Instrumentation and Control

Overview & Update

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Idaho National Laboratory | Oak Ridge National Laboratory | MRP Microreactor Program | Los Alamos National Laboratory | Argonne National Laboratory

Contents

- Safety-Related I&C
- Non-Safety-related I&C
- Full Power additions

- Status

MRP Microreactor Program

Contents

- Safety strategy & design

- Safety-Related I&C
- Non-Safety-related I&C
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- Mapping the path to remote control

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MARVEL Safety Design

- Design Basis Accidents (MARVEL PDSA, ECAR-6440, ECAR-6332, etc.)
  - Loss of cooling (LOC)
  - Unprotected transient overpower (UTOP)
- Fuel feedback & passive heat loss are sufficient
- “Walk away safe”

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Reactor Trips

- Manual
- Seismic
- Others (temp, power, period, reactivity)

AI-generated image of a Reactor Trip System

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Motion System Classifications

System, Structure, or Component (SSC)	Classification
Clutch, springs, shafts, bearings	Safety-related
Motors, drives, controllers	Non-safety-related
Central Insurance Absorber	Non-safety-related

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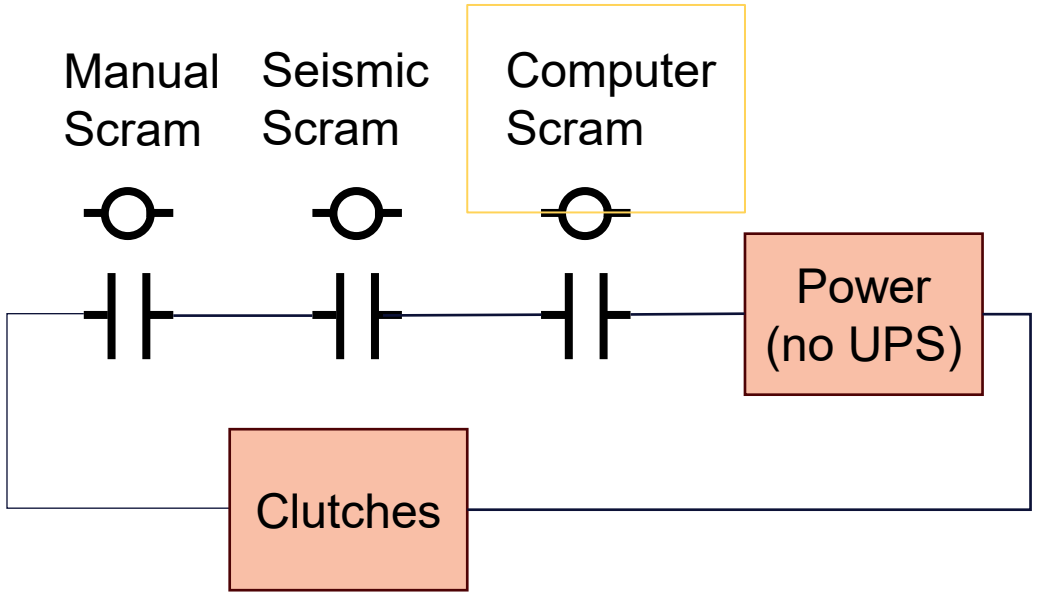
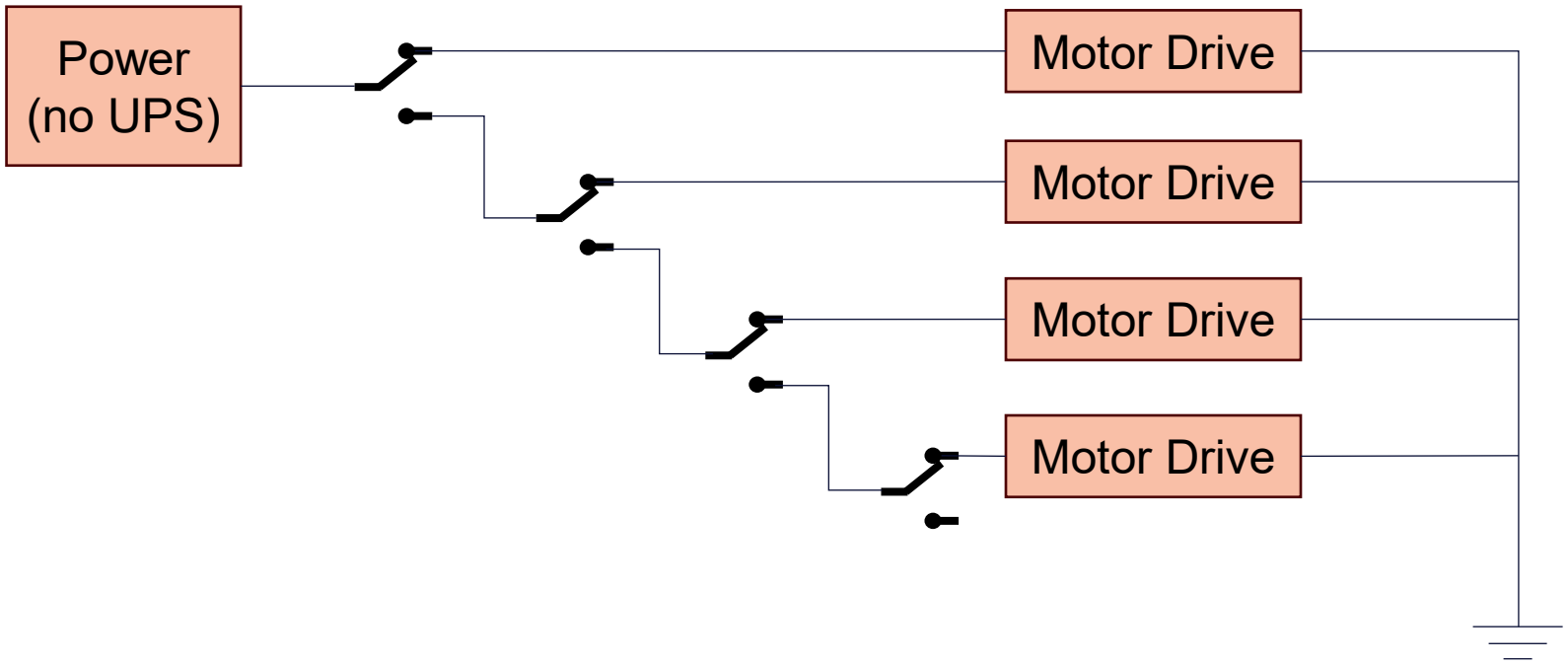
Scram Circuit

