution:
  - IceCube EHWD
  - —> Upgrade: refurbishments and modifications
  - —> Gen2 configuration
- Construction on large sleds:
  - Transport to Pole and mobility at Pole



Logistical Support

1. Logistical Support: IceCube Gen1 had 9.5 million lb of cargo + fuel delivered by plane, more than 300 LC 130 missions. Construction took place simultaneously with South Pole station completion and SPT construction.
2. In recent years logistical support has dropped compared to 10 years ago. This is primarily funding driven. However, funding for logistical support is provided by the project.
3. Strategies for logistical support exist and have been discussed with ASC.
    1. Population of 60 people: —> separate field camp.
    2. Cargo: Traverse is scalable and can take care of fuel (2/3) and possibly cargo but this is not current practice.
4. Successful support will require high level prioritization and strategic planning at NSF's Polar Program.

Cost

L2	Task	Total cost	In-Kind	NSF
1.1	Project Office	28.1	.0	28.1
1.2	Implementation	61.6	.0	61.6
1.3	Instrumentation - Deep	151.9	64.0	87.9
1.4	Instrumentation - Radio	25.9	5.0	20.9
1.5	Data Systems	13.1	.0	13.1
1.6	Commissioning and Calibration	12.2	.0	12.2
1.7	ASC Coordination / Polar Support	53.9	.0	53.9
Total w/o contingency		346.8	69.0	**277.8**
Contingency		61.1		61.1
Total with contingency		407.9	69.0	**338.9**

Cost Drivers:

—> Instrumentation: 12,000 Optical modules for the array of 120 deep strings

—> Construction: Implementation (Drilling + installation) and Antarctic Support.

Contingency:

- DOMs provide options for scope contingency.

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International collaboration

Built on history:

- IceCube Gen2 builds on IceCube, a truly international collaboration.
- The international character builds on 30 years of collaboration when groups in Sweden and in Germany joined forces with US groups to develop AMANDA and 10 years later IceCube.
- Strong traditions and well established relations.
- Today, the collaboration is almost precisely half and half US and Non-US.

Large contributions:

- For Gen2, the hardware contributions in DOMs and radio will be almost 1/2 of instrumentation.
- Assumed contributions expressed monetarily: $69M (In US counting this would be well above $100M*)
- Contributions in other areas, including logistics and field work being explored.

