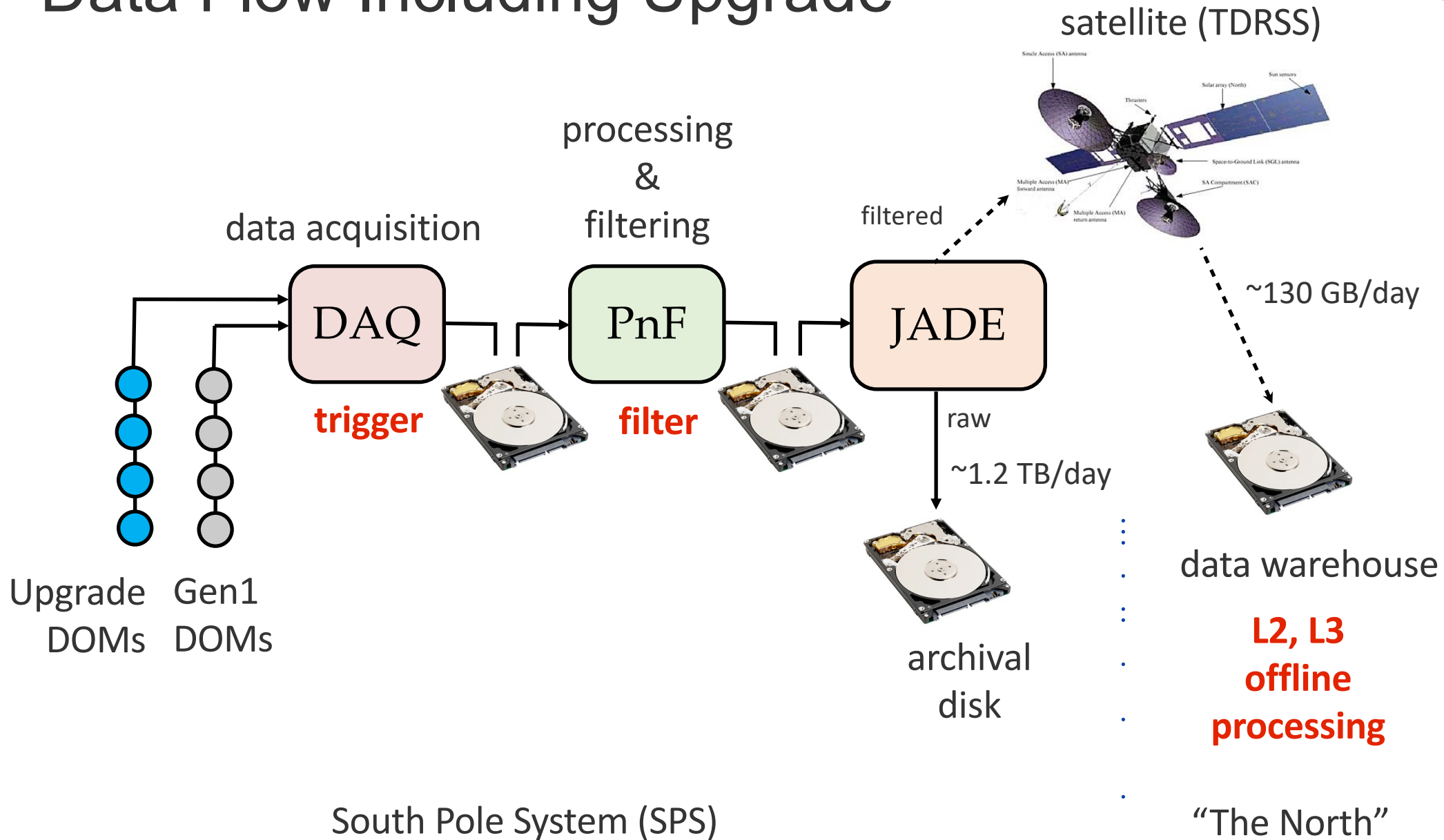