Developing a Graphical User Interface for Simulating NBSR Reactivity Controls

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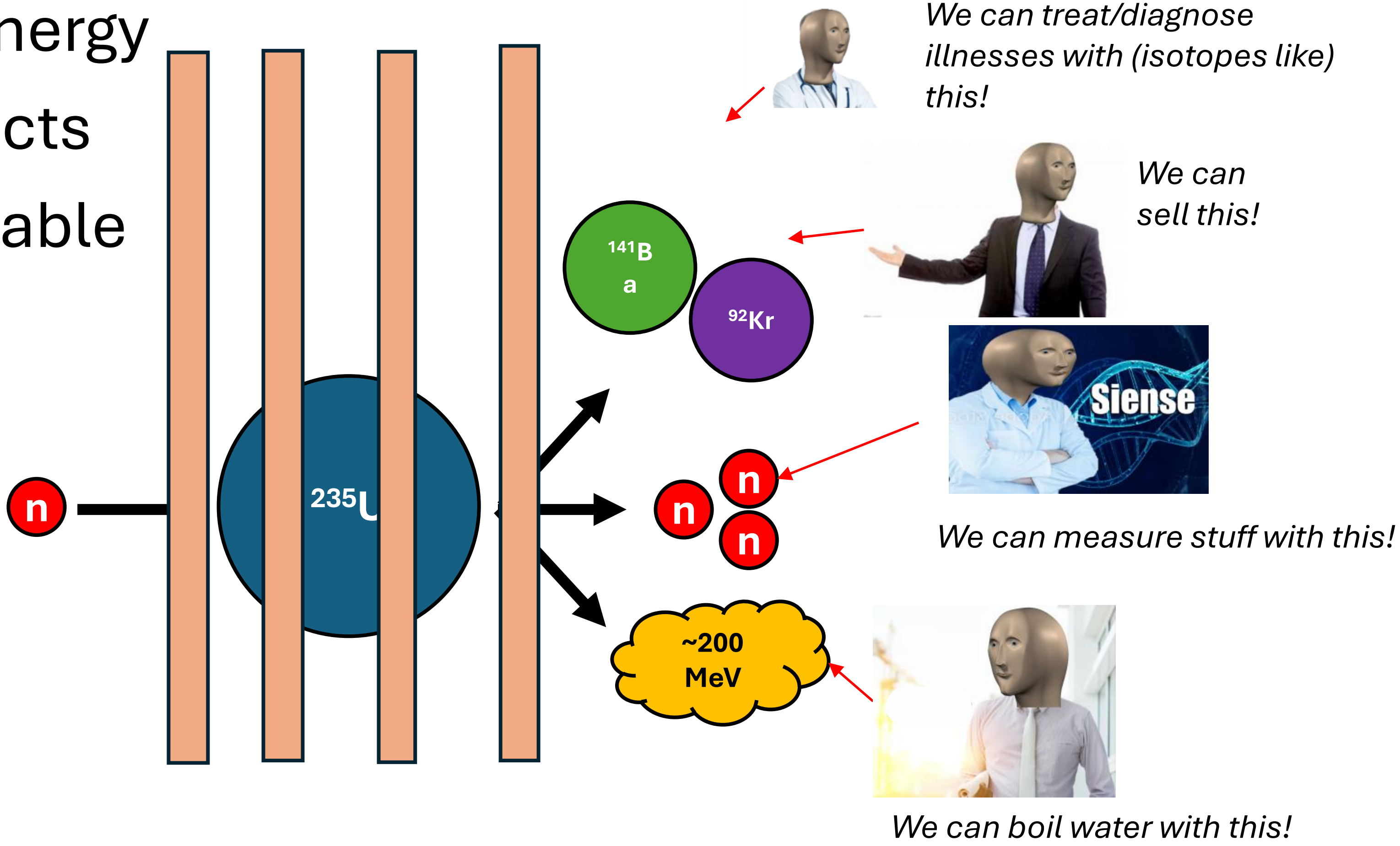
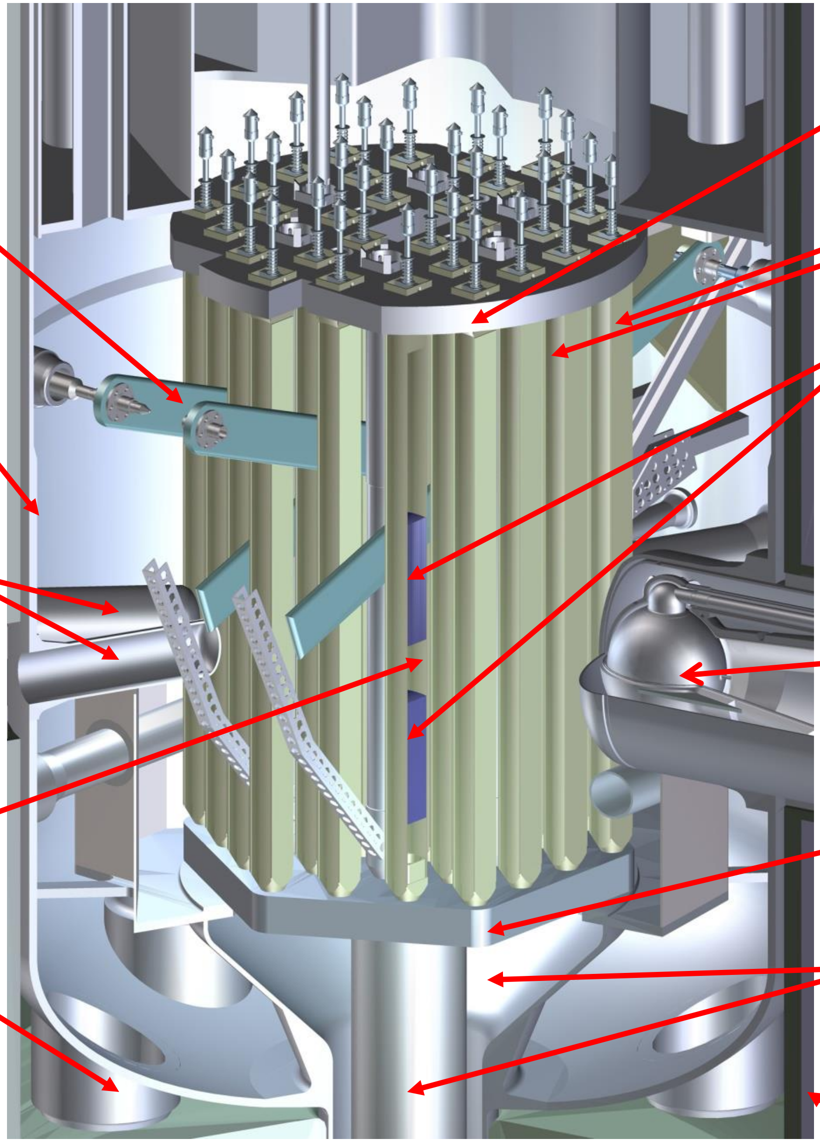
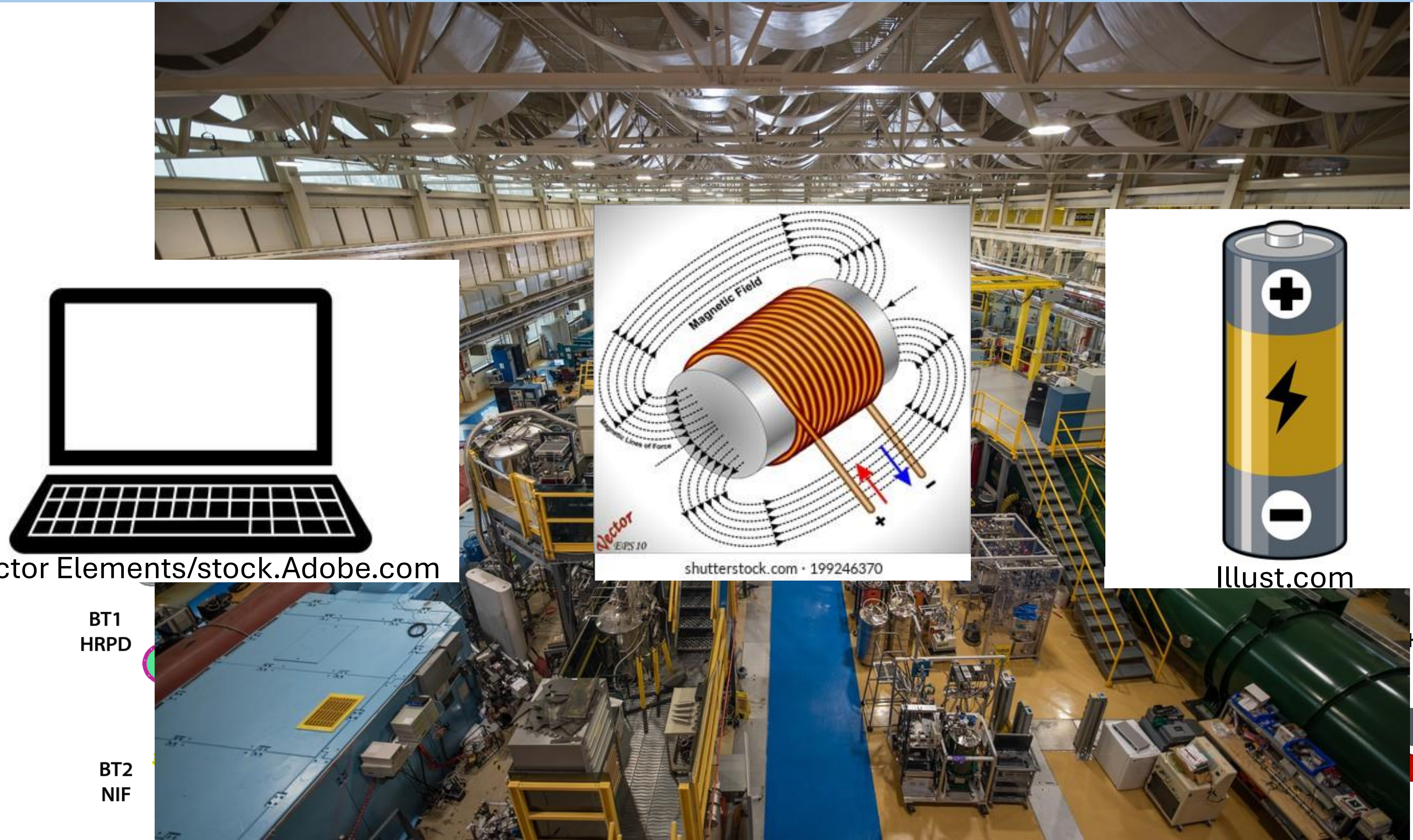
Nuclear Basics

