SAND2015-20764PE

Sandia National Laboratories

TECHNICAL AREA V – UNIQUE NUCLEAR FACILITIES

R. A. Knief
Organization 1382

SAND155540

Slide Pool
9/11/2014

Sandia National Laboratories

TECHNICAL AREA V – UNIQUE NUCLEAR FACILITIES

NUCLEAR REACTORS

CRITICAL ASSEMBLIES

HOT CELLS

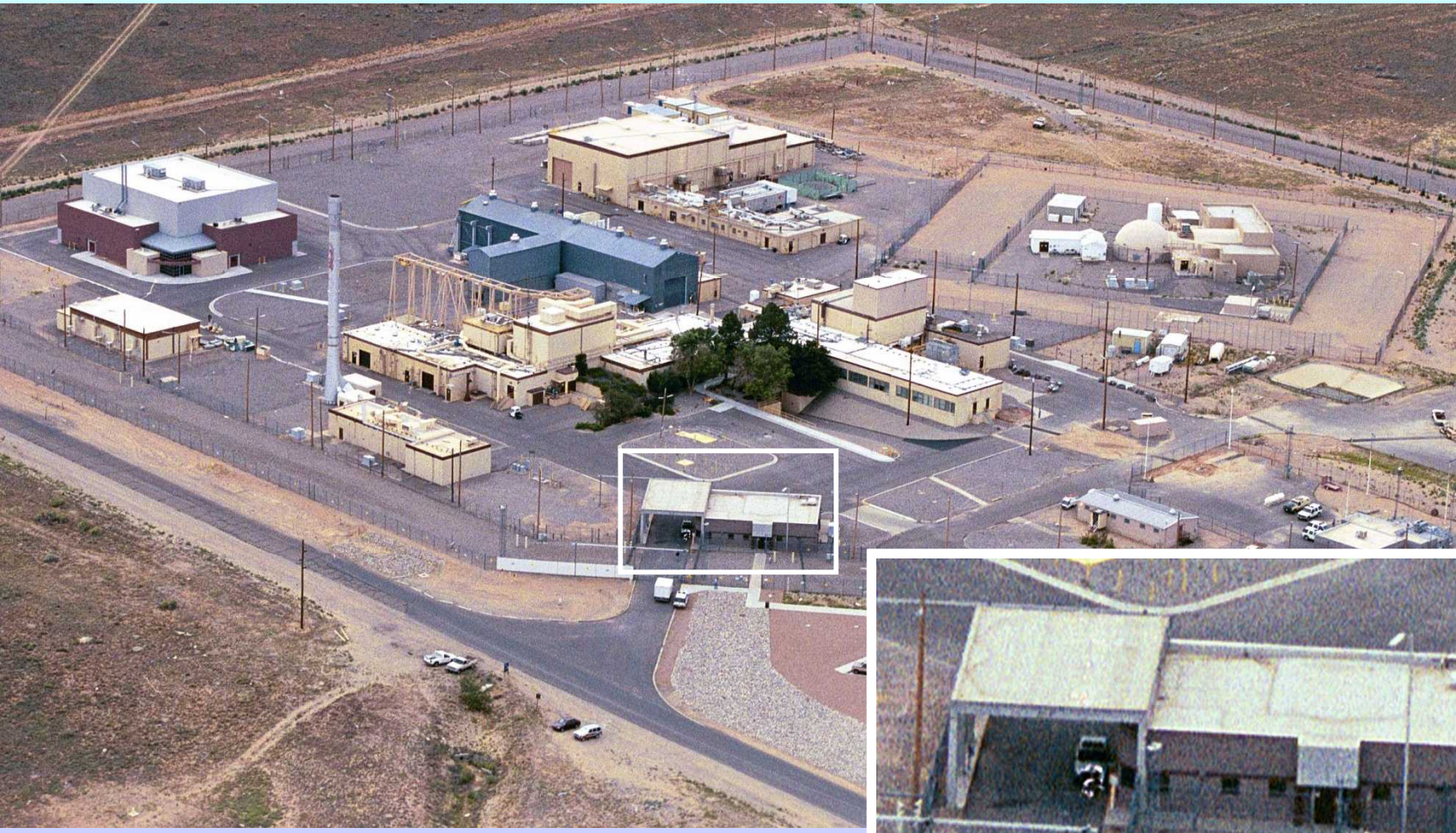
GAMMA IRRADIATION FACILITY

Ronald Allen Knief
Organization 1382

_____
__/__/20__

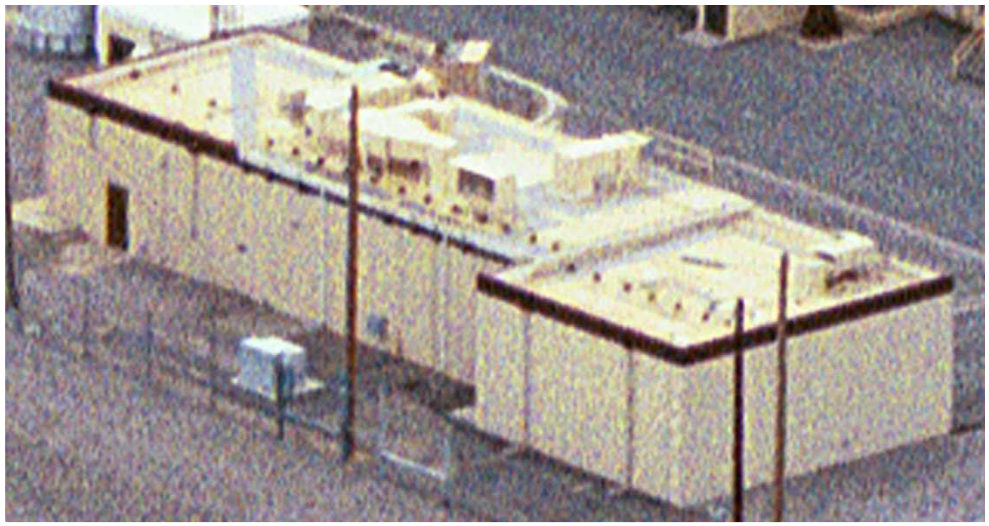
TA-V

TA-V – “C5”



Security Control

TA-V – 6582



TA-V Emergency Evacuation Center

SNL TA-V NUCLEAR FACILITIES

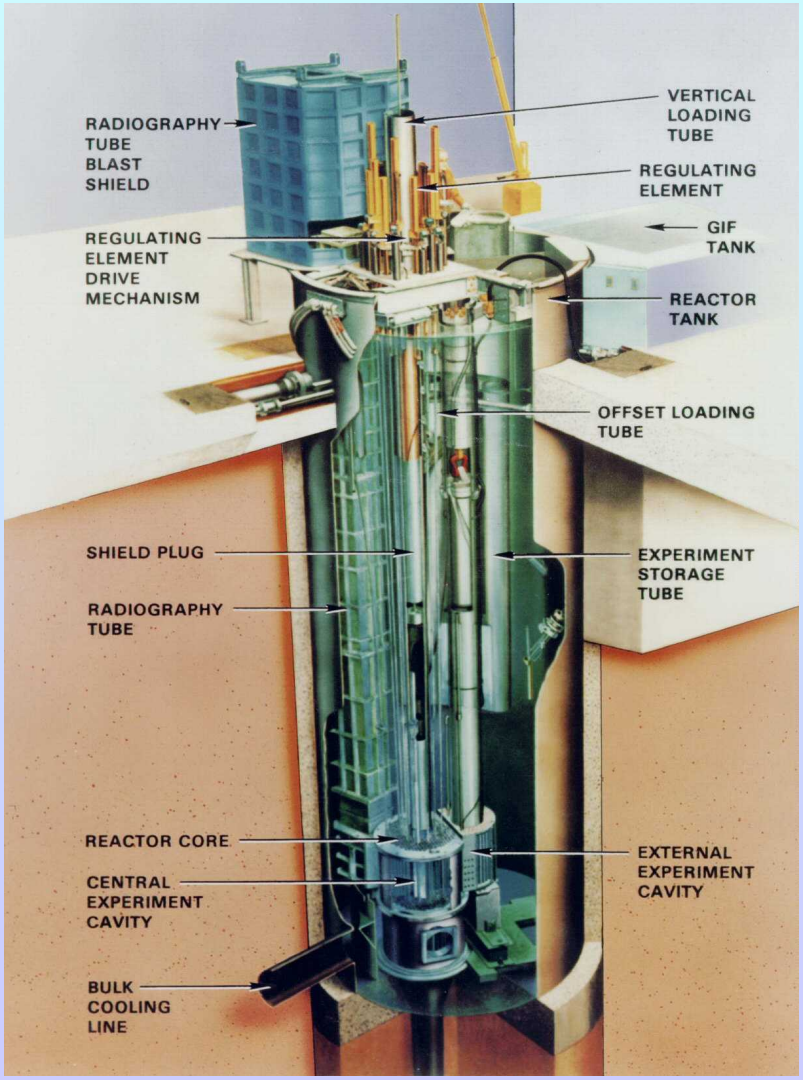
- REACTORS

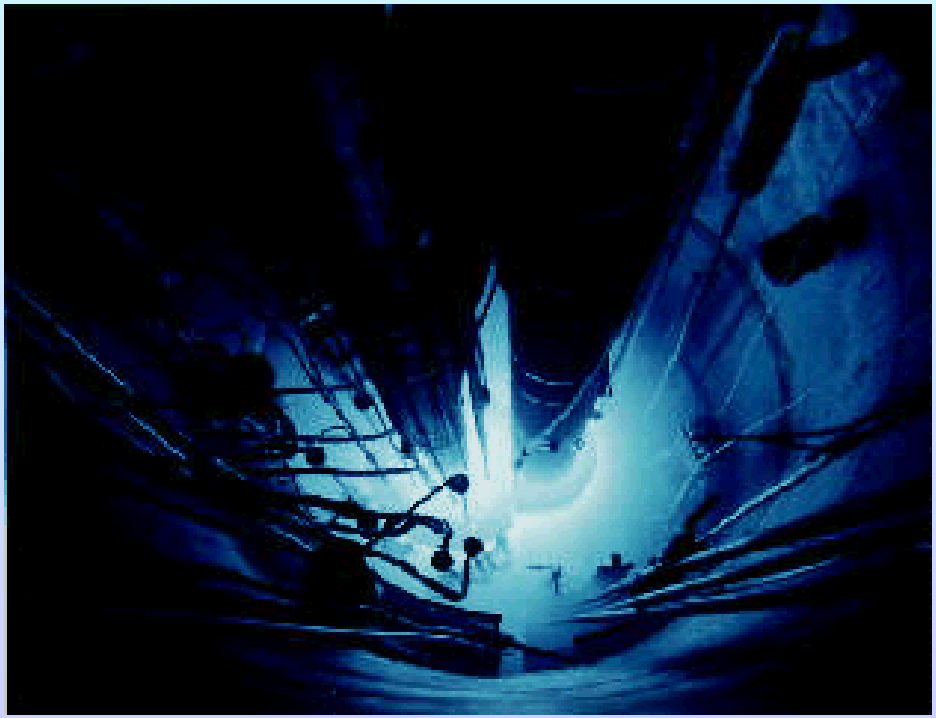
- HOT CELL & IRRADIATION FACILITIES

SNL TA-V Nuclear Facilities

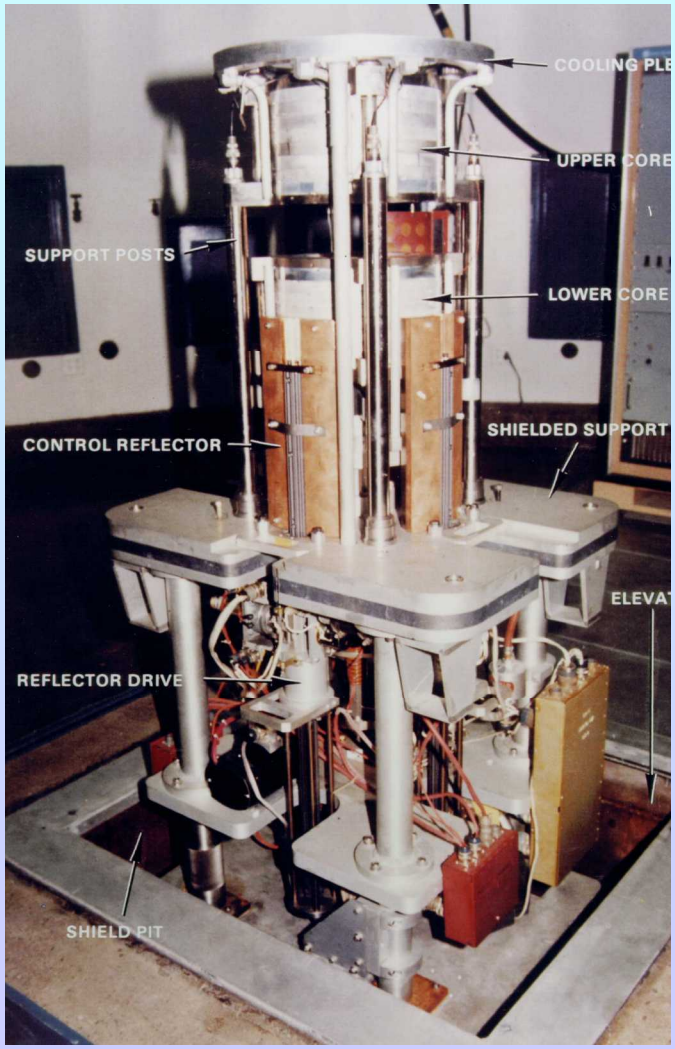
- REACTORS & CRITICAL ASSEMBLIES
  - Annular Core Research Reactor (ACRR)
  - Sandia Pulse Reactor (SPR) & Sandia Critical Experiments (SCX)
- HOT CELL & IRRADIATION FACILITIES

ACRR Facility



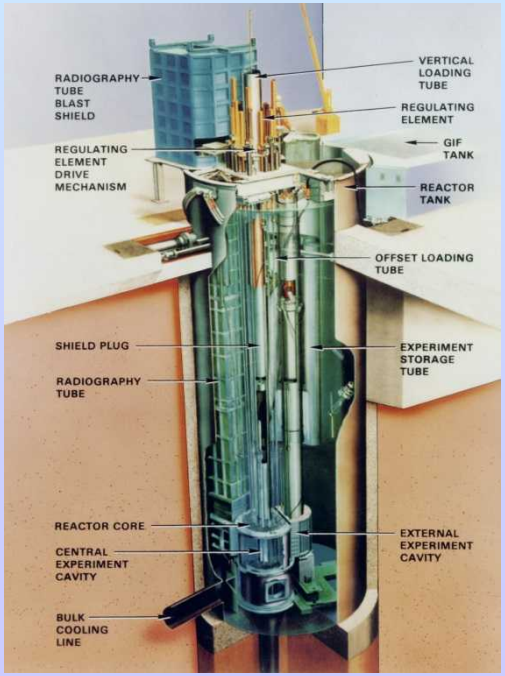


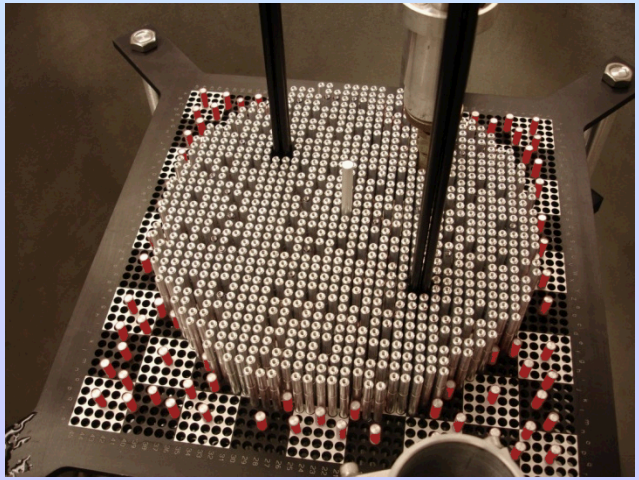
SPR-III Facility



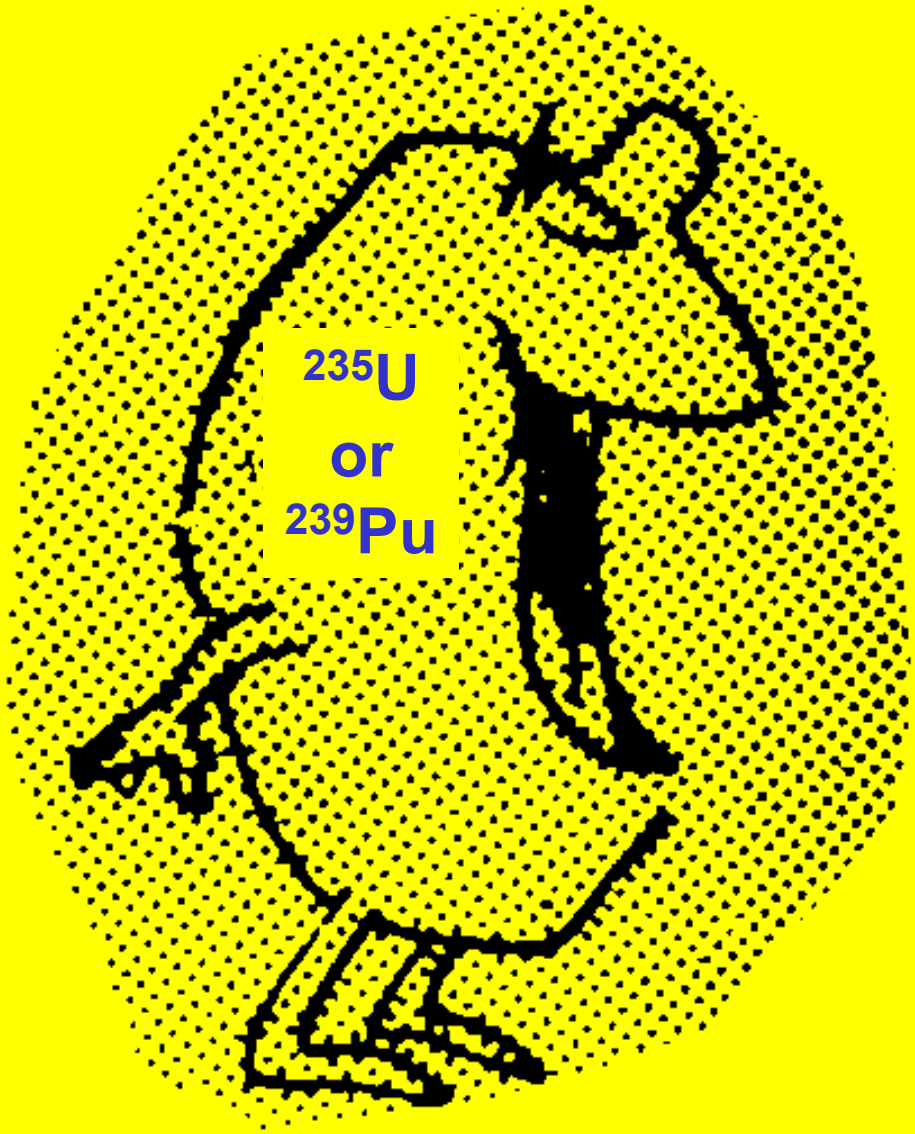
SNL TA-V NUCLEAR FACILITIES

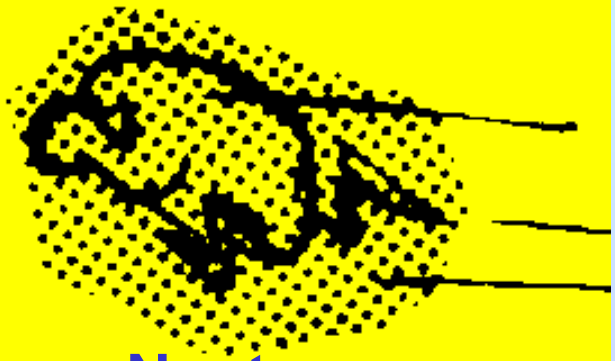
- REACTORS
  - Annular Core Research Reactor (ACRR)
  - Sandia Pulse Reactor (SPR)