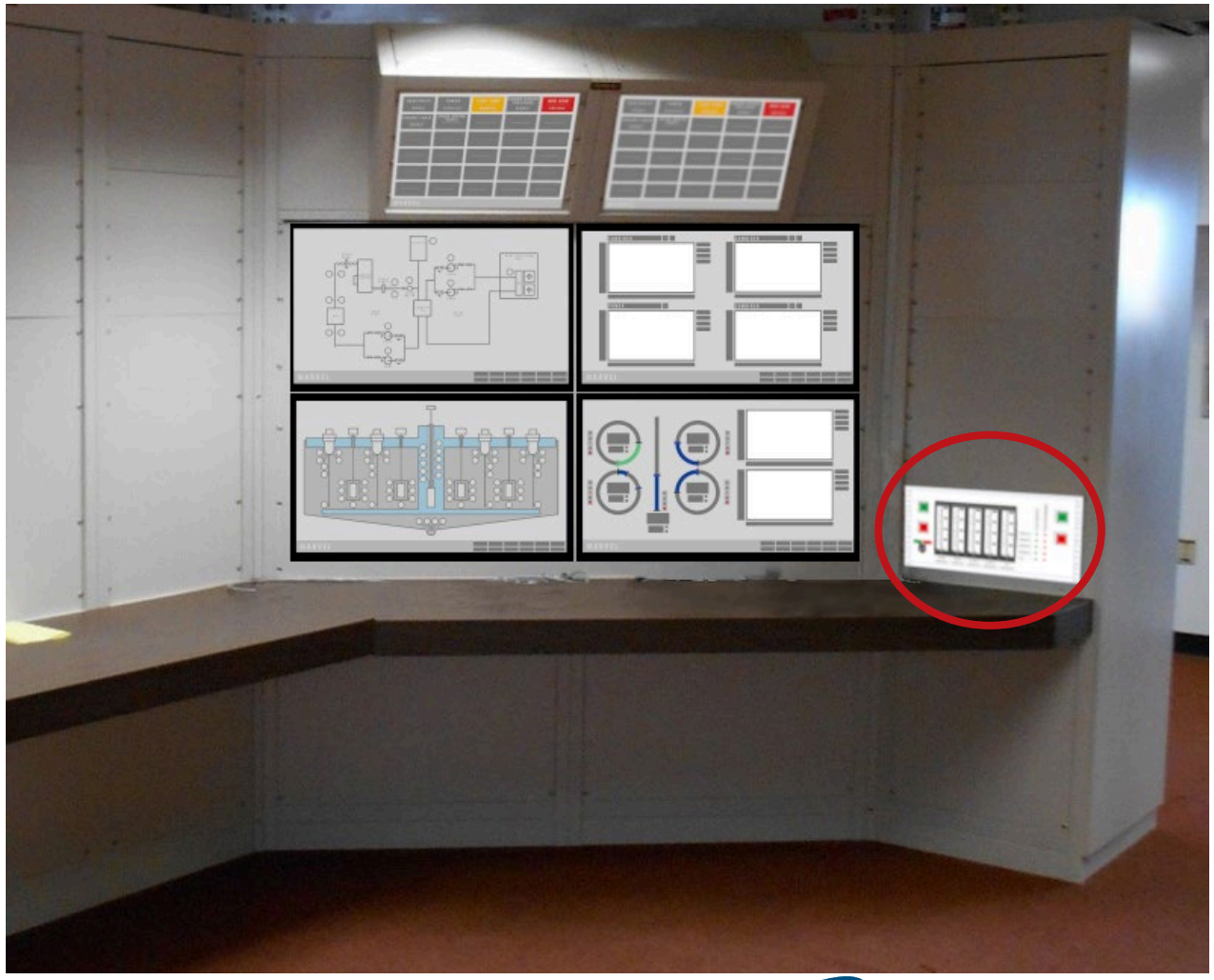


Interlocks


Power
(no UPS)
Motor Drive
Motor Drive
Motor Drive
Motor Drive

Analog monitoring panel

- Everything safety-related in the control room is on this panel
- Controls
  - Scram button
  - NSR
    - Reset button
    - Key switch
- Indicators
  - Pressures (not dry crit)
  - NSR
    - Scram indicator
    - Drum Full in / Out



