MIT Research Reactor

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Status Update on MITR Nuclear Safety System Upgrade

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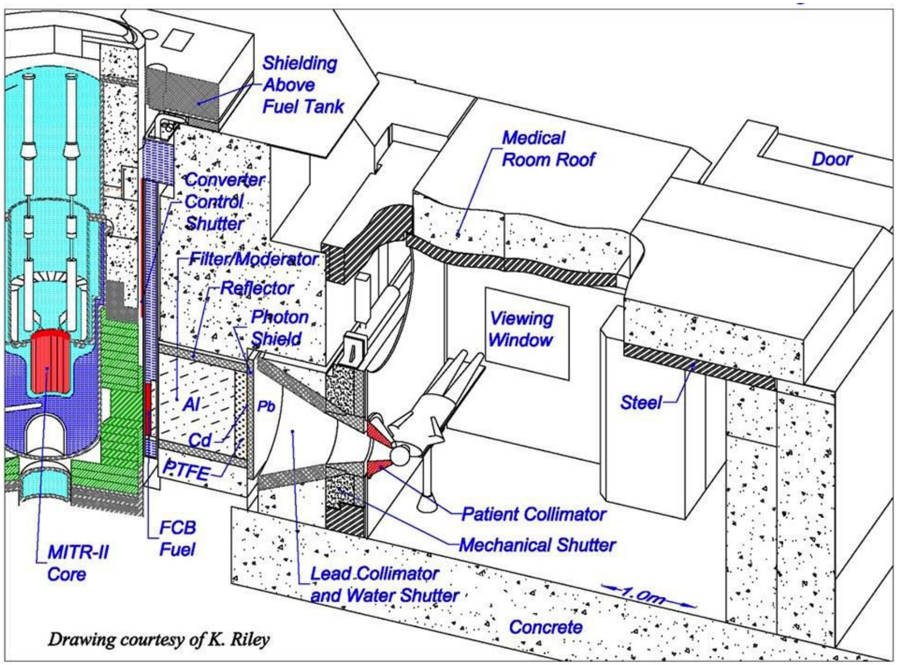
Discussion Topics

- Introduction to the MIT Research Reactor
- Current Status of Reactor Nuclear Instrumentation & Control
- Upgrade to Digital Nuclear Instrumentation
- MITR Experience in the Upgrade
- Logic Circuit Design
- Summary of Regulatory Interface

MIT Research Reactor (i)

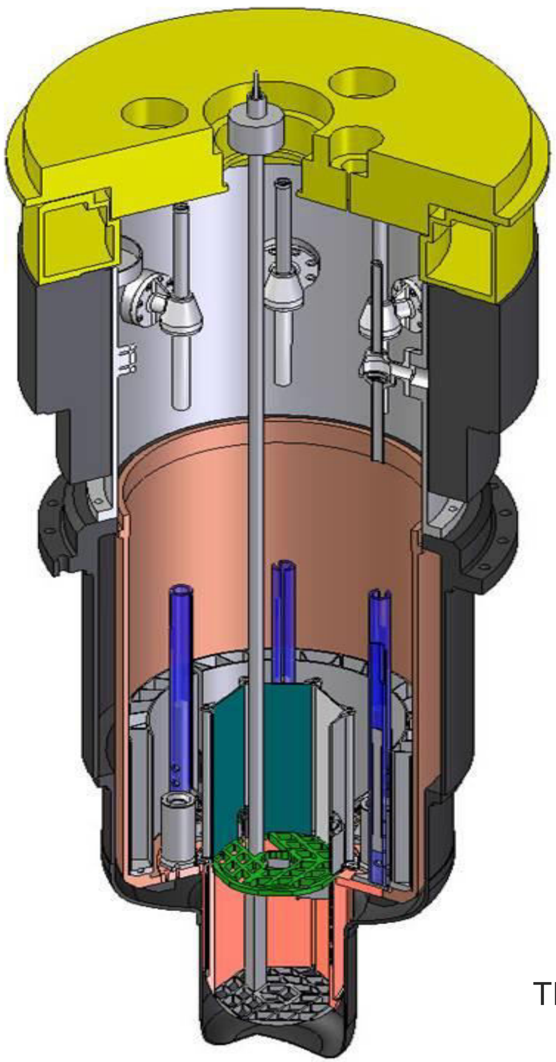
- Constructed in 1958
- Upgraded in 1975
- Capable of operating 24/7 at up to 6 MW thermal power
- Tank-type, light water to cool and moderate
- Two-loop cooling system, modern cooling tower
- Uses heavy water D_2O for neutron reflection
- Graphite outer reflector

MIT Research Reactor (ii)



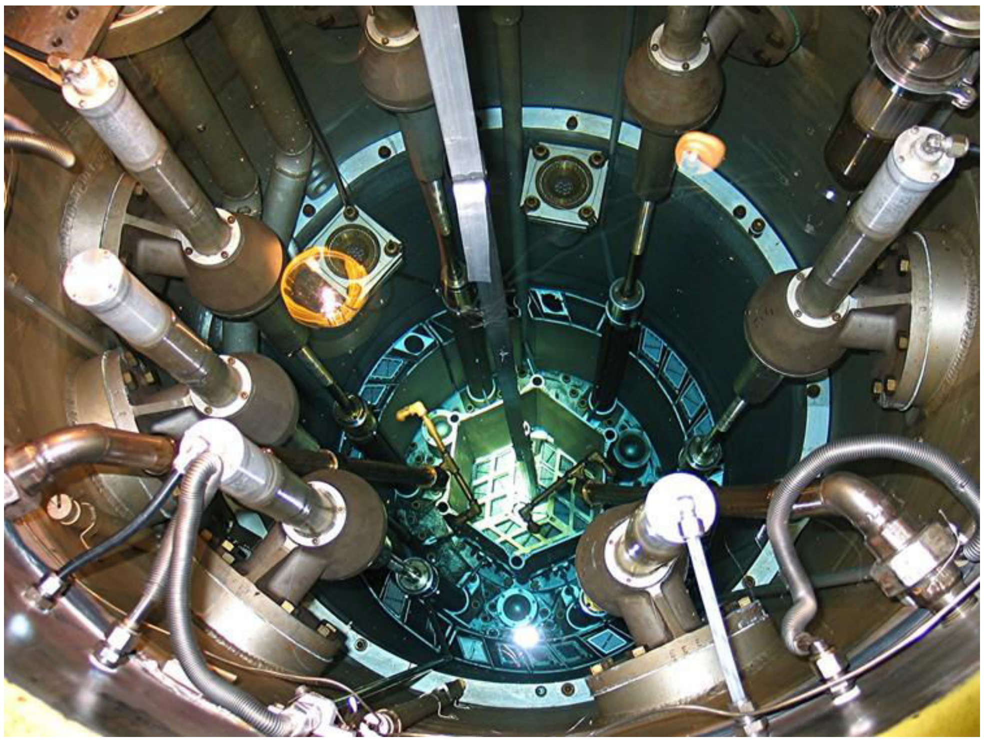
- U-235 fuel
- Primary loop circulates at ~2000 gpm
- Secondary loop circulates at ~1800 gpm
- Six shim blades and one regulating rod
- Safety channels: three on power level, three on reactor period
- Three more channels, displaying megawatts