- Releases a lot of thermal energy
- Also releases fission products
- Fuel with fissile and fissionable material




Cd Shim Safety Arms (4)
Reactor Vessel
Radial Beam Tubes (9)
Split Core: 18-cm Unfueled Gap – Flux Trap
Primary Outlet (2)
Top Grid Plate
Fuel Elements (30)
Fuel Plates
Liquid Hydrogen Cold Neutron Source
Bottom Grid Plate
D_2O Primary Inlet Plenums
Thermal Shield

Intro



Vector Elements/stock.Adobe.com

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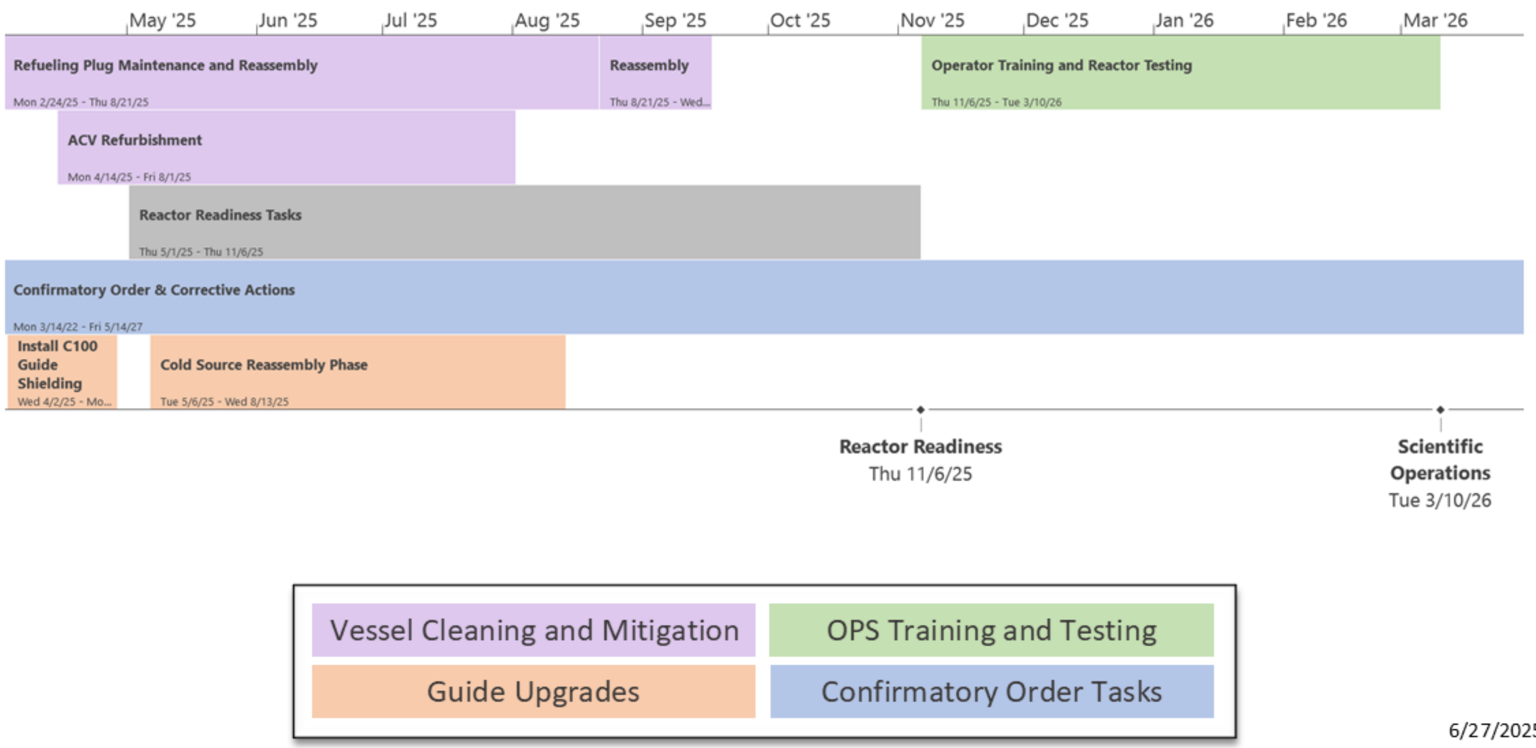
BT1
HRPD

BT2
NIF

HYS

CNI

NCNR Integrated Projects

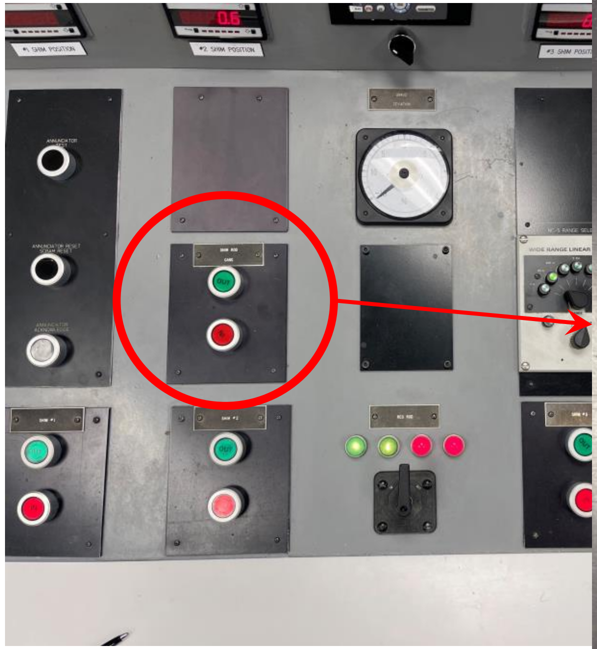


6/27/2025 Baseline

Objective

- Build a GUI to simulate power relevant areas of the control room
- Expedite the reactor training process by allowing the operators to get a feel for how moving control rods affects power and period

