Penn State Control System Upgrade

TRTR 2017

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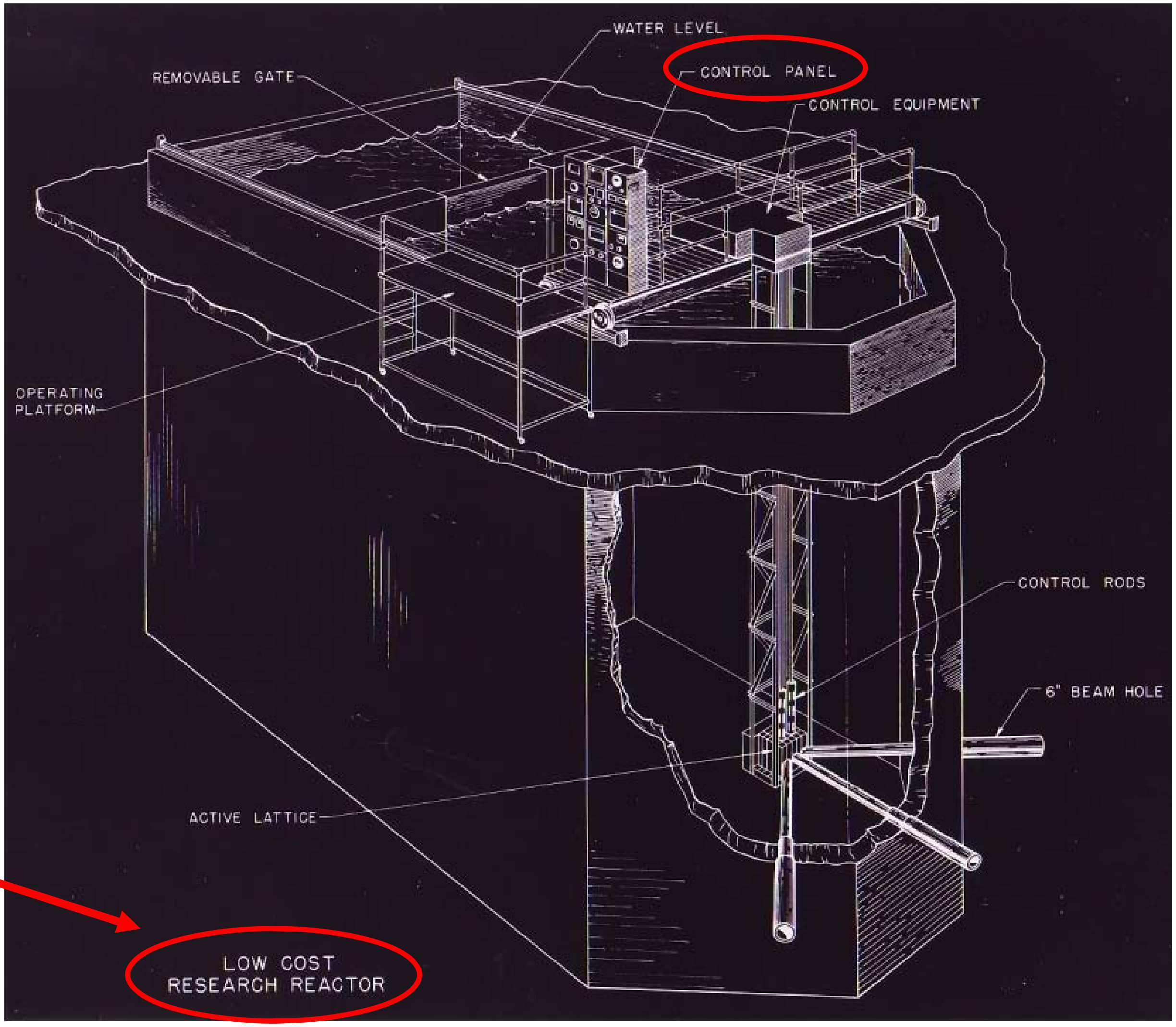
Radiation Science and Engineering Center

Overview

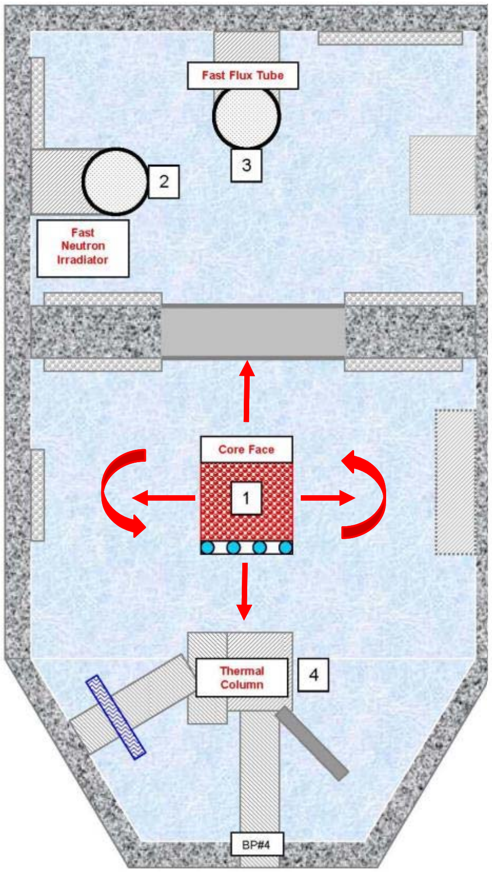
- PSBR TRIGA Description
- Existing Console
- If it ain't broke….Motivation
- New Control System
- AGARA
- Schneider Equipment Grant – Student Lab/Software Staging Area
- Preliminary Schedule

