Strategy for Modernizing a 40-Year-Old Accelerator Control System (WEO13)

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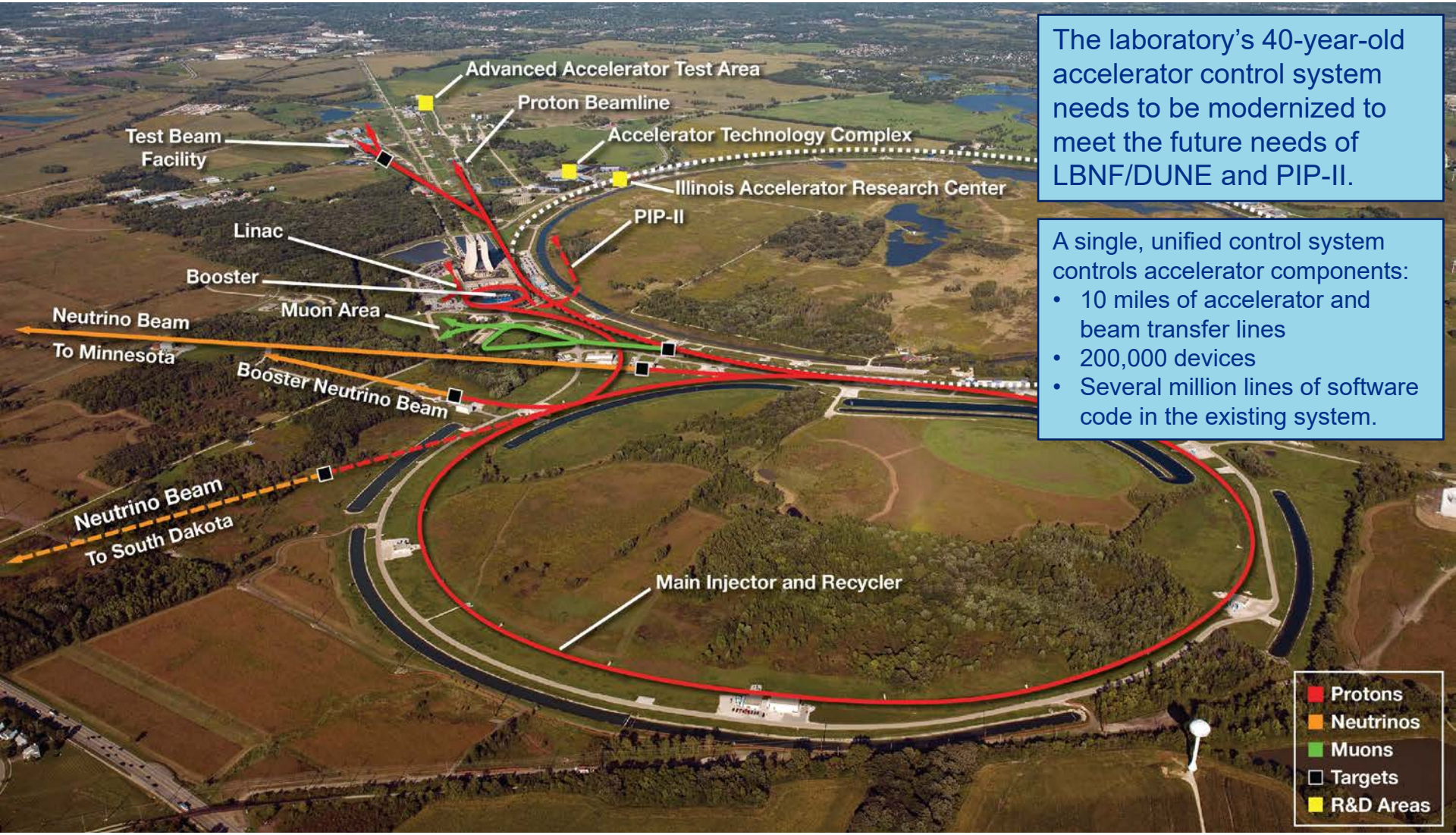
About Me

- Software Engineering Manager in Accelerator Division, Controls Department (**current assignment**)
  - Level 2 Manager for the ACORN Project, Control System Applications (WBS 204.05)
- Software Developer II in Accelerator Division, Controls Department (**previous assignment**)
- Senior Accelerator Operator in Accelerator Division, Operations Department (**previous assignment**)

Fermilab Accelerator Complex



The laboratory's 40-year-old accelerator control system needs to be modernized to meet the future needs of LBNF/DUNE and PIP-II.