Control Room

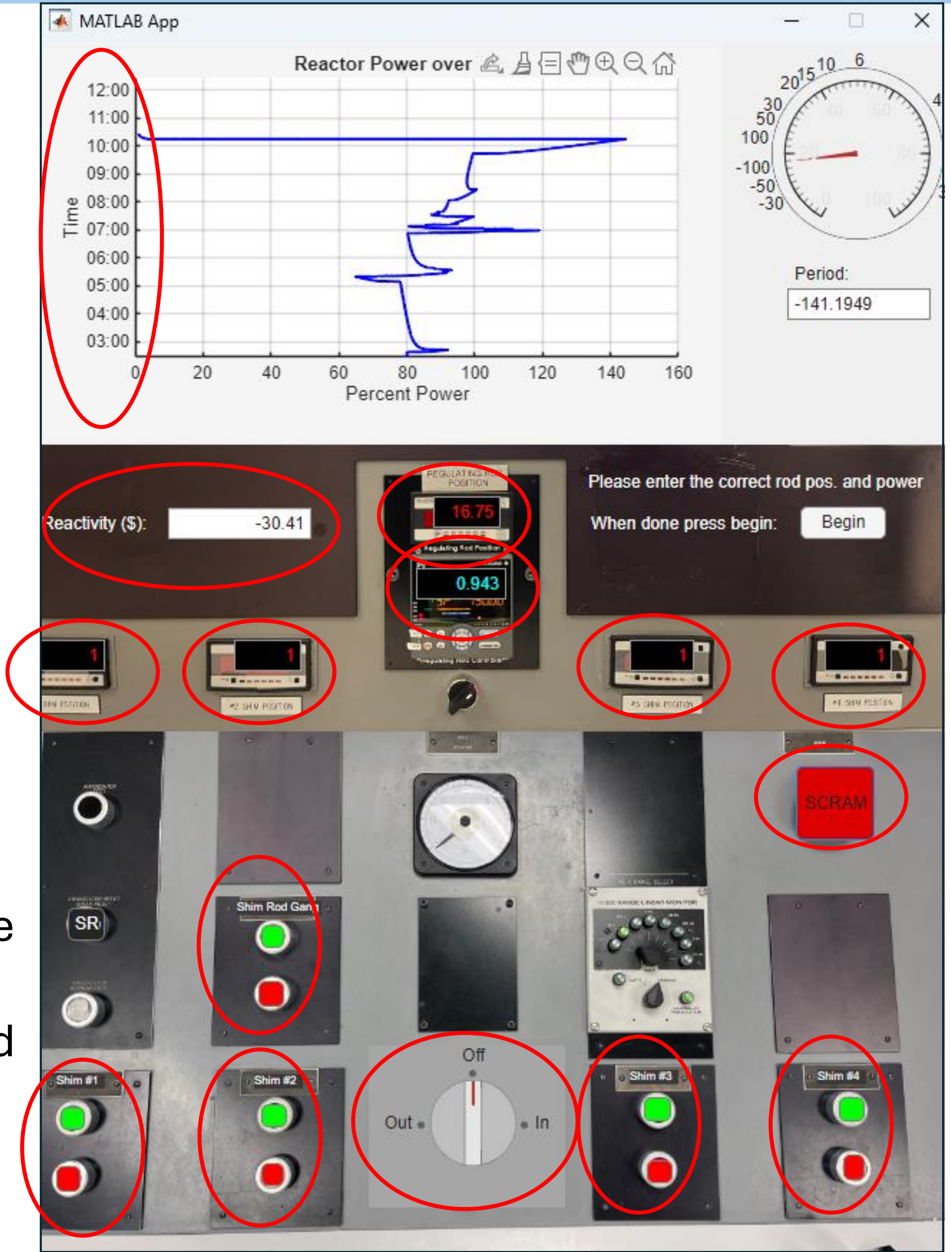


GUI Layout

Scrolling time scale

Tells the operator power and reactivity

Buttons to move the shim arms. The operator has to hold



Tells the operator the position of the shim arms and reg rod

Safety Control Rod Axe Man

Switch to move the reg rod (no need to hold)