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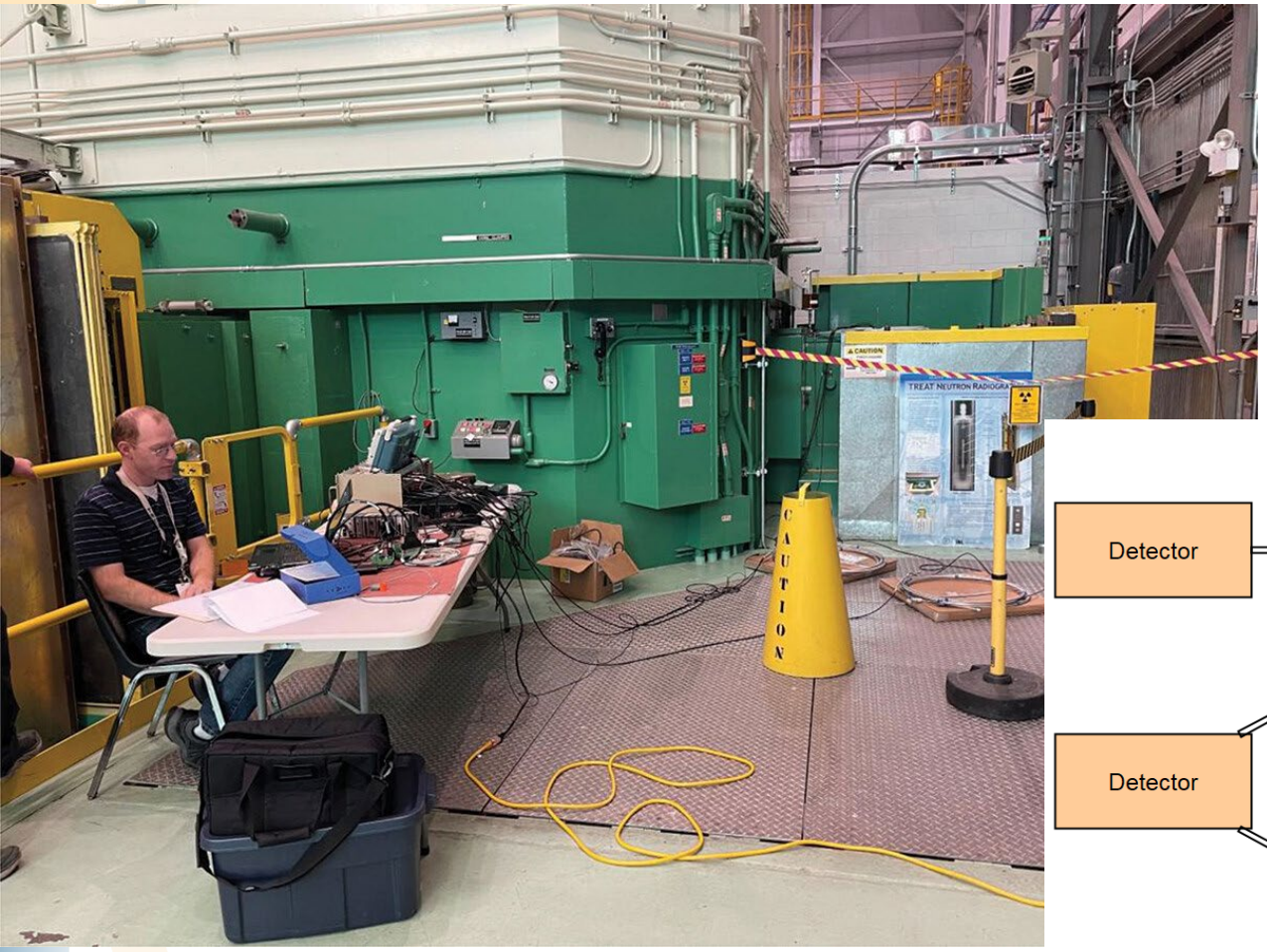
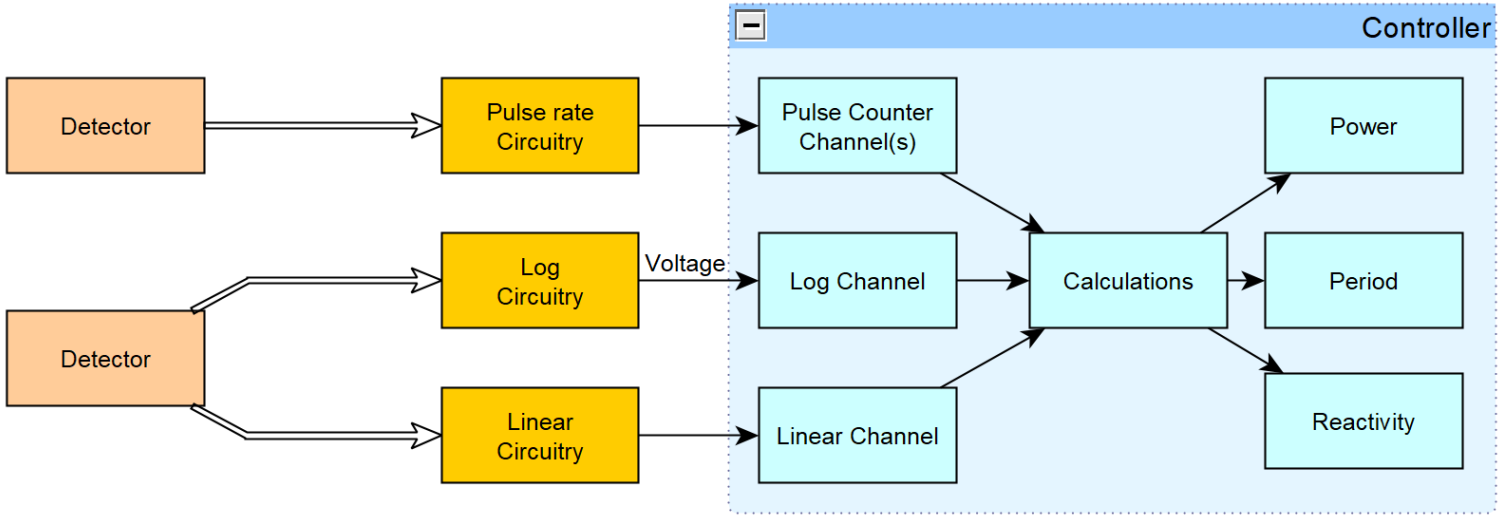
Neutron Detectors



Benjamin Baker running a proof-of-concept test of MARVEL nuclear instruments at TREAT, circa 2021



