

# ACORN

## Accelerator Controls Operations Research Network

Collaboration and R&D

October 2023

### ACORN Overview

ACORN aims to modernize the Fermilab accelerator control system by replacing obsolete components. The project will integrate new capabilities into the existing accelerator complex to enable the most intense high-energy beam of neutrinos for the Deep Underground Neutrino Experiment at the Long Baseline Neutrino Facility (LBNF).

At this early stage in the project, the ACORN team is focused on control system R&D and on collaborating with other projects.

### Collaboration with PIP-II

In collaboration with the Proton Improvement Plan II (PIP-II) Project, the ACORN team is working with the PIP-II team to deliver a minimally viable core application (Parameter Page) to PIP-II stakeholders. The two teams are developing a user acceptance plan to validate that applications meet user requirements. For members of the ACORN team, this **R&D enables fast feedback** on design and process concepts that ACORN will use to develop cost estimates for future project reviews. The collaboration also helps define interfaces for integrating PIP-II applications with future applications that will be developed by the ACORN team.

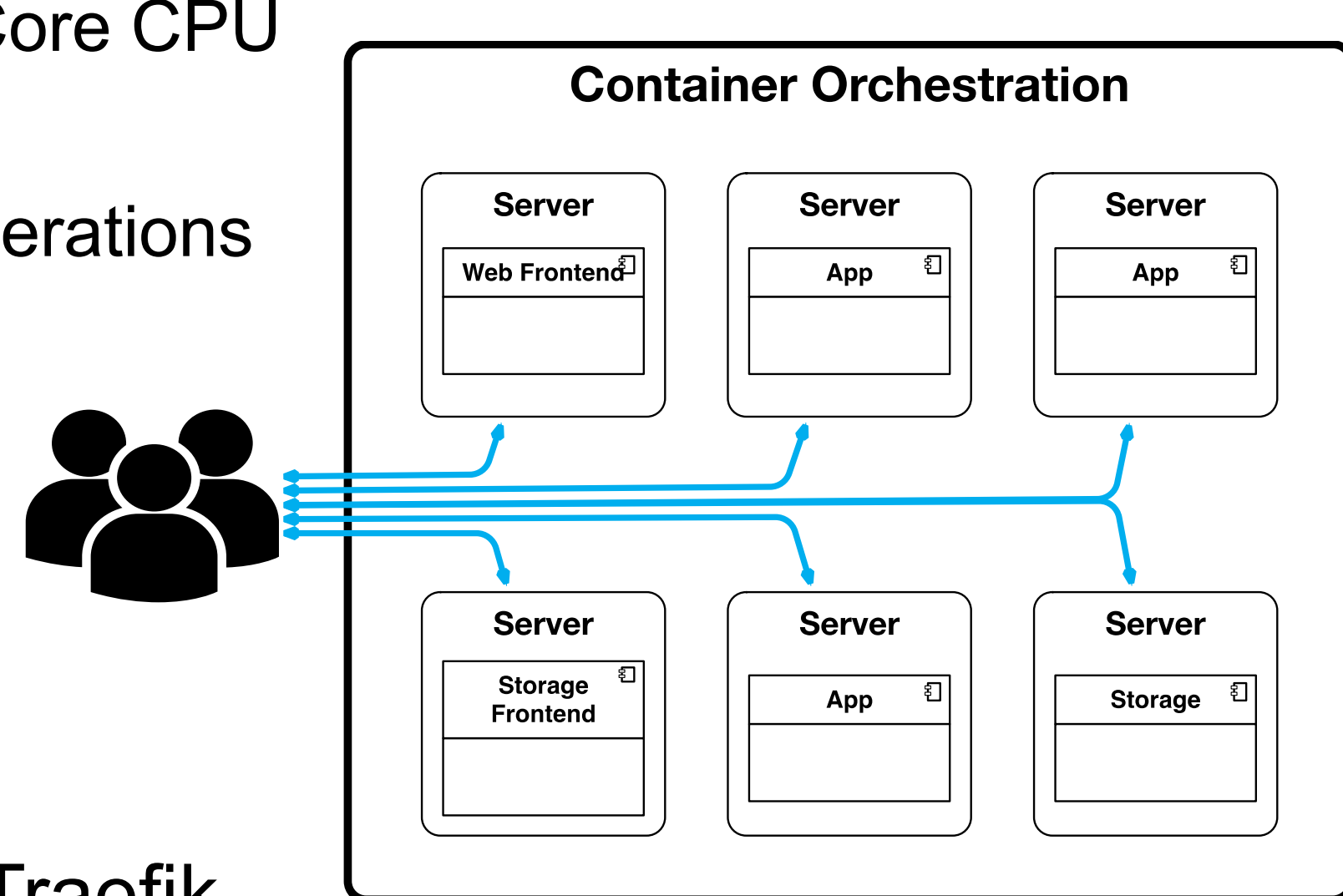
The experience from developing this application will give the ACORN team a basis of estimate for converting core applications from the legacy control system to the modernized control system. Approximately **800 legacy applications totaling several million lines of code are under consideration for conversion**. The complexity of the conversion process requires accurate labor estimates to determine the amount of effort needed to modernize applications.