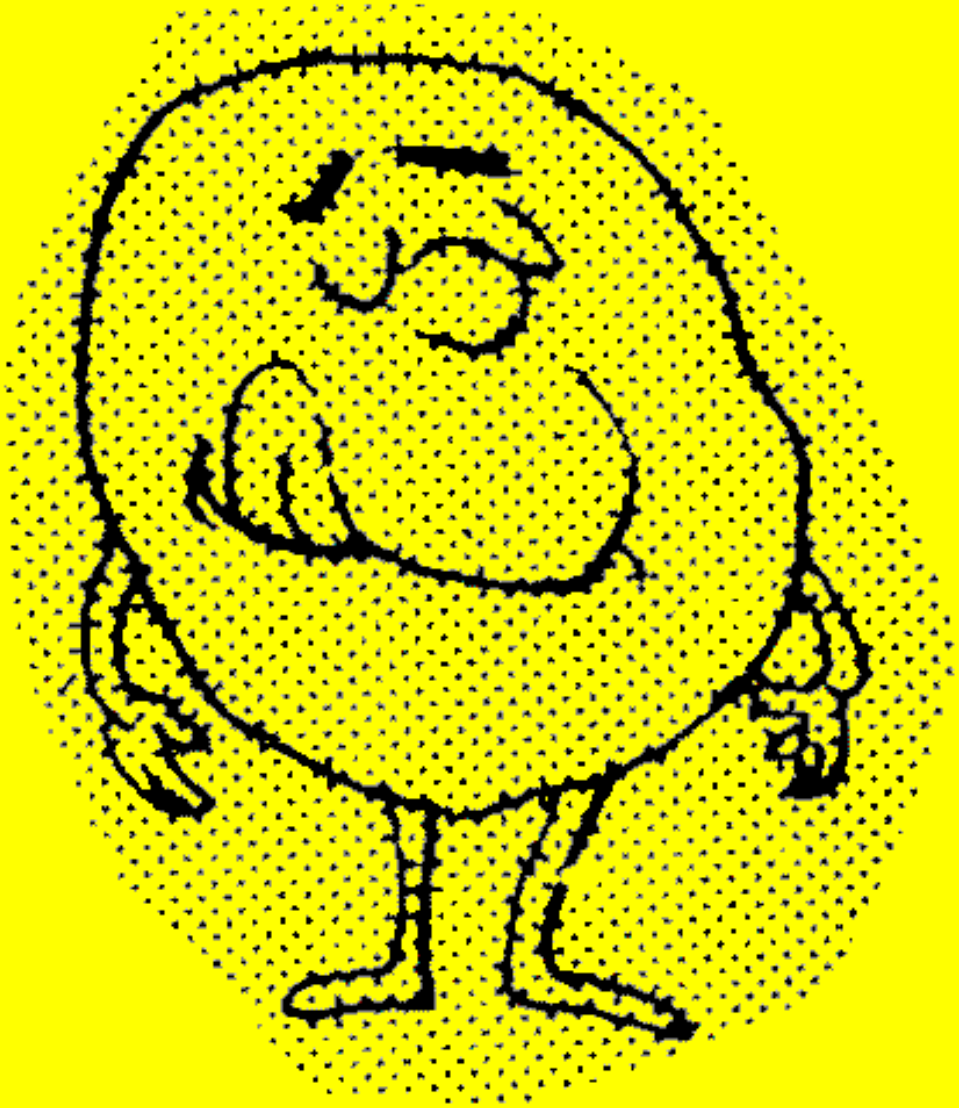


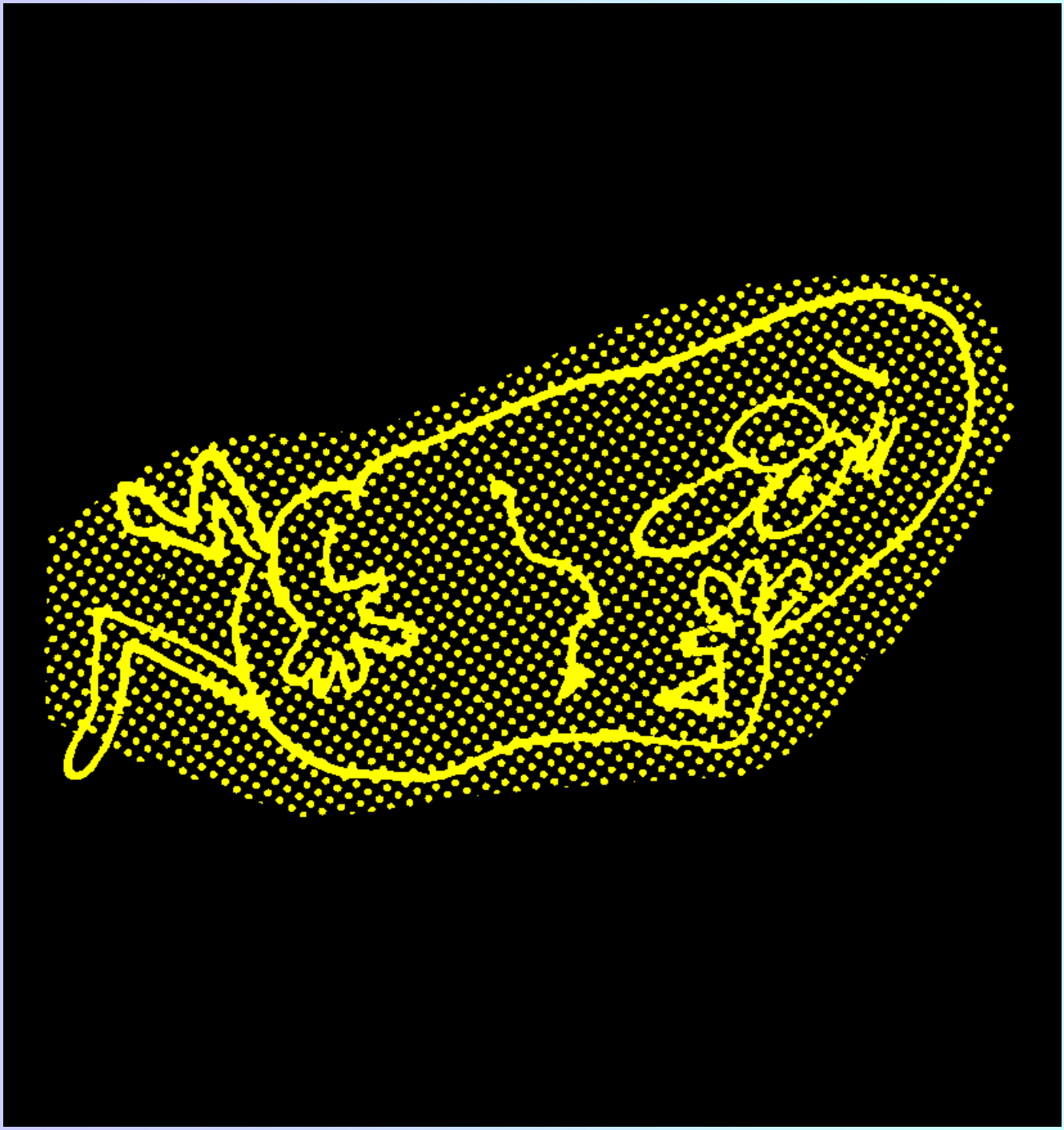
FISSION

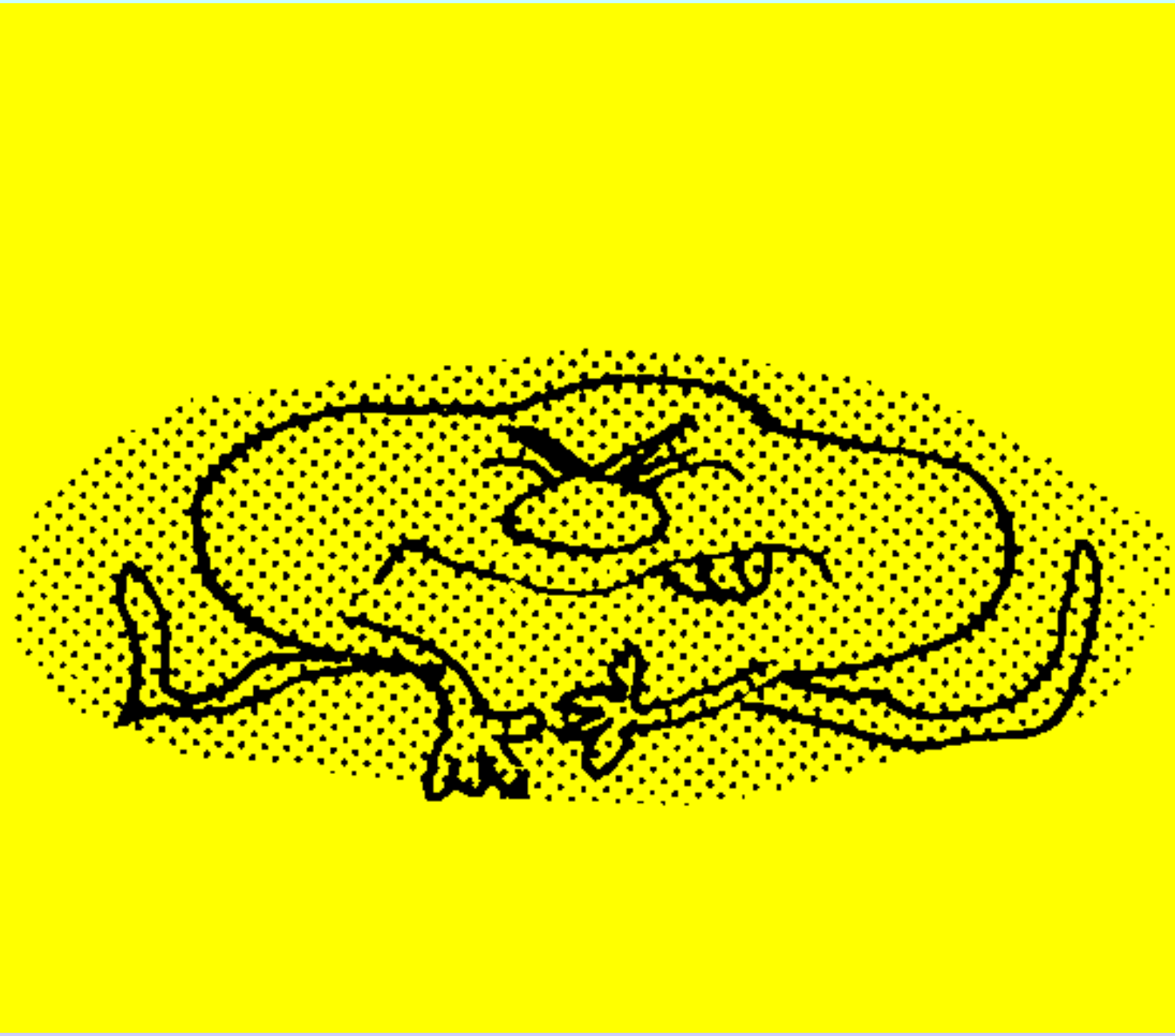


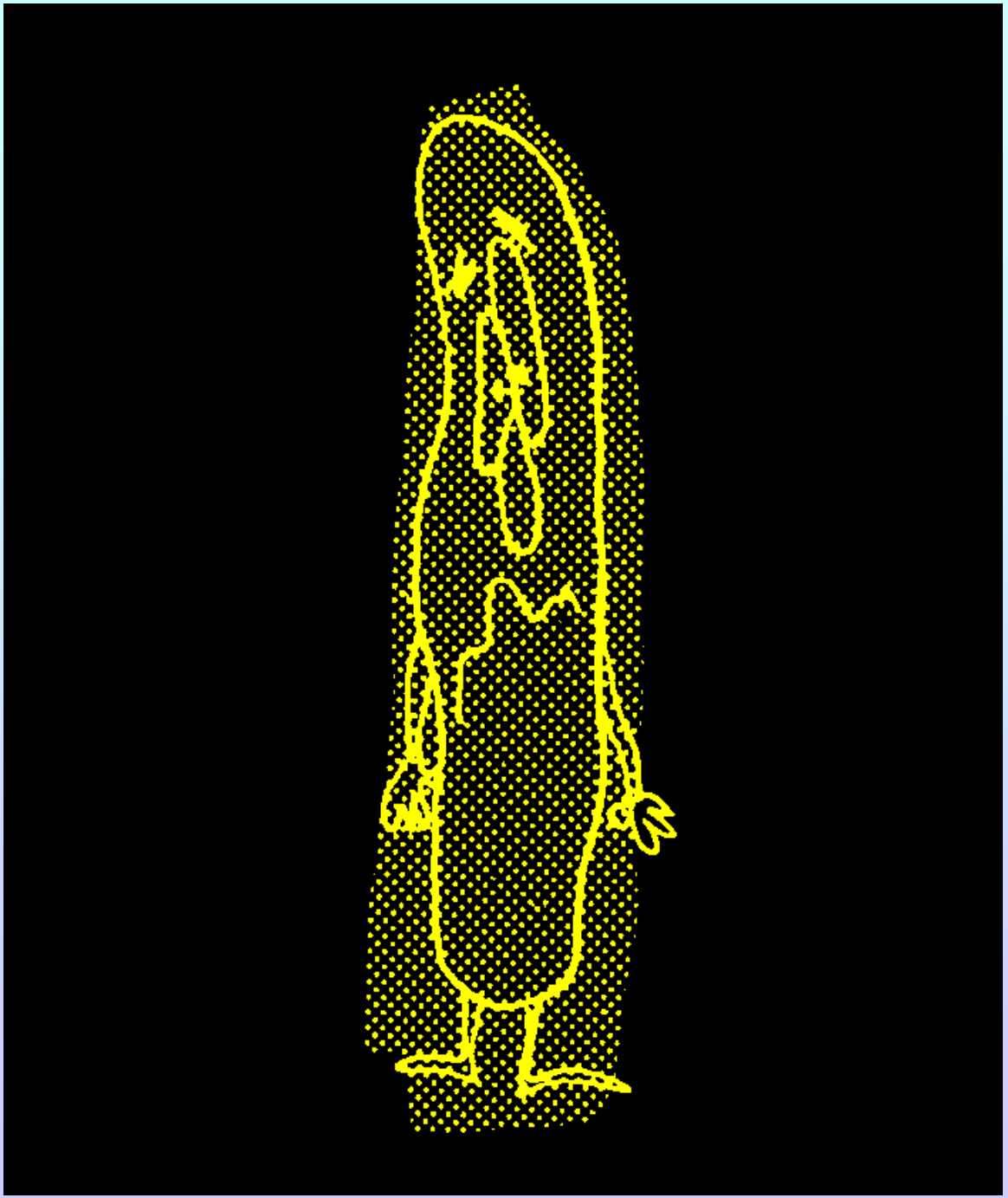


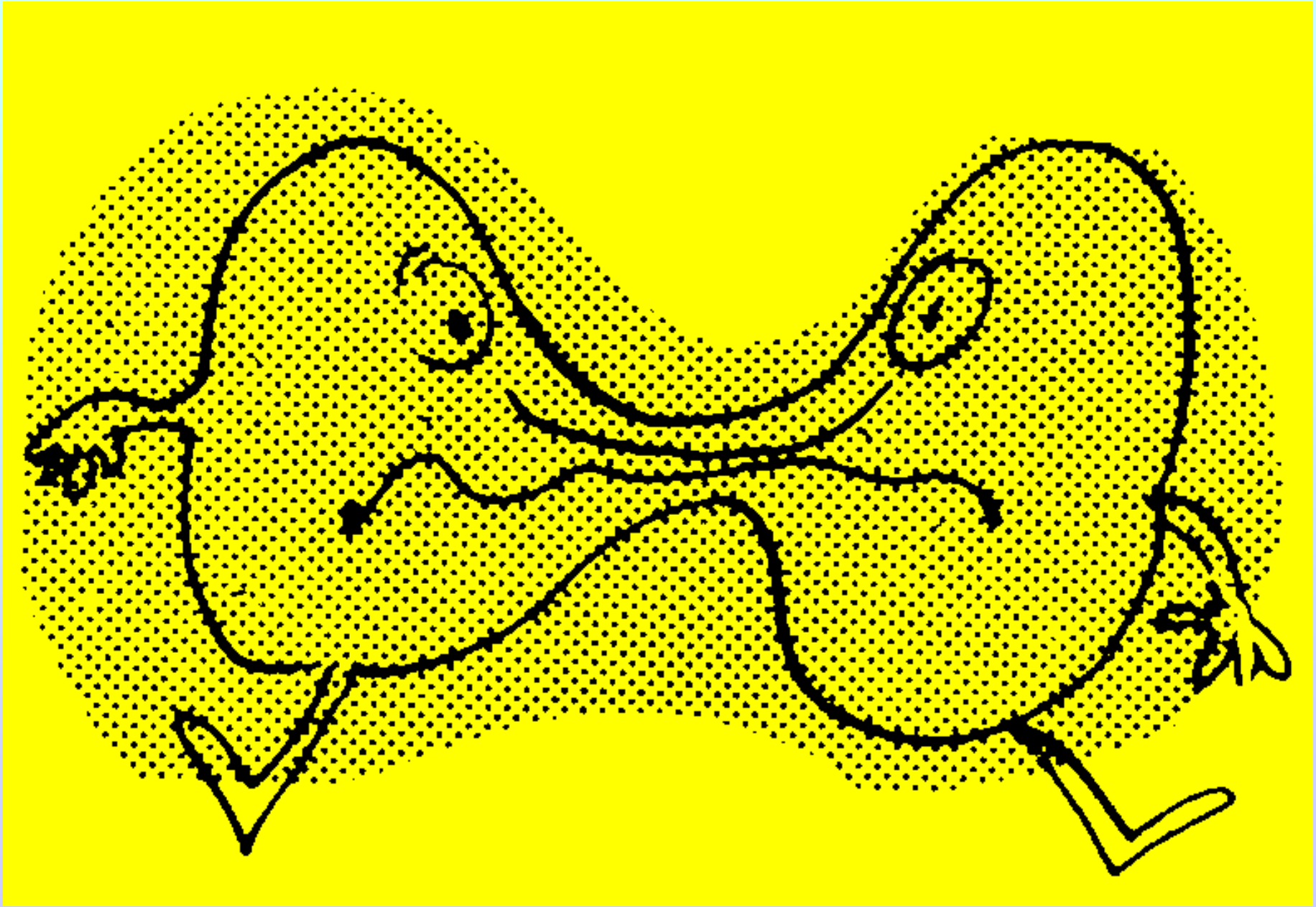
Neutron

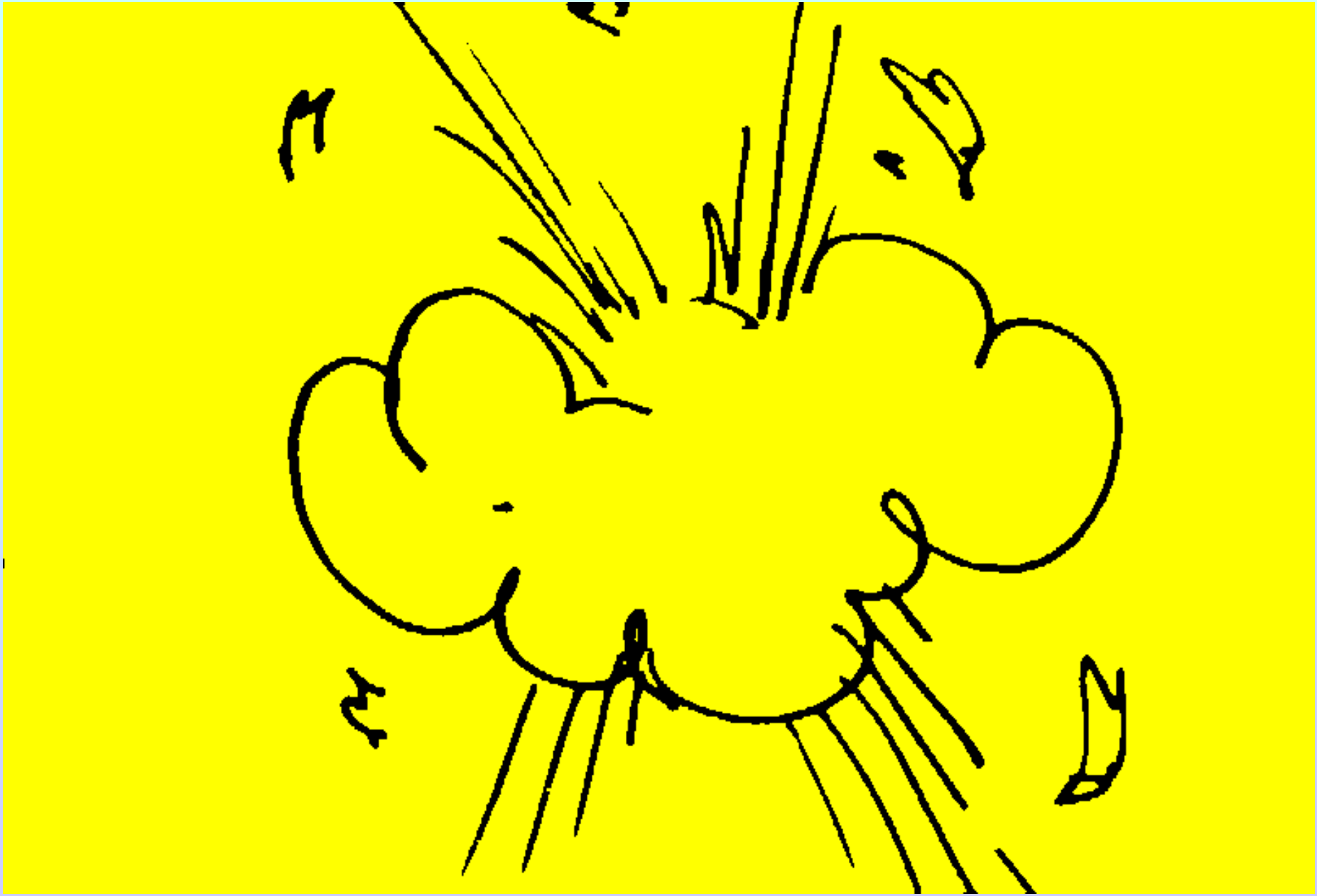


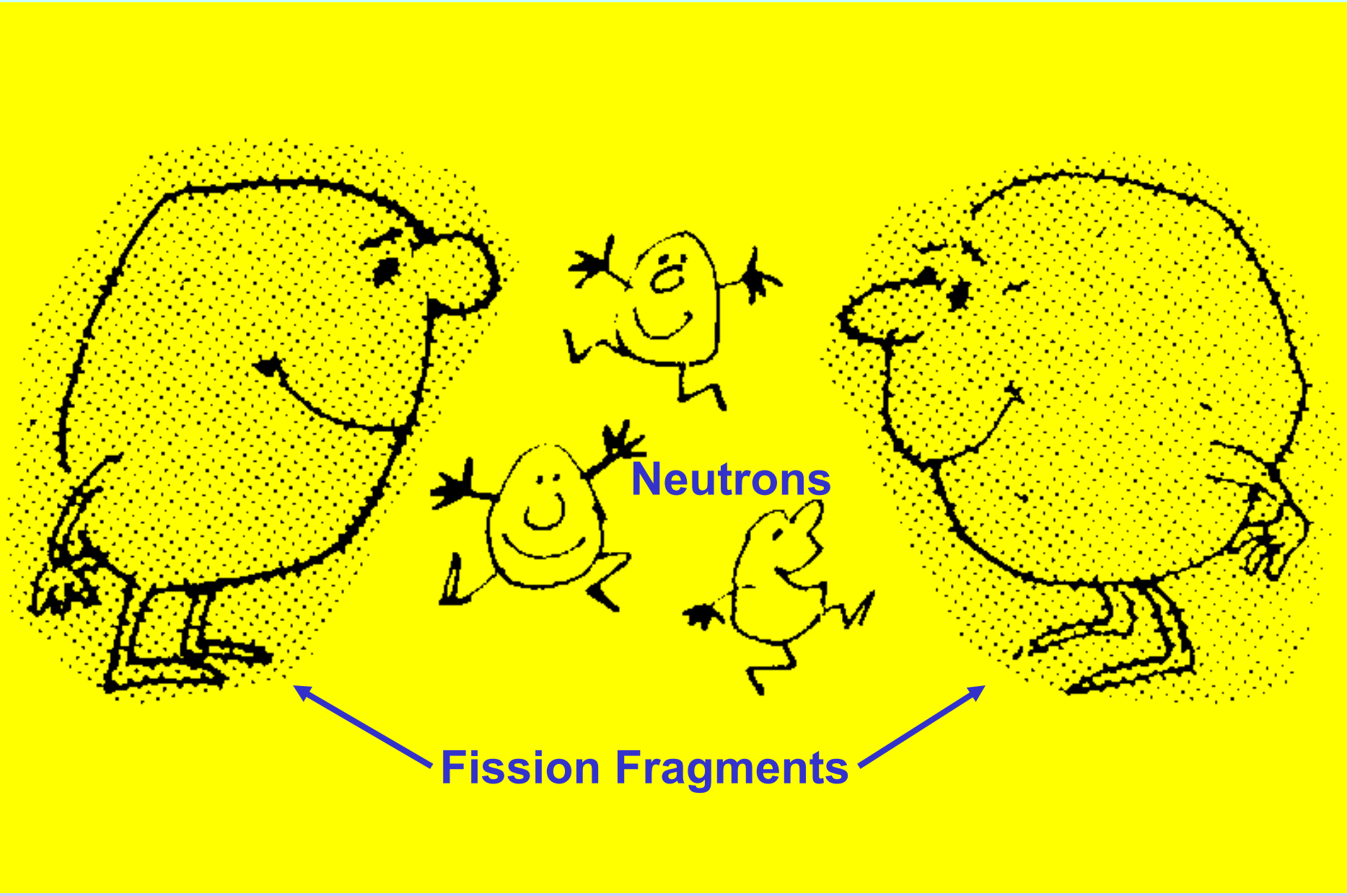











Neutrons
Fission Fragments

Nuclear Fission

- ADVANTAGES
  - Energy Output / Heat


1 LB U-235
=
COAL

NUCLEAR FISSION

- ADVANTAGES
  - Energy Output / Heat

Nuclear Fission

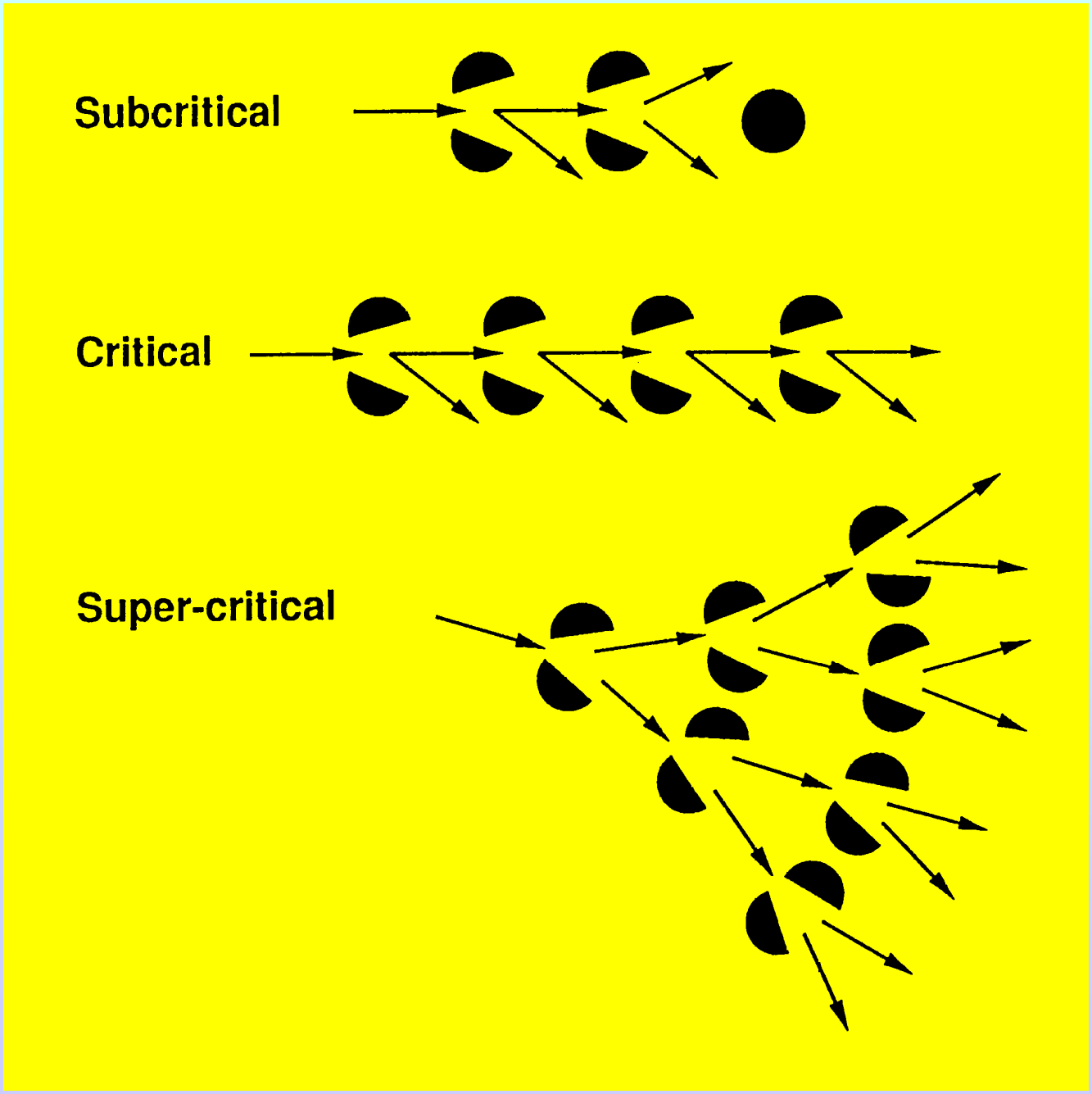
- ADVANTAGES
  - Energy Output – Exploitation
    - "Manhattan Project"
      - Nuclear-Weapon Concept
      - Research & Production Reactors
      - Nuclear Weapons
    - Naval Propulsion
    - Commercial Nuclear Power

Nuclear Fission

- COMMERCIAL NUCLEAR POWER
  - Palo Verde Nuclear Station
    - Near Phoenix, Arizona
    - Largest Nuclear Site in the United States
      - 3 Units @ 1270 MWe Each
      - 3 810 MWe Total – ~12 000 MWth
    - Owned 10% by Public Service of New Mexico (PNM); Electricity for ~400,000 Homes

Nuclear Fission

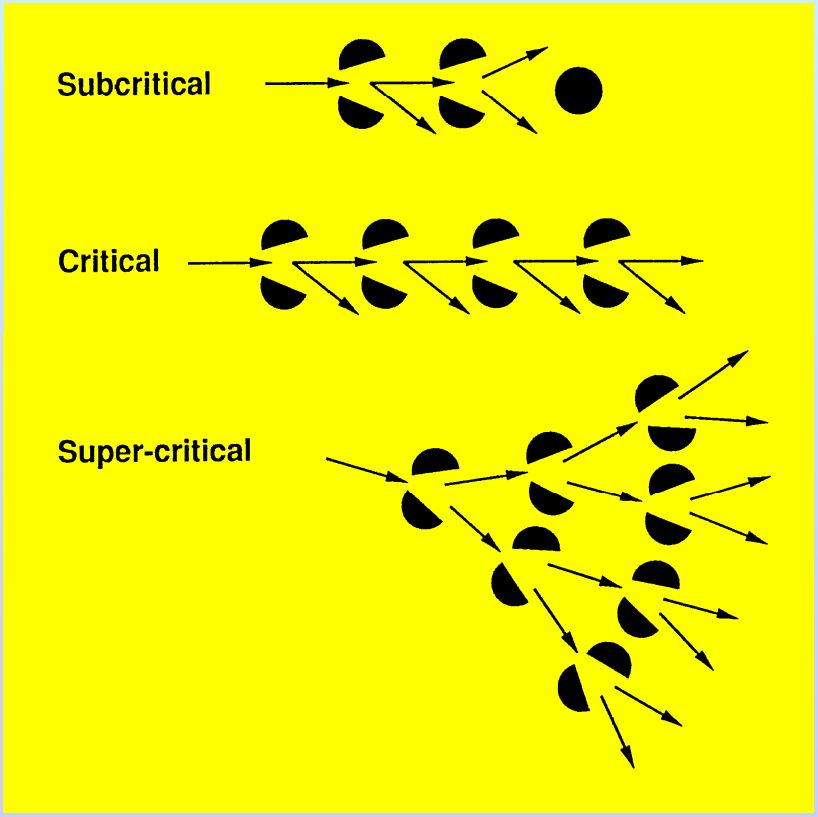
- ADVANTAGES
  - Energy Output / Heat
  - Neutrons



Neutron Chain Reaction

NUCLEAR FISSION

- ADVANTAGES
  - Energy Output / Heat
  - Neutrons



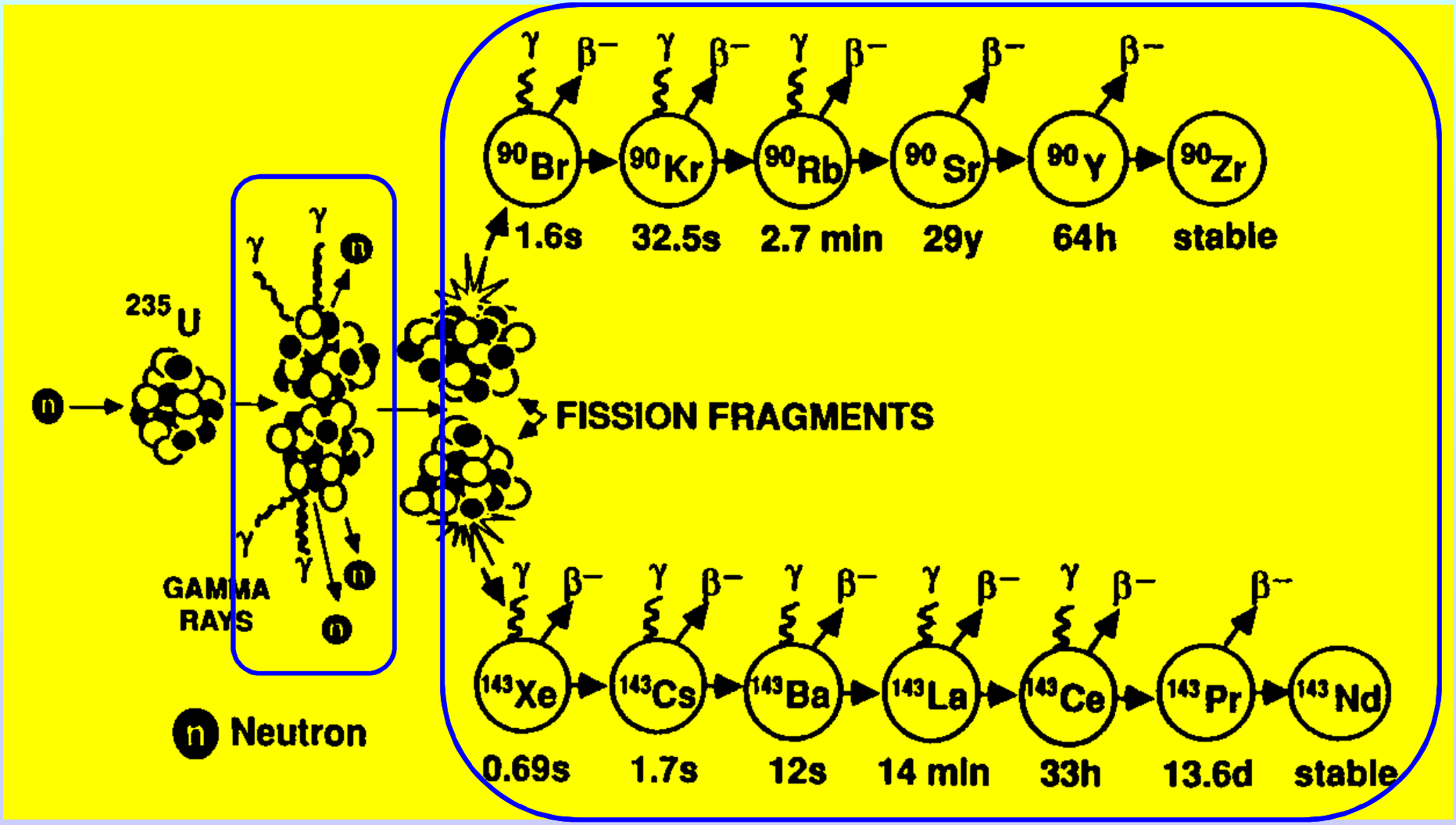
Nuclear Fission

- ADVANTAGES
  - Energy Output / Heat
  - Neutrons
- DISADVANTAGES
  - Fission Radiation
  - Fission-Product Radiation

NUCLEAR FISSION

- ADVANTAGES
  - Energy Output / Heat
  - Neutrons
- DISADVANTAGES
  - Fission Radiation
  - Fission-Product Radiation

Nuclear Fission



NUCLEAR FISSION

- ADVANTAGES
  - Energy Output / Heat
  - Neutrons

- DISADVANTAGES
  - Fission Radiation
  - Fission-Product Radiation

← Only reason why most SNL TA-V reactors have existed!