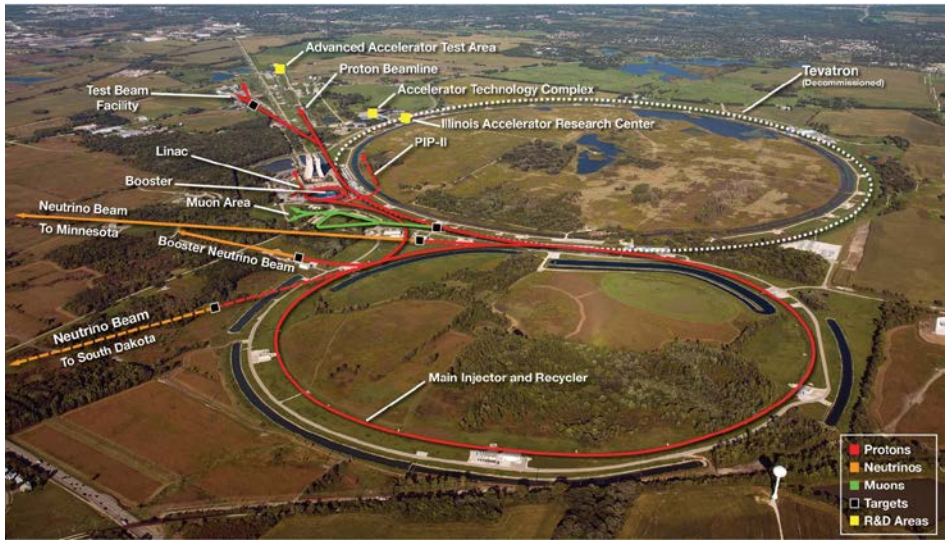
A single, unified control system controls accelerator components:

- 10 miles of accelerator and beam transfer lines
- 200,000 devices
- Several million lines of software code in the existing system.

Accelerator Controls Operations Research Network (ACORN)

- ACORN will modernize the accelerator control system and replace end-of-life accelerator power supplies to enable future operations of the Fermilab Accelerator Complex with megawatt particle beams.

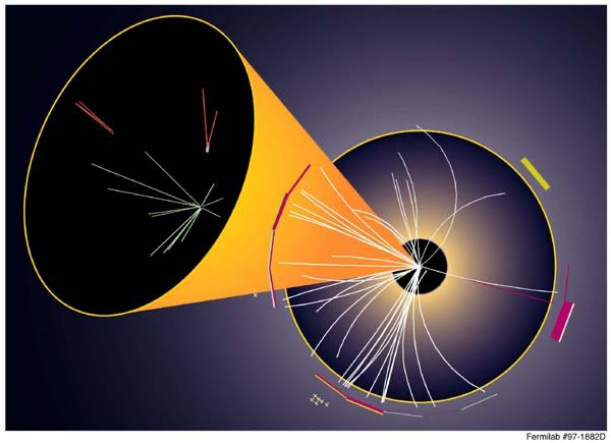
- ACORN is a United States Department of Energy (DOE) O413.3B project.
- Total Project Cost: 100 – 142 M$
- Project Duration: 8 – 10 years

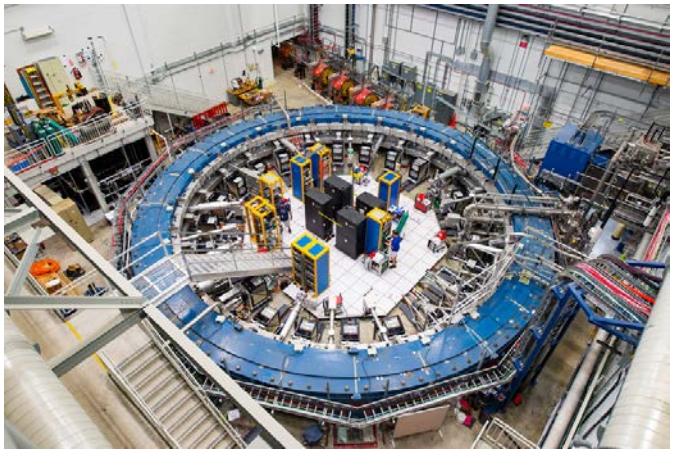


- As an upgrade of the accelerator complex, the ACORN team is analyzing risk associated with current accelerator operations and is developing requirements for modernization.

The Current Control System

- Fermilab's accelerator control system has enabled major scientific discoveries such as the top quark with the Tevatron collider program and most recently the g-2 anomalous muon magnetic moment measurement.