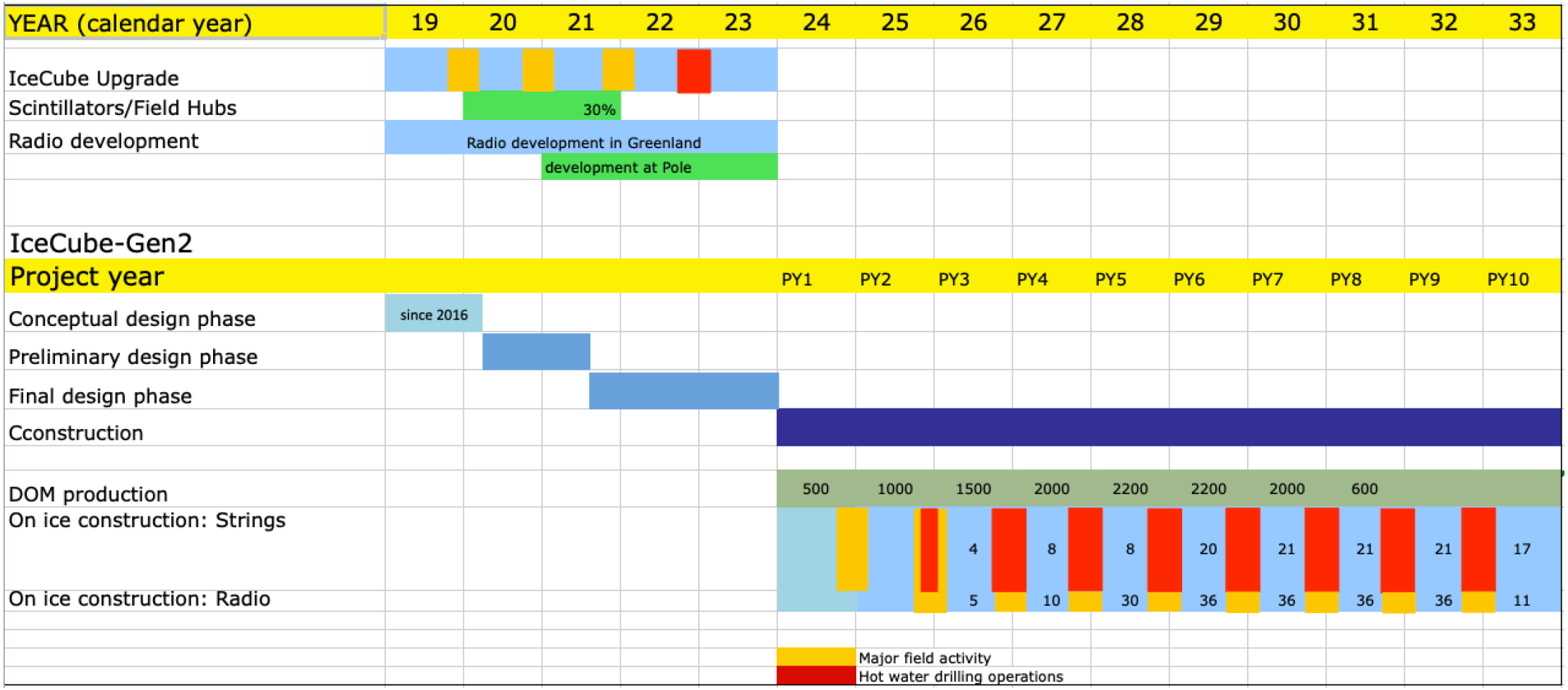
—> These pledges will help Gen2 in the US and thus all of us enormously

Footnote:

* The construction of the budget will usually under-represent in-kind contributions for two reasons:

- contributions are formulated primarily as hardware and other products.
- —> contingency is largely owned by the country that commits hardware.
- Labor does not even appear as contribution and is supported off project.

Timeline



Notes:
Drilling possibly 1.5 seasons shorter, also cost savings (—> Jeff Cherwinka's talk)
No formal linkage between Upgrade and Gen2
No formal linkage between RNO-G (or Arianna) and Gen2

