SAND2012-2384C

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Module 2: Nuclear Energy Nonproliferation & Safeguards (Week 5/Day 1)

Review of Module I
Nuclear Technology Applications

Gulf Nuclear Energy Infrastructure Institute – 2012 Fundamentals Course

Dr. Cable Kurwitz
Texas A&M University

Module 2/Week 5:

- **Nuclear Technology Operations**

Week 5 Learning Objectives:

- How do we manage and operate nuclear technology systems?
- How are nuclear power plants organized?
- How do we operate nuclear power plants?
- How do we show that we run a nuclear power plant correctly?
- How do we identify and fix problems?
- How can we apply these principles to new situations?

Module 2: Nuclear Energy Nonproliferation & Safeguards (Week 5/Day 1)

Lecture #1: Review of Module 1

Dr. Cable Kurwitz

Today's Primary Learning Objective

Primary Day 1 Learning Objective:

- The broad spectrum of nuclear technology applications.

Take away from this lecture:

- There are a large number of peaceful uses of nuclear technology.

Lecture Outline

1. Goals and Objectives of GNEII

2. Critical Thinking

3. Nuclear Physics

4. Reactor Physics

5. Major Components of a Nuclear Power Plant

Mission and Vision

- Mission:
  - Develop a responsible nuclear energy culture and institutionalize key safety, security, and nonproliferation norms in the future decision-makers of Gulf-region nuclear energy programs through professional development and training

- Vision:
  - provide a continual source of regional nuclear energy professionals with whom the global community can effectively collaborate to achieve broader nuclear energy security and safety priorities

Goals of GNEII

- Establish GNEII as a regional educational and training hub for promoting a nuclear safety, safeguards, and security culture;

- Establish and maintain regional relevancy among participating Middle East states demonstrated by regular participation by students from regional states and active membership on the GNEII Advisory Council by regional state representatives; and

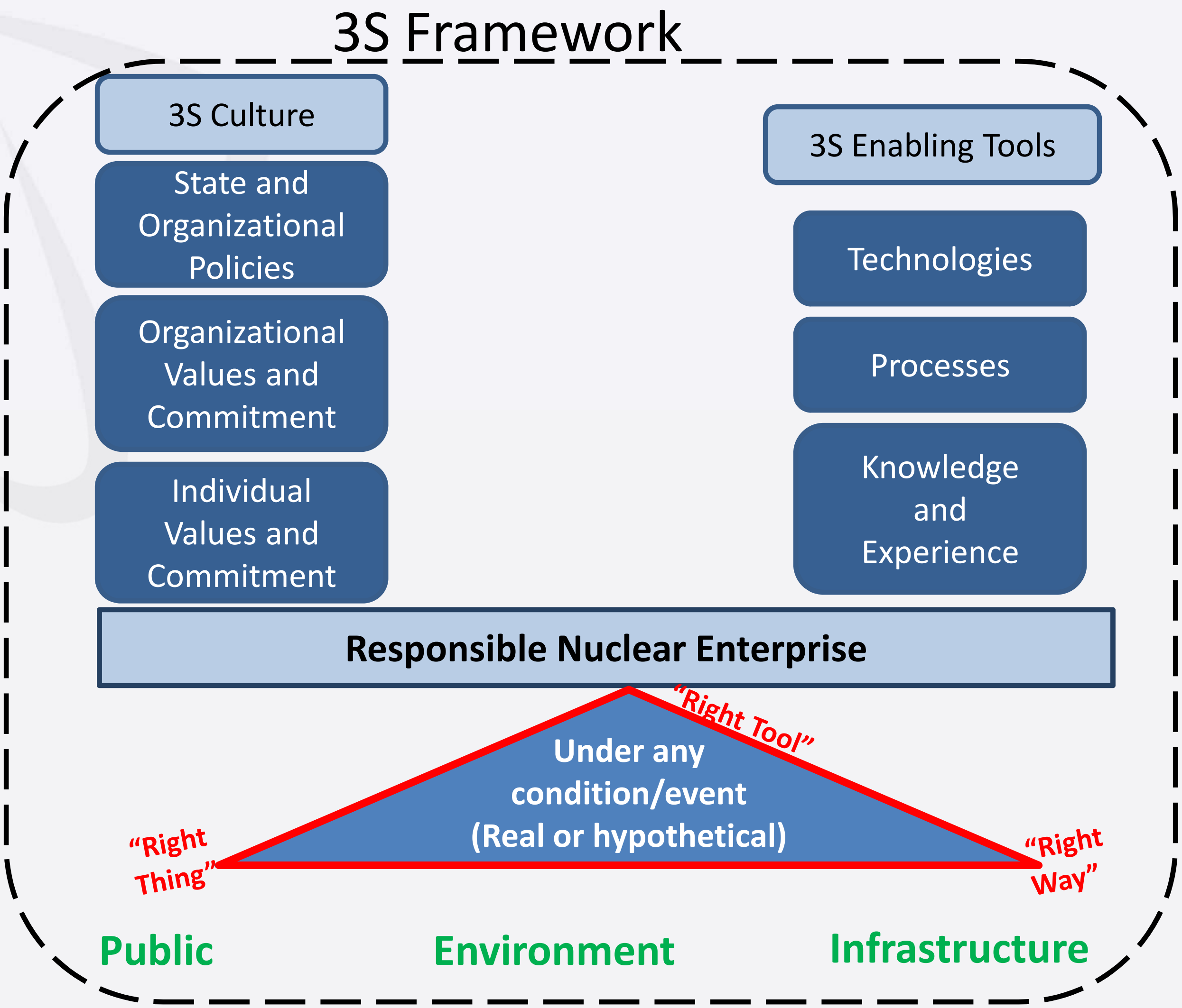
- Establish an indigenously sustainable educational institute by transitioning operational ownership of GNEII to KUSTAR and a majority of educational duties to regional instructors

Long Term Objectives

- Become the premier, regionally based institutional capability for human resource development in nuclear energy infrastructure;
- Assist states with the development and inculcation of nuclear safety and security norms into plans for developing peaceful nuclear power programs;
- Maintain its status as a “demand-driven” source of educational excellence on nuclear safety, safeguards, and security within the region;
- Develop a responsible nuclear energy culture in individuals who will be making policy and managerial decisions within Middle Eastern nuclear energy programs.

Our Proposed Model for Integrated 3S Framework

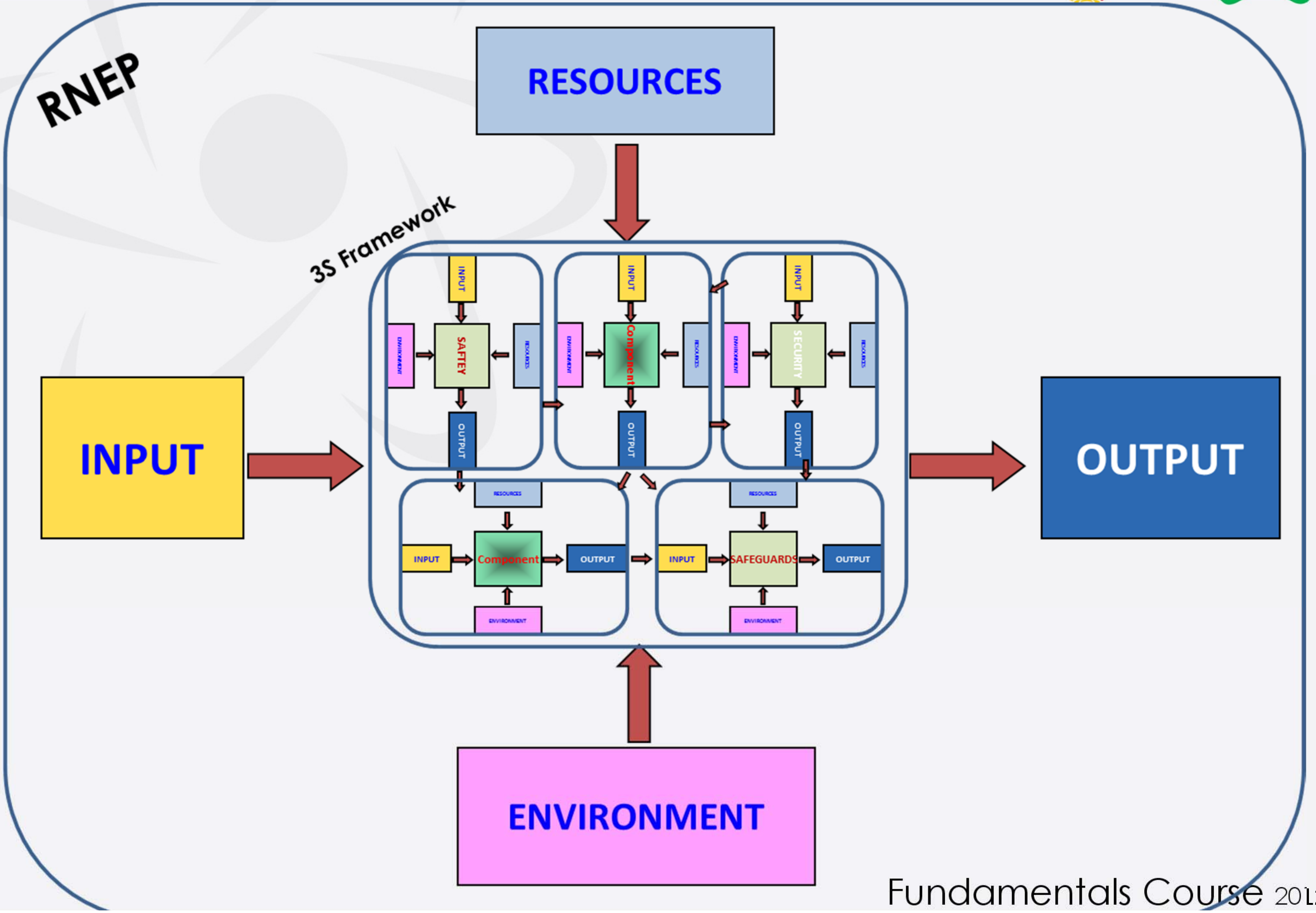
- Dynamic
  - Based on combining right thing, way and tool in timely manner
- Adaptive
  - Able to easily (and dynamically) find the balance; focuses on integrating necessary components of culture/tools
  - Feedback capable
- Proactive
- Comprehensive understanding across areas of expertise



Fair-minded Critical thinkers

- Work to improve their thinking whenever they can
- They are generous
  - Willing to give up things to help other – when it makes sense to do so
- They think a lot!
- Want to understand what other people think
- Do not always believe what others say
  - Try to question and understand other people's motives

The System of Systems – 3S Framework



Scientific Method

Connection to Critical Thing and System Analysis Approach

1. Ask a question or state a problem. (one of elements of Thought)

2. Propose an "Educated " answer /opinion/ view for /on the question /issue/topic/ or solve the problem (Hypothesis). (requires collection of data/information and check assumptions before developing a view or opinion – an element of critical thinking)

3. Provide supporting arguments / evidence for your answer /opinion/ view AND those against ;
   - Provide arguments against other views – why you disagree? Why they will not work? What are their risks / un-intended consequences? (similar to elements of Thought and Critical Thinking).

4. Summarize your analyses/ results; and provide potential challenges with implementation/adoption of your answer /opinion/ view (similar to elements of Thought and Critical Thinking).

5. Draw (make) Conclusions *(How does the conclusion compare to the hypothesis?) What the unintended consequences.* (similar to elements of Thought and Critical Thinking).

Fundamental Particles

Proton +

Neutron

β-

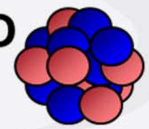
β+

γ

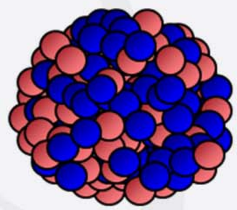
Nuclei *~10^{-14}m*

^{4}He

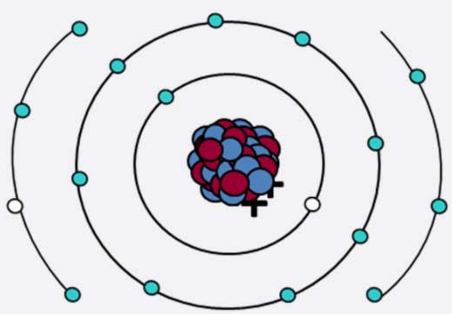
^{16}O



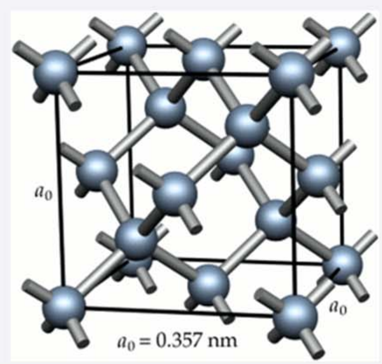
^{235}U



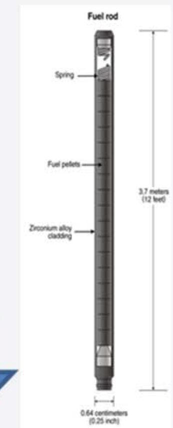
Atoms *~10^{-10}m*



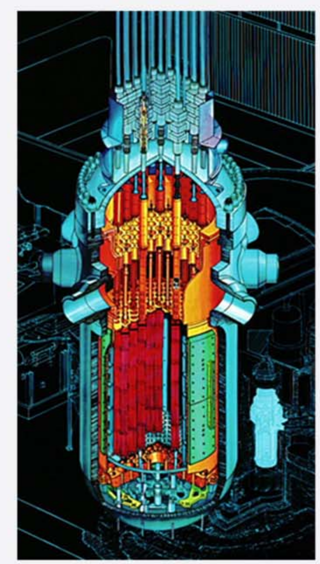
Crystal Structures *~10^{-9}m*



Materials *~10^{-2}m*



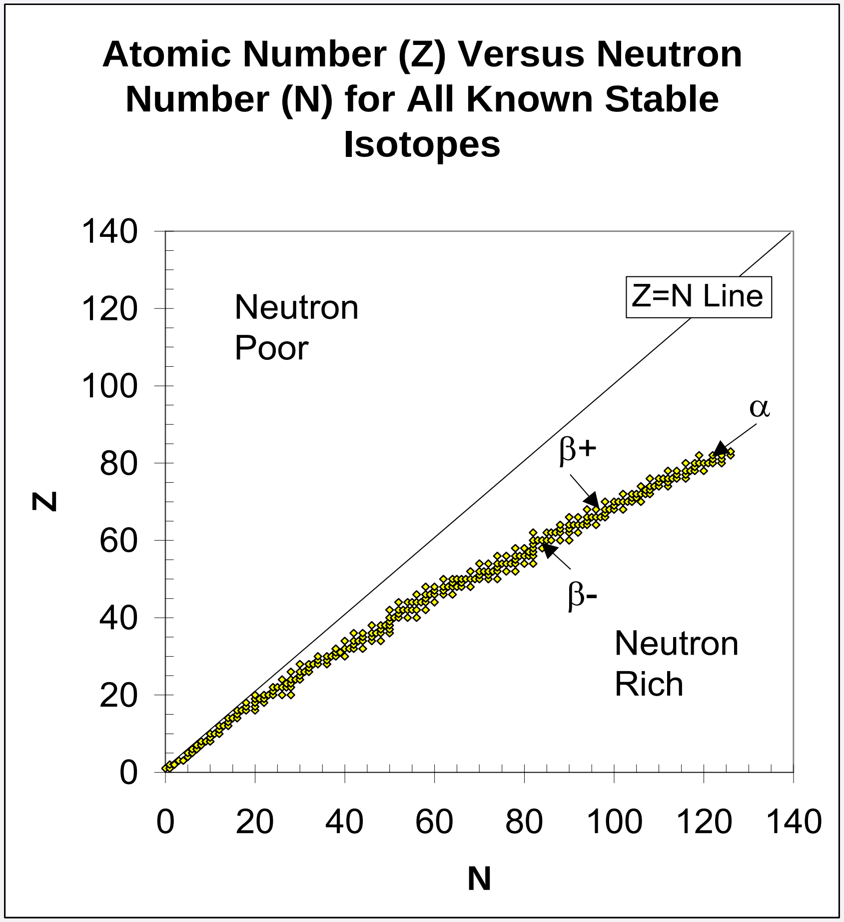
Machines ***(meters)***



Radioactive Decay

- The figure shows all of the stable nuclides as a function of Z (vertical axis) and N (horizontal axis)
  - note that there are more neutrons than protons in most nuclei
  - the extra neutrons provide nuclear stability

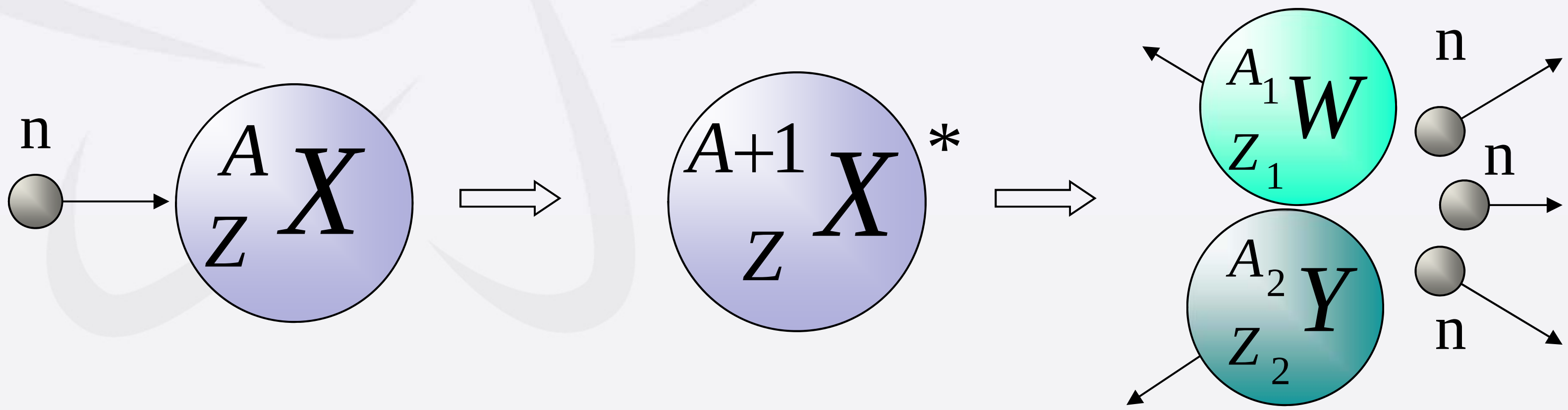
- There are only certain combinations of N and Z that produce stable nuclei
  - the rest are radioactive



Author: Dr. Charlton, NUEN, TAMU

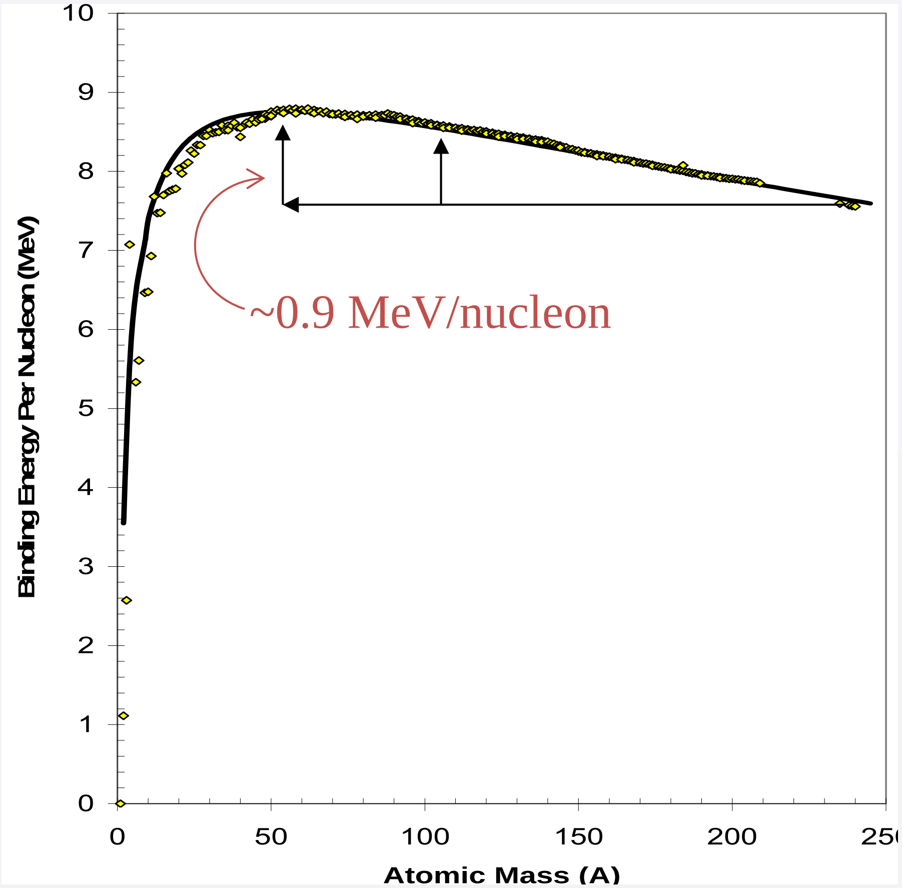
Neutron-induced Fission

- A neutron is absorbed by a target nucleus: a compound nucleus is formed in an excited state.