### Rapid Prototyping Platform for R&D

**Goal:** Create a **reusable** platform where concepts and tools can be rapidly **prototyped**, **tested**, and **evaluated**.

**Implementation:** Kubernetes, Ceph+Rook

- 6 nodes (single master) vanilla Kubernetes cluster - v1.26.0
- Each node has:
  - 2xAMD EPYC 7543 32-Core CPU
  - 256GB memory
  - 960GB SSD for node operations
  - 2x7TB partitions for Ceph storage
- 16 distinct users
- 51 namespaces
- 28 LoadBalancer IPs
- 17 L7 ingress routes on Traefik
- 149 running pods



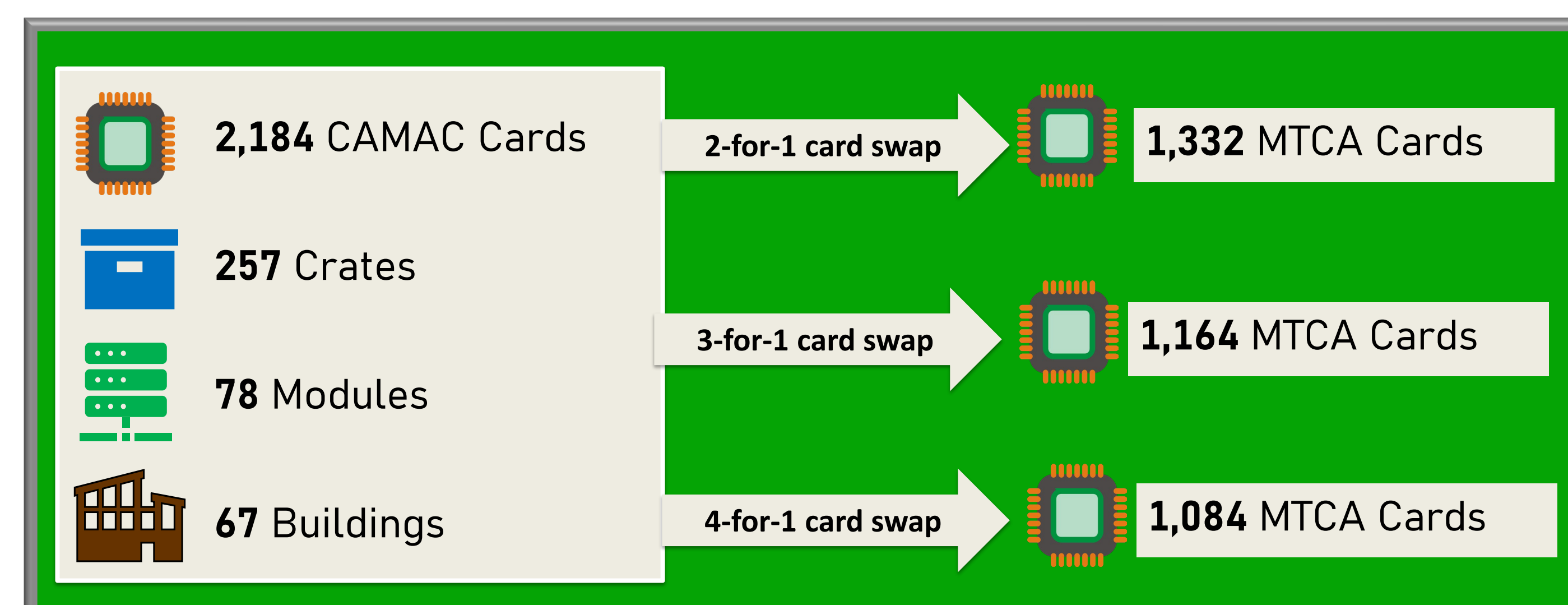
**Future:**

ACORN is proposing the use of Kubernetes for the production computing facility, allowing the consolidation of computing resources as well as providing automatic scaling based on load and other metrics.