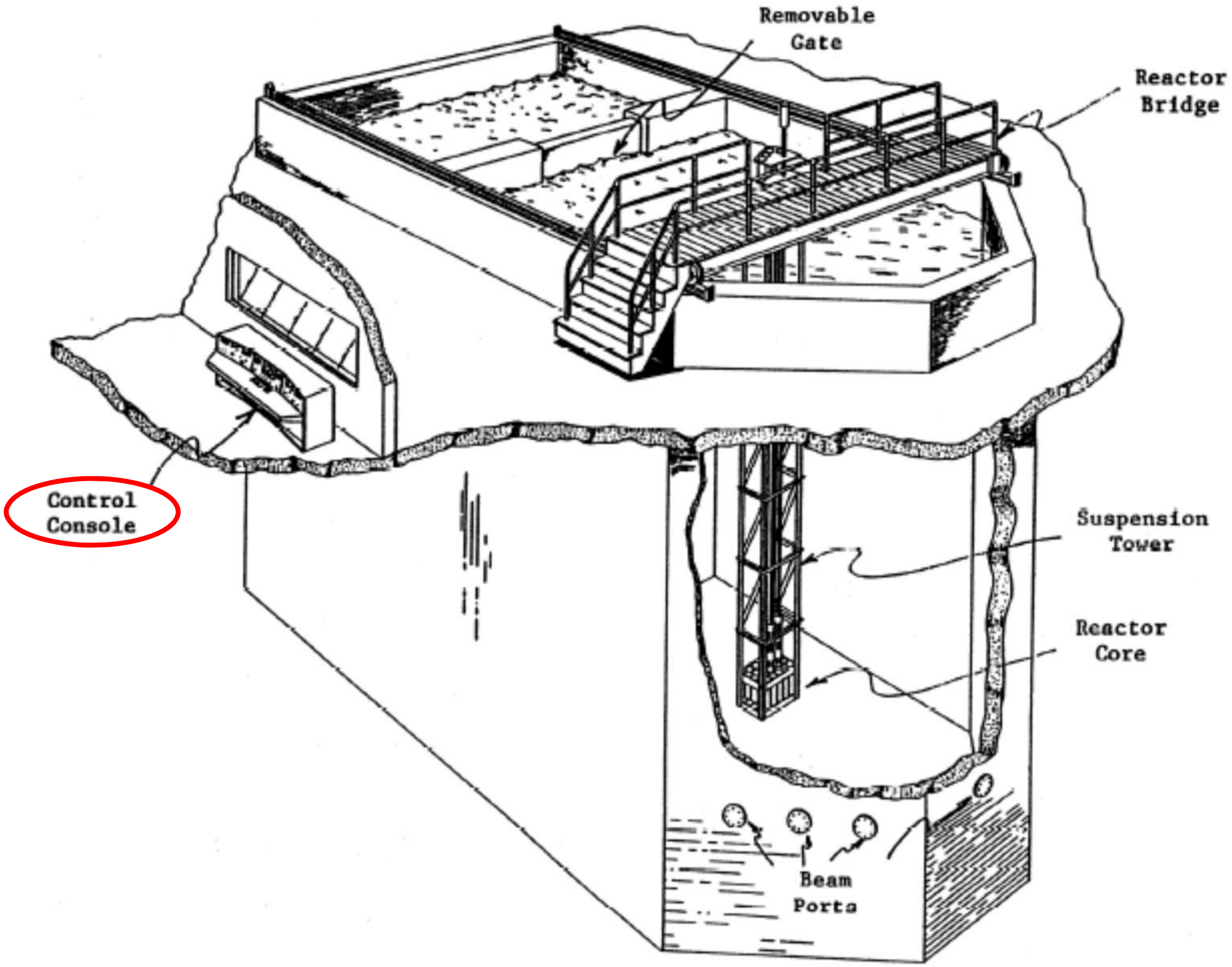
PSU TRIGA



Good Old Days…

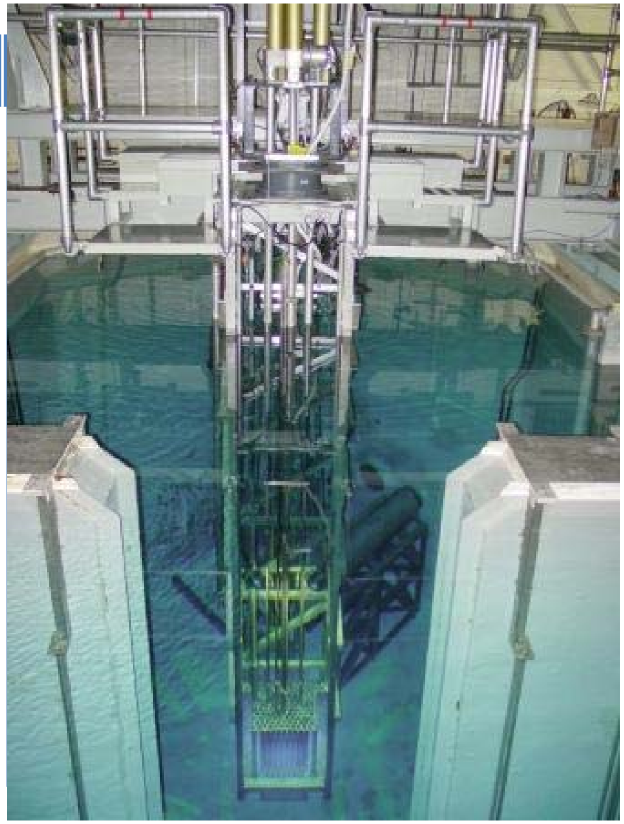
PSU TRIGA


Fast Flux Tube
3
2
Fast Neutron Irradiator
Core Face
1
Thermal Column
4
BP#4


Removable Gate
Reactor Bridge
Control Console
Suspension Tower
Reactor Core
Beam Ports

PSU TRIGA SPECIFICATIONS

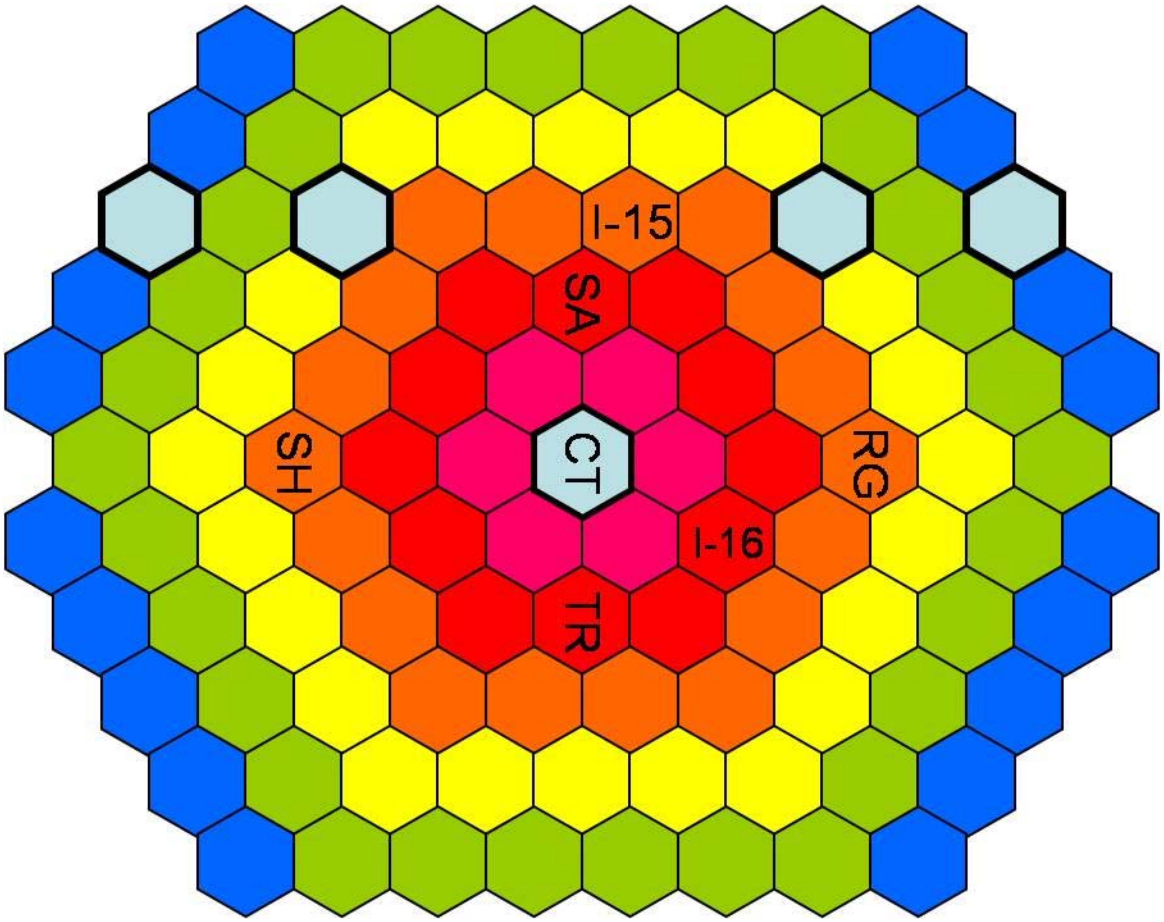
	TRIGA
Purpose	Research and Education use of radiation
Thermal Power	1 MW_{th}
Fuel Design	
Enrichment – U235	< 20%
Physical Size	~0.8 m
Fuel Matrix	Uranium metal
Primary moderator	$Zr_1 H_{1.65}$
Cladding	Stainless Steel