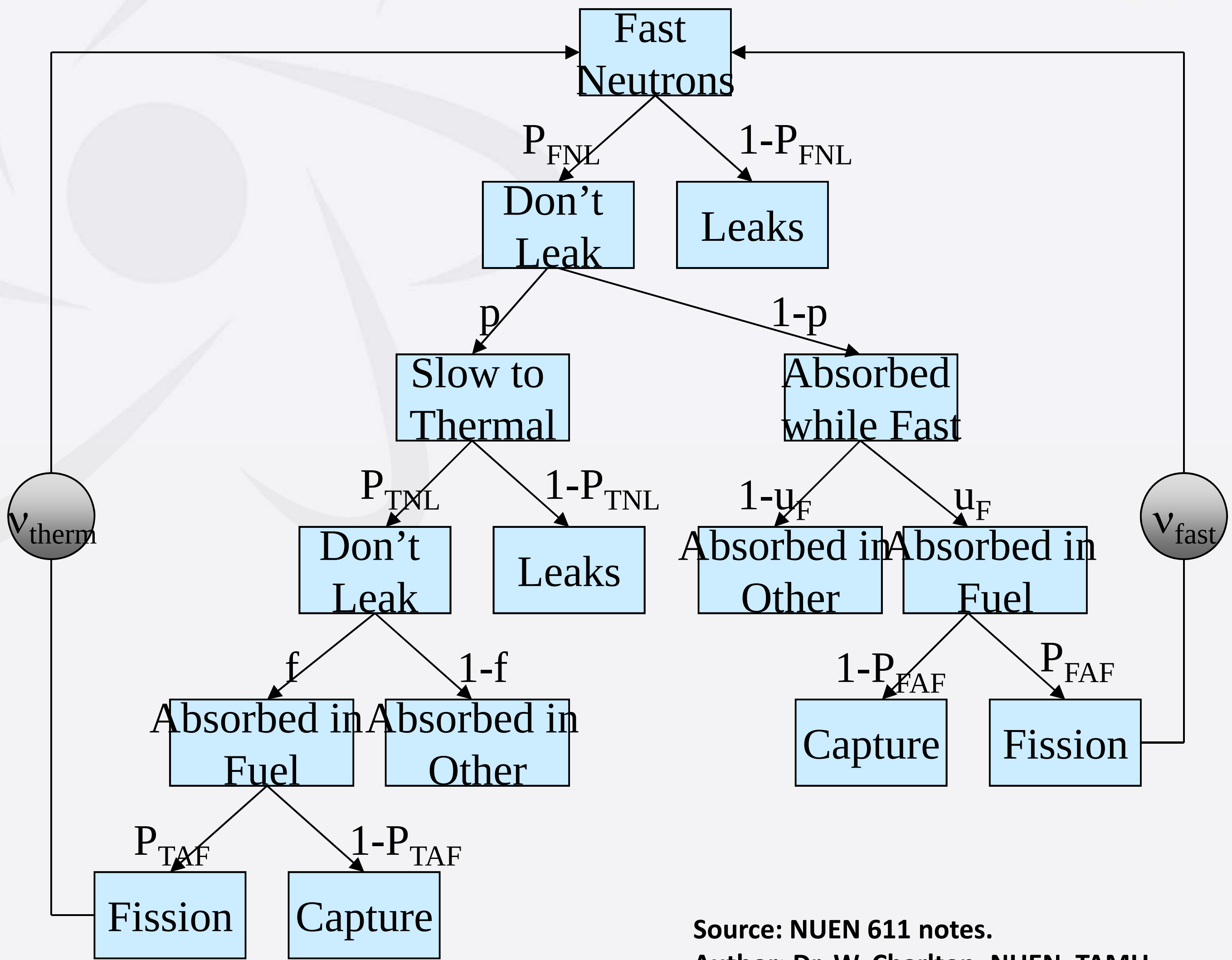
Why Fission Occurs

- The liquid drop model binding energy curve explains why fission occurs
  - The binding energy per nucleon of nuclei decreases with increasing atomic mass for *A > 50*
  - Thus, a more stable configuration of nucleons is produced when a heavy nuclei is split into two or more parts



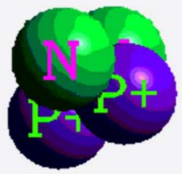
Author: Dr. Charlton, NUEN, TAMU

Life Cycle of a Neutron



Source: NUEN 611 notes.
Author: Dr. W. Charlton, NUEN, TAMU

Types of Ionizing Radiation

- Alpha (a) - particle 

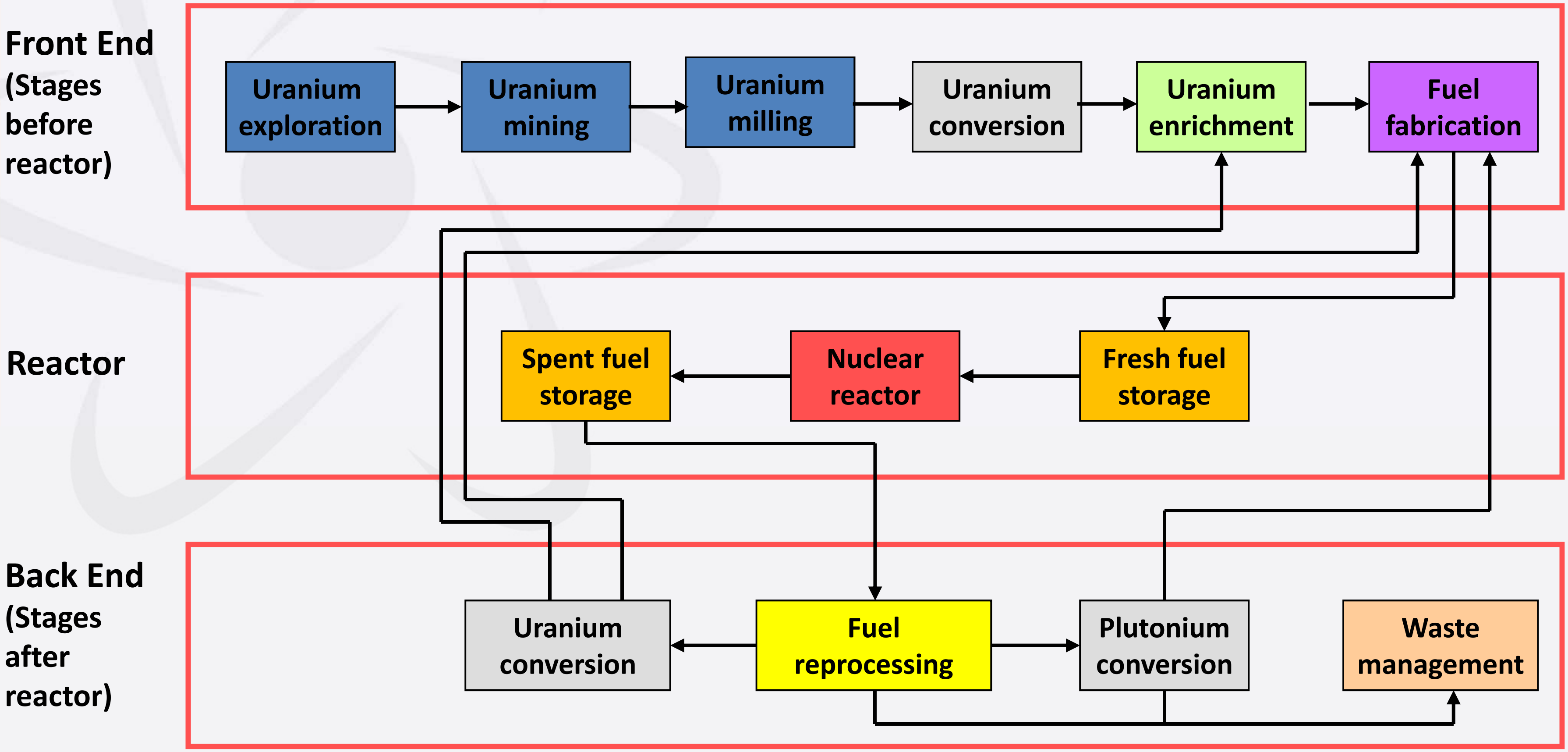
- Beta (b) - particle 

- Gamma (g) / X - ray 

- Neutron (h) - particle 

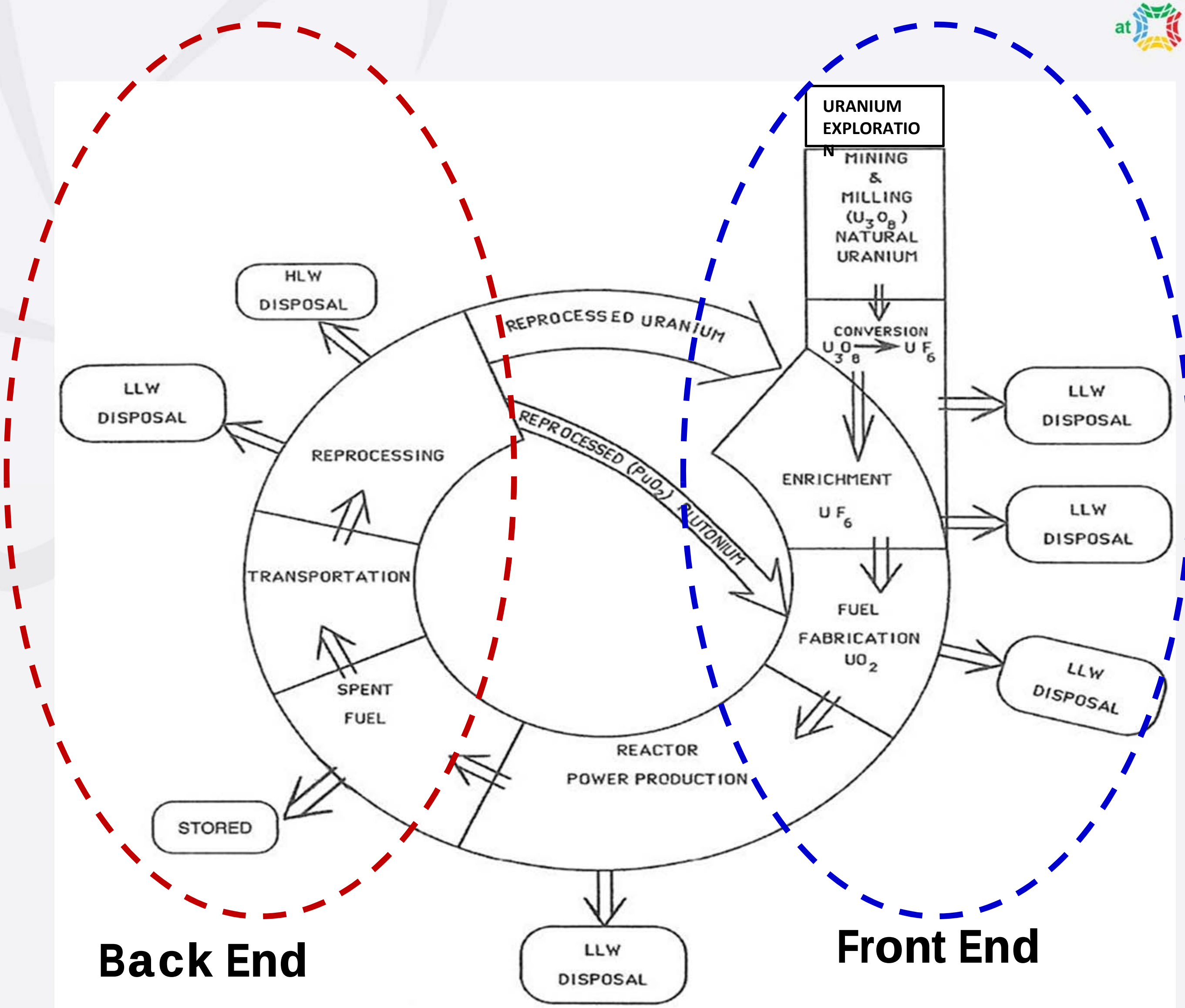
Definition of Nuclear Fuel Cycle (NFC)

Schematic of Generic Commercial NFC



The path followed by nuclear material (in its various states) during its use, through a system of interconnected nuclear facilities (from mining of ore to disposal of the final waste).

Nuclear Fuel Cycle



R.G. Cochran and N. Tsoulfanidis, *The Nuclear Fuel Cycle: Analysis and Management, 2nd Edition,* ISBN: 0894484516, American Nuclear Society, La Grange Park, IL, 1999

Module 2: Nuclear Energy Nonproliferation & Safeguards (Week 5/Day 1)

Lecture #2: The Operation and Management of Nuclear Technology and Applications.

Dr. Cable Kurwitz

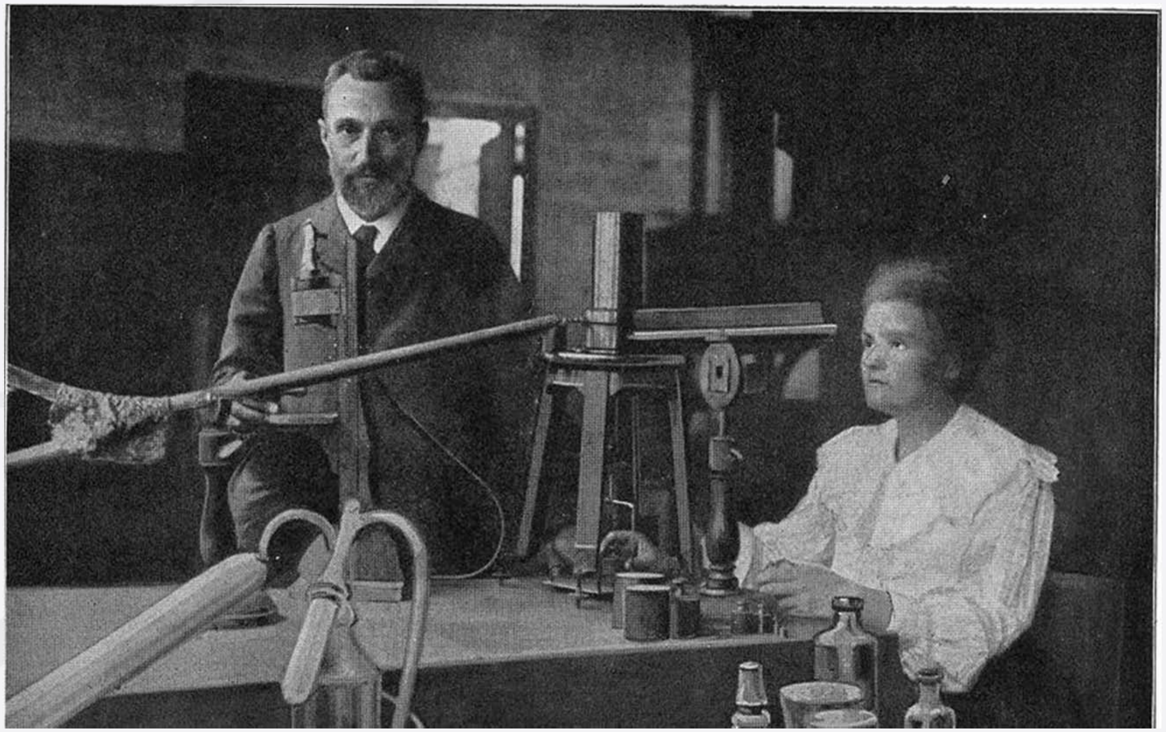
Lecture Outline

1. Education and Research
2. Medical
3. Industrial
4. Agriculture
5. Security

Applications of Nuclear Technologies

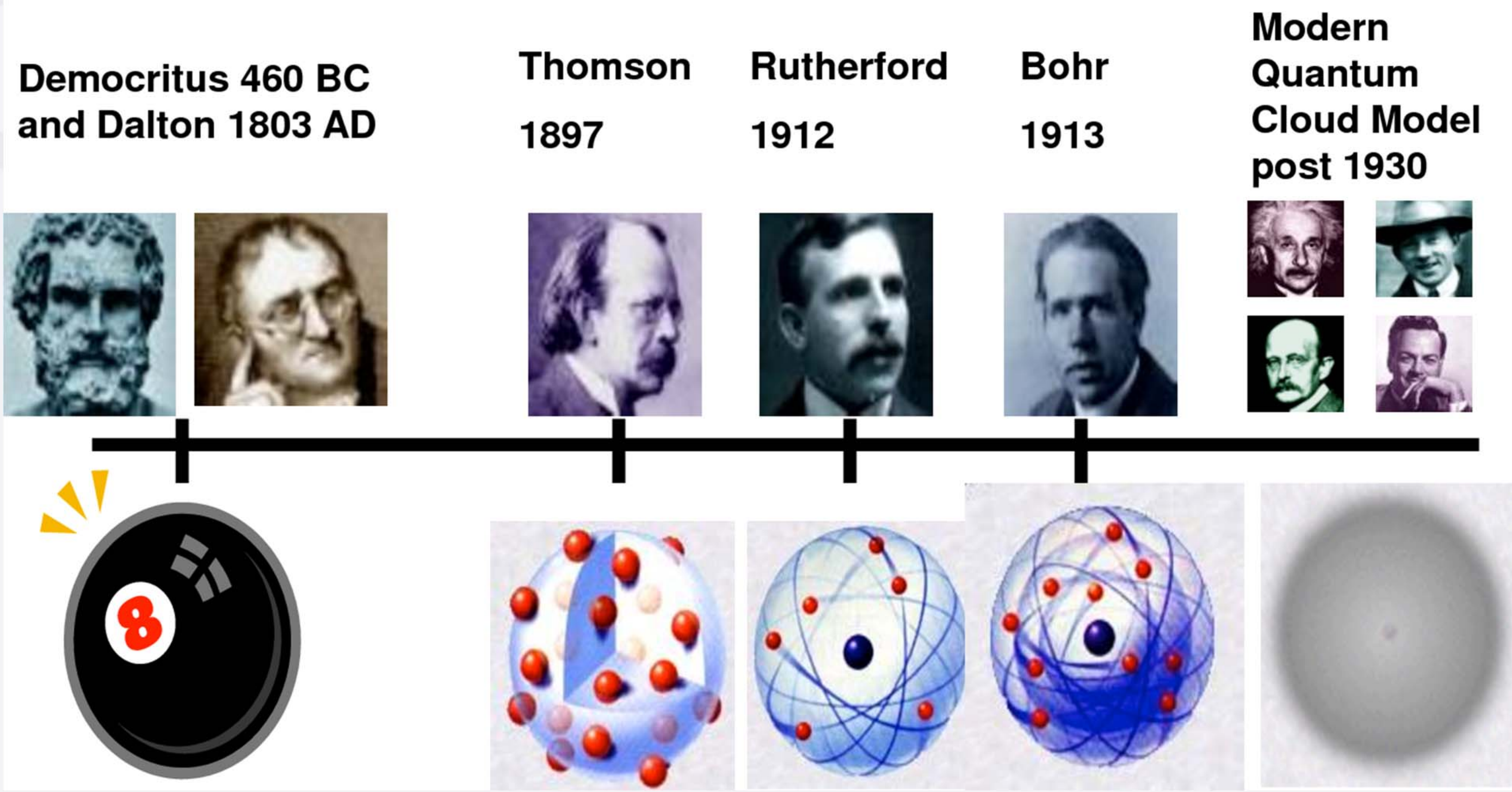
- Nuclear technology has a large number of applications in the education and research community
- The universe of modern atomic theory was created in 1803 when chemist John Dalton published his paper, A New System of Chemical Philosophy.
  - Matter is made of indivisible atoms
  - Each element consists of identical atoms
  - Atoms are unchangeable

…*although the Greeks may argue who was first*



In 1898, French physicist Pierre Curie and his wife Maria Curie had discovered that present in pitchblende, an ore of **uranium**, was a substance which emitted large amounts of radioactivity, which they named **radium**.

Reference: Wikipedia



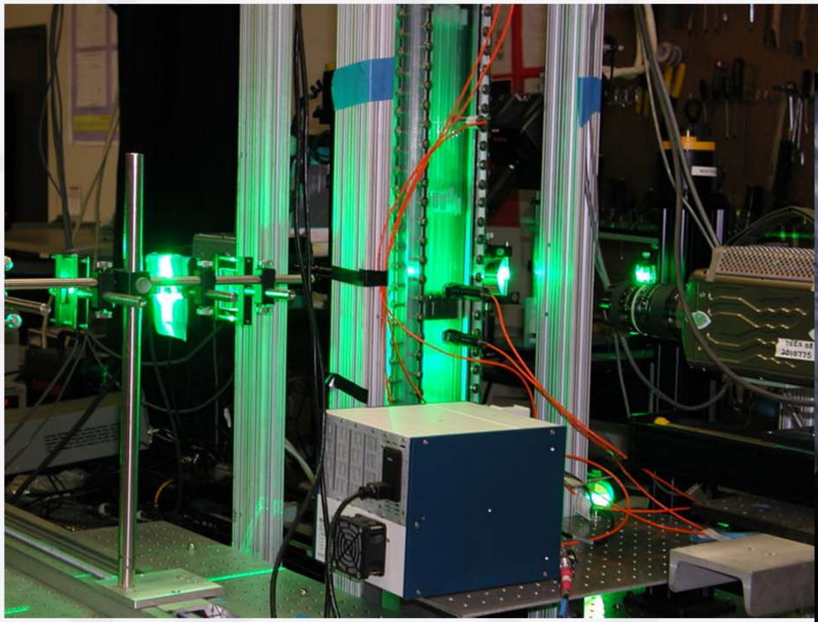
Reference: http://www.docstoc.com

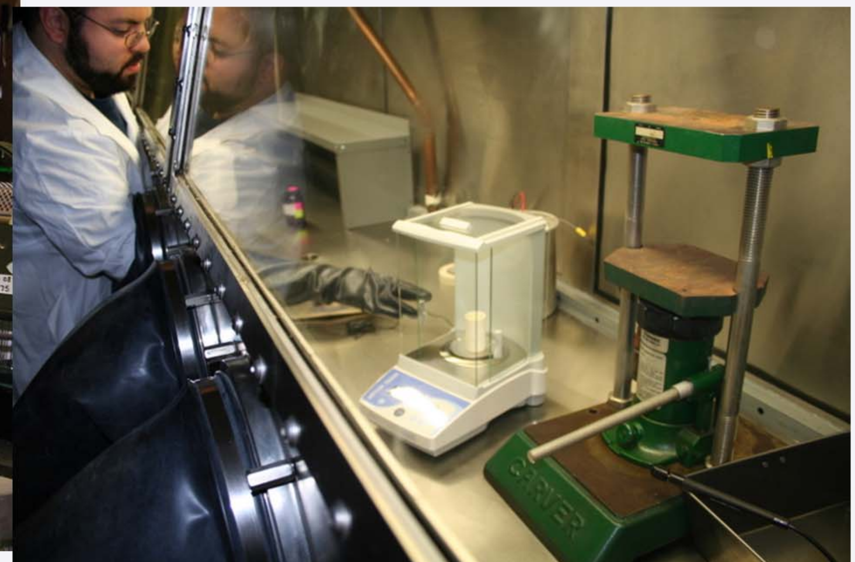
Education and Research

- Education in the understanding of atomic theory and nuclear applications drives modern curricula
  - Physics, chemistry, etc.
  - From Elementary through post-graduate
  - Industrial training
- Nuclear physics is a continuing area of research that provides insight into the structure of matter and our understanding of the universe
- Atomic theory is the basis for our understanding and utilization of nuclear applications

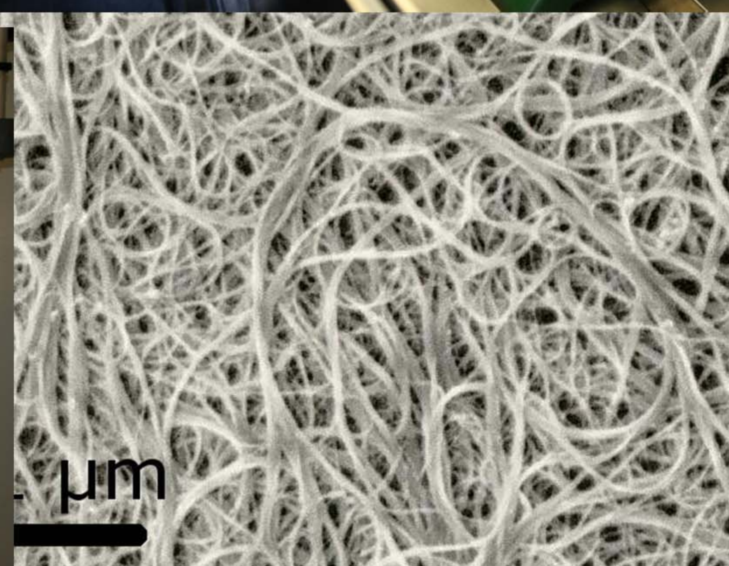
Education and Research

- Research benefits from technologies derived from nuclear knowledge
  - Development of models to describe phenomena
    - Atomic and sub-atomic models
    - Quantum mechanics
    - Radioactive decay, fission, fusion, …
  - Diagnostic tools used to observe and/or quantify
    - Imaging
    - Radioactive dating
    - Radioactive tracers-labeling
- Education and research activities cover a wide gamut of activities
  - Requires a broad set of equipment, radioactive materials, facilities
  - Diverse set of users
  - Communication, Documentation, and Actions