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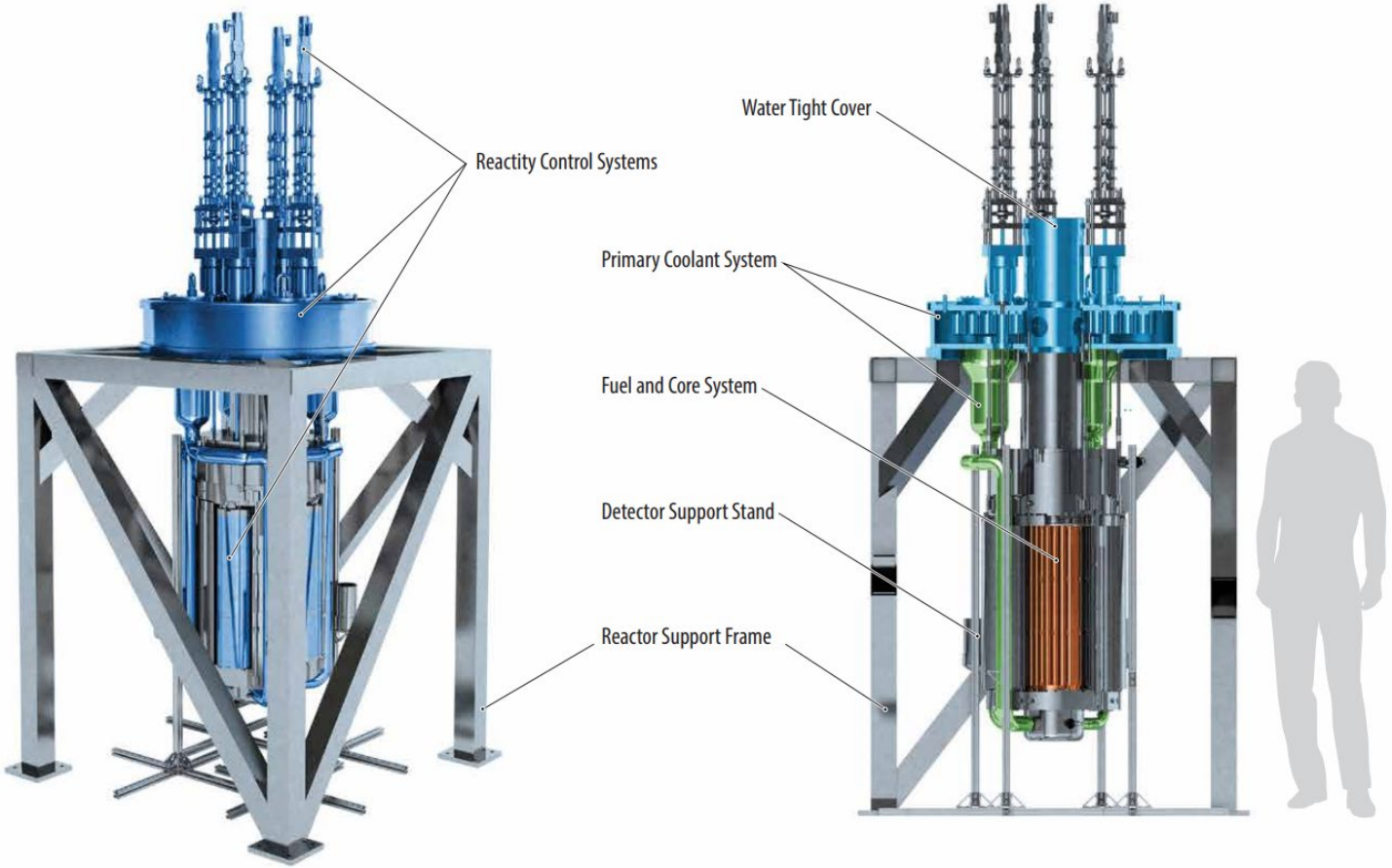
Fuel Thermocouples

