

BUQ Project Meeting 2026-07-15

13:54(GMT-7:00)

Key Outcomes

The team reviewed five Genesis mission proposals spanning chemistry, microbiology, nuclear physics, and particle physics. A recurring theme across all proposals is **closed-loop, autonomous, uncertainty-aware AI frameworks** combining Bayesian optimization, LLMs, and transfer learning. Results for nuclear and high-energy physics proposals have been released; others are still pending. [1](#) [2](#)

Decisions Made

- Genesis mission results are partially out; nuclear and high-energy physics decisions confirmed released [2](#)
- FPGA deployment is appropriate for **microsecond-level** real-time decisions; slow control monitoring can run on standard computers [3](#)
- Fermilab will fund the DUNE neutrino platform via **LDRD** if the Genesis proposal is not funded [4](#)

Proposals Presented

Simon – Chemistry (Inorganic Oxide Nanocrystals)

- Closed-loop Bayesian optimization with robots running experiments 24/7; each run takes weeks and generates ~100 TB of imaging data [5](#) [6](#)
- LLMs used for literature mining + **transfer learning** to bridge domain gaps between studied and target nanocrystals [7](#) [8](#)
- Note: PI submitted Phase 2 (\$5M) version; Simon's budget was Phase 1 — follow-up needed [9](#)

Simon – Microbiology (Genome-to-Function Mapping)

- Deep Bayesian GP encoder-decoder maps thousands of genomes to phenotypes in microbial communities [10](#)
- Transfer learning applied across in vitro → in planta (higher fidelity) data; active learning guides experiment selection [11](#) [12](#)
- Physics-informed constraints (differential equations) baked into model for interpretability and data efficiency [13](#)

Ann-Kathrin – Foundation Model for Germanium Detectors

- Single detector-conditioned model pre-trained on shared germanium signal physics (charge creation, drift, trapping) across **Legend** and **COSI** detectors [14](#) [15](#)
- Goal: transfer learned representation across different geometries and readout schemes; potential use for designing new detector geometries [16](#)
- Phase 1 relies primarily on simulation data [16](#)

Aobo – Foundation Model for Neutrinoless Double Beta Decay

- Led by University of Hawaii; uses **tokenization** to unify five open datasets (waveforms, images, 3D tracks) across different detectors and modalities [17](#) [18](#)
- Single transformer model trained via self-supervised learning, fine-tuned per dataset [18](#)

Aobo – DUNE Neutrino Discovery Platform (Fermilab-led)

- Four components: open data (MINERvA, MicroBooM), surrogate model, simulation-based inference, LLM-based AI agents [19](#)
- Aobo's role: surrogate model for full momentum reconstruction using **MLP + variational Bayesian last layer** [20](#)

Aobo – Legend FPGA Waveform Classification (PNL-led)

- APSVM algorithm classifies waveforms (normal, discharge, crosstalk, etc.) in real time; outperforms current Legend data cleaning [21](#)
- Aobo's role: quantize and prune trained SVM for FPGA deployment; PNL team handles board deployment [22](#)
- Long-term Phase 2 goal: spatiotemporal anomaly detection via self-supervised learning [22](#)

Cross-Cutting Themes

- **LLMs + transfer learning:** generalizable framework for mining literature and adapting prior data to new experimental systems 6
- **Physics-informed Bayesian models:** improve interpretability and reduce data requirements across all domains 5 13
- **Active learning / Bayesian optimization:** maximizes information gain per expensive experiment 12

Pending Confirmation

- Simon to follow up with chemistry PI on whether Phase 1 or Phase 2 was officially submitted 9
- Aobo's Legend emulation results ready to present — awaiting scheduling 24
- Yuri's group (UC Berkeley) proposed for next meeting to present new fast **Sampler algorithms** 24

Action Items

- **Simon:** Confirm Phase 1 vs. Phase 2 submission status with chemistry PI
- **Aobo:** Email Alan directly about Legend emulation results for next meeting slot 24
- **All:** Upload talk slides to shared repository 25

Next Meeting

- Topic: Yuri's group presenting new Sampler algorithms; Aobo's Legend emulation results (pending confirmation)