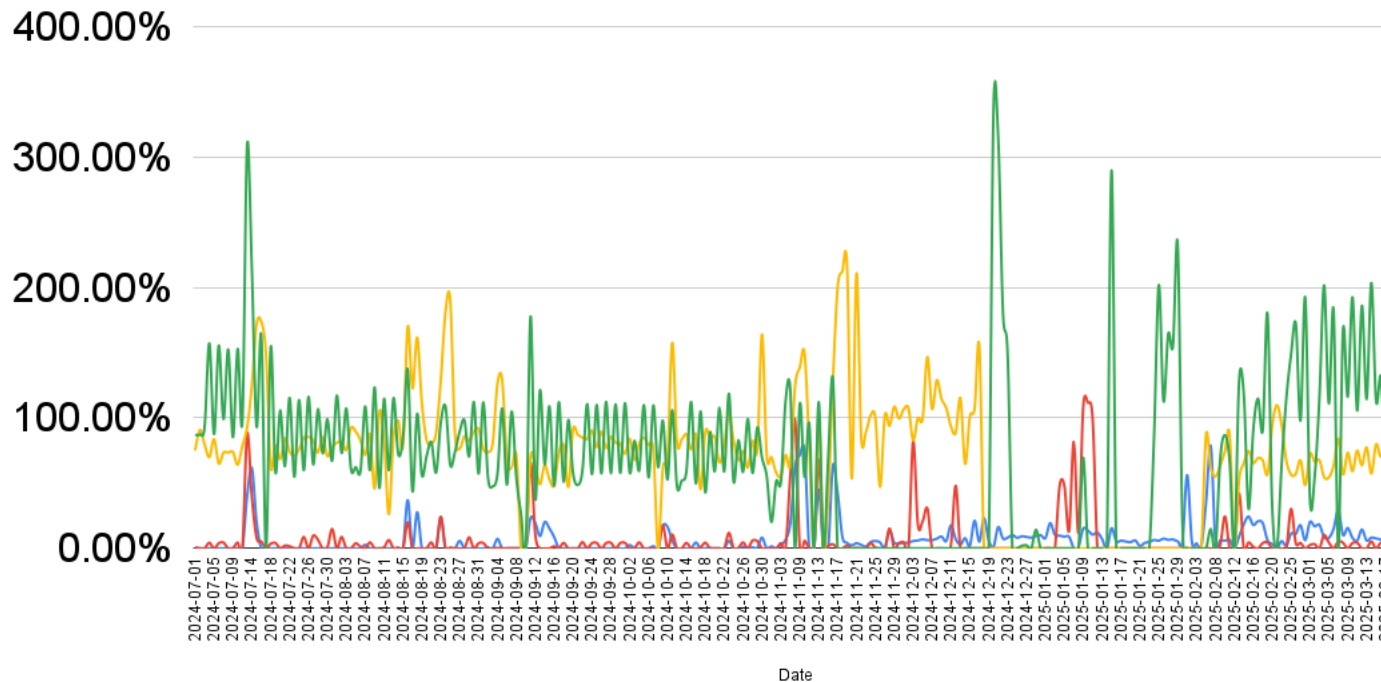# Upgrade and Beyond – Landscape

- Upgrade will double the photon collection area

- Software and analyses will need to adjust to multi-PMT modules, varying readout electronics, etc. – Breaks basic assumptions in software

- AI/ML becoming more popular

Upgrade Data Rate

% Over Allocation By Project
— IceCube — BICEP 3 — SPT — SPUD

- Biggest hurdle to get data from South Pole is the satellite bandwidth
- There is extra bandwidth that is not officially allocated – Used by other experiments
- Starlink has been tested – Concerns from CMB experiments with EM inference
- Alternative locations for Starlink terminal TBD

Upgrade Storage

Detector Component	DAQ(MB/s)	Archive(TB/yr)	Satellite(GB/day)
IceCube			
In-ice/Icetop	10-12	375	145
IceCube Supernova	1.2	40	5
Subtotal		415	150
Upgrade			
In-ice	2.1	56	18
Subtotal		56	18
Gen2			
In-ice	12	322	104
Surface	11.5	308	15
Radio	11	350	15
Subtotal		980	134
Total		**1451**	**302**

- For 2023 storage replacement we assumed a 30% increase in data rate
- Today 30% is the lower end of the increase
- New Offline Processing/Pass3 designed with Upgrade (and beyond) storage uncertainty in mind
- Lower on-disk footprint of data and storage – Trading CPU/GPU cycles for storage

Upgrade Computing

- Computing requirements for Upgrade are somewhat unclear, particularly on the simulation side
  - Memory usage for calibration constants, etc. – Development in progress
  - New Triggers and data processing – Will there be AI? Most likely
  - Leveraging in module computing to reduce computing and storage needs

- Upgrade data processing, triggers, etc. will evolve significantly throughout 2026 and 2027 – Plan is to reprocess data (Pass4) in 2027

- AI Training and Inference demand is biggest question
  - AI training resources are mostly contributed – Limited easily accessible collaboration-wide resources
  - AI Inference will need to be optimized in light of GPU needs for simulation
    - ML-Inference-as-a-Service/SONIC is the most resource efficient option, requires more development

IceCube Gen2 Storage

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- 200 TB storage in 2023 storage purchase are planned for Gen2 simulation
- At current stage of project (R&D, ~8 years out) this will be sufficient

IceCube Gen2 Computing

- Similar concerns as Upgrade
  - Increased PMT count and corresponding calibration constants, etc. – Increased RAM usage
  - Number of photons simulated that will not be detected increases considerably – Wasted computing
  - Longer run times for simulation

- AI Training for Gen2 is limited by GRAM – Over 80 GB
  - Multi-GPU training?
  - Inefficiency in ML code?

Summary

- Upgrade computing needs are crystalizing
  - Satellite bandwidth a potential roadblock
  - New offline processing meant to reduce storage footprint
  - AI/ML appears the way forward for Upgrade analyses
- Gen2 requirements are still being worked on
  - R&D computing requirements are manageable but may require specialized resources