MIT Research Reactor

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MITR Upgrade to Digital Nuclear Safety System

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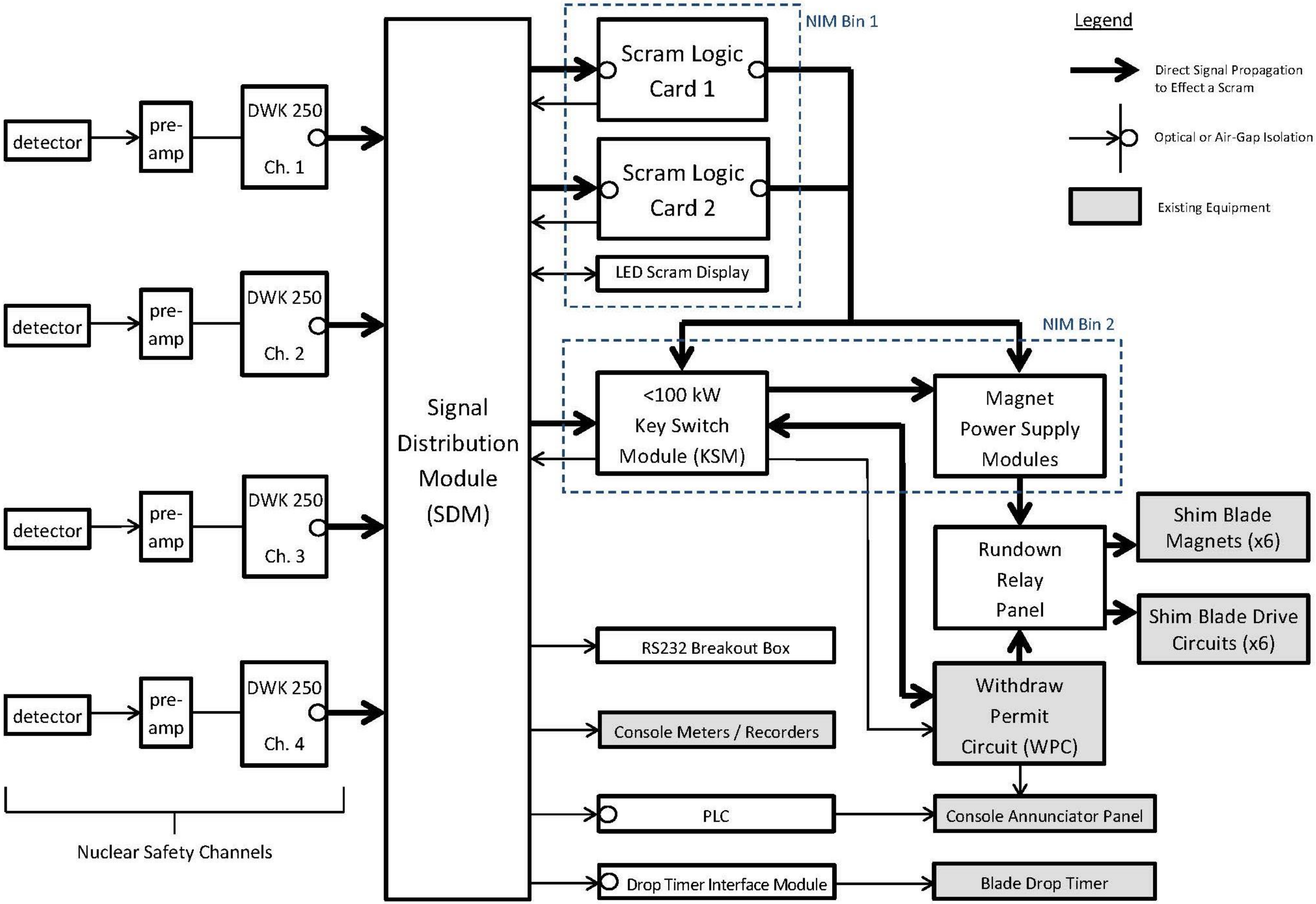
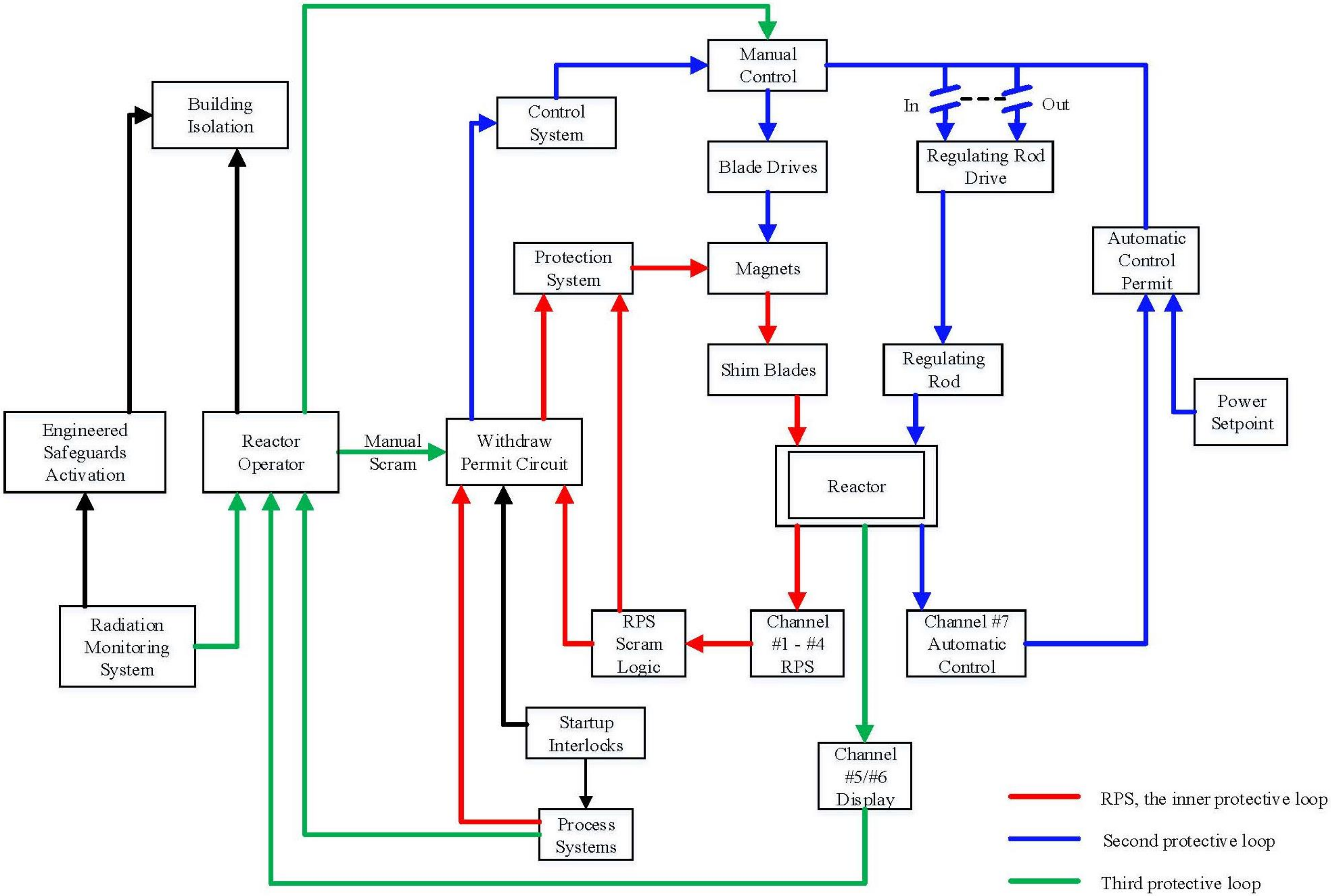
Discussion Topics