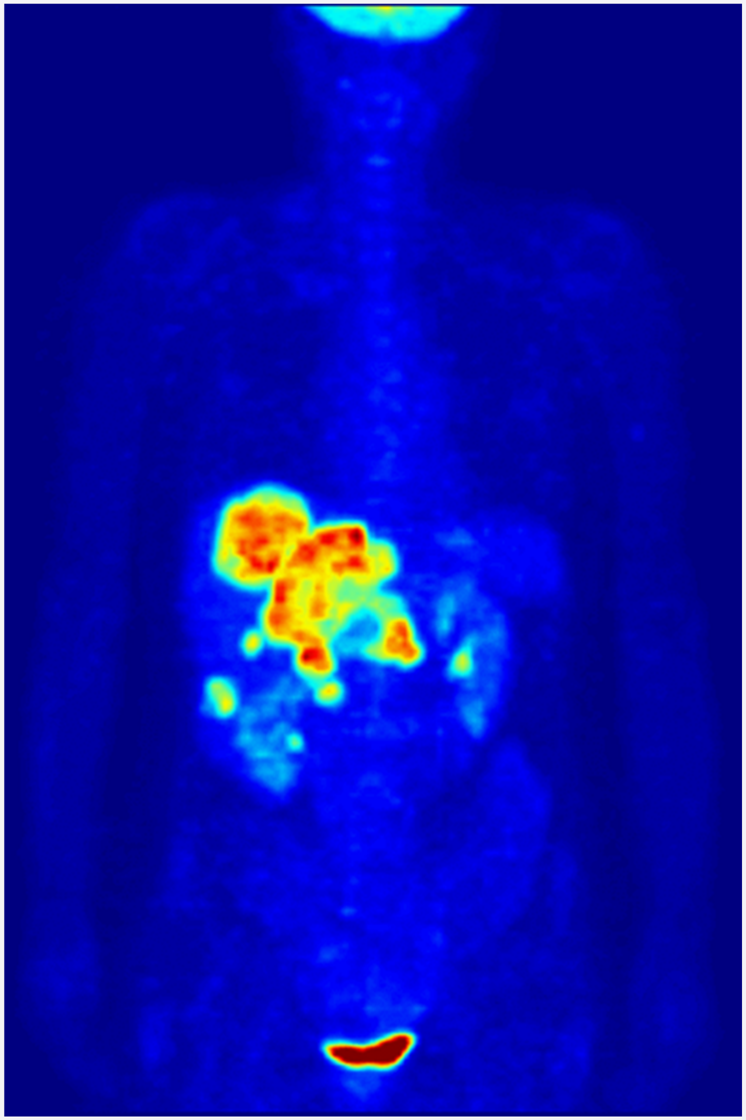



CAUTION
HIGH
RADIATION
AREA


µm

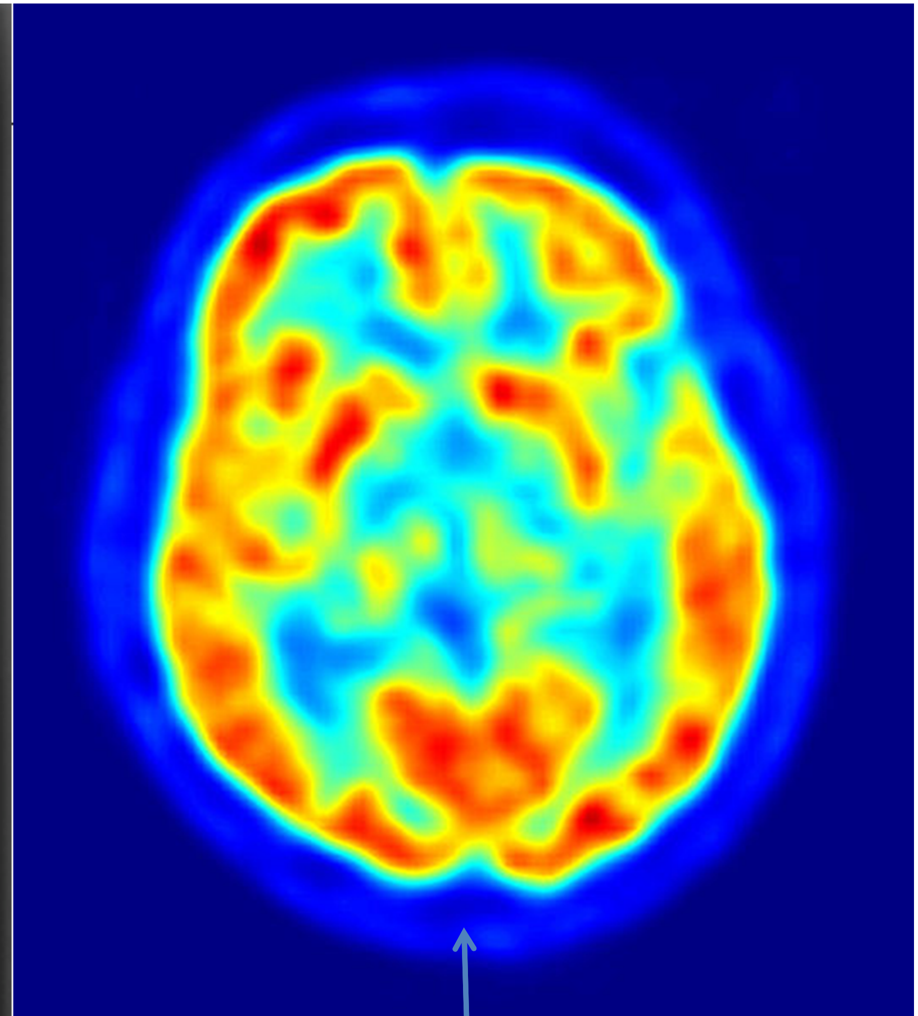
Medical

- The medical field has embraced the use of nuclear technologies to diagnose, monitor, and treat a wide assortment of metabolic processes and medical conditions



Medical

- Diagnostic applications include a variety of imaging applications that either supply an external source of radiation that passes through the subject or through an internal radiation source from a dose administered to the subject
  – Utilizes different phenomena to gain insight into condition of interest
    - X-rays versus gamma rays versus positrons
    - Tagging of materials to determine location



PET scan of human brain

X-Ray of Fractured Hand

Medical

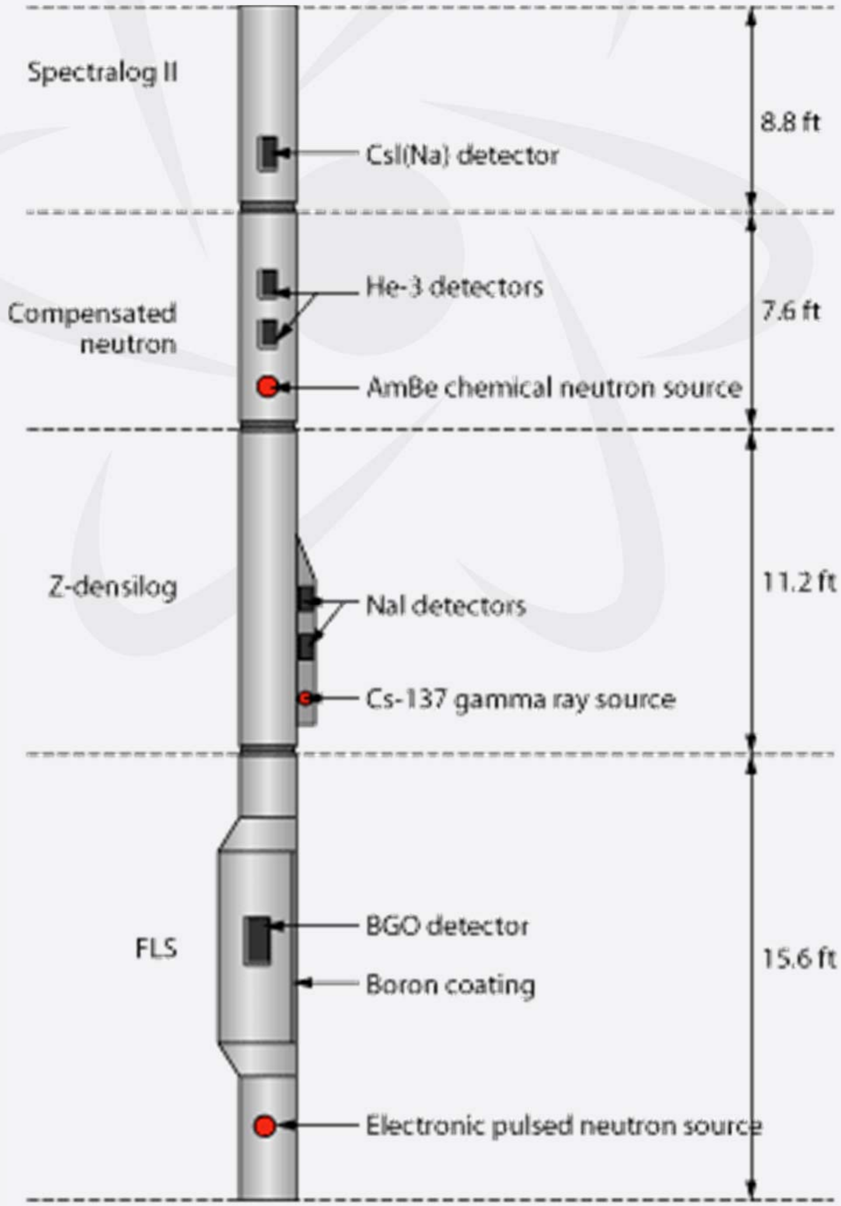
- Therapeutic applications also utilize various forms of radiation but are mainly focused on the destruction of specific tissue within the body
  - Implant of radioisotope capsules
  - External beam therapy
  - Other Radioisotope therapies
- Sterilization of medical equipment
- Requires a broad set of equipment and radio-pharmaceuticals
    - Responsibility, Communication, and Actions

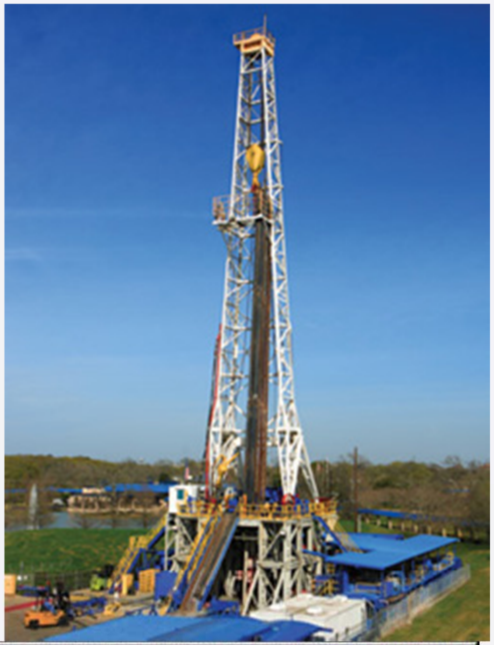
Industrial

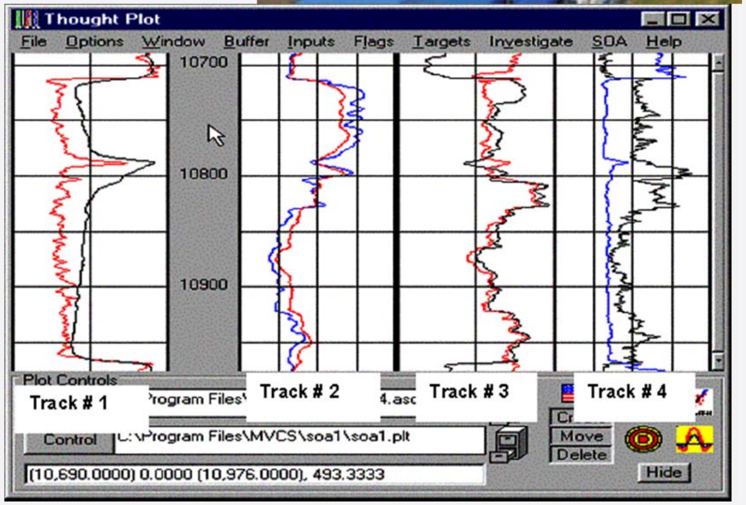
- Outside of nuclear power, there are a number of uses for nuclear technology
- As with Medical applications, industrial uses follow developments in R&D closely
- Diagnostic
  - Gauging Devices
    - Soil moisture/density, material thickness
  - Well Logging
  - Surface Preparation
    - Decontamination, sterilization, chemical preparation

Industrial

- Well logging records rock and fluid properties to identify geological formations of interest intersected by a borehole.
- The logging procedure consists of lowering sensors and related equipment into the hole to gain information – the log.
- This data is then used to make important decisions regarding the well
- A number of different radioisotopes or radiation generating equipment is used in well logging operations by different organizations at the well site.
  - Communication, Documentation, and Actions


Spectralog II
CsI(Na) detector
8.8 ft
Compensated neutron
He-3 detectors
7.6 ft
AmBe chemical neutron source
Z-densilog
NaI detectors
11.2 ft
Cs-137 gamma ray source
FLS
BGO detector
Boron coating
15.6 ft
Electronic pulsed neutron source




Thought Plot
File Options Window Buffer Inputs Flags Targets Investigate SOA Help
10700
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10900
Plot Controls
Track # 1
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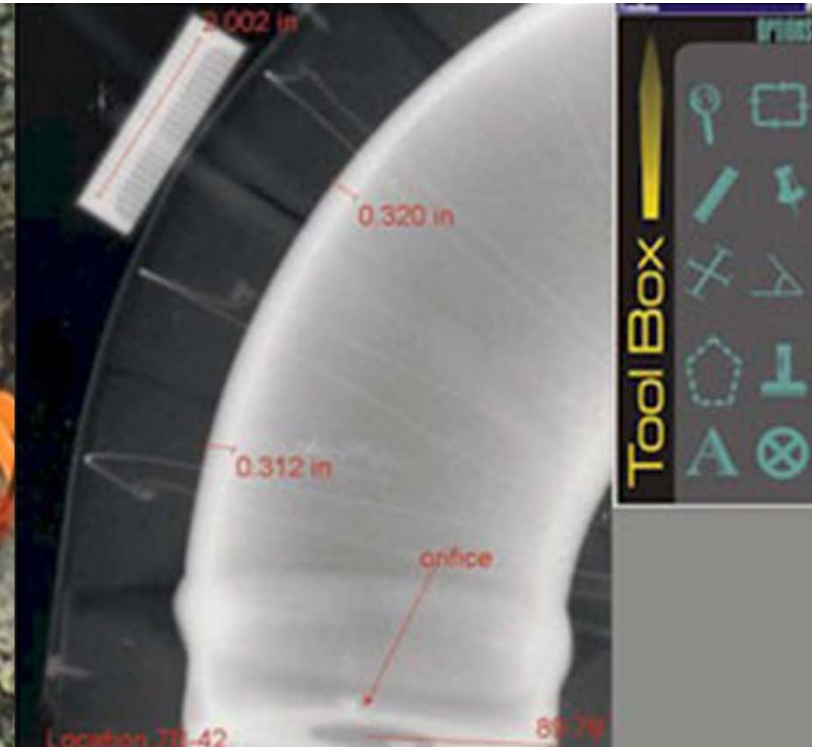
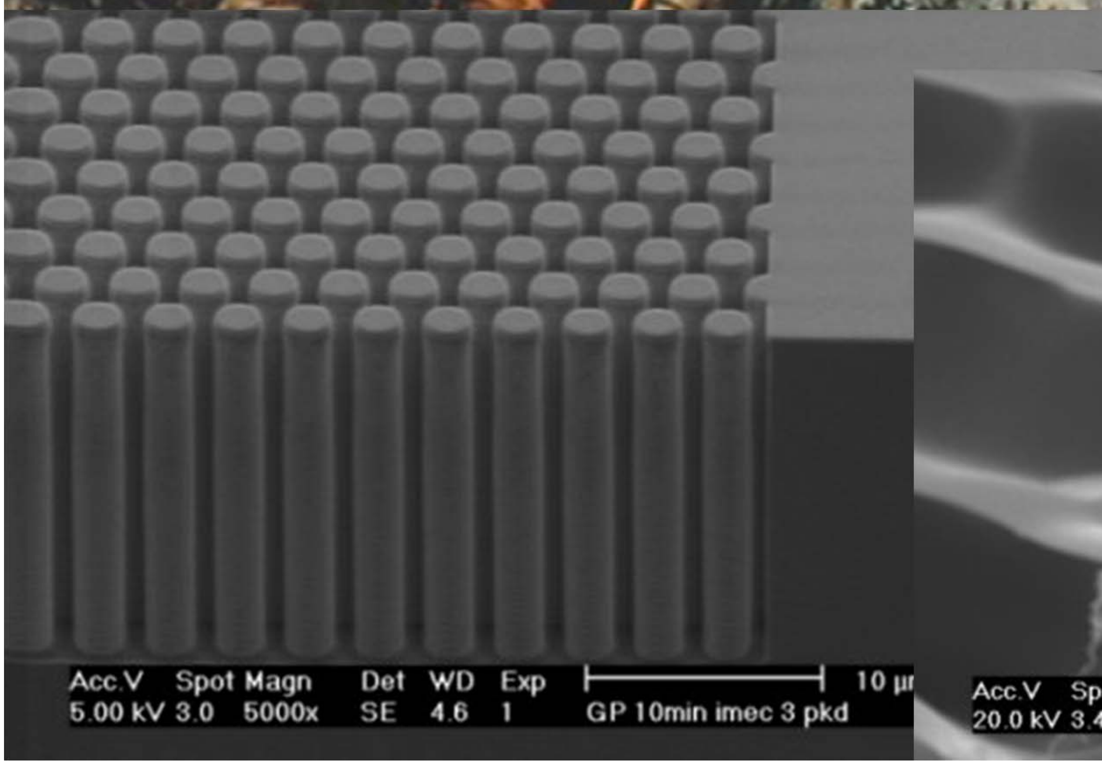
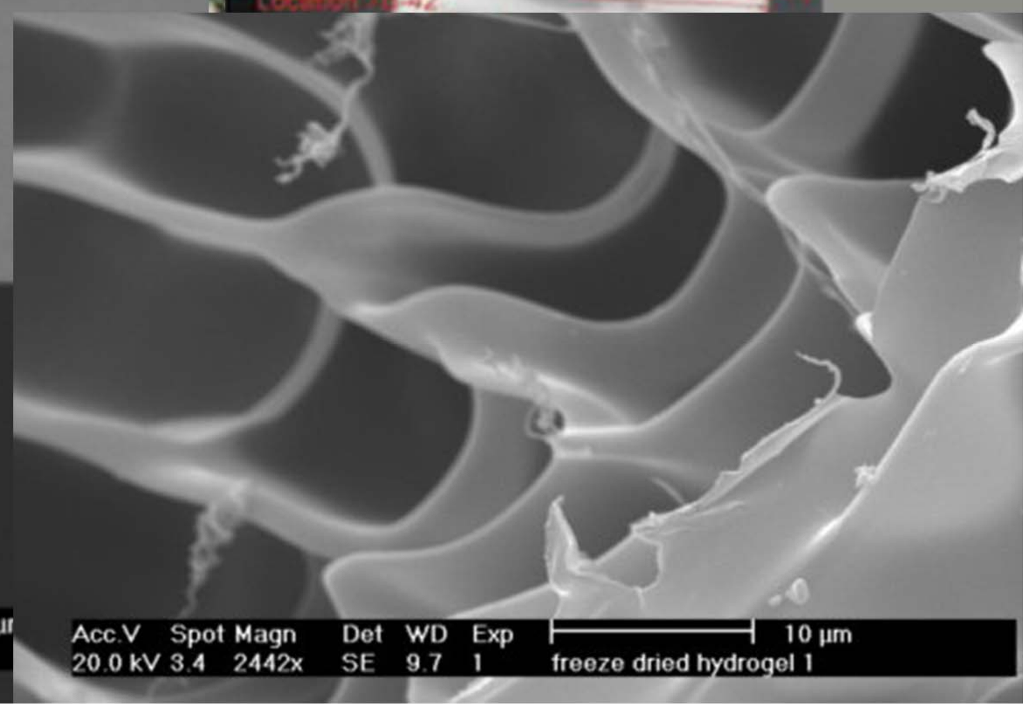
Track # 3
Track # 4
Control
C:\Program Files\MVCS\soa1\soa1.plt
Move
Delete
Hide
(10,690.0000) 0.0000 (10,976.0000), 493.3333

Applications of Nuclear Technologies

- Utilizing the characteristics of radiation allows one to carry out functions previously not achievable and improved the cost/performance of other processes.
  - Inspection techniques
    - Weld inspection
    - Leak detection
    - Tracer tracking
  - Material processes
    - Polymer cross-linking
      - Polyethylene shrink wrap that has been irradiated so that it can be to elevate melting point
    - Coatings and surface preparation


0.320 in
0.312 in
orifice
Tool Box


Acc.V Spot Magn Det WD Exp
5.00 kV 3.0 5000x SE 4.6 1 GP 10min imec 3 pkd


Acc.V Spot Magn Det WD Exp 10 µm
20.0 kV 3.4 2442x SE 9.7 1 freeze dried hydrogel 1

Products	Uses	Radiation sources
Cross-linking of insulation of wires and cables	Heat-resistant wire and cable	Accelerator
Polyethylene foam	Thermal insulation, backing, mats, sports clothing, etc.	Accelerator
Curing of surface-coating	Wood panel, steel, ceramic tiles, plastic film, paper, etc.	Accelerator
Heat-shrinkable tubing and sheets	Electrical insulation, corrosion protection of pipelines, food packaging	Accelerator
Wood/plastic composite	Flooring, furniture, sporting goods, etc.	Co-60
Acrylic-acid grafted polyethylene	Lamination on metal foil	Accelerator
Degradation of PTFE	Solid lubricants	Co-60, accelerator
Polymer flocculant	Treatment of waste water	Co-60
Synthesis of chemicals	Synthetic detergent, chlorinated paraffin, etc.	Co-60, accelerator
Super absorbant products	Disposable diapers, air freshener, etc.	Accelerator
Pre-vulcanized rubber	Automobile tyres	Accelerator
Conservation of historical works	Wooden and stone works	Co-60
Sterilization of medical supplies	Needles, syringes, sutures, blades, dialyser, bandages, etc.	Co-60, accelerator
Food irradiation	Potatoes, onions, shrimps, etc.	Co-60