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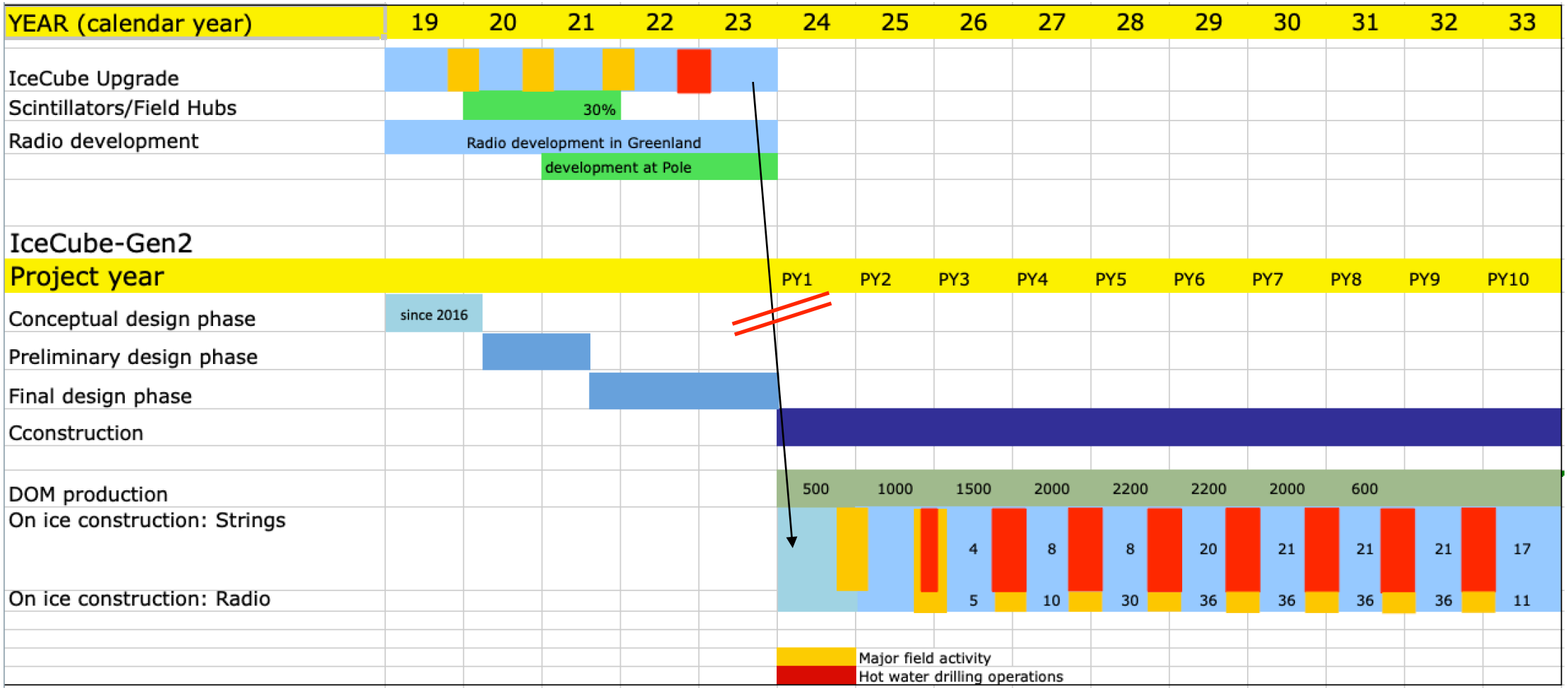
IceCube GEN2

Timeline



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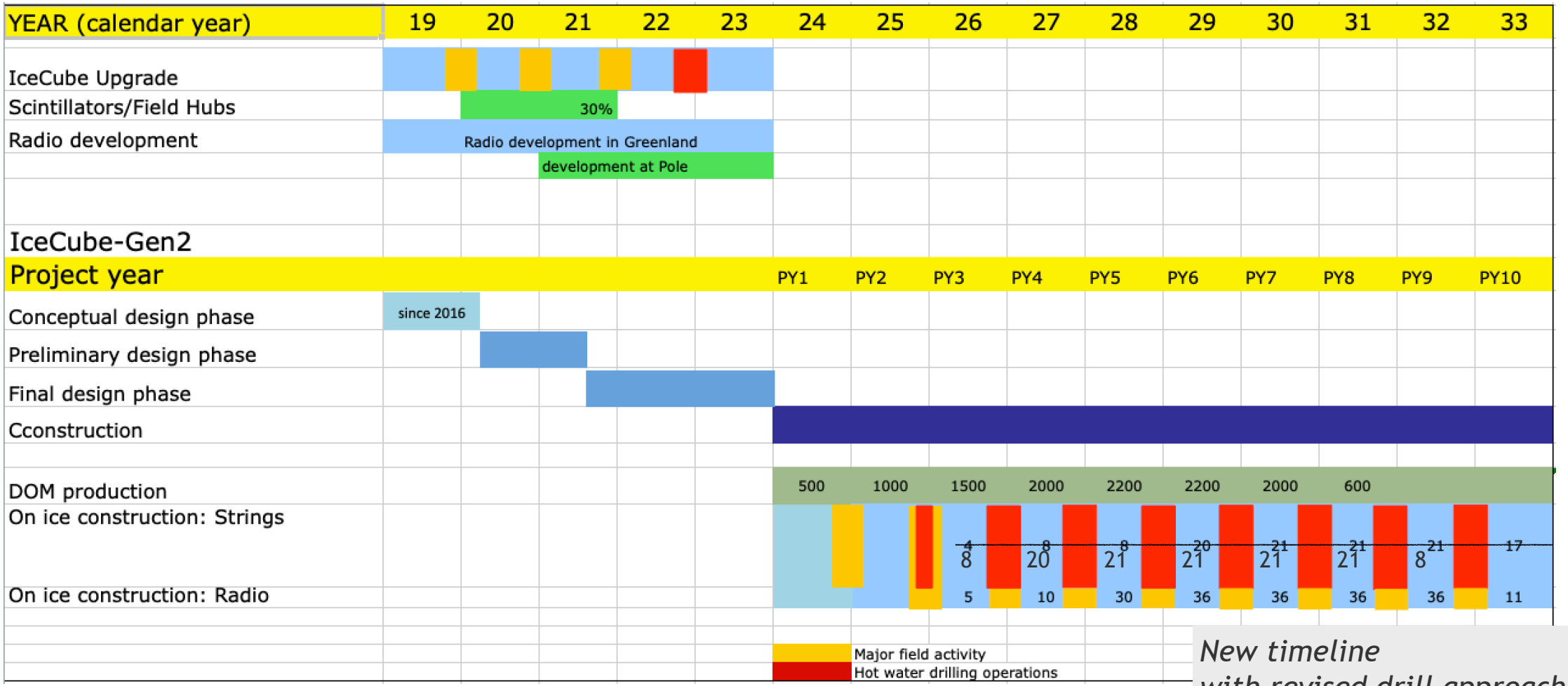