MIT Reactor In-Core Experiment Capability



- Capable of performing up to three in-core experiments simultaneously for the highest neutron fluxes
- In-core thermal neutron flux is $3x10^{13}$ #/cm^2-s, and fast flux is $1x10^{14}$ #/cm^2-s; similar to full-size commercial light-water power reactors
- U.S. NRC authorized in-core fuel irradiations of up to 100 grams of fissile material
- Advanced materials and fuel research

MIT Reactor Experiment Capability

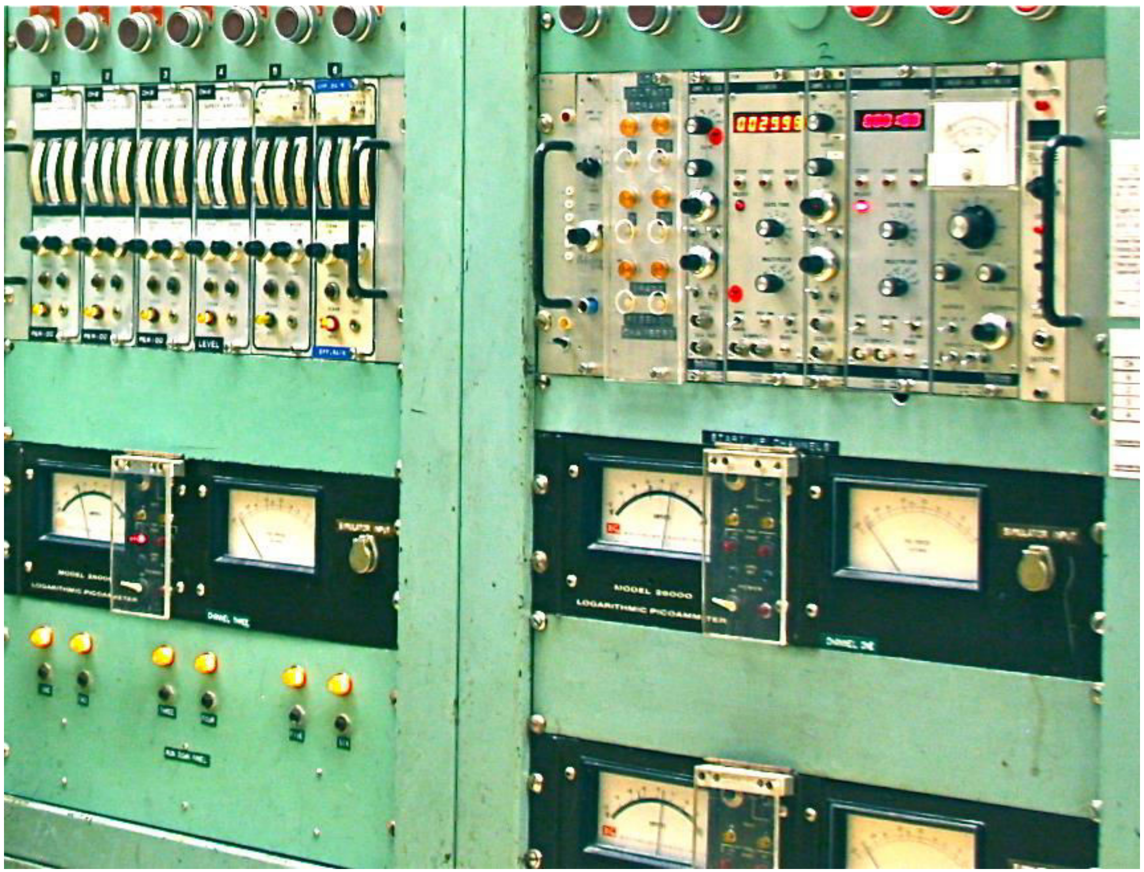


- In-Core Sample Irradiation Facility (ICSA) provides fast neutron flux of up to $1x10^{14}$ #/cm^2-s
- Other facilities provide thermal flux up to $5x10^{13}$ #/cm^2-s for NAA and isotope activation

Reactor Operator Training

Primary Heat Exchanger & Major Coolant Piping – New in 2010

Analog Nuclear Instrumentation Channels – since 1975

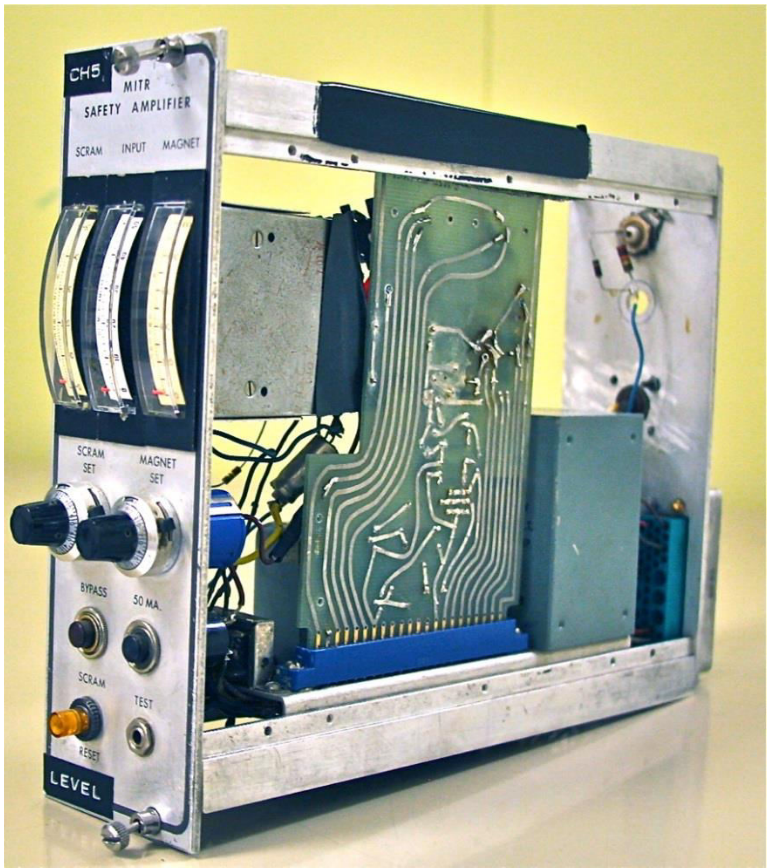


- Channels #1 through #6
- Ch. #1 - 3 for short reactor period scram
- Ch. #4 - 6 for high reactor power scram
- Ch. #1 - 3 Keithley model 26000 meters (circa 1958) measure period
- Ch. #1 & #2 operate on fission chambers for source range or on ion chambers for power range
- Ch. #5 & #6 can switch to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