Power

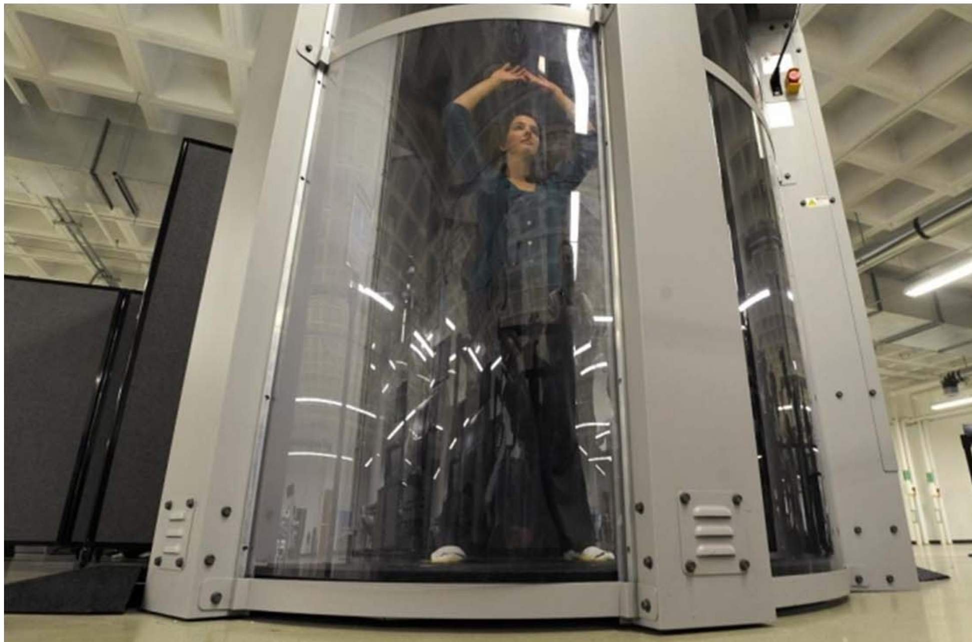
- Radioisotope generators are used primarily in space applications but have been used for terrestrial applications such as powering medical devices and unmanned remote power applications.
- Industrial uses of radiation covers a wide gamut of activities
  - Requires a broad set of equipment, radioactive materials, facilities
  - Diverse set of users
  - Communication, Documentation, and Actions

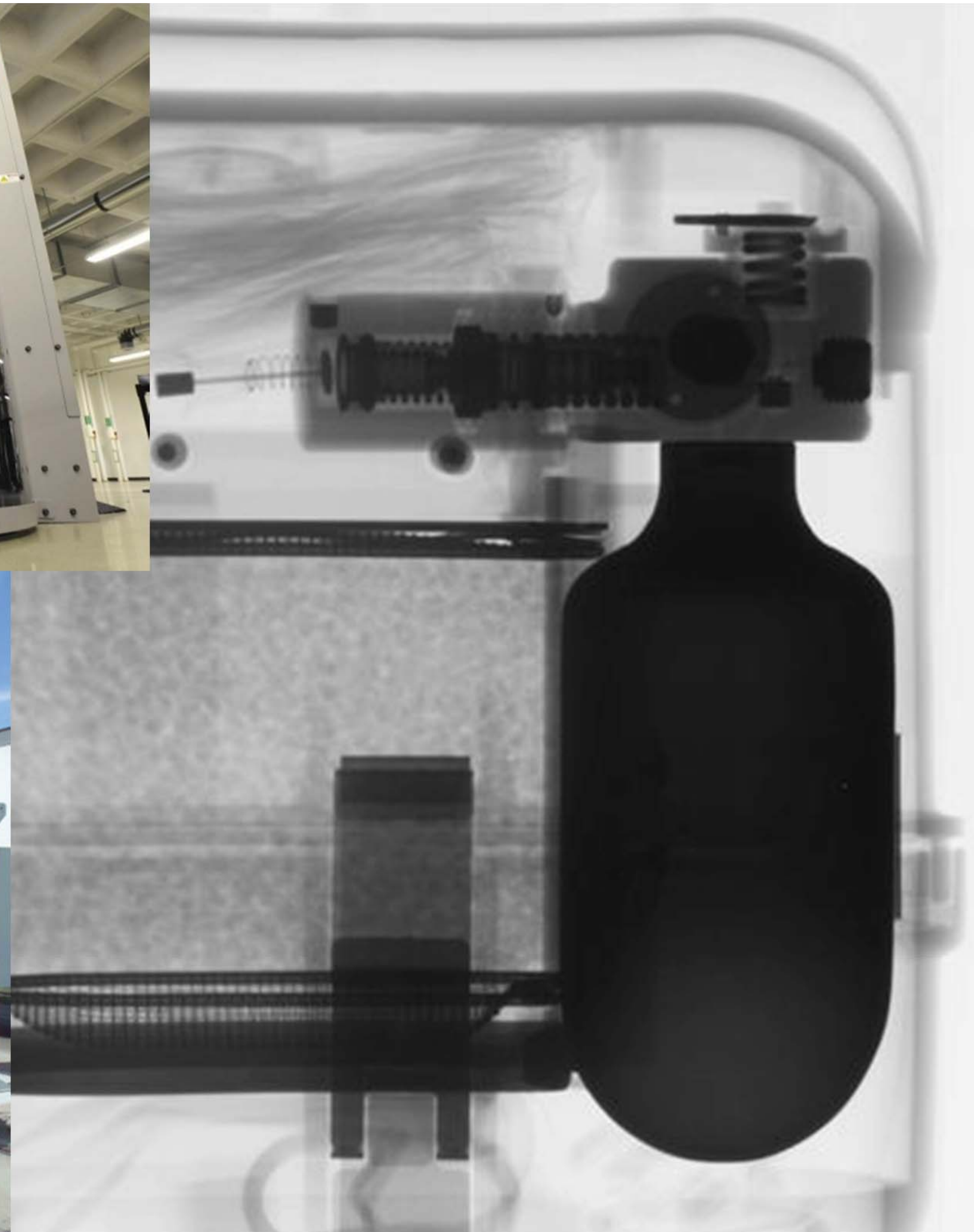
Agriculture

- The agricultural industry makes use of radiation to improve food production and packaging.
  - Use as a diagnostic
    - Understand chemical and biological processes in plants and soils
    - Measure egg shell thickness
  - Pest control
    - Irradiation to sterilize pests
    - Quarantine or 'Sterilization' systems
  - Development of higher performance crops
    - Radiation-induced genetic alterations have improved both crop and ornamental plant varieties
  - Food preservation
    - Food irradiation

Security

- The use of radiation systems in the field of security has increased significantly to include a range of applications as well as types of systems utilized.
  - Inspection systems
    - Airport baggage
  - Access point screening
    - Transportation portals
  - Sterilization or inerting





Fundamentals Course 2012

Nuclear Technologies

- The practice of nuclear technology encompasses multidisciplinary skills, which use rapidly evolving instrumentation, radioisotopes/radiation generating equipment, and techniques
- The use of nuclear technologies covers a number of areas of society requiring a comprehensive program
  - Management and use
  - Regulation
- This requires a well integrated program that emphasizes safety
  - Communication
  - Documentation
  - Actions

Management and Use

- The use of nuclear technologies covers a whole range of actions:
  - Selection and design
  - Acquisition and installation
  - Transportation and storage
  - Utilization
  - Cleanup and disposal
- It also requires the proper knowledge by personnel at all levels from the front line worker to senior management.
  - Training and education

- Communication, Documentation, and Actions

Training and Education

- The use of a broad spectrum of radioisotopes and/or radiation generating systems
  - General radiation radiation safety
  - Procedure based training
    - Normal and off-normal
  - Personnel that may not have a background in nuclear technologies
    - Spectrum of workers with varying knowledge
- Education programs are carried out in academic settings such as universities or continuing education settings
  - Education programs are overseen by the accreditation body but may also include industry or regulatory inputs
- Communication, Documentation, and Actions

Training and Education

- Training programs provide job specific skills
  - Usually carried out on the job or at site
  - Can cover documentation (procedures, reports), communication (equipment, protocols), and actions (skills, environment)
- Take place throughout the career of worker
  - Pre-hire to on-the-job
  - Ongoing, pre-job, post job
- Training programs are usually monitored by the regulatory body

Training and Education

- Education develops the intellect and allows one to apply this knowledge to new problems
  - Usually carried out prior to career but can include continuing education
    - Education is viewed as far term versus training which is near term
  - Education can be transferable across job duties/sectors whereas training is job specific
- Education programs are usually monitored by an accreditation body but may include input from various organizations
- Communication, Documentation, and Actions

Conclusion

- Nuclear technologies are found throughout society from power to education and research
  - Education and research
  - Medical
  - Industry
  - Agriculture
  - Security
- The application of radioisotopes and radiation producing sources focuses on safety and security which requires proper management
- Communication, Documentation, and Actions

- Use of radiography to inspect pipeline welds
  - Facets of program
    - Description of process
    - Personnel involved
    - Radiation source and actions
    - Location
      - Use, storage, transportation
    - Acquisition and disposal
  - Communication, Documentation, and Actions

Discussion

- Use of radioisotope for medical imaging
  - Facets of program
    - Description of process
    - Personnel involved
    - Radiation source and actions
    - Location
      - Use, storage, transportation
    - Acquisition and disposal
  - Communication, Documentation, and Actions

Module 2: Nuclear Energy Nonproliferation & Safeguards (Week 5/Day 1)

Review of Module I
Nuclear Technology Applications

3S Systems Interactions

Topic Connectivity to 3S's

- Define the key or major aspects of this week's topic as they relate to applying the topic to the 3 S's

Topic Connectivity to 3S's

- Identify Primary connections between the topic and one or more S's
- Identify Secondary connections between the topic and one or more S's
- Briefly describe your rationale for these connections

- Which connection(s) is (are) most important for this topic?

- Where are there confluences between S's for this topic?
  - Do these confluences allow combining of procedures, personnel, or equipment to cover both aspects?

- Where are there conflicts between S's for this topic?
  - How can you resolve the conflicts?

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 2)

Review of Nuclear Power Plant Systems
Nuclear Power Plant Operating Modes

Gulf Nuclear Energy Infrastructure Institute – 2012 Fundamentals Course

Dr. Cable Kurwitz
Texas A&M University

Module 2/Week 5:

- **Nuclear Technology Operations**

Week 5 Learning Objectives:

- How do we manage and operate nuclear technology systems?
- How are nuclear power plants organized?
- How do we operate nuclear power plants?
- How do we show that we run a nuclear power plant correctly?
- How do we identify and fix problems?
- How can we apply these principles to new situations?

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 2)

Lecture #1: Review of Nuclear Power Plant Systems

Dr. Cable Kurwitz

Today's Primary Learning Objective

Primary Day 2 Learning Objective:

- The primary operating modes of a nuclear power plant.

Take away from this lecture:

- The key safety, security, and safeguards concerns in different plant modes.

Lecture Outline

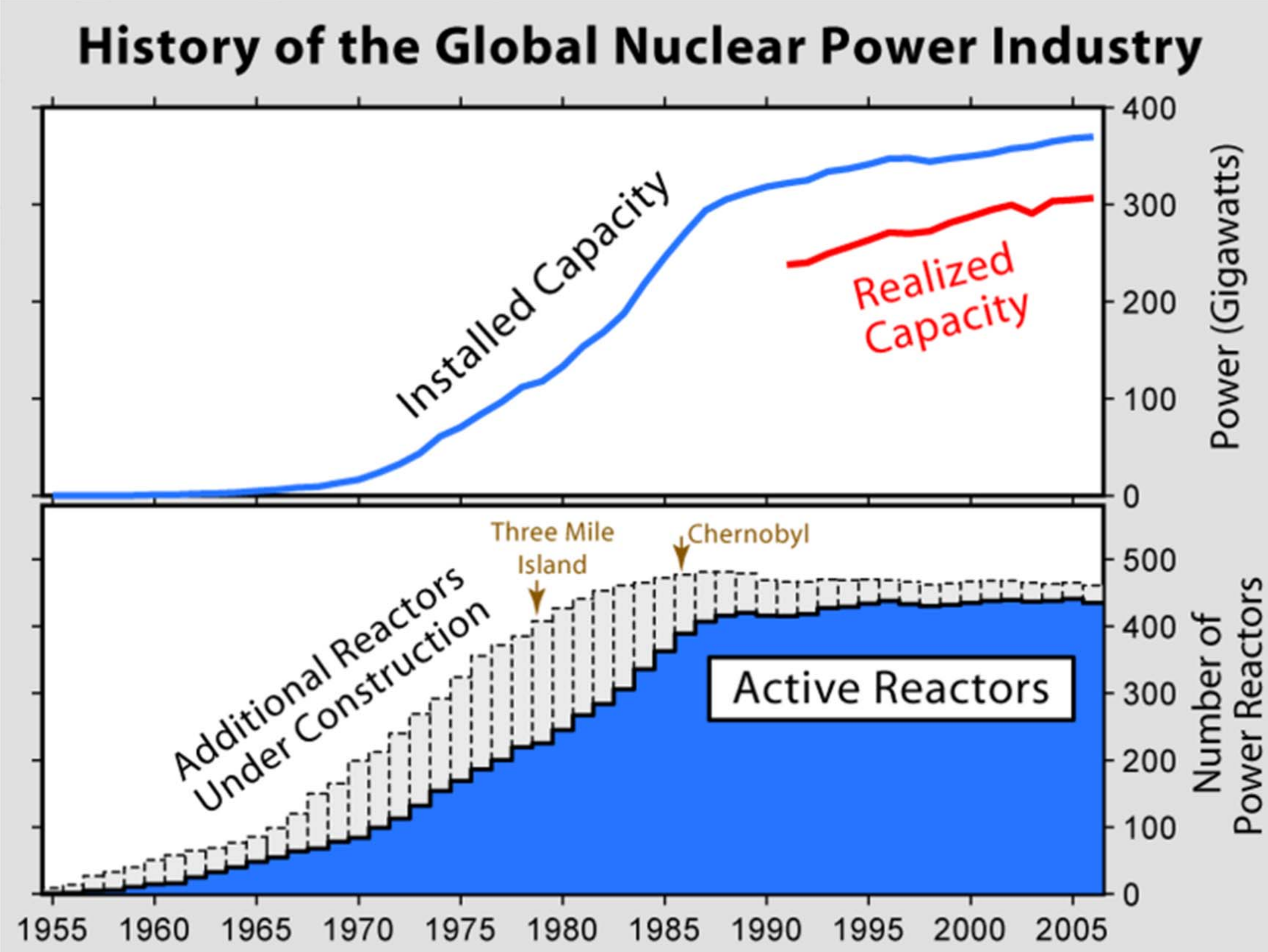
1. Nuclear Energy Production
2. Defense-in-Depth
3. Reactor Types
4. PWR Primary Systems
5. PWR Secondary Systems
6. Emergency Systems
7. Auxiliary Systems

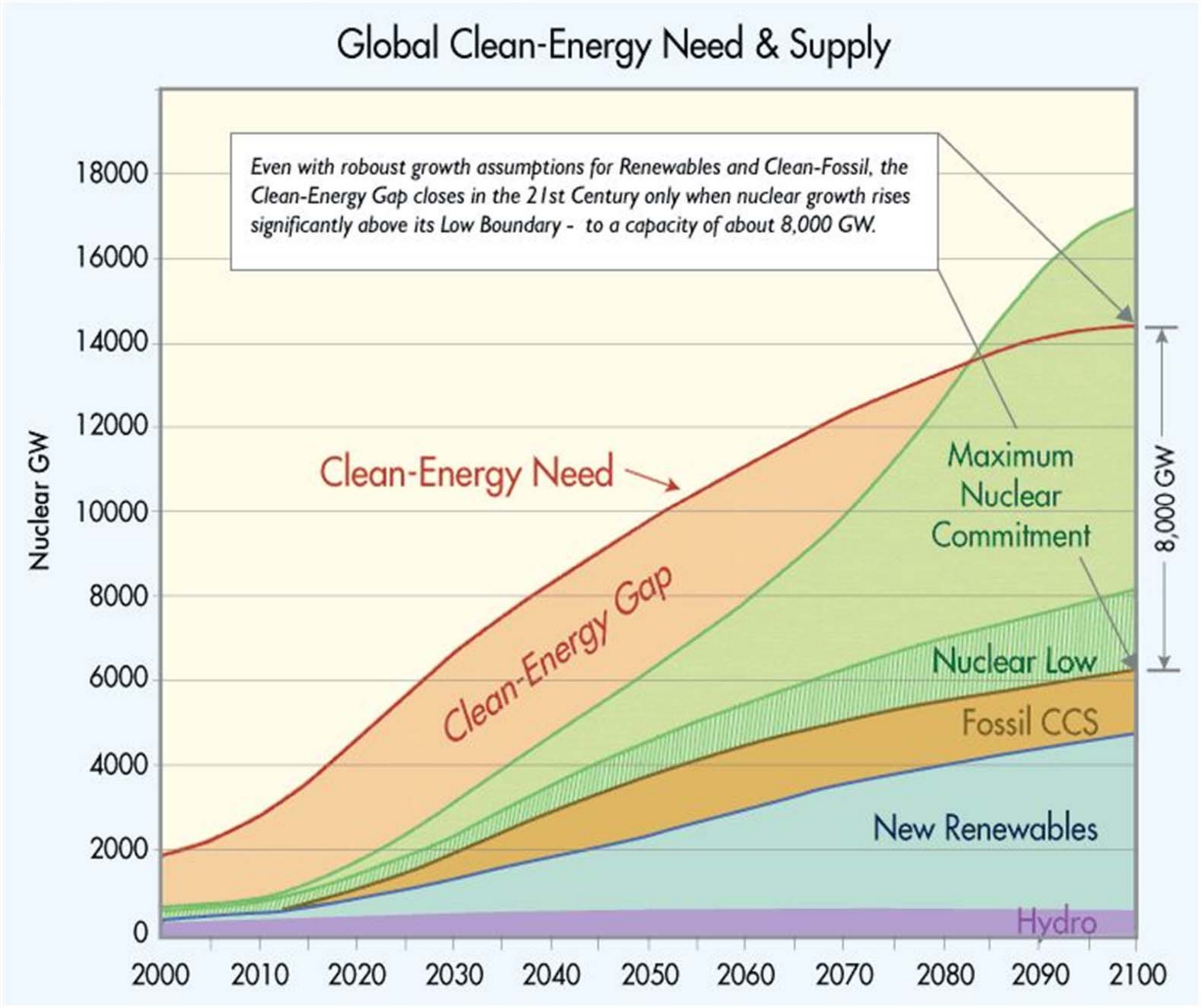
Introduction

- Nuclear energy production is currently a straightforward process of using the fission of fissile material to produce thermal energy that is converted into electricity
- Nuclear power was developed and matured during the later half of the 20^{th} century
- The growth in world economies and the standard of living are placing high demand on energy resources

A Brief History of Nuclear Power

- Discovery of Fission in 1939
    - Dec 2, 1942: First reactor went into operation under the west stands of the football field at the University of Chicago
        - Demonstration of self-sustaining chain reaction using natural occurring Uranium
- Dec 20, 1951: First electricity produced from nuclear energy in Idaho at Experimental Breeder Reactor 1
- Feb. 1958: First commercial operating reactor went into operation in Shippingport, PA.
- Reactor orders dramatically increase through the early 70s as uncertainty of fossil fuels drive utilities to ramp up nuclear power program
- Three Mile Island 1979 and Chernobyl
- Plant up-rates and the quiet improvement of nuclear power
- Nuclear renaissance

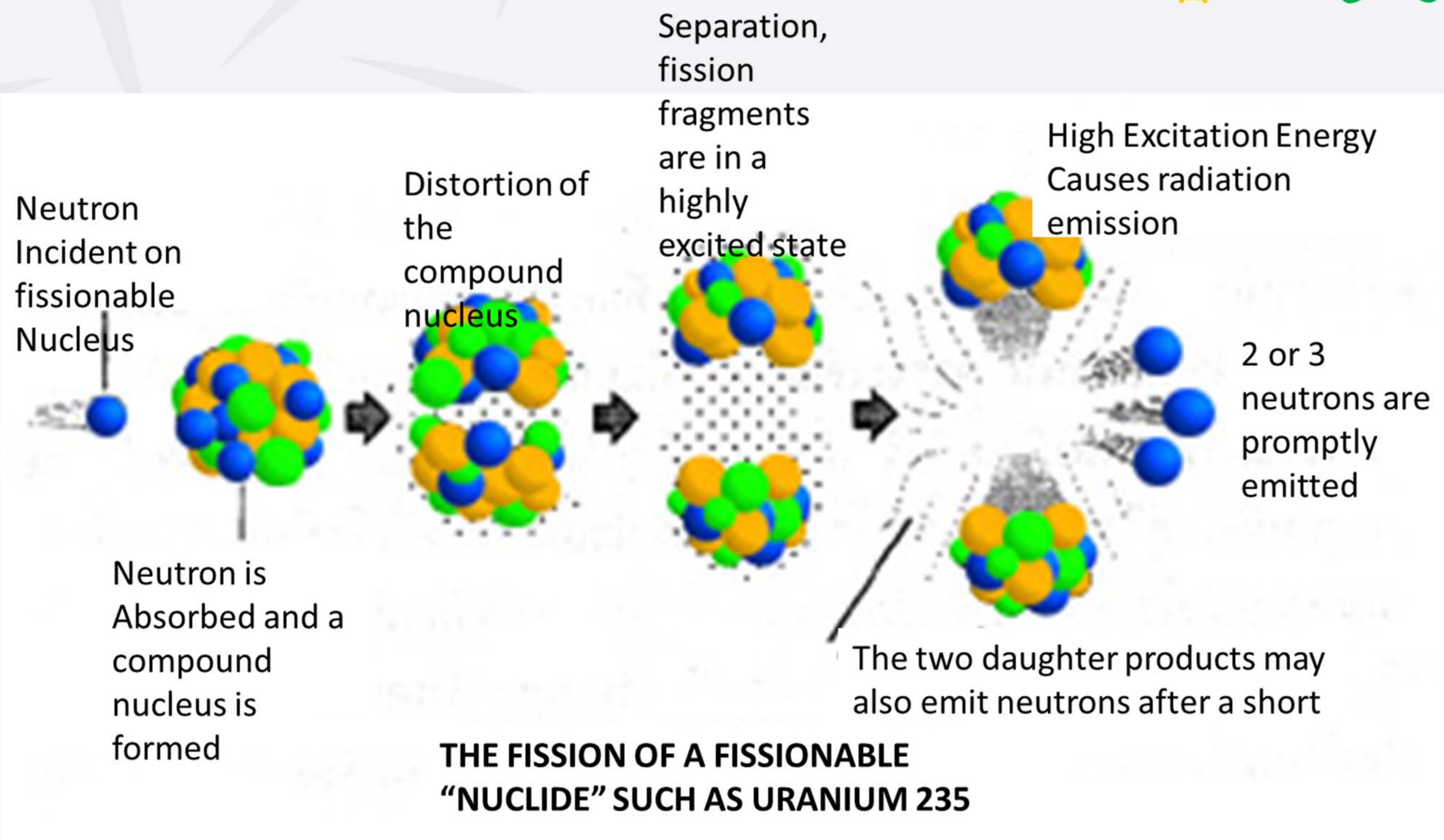

History of the Global Nuclear Power Industry
Installed Capacity
Realized Capacity
Power (Gigawatts)
400
300
200
100
0
Three Mile Island
Chernobyl
Additional Reactors Under Construction
Active Reactors
Number of Power Reactors
500
400
300
200
100
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005