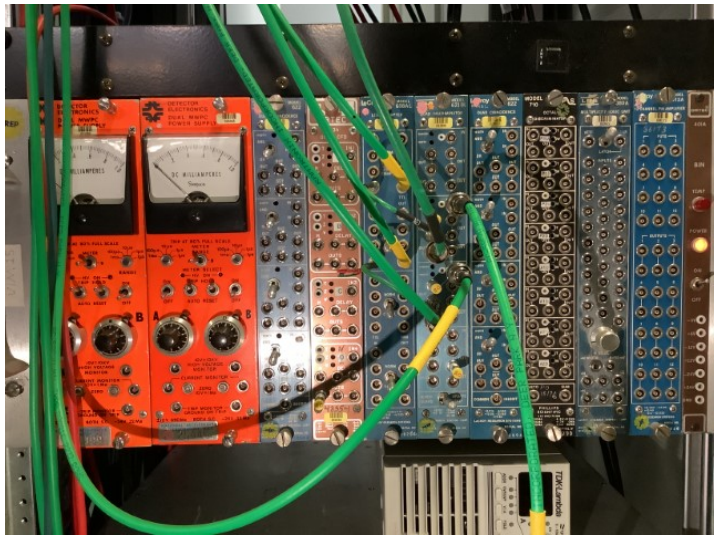




- The control system has never taken beam down for a major upgrade.
- All upgrades have been incremental without interrupting the beam delivery program.
- ACORN is Fermilab's first opportunity to take a large-scale and deliberate approach to modernizing the control system by "standing on the shoulders of giants".
- ACORN will build on the success of the current control system, upgrading to modern architectures, hardware, user interfaces, software, development processes, documentation, and integrating with modern toolkits like EPICS.

Evaluating Risks and Developing Requirements

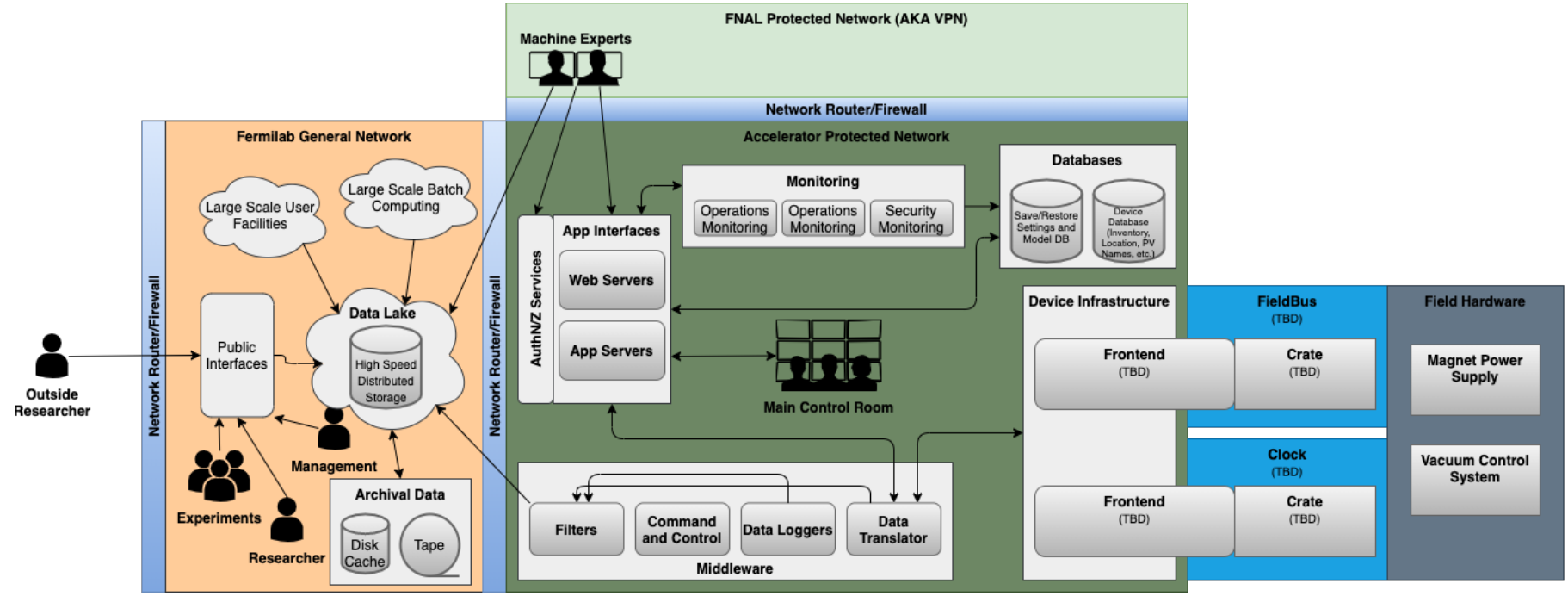
1. Perform risk analysis for accelerator operations risks.
2. Use the risk ranking to define ACORN's scope.
   - We know that we have more work than our funding can support. The risk ranking allows us to prioritize and include the most important work in the project scope.
3. Develop functional requirements for the existing accelerator control system.
4. Identify new requirements needed to implement new capabilities.