- Proposed Upgrade to Digital Nuclear Safety System
- Current Nuclear Safety System
- Common-Mode Failure Analysis – Placement of Detectors and Nuclear Safety System Components
- Scram Logic Circuitry
- LED Scram Display for Latched Trips from the Scram Logic Cards
- Cyber Vulnerability Evaluation

Proposed Upgrades for the Nuclear Safety System (NSS)



MIT Reactor I&C System with the Proposed Upgrades



Current Nuclear Safety System

- Six Channels #1 – 6
- Ch. #1 - 3 for short reactor period scram
- Ch. #4 - 6 for high reactor power scram
- Ch. #1 - 3 Keithley model 26000 meters (circa 1958) measure period
- Ch. #1 & #2 operate on fission chambers for source range or on ion chambers for power range
- Ch. #5 & #6 can switch to low-range amplifiers for <100 kW operation

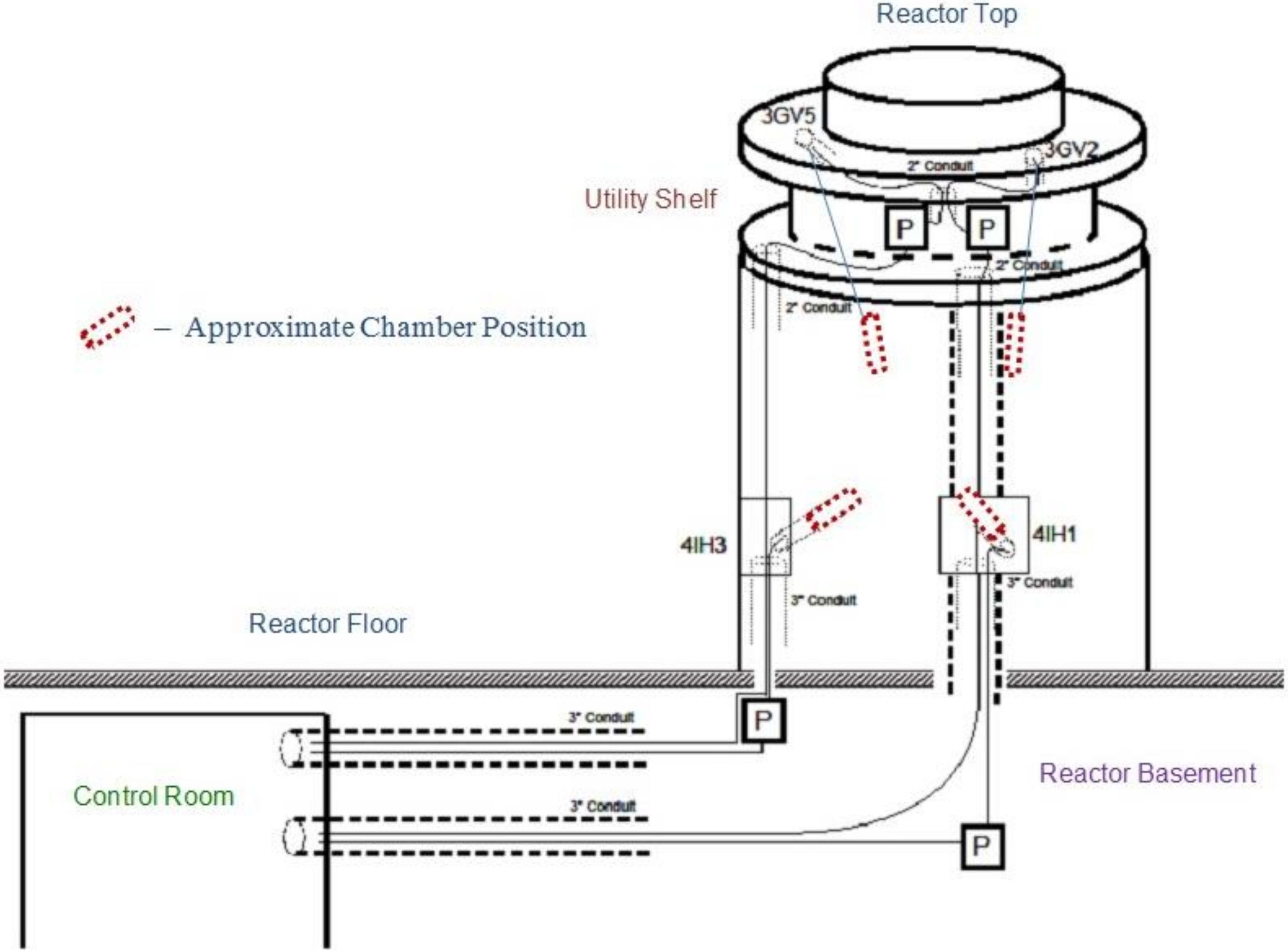
Operational Specifications for Existing Nuclear Safety System Ch. #1 - 6

- Two out of three period and flux level channels must be operable whenever the reactor is critical.
- Any channel reaching its trip point will cause a scram.
- Short period trip at 10 seconds.
- High neutron flux level trip at 6.5 MW.
(80 kW without primary flow)
- Time from initiation of scram signal to 80% control rod insertion is < 1 second.
- Channel tests quarterly, before each startup, and after repair or de-energizing.