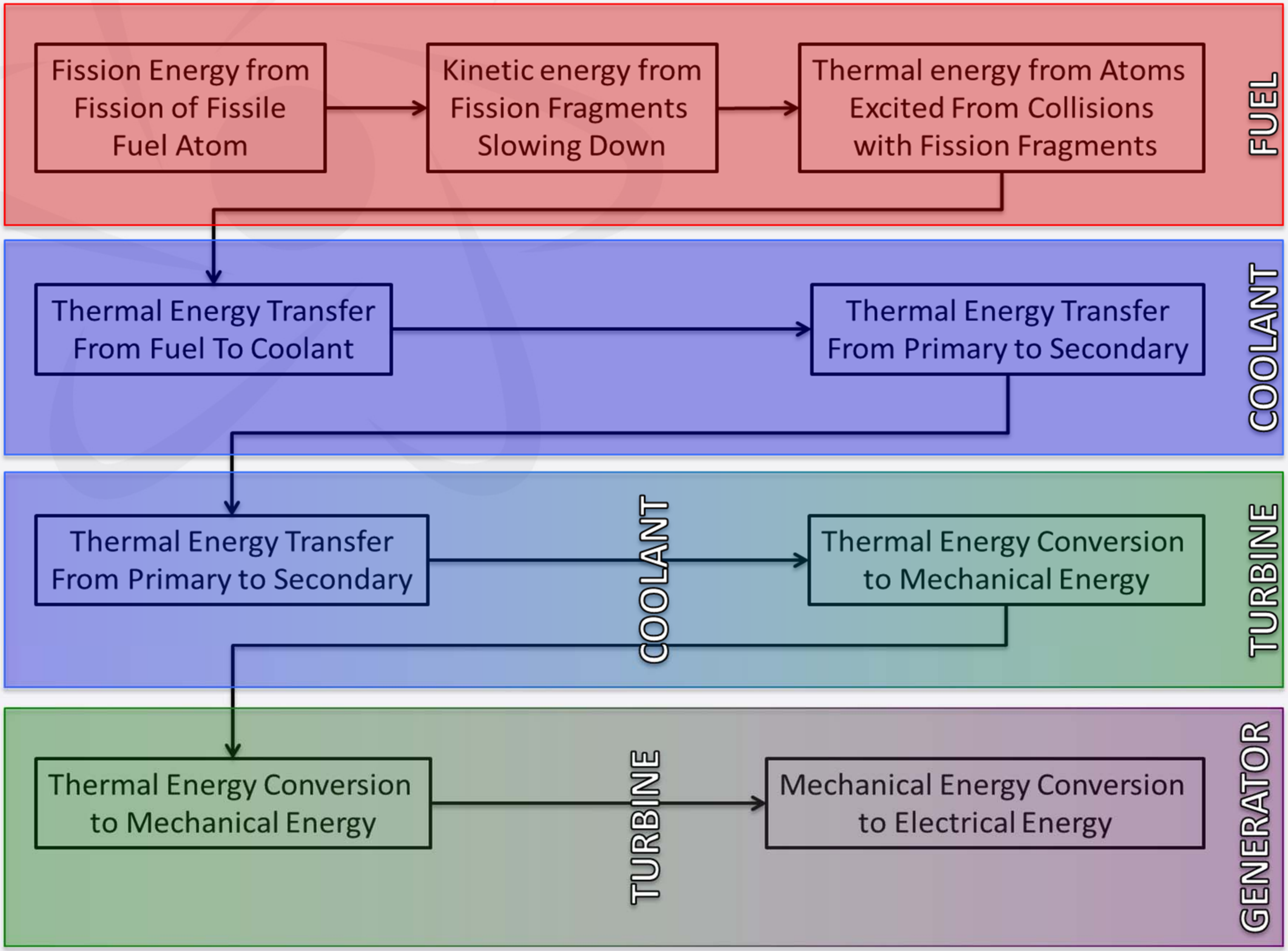

Global Clean-Energy Need & Supply
Even with roboust growth assumptions for Renewables and Clean-Fossil, the Clean-Energy Gap closes in the 21st Century only when nuclear growth rises significantly above its Low Boundary - to a capacity of about 8,000 GW.
Nuclear GW
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
Clean-Energy Need
Clean-Energy Gap
Maximum Nuclear Commitment
Nuclear Low
Fossil CCS
New Renewables
Hydro
8,000 GW

Weight of Uranium vs. Coal

- One pound of Uranium^{235} when totally fissioned will produce approximately 3 X 10^{10} BTU of energy

- This is equivalent to 3 billion pounds of coal


Neutron
Incident on
fissionable
Nucleus
Neutron is
Absorbed and a
compound
nucleus is
formed
Distortion of
the
compound
nucleus
Separation,
fission
fragments
are in a
highly
excited state
High Excitation Energy
Causes radiation
emission
2 or 3
neutrons are
promptly
emitted
The two daughter products may
also emit neutrons after a short
THE FISSION OF A FISSIONABLE
"NUCLIDE" SUCH AS URANIUM 235

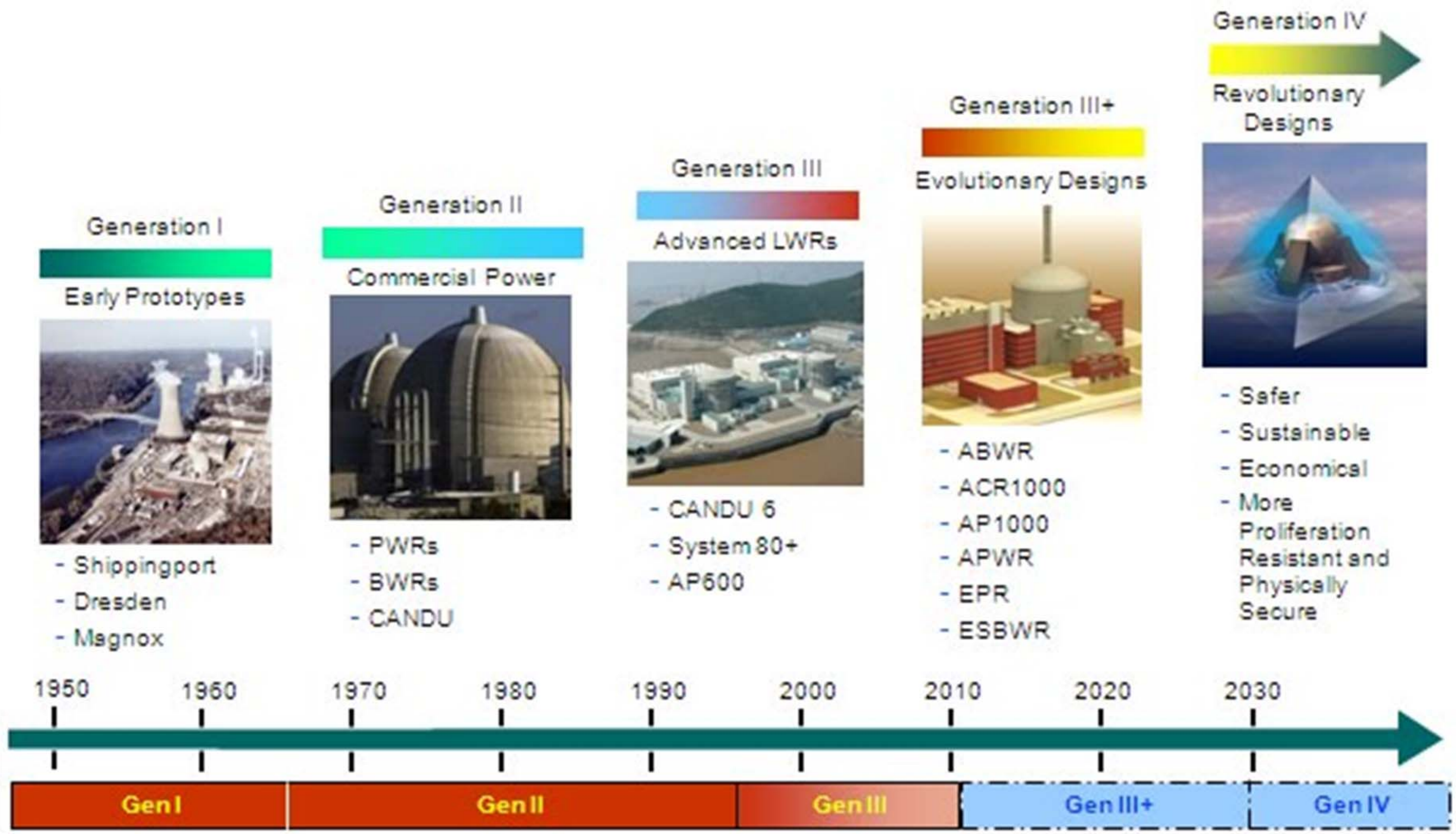

Fission Energy from Fission of Fissile Fuel Atom
Kinetic energy from Fission Fragments Slowing Down
Thermal energy from Atoms Excited From Collisions with Fission Fragments
FUEL
Thermal Energy Transfer From Fuel To Coolant
Thermal Energy Transfer From Primary to Secondary
COOLANT
Thermal Energy Transfer From Primary to Secondary
COOLANT
Thermal Energy Conversion to Mechanical Energy
TURBINE
Thermal Energy Conversion to Mechanical Energy
TURBINE
Mechanical Energy Conversion to Electrical Energy
GENERATOR

Reactor Requirements

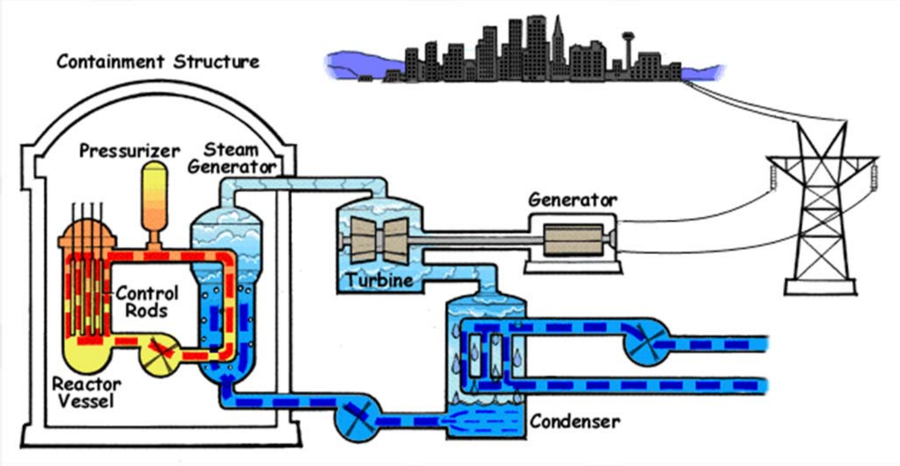
- Fuel
  - Form – Ceramic, metal, aqueous
  - Type – Uranium, Plutonium, Thorium
- Coolant
  - Fluid – light water, heavy water, Sodium, Helium
  - State – single phase, two phase
- Neutron Spectrum
  - Fast vs. Slow
  - Moderator
  - Control Action
    - Material
    - Geometry

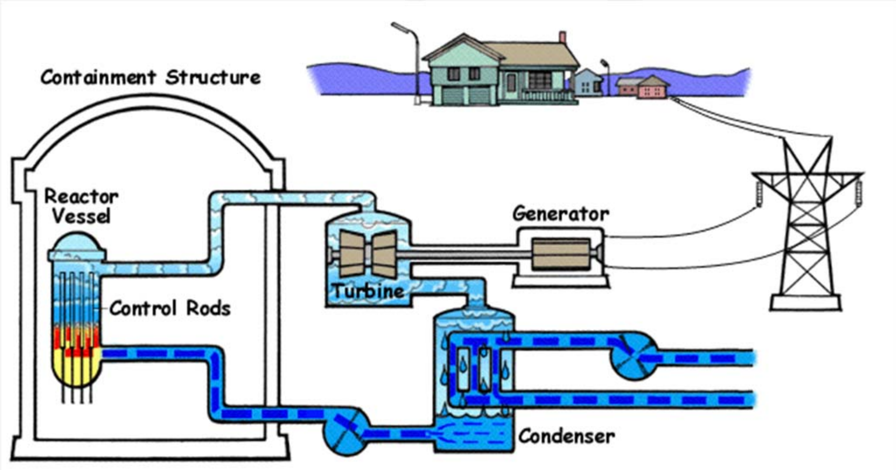
- Pressurized Water Reactors (PWR) are a common reactor type along with Boiling Water Reactors (BWR) used for power production
- PWR systems are commonly classified as part of the primary, secondary, and tertiary loops.
- There is also a number of auxiliary systems that are used to support plant functions

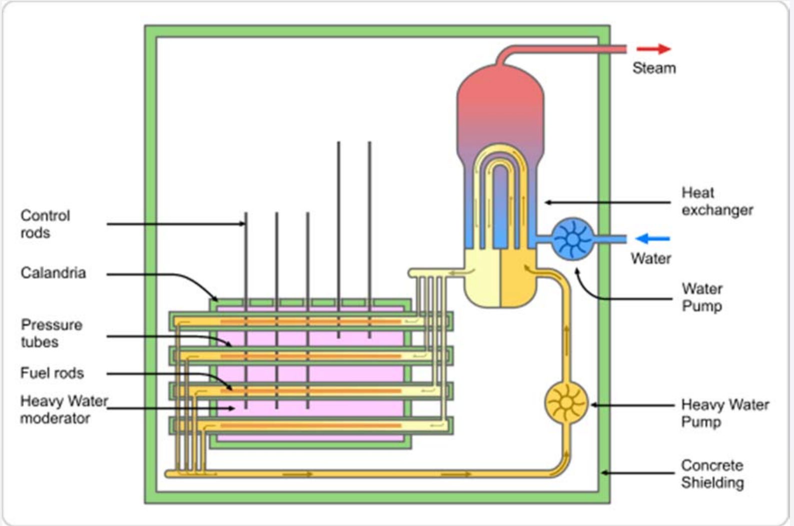
Evolution of Nuclear Power

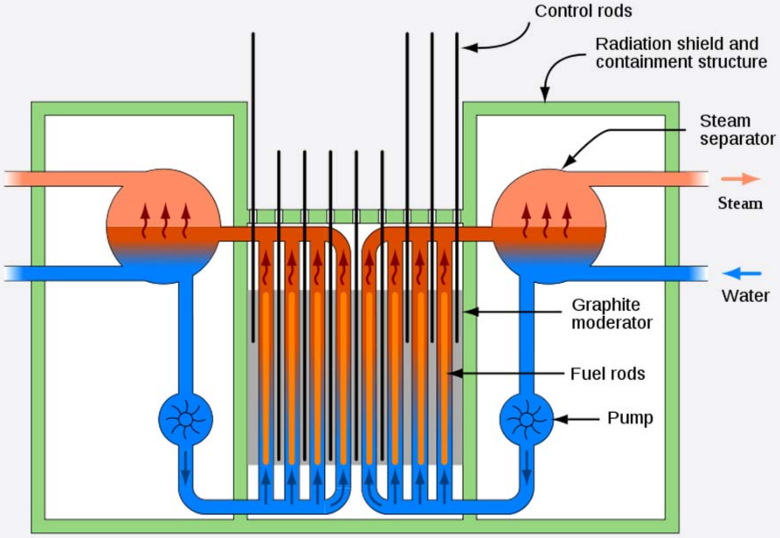


Pressurized Water Reactor (PWR)









Defense-in-Depth

- Nuclear plants are designed using a 'defense-in-depth' approach, with multiple safety systems
- Plants are designed to handle extreme accident scenarios or ‘design basis’ accidents
  - Redundant and diverse systems are utilized to protect the barriers that guard against the release of radioactivity
  - Provision to confine the effects of severe fuel damage (or any other problem) to the plant itself.
- Plant operation is focused on the integrity of the barriers to the release of radioactivity.
  - Prevention (to stay within safe operating parameters)
  - Monitoring (to ensure one is operating within these bounds)
  - Action (to mitigate consequences of failures).

Defense-in-Depth

- The barriers in a typical plant are:
  - Fuel
    - Fuel is usually made up of ceramic (UO_2) pellets and metal alloyed cladding. Radioactive fission products remain largely bound inside the fuel during operation. Sealed zirconium alloy tubes house the ceramic fuel pellets and contain fission product gases.
  - Reactor vessel and reactor coolant system
    - The reactor vessel and coolant system serve as the second boundary in the event of fuel failure.
  - Containment
    - The containment building houses the reactor and coolant system. It serves as a final boundary in the event of failure of the reactor coolant system boundary.

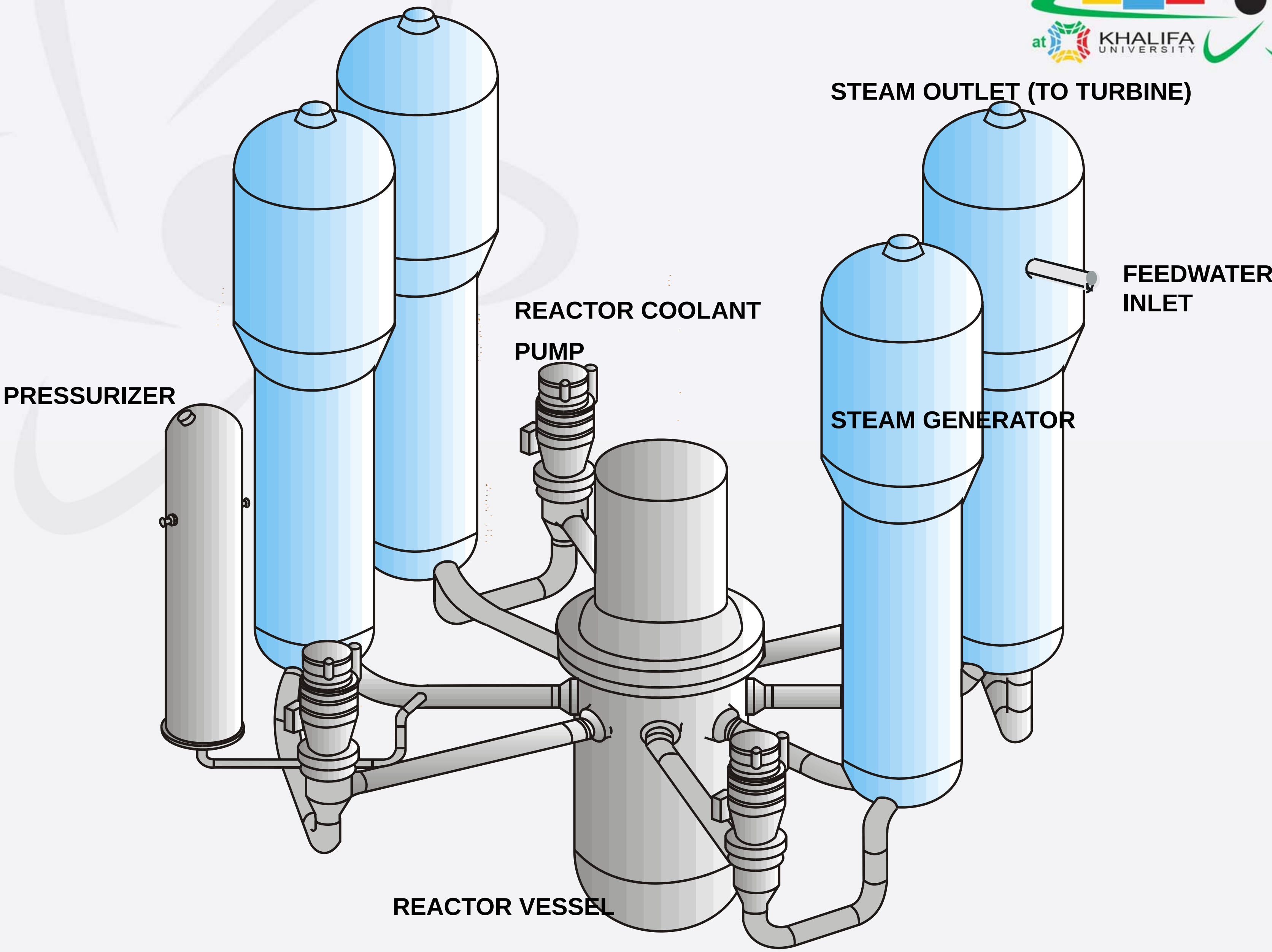
Primary Systems

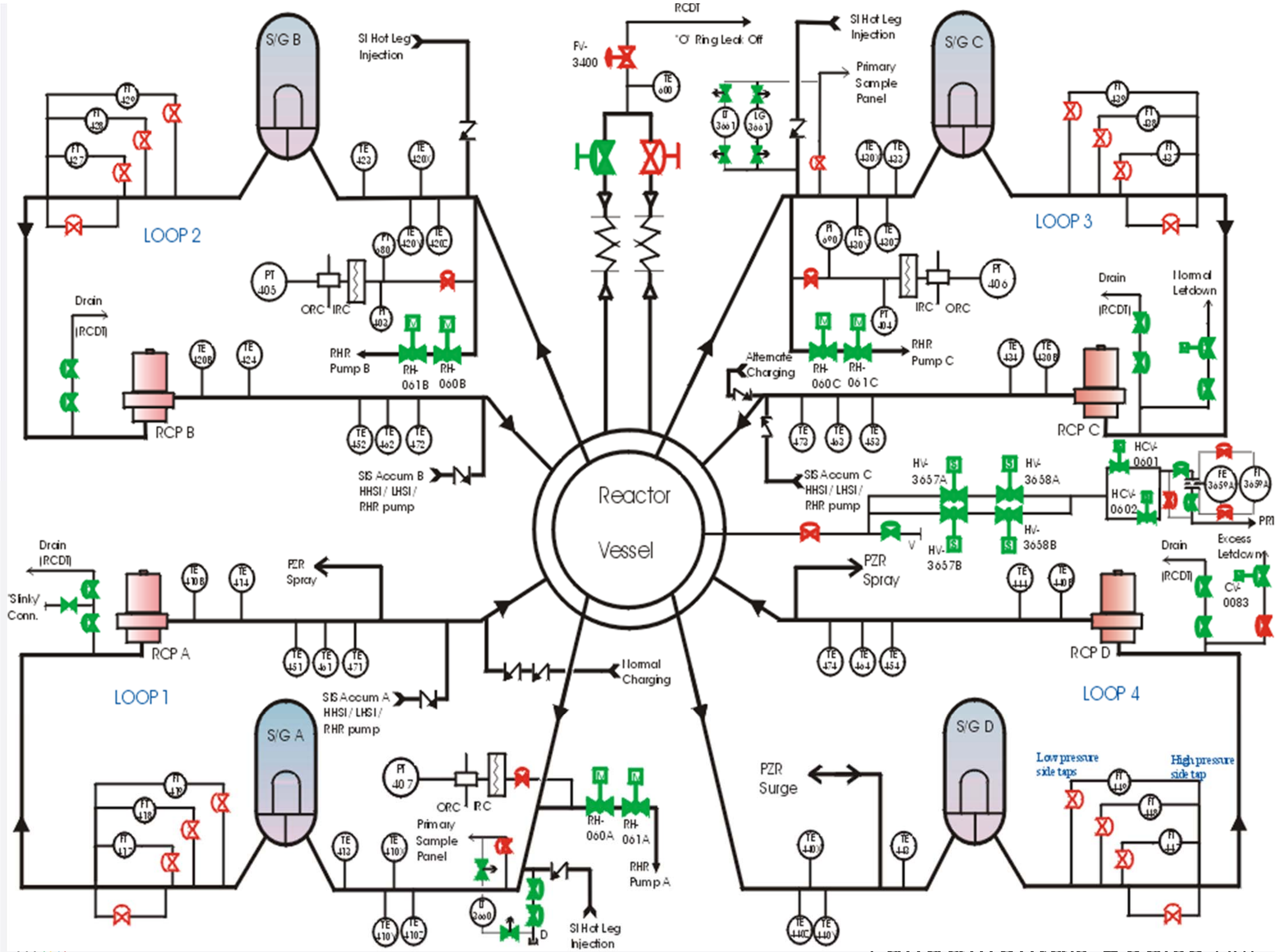
- PWR systems are commonly classified as part of the primary, secondary, and tertiary loops.
- There is also a number of auxiliary systems that are used to support plant functions
- The primary includes the following systems
  - Reactor vessel and fuel
  - Reactor coolant system
  - Chemical and volume control system
  - Residual heat removal system
  - Component cooling water
  - Engineered safety features and emergency core cooling system