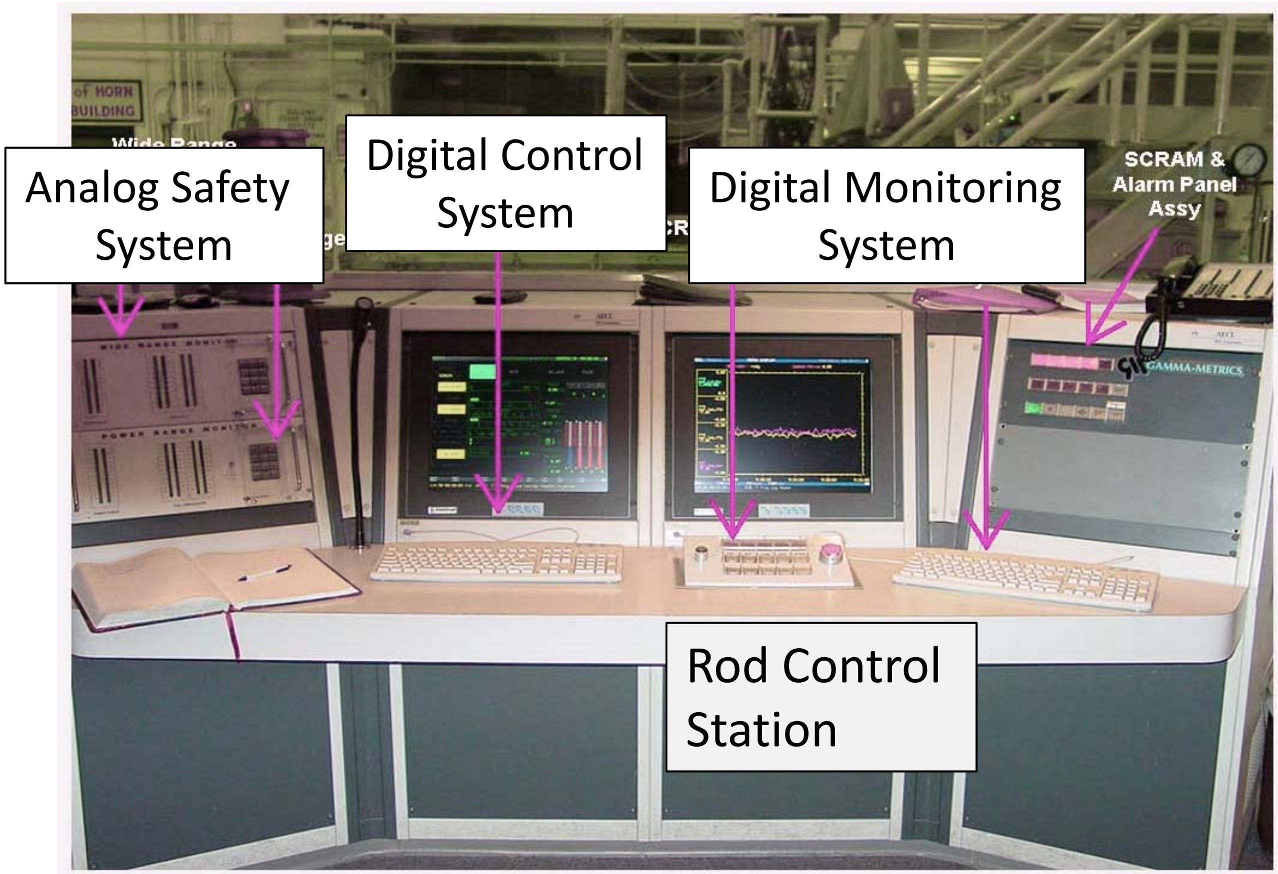
PSU TRIGA CORE MAP

2 Dry irradiation tubes
1 wet irradiation tube
1 source location

4 Control Rods
2 inst. Elements



Existing AECL System… Installed 1991



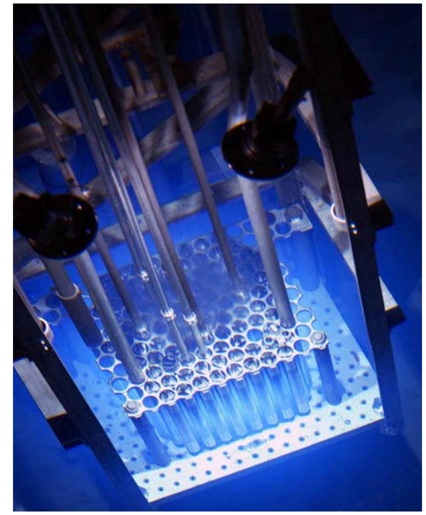
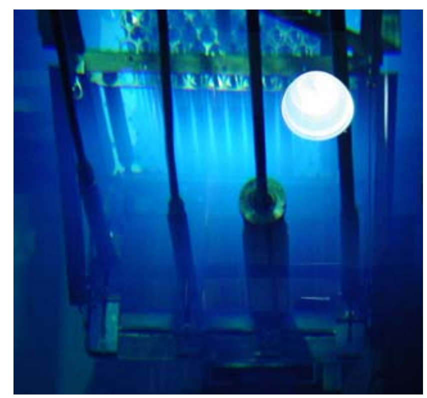
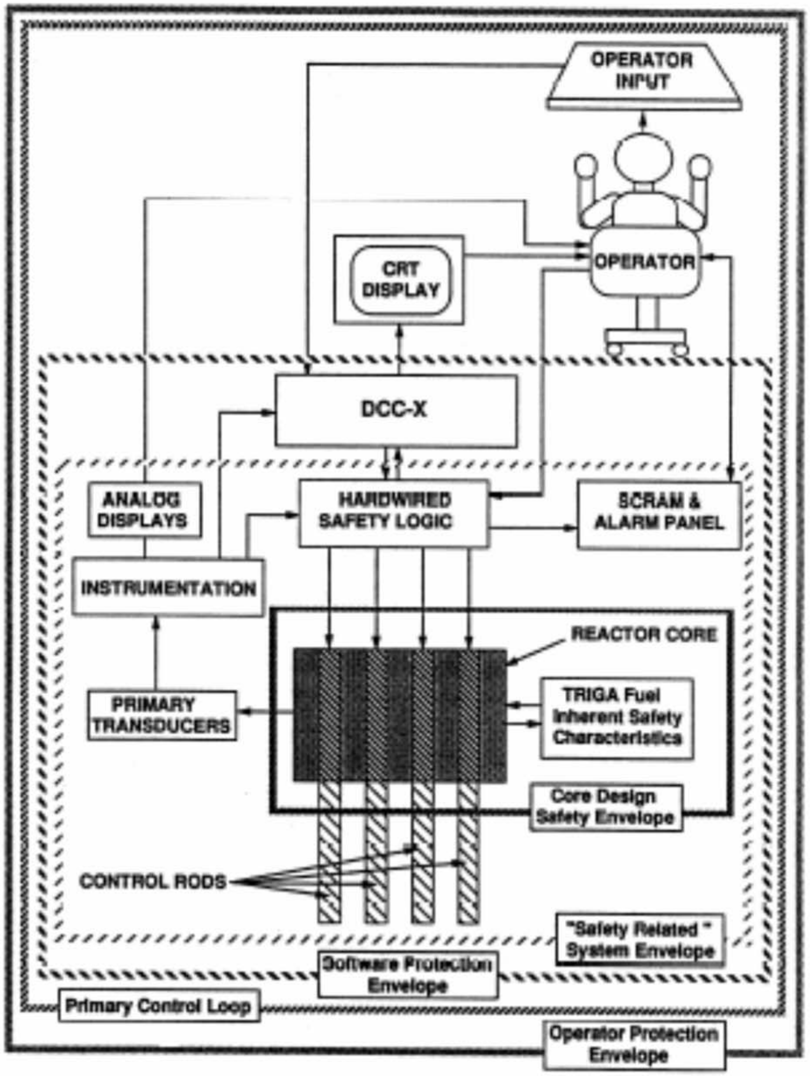


Figure 1 – The U2RR reactor Core.