Analog Nuclear Instrumentation Channels – since 1975

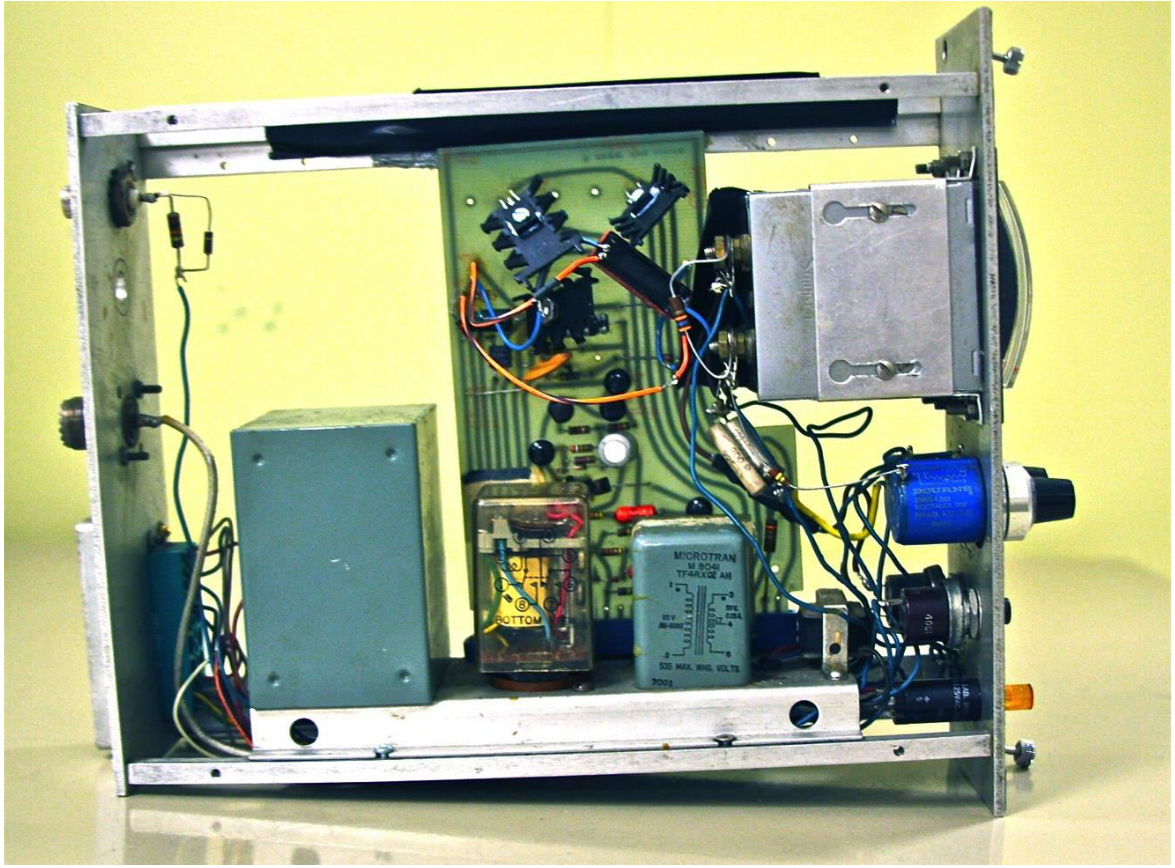
- Custom built by MIT-NRL
- Analog components subject to aging
- No more spare parts
- Do not over-maintain!
- 120-volt operation
- Set-points drift, particularly with ambient temperature and component heat-up over time
- Channel calibrations and scram checks only with the reactor shut down

Analog Nuclear Instrumentation Channels – since 1975



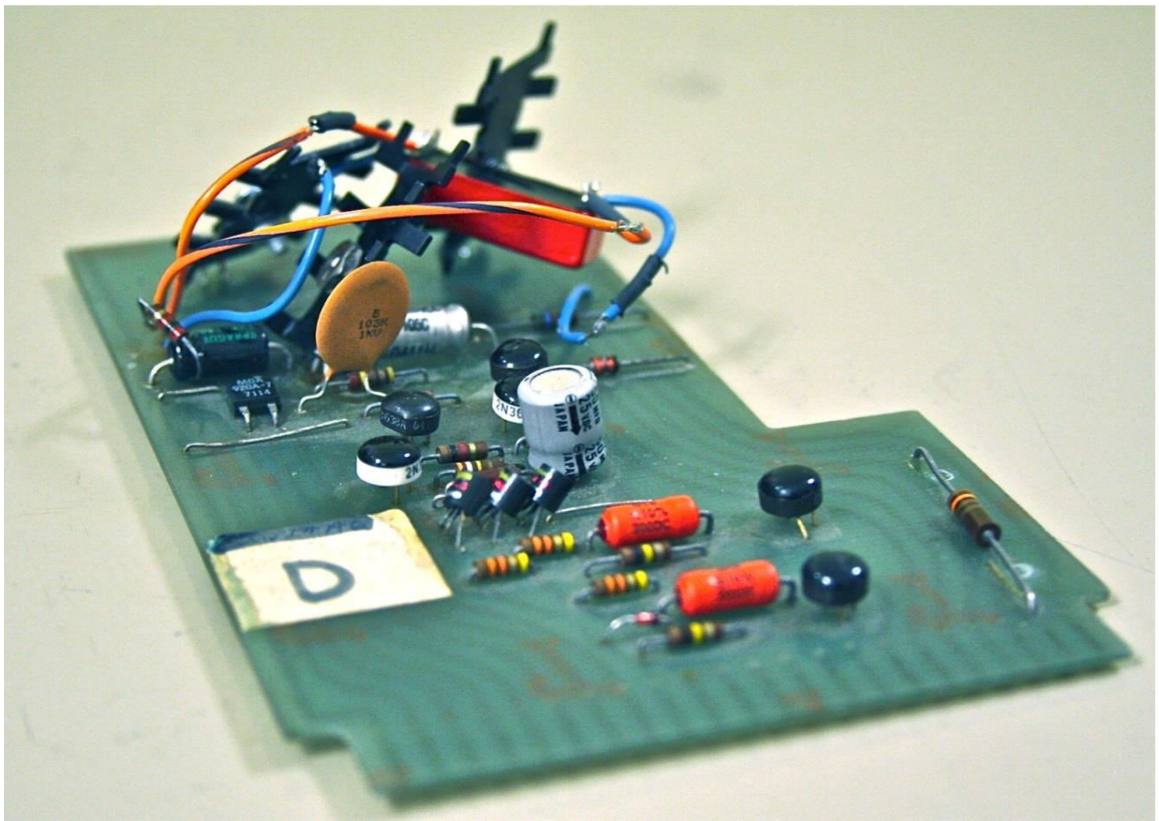
- Fully analog safety amplifier for each channel
- Curved meter faces
- Non-adjustable zeroes
- Scram test signal doesn't follow the path of the input signal from the detector
- Meter response imperceptible for the high-range amplifiers at low power
- Potentiometers are subject to dirt and wear
- No indication whether the detector is unplugged