Research and Development

- ACORN is exploring unique engineering challenges to enable new capabilities for future accelerator operations.
  - ACORN will perform or support R&D efforts as part of the project's R&D program.
- ACORN R&D activities include research into:
  - New data acquisition capabilities
  - Support for AI/ML for accelerator operations
  - Evaluation of 5G technology
  - Support for robotics
  - Evaluation of Experimental Physics and Industrial Control System (EPICS)

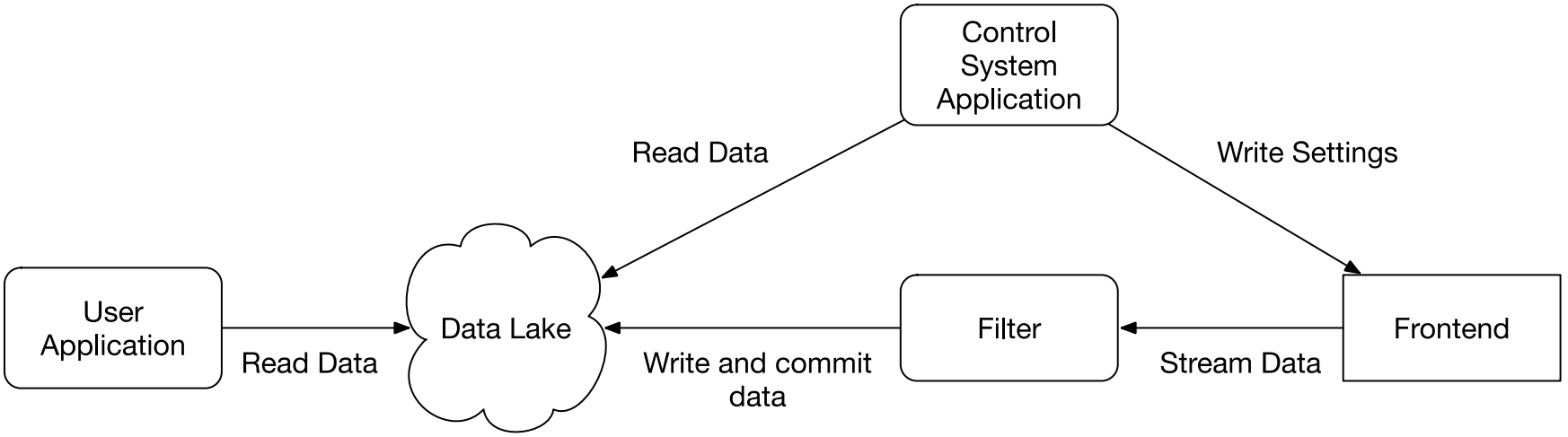
Data Acquisition R&D – Centralized Architecture