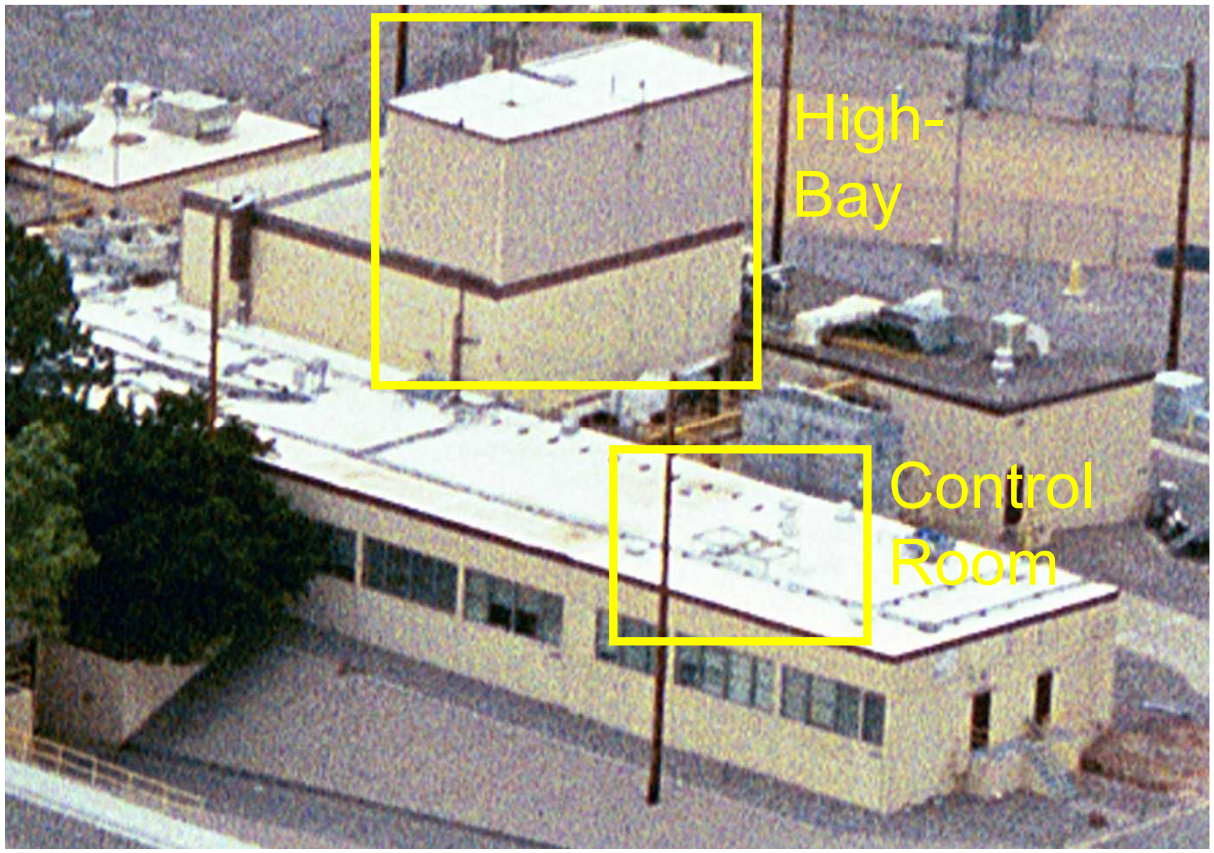
ANNULAR CORE

RESEARCH REACTOR

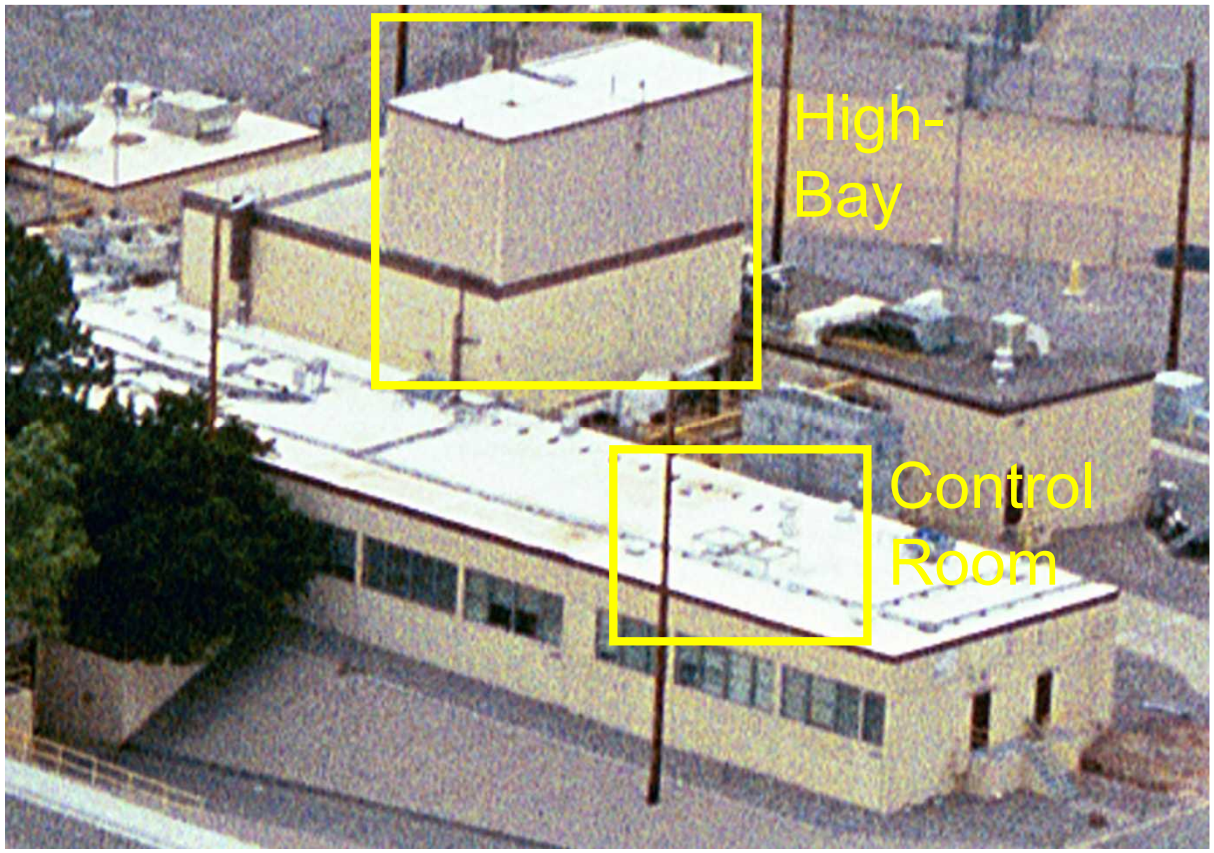
(ACRR)

FACILITY

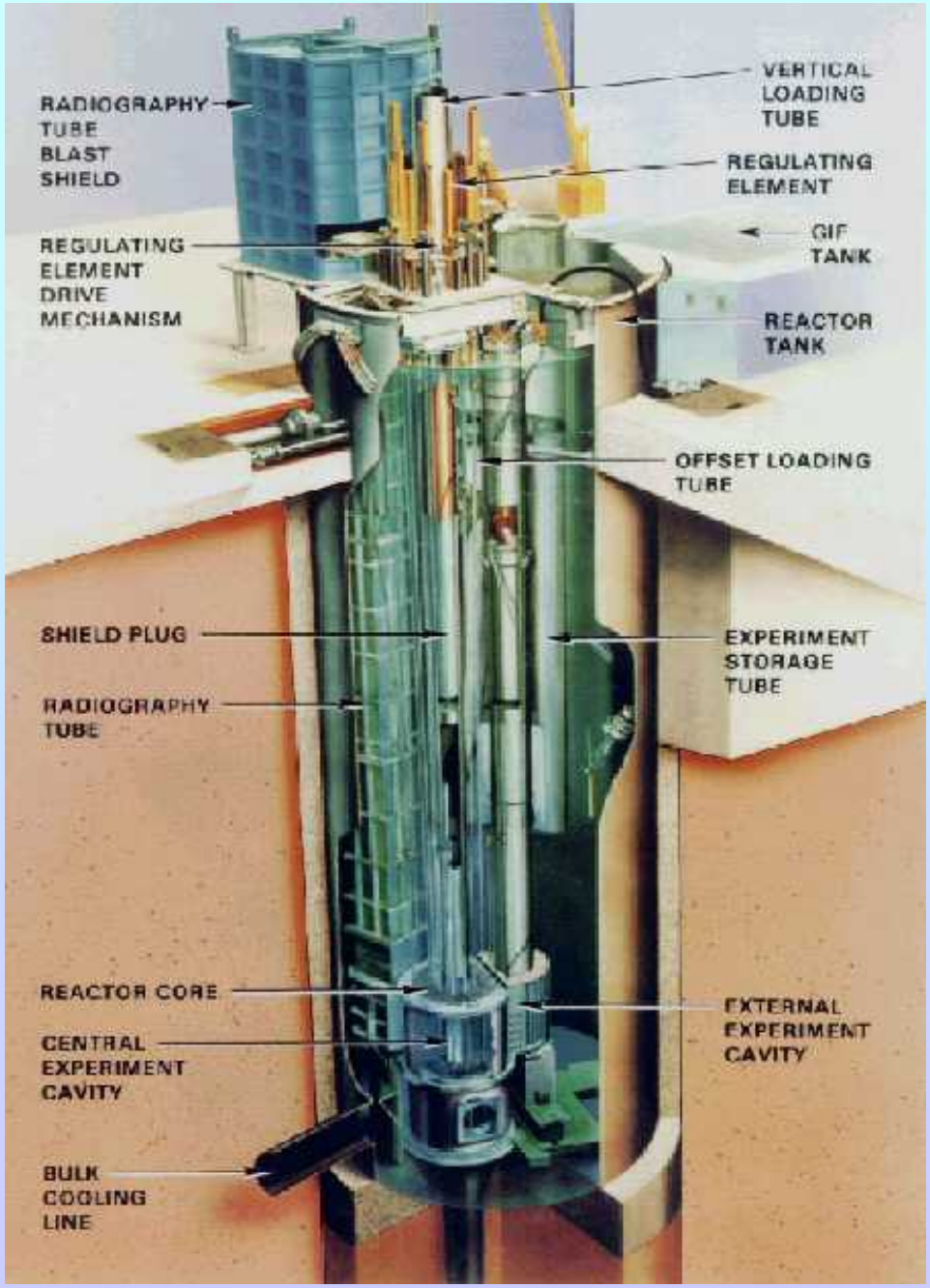
TA-V – ACRR



TA-V – ACRR

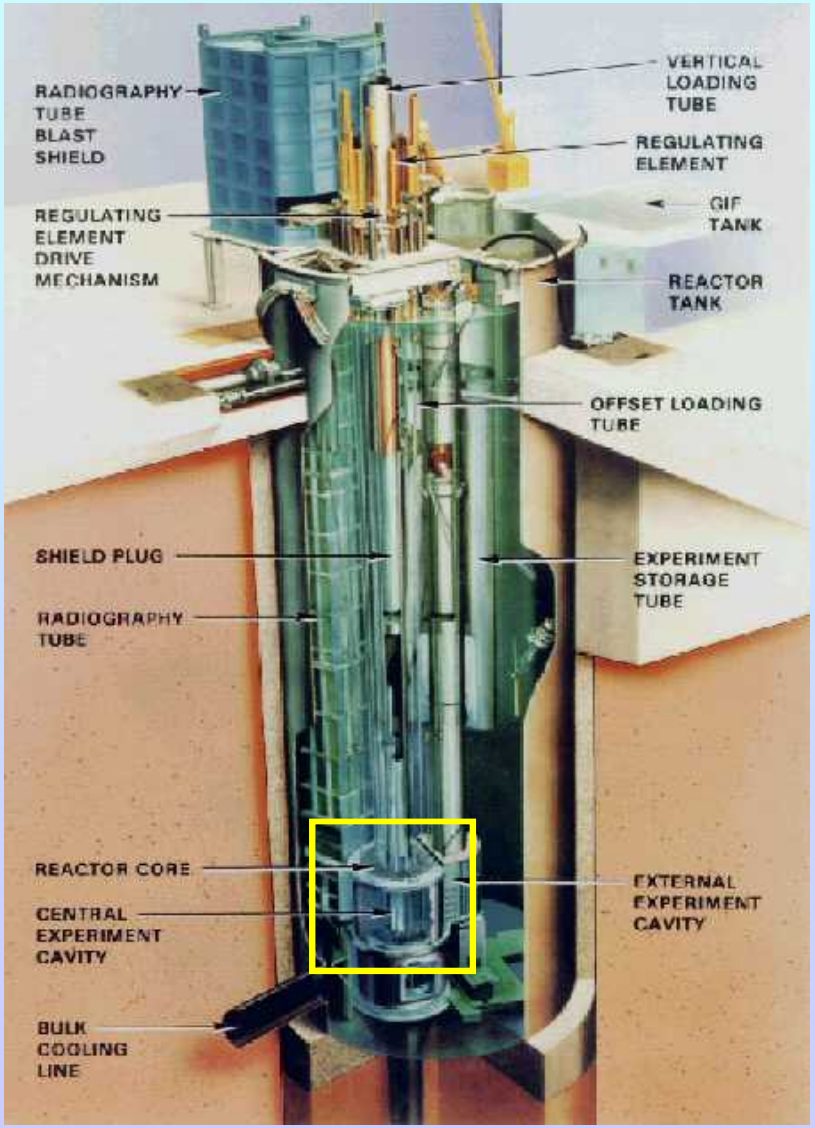


ACRR Facility



ACRR FEATURES

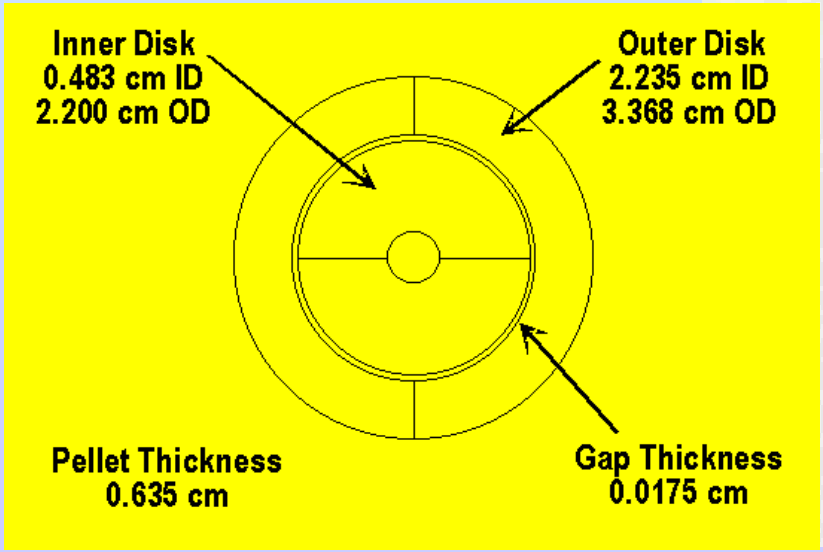
- "POOL-TYPE" REACTOR DESIGN
  - Water in Pool
    - Moderates/Thermalizes Neutrons in Chain Reaction
    - Provides Convective Cooling
    - Provides Radiation Shielding

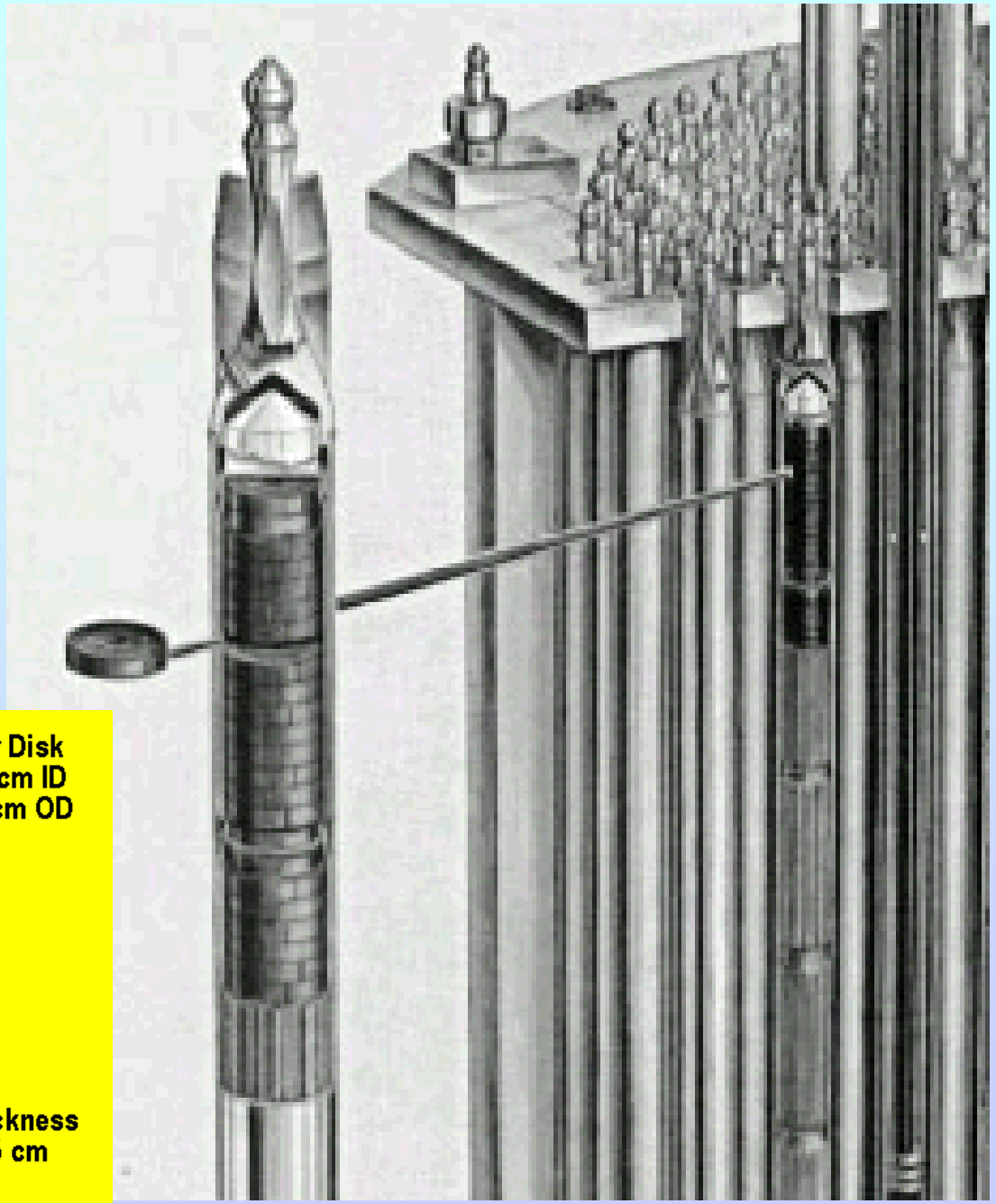


ACRR FEATURES

- POWER CAPABILITY
  - 2-4 MW(th) Steady-State
  - 35,000 MW(th) Maximum Pulse

ACRR Fuel


Inner Disk
0.483 cm ID
2.200 cm OD
Outer Disk
2.235 cm ID
3.368 cm OD
Pellet Thickness
0.635 cm
Gap Thickness
0.0175 cm

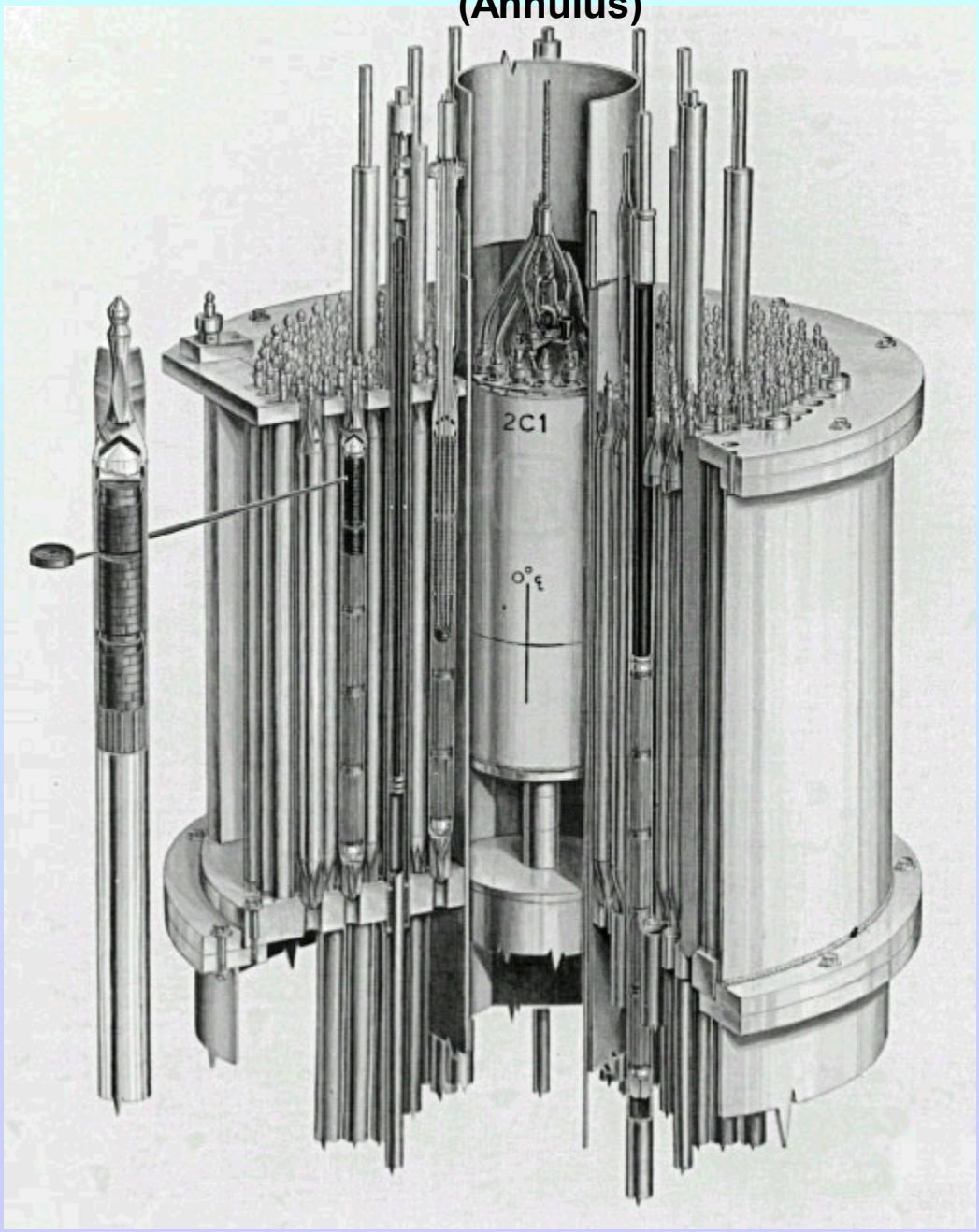


CRITICALITY CONTROL

- REACTOR – ACRR
  - Production ⇨ Uranium

Form	$UO_2 + BeO_2$
Enrichment	35 wt% ^{235}U
Amount	~102 g^{235}U/Element 228 elements
Fuel Followers on CR & SR	