Analog Nuclear Instrumentation Channels – since 1975



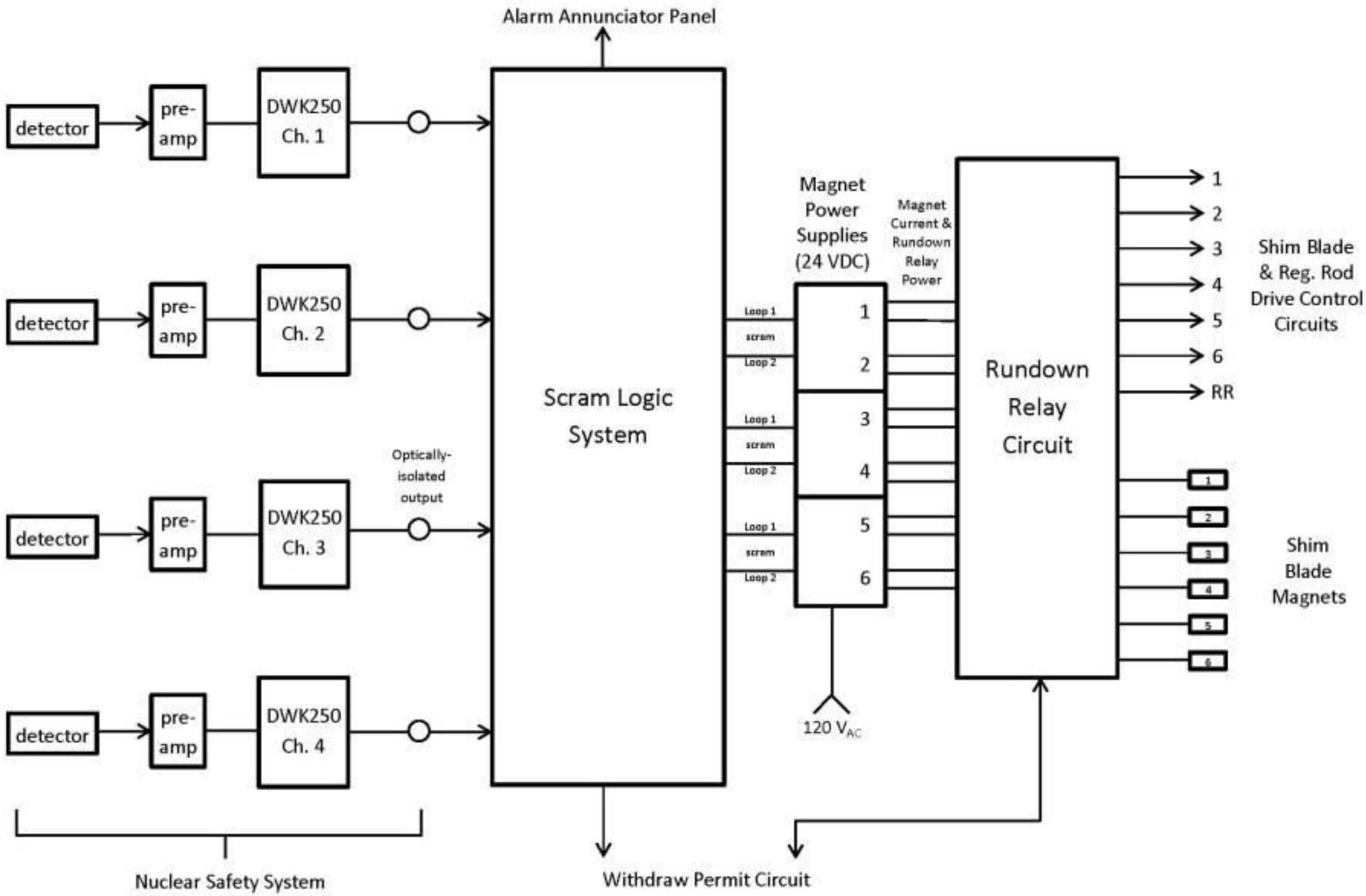
- Ch. #5 & #6 amplifier NIM bins (rear pin receptors) began to fail frequently from repeated connection and disconnection
- Ch. #5 & #6 require circuit board switching between low–range amplifier and full power amplifier; this accelerated failure of the circuit board
- Circuit connection strips on installation-edge of board physically wearing out
- Circuit paths fading

Analog Nuclear Instrumentation Channels – since 1975



- Circuit board layout is different for every amplifier, to compensate for different detector characteristics
- Components and wiring susceptible to noise interference, resulting in frequent spurious trips
- Solder joint corrosion
- Large heat sinks are a must for heat-producing transistors; active local fan cooling was also required, which added vibration