Point Kinetics Model

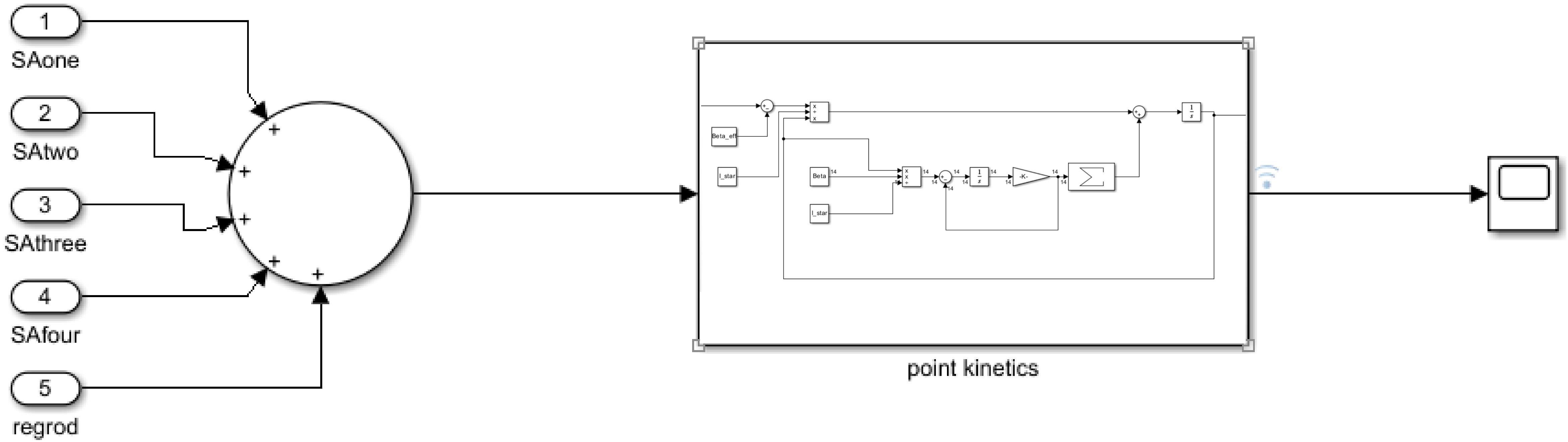
- Power over time
- Delayed neutrons

$$\frac{dn}{dt} = \frac{\rho - \beta}{\Lambda} n + \sum_{i}^{14} \lambda_i C_i$$

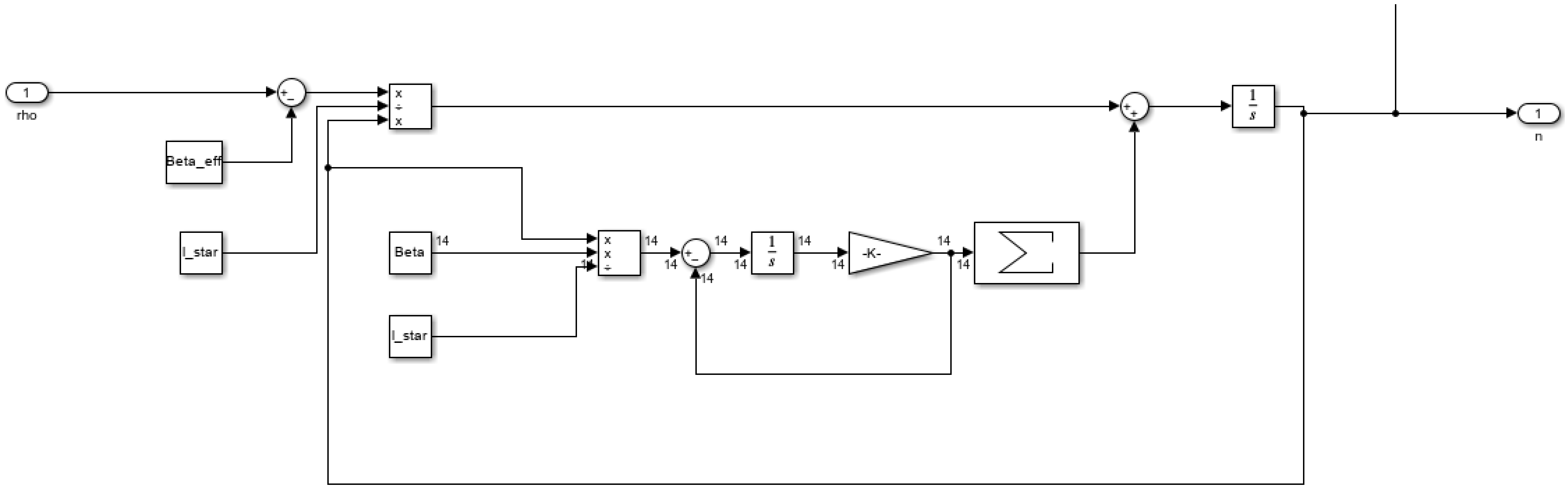
$$\frac{dC_i}{dt} = \frac{\beta_i}{\Lambda} n - \lambda_i C_i$$

- n = neutron population
- ρ = reactivity
- β = sum of delayed neutron fractions
- Λ = prompt generation time
- λ = precursor decay constant
- C = number of precursors