ACRR Core



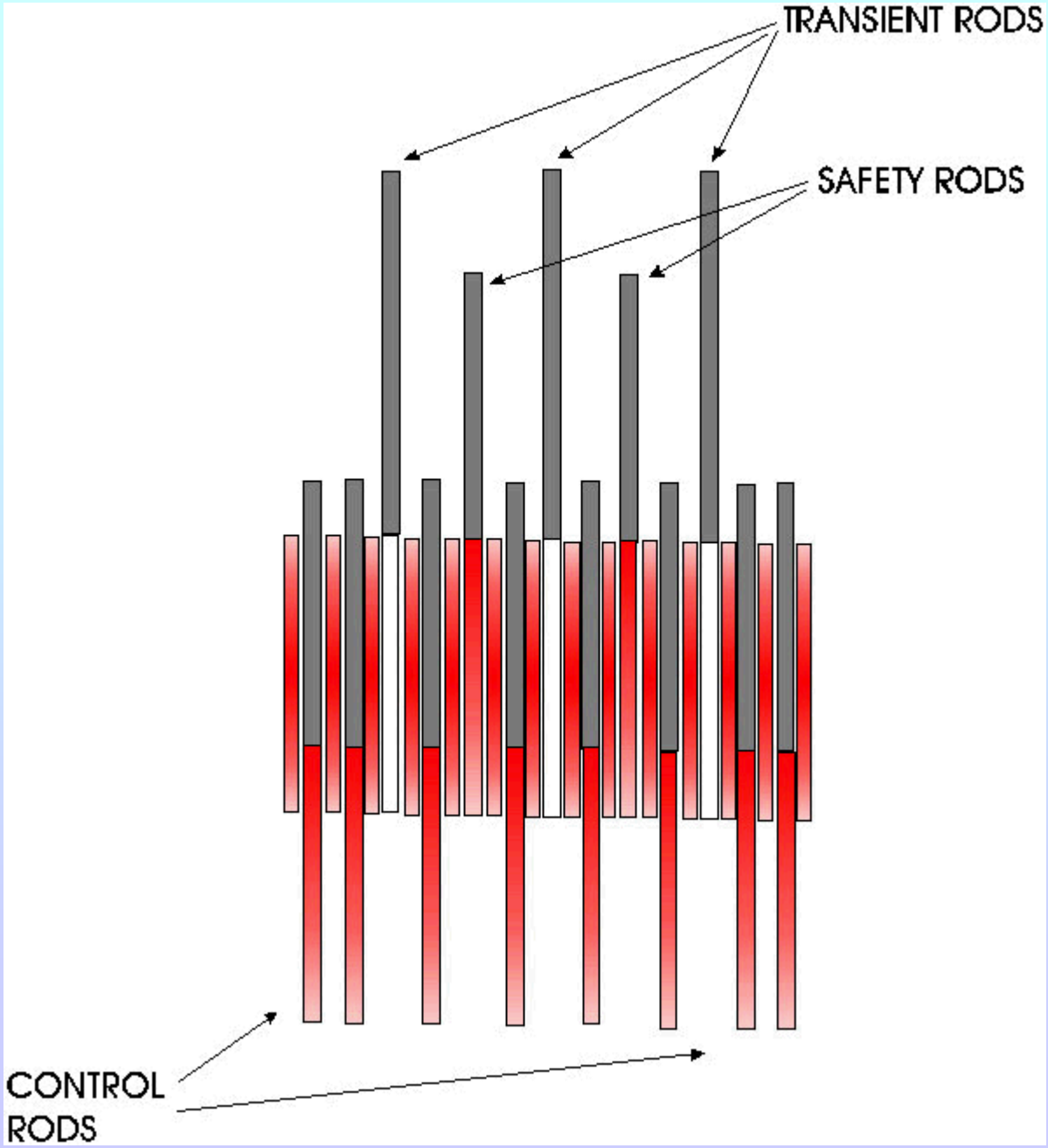
CRITICALITY CONTROL

- REACTOR – ACRR
  - Production
  - Absorption ⇨ B_4C “Poison” Control Rods
    - Change Power Level / Adjust to Maintain Steady Power — CR
    - Rapid Safety Shutdown ⇒ “Scram” — SR
    - ACRR: “Fire Out” to “Pulse” — TR

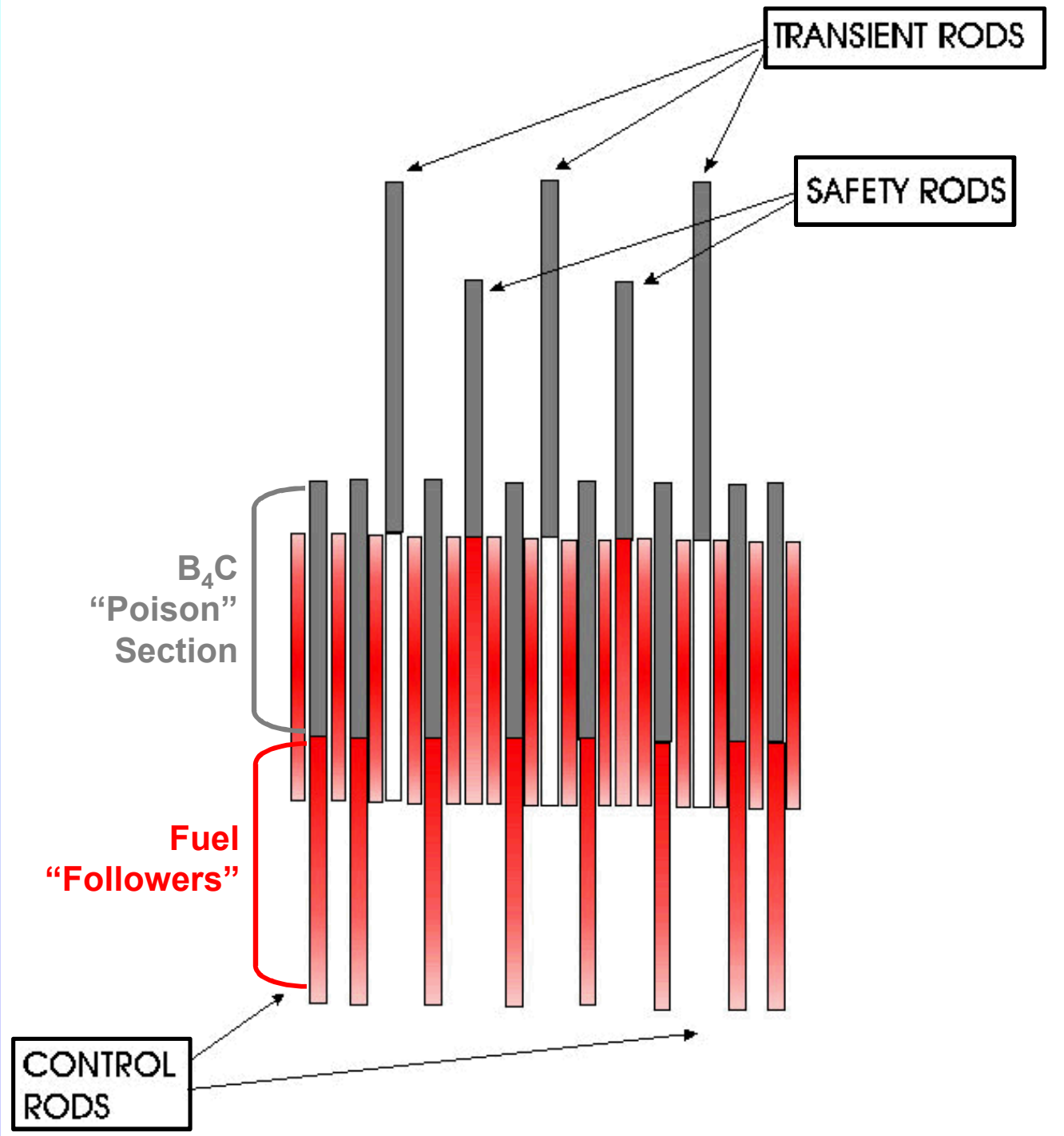
    - - - - -

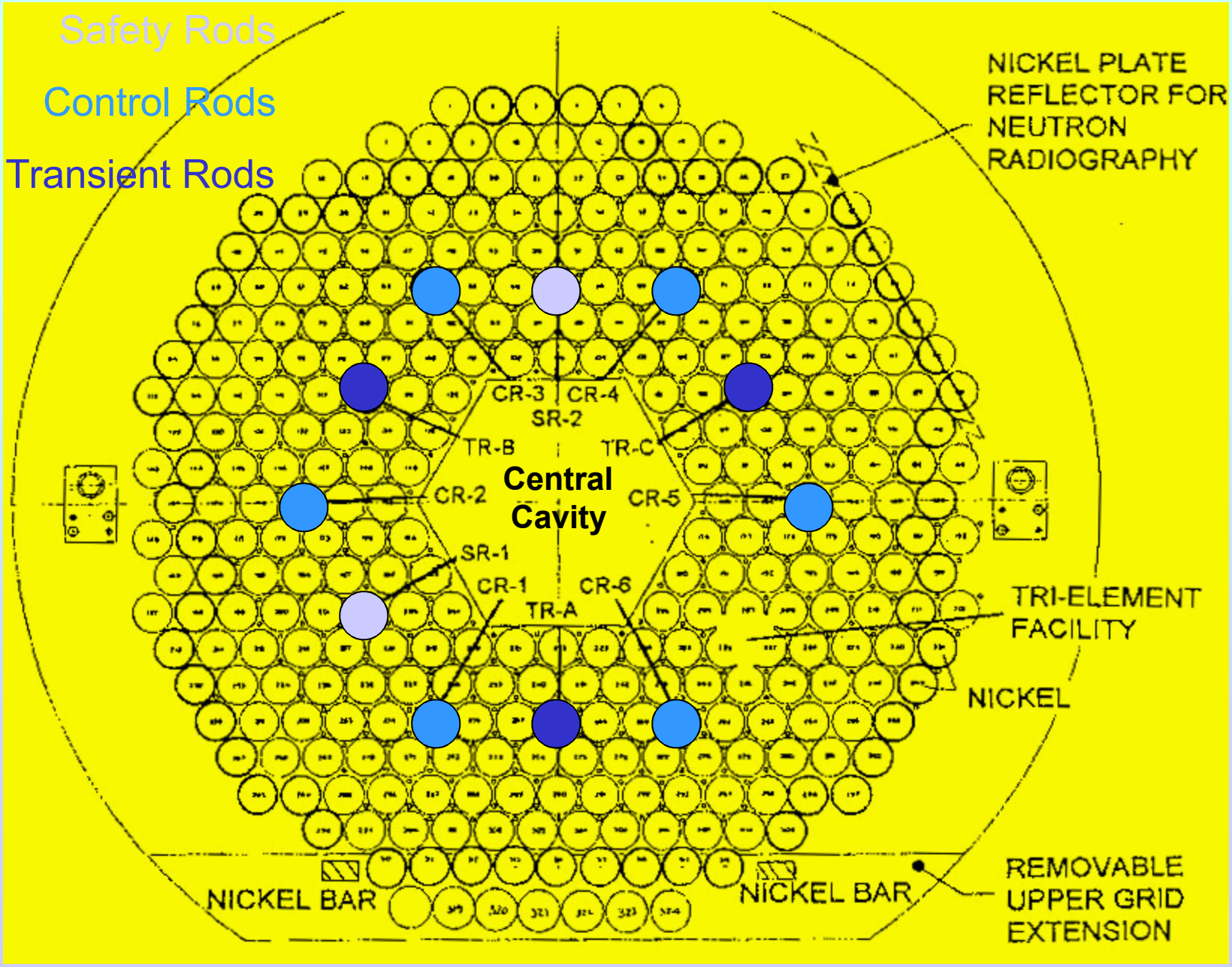
    - Rods Coupled to Drive Motors using Electromagnets
    - Scram on Loss of Power or Out-of-Range Parameter

ACRR Controlling Rods

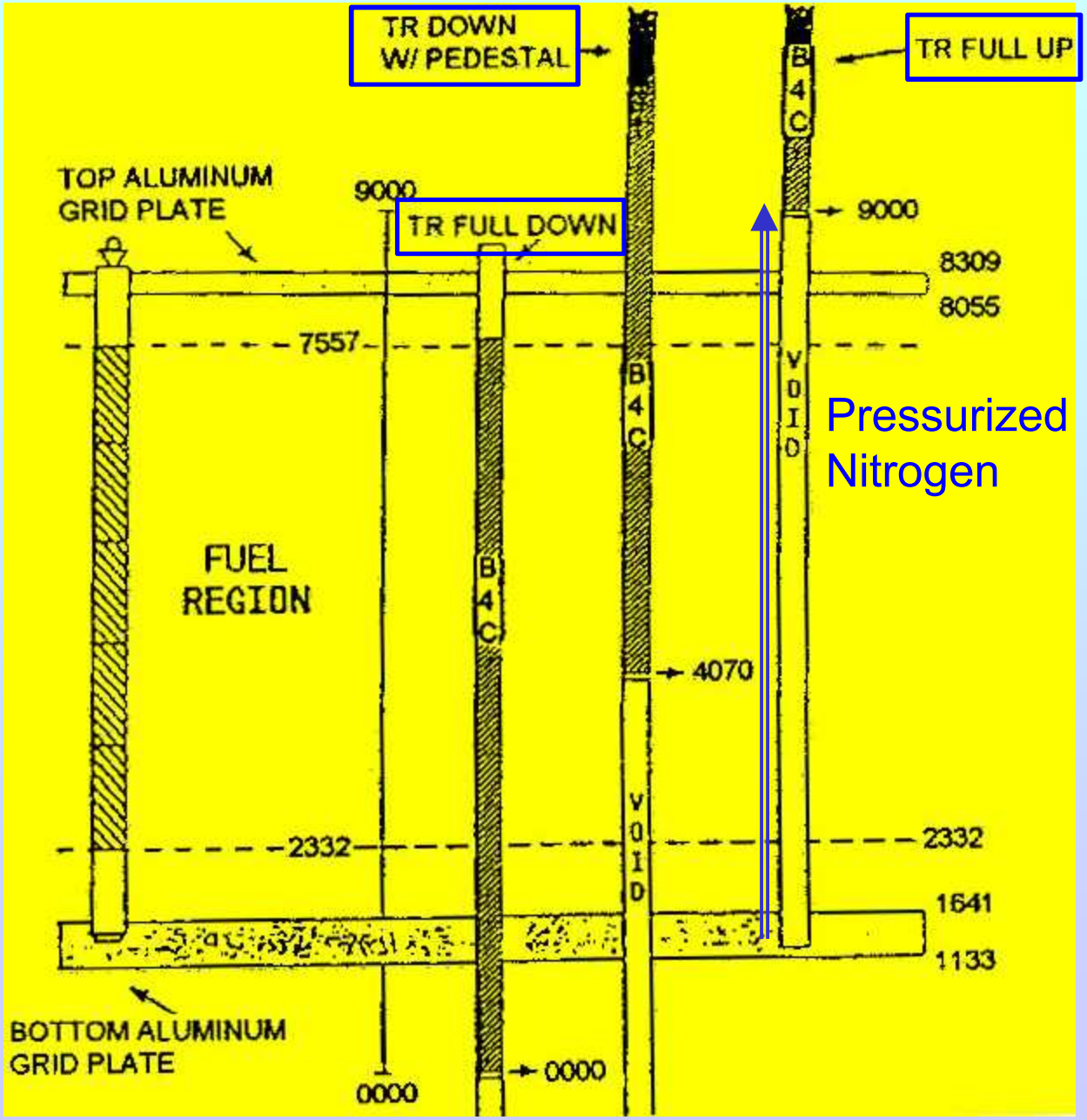


Controlling Rods



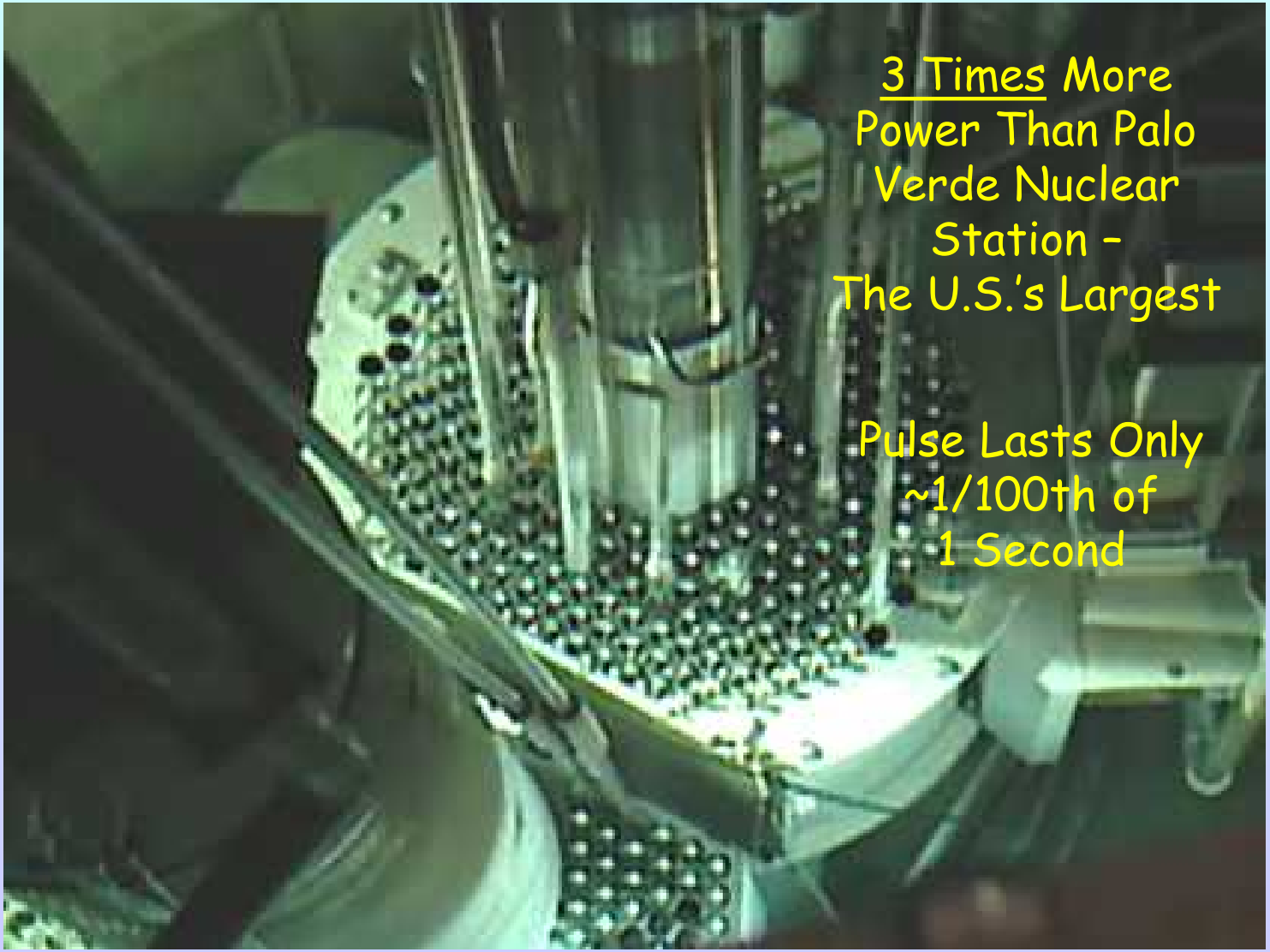

Safety Rods
Control Rods
Transient Rods
NICKEL PLATE
REFLECTOR FOR
NEUTRON
RADIOGRAPHY
CR-3
CR-4
SR-2
TR-B
TR-C
CR-2
Central
Cavity
CR-5
SR-1
CR-1
CR-6
TR-A
TRI-ELEMENT
FACILITY
NICKEL
NICKEL BAR
NICKEL BAR
REMOVABLE
UPPER GRID
EXTENSION

Transient Rod Operations



ACRR Pulse

[ACRR.mwv]




“Cherenkov”
Radiation

Pulse to 35 000 MWt

3 Times More Power Than Palo Verde Nuclear Station – The U.S.'s Largest

Pulse Lasts <1/100th Second

Palo Verde units have each run >500 days

"Cherenkov" Radiation

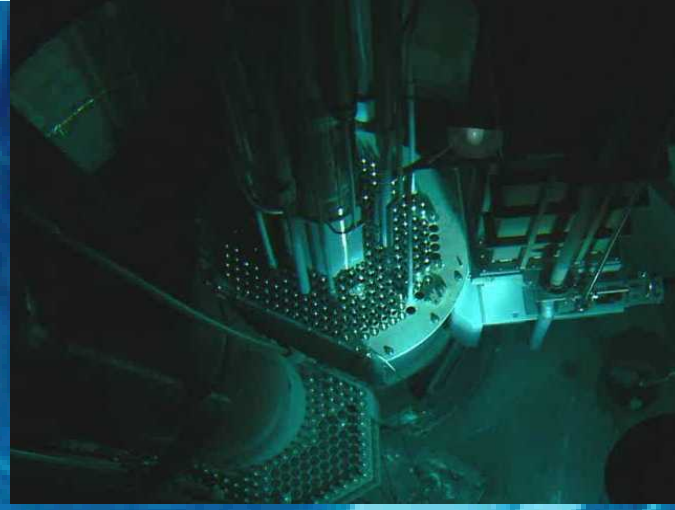
Fuel-Ringed Experiment Cavity (FREC-II)

ACRR

10,000th Pulse
https://www.youtube.com/watch?v=pa0Fmcv83nw

Pulse has 3 Times More Power Than Palo Verde Nuclear Station – The U.S.'s Largest

Pulse Lasts <1/100th Second



ACRR

Fuel-Ringed Experiment Cavity (FREC-II)

"Cherenkov" Radiation

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Pulse to 35 000 MWt

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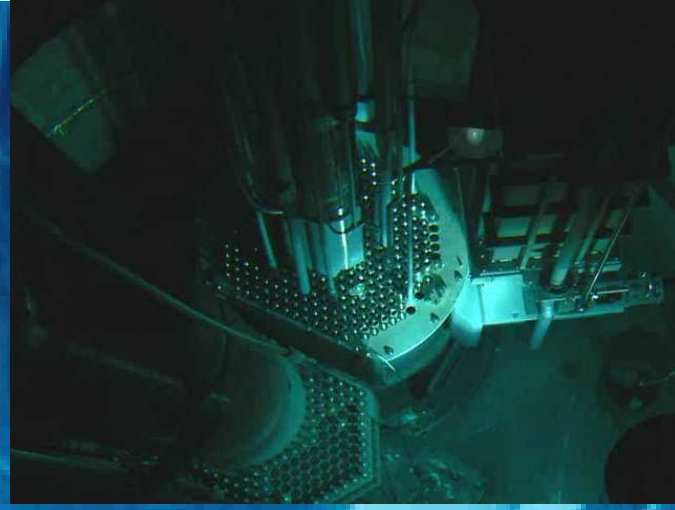


"Cherenkov" Radiation

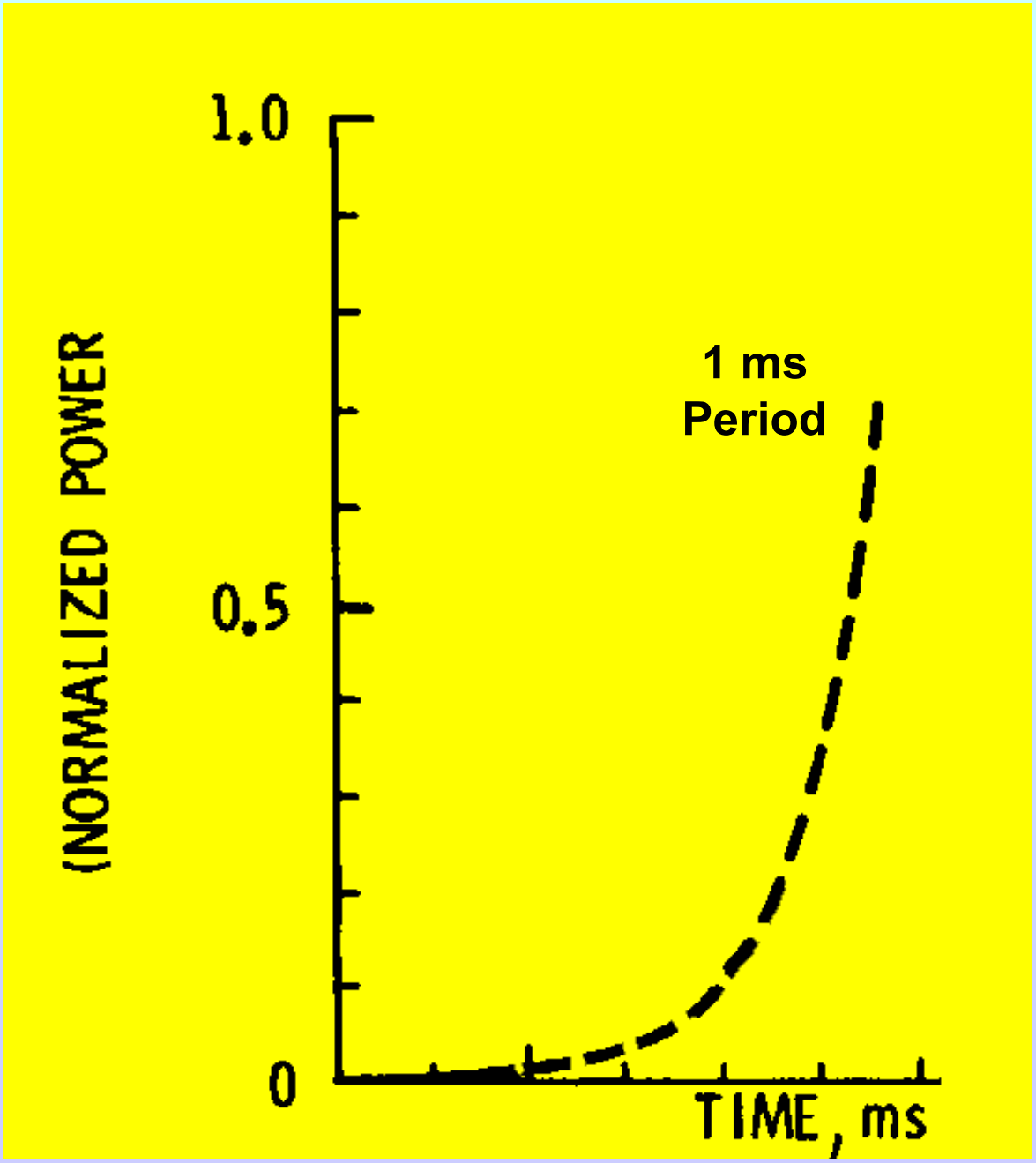
ACRR

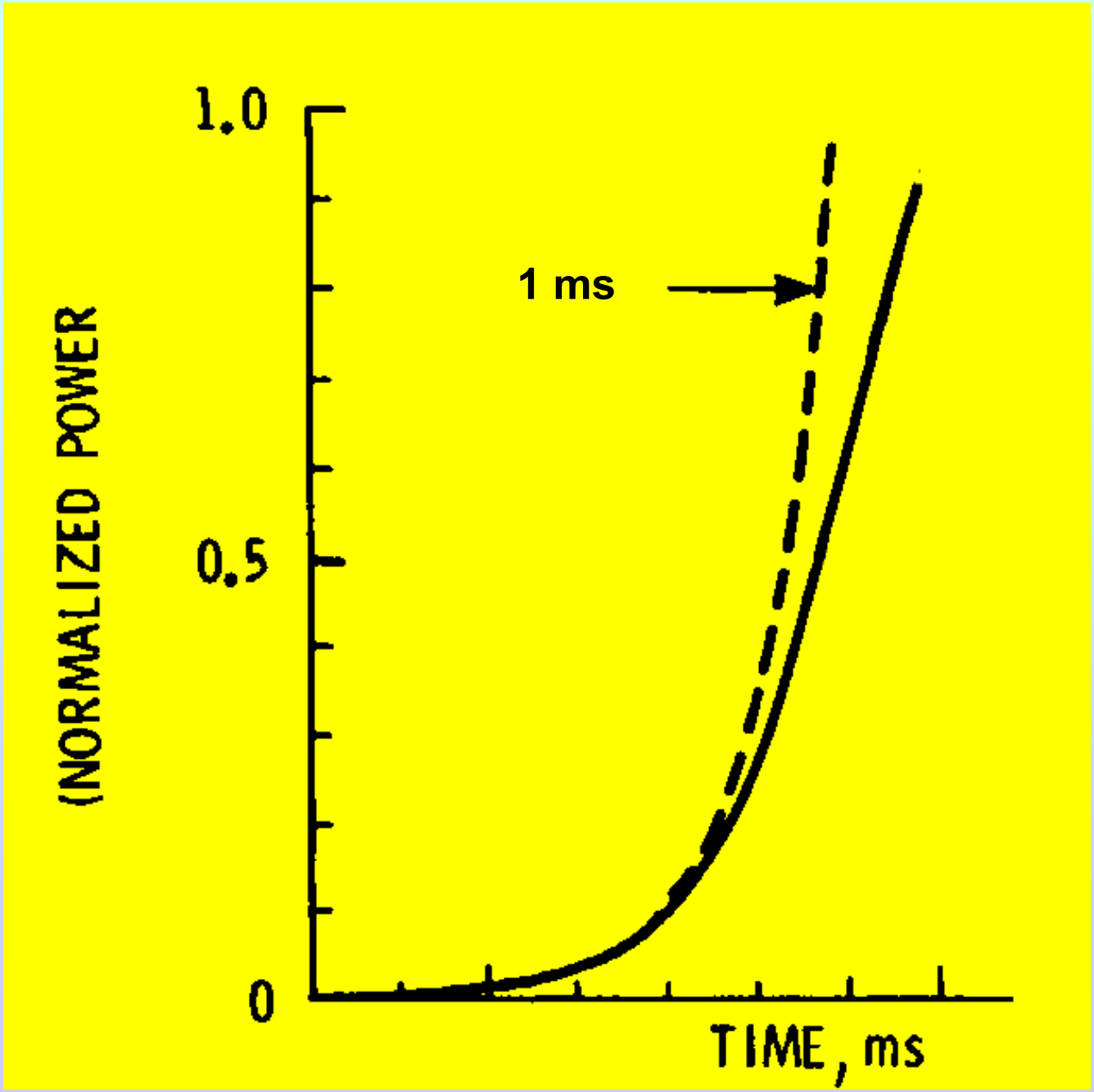
Fuel-Ringed Experiment Cavity (FREC-II)