Proposed Upgrades for the Nuclear Safety System

- Four Channels #1 – 4
- Each channel provides trip signals on short reactor period and high neutron flux level (same set points and scram time as previous)
- Wide-range operation with one fission chamber for each channel, so there will be no detector switching from source range to power range.
- Trips from two out of the four channels are required in order to generate a reactor scram
- Channel test/calibration possible with the reactor operating
- Neutron flux monitor uses microprocessors and firmware

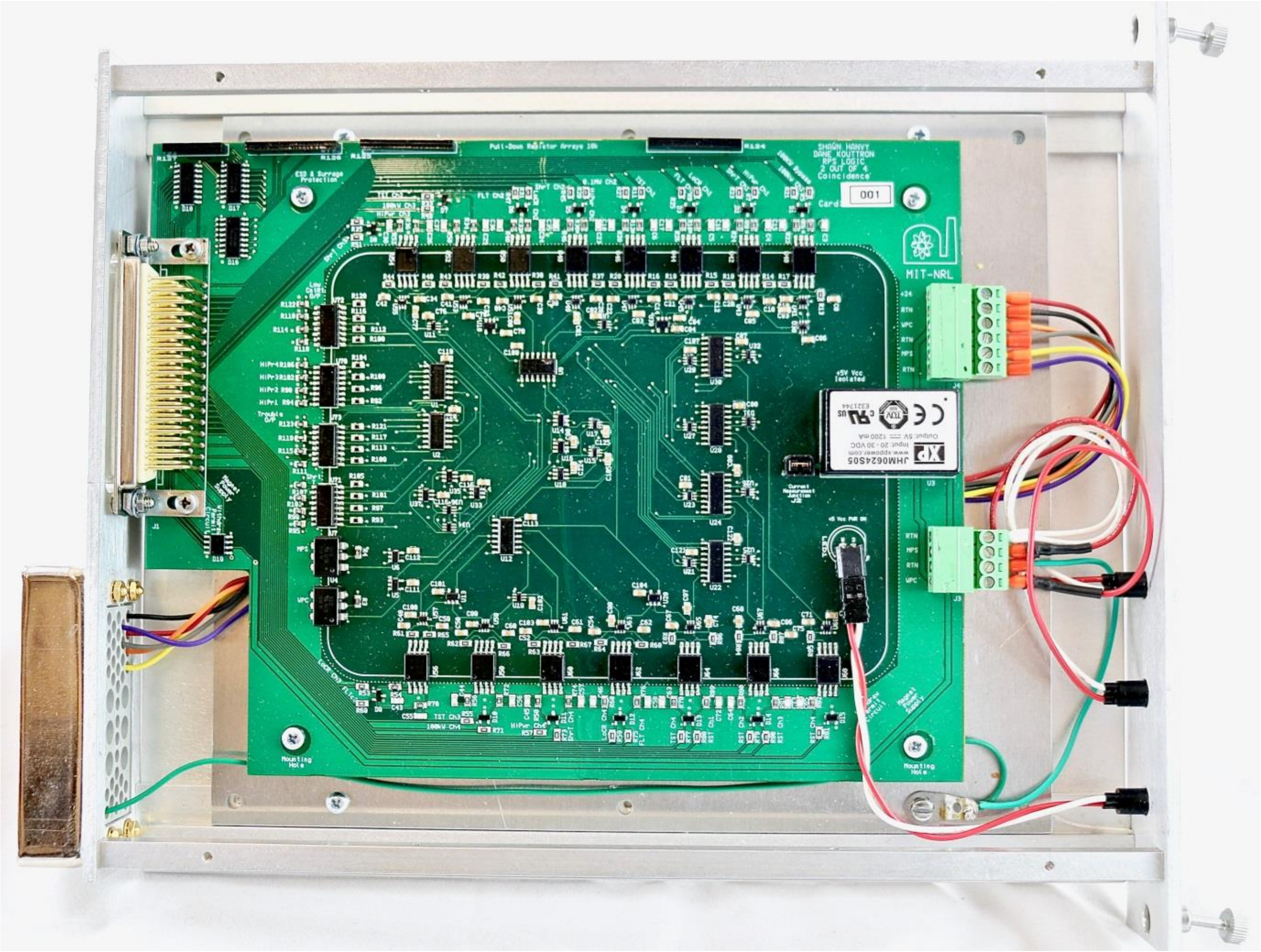
Fission Chamber Detector Placement at MITR – Cable Runs