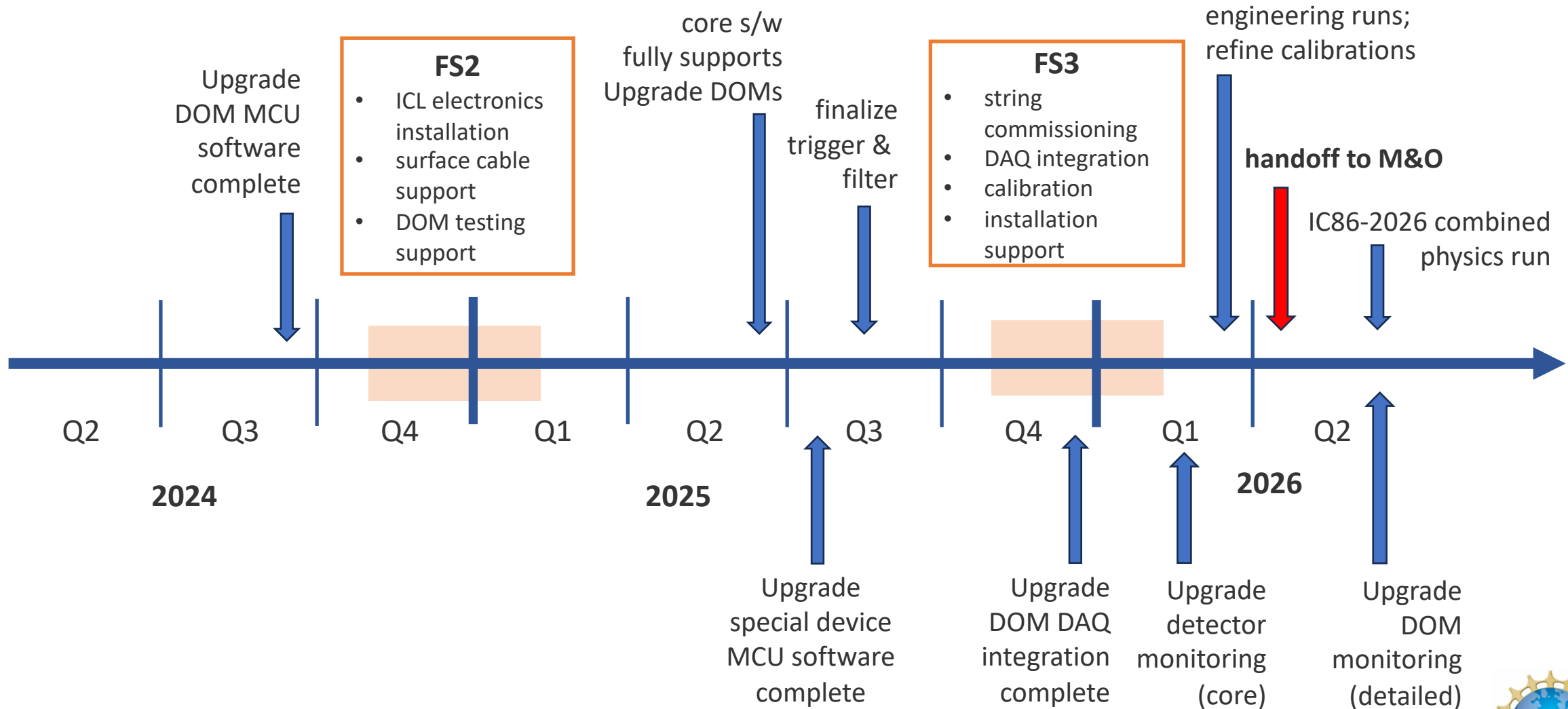# Outline