### Data Acquisition and Control R&D

Fermilab's obsolete CAMAC control system hardware needs to be replaced. An R&D effort by the ACORN team is assessing the replacement of CAMAC hardware with  $\mu$ TCA hardware that integrates Experimental Physics and Industrial Control System (EPICS) capabilities into the modernized control system.

Fermilab's CAMAC hardware consists of **over 250 CAMAC crates** with **over 2,100 CAMAC cards** and **over 70 card types** and **13 VME front-end crates**. The CAMAC crates communicate with VME front-end crates through three CAMAC links.



Summary of card replacement strategies that maintain: (1) crate separation, (2) machine separation, and (3) card functionality separation.

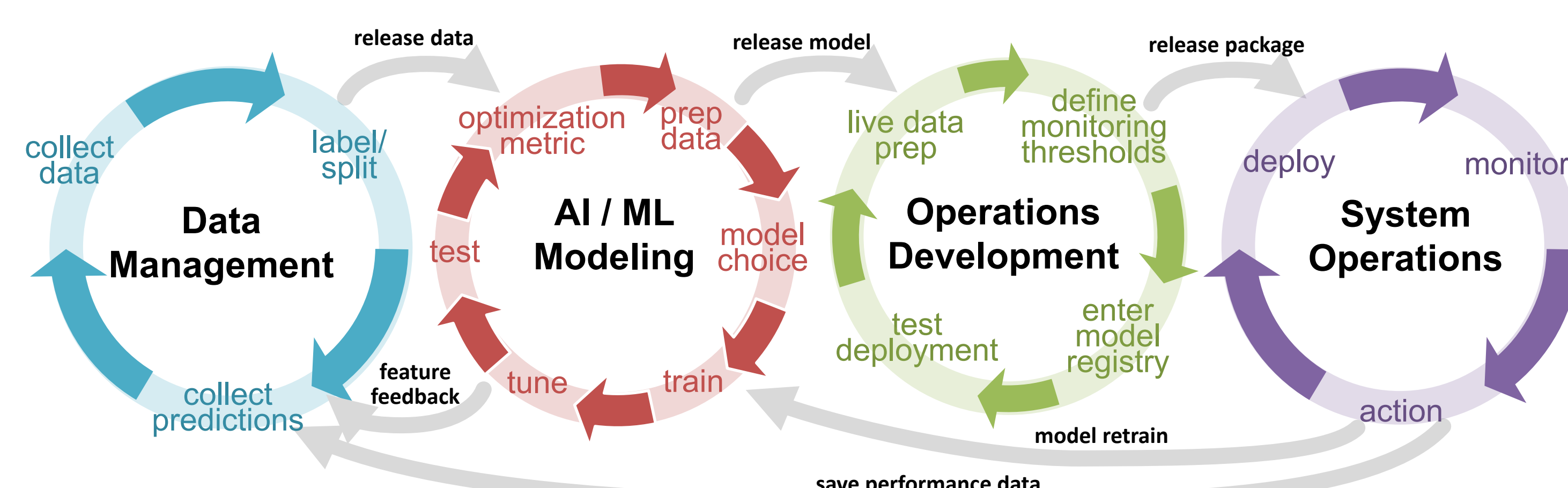
The R&D is evaluating card replacement strategies and is looking into the MTCA.4 extension to the  $\mu$ TCA standard. MTCA.4 adapts the  $\mu$ TCA specification for scientific applications by adding rear I/O. To avoid re-cabling and its associated costs, the ACORN team is planning a crate-for-crate replacement maintaining the current connectors to the CAMAC cards. However, to maintain the current crate density, a single MTCA card will be replacing multiple CAMAC cards.

### Collaboration with AI Projects

AI research projects at Fermilab **push the limits** of the existing control system and **determine requirements** for ACORN for the future control system.

- **READS:** Edge deployment on FPGAs to determine source of beam loss monitor signals in a shared beam enclosure.
- **LCAPE:** Use anomaly detection techniques to predict beam downtime in the linear accelerator (Linac).

To ensure **sustainable operations** of AI control algorithms, the following MLOps infrastructure will be supported by ACORN.



Machine learning operations (MLOps) is a collection of linked frameworks designed for applying ML/AI technology to live systems. MLOps ensures verification, validation, assurance, and trust for data collection and model building, deployment, and monitoring.