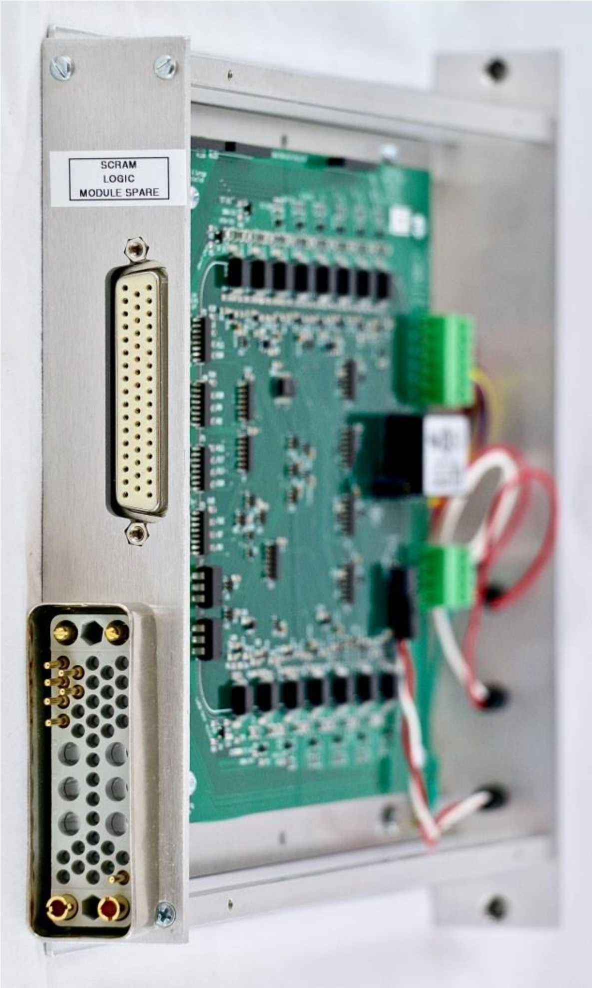
Scram Logic Circuitry

- Two-out-of-four coincidence logic is used in this design
- A single trip output from a DWK 250 will not result in an immediate reactor scram unless a second DWK 250 unit has already tripped or faulted.
- Designed in-house with all solid-state binary logic devices and electronic components – no microprocessor
- Total of 29 inputs to the each Scram Logic Card
- Two identical logic circuits – Scram Logic Card 1 and Scram Logic Card 2 – operate in parallel in NIM Bin 1, each in its own protective housing
- A scram signal from either Scram Logic Card will scram the reactor

Scram Logic Card in a Scram Logic Card Module (i)



Scram Logic Card
in a Scram Logic Card Module (ii)