New timeline with revised drill approach

Notes:
Drilling possibly 1.5 seasons shorter, also cost savings (—> Jeff Cherwinka's talk)
No formal linkage between Upgrade and Gen2
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Developing Project

Next big milestone: ‘Preliminary Design’ by fall 2021

(PD is as much about project plans, cost, risk schedule, as it is about technical matters. Eg. PD total cost will be seen as final)

- Optical sensor design progress.
- Project support starting to come into place
- Working towards a organizational structure
  - Project team, Project office, Level 2, Level 3 coordinators
  - Advisory committees

IceCube GEN2

Near term timeline

Internal Review by January/February 2021

- Radio by January,
- Project total by February

Possible workshop later in spring 21, perhaps May, immediately after Astro2020 decadal review report released.

Preliminary design

Challenges:

- Preliminary Design
- Bridging from Gen2 development phase and Upgrade to Gen2 construction

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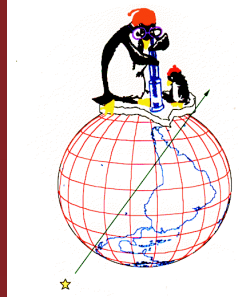
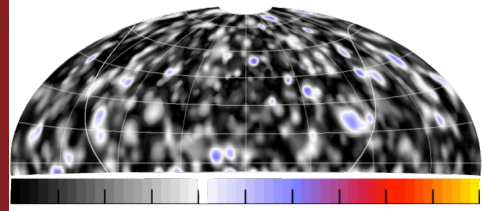
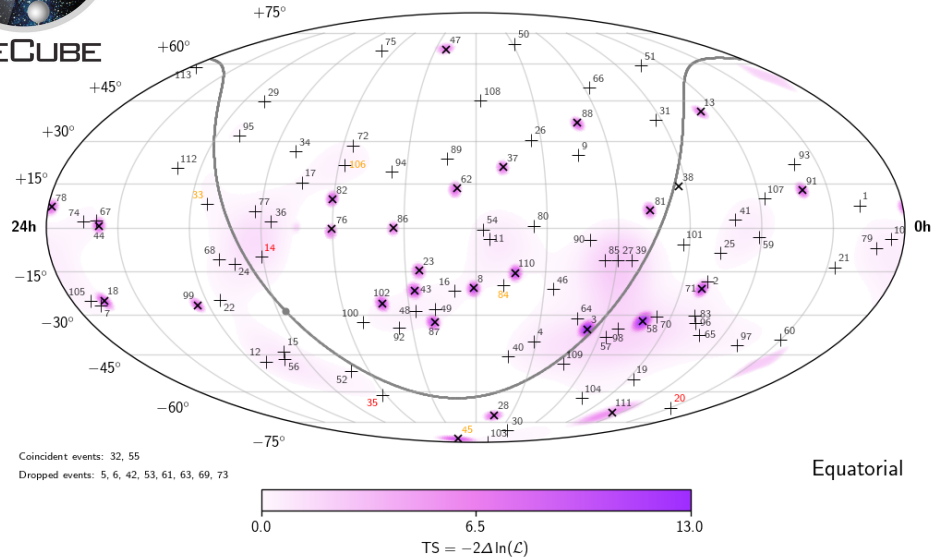
IceCube-Gen2: *From Discovery to Astronomy*