Upgrade to MITR Protection System



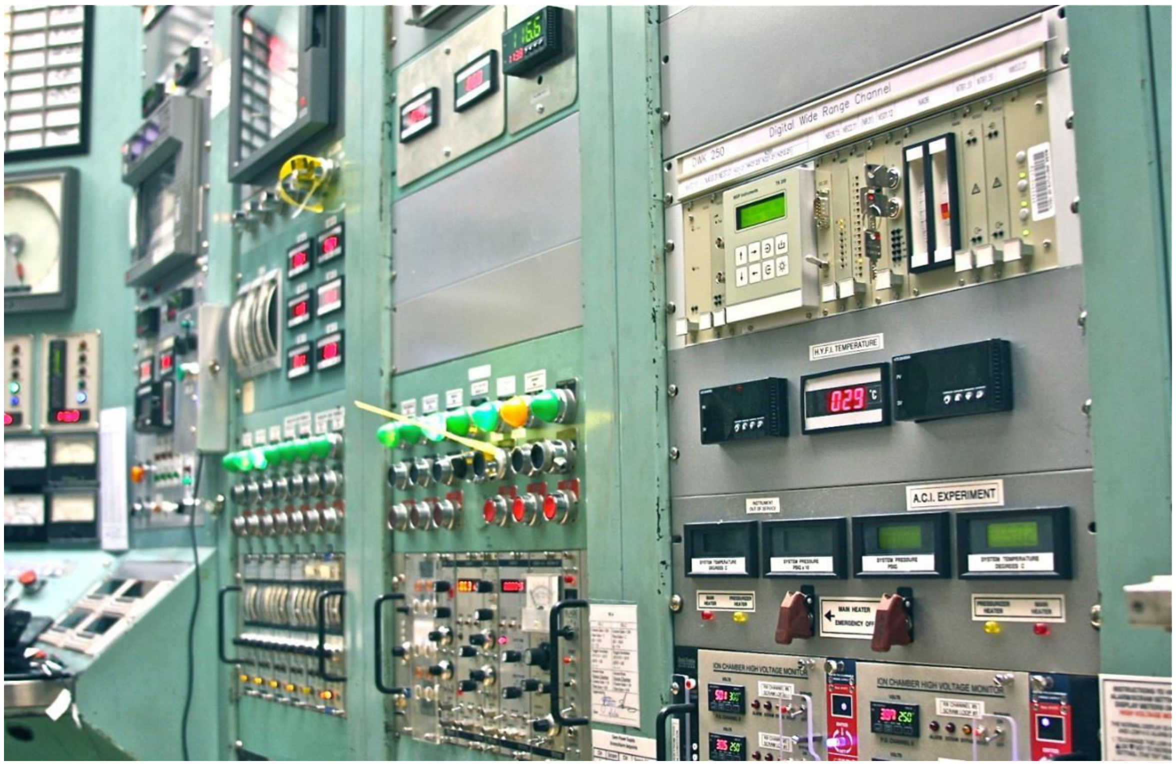
One of Four New
Mirion DWK250 Channels for MITR

- Each channel provides short reactor period scram & high reactor power scram
- Each channel utilizes one fission chamber for wide-range power operation
- Reactor power and period calibration and scram checks can be done with the reactor operating
- Test signal travels along the detector signal path starting from the fission chamber pre-amplifier

One of Four New Mirion DWK250 Channels for MITR

- Each DWK250 monitor incorporates three different microprocessor modules for signal processing
- Each microprocessor executes its function as set by the firmware permanently programmed into its non-volatile memory EPROMs.
- Execution of firmware is confirmed by continual checksum comparison
- Microprocessors and firmware have field-proven reliable for >25 years in European nuclear industry

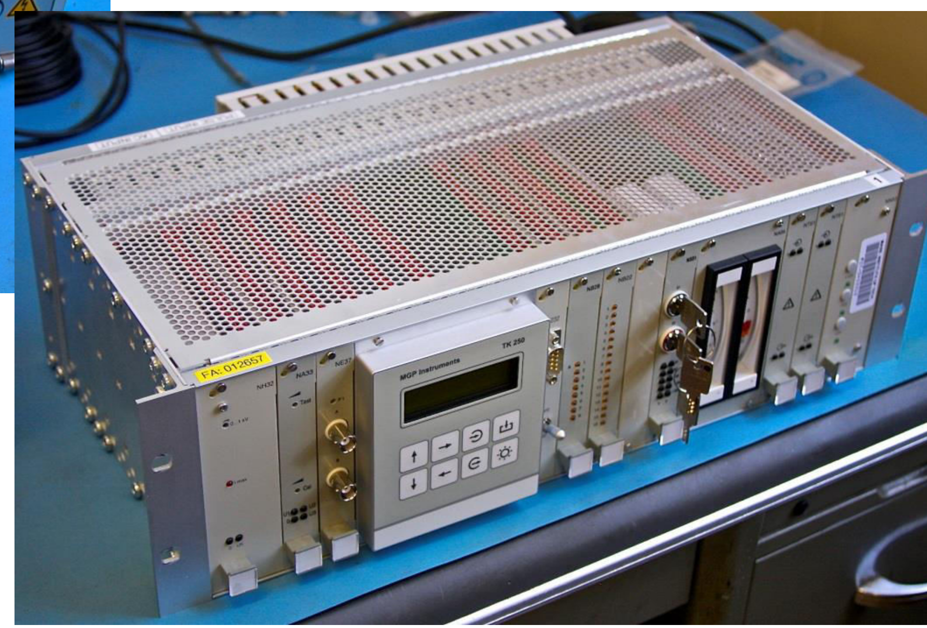
One of Four New Mirion DWK250 Channels for MITR



- The microprocessors handle pulse signals and also perform “Campbelling”, allowing wide-range indication
- Trip set-points do not drift
- Detector voltage and internal operating voltages monitored for compliance with adjustable tolerances
- Continuous Op-code handshaking between the DWK’s microprocessors as an active check of functionality