Simulink Model

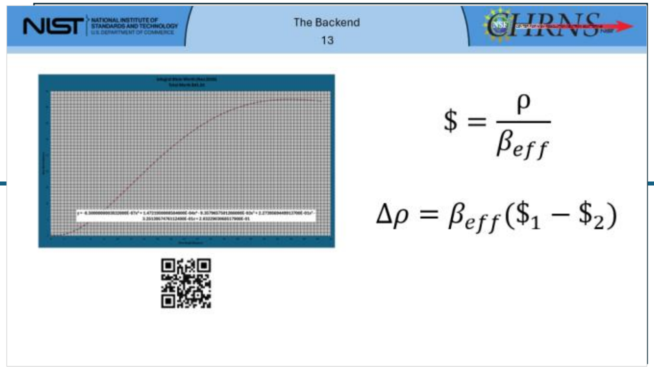


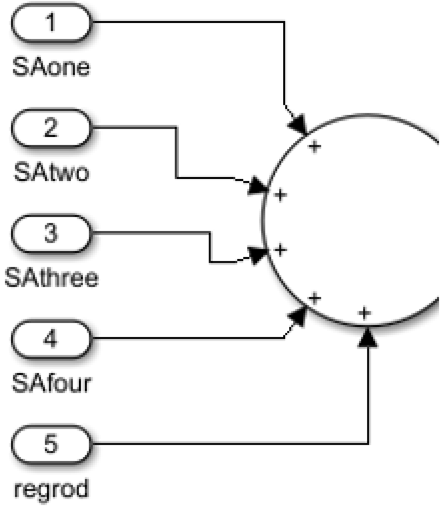
The Backend



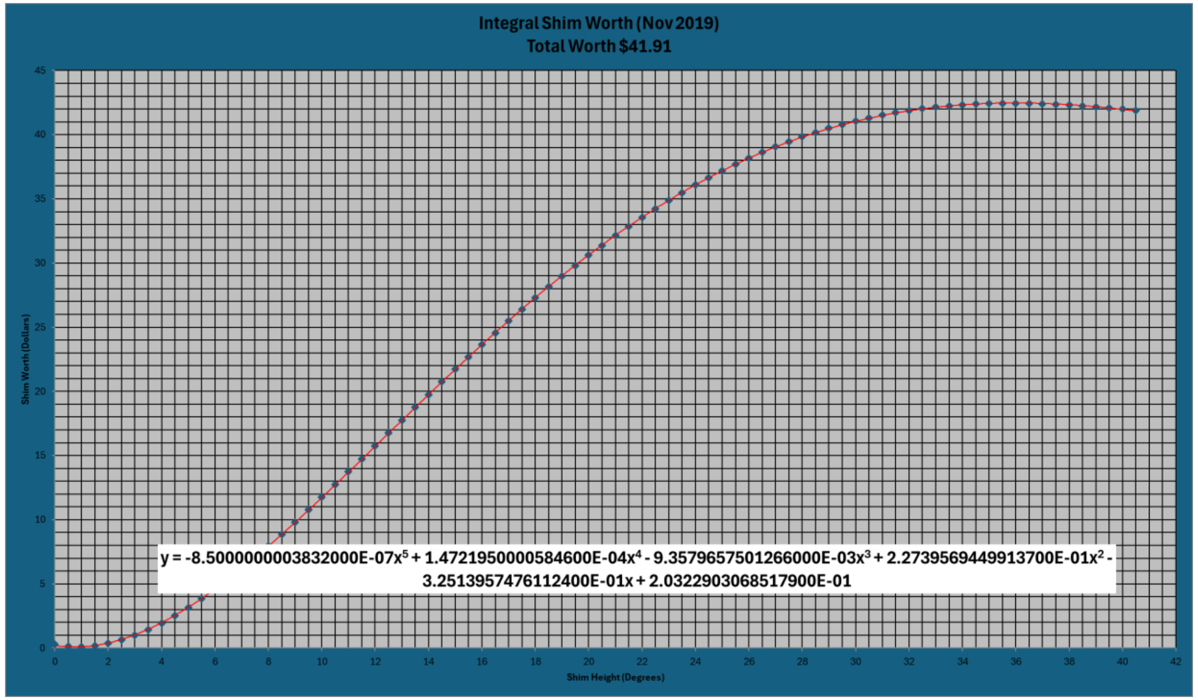
Big thanks to the NCNR team!