…building the future of a new field







Gen2 Phase 1 (Upgrade) drill camp; January 29, 2020

1st atmospheric neutrinos in ice

Discovery of astrophysical neutrino flux

First source identified

$E < 300\,\text{TeV}$ $300\,\text{TeV} < E < 1\,\text{PeV}$ $1\,\text{PeV} < E$

2002 2004 2013 2018 2020 2023 2026 2032

AMANDA **IceCube** **Gen2 Phase 1 (Upgrade)** **IceCube-Gen2**

First full Gen2 deployment season

Gen2 full detector completion

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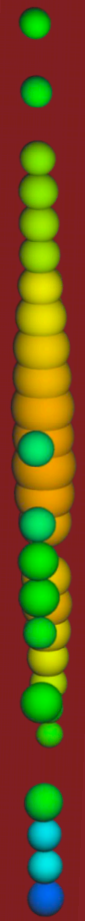
IceCube GEN2

Backup slides



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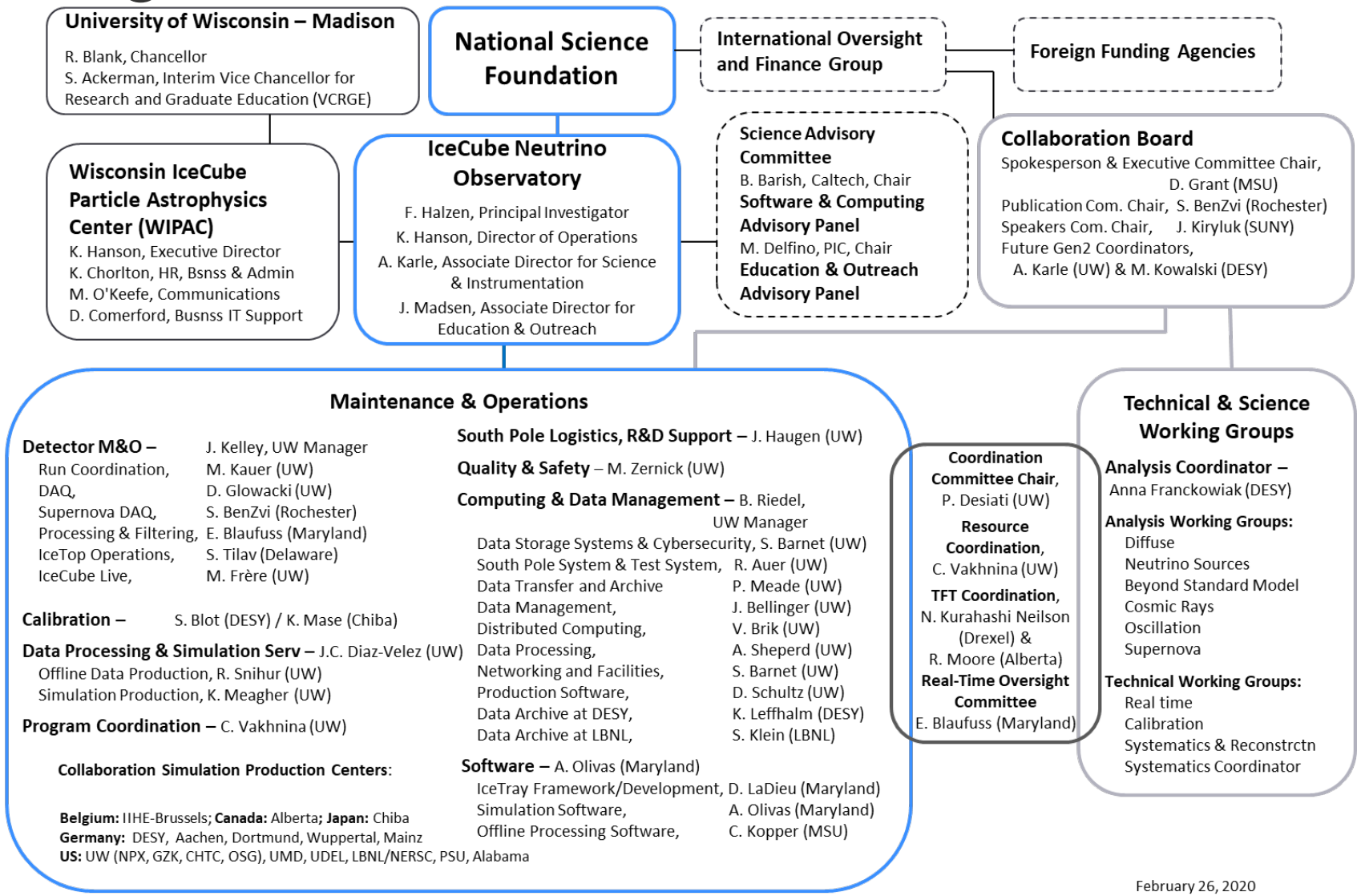
IceCube Organization Structure