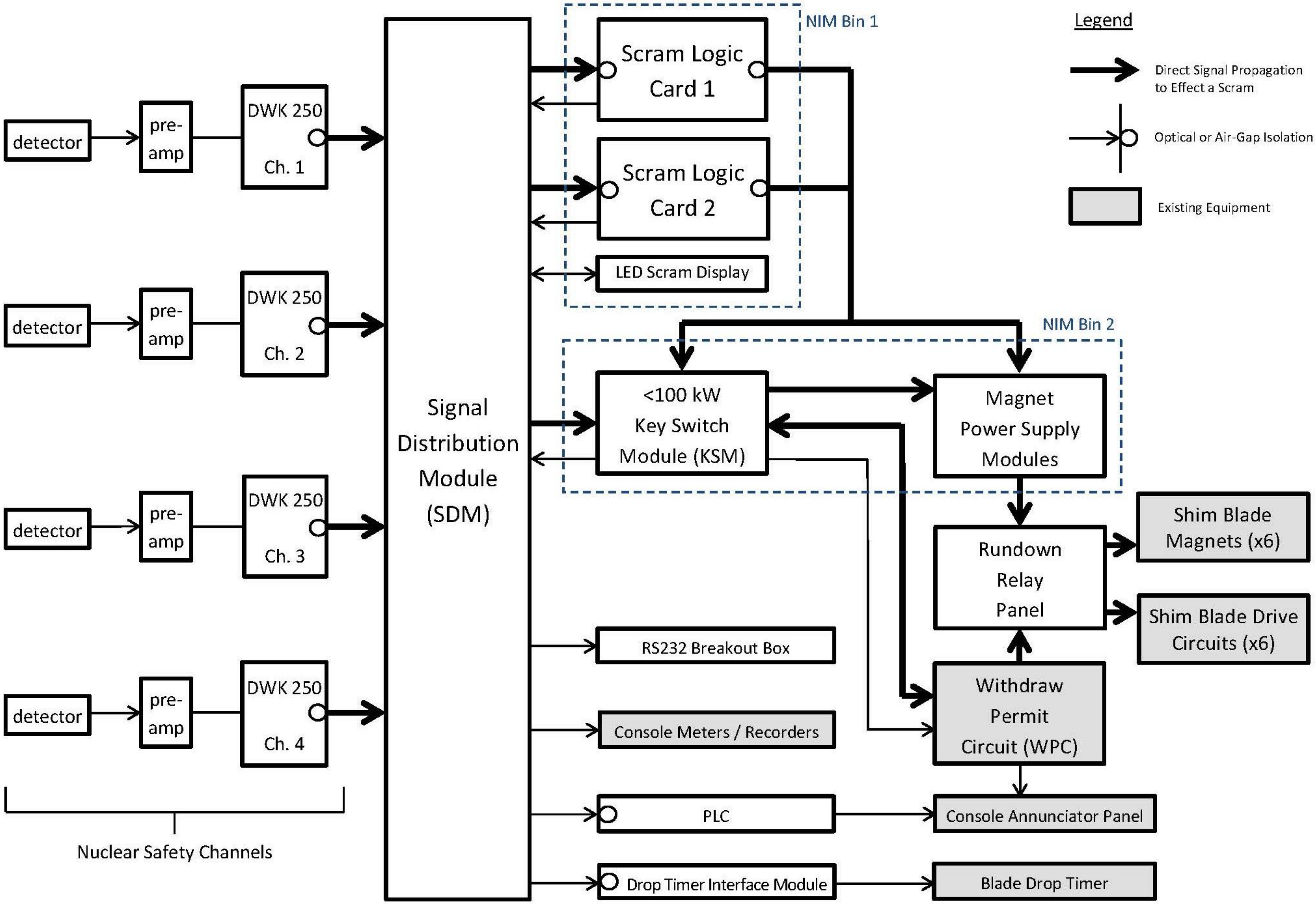
Scram Logic Card Development

- Boolean logic developed
- Logic diagram refined using field-programmable gate array (FPGA) for simulation and testing
- Logic circuit constructed using circuit-design software
- Component and wire layout created using printable circuit board (PCB) design software
- Gerber-format file sent to intermediate manufacturer for fabrication of prototypes
- Circuit board layout refined through iterative testing
- Final circuit design sent to U.S. manufacturer Advanced Circuits