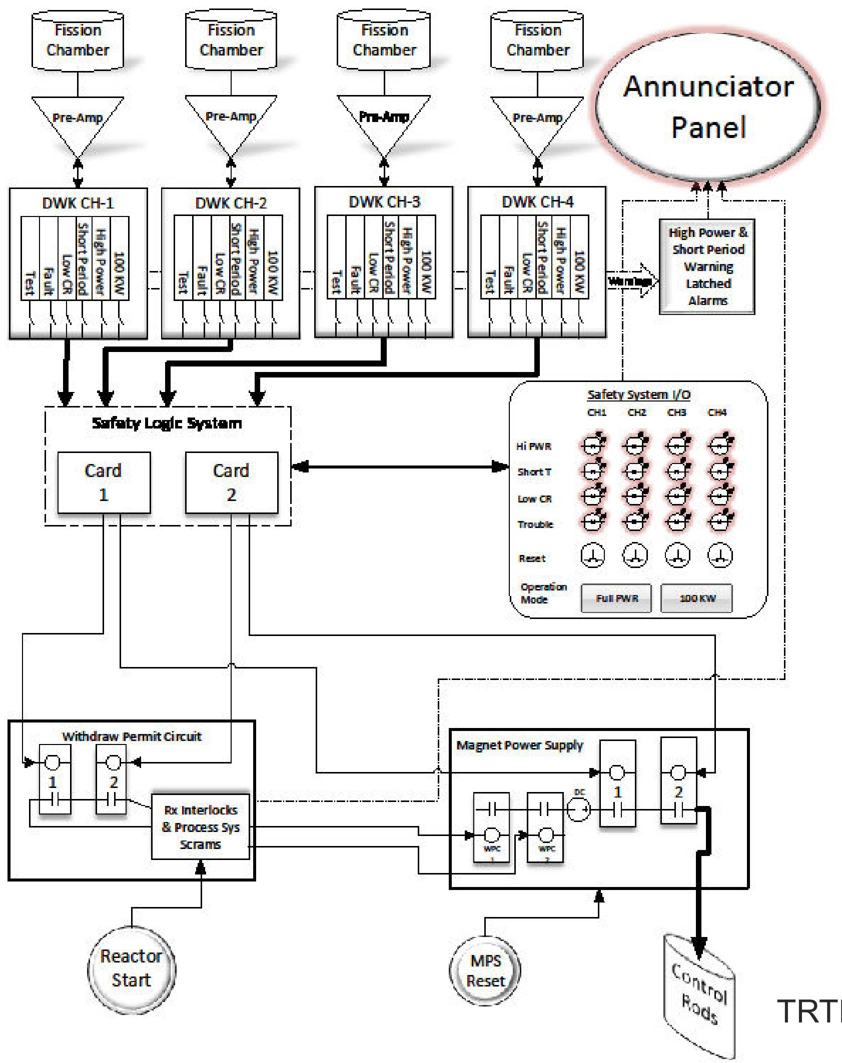
One of Four New Mirion DWK250 Channels for MITR

- Eight binary (relay) outputs – DWK uses two for internal fault indication; MITR uses two for scram circuit



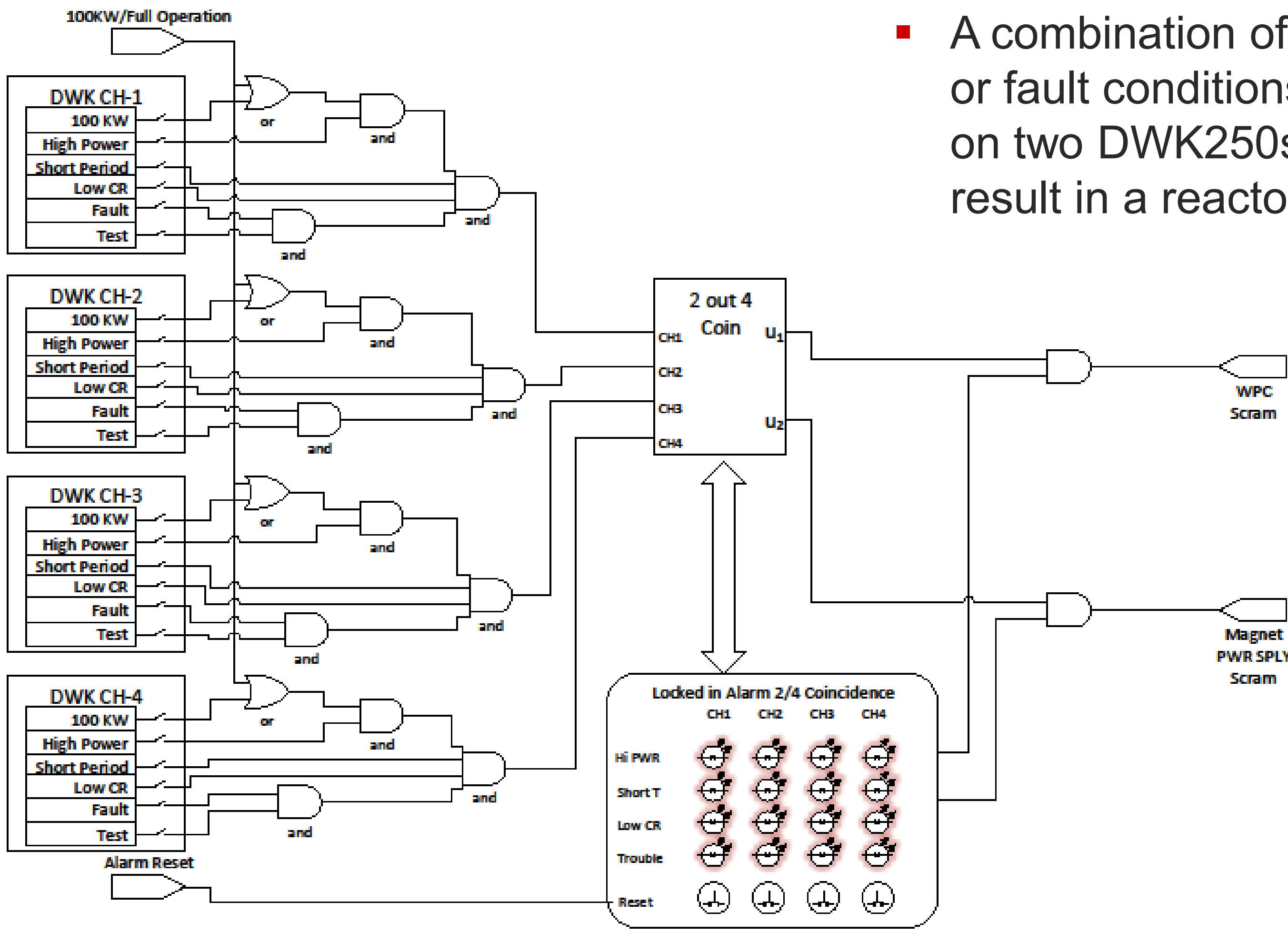
- Two analog outputs
- One digital output
- MITR will use for display and recording