Safety System: TRIGA Fuel



3. DESIGN OF STRUCTURES, SYSTEMS, AND COMPONENTS

3.1 Design Criteria

The major design feature criterion to protect the safety of the public is the physical mechanisms and characteristics of the stainless steel clad TRIGA fuel elements (see section 4.5). The facility confinement (see section 6.2.1) and facility emergency exhaust system (see section 13.1.1, Engineered Safety Features) are adequate to help mitigate any airborne environmental release and limit any significant hazard to the public.

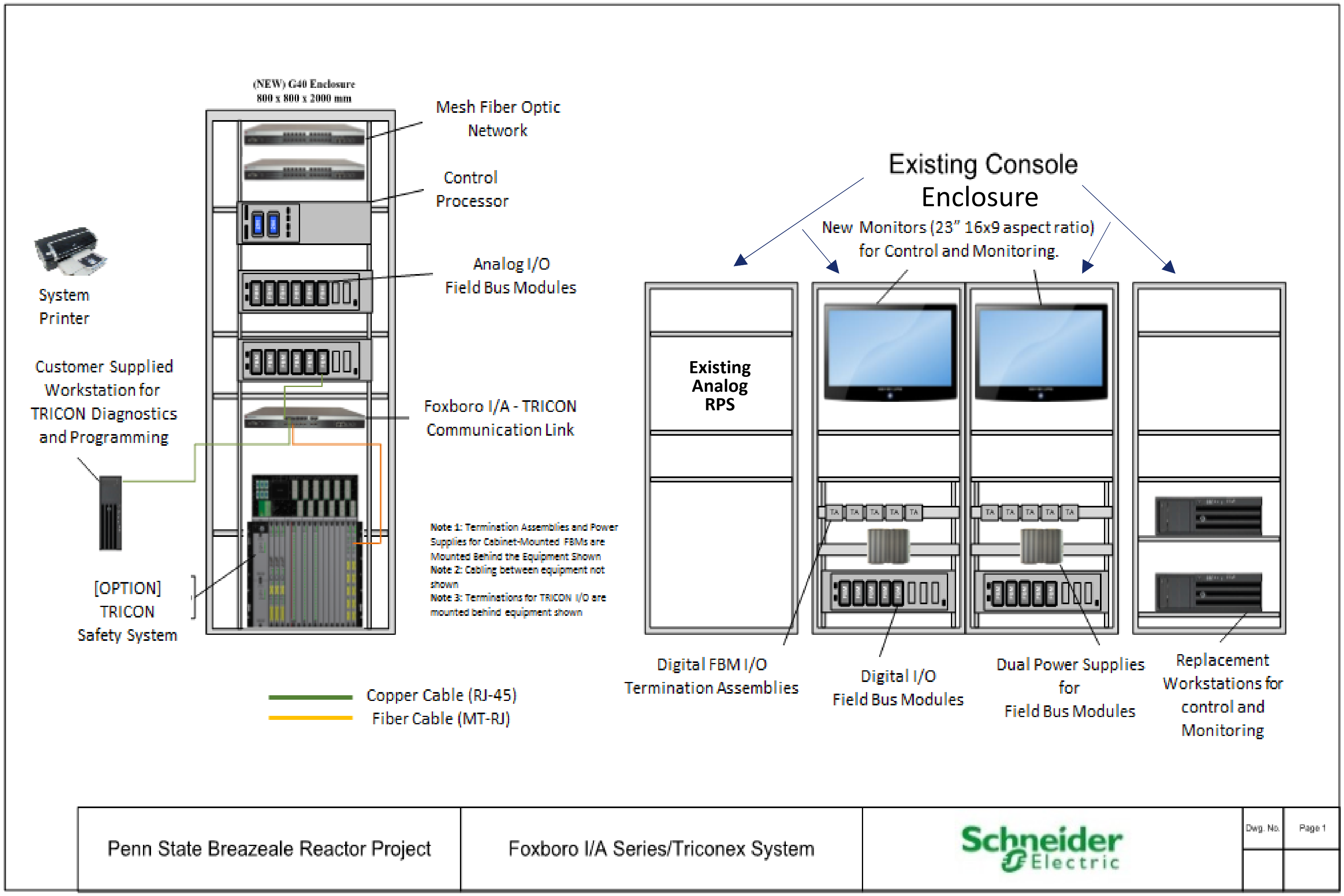
3.5 Systems and Components

Reliance on the safety of the TRIGA fuel precludes the need for reliance upon other systems, structures, and components to ensure the safety of the general public. The emergency exhaust system would mitigate the consequences of the MHA (section 13.1.1) but is not required to be operable when the reactor is secured (see section 7.5).

PSU Control System Replacement

- AECL Console: Outstanding Performance for 26 years
- Still Operating: OEM No Longer Supports/Software Upgrades Costly
- PSU Pursuing Obsolescence Upgrade (Replacement of Digital Components) - $1M DOE Grant
- Keep Analog Safety System (Initially)
- Replace Digital Control System (50.59)
- Phase-In 1E Digital Safety System (License Amendment)

New Control Console



PSU Control System Replacement – Other Goals:

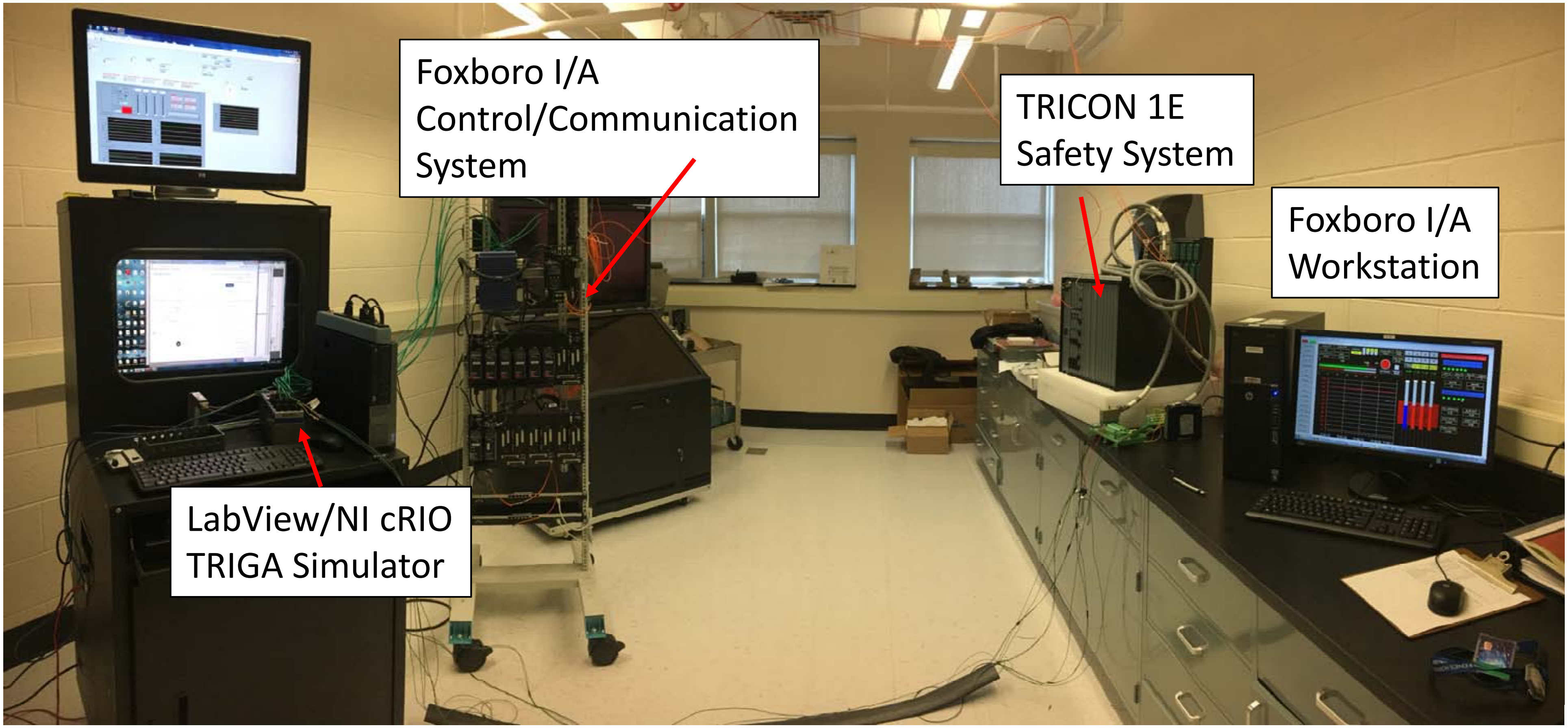
AGARA

(As Generic As Reasonably Achievable)