Fermilab

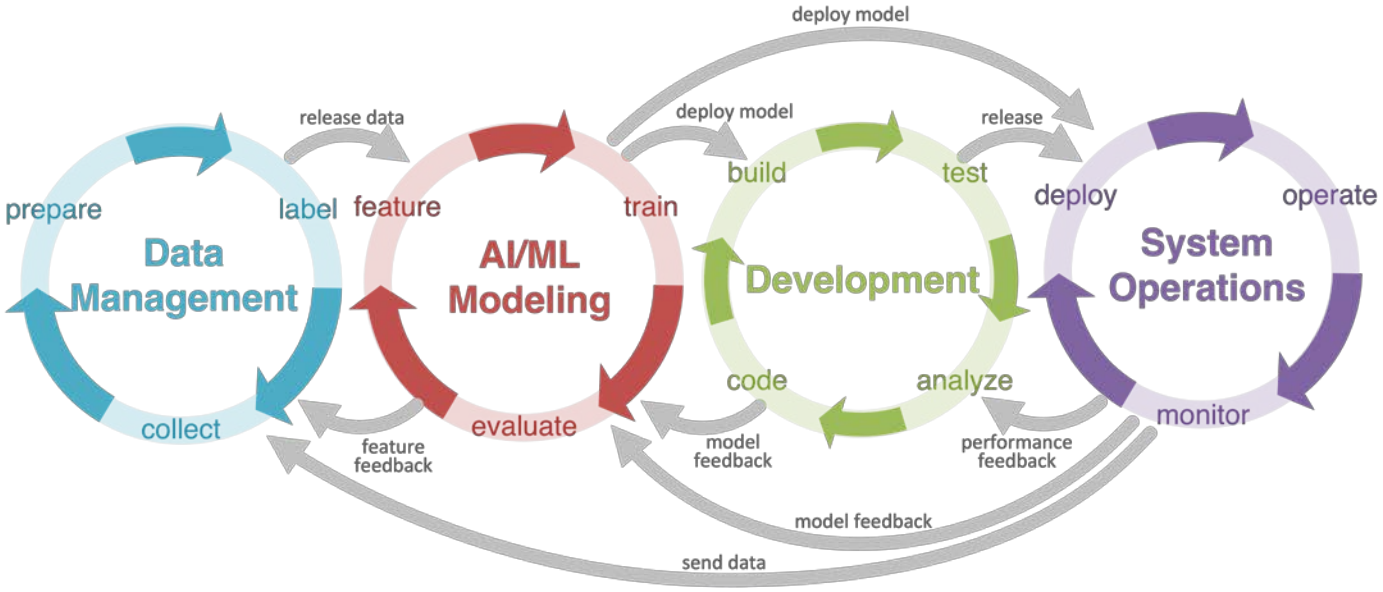
Data Acquisition R&D – Data Lake

- Measure expected data flows from different types of front-ends
- Create a testbed Data Lake
  - Measure total data volumes
  - Test filters to select and store relevant and interesting data
  - Measure commit latencies for writing data
  - Measure latencies for reading data
- Determine if a Data Lake satisfies accelerator control system requirements



AI/ML Infrastructure R&D

- Mission
  - Enable safe and reliable improvements to accelerator operations by applying modern artificial intelligence and machine learning (AI/ML) techniques.
- R&D
  - Investigate machine learning operations (MLOps) frameworks to develop, deploy, and monitor AI/ML applications for accelerator operations.
  - Design MLOps processes to ensure verification, validation, assurance, and trust for data collection and model building, deployment, and monitoring.



5G R&D

- Use Cases
  - Accelerator control system integration in challenging environments, such as locations that are difficult or expensive to service with wired network connections.
  - Provide ubiquitous, non-static data access underground (for example: mobile phones, tablets, robots)
  - High data rate, low-latency communication without cable cost
    - Underground instrumentation
  - New use-cases with custom solutions:
    - Ultra-Reliable Low Latency Communications (URLLC)
    - Massive Machine Type Communications (mMTC)
    - Industrial Internet-of-Things (IIOT)
- R&D
  - Multiband on single radiating coax antenna
  - Equipment lifetime in a radiation environment
  - Interference with accelerator equipment
  - Signal propagation in accelerator tunnels

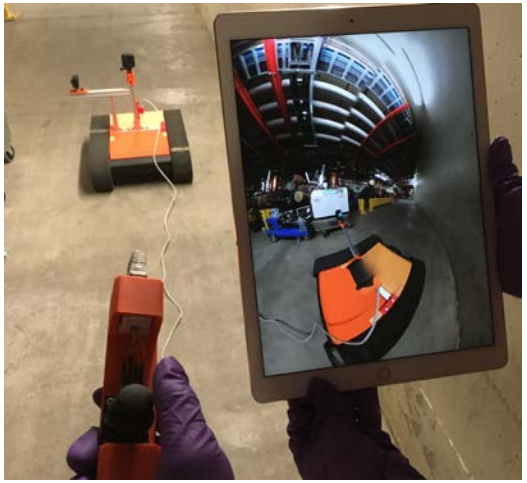
Robotics R&D

Development and proliferation of robotics at Fermilab will bring novel technical challenges to the future accelerator control system. Technical challenges include the following:

- Low-latency feedback and control between robot and operator to minimize errors
- High-resolution and frame-rate video streaming for navigation feedback and reconnaissance
- Transmitting and logging data from a diverse array of sensors such as temperature, humidity, photography, thermal imaging, and radiation mapping.
- Data storage and computation for training robots to autonomously navigate and manipulate tooling for maintenance and installation tasks.

Commercial robot platform: SPOT from Boston Dynamics

Homebrew robot platform: RVR



Human Factors and User Design Principals

The ACORN team has been working with INL Human Factors team on interviewing operators and developing a guide for intuitive user interfaces.

We plan to build our framework around this guide to give a sane set of defaults to our software developers.