MITR Protection System Logic Circuit



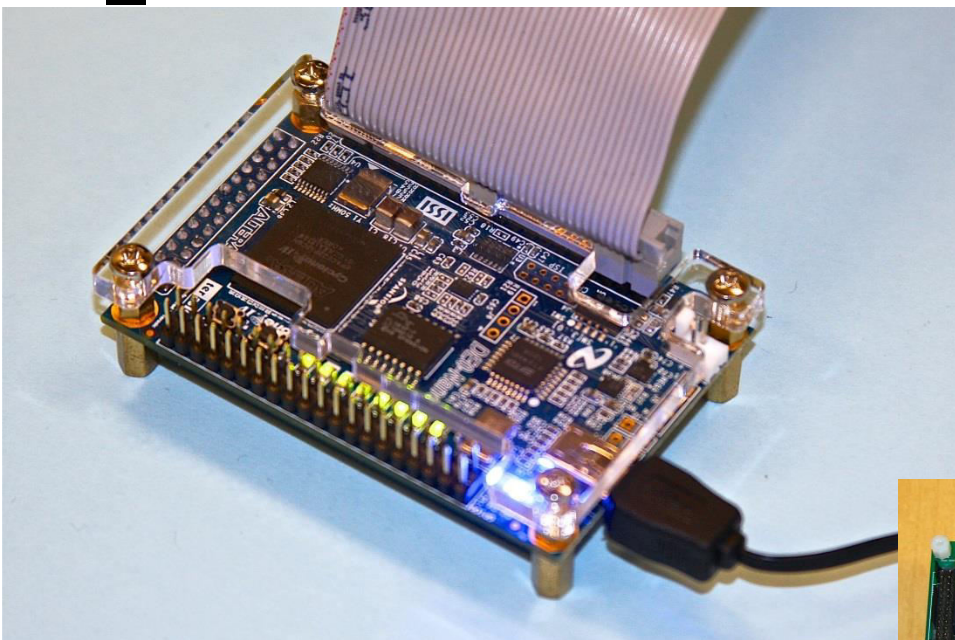
- Two-out-of-four coincidence logic used in this design
- Scram outputs from the DWK250 do not result in an immediate reactor scram
- Logic circuit is in Card 1 and Card 2
- Coincidence logic is applied in the cards to produce a reactor scram
- Card 1 and Card 2 are identical

Logic Circuit – detail



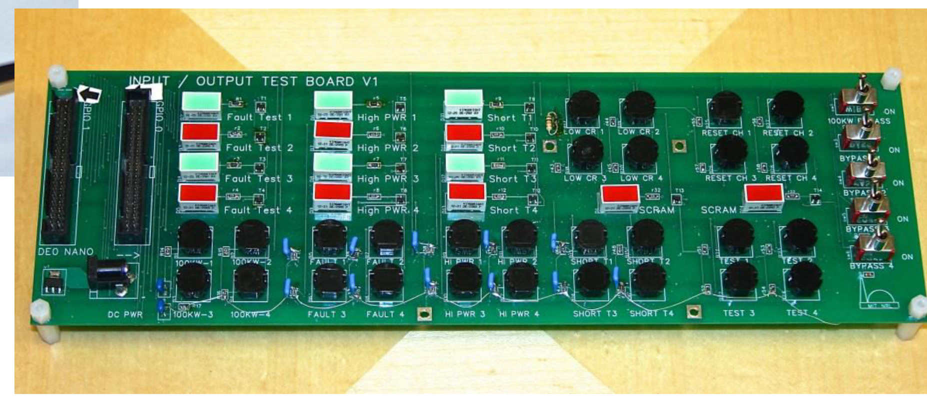
- A combination of trips or fault conditions on two DWK250s will result in a reactor scram

Logic Circuit – development

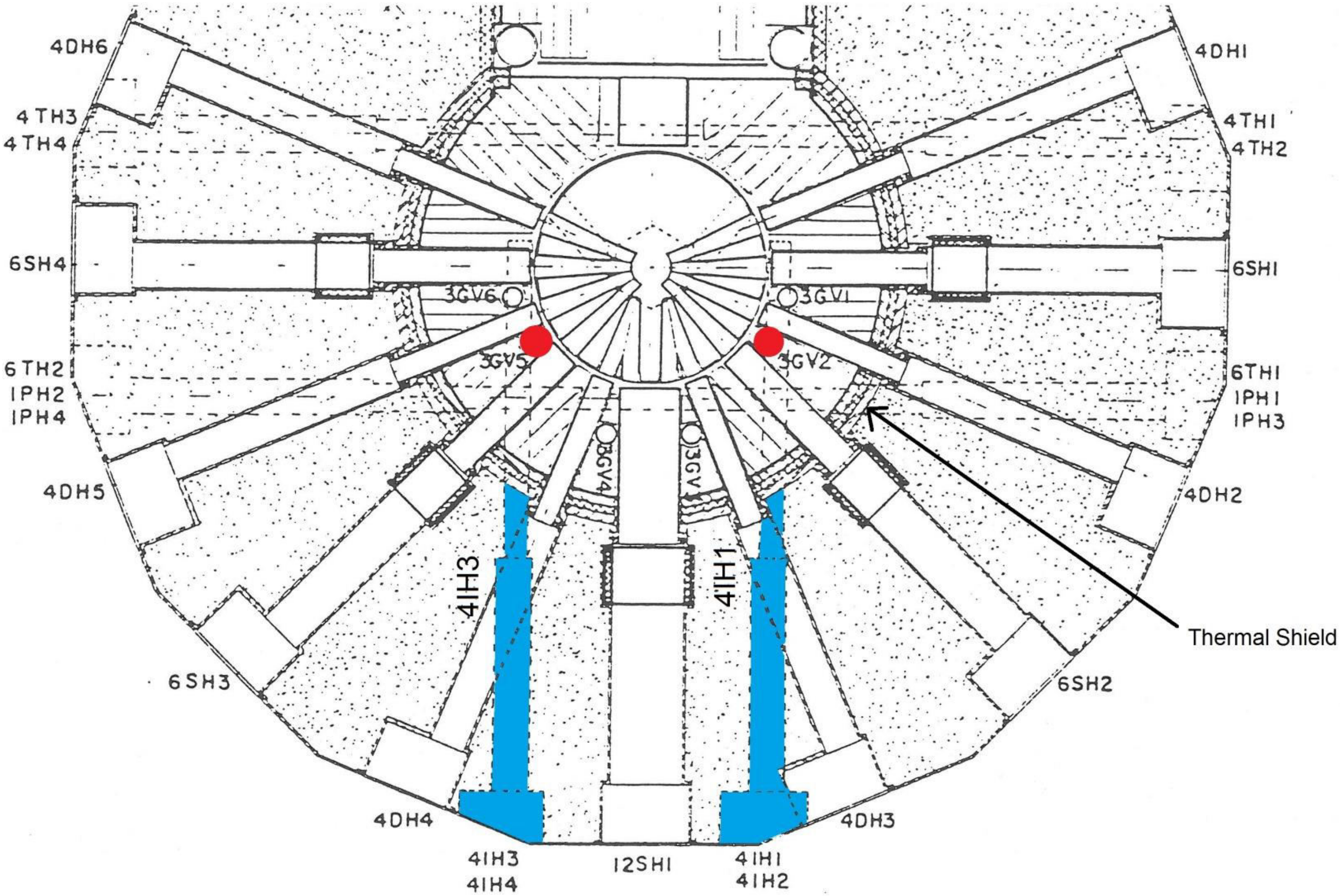


- Boolean logic diagram for two-out-of-four coincidence
- Verified by computer-based logic gate simulator
- FPGA device for logic test