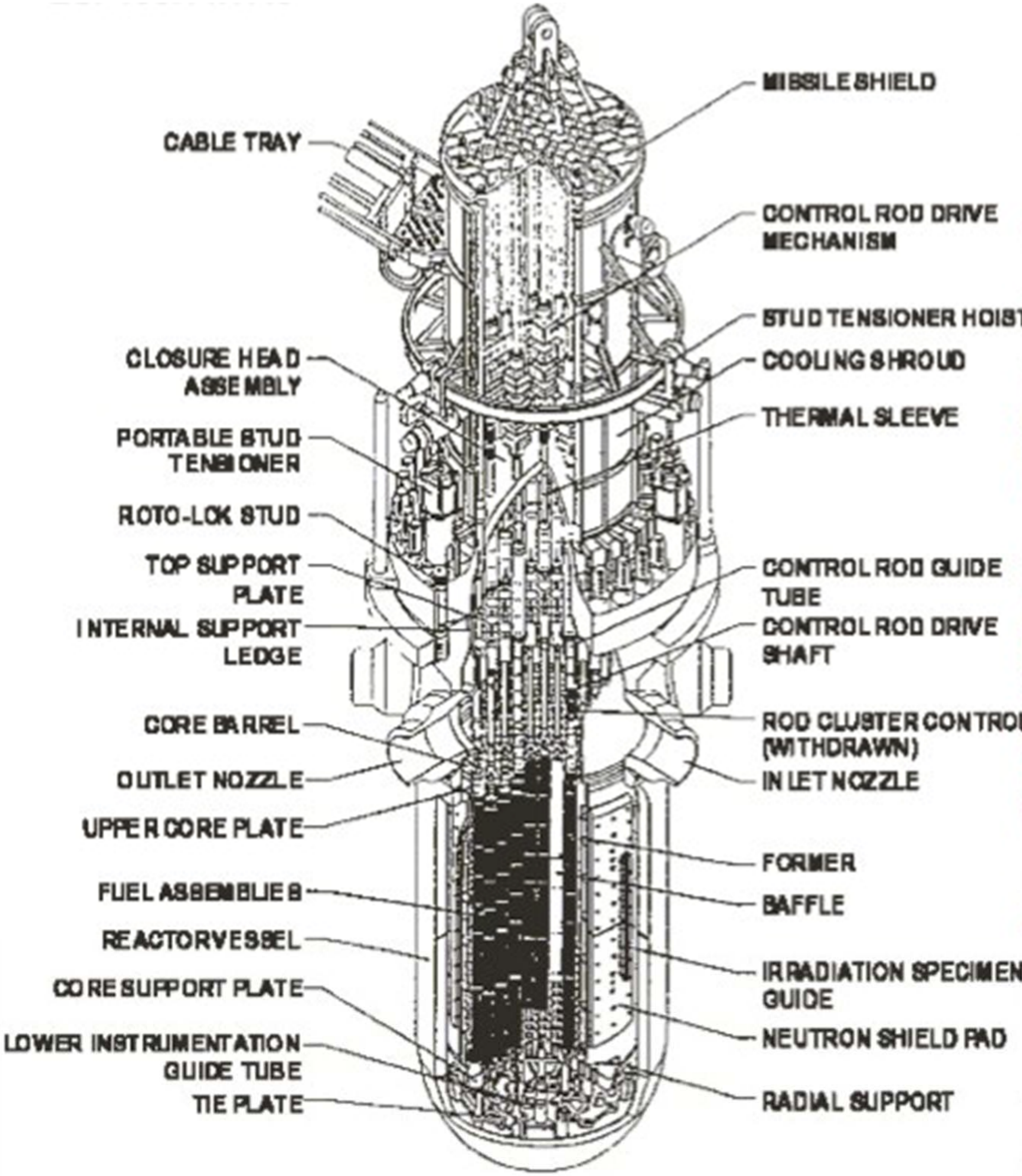
Reactor Coolant System (RCS)

- Fuel
  - Primary boundary against release of radioactive fission products
  - Holds inserts in correct configuration
  - Holds RCCA in correct geometry
  - Aligns incore instrumentation
- Reactor Coolant System
  - Transport heat from reactor to steam generator
  - Act as a neutron moderator and a reflector
  - Solvent for chemical neutron absorber
  - Boundary of protection against release of radioactive fission products
- Reactor Vessel
  - Boundary against release of radioactive fission products
  - Direct coolant flow
  - Guides the fuel inserts
  - Support and align components
    - Incore instrumentation
    - Internals package and fuel
  - Guides the RCCA into the fuel array
  - Controls the flow of coolant across the fuel surface

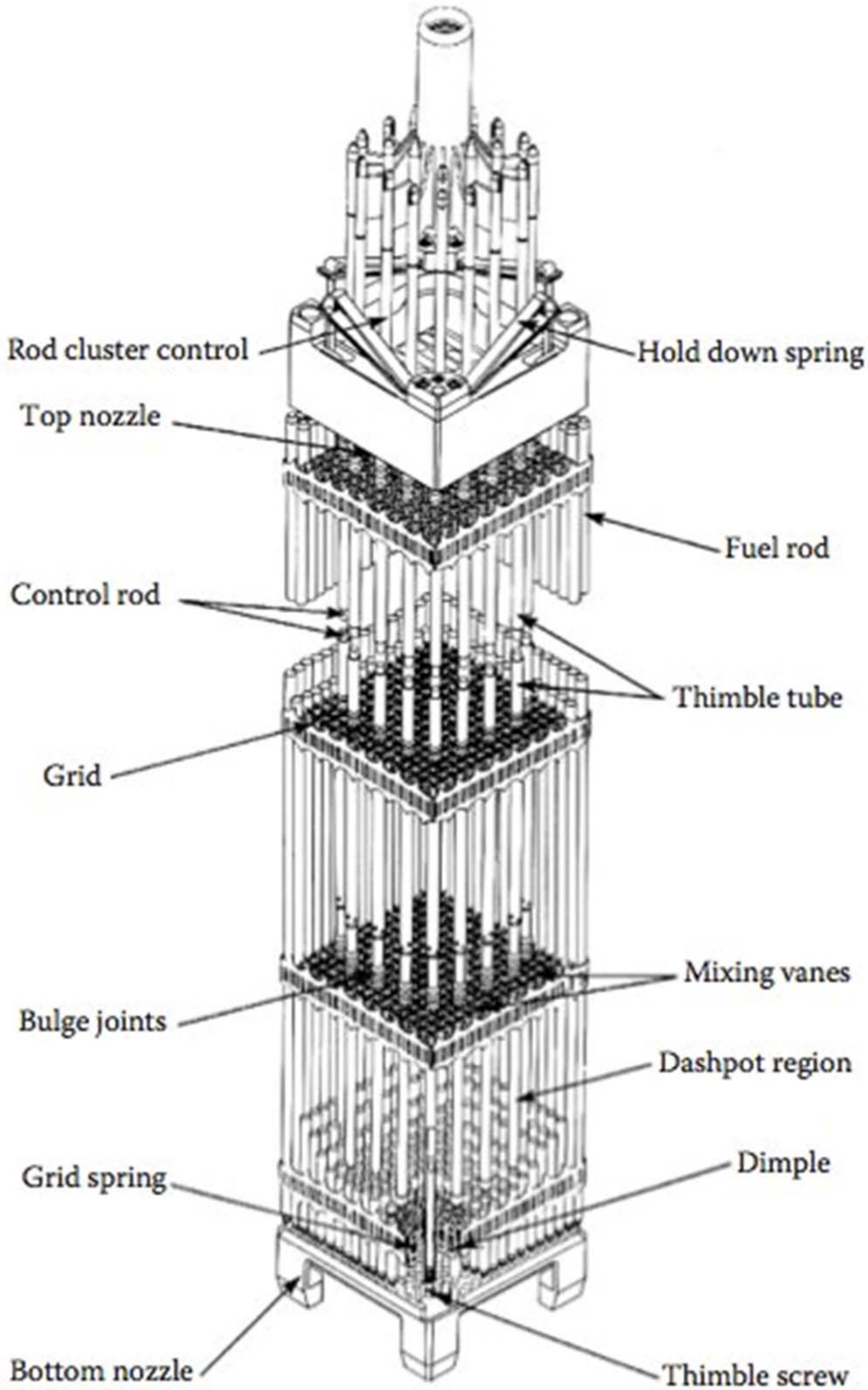
Reactor Coolant System Elevation

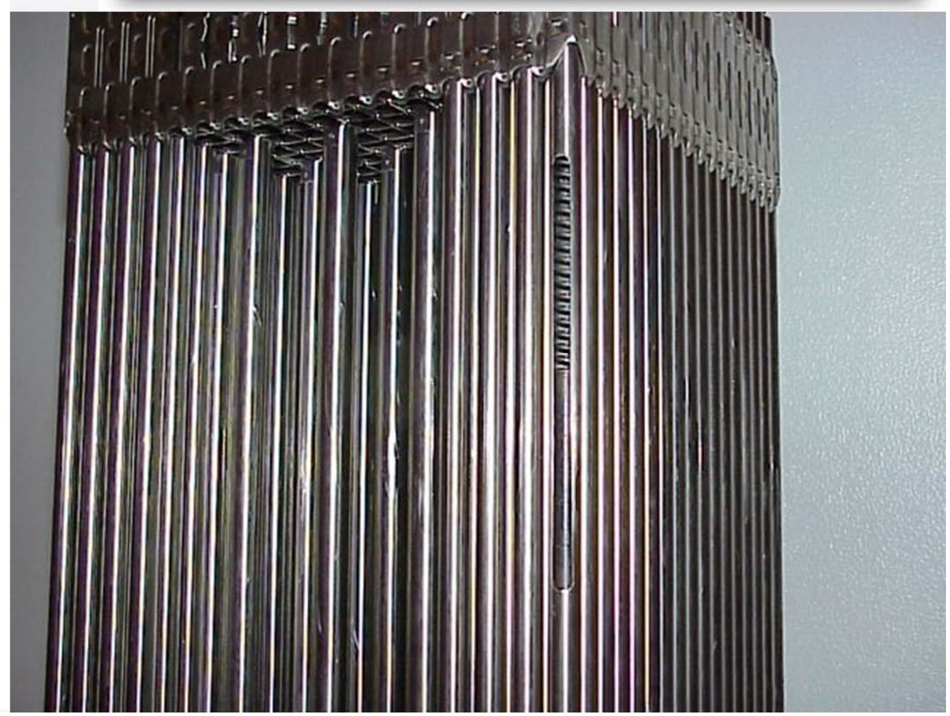



Reactor
Vessel
LOOP 1
LOOP 2
LOOP 3
LOOP 4
S/G A
S/G B
S/G C
S/G D
RCP A
RCP B
RCP C
RCP D
RCDT
'O' Ring Leak Off
FV-
3400
SI Hot Leg
Injection
Primary
Sample
Panel
RHR
Pump A
RHR
Pump B
RHR
Pump C
RH-
060A
RH-
061A
RH-
061B
RH-
060B
RH-
060C
RH-
061C
ORC
IRC
Drain
(RCDT)
Normal
Letdown
Alternate
Charging
Normal
Charging
SIS Accum A
HHSI / LHSI /
RHR pump
SIS Accum B
HHSI / LHSI /
RHR pump
SIS Accum C
HHSI / LHSI /
RHR pump
HV-
3657A
HV-
3658A
HV-
3657B
HV-
3658B
HCV-
0601
HCV-
0602
PRT
Excess
Letdown
CV-
0083
PZR
Spray
PZR
Surge
'Slinky'
Conn.
Low pressure
side taps
High pressure
side tap



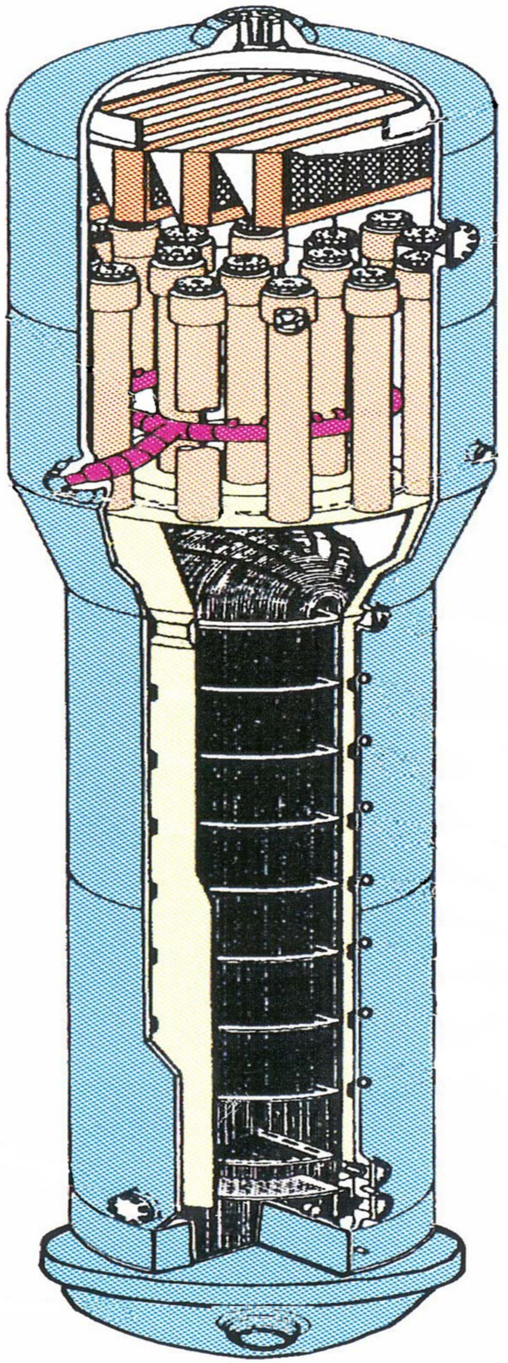
Rx Vessel Cutaway


Rod cluster control
Hold down spring
Top nozzle
Fuel rod
Control rod
Thimble tube
Grid
Mixing vanes
Bulge joints
Dashpot region
Grid spring
Dimple
Bottom nozzle
Thimble screw