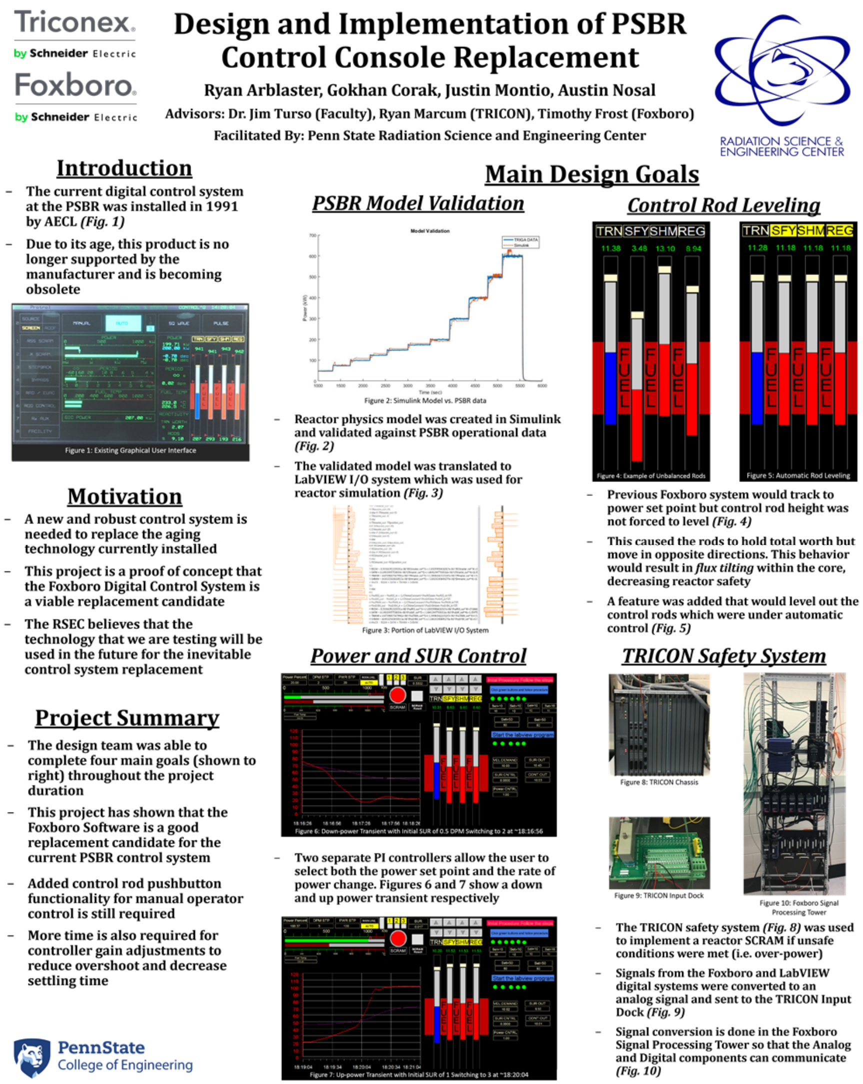
Share Project Artifacts With TRTR Community:

- Regulatory Documents (50.59 Screening/Evaluations)
- Design Documents/Schematics/BOM
- Software
- License Amendment Documents / SAR Upgrades

Foxboro Control and Monitoring System
Potential Replacement for PSU System
$300K Equipment Donation

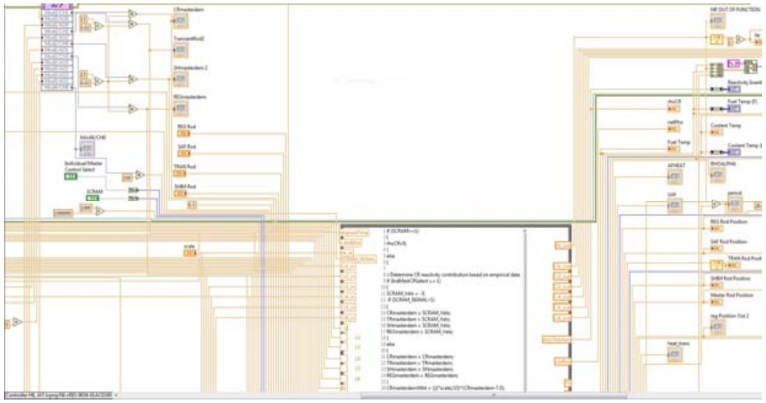


Familiarization Through Senior Design Projects

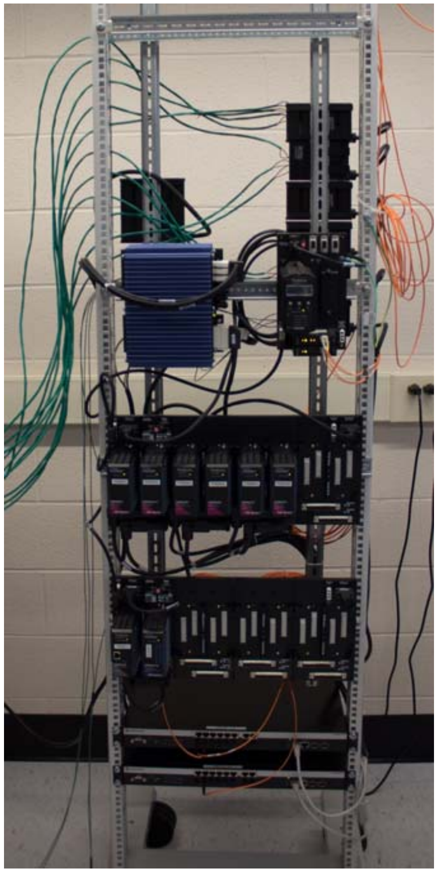


Foxboro Control and Monitoring System
Potential Replacement for PSU System

LabVIEW Reactor Simulator

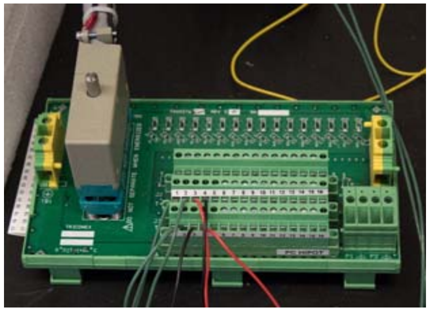


Foxboro Control Workstation



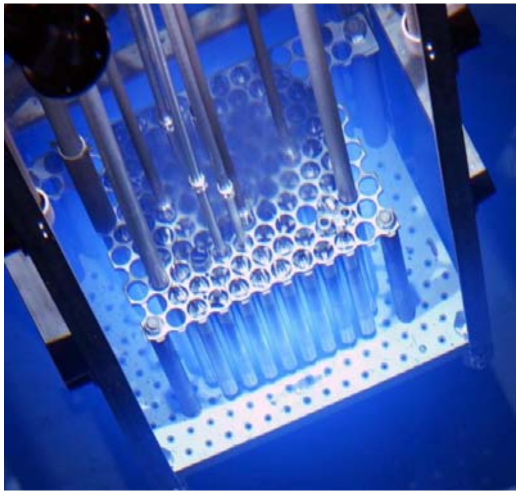
Foxboro System

TRICON System Chassis



TRICON I/O Connector Block

LabView HIL cRIO-Based Simulator



PKE – Based Neutron Dynamics

$$\frac{dn(t)}{dt} = \frac{(\rho - \beta) * n(t)}{\Lambda} + \frac{\sum_{i=1}^{i=6} \beta_i C_i(t)}{\Lambda}$$