10,000th Pulse
https://www.youtube.com/watch?v=pa0Fmcv83nw

10,000th Operation
September 2011

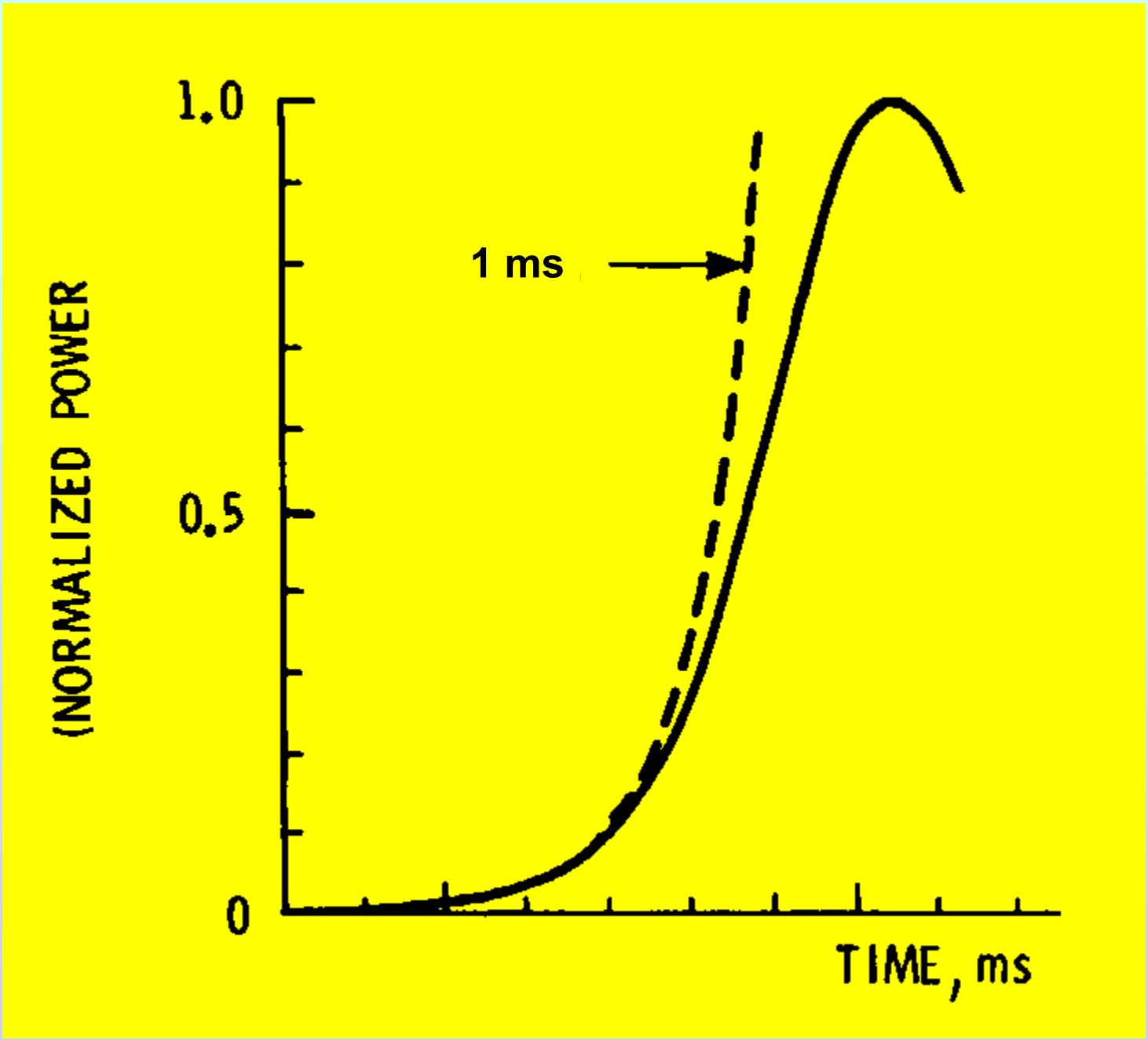
http://www.youtube.com/ watch?v=pa0Fmcv83nw

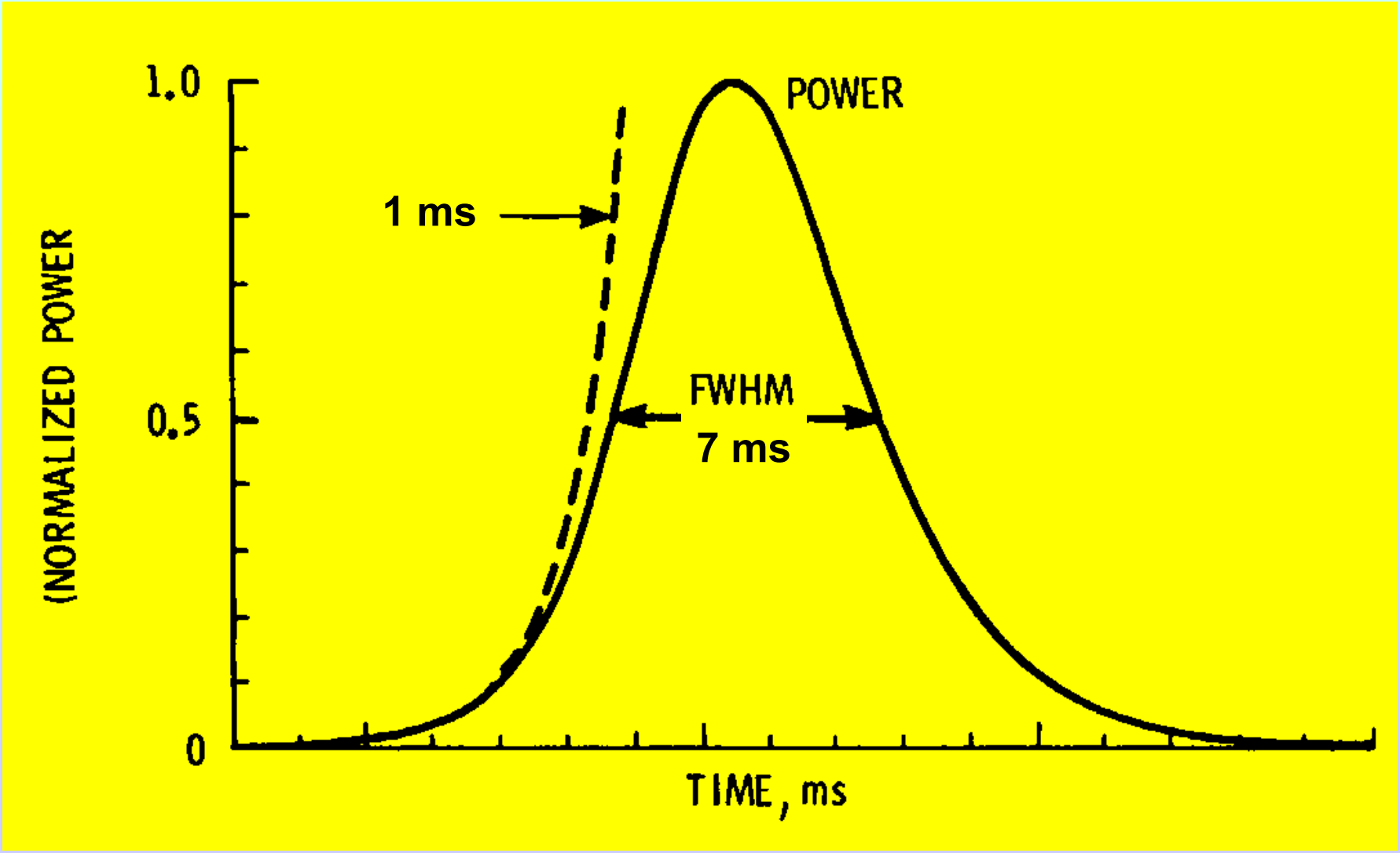

1.0
0.5
0
(NORMALIZED POWER
1 ms
Period
TIME, ms

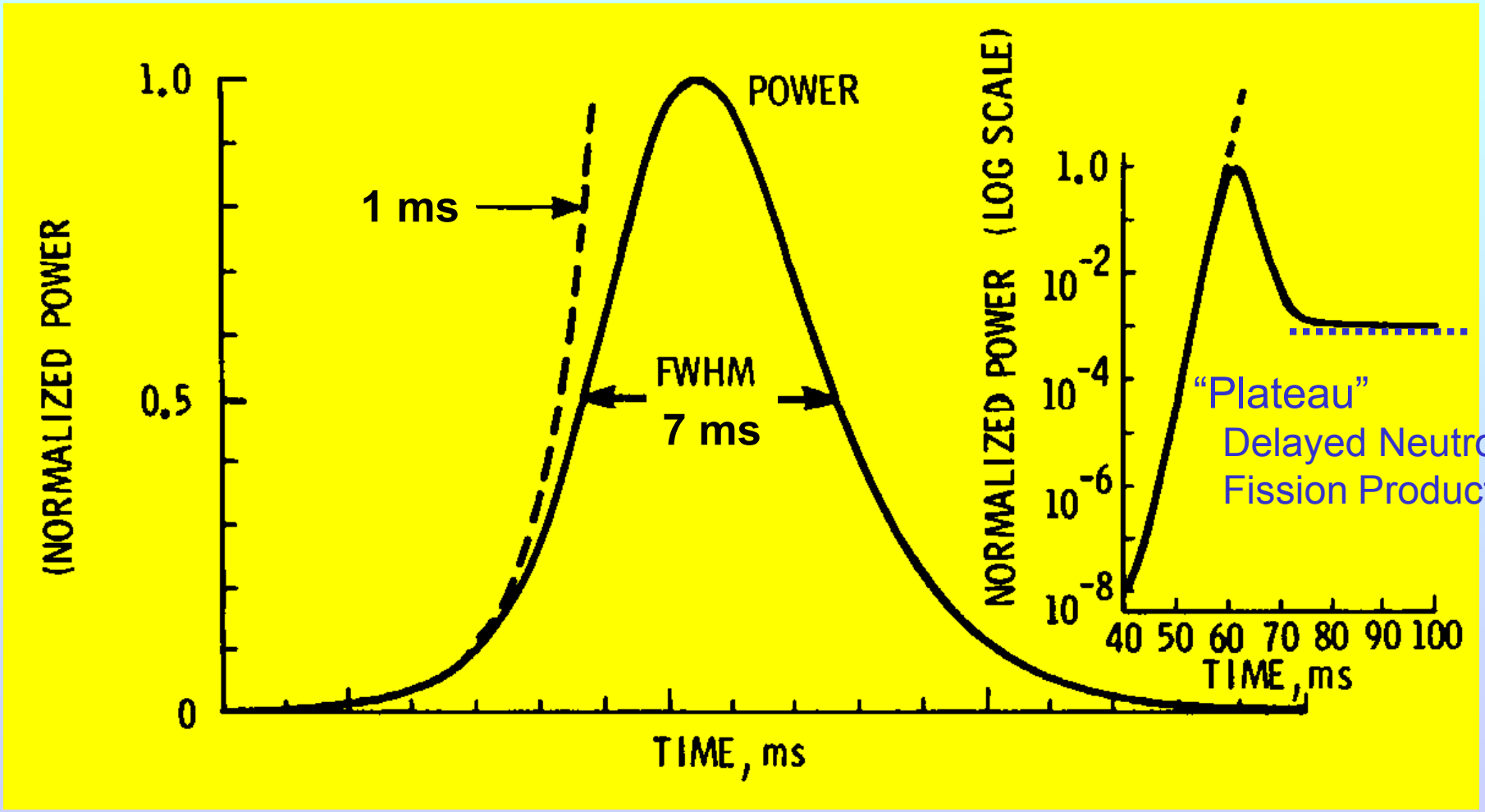

1.0
0.5
0
(NORMALIZED POWER
1 ms
TIME, ms

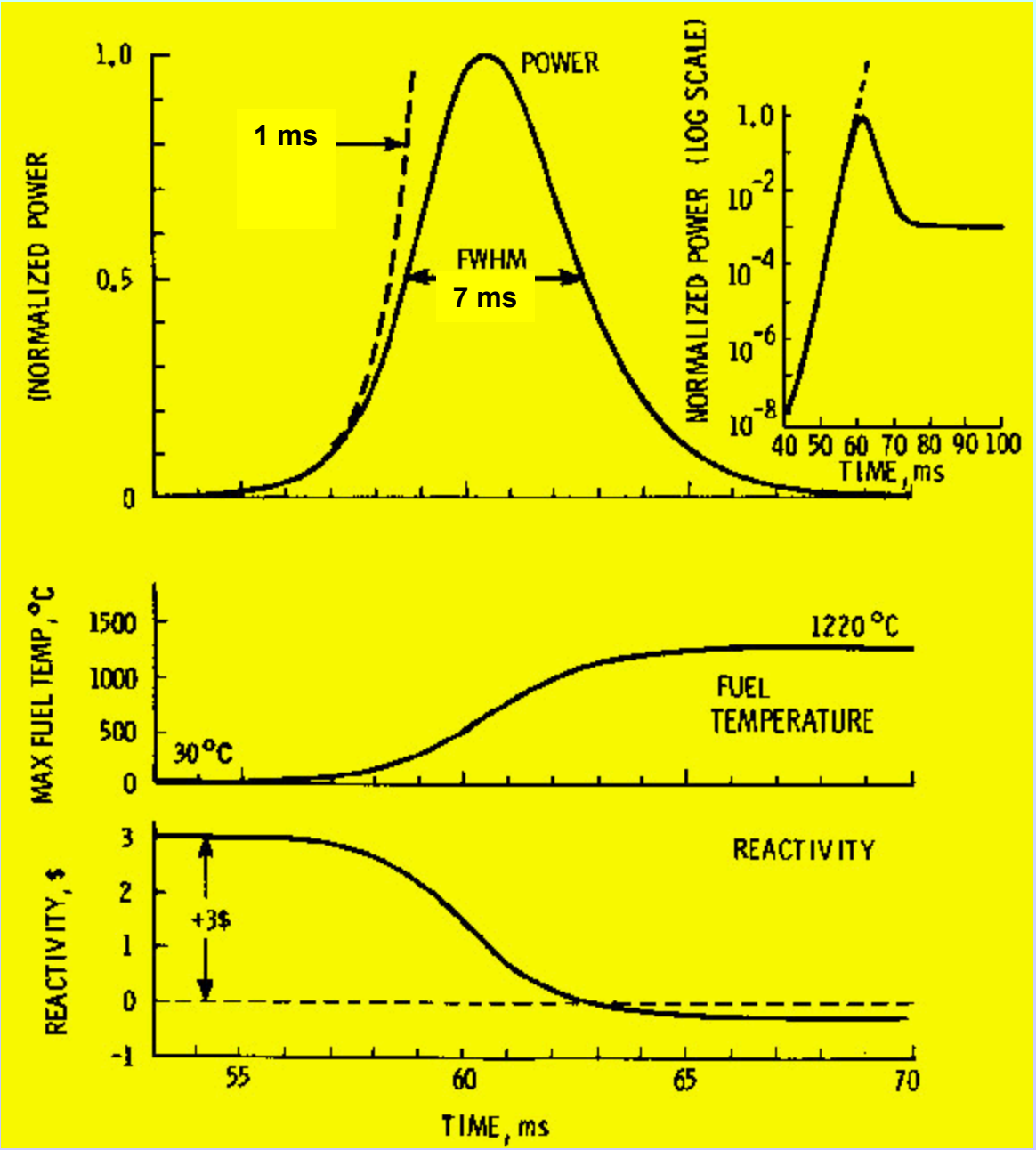
CRITICALITY CONTROL

- FEEDBACK
  - Negative Temperature Feedback
    - Fuel Temperature Increases
    - Fuel Becomes Less Able to Support Neutron Chain Reaction
  - ACRR MECHANISM
    - “Doppler Effect” in Fuel - Increasing Non-Fission Neutron Absorption Reactions in ^{238}U Isotope
    - Be “Upscatter”


1.0
0.5
0
(NORMALIZED POWER
1 ms
TIME, ms


1.0
0.5
0
(NORMALIZED POWER
POWER
1 ms
FWHM
7 ms
TIME, ms


1.0
0.5
0
(NORMALIZED POWER
POWER
1 ms
FWHM
7 ms
TIME, ms
NORMALIZED POWER (LOG SCALE)
1.0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
40 50 60 70 80 90 100
TIME, ms
"Plateau"
Delayed Neutrons
Fission Products



Initial Period ~1ms

Maximum Power

35,000 MWth

Pulse Width 7ms

Fuel Temperature Rises

Reactivity (Multiplication) Falls

SANDIA PULSE

REACTOR

(SPR)

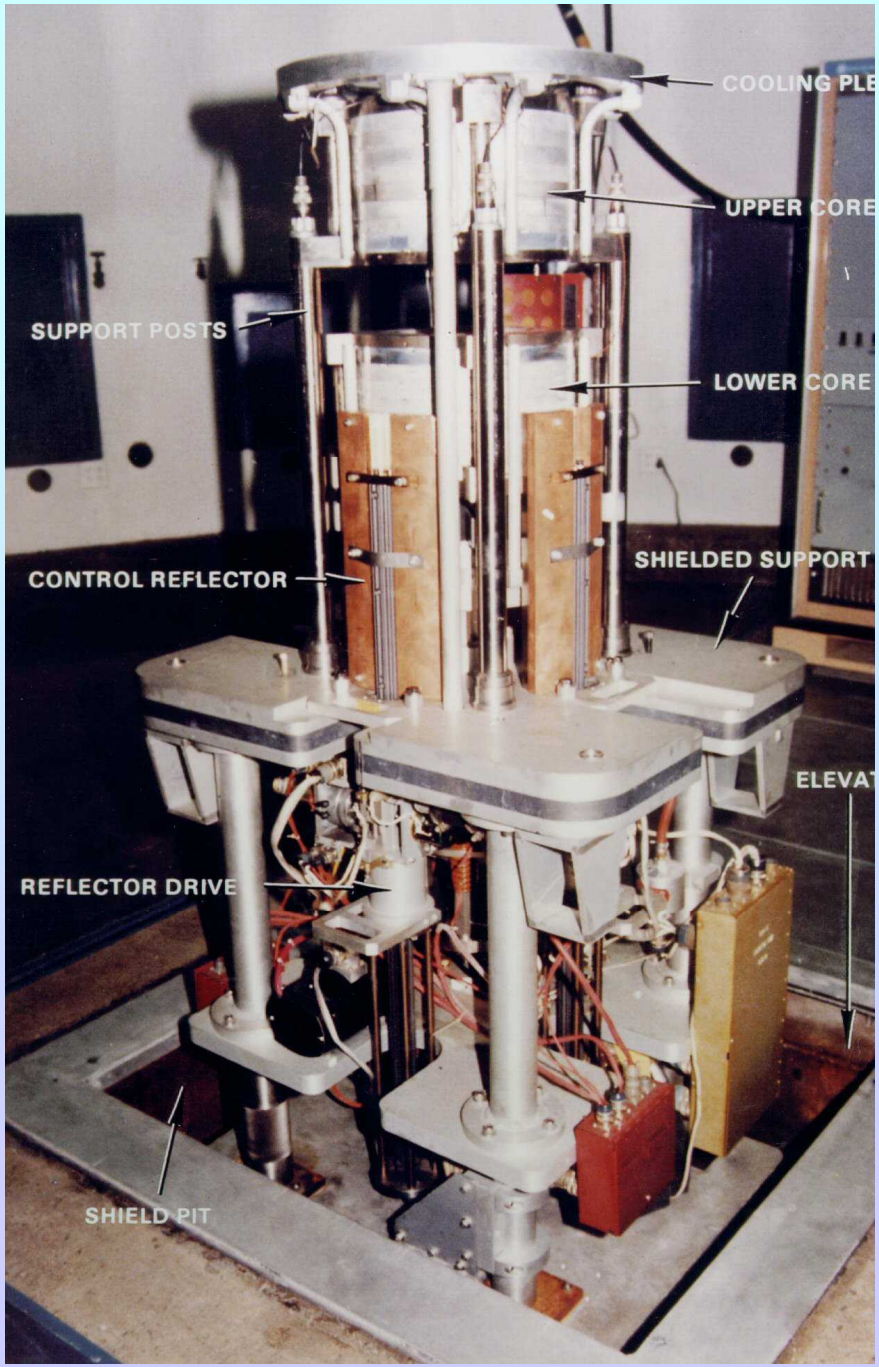
FACILITY

Sandia Pulse Reactor (SPR)

Sandia Critical Experiments (SCX)

TA-V – SPR

SPR-III

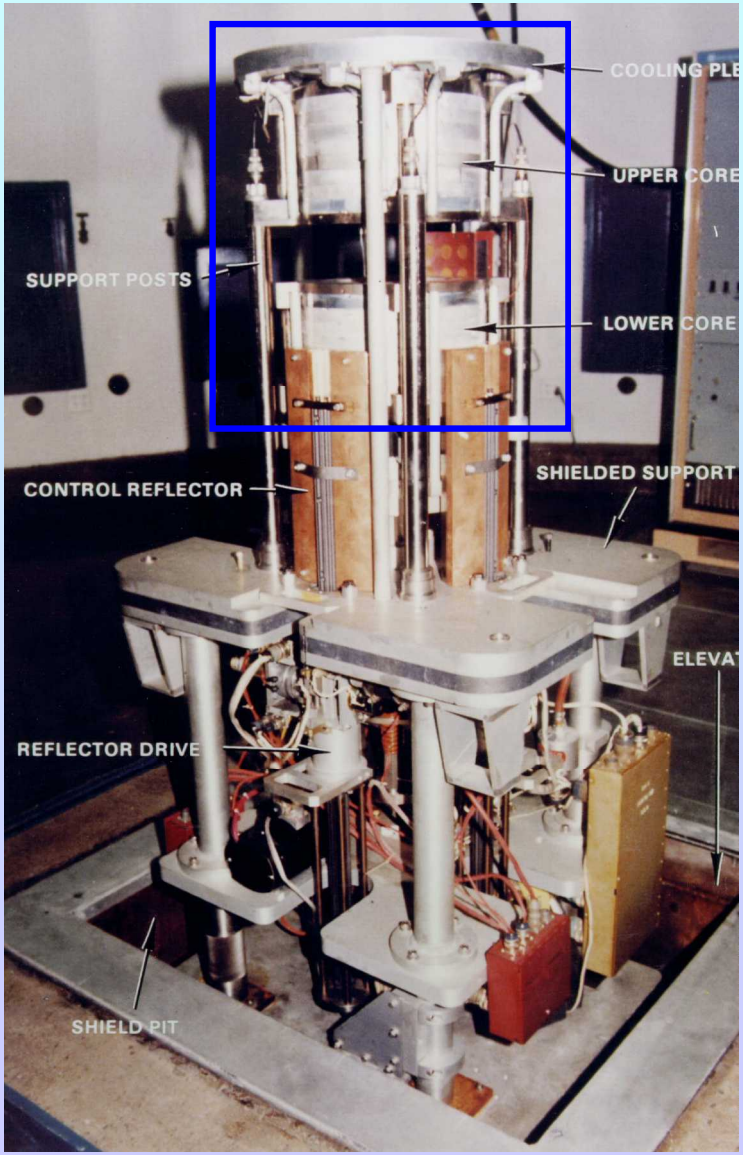

COOLING PLE
UPPER CORE
SUPPORT POSTS
LOWER CORE
CONTROL REFLECTOR
SHIELDED SUPPORT
ELEVAT
REFLECTOR DRIVE
SHIELD PIT

SPR FEATURES

- POWER CAPABILITY
  - 15 kW(th) Steady-State
  - 150,000 MW(th) Maximum Pulse

SPR FEATURES

- METAL-REACTOR DESIGN – SPR-III
  - No Neutron Moderation
  - Reactor Building & Distance Provide Shielding
  - Auxiliary Cooling w/ Nitrogen Gas