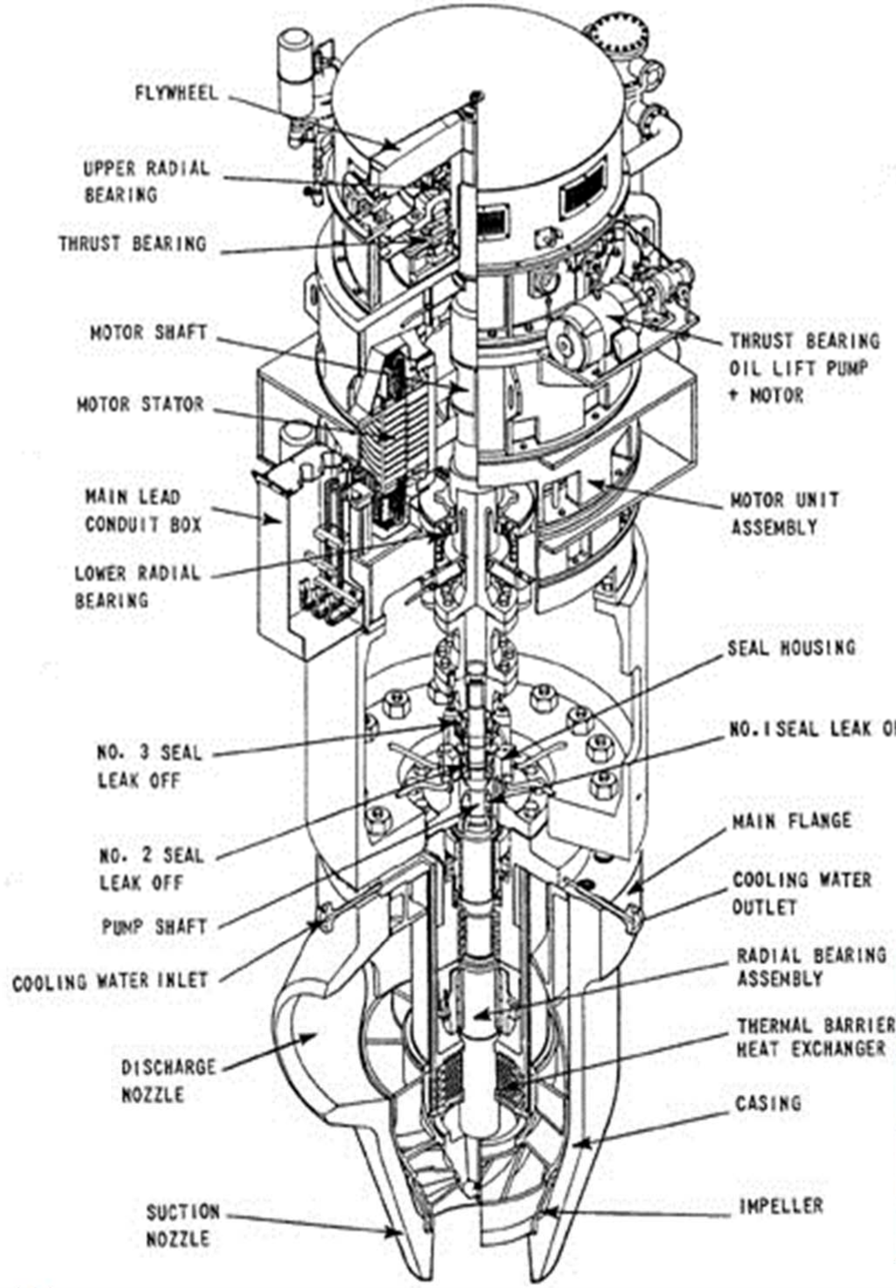


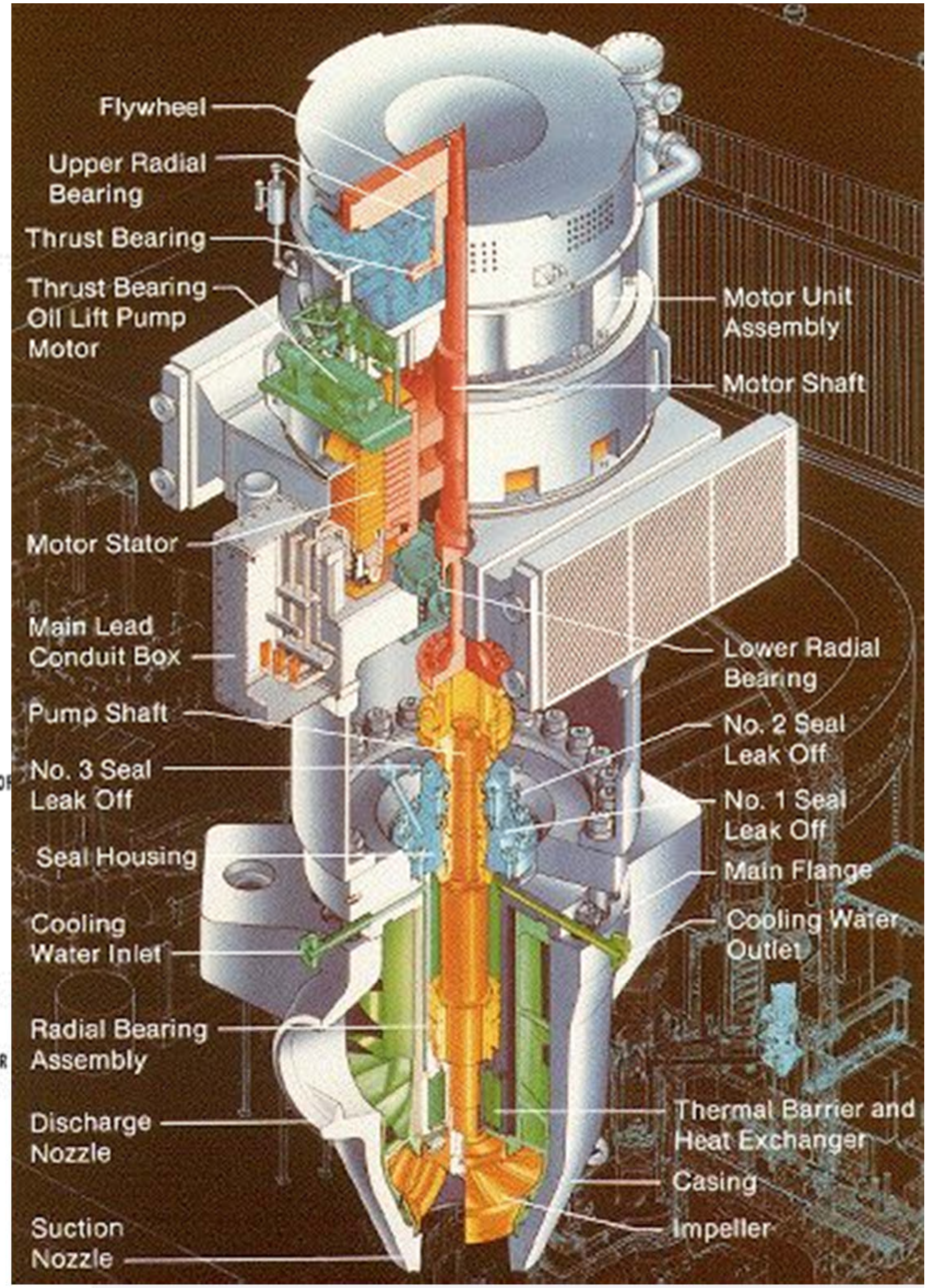
Steam Generator Cutaway

D-94



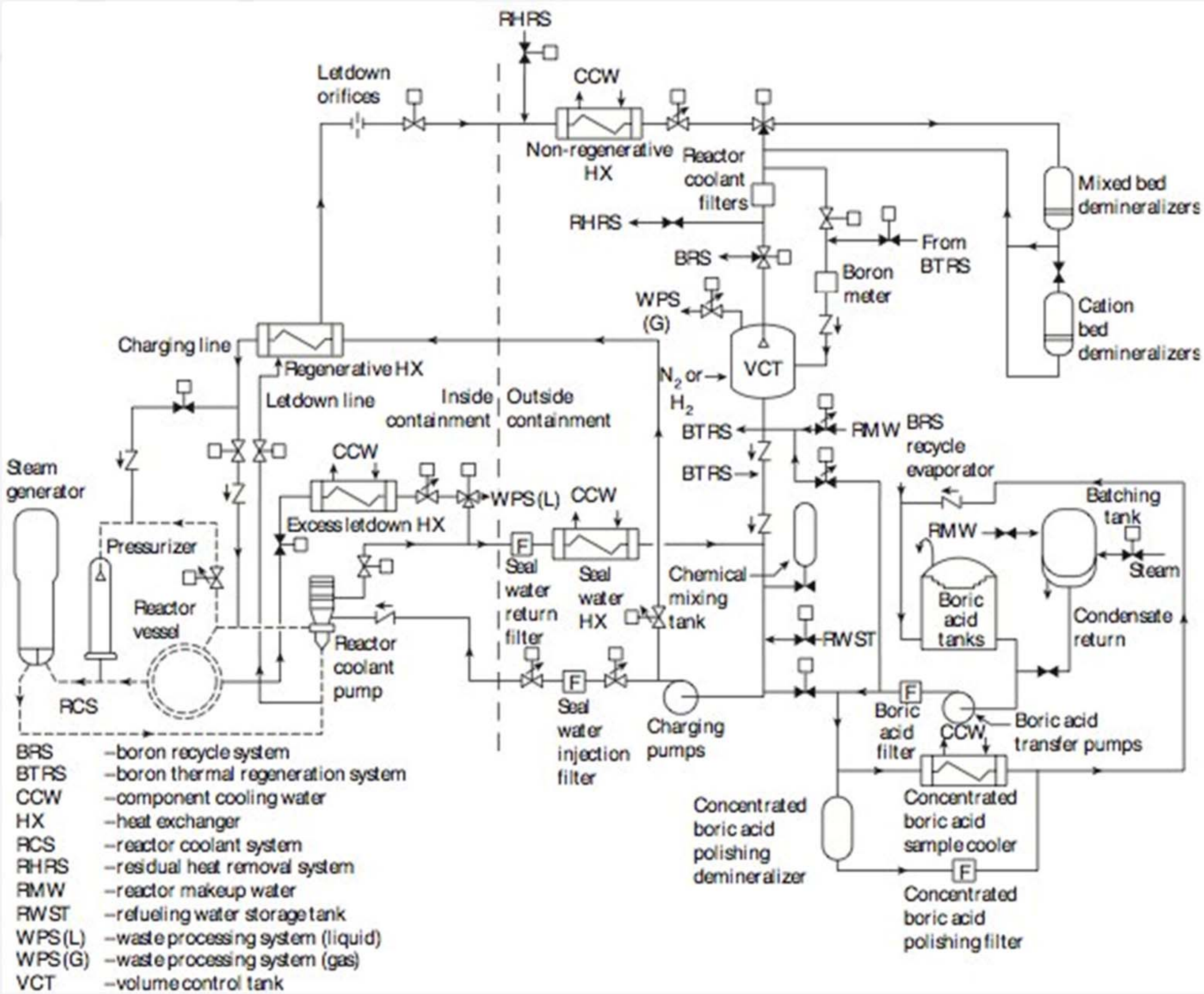
REACTOR COOLANT PUMP



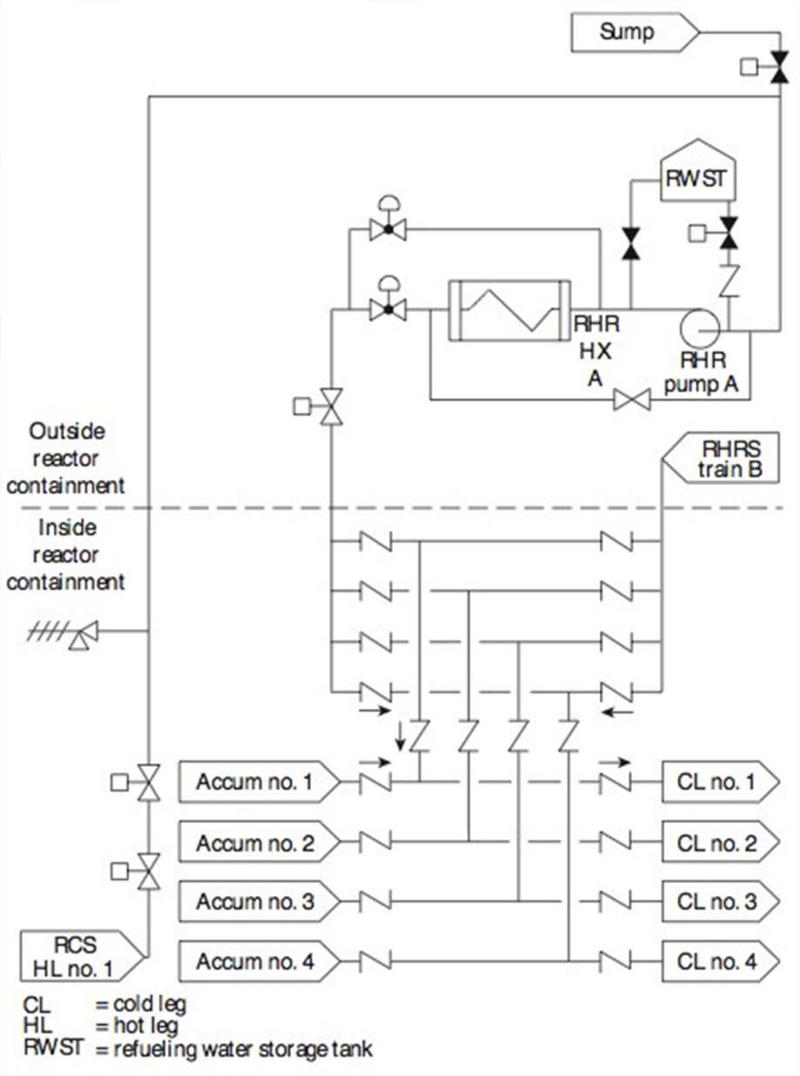


Chemical and Volume Control System (CVCS)

- Maintains programmed water level in the Pressurizer, i.e. maintains required water inventory in the Reactor Coolant System.
- Maintains seal water injection flow to the Reactor Coolant Pumps.
- Controls reactor coolant water chemistry conditions, activity level, and soluble chemical neutron absorber concentration.
- Provides a means for filling, draining, and pressure testing the Reactor Coolant System.


RHRS
CCW
Letdown orifices
Non-regenerative HX
Reactor coolant filters
Mixed bed demineralizers
RHRS
BRS
From BTRS
Boron meter
WPS (G)
Cation bed demineralizers
Charging line
Regenerative HX
VCT
N_2 or H_2
Letdown line
Inside containment
Outside containment
BTRS
RMW
BRS recycle evaporator
BTRS
Steam generator
CCW
WPS(L)
CCW
Batching tank
Excess letdown HX
RMW
Pressurizer
Seal water return filter
Seal water HX
Chemical mixing tank
Steam
Reactor vessel
Boric acid tanks
Condensate return
Reactor coolant pump
RWST
RCS
Seal water injection filter
Charging pumps
Boric acid filter
CCW
Boric acid transfer pumps
Concentrated boric acid polishing demineralizer
Concentrated boric acid sample cooler
Concentrated boric acid polishing filter
BRS -boron recycle system
BTRS -boron thermal regeneration system
CCW -component cooling water
HX -heat exchanger
RCS -reactor coolant system
RHRS -residual heat removal system
RMW -reactor makeup water
RWST -refueling water storage tank
WPS(L) -waste processing system (liquid)
WPS(G) -waste processing system (gas)
VCT -volume control tank

Residual Heat Removal (RHR) System



- Removes decay heat from the core via the Reactor Coolant System in Modes 4, 5, and 6.
- Provides a flow path to transfer water between the Refueling Water Storage Tank and the Refueling Cavity.
- Cools emergency core cooling recirculation water.

Component Cooling Water (CCW) System

- Provide cooling water for removal of thermal energy from ESF and non-ESF systems during various plant modes
- Provide an intermediate fluid barrier between possible radioactive fluid systems and the cooling systems interfacing with the environment

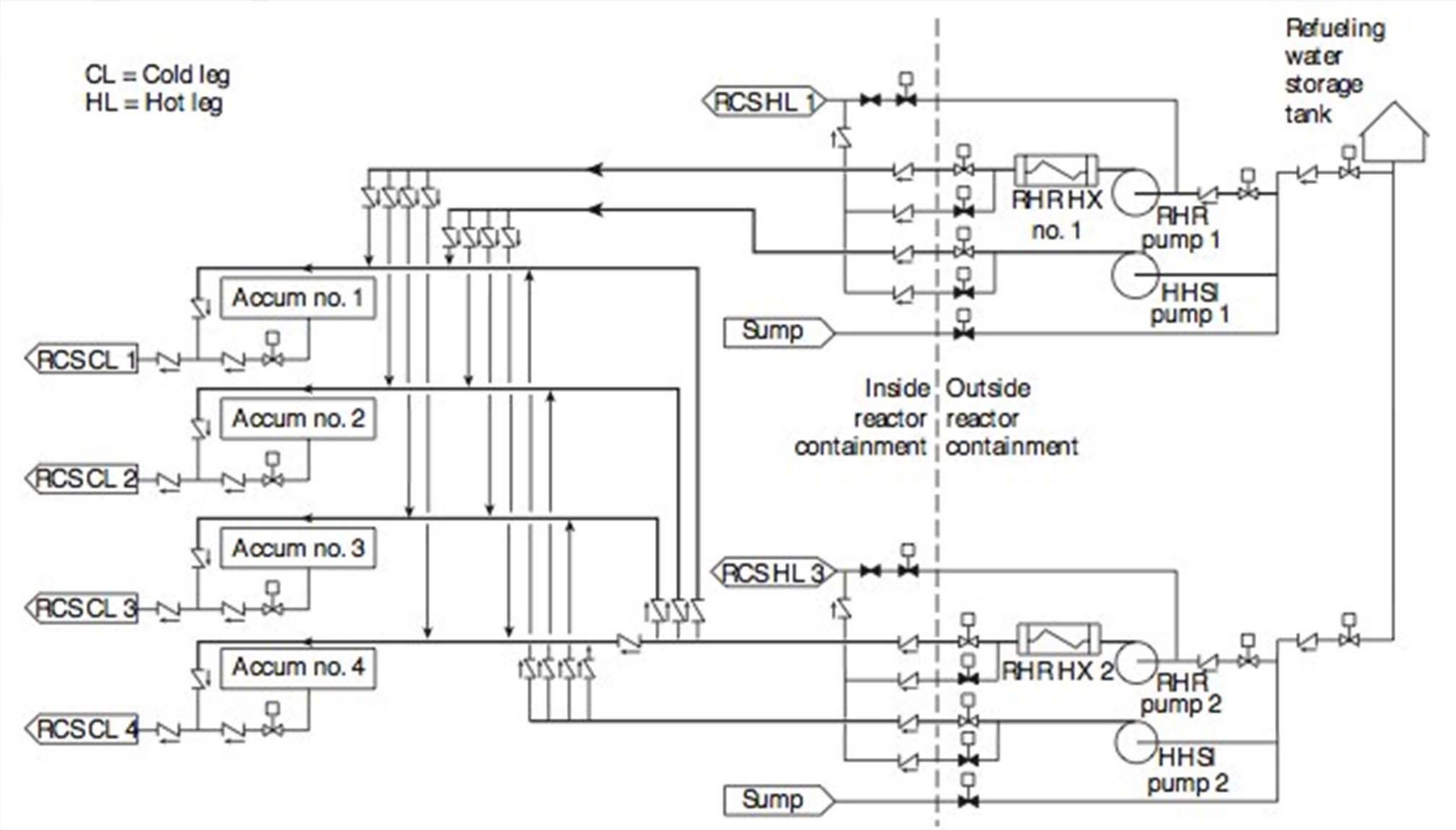
Engineered Safety Features (ESF)

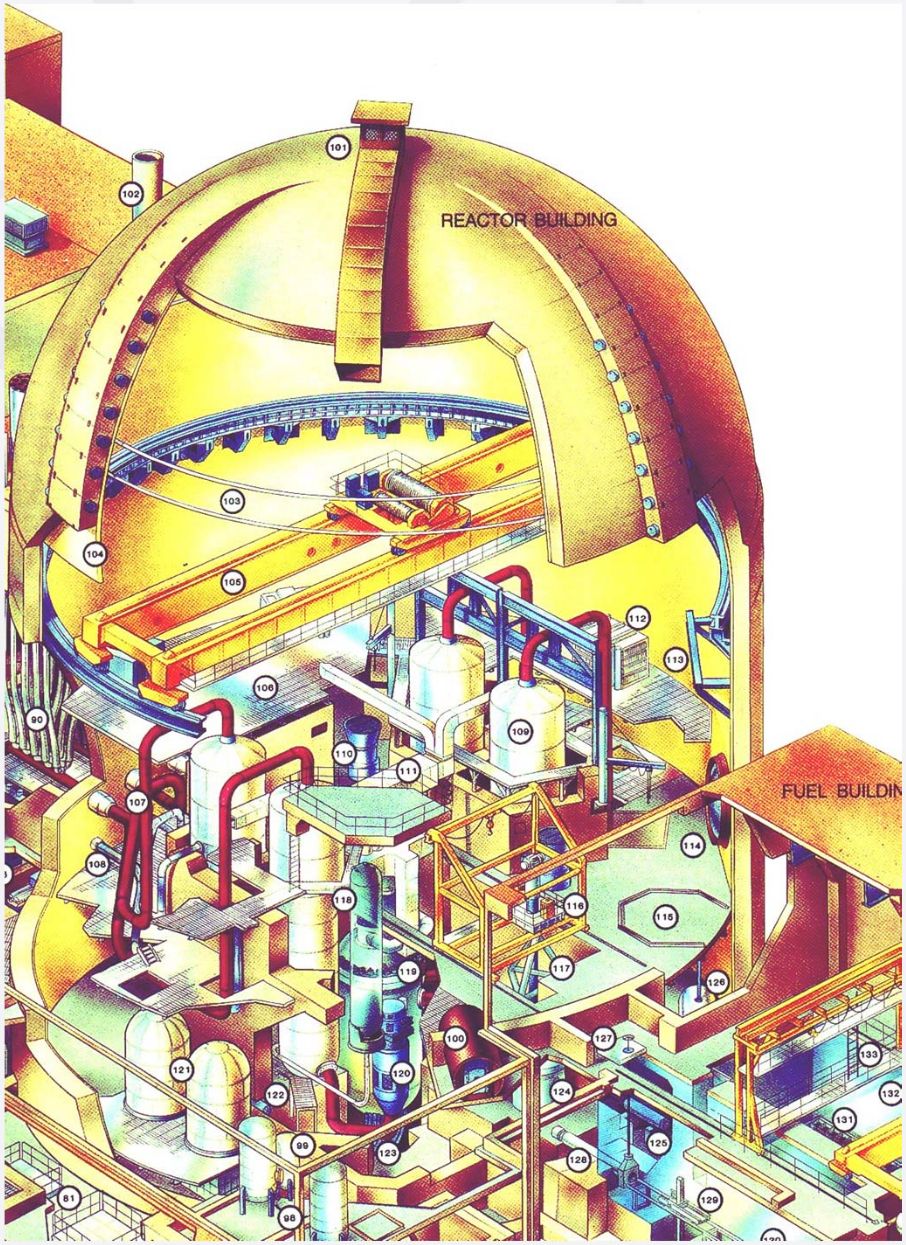
- Maintain the integrity of the defensive barriers during accident conditions that protect the employees, the public, and the environment.
- Part of the ESF system is the Emergency Core Cooling System (ECCS) whose function is to:
  - Remove stored energy and fission product decay heat from the reactor core during accident conditions
  - Provide reactor shutdown capability during accident conditions.

Engineered Safety Features (ESF)

- Containment isolation
- Containment heat removal
- Containment hydrogen control
- Control room HVAC
- Fuel handling building HVAC
- Auxiliary feedwater
- High head safety injection (HHSI)*
- Low head safety injection (LHSI)*
- Safety injection (SI) accumulators*

* These systems make up the Emergency Core Cooling System (ECCS)

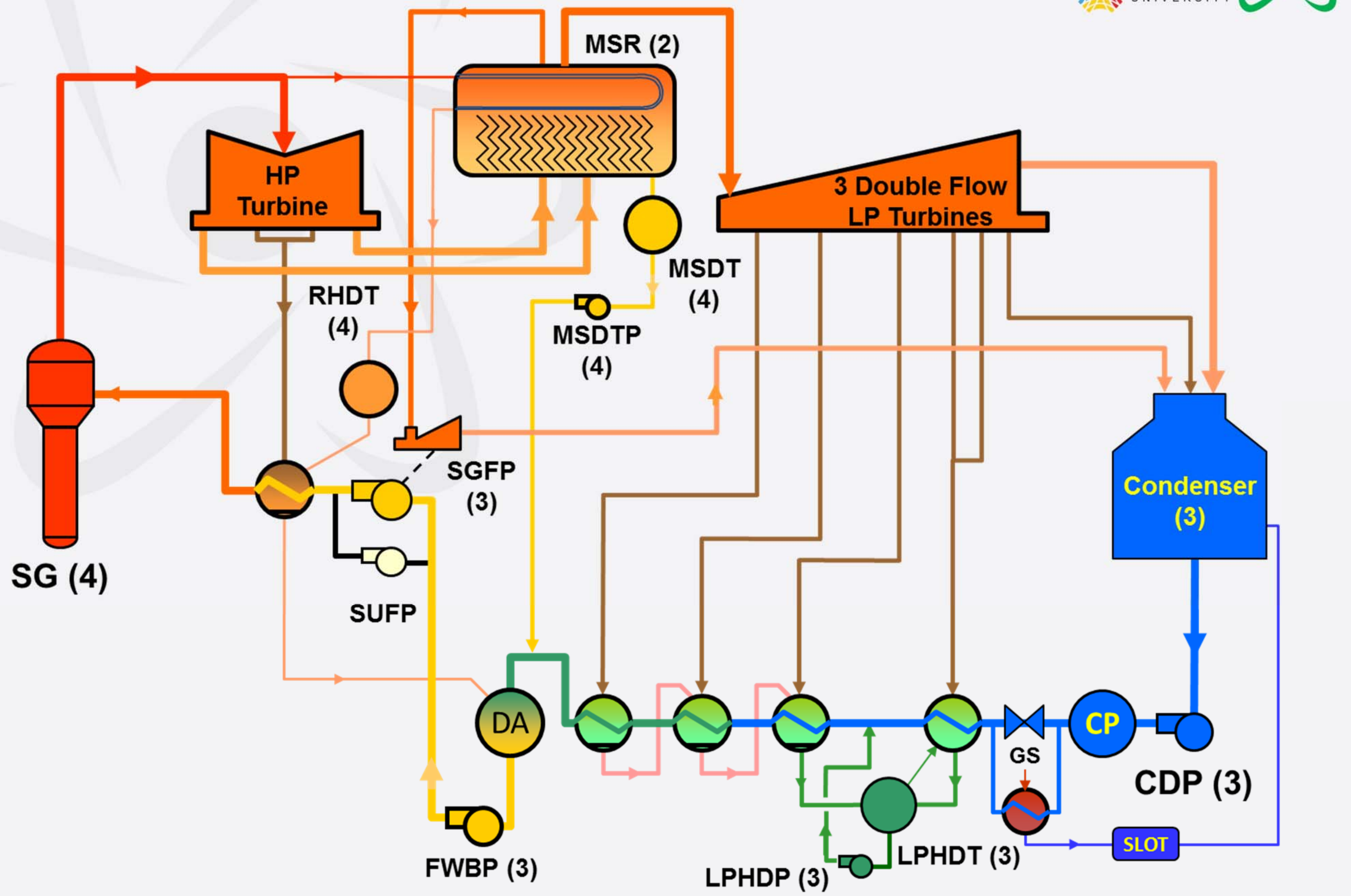

CL = Cold leg
HL = Hot leg
RCS HL 1
Refueling water storage tank
RHR HX no. 1
RHR pump 1
HHSI pump 1
Accum no. 1
RCS CL 1
Sump
Accum no. 2
RCS CL 2
Inside reactor containment
Outside reactor containment
Accum no. 3
RCS HL 3
RCS CL 3
RHR HX 2
RHR pump 2
Accum no. 4
RCS CL 4
HHSI pump 2
Sump



Containment

- Protects the Reactor Coolant System (RCS) and other components located inside the RCS from site environmental conditions including earthquakes and tornadoes.
- Protects the public against the release of radioactivity material in the unlikely event of a Loss Of Coolant Accident (LOCA).
- Serves as a biological shield against high levels of radiation released during normal power operations and possible accidents.

Secondary System Cycle - Simplified



Auxiliary Systems

- Fuel handling
- Spent fuel storage
  - Wet and dry
- Cooling water systems
- Electrical distribution
- Etc.