- “Temporary” thermocouples placed on the fuel cladding



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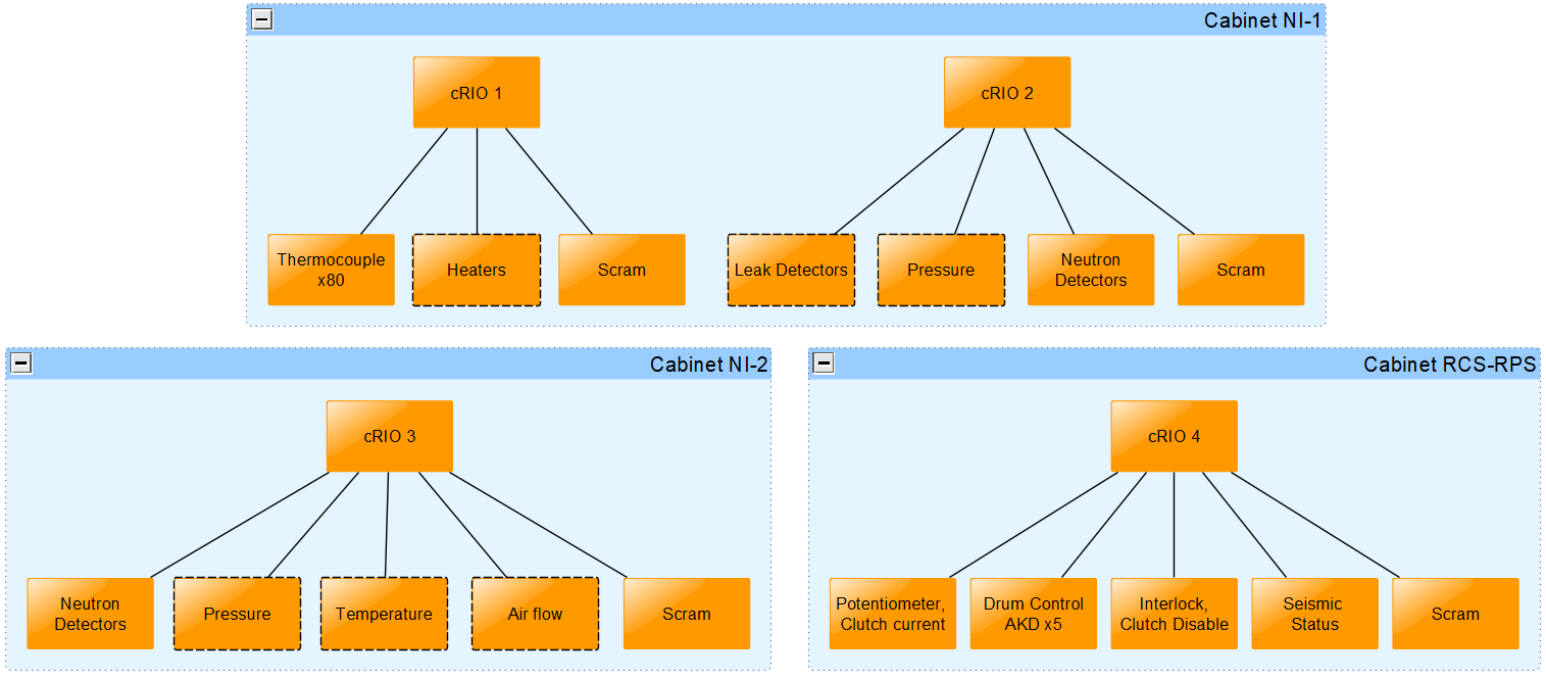
Software Control system



- Distributed across 4 controllers (dry crit), HMI machines
  - Embedded Controllers (NI cRIO)
    - Real-time operating system, FPGA on each controller
  - Located in 3 cabinets, control room, and virtual machines
  - Network communications of various sorts