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  - Reactor Building & Distance Provide Shielding
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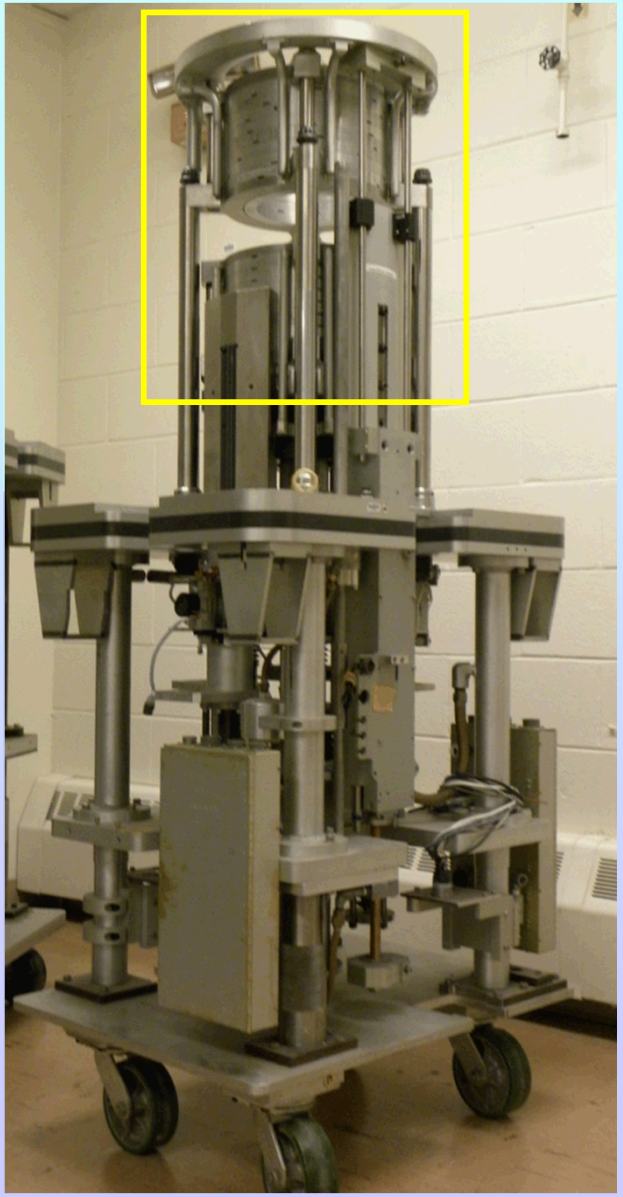
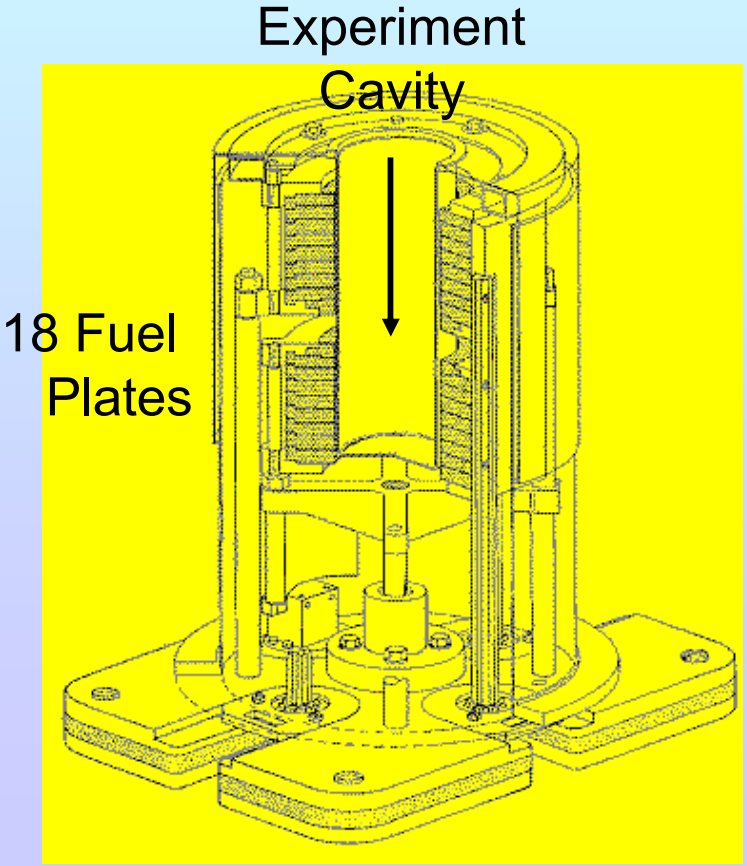


CRITICALITY CONTROL

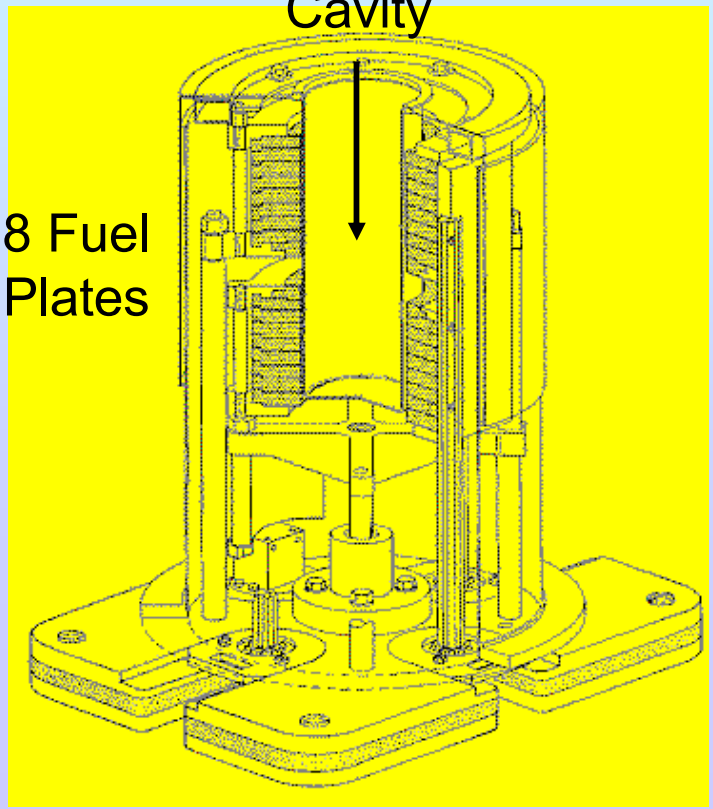
- REACTOR – SPR-III
  - Production ⇨ Uranium



Form	U(10% Mo) Metal Annular Plates
Enrichment	93 wt% ^{235}U
Amount	250+ kg

CRITICALITY CONTROL

- REACTOR – SPR-III
  - Production ⇨ Uranium



Form	U(10% Mo) Metal Annular Plates
Enrichment	93 wt% ^{235}U
Amount	250+ kg

[Fuel is Off-Site
in Storage]

CRITICALITY CONTROL

- REACTOR – SPR-III
  - Production
  - Absorption ⇨ No Absorber-Based Control

CRITICALITY CONTROL

- REACTOR – SPR-III
  - Production
  - Absorption ⇨ Cadmium Shroud to Limit Room Return

Feature Associated w/ Many Experiments ("Thimble")

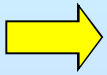
(No Absorber-Based Control Elements)

CRITICALITY CONTROL

- REACTOR – SPR-III
  - Production
  - Absorption
  - Leakage ⇨ Core Annular Configuration (7” Cavity)

    Safety “Block” (Separated Lower Core Half)

CRITICALITY CONTROL

- REACTOR – SPR-III
  - Production
  - Absorption
  - Leakage 

    Core Annular Configuration

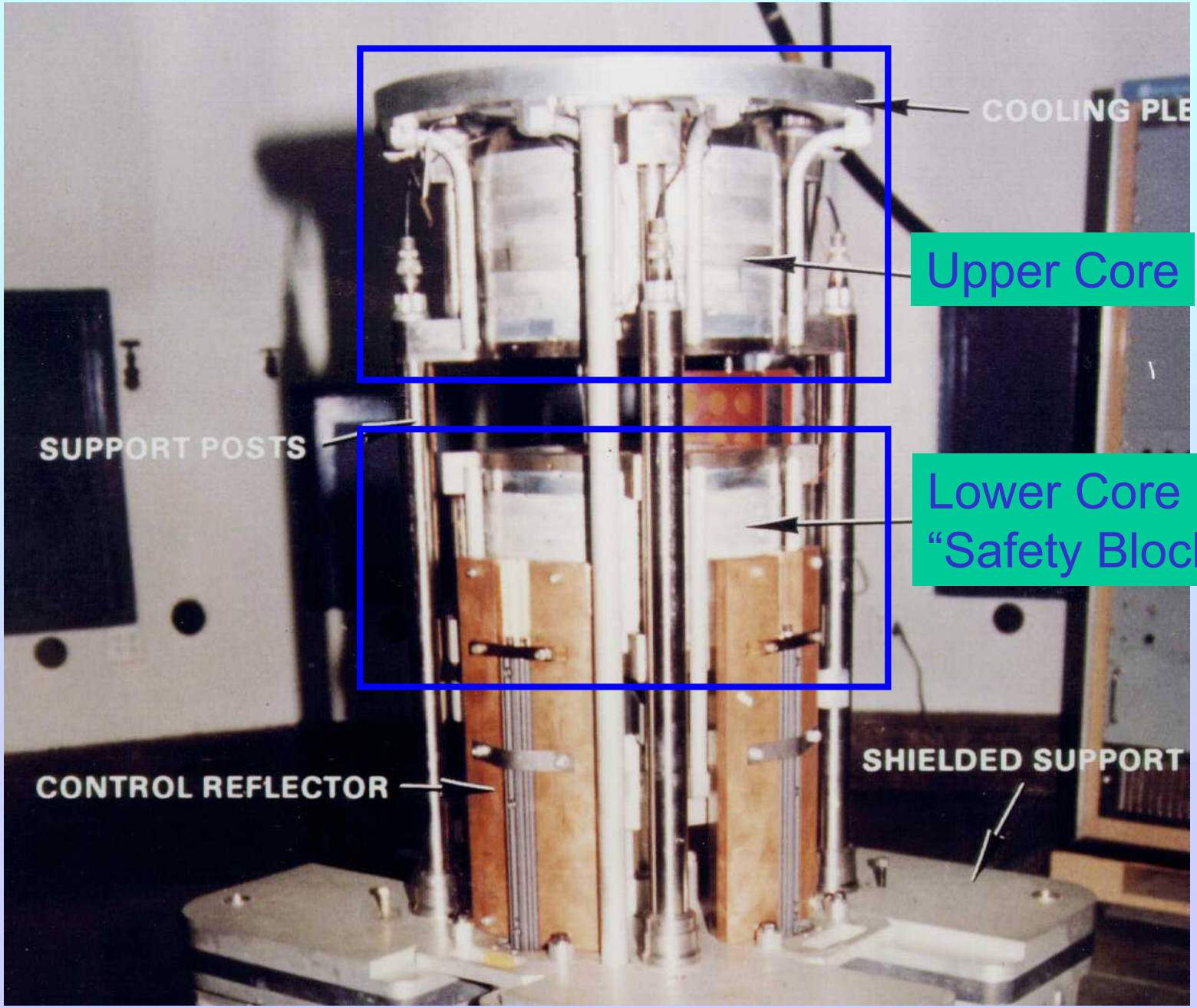
    Safety “Block” (Separated Lower Core Half)

    Control-Element Reflector

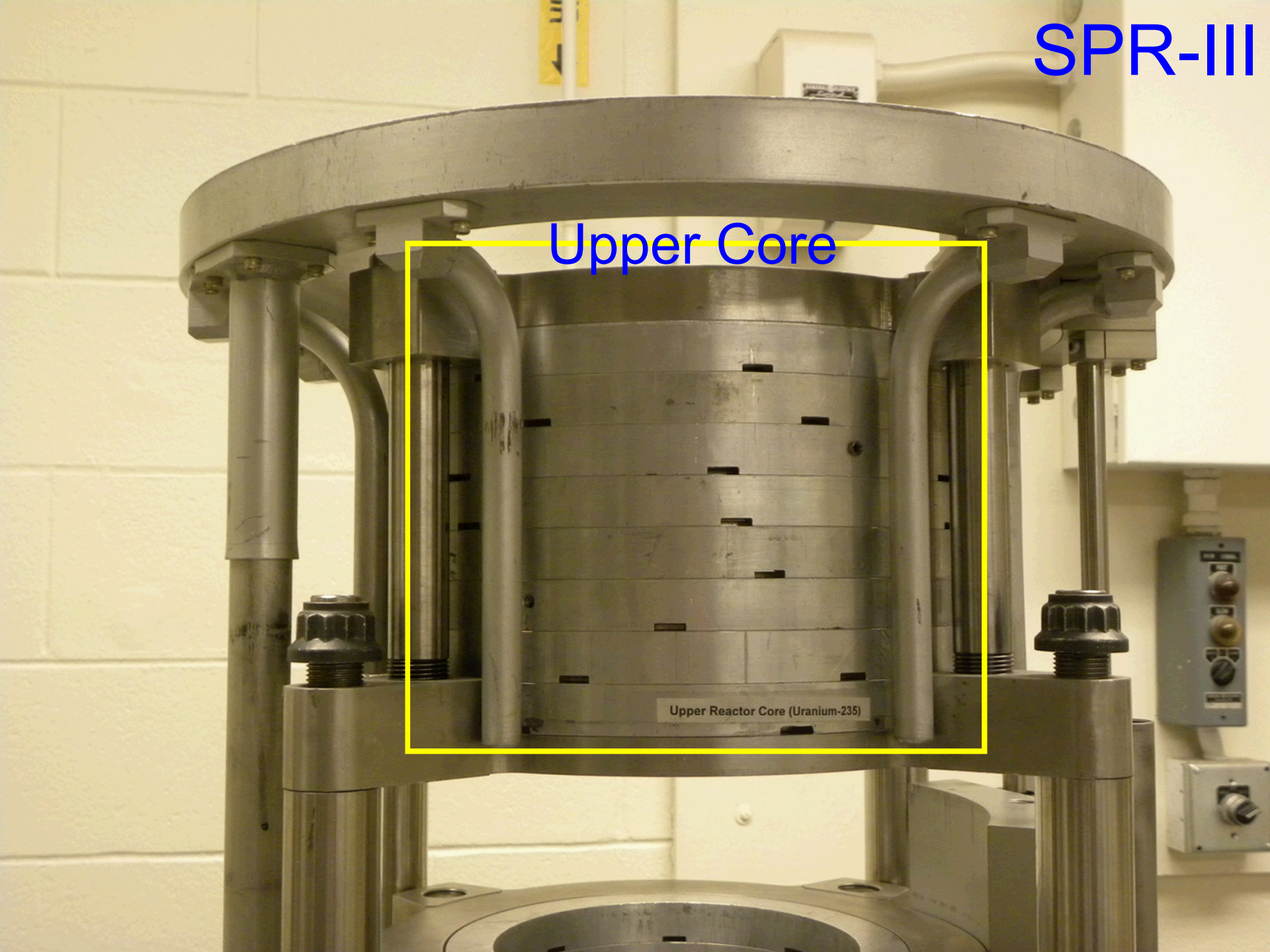
    Pulse-Element Reflector

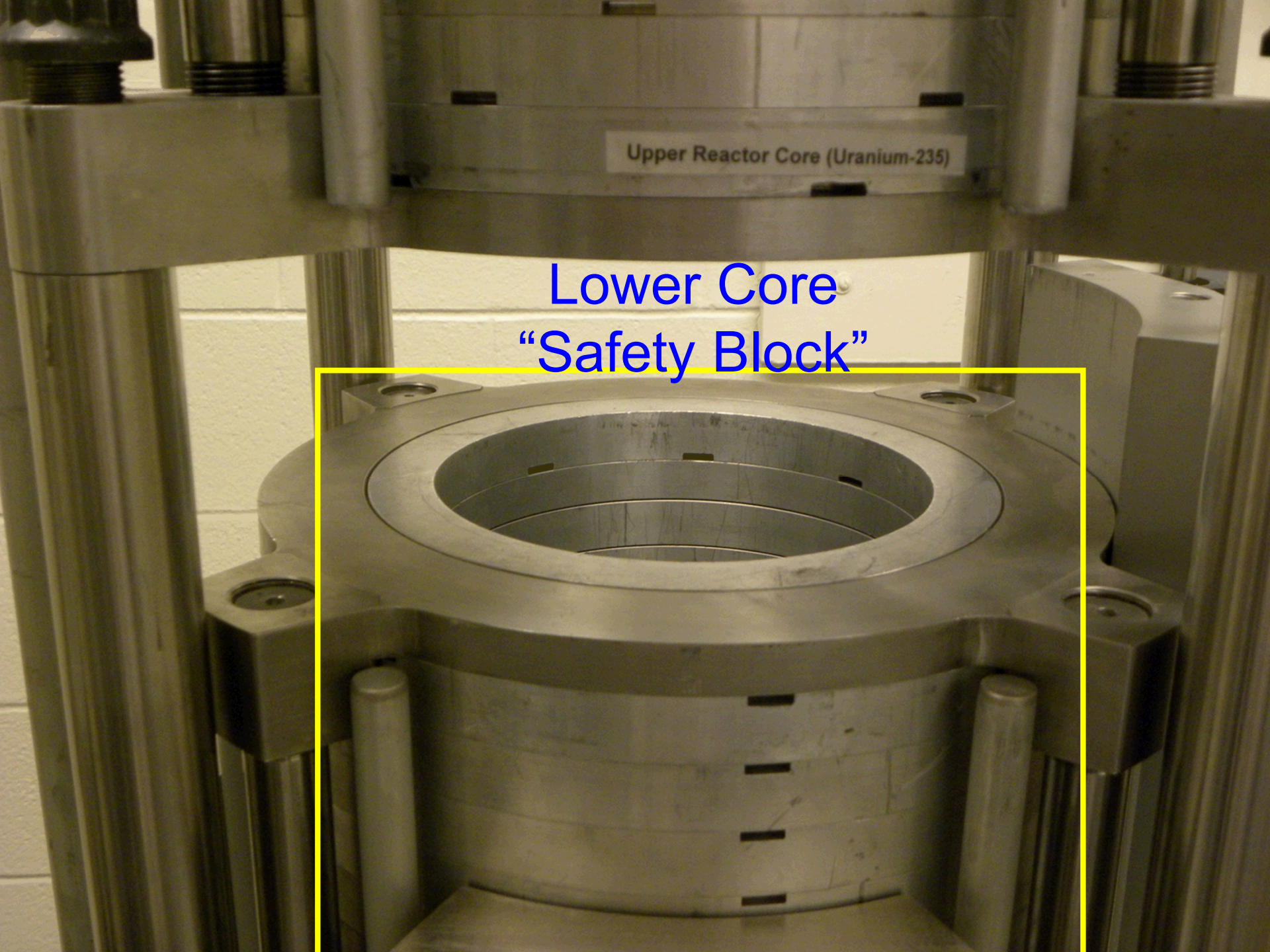
    [No Global Reflector]

SPR-III Core


COOLING PLE
Upper Core
SUPPORT POSTS
Lower Core
"Safety Block"
CONTROL REFLECTOR
SHIELDED SUPPORT

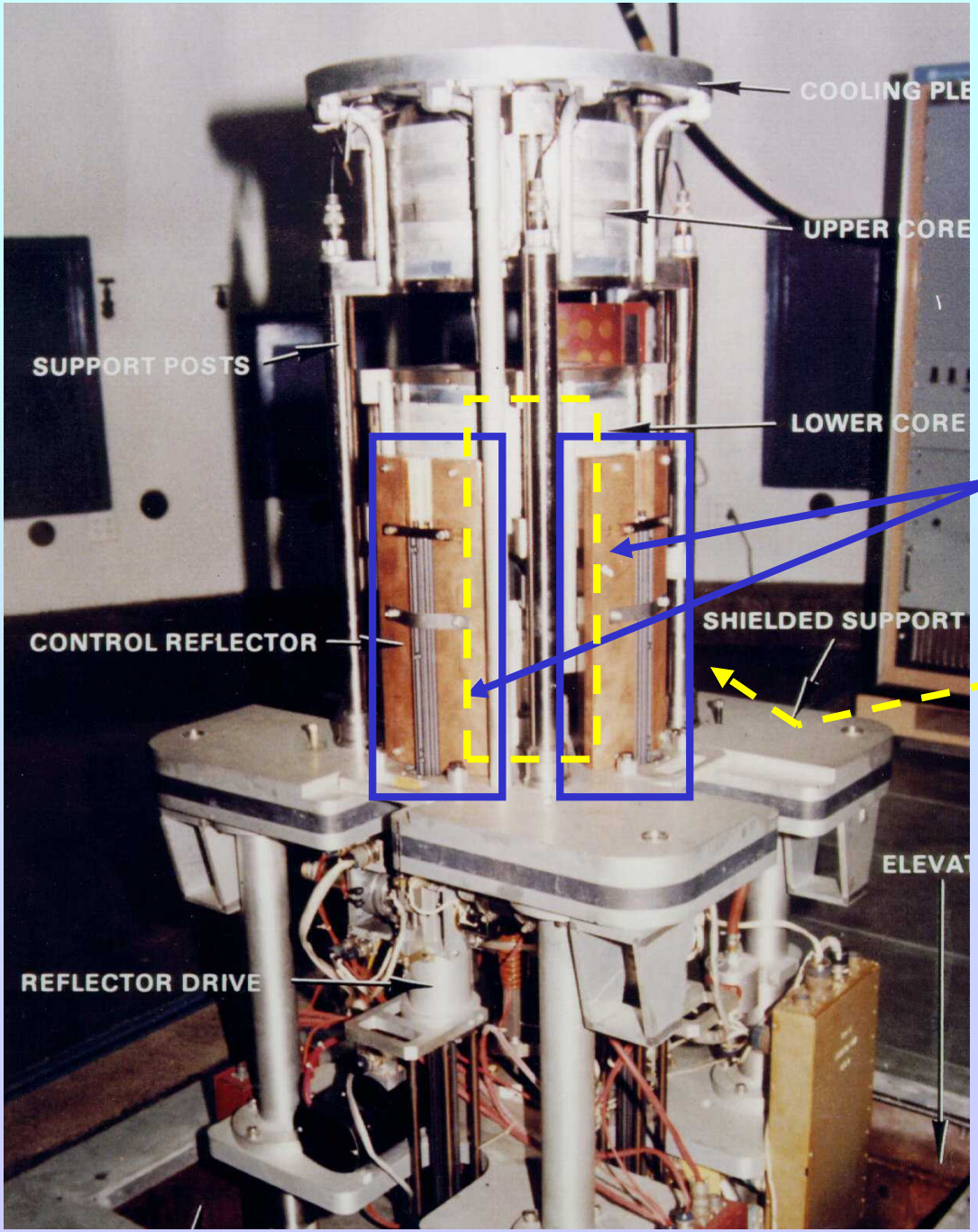
SPR-III




Upper Reactor Core (Uranium-235)
Lower Core
“Safety Block”

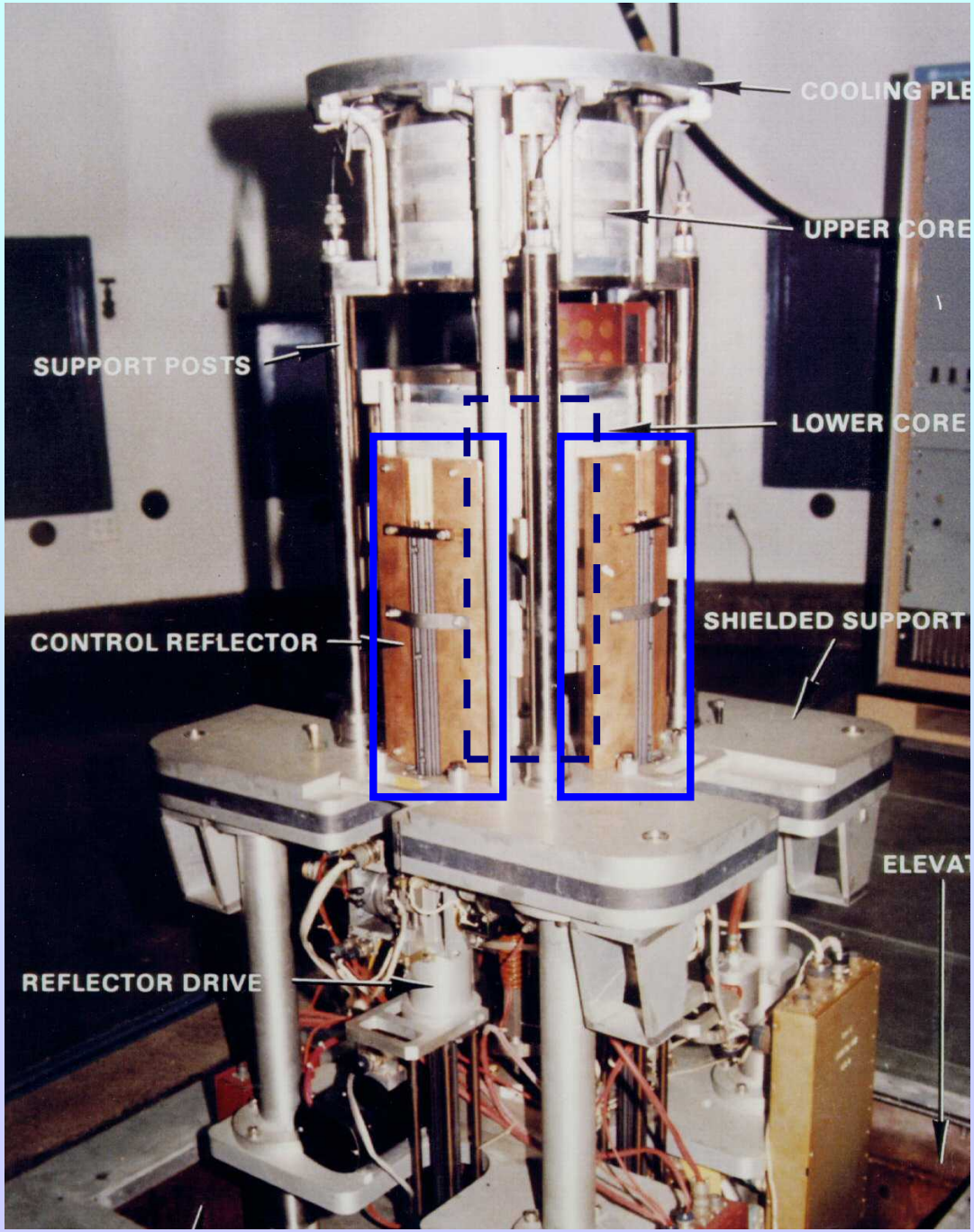

SPR-III
EXIT

SPR-III Control Elements



Copper Control Reflectors

Aluminum Pulse Reflector (Opposite Side, Not Visible Here)