Delayed Neutron Precursor Dynamics

$$\frac{dC_i(t)}{dt} = \lambda_i\big(n(t) - C_i(t)\big)$$

Thermal Power Produced in Fuel

$$\dot{Q}_{fuel} = P_{average\ fuel\ element}\ x\ n(t)$$

Fuel Temperature Dynamics

$$M_f C_f \frac{dT_f(t)}{dt} = \dot{Q}_{fuel} - U_f A_f\big(T_f - T_c\big)$$

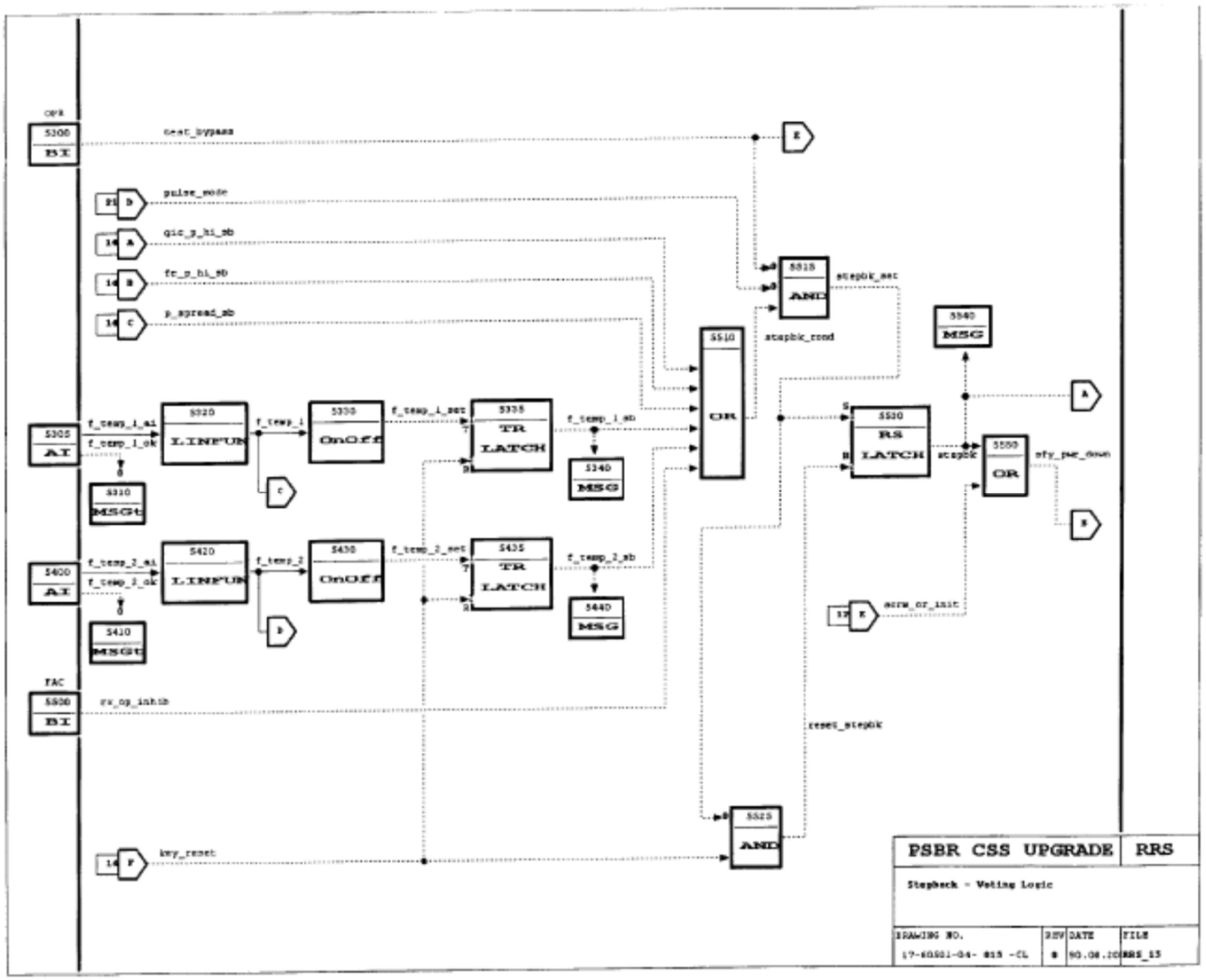
Coolant Temperature Dynamics

$$M_C C_C \frac{dT_C(t)}{dt} = U_f A_f\big(T_f - T_c\big) - 2\dot{m}_C C_{Cp}(T_c - T_{into\ core})$$