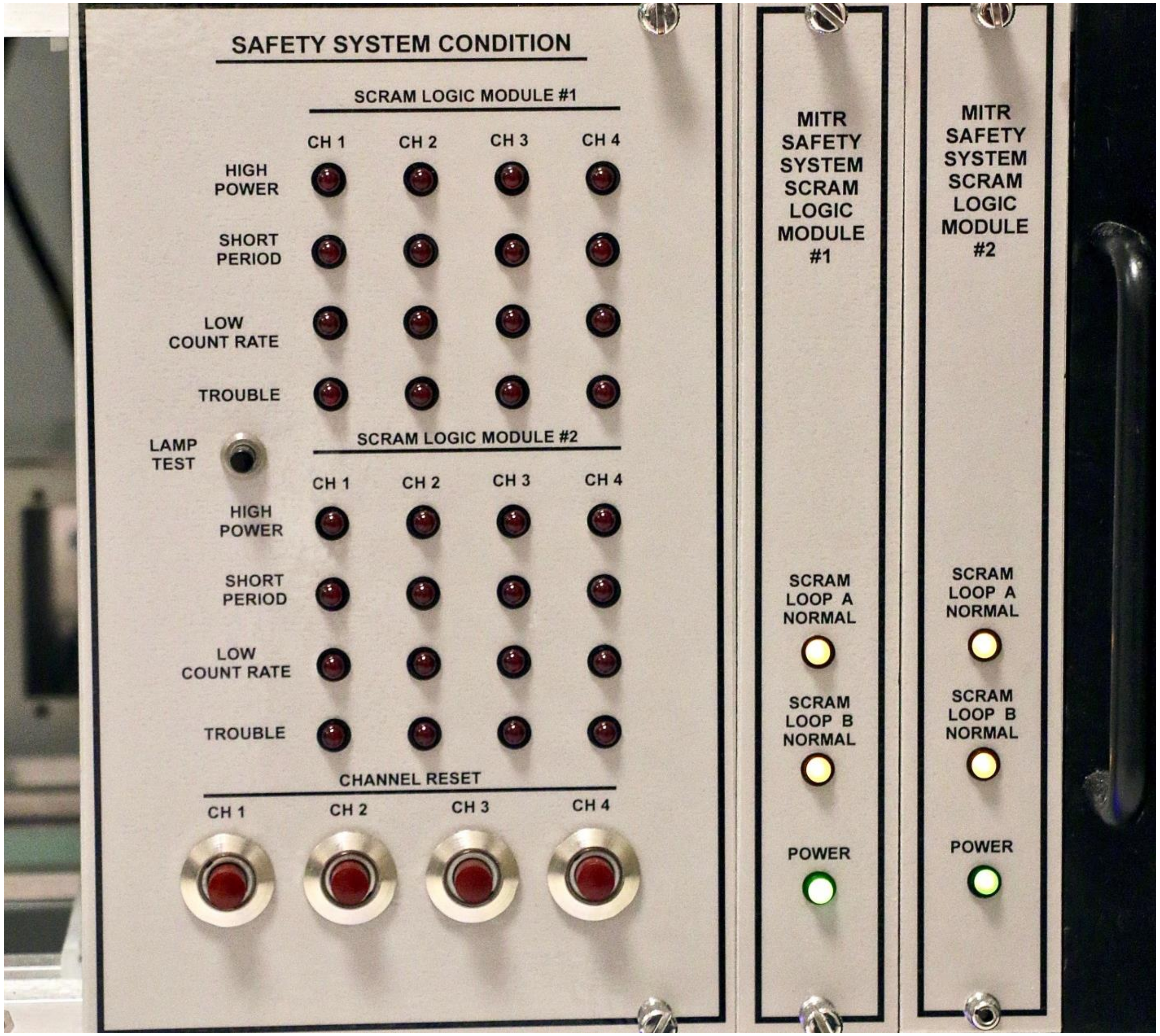
Scram Logic Card Features

- Asynchronous sequential binary logic – no clock
- No microprocessor, no software or firmware
- Low power operation (24 V_{DC} for input/output and alarm latching, 5 V_{DC} for all logic operation)
- Optical isolation and coupling at all signal inputs and outputs, assuring one-way signal flow
- Fast operation – measured signal transition time is 38 microseconds.
- All key logic components meet automotive standards
- The Nuclear Safety System is energized when operating; a scram "signal" is when any part of the NSS circuit becomes de-energized, interrupting current to the shim blade electromagnets