Summary

- Nuclear power plants are complex machines that convert fission energy to electrical energy for use by the public.
- There is a growing demand for new energy sources and nuclear power is an attractive option.
- Nuclear power plant designs have matured with current Gen III+ and new designs are being pursued as part of Gen IV.
- The NPP is designed to protect the workers, the employees, and the environment in the event of an accident.
  - Defense-in-depth utilizing multiple barriers against the release of radioactivity

Module 2: Nuclear Energy Nonproliferation and Safeguards
(Week 5/Day 2)

Lecture #2: Nuclear Power Plant Operations

Dr. Cable Kurwitz

Lecture Outline

1. Modes
2. Key Evolutions
3. Key Groups

- Nuclear power operations encompass a wide array of activities ranging from the steady state operation to complex evolutions.
- These operations require a whole range of plant personnel.
- Documentation, Communication, and Actions
- Consideration of the 3s'

Operating Modes

Actual values will be found in technical specifications			
Mode	Reactivity - Keff	% Thermal Power*	Average RCS Temperature
1 Power Operations	≥0.99	> 5 %	≥ 180 C
2 Startup	≥0.99	≤ 5 %	≥ 180 C
3 Hot Standby	<0.99	0 %	≥ 180 C
4 Hot Shutdown	<0.99	0 %	>200 and < 350 C
5 Cold Shutdown	<0.99	0 %	≤ 200 C
6 Refueling**	≤0.95	0 %	≤ 200 C
*Actual values will be found in technical specifications			
**Time during which reactor vessel head closure bolts are not fully tensioned			

MODE 5 - (COLD SHUTDOWN)

- Reactor shut down, RCS average temperature less than 200ºF
- All control rods inserted into core, boron concentration sufficient to ensure subcriticality
- RHR flow diverted to CVCS letdown through demineralizers for cleanup, charging pumps return water to RCS
- Decay Heat removed by RHR, CCW, ECW, ECP
- Any decay heat from the core is removed by circulation of the RCS by the Residual Heat Removal (RHR) pumps
- The heat is transferred to Component Cooling Water (CCW) through the RHR heat exchangers

MODE 5

- S/Gs maintained nearly full of water with nitrogen gas blanket
- Main Steam lines are maintained dry
- Turbine-Generator Lube Oil pumps supply oil to the bearings rotor is being turned by turning gear
- To approach Mode 4, the RCS temperature and pressure must be increased
- Steam bubble is formed in the Pressurizer by energizing heater
- RCS pressure can be controlled by Pressurizer heaters and spray
- RCS Thermal Energy Input
  - RCP and Decay Heat
- CVCS/RHR Operation
  - Seals, drains, etc.

MODE 4 (HOT SHUTDOWN)

- When RCS average temperature is greater than 200°F, Hot Shutdown Mode 4 is achieved
- A vacuum may be drawn in the Main Condenser.
  - Condensate and Feedwater Systems recirculated through Main Condenser and Condensate Polishers.
- RCP heat continues heat up of the RCS at about 50°F an hour, RCS pressure is gradually increased
- When RCS temperature is about 212°F, steam formation begins in the S/Gs. When S/G pressure increases, steam is directed into the Main Steam lines to begin warming of the system
  - S/G water level maintained by AFW or the Startup Feedwater Pump
- RCP heat continues heat up of the RCS at about 50°F an hour, RCS pressure is gradually increased
  - Heat up continues until RCS average temperature reaches 350°F
- EHC, Gland Seal Steam, Condenser Air Removal, and Circulating Water Systems are started to facilitate warming the plant

MODE 3 (HOT STANDBY)

- Reactor subcritical, RCS average temperature greater than 350ºF, RCS heat up continues until RCS is 567ºF and pressurized to 2235 psig
- Shutdown banks of control rods pulled out, Reactor subcriticality is maintained by inserted control banks of control rods and soluble boron
- Condensate, Feedwater, Main Turbine-Generator and auxiliary systems are warmed and ready for power operations
- Reactor Coolant System Tave is maintained at 567ºF by the Steam Dump System bypassing the Main Turbine
- Primary and Secondary Systems are ready for a Reactor startup and power operations.

MODE 2 (STARTUP)

- Mode 2 brings Reactor critical but less than 5% Reactor power
- Reactor Operations calculates an Estimated Critical Condition (ECC).
  - The ECC predicts position of control rods as compared to RCS temperature and boron concentration.
  - Calculation usually done with desired rod position and boron concentration is adjusted to achieve the desired position
- Control Rods pulled at 50 step increments until critical
- Reactor power raised to the point where fission process adds heat to RCS (1-2%).
  - Heat produced dumped by Steam Dumps to Condenser and RCS Tave is maintained at 567°F
- Enough steam is being produced in the Steam Generators (S/Gs) to start a Steam Generator Feedwater Pump Turbine.
- The Primary and Secondary Systems are now ready for power operations

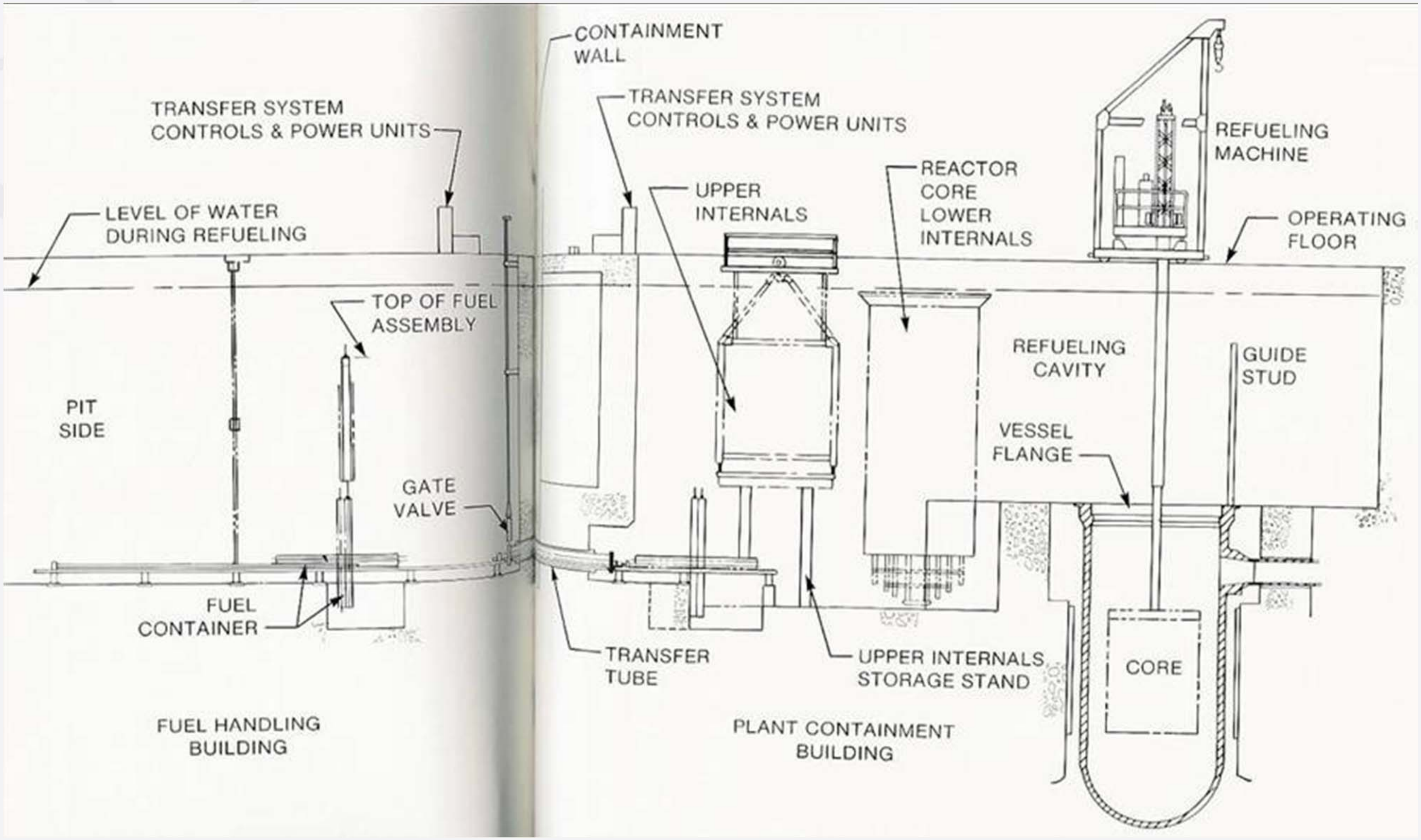
MODE 1 (POWER OPERATIONS)

- To minimize Reactor transient caused by rolling and loading the Turbine-Generator, a false load is supplied.
  - Control rods can be pulled to raise Reactor power to 10-12%
- RCS temperature and Steam Generator pressure will increase
- Main Turbine rolled up to speed, the steam it draws will decrease steam pressure, Steam Dumps will modulate closed to accommodate a constant pressure
- Main Generator is loaded and more steam is required by the Turbine
- Steam Dumps will modulate fully closed
- The Turbine-Generator is now on line supplying power to the grid and the Reactor saw no transient
- The most economical operation is 100% power.
  - The increase to full power is accomplished by picking up more load on the Main Generator and diluting boron out of the RCS to increase the Reactor power. Reactor power will follow steam demand

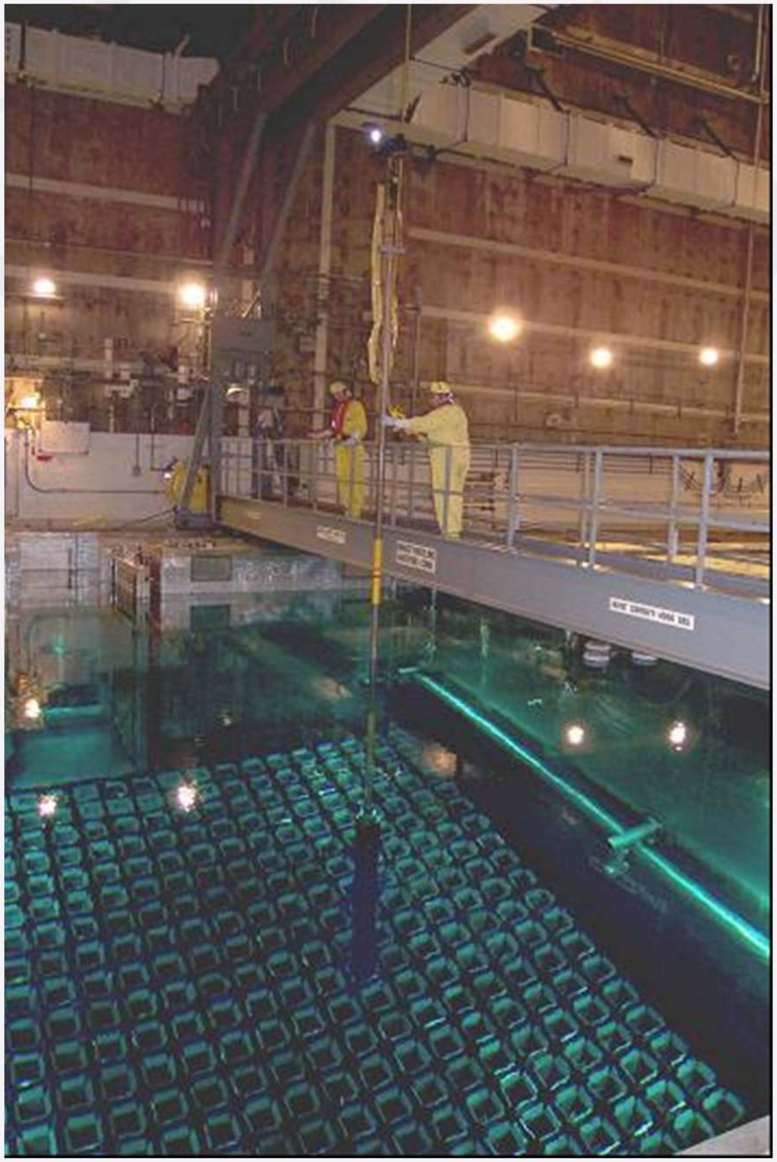
Mode 6 Fuel Evolutions

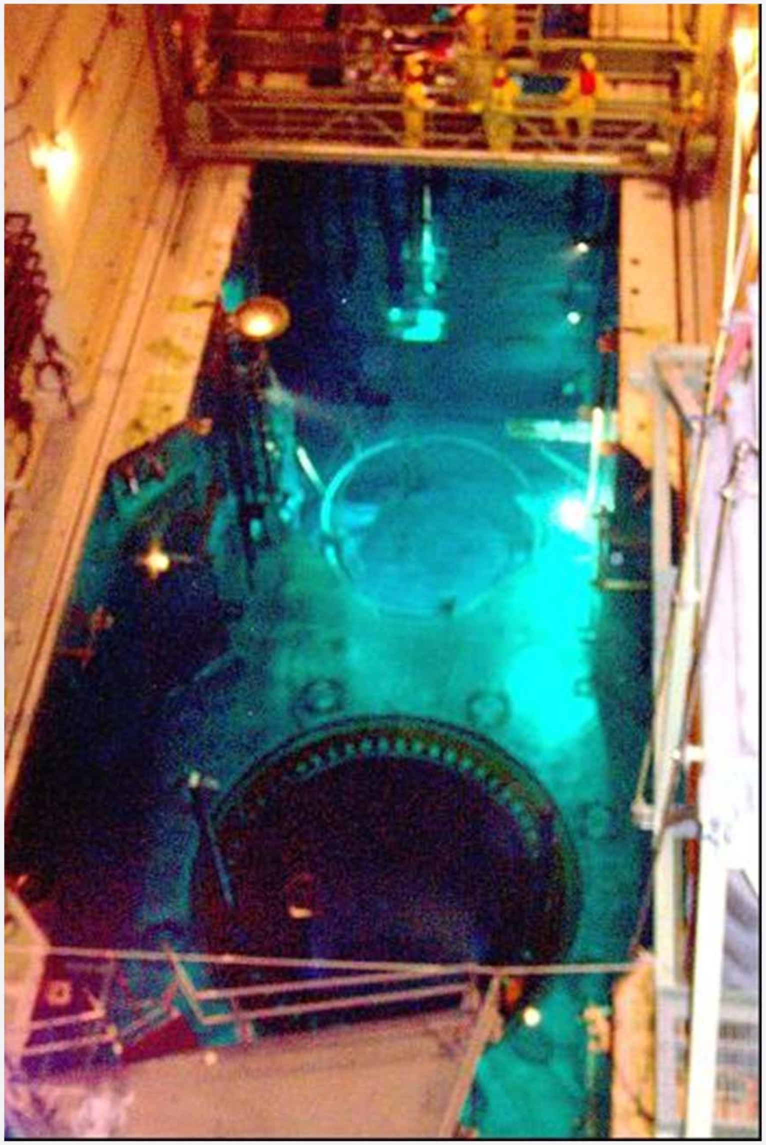
- Nuclear power operations consume fissile material resulting in a need to replace fuel
  - Cycle lengths are typically ~18 months
  - Industry focus is on reducing outage length
  - Requires the acquisition, storage, and placement of new fuel
  - The removal and storage of spent fuel
    - Wet and dry cask storage

PWR Fuel Handling System

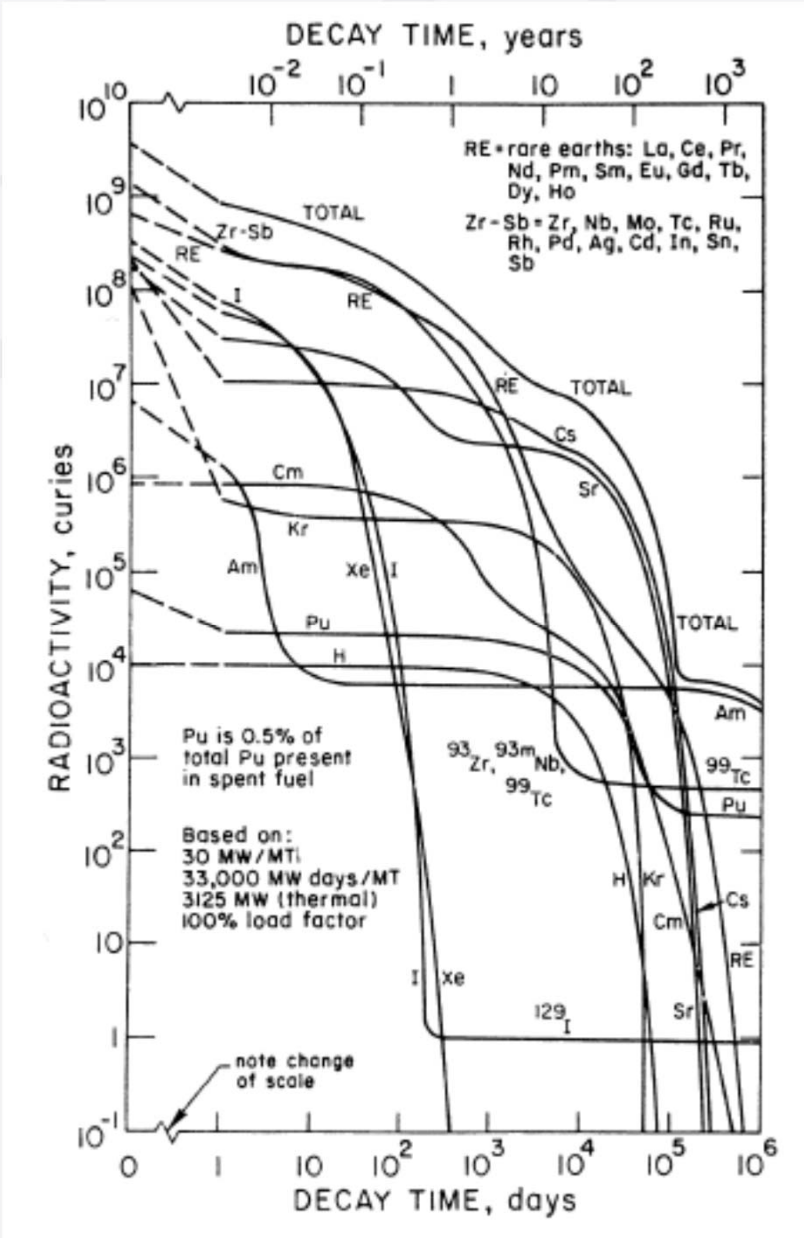


PWR Fuel Handling in Spent Fuel Pool and Inside Containment





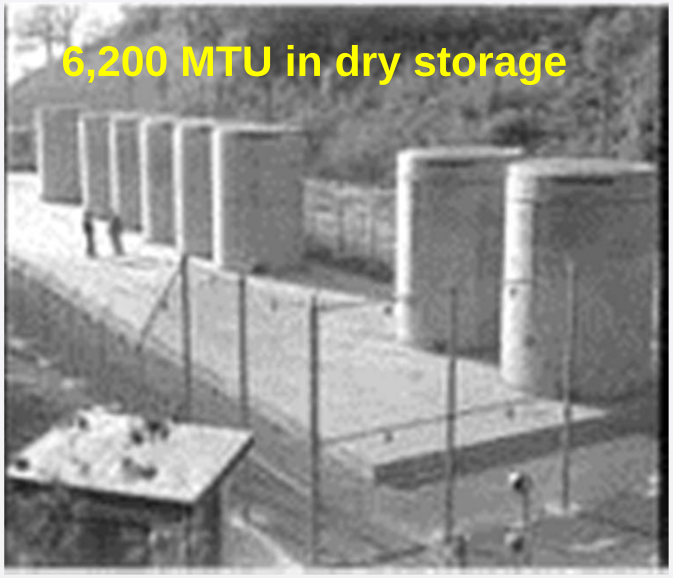
- Spent fuel is typically stored onsite under water
  - Radioactivity
  - Thermal energy generation
- Depending on regulatory requirements, the final disposition of nuclear fuel may stipulate extended temporary storage onsite
  - Dry vs. wet storage



Radioactivity of fission products and actinides in high-level wastes produced in 1 year of operation of a U-fueled 1,000 MWe PWR.

from Benedict,Pigford, and Levi

Spent Nuclear Fuel Storage



Pool Storage:

- **All 65 sites with operating power reactors (At Reactor = AR)**
- **8 sites with reactors shut down**
- **GE Morris Facility in IL (Away From Reactor = AFR)**

Dry Storage:

- **4,500 MTU at 22 sites with operating reactors**
- **Remainder at 6 sites with reactors shut down (AFR)**
- **US Gov't dry storage at INEL**

Onsite Wet Storage

- Assumption until 1977 in US (Government's decision against spent fuel reprocessing)
  - Spent fuel will be shipped to a federal facility a few years after discharge from the core
  - NPPs had provisions to store the spent fuel on-site, in water pools, for about 5 years
  - The minimum amount of onsite capacity should be at least equal to 4/3 cores (one full core plus 1/3 of a fresh fuel reload)

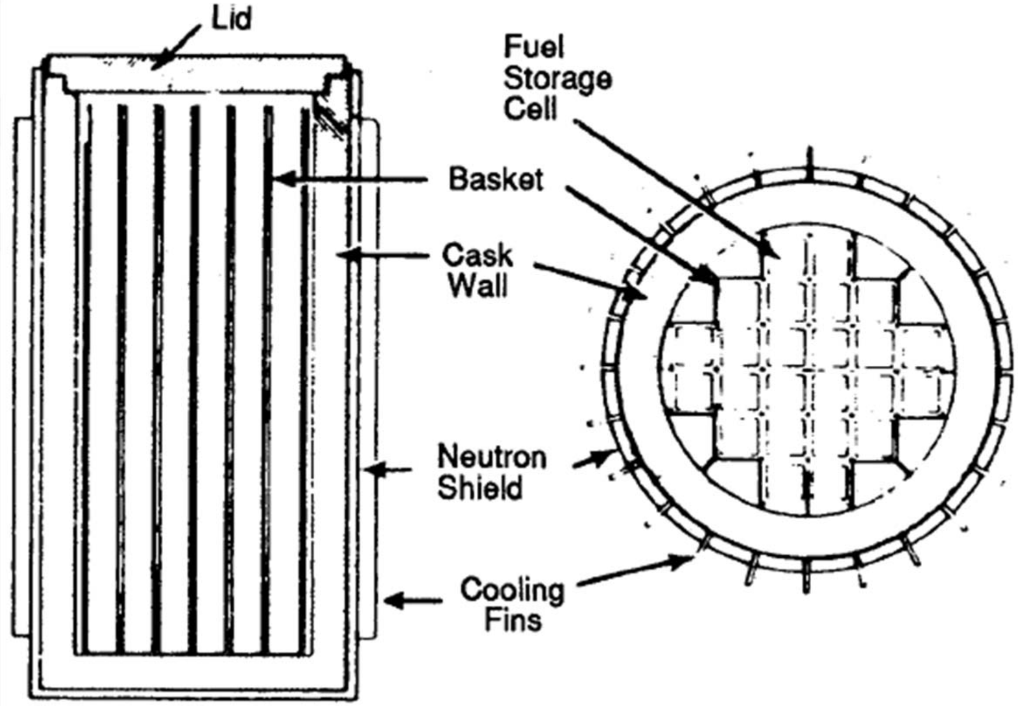
- After 1977, utilities operating the NPPs were forced to expand their on-site storage capacity or other means to store their fuel
  - By then at least 20 years of experience in "wet storage method" with negligible environmental impact
  - Utilities sought to increase the on-site spent fuel pool capacity

Wet Storage Requirements

- SS storage racks with 6" or more of water between fuel assemblies
- SS replaced with Boral (a neutron-absorbing composite material consisting of boron carbide evenly dispersed within a aluminum matrix)
  - Permitted close spacing of fuel assemblies without criticality problems
  - Boron absorbs thermal neutrons without producing significant secondary radiation
  - Only alpha particles, which is easily absorbed by water, and a soft 0.48-MeV gamma emitted
- Basic requirement of any spent fuel storage facility is that the neutron multiplication factor, $k < 1.0$
  - By appropriate distance between fuel assemblies
  - Use of solid neutron poisons (eg., Boral) and no dissolved boron