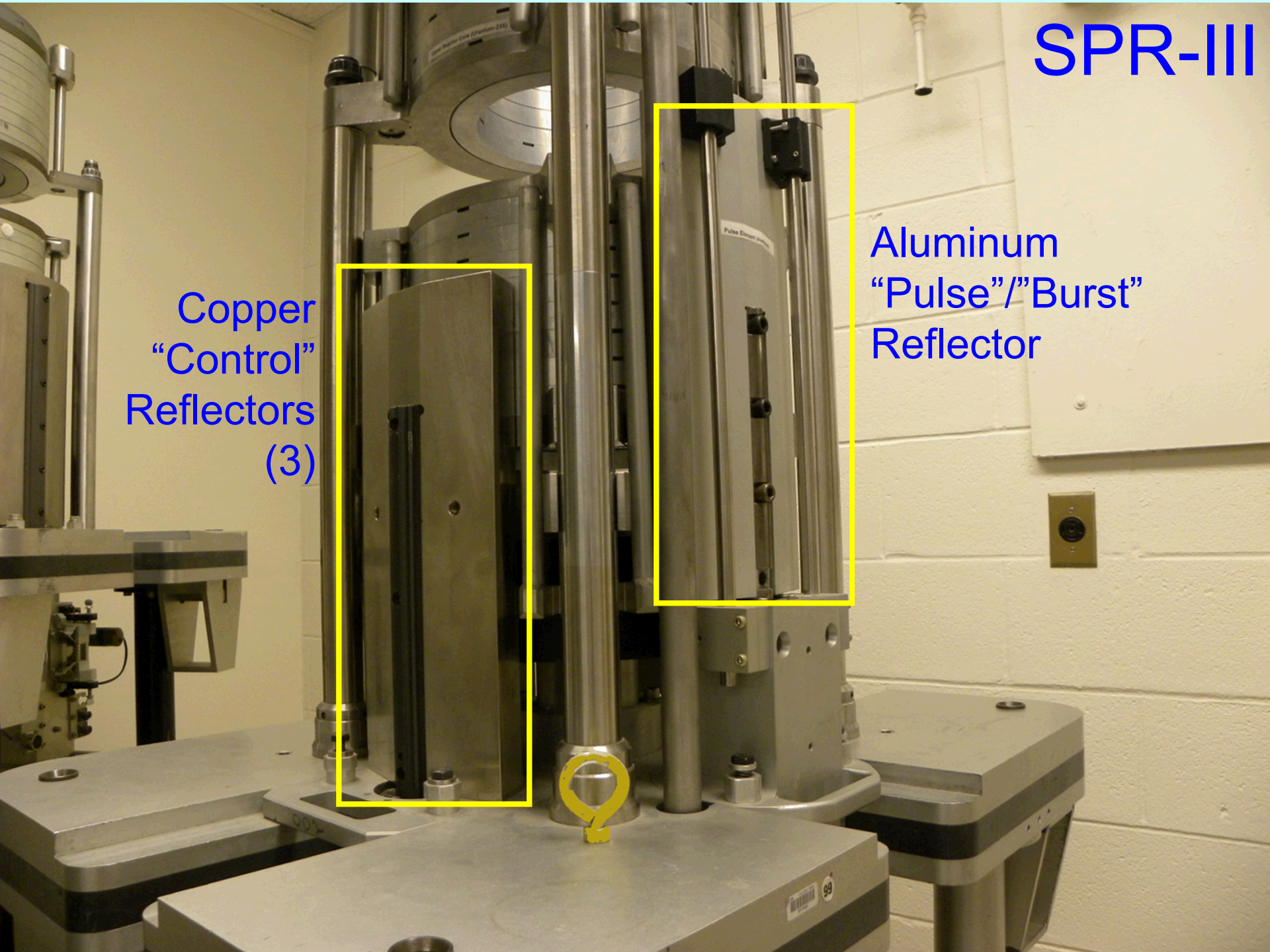


SPR-III Control & "Burst" Elements

~5 Times More Power Than ACRR

Over 12 Times More Than Palo Verde

Burst Lasts Only ~1/10,000th of 1 Second


SPR-III
Copper
"Control"
Reflectors
(3)
Aluminum
"Pulse"/"Burst"
Reflector

CRITICALITY CONTROL

- FEEDBACK
  - Negative Temperature Feedback
    - Fuel Temperature Increases
    - Fuel Becomes Less Able to Support Neutron Chain Reaction
  - SPR MECHANISM
    - Expansion (Decreased Density) of Metal Fuel
    - Increasing Neutron Leakage

PULSE

- SPR-III

		ACRR
– Initial Period	27 μs	*1 ms*
– Peak Power	150,000 MWth	*35,000 MWth*
– Duration	76 μs	*7 ms*
	Exo-Atmospheric Simulation	*Endo-Atmospheric Simulation*

SNL TA-V NUCLEAR FACILITIES

- REACTORS
  - Annular Core Research Reactor (ACRR)
  - Sandia Pulse Reactor (SPR)
- SANDIA CRITICAL EXPERIMENTS (SCX)
  - Burnup-Credit – 4.31 wt% ^{235}U w/ Fission-Product Simulant
  - 7uP – 6.90 [“7”] wt% ^{235}U

CRITICALITY CONTROL

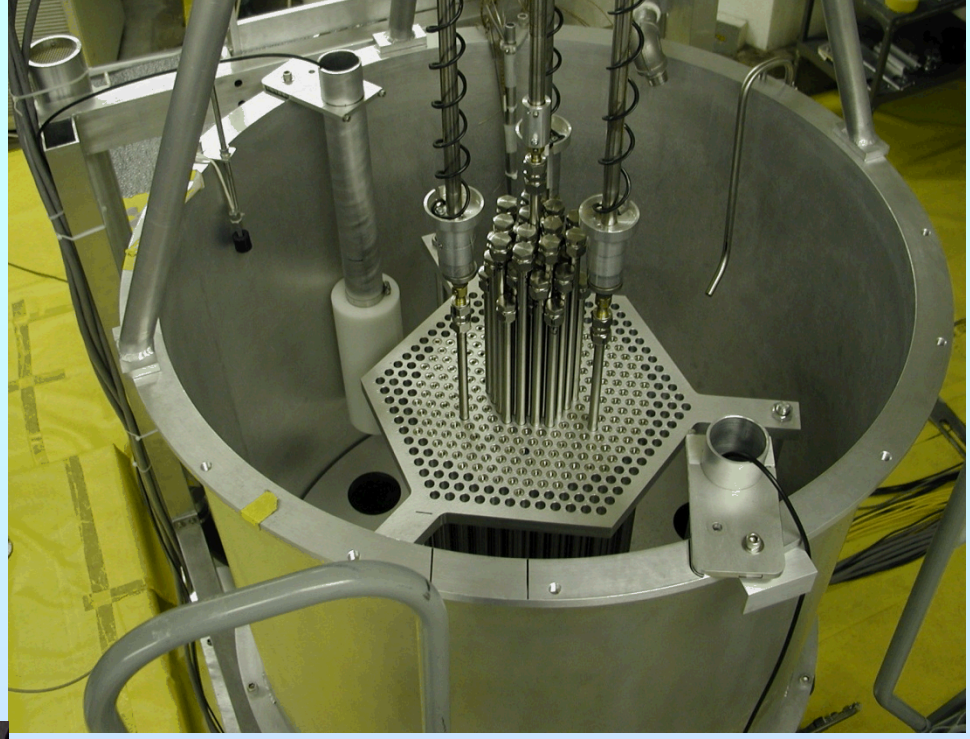
- REACTOR – Critical Experiment (CX)
  - Production ➡ Uranium

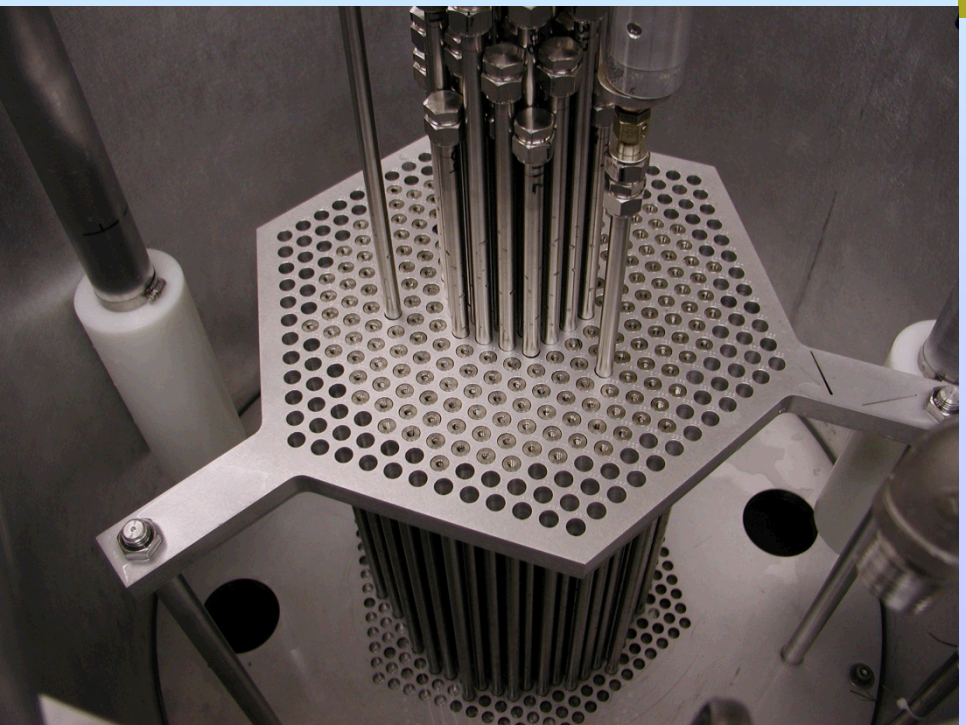
Form	UO_2
Enrichment	4.31 wt% ^{235}U “BUC”
Enrichment	6.90 wt% ^{235}U “7uP”

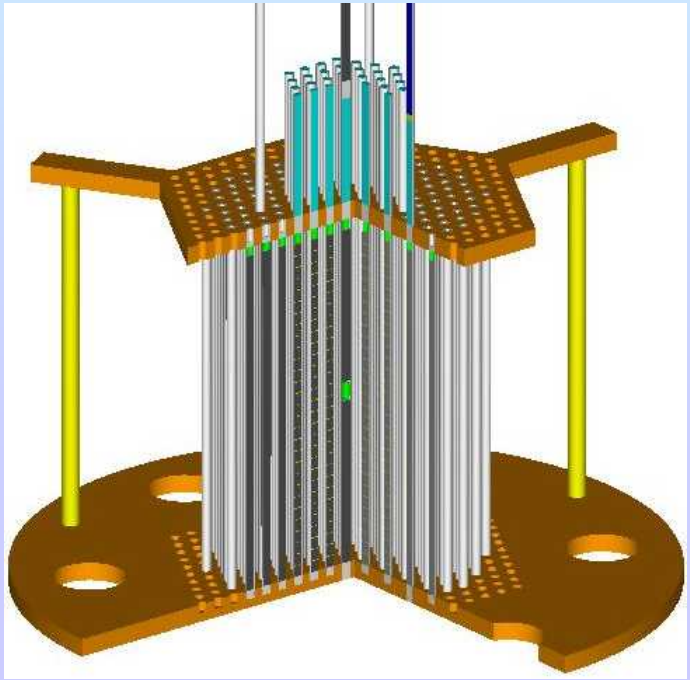
    - Initial Loading as Starting Point
    - Load-to-Critical
      - Incremental (# Fuel Rods or Water Height)
      - Final May Include Low-Power Operation

CX – BUC

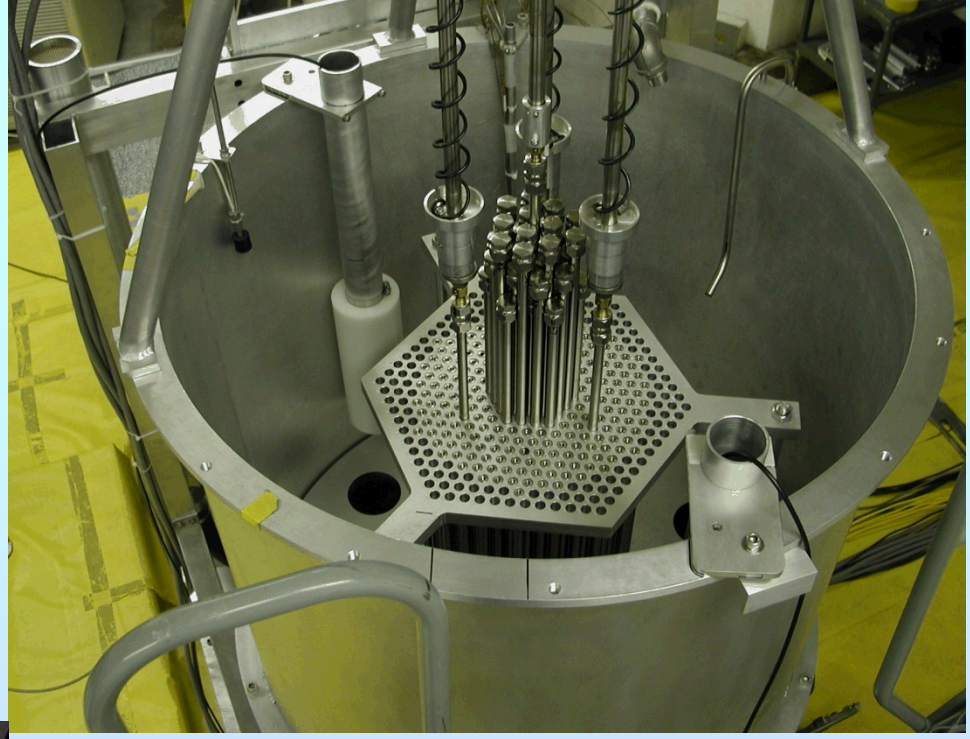
4.2 wt% ^{235}U w/ Fission-Product Simulant

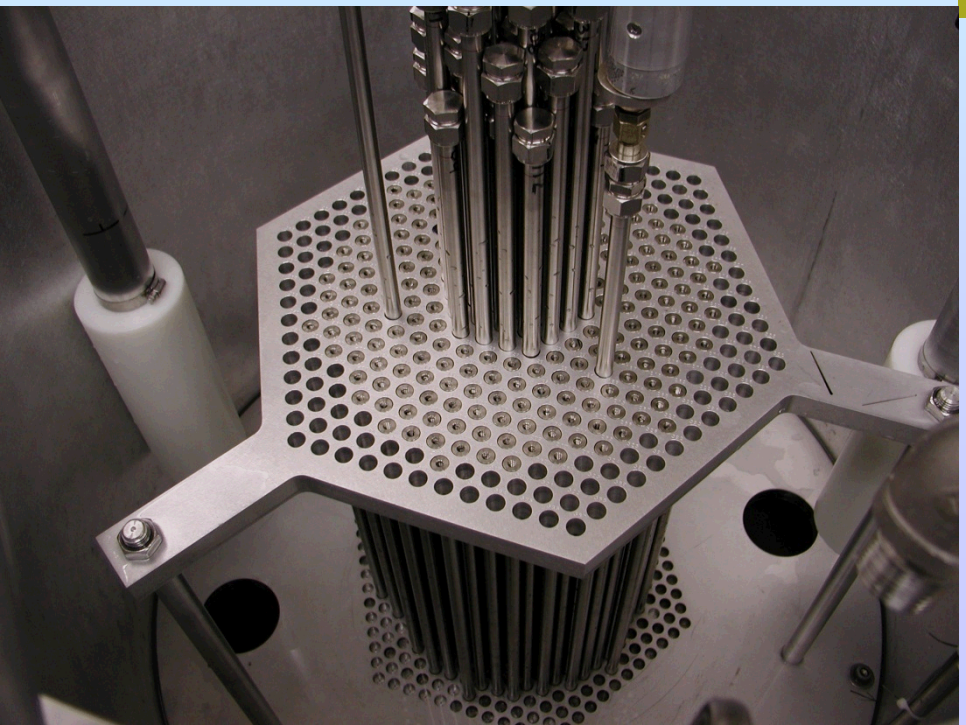


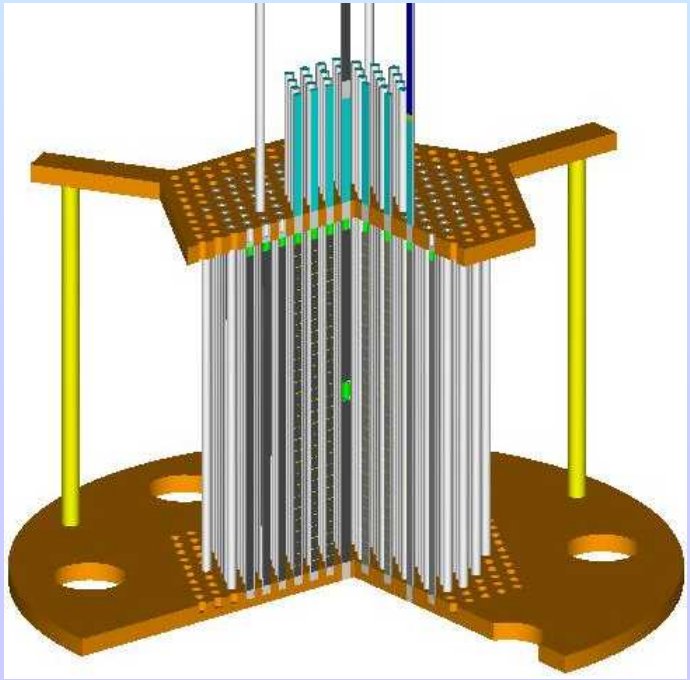




BUCCX

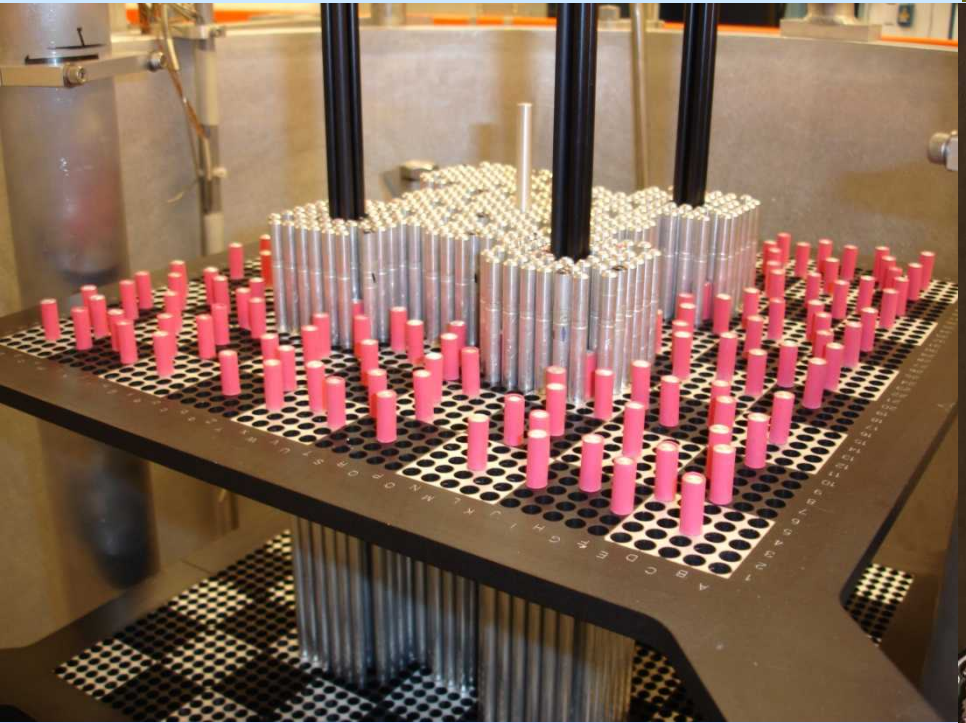


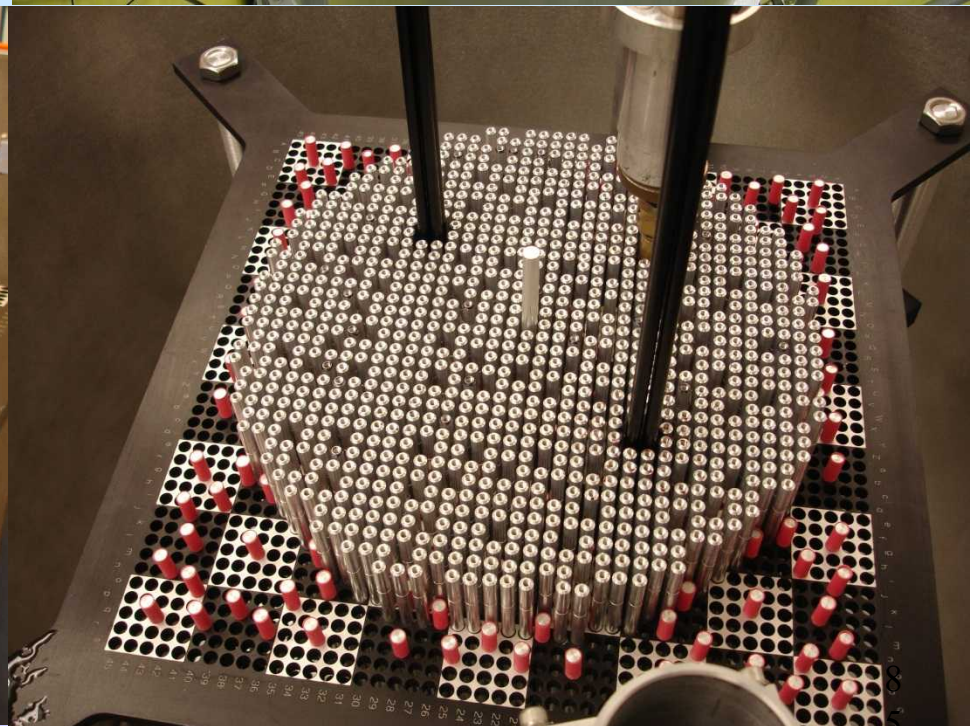




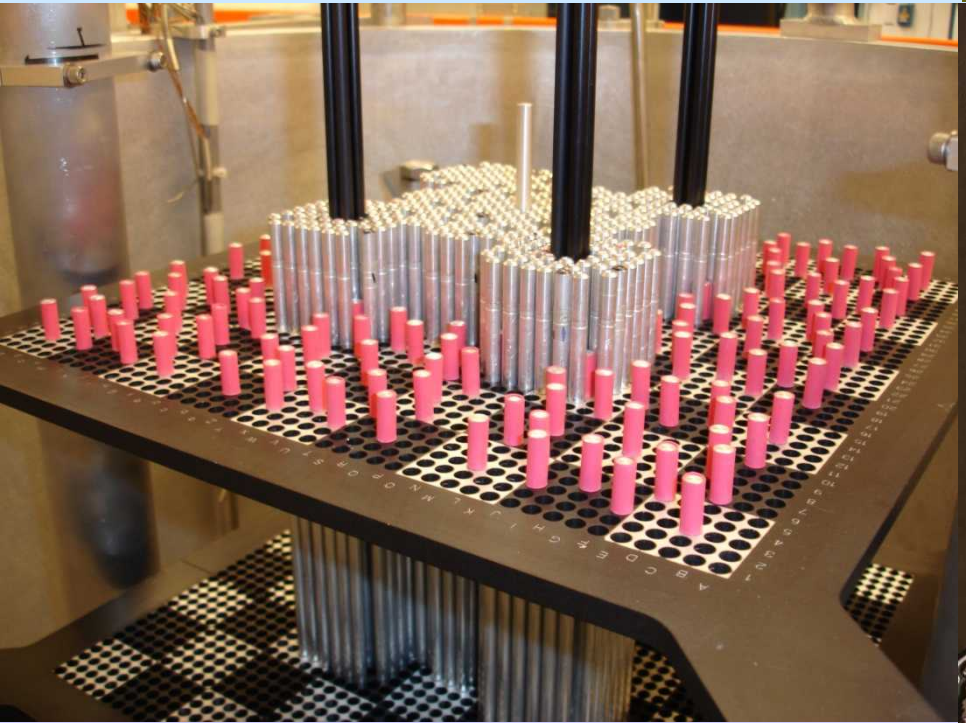
CX – 7uP/ Pathfinder

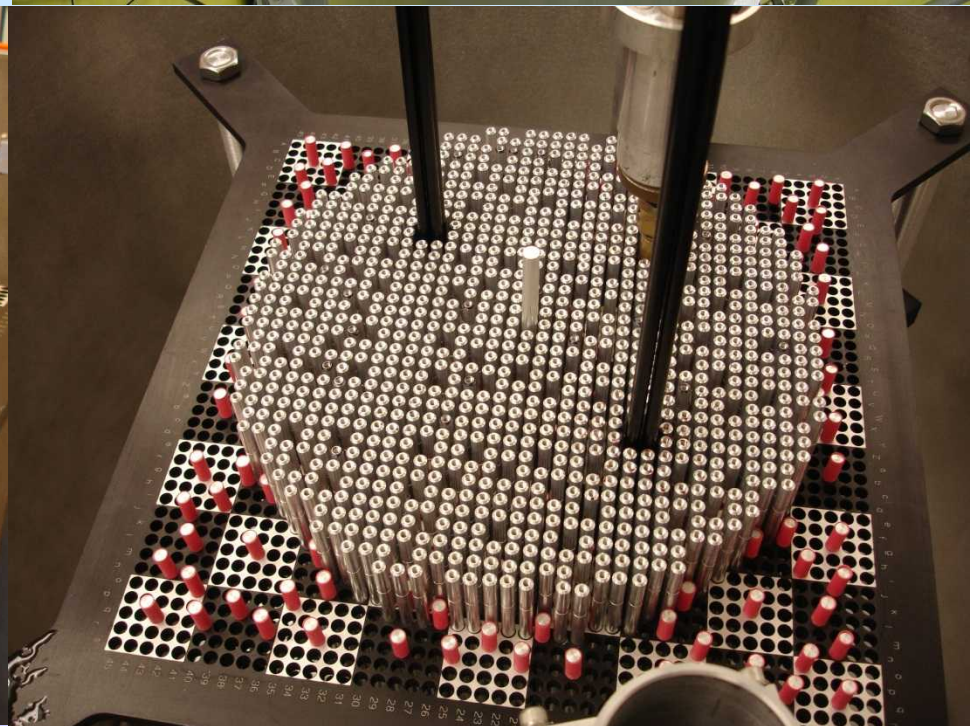
7 wt% ^{235}U





7uPCX





CRITICALITY CONTROL

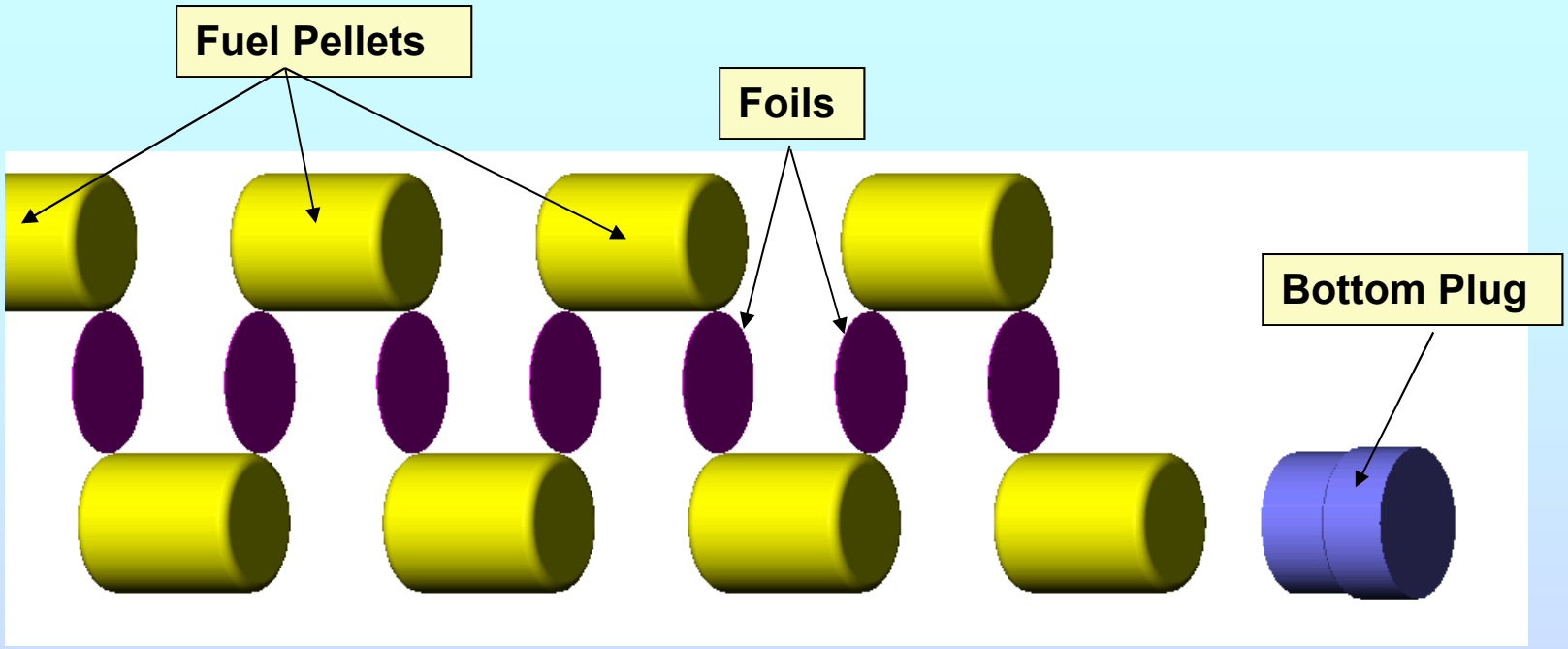
- REACTOR – Critical Experiment (CX)
  - Production
  - Absorption ⇨ B_4C Control Rods