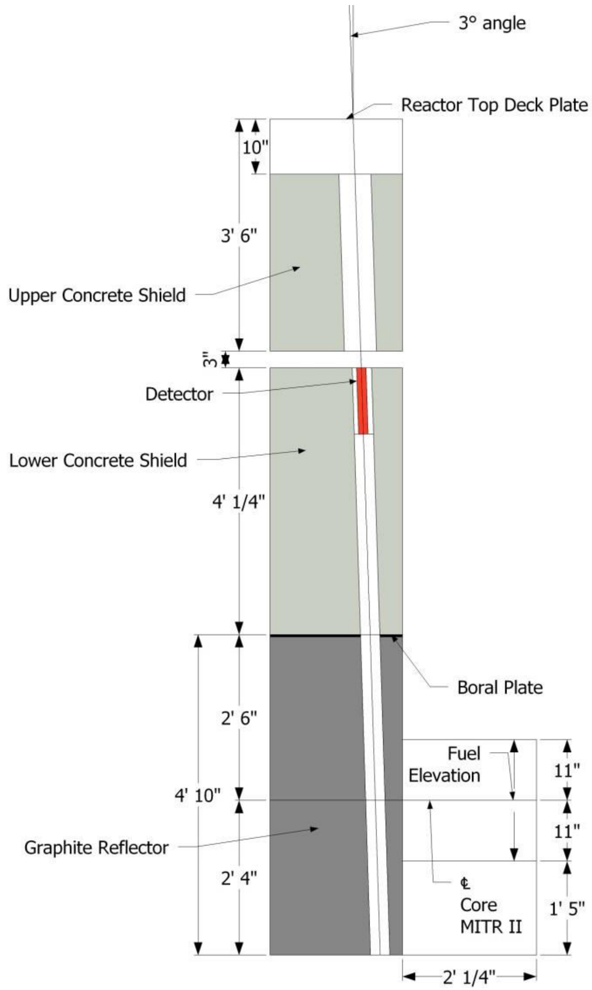
- 29 inputs to logic circuits
- Testing board created
- Generation of CAD layout for prototype printed circuit board



Fission Chamber Detector Placement at MITR

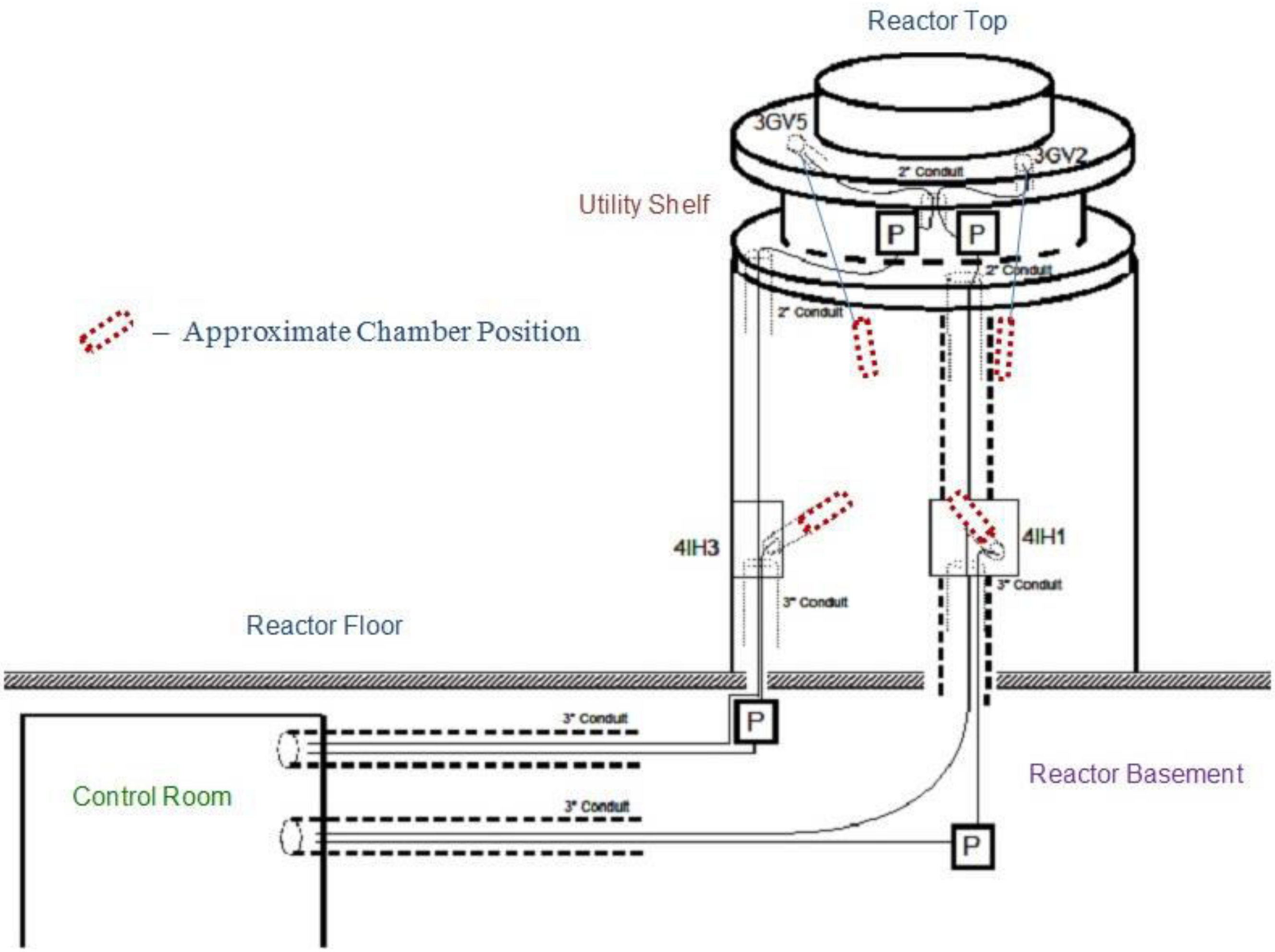


Fission Chamber Detector Placement at MITR – 3GV Ports



- In a 4IH port, the detector is about 4 feet outside the core, and about 20” below it
- In a 3GV port, the detector is about 5 feet above the center line of the core

Fission Chamber Detector Placement at MITR – Cable Runs



Concluding Material

- Questions & Answers

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