Converting Inputs





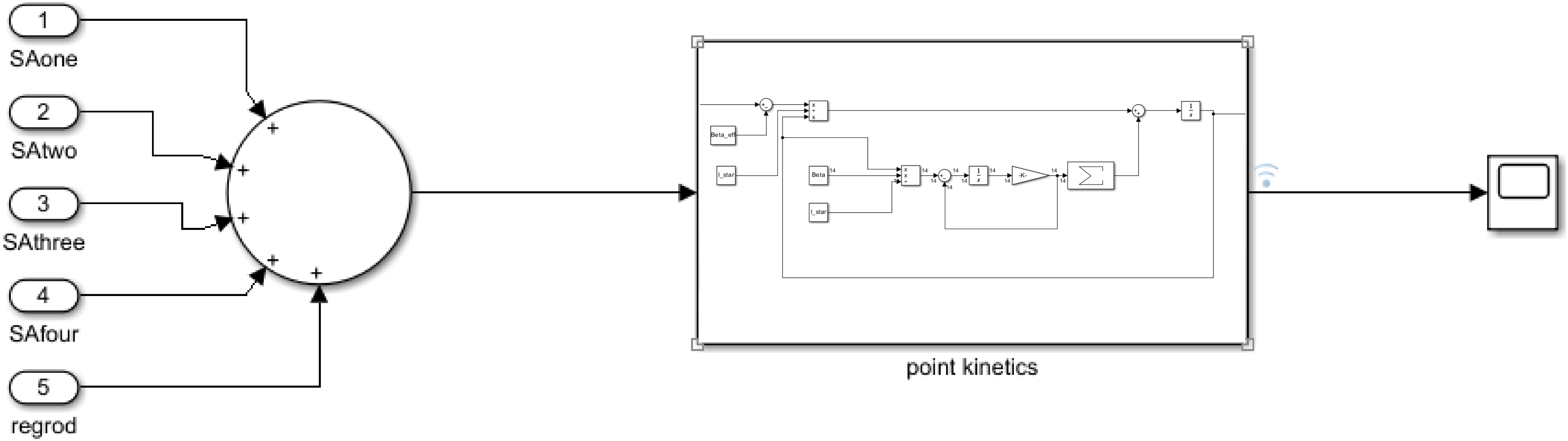
The Backend



$$\$ = \frac{\rho}{\beta_{eff}}$$

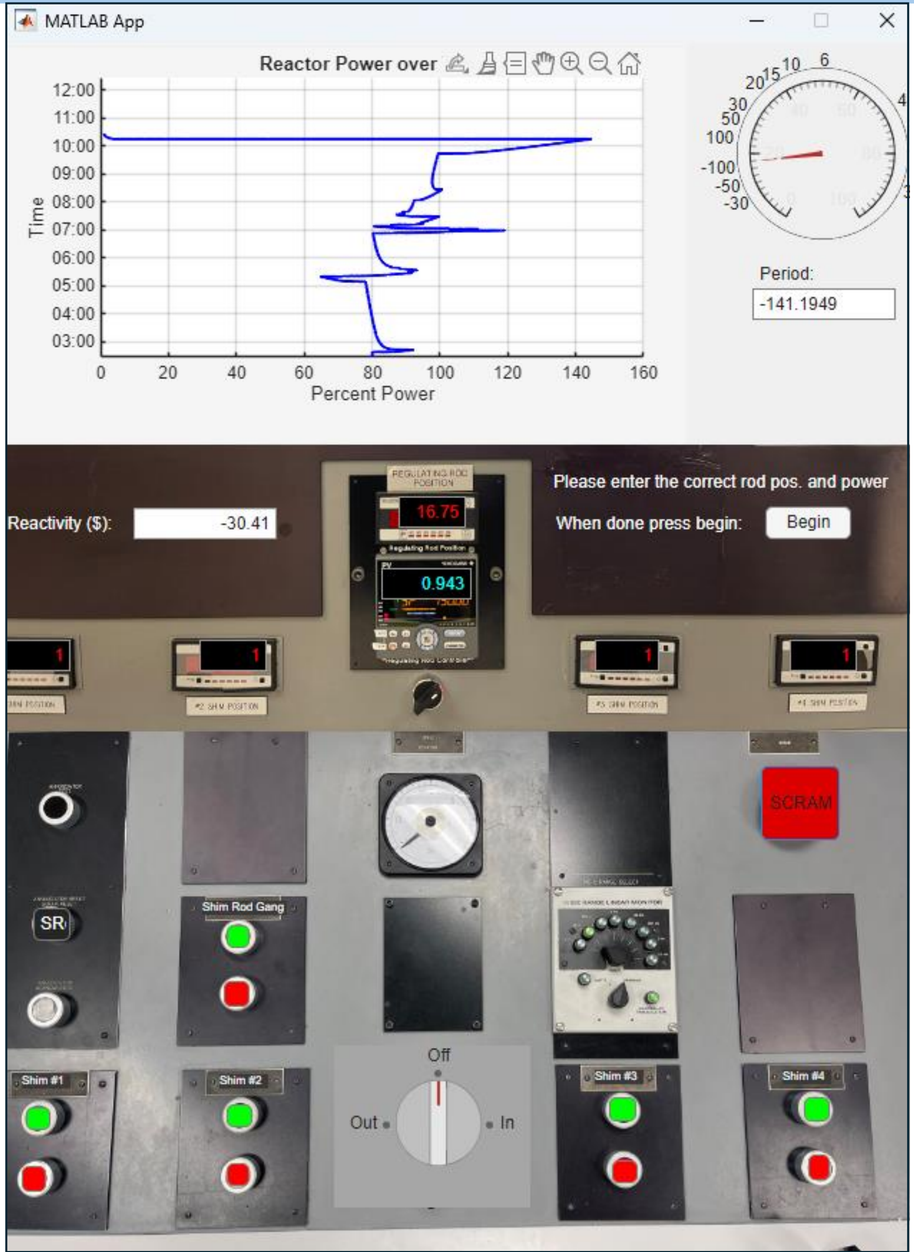
$$\Delta\rho = \beta_{eff}(\$_1 - \$_2)$$

Simulink Model



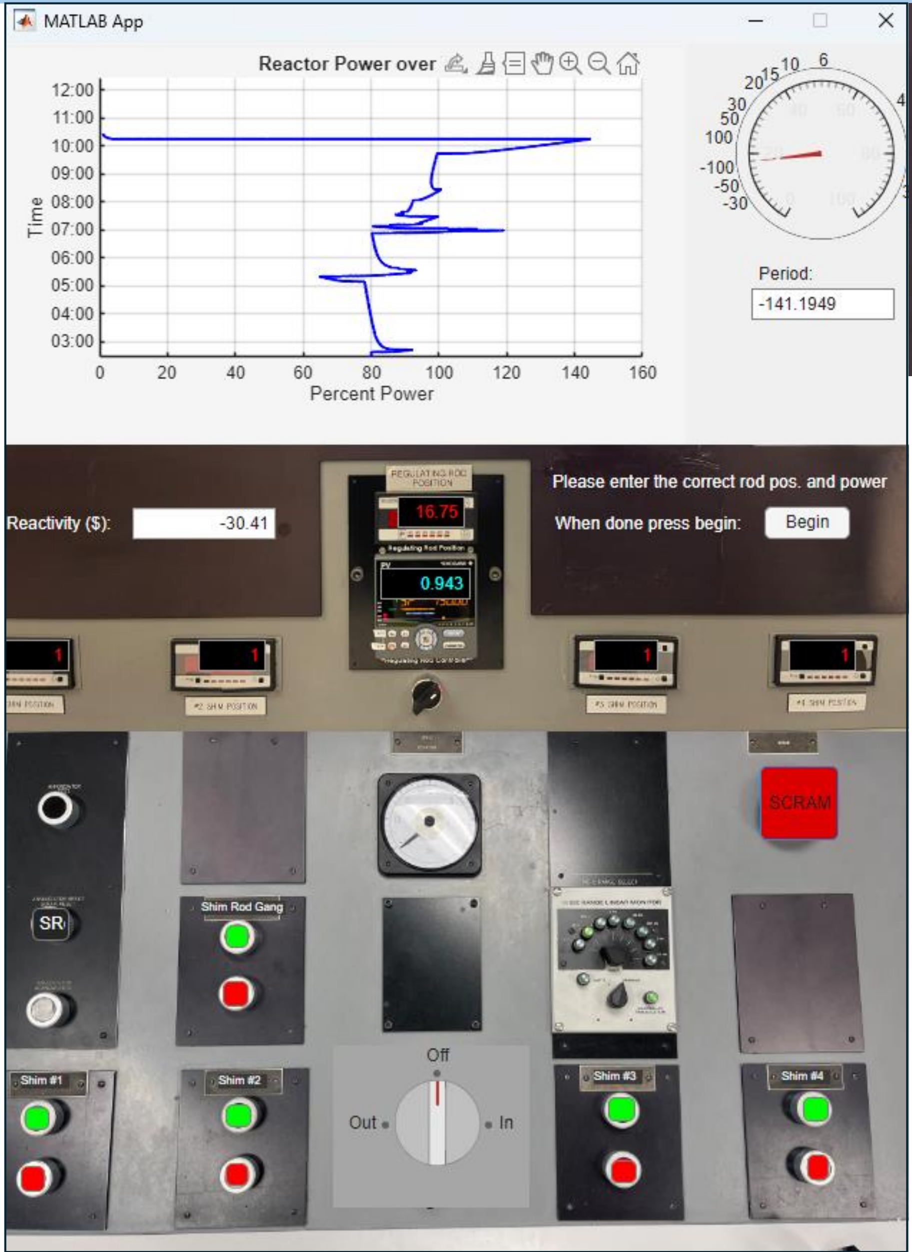
Graph Display

- Linear conversion to power
- Magnitude changes as expected
- SCRAM locks power to zero