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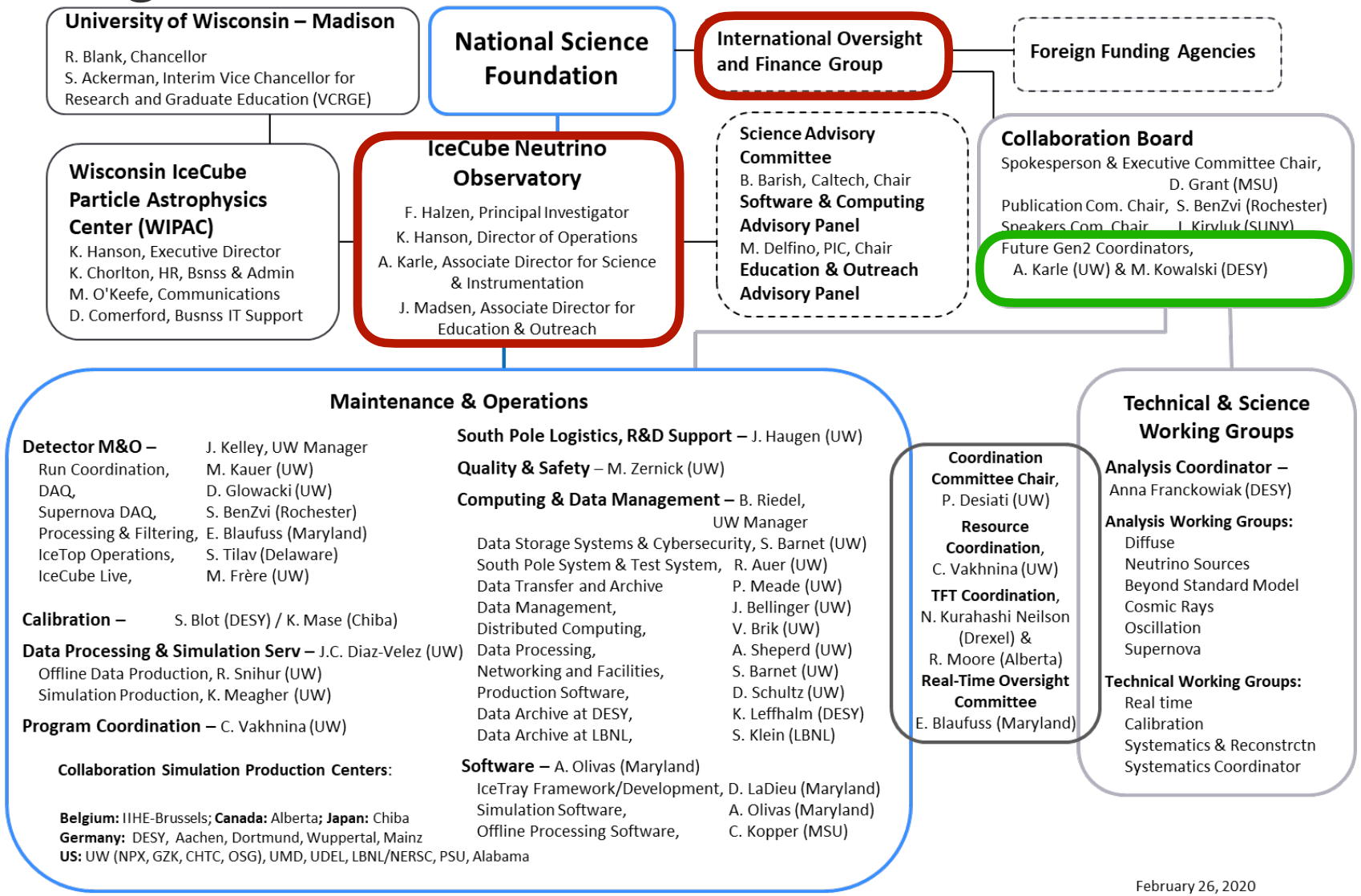