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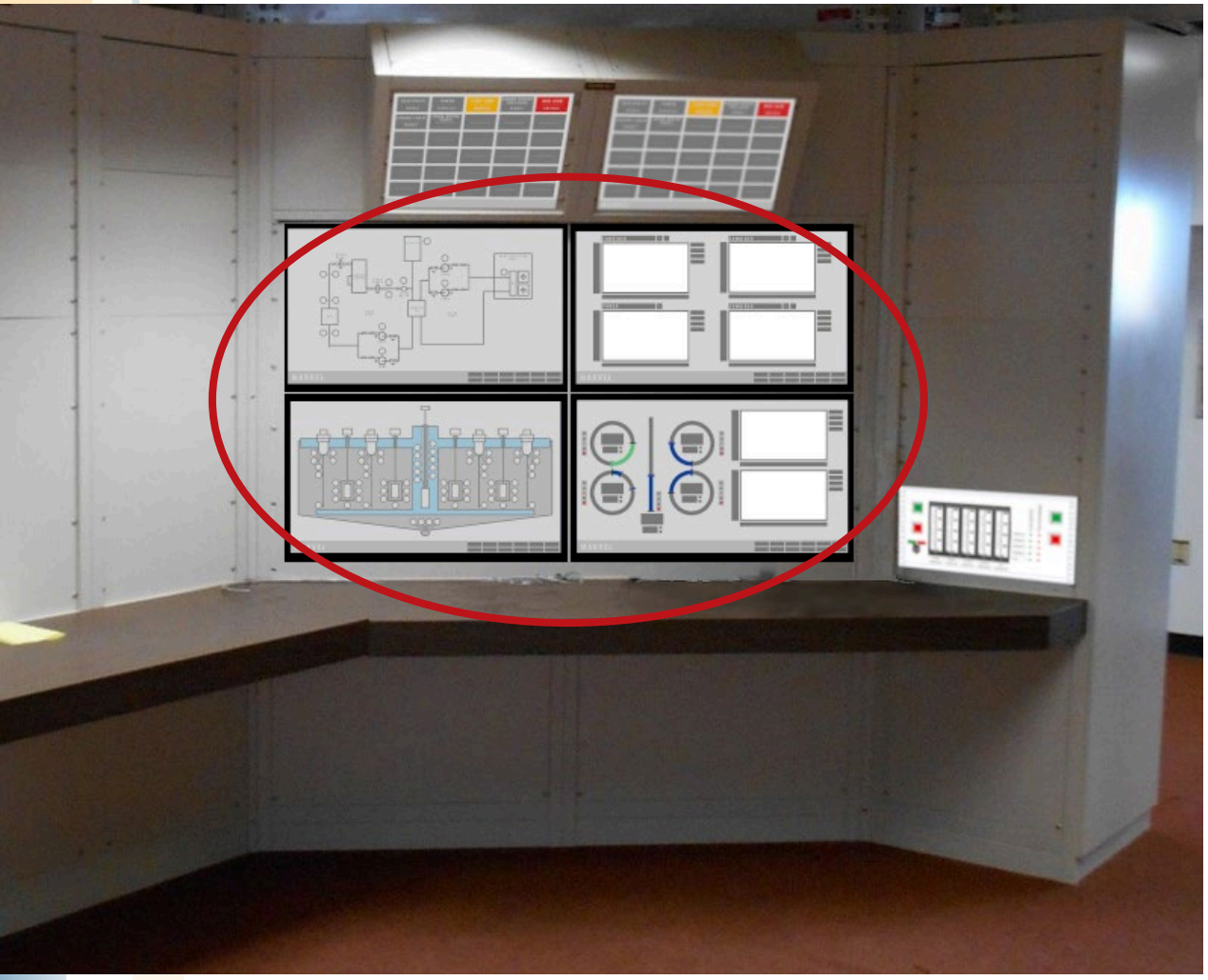
Software Operator HMI



- Display to operators
  - Power, Period, Reactivity
  - Temperatures
  - Alarm status
- Operator control
  - Drum position
  - Nuclear Instruments
  - Alarm interactions