Period

- Time it takes for power to change by a factor of e
- Easy way of expressing instantaneous **rate of change**
- Measure of stability



$$p(t) = p_0 \times e^{\left(\frac{t}{period}\right)}$$

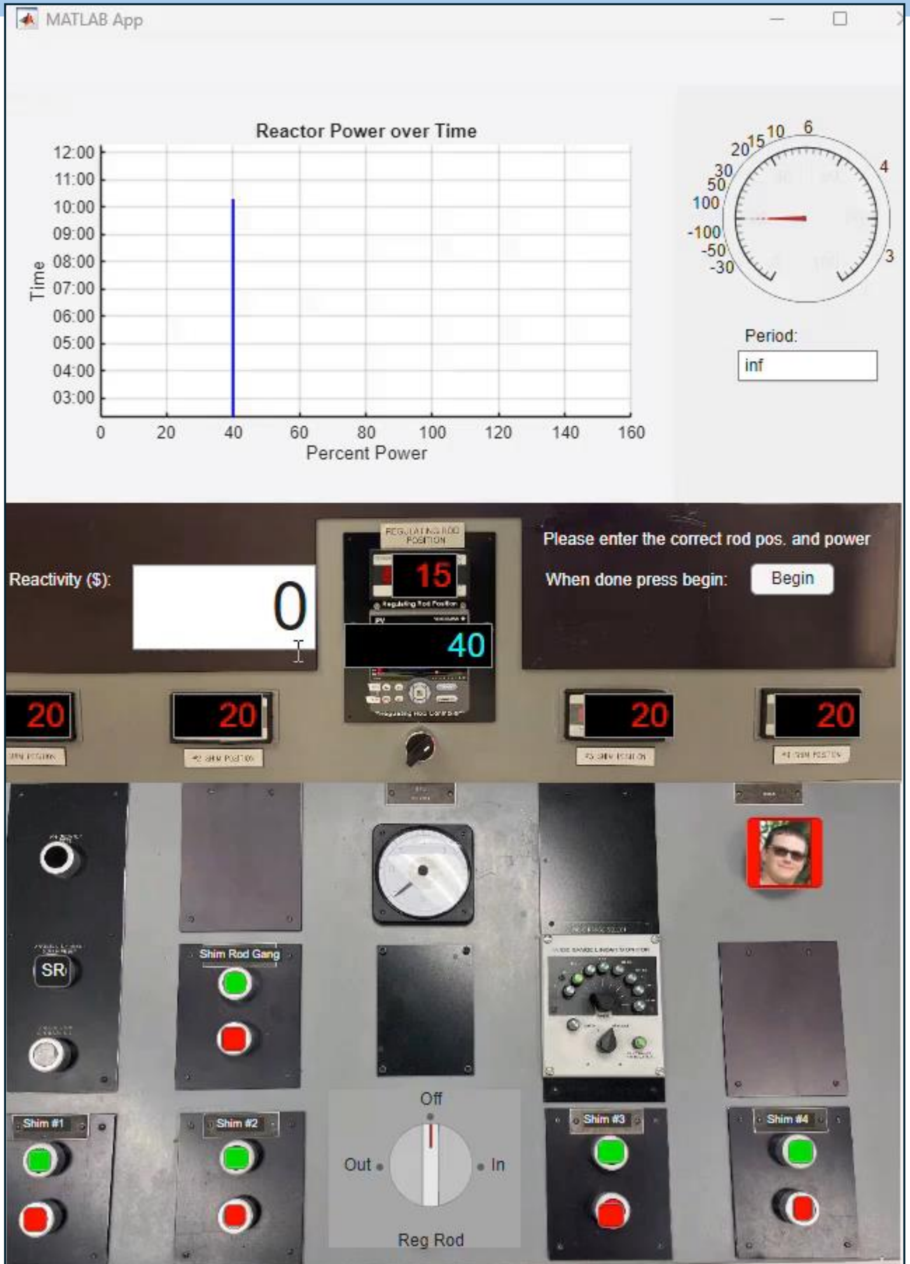
$$period = \frac{\Delta t}{\ln\left(\frac{p(t)}{p_{t-\Delta t}}\right)}$$

Improvements

- Continue to update data
  - Currently using 2019
- Automated reg rod to keep reactivity hovering around zero
- Testing against the real reactor for true calibration

Demo

- Video 1: 4x Speed
- Video 2: Real time
- Video 3: 4x Speed



Special Thanks

- Mentor: Dr. Abdullah Weiss
- Customer: Dr. Jacob Seiter
- CHRNS
- Coordinators: Dr. Julie Borchers, Dr. Leland Harriger

References

- [1] *Point Kinetics Equations | Definition & Derivation | nuclear-power.com*. (n.d.). Nuclear Power. https://www.nuclear-power.com/nuclear-power/reactor-physics/reactor-dynamics/point-kinetics-equations/
- Desmos Graphing Calculator. (2011, June 30). Retrieved July 30, 2025, from Desmos: https://www.desmos.com/calculator.