- Data flow and integration timeline

- Online hardware and software integration

- Offline software integration and computing

- View of unified operations

Data Flow Including Upgrade

data acquisition

processing & filtering

satellite (TDRSS)

DAQ — **trigger**

PnF — **filter**

JADE

filtered

~130 GB/day

raw

~1.2 TB/day

archival disk

data warehouse

L2, L3 offline processing

Upgrade DOMs   Gen1 DOMs

South Pole System (SPS)

"The North"

M&O Integration Timeline

Upgrade DOM MCU software complete

FS2
- ICL electronics installation
- surface cable support
- DOM testing support

core s/w fully supports Upgrade DOMs

finalize trigger & filter

FS3
- string commissioning
- DAQ integration
- calibration
- installation support

engineering runs; refine calibrations

handoff to M&O

IC86-2026 combined physics run

Q2   Q3   Q4   Q1   Q2   Q3   Q4   Q1   Q2

2024   **2025**   **2026**

Upgrade special device MCU software complete

Upgrade DOM DAQ integration complete

Upgrade detector monitoring (core)

Upgrade DOM monitoring (detailed)

Upgrade ICL Electronics

ICL Rack 14 Map

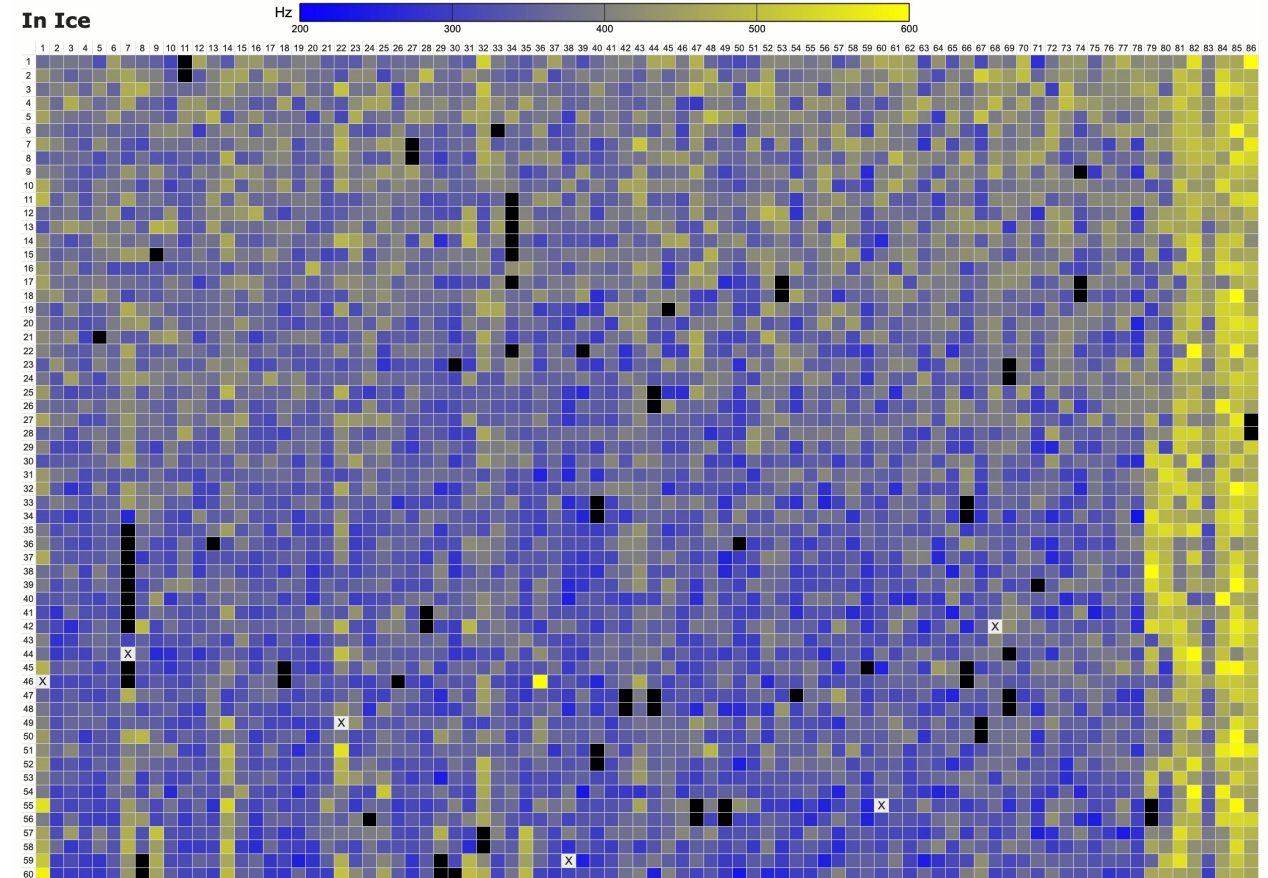| U#	
U47	White Rabbit grandmaster
U46	
U45	DOM power supply 87
U44	DOM power supply 88
U43	DOM power supply 89
U42	DOM power supply 90
U41	DOM power supply 91
U40	DOM power supply 92
U39	DOM power supply 93
U38	DOM power supply spare
U37	network switch 1
U36	network switch 2
U35	
U34–U32	fieldhub87
U31–U29	fieldhub88
U28–U26	fieldhub89
U25–U23	fieldhub90
U22–U20	fieldhub91
U19–U17	fieldhub92
U16–U14	fieldhub93
U13	
U12–U7	UPS, 8kW non-redundant
U6–U1	UPS, 8kW non-redundant