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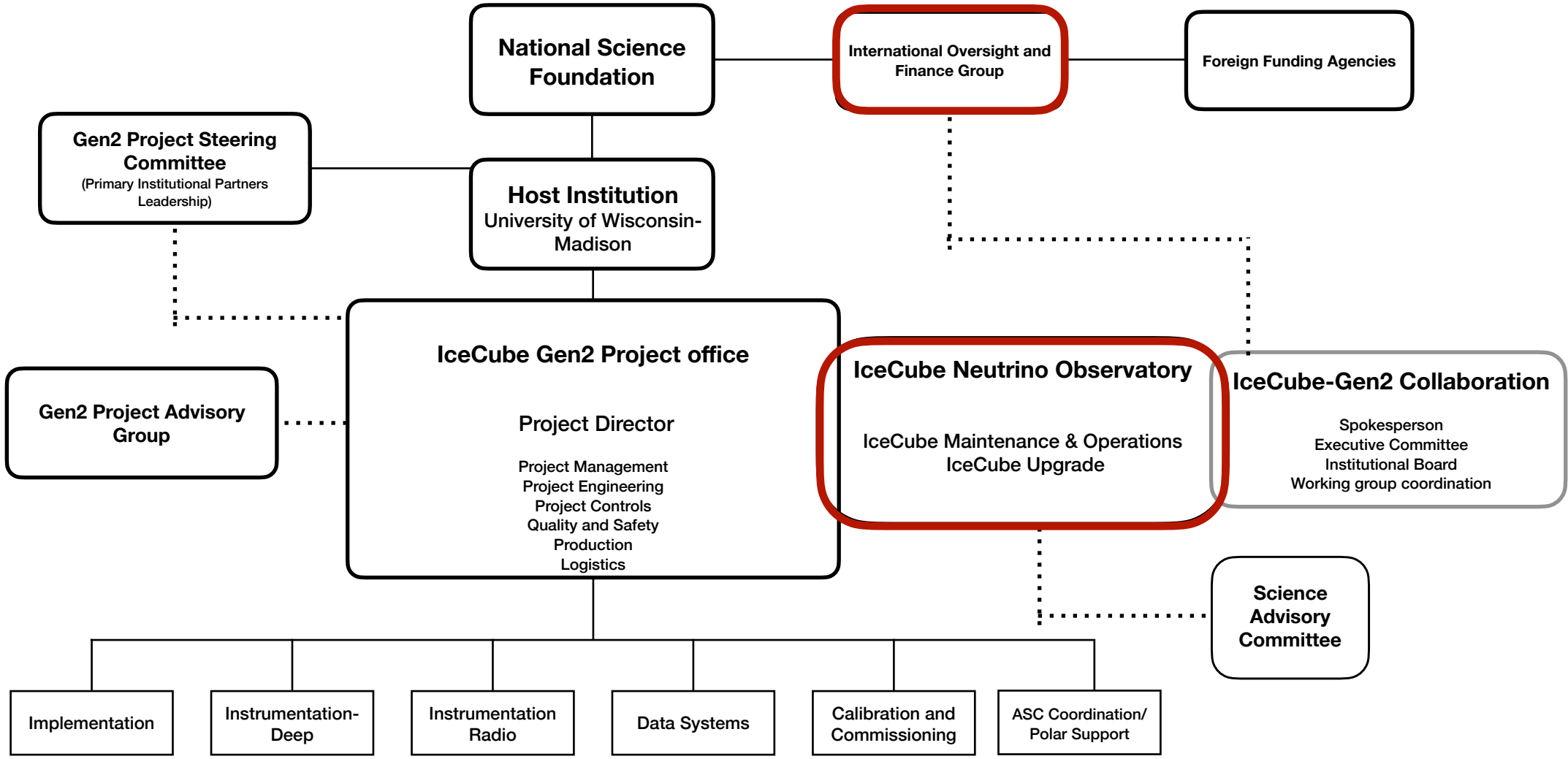
IceCube-Gen2 Organization Structure