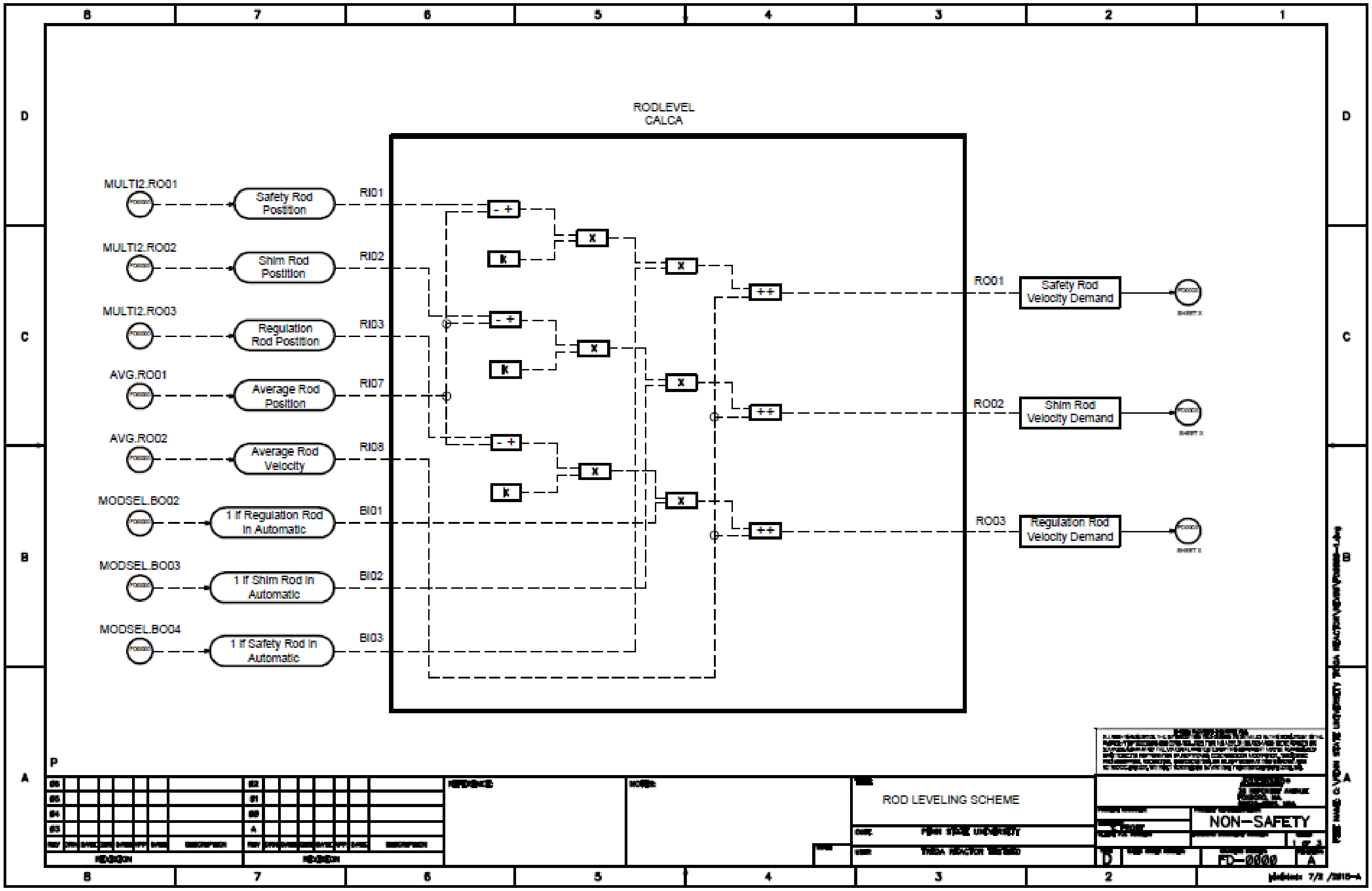
Reactivity Feedback

$$\rho_{net} = \rho_{rods} + \alpha_f\big(T_f - T_o\big) + \rho_{fission\ products} + \rho_{shutdown}$$

Existing AECL Console Programmed With PROTROL Configuration Software



Foxboro System Programming
Integrated Control Configurator



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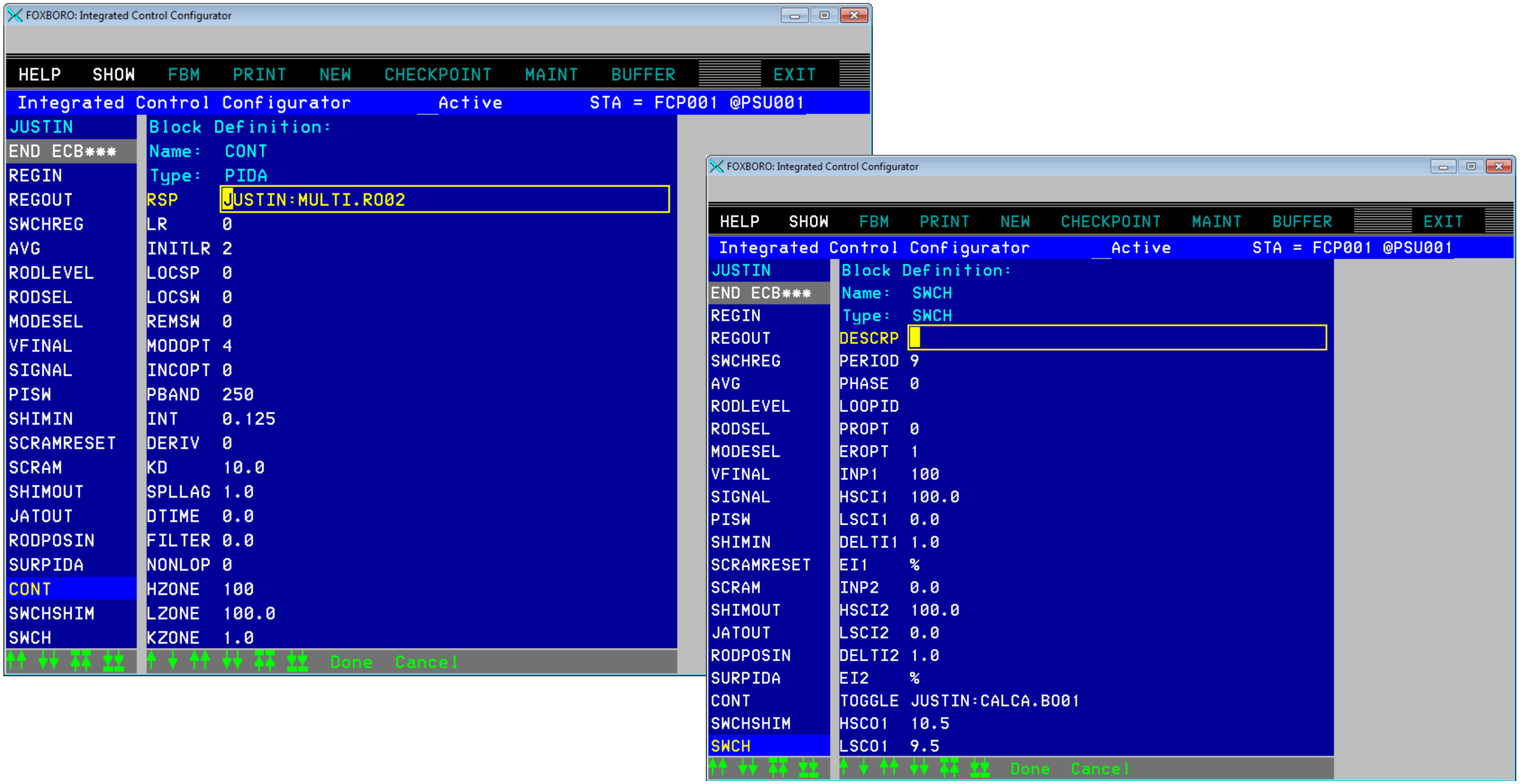
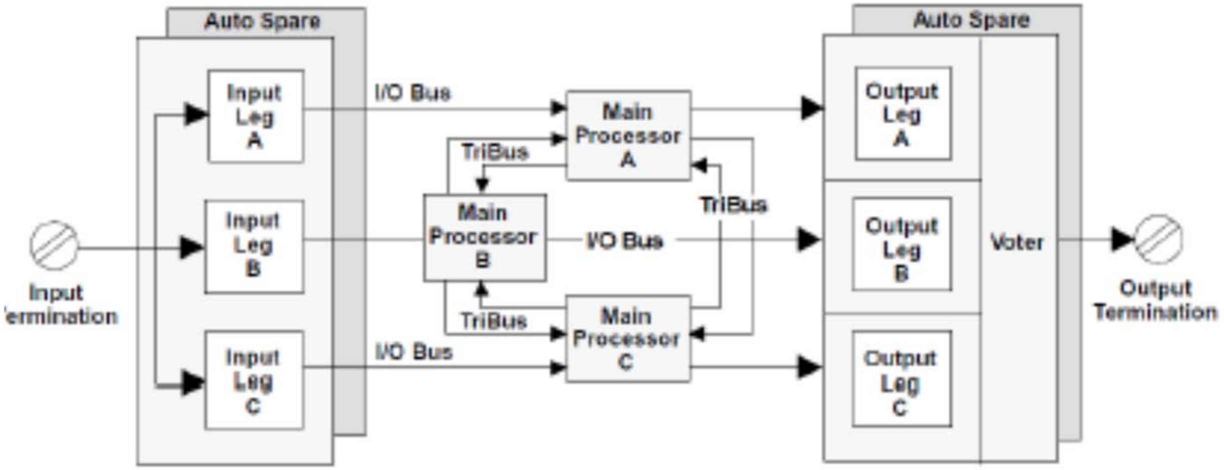