Proposed Upgrades for the Nuclear Safety System



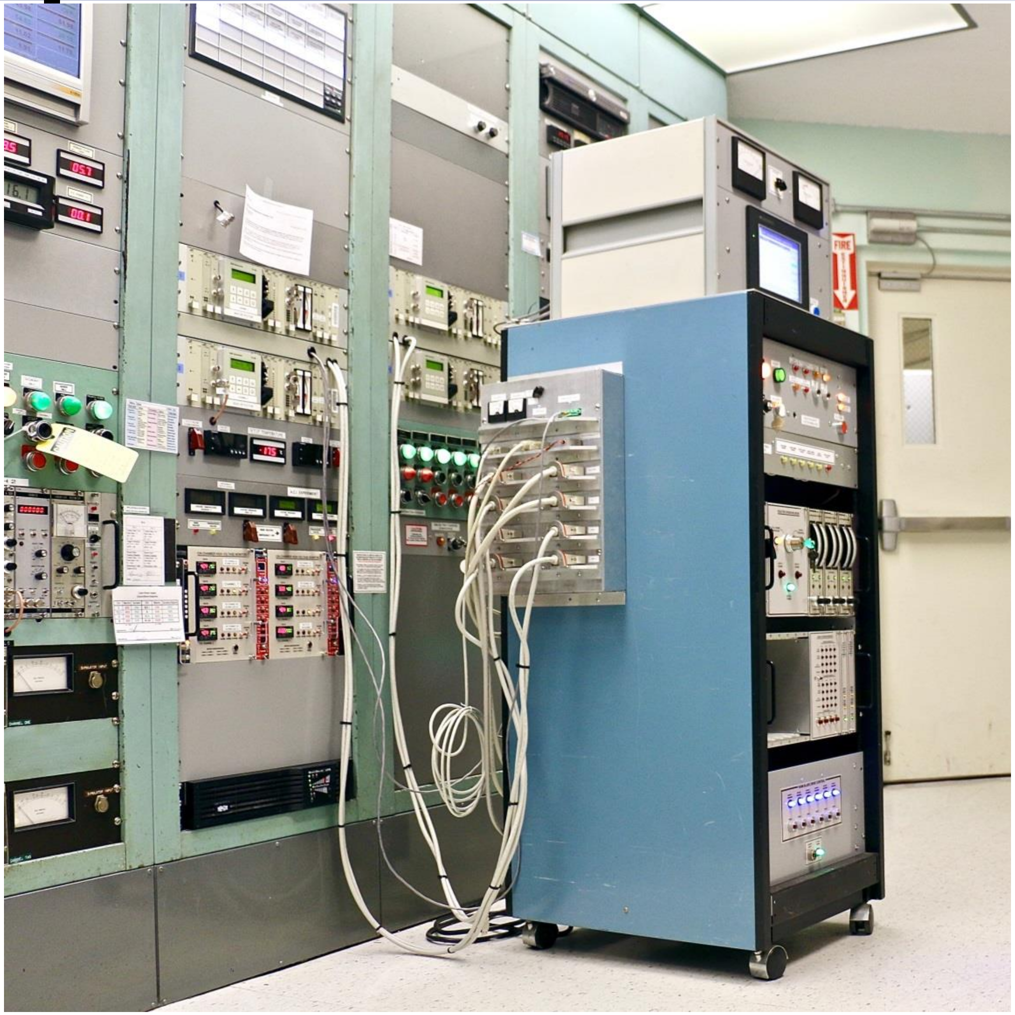
LED Scram Display for Latched Trips from the Scram Logic Cards

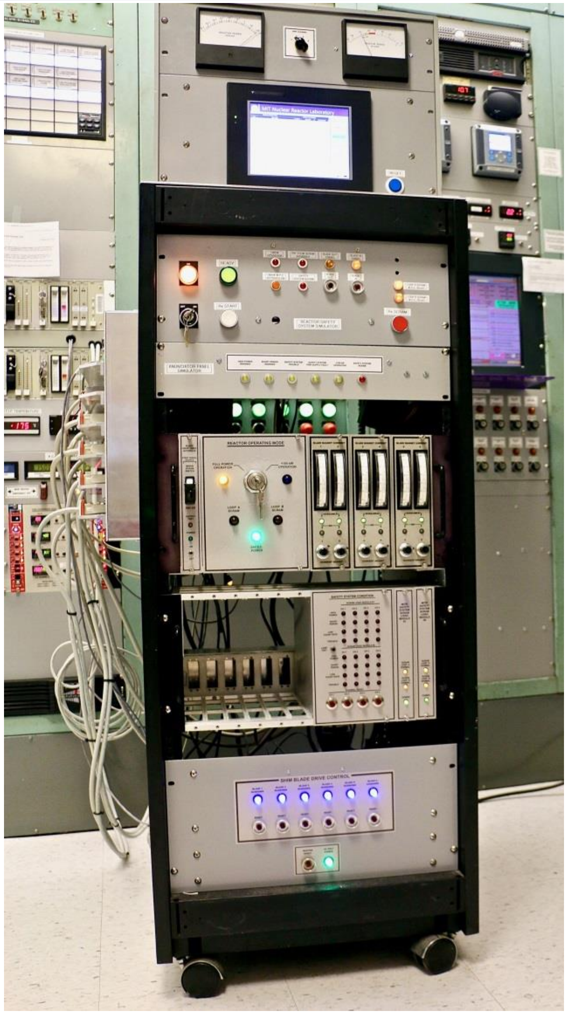


Cyber Vulnerability Evaluation

- Firmware on the three microprocessors for each DWK 250 cannot be altered
- Adjustable parameters (alarm set points, discriminator threshold, etc.) can be changed on the DWK 250 from the front keypad only when a key switch is enabled; key is safeguarded
- Final position of DWK 250s will be in the control room, which is continuously monitored or safeguarded
- The NSS is not connected to any network
- Wherever possible, optical isolation is used to provide air-gap protection to safety-related components

Parallel Test Rack in Control Room





Concluding Material

- Questions & Answers