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Cost

Cost Profile - US [Real Year, M$)																
		Development				Project Year										
L2	Task	2020	2021	2022	2023	PY01	PY02	PY03	PY04	PY05	PY06	PY07	PY08	PY09	PY10	TOTAL
1.1	Project Office	.26	.72	.74	.80	2.83	2.89	2.95	3.01	3.08	2.73	2.66	2.72	2.77	2.45	**28.08**
1.2	Implementation	1.73	.91	1.15	1.98	21.68	5.09	4.25	4.34	4.57	4.61	4.27	4.35	4.44	4.06	**61.64**
1.3	Instrumentation - Deep	.11	.22	.22	.23	6.28	6.84	9.38	14.70	16.45	16.59	12.35	5.32			**87.91**
1.4	Instrumentation - Radio	.21	.44	.45	.46	1.51	1.93	2.67	2.69	3.11	2.73	2.83	2.14	.66	.68	**20.92**
1.5	Data Systems					1.27	1.03	1.06	1.37	1.44	1.28	1.35	1.36	1.43	1.51	**13.10**
1.6	Commissioning and Calibration					1.13	1.15	1.18	1.20	.99	1.26	1.28	1.31	1.34	1.37	**12.22**
1.7	ASC Coordination / Polar Support					.91	7.98	10.70	8.33	7.70	7.55	3.82	3.31	2.74	.91	**53.94**
	Total development	**2.32**	**2.30**	**2.56**	**3.47**											
	Total US w/o contingency					**35.59**	**26.90**	**32.19**	**35.64**	**37.32**	**36.74**	**28.57**	**20.50**	**13.38**	**10.98**	**277.81**
	Contingency (22%)															**61.12**

Assumed in-kind contributions: $76.2 M (90% in instrumentation)

Note:
Instrumentation budgets do not include in-kind contributions.
This is not a total project cost.
Also, L2 radio is not a standalone project budget (does not include deployment, project office, data, etc.).

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