- To be installed by M&O team in 24–25 field season

- Upgrade power, communications, and timing system

- FieldHubs designed to be backward-compatible with IceCube and forward-compatible with IceCube-Gen2

FieldHub testing at DESY Zeuthen, March 2024

Detector Monitoring via IceCube Live

- Upgrade will be integrated into existing monitoring system

- Phase 1: detector health / stability
  - high-level monitoring of DAQ
  - trigger / filter stability
  - component health
  - straightforward extension of current capabilities

- Phase 2: Upgrade-specific extensions
  - new per-DOM quantities, tests, and plots
  - enhanced Upgrade subdetector visualizations

in-ice "DOM map" of noise rate, run 139285

IceTray, Offline Software, and Simulation

base processing TODO list

- IceTray core software support for the Upgrade
  - support for new DAQ formats
  - new waveform calibrations
  - superDST for multi-PMT modules

- Full-fidelity simulation of Upgrade DOMs

- Some recent success identifying in-kind effort to assist with this

Upgrade Computing
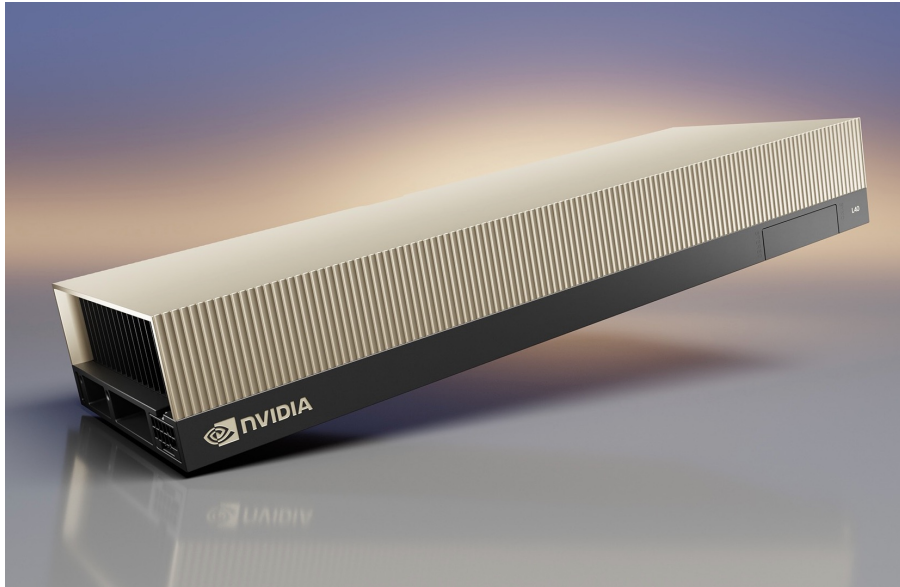
Nvidia L40S GPU

- Continue to grow data warehouse for experimental and simulated data

- Continue to leverage worldwide grid resources
  - support wide collaboration use

- Add both hardware and developer expertise to support ML / AI

Deferred Maintenance

- Successfully prioritized critical maintenance during COVID and post-COVID periods
  - South Pole logistics constraints
  - inflationary pressure

- Post-Upgrade completion priorities:
  - SPS server upgrade
  - northern CPU / GPU cluster upgrades
  - surface array enhancement