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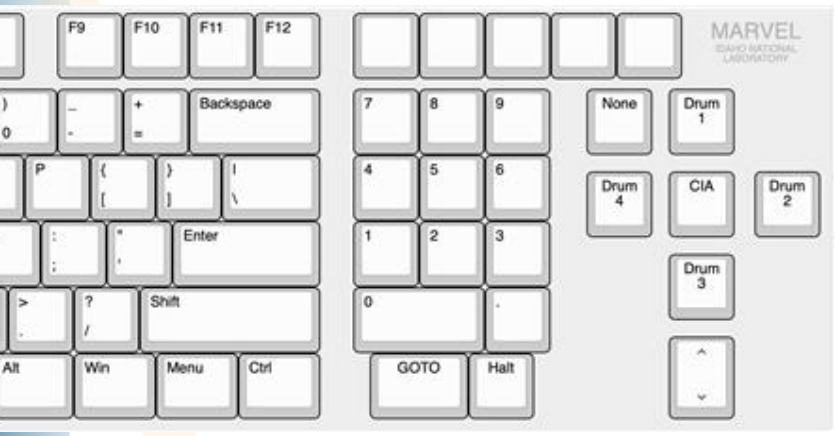
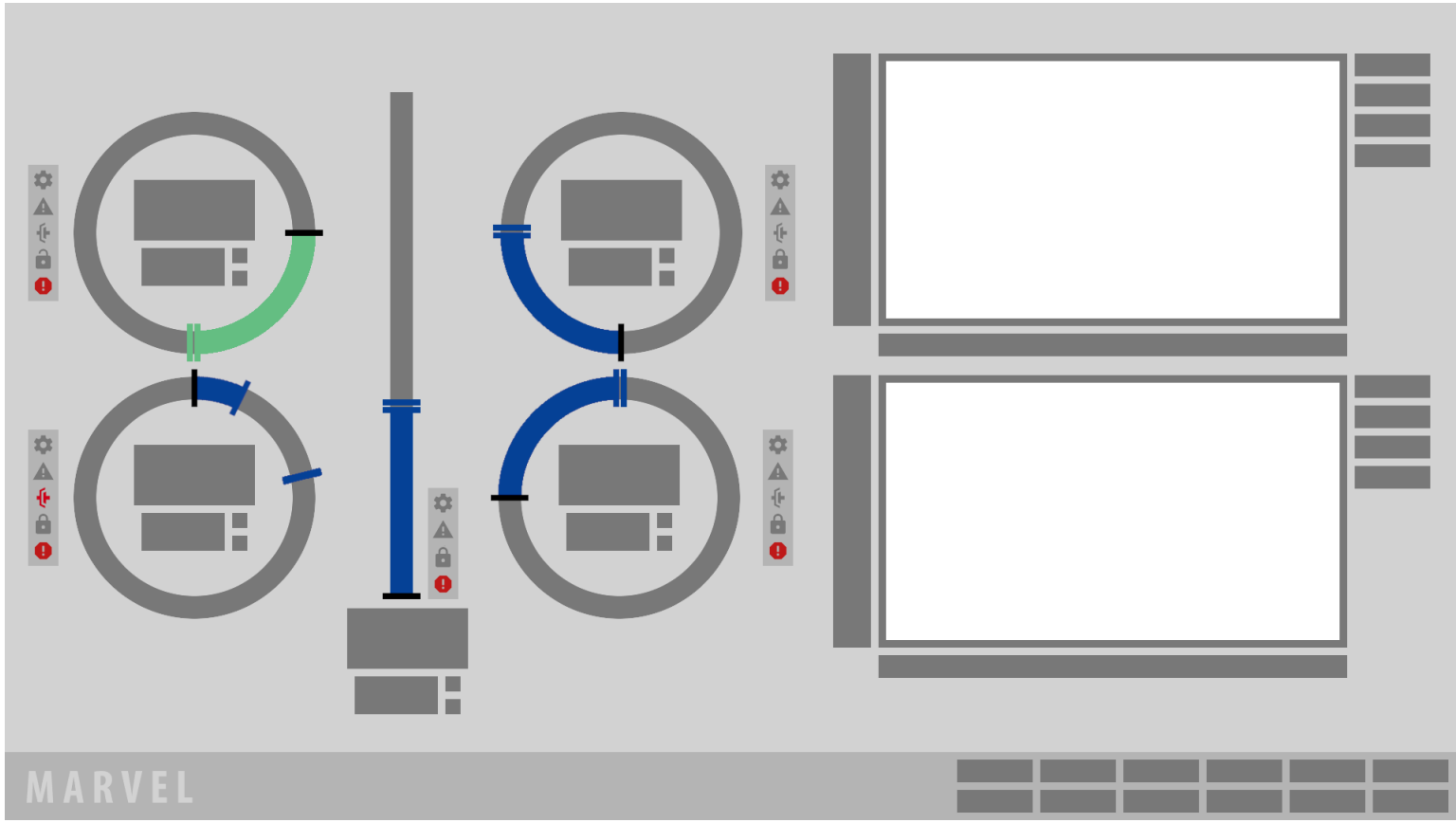
Drum controls & monitoring

- Drum control handled through software
- Custom Keyboard





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Additional for Full Power

- Sensors
  - Pressure sensors (SR)
  - Leak detectors
  - Thermocouples
- Actuators
  - Heaters
  - Ventilation
- UPS to HMI / control system

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- UPS to HMI / control system
- Heat Extraction System
  - Pumps – VFDs
  - Valves
  - Thermocouples
  - Flow meters
- Electrical Generation System
  - Control of Stirling Engines over CAN
  - Pumps
  - Valves
  - Thermocouples
  - Flow meters

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Status

- I&C hardware
  - Received components
  - Built cabinets
- I&C software
  - Main development stretch
    - Most software components exist in some way
    - Ready to test Nuclear Instrument portion
    - Testing motion with MACS for motion platform

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Mapping the scope of remote / autonomous operations

Remote monitoring

+ Remote control of non-safety systems while shut down
+ Remote control of non-safety systems while operating
+ Remote control of safety systems

- Wireless?
- Geographic distance?
- Cyber Architecture? Cloud?
  - Autonomous can become remote

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Process

Nuclear safety

- SAR, DOE approval
  - Follows nuclear safety
  - Follows DOE-STD-1271 guidance on remote & autonomous systems

Cybersecurity

- Cyber report, DOE approval
  - Follows NIST standards

These processes mirror each other

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Summary

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