    Neutron-Poison Simulant (^{103}Rh) Foils in BUC-CX Fuel

CRITICALITY CONTROL

- REACTOR – CX
  - Production
  - Absorption ⇨
    - Control Rods (Boron Carbide [B_4C] – Neutron “Poison”)
      - Remove for Maximum Multiplication
      - Insert for Minimum Multiplication
      - Rapid Safety Shutdown ⇒ “Scram”
    - Burnup Credit
      - Fission-Product “Poisons”
      - Transuranic-Product “Poisons”
    - 7uP Includes Boric Acid Experiments

CX - BUC Fuel Rods w/ Foils



CRITICALITY CONTROL

- REACTOR – Critical Experiment (CX)
  - Production
  - Absorption
  - Moderation ⇨
    - Assembly Requires H_2O Moderation for Criticality
    - Fuel Loaded in Dry Vessel
    - H_2O Pumped Remotely from Storage Tank for Experiment

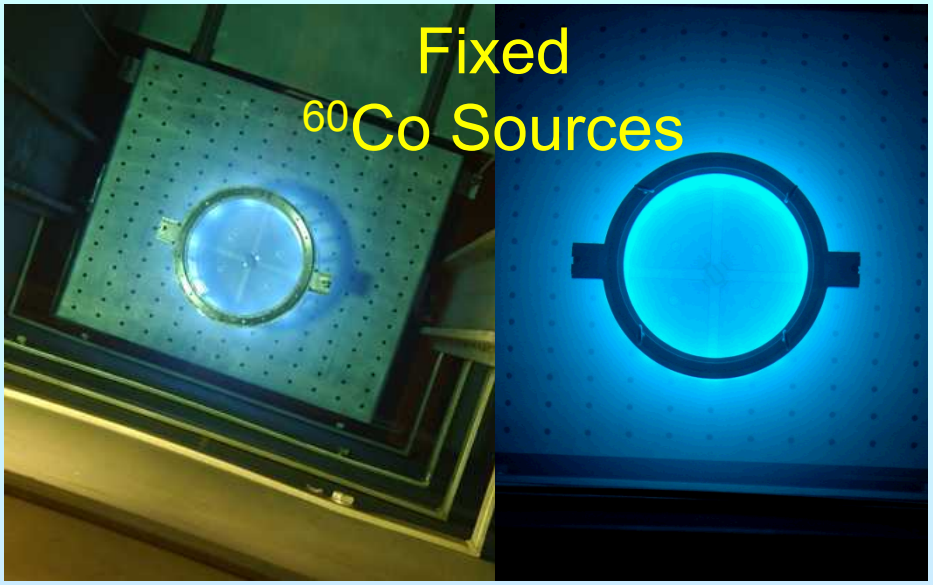
SPRF/CX Critical-Assembly & Moderator-Storage Tanks

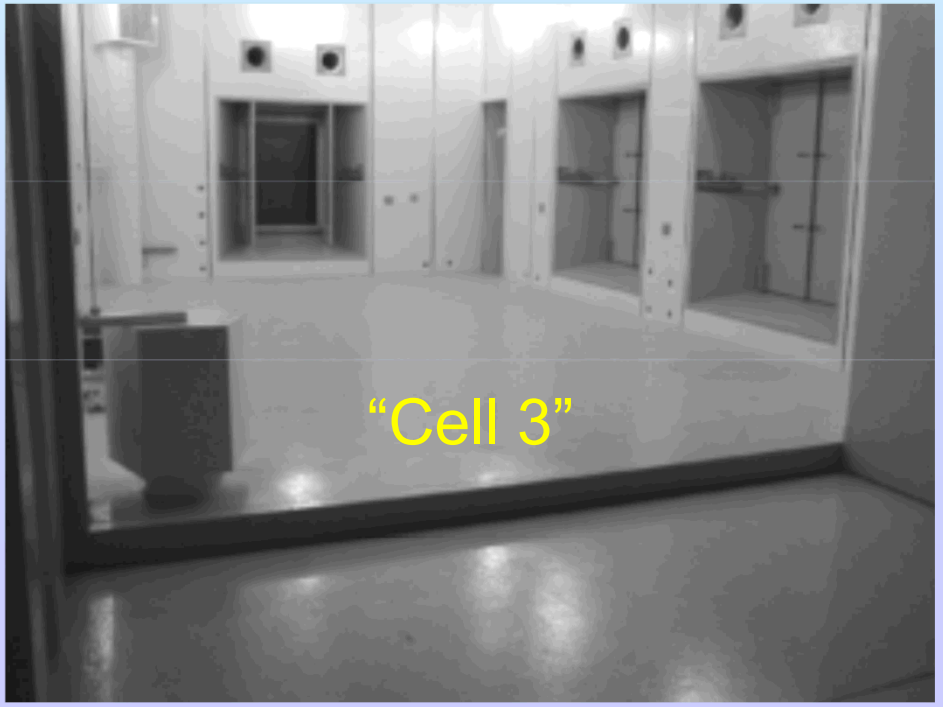
SNL TA-V Nuclear Facilities

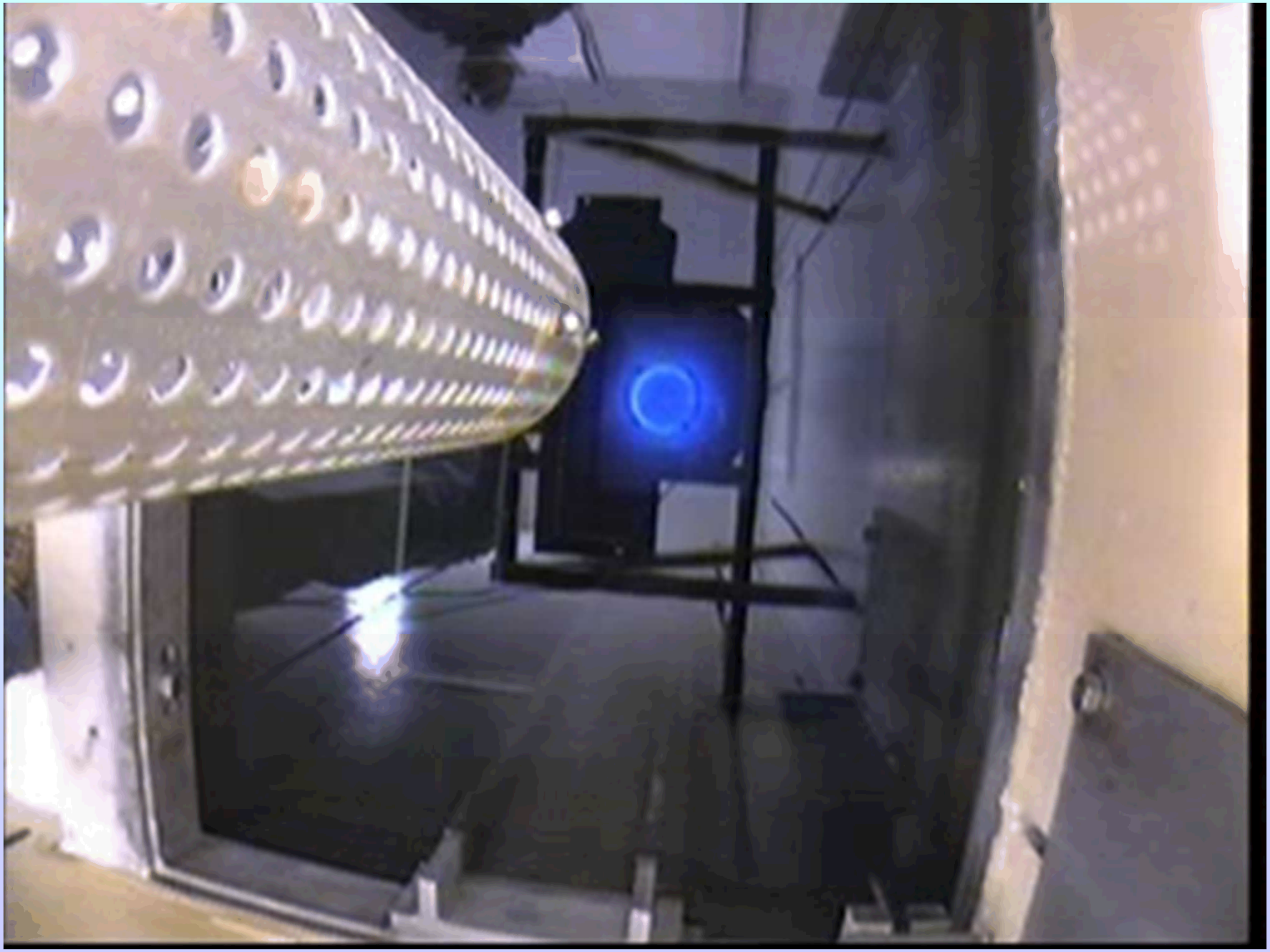
- REACTORS
  - Annular Core Research Reactor (ACRR)
  - Sandia Pulse Reactor (SPR) & Sandia Critical Experiments (SCX)
- HOT CELL & IRRADIATION FACILITIES
  - Gamma Irradiation Facility (GIF)
  - Auxiliary Hot Cell Facility (AHCF)
  - Hot Cell Facility (HCF) (Inactive)

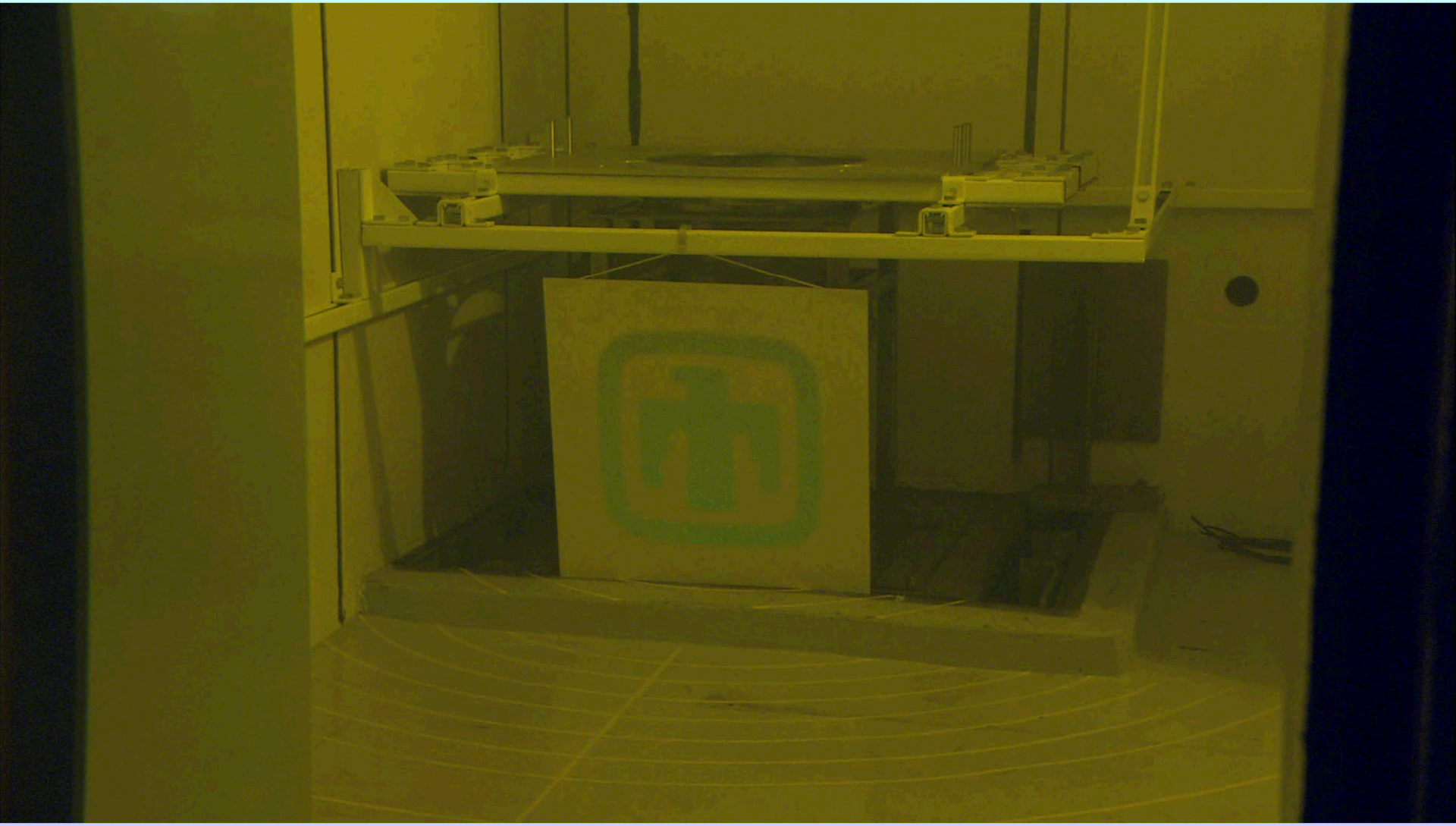
TA-V – GIF

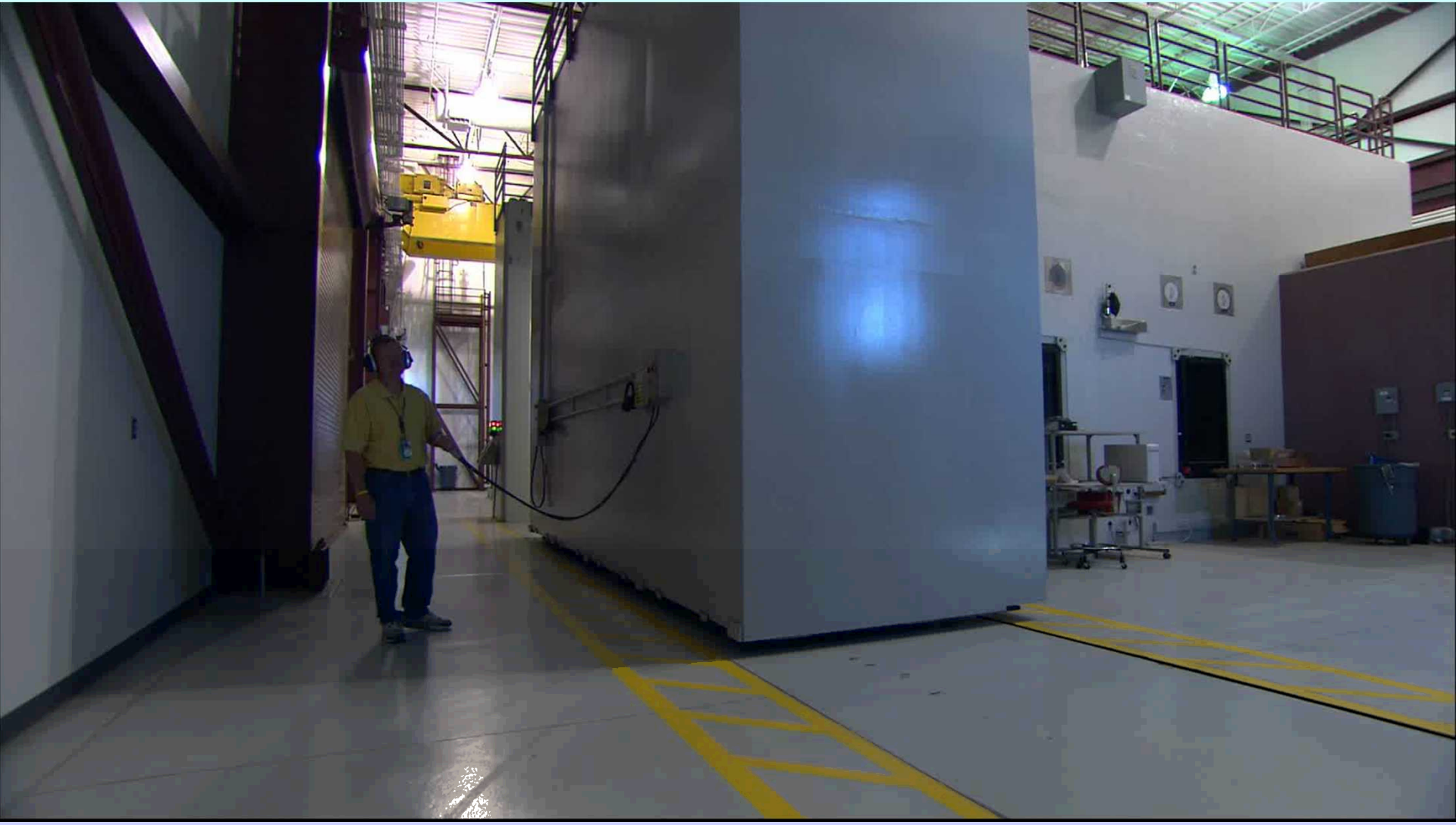
GIF









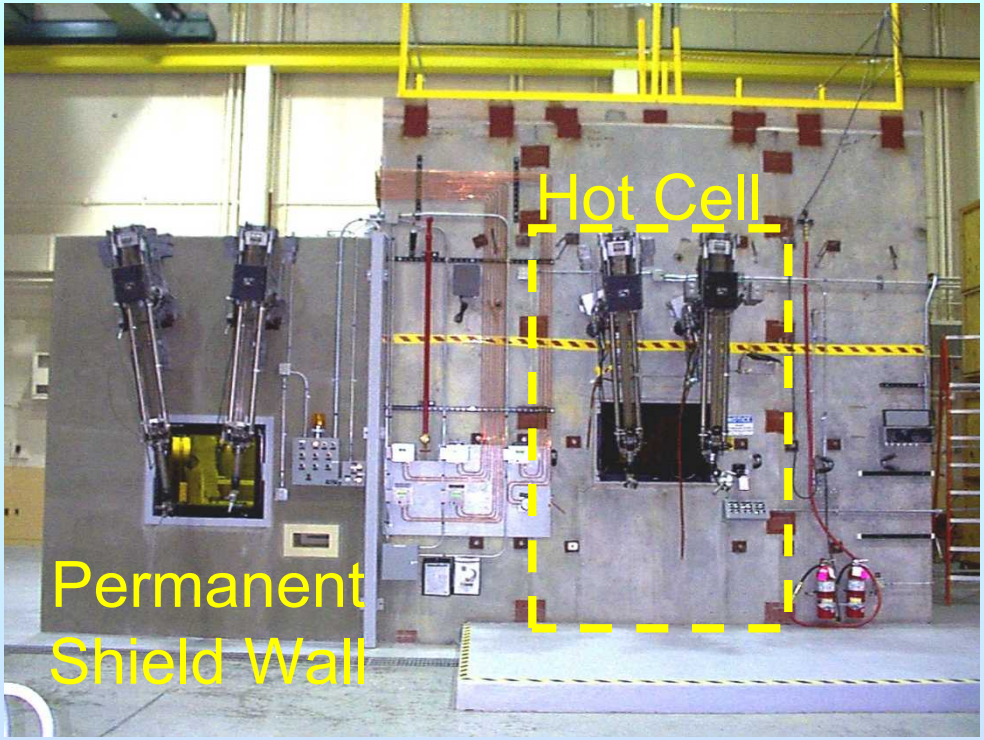


GIF

TA-V – AHCF

AHCF


External Silos


Hot Cell
Permanent
Shield Wall


Fume Hood


Hot-Cell Silos

TA-V – HCF (Inactive)

SNL TA-V Nuclear Facilities

- REACTORS
  - Annular Core Research Reactor (ACRR)
  - Sandia Pulse Reactor (SPR) & Sandia Critical Experiments (SCX)
- HOT CELL & IRRADIATION FACILITIES
  - Gamma Irradiation Facility (GIF)
  - Auxiliary Hot Cell Facility (AHCF)
  - Hot Cell Facility (HCF) (Inactive)
- RADIATION METROLOGY LABORATORY (RML)

TA-V – RML

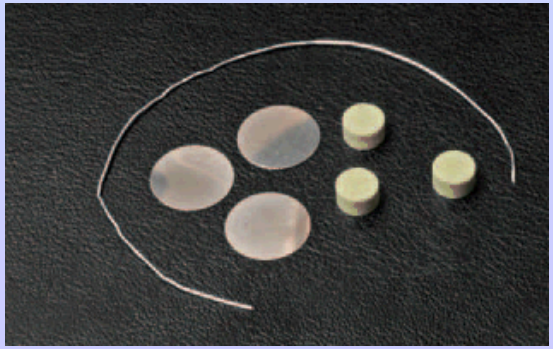
RADIATION METROLOGY LABORATORY (RML)

- PHOTON DOSIMETRY
  - Thermoluminescence Dosimetry (TLD)
  - Electron Spin Resonance – Alanine
  - Ionization Chambers

- NEUTRON DOSIMETRY
  - Activation Analysis
  - Sulfur

RML Basics

- SERVICES AVAILABLE:
  - Gamma spectroscopy
    - Activation foils
    - Fission foils/wires
  - General dosimetry
    - TLD
    - EPR
    - Ionization chamber
  - Proportional counting
    - Sulfur activation pellets



Sandia National Laboratories

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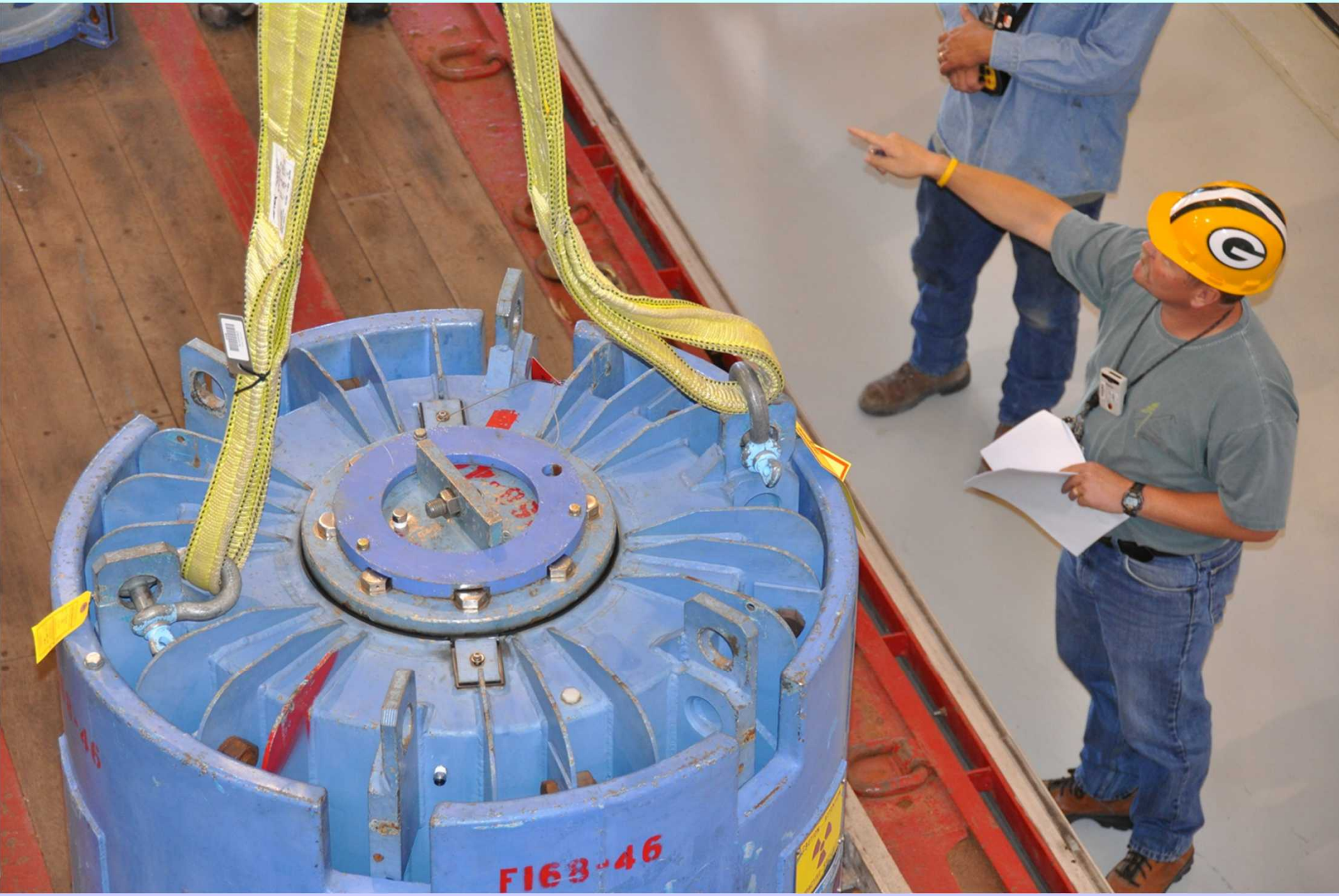
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