M&O funding vs. inflation
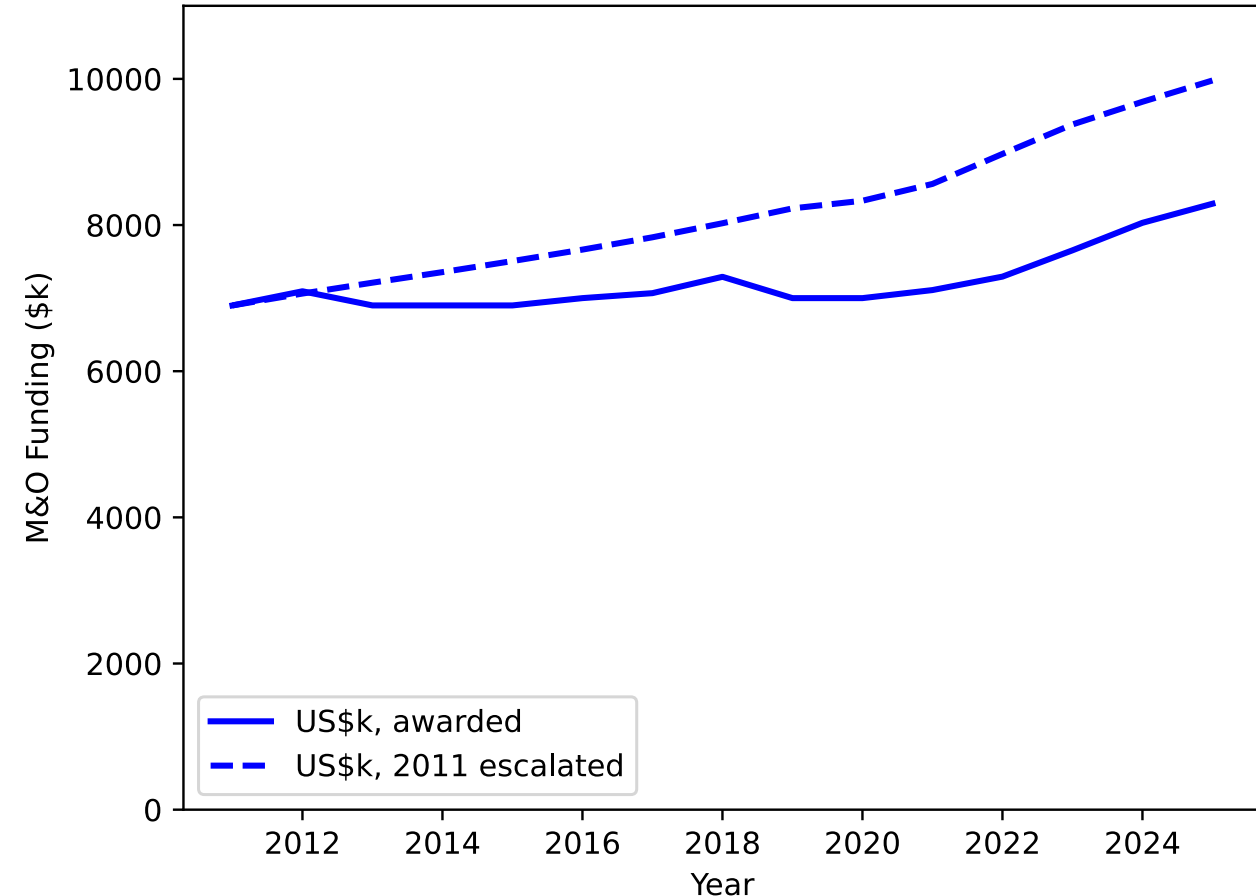
Post-Upgrade Logistics Estimates

- Power: 73–75 kW (+11–13 kW)

- Satellite bandwidth: 135–155 GB/day (+30–50 GB/day)

- Winterovers: 2 (no change)

- Summer field population: similar levels to (pre-COVID) M&O
  - 8–9 beds incl. WOs
  - 14–16 deployers incl. self-ticketers
  - NB: plans rely on population rotation

Nominal Upgrade power estimates

Item	NOMINAL		
	Power (W)	Quantity	Total (kW)
String power	1251	7	8.76
DOM supply AC-DC losses	963.27	1	0.96
UPS	4	2	0.01
PDU	10	2	0.02
network switch	350	2	0.70
weather goose	20	1	0.02
FieldHub	75	7	0.53
WR switch	80	1	0.08
Total			11.07

Post-Upgrade Operations Outlook

- Ensure stability of the detector, DAQ, and data processing

- Support new calibration runs

- Promptly deliver processed experimental data and simulation
  - support ML-enhanced data processing

- Deferred hardware maintenance

- Replace DOMHubs with Upgrade ICL FieldHubs
  - ensure long-term health of experiment
  - provide unified system for efficient maintenance

- Continue to expand IceCube science!

Summary

- Upgrade integration leverages well-maintained IceCube software
  - systems are being adapted, not re-written

- Unified DAQ output will flow naturally into existing data pipeline
  - changes needed for data formats, new devices, etc.

- Focus of M&O team in upcoming field seasons is Upgrade integration and support

- On track for unified operations in 2026