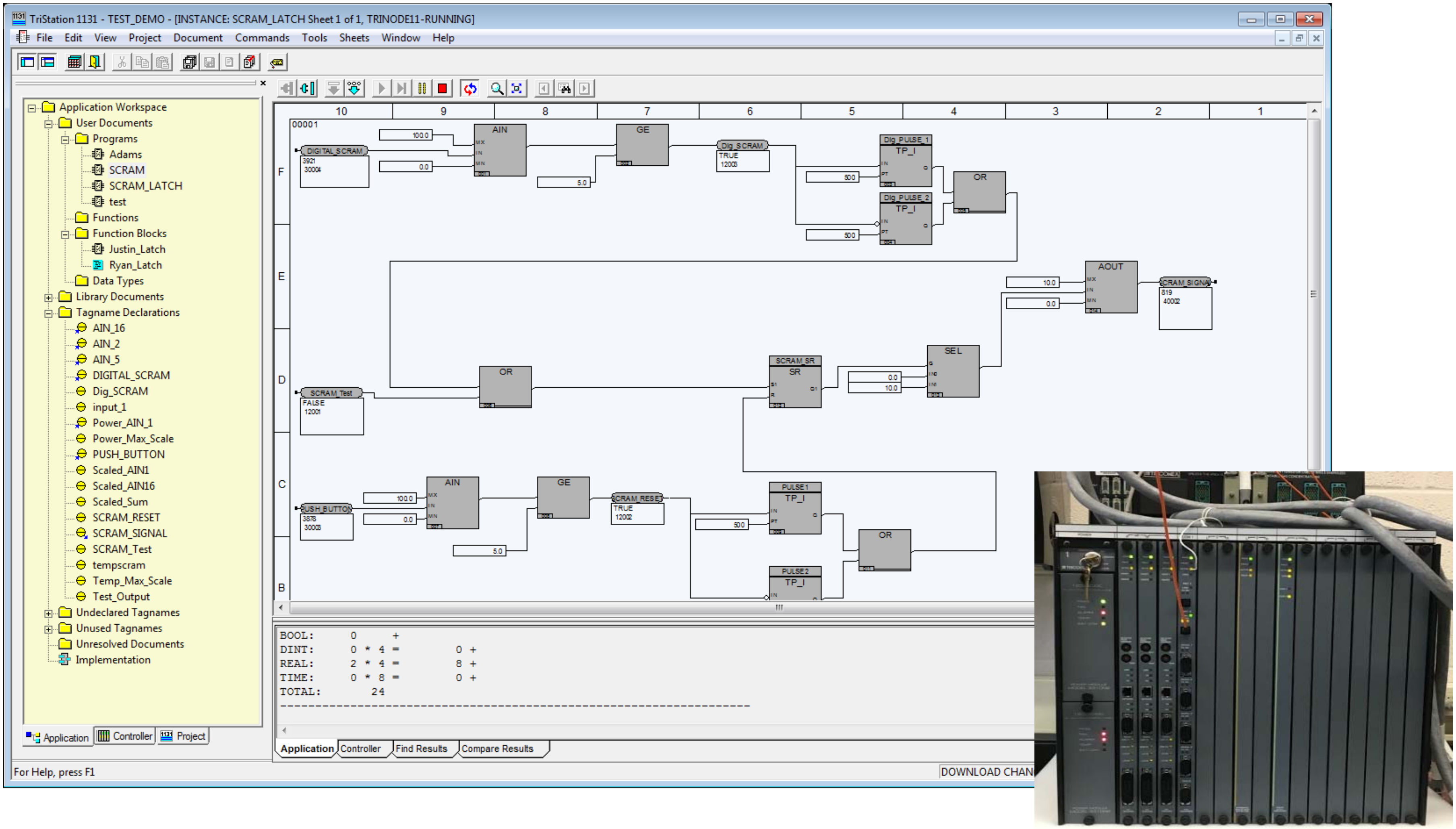
TRICON 1E Safety System

TRICON Enclosure

TRICON: Triple Redundant Architecture



TRICON 1E Safety System Programming



PennState College of Engineering

RADIATION SCIENCE & ENGINEERING CENTER

Work With GSE Systems to Develop 3D RELAP-Based Hardware-In-The-Loop Test Bed for New Console

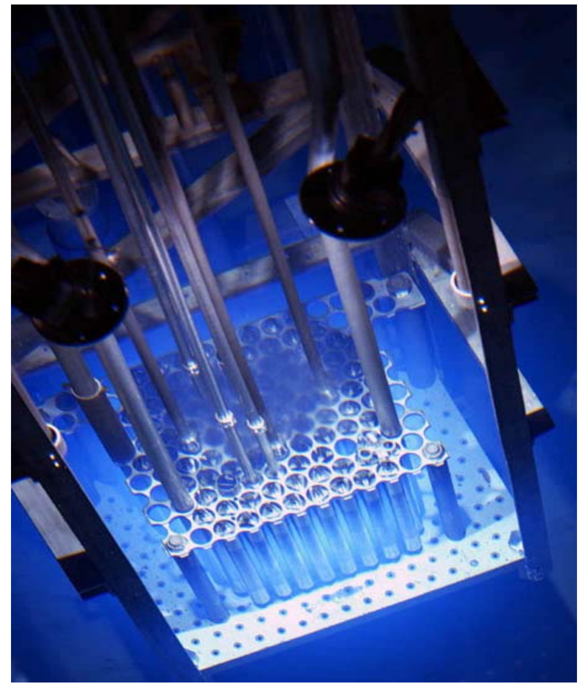
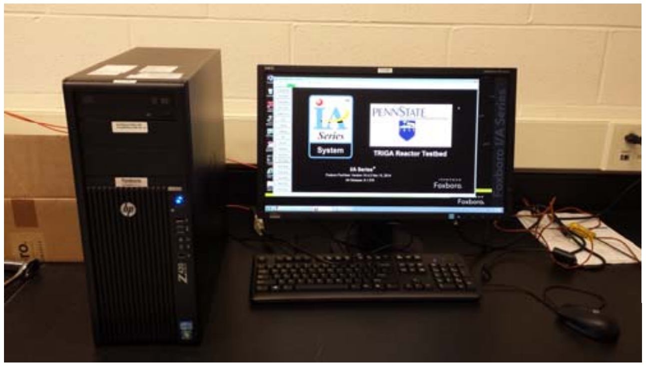


Figure 1 – The U2RR reactor Core.

Work With GSE Systems to Develop 3D RELAP-Based Hardware-In-The-Loop Test Bed for New Console

Operator Station



Digital Control System

3D RELAP-Based Simulator

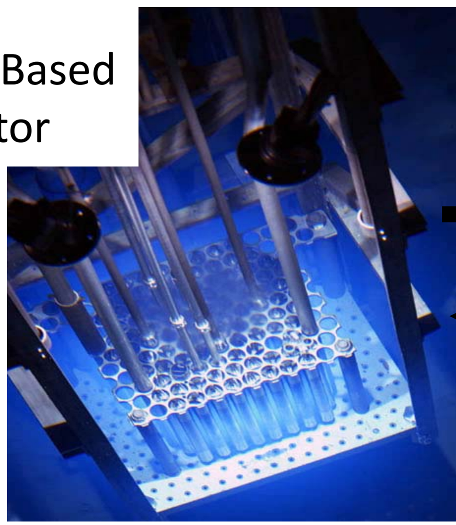


Figure 1 – The U2RR reactor Core.

Power, Temperature signals from Reactor

Velocity DMD To CRDM

PSU Console Replacement Timeline

October 2015: Received Equipment Grant from Schneider Electric (Foxboro I/A and TRICON systems)

Spring 2016/2017: 2 Student Senior Design Groups Implemented Existing Console's Algorithms in Foxboro/TRICON Equipment

September 2017: Received DOE Grant for PSU Control System Modernization

December 2017: Develop Project Requirements/SOW

June 2018: Contract Award / Project Kick-Off

September 2019: Factory Acceptance Tests, Foxboro MA

January 2020: Delivery of System to PSU/Beginning of Site Acceptance Tests

May 2020: Disassembly of Old Console / New Console Installation

July 2020: Testing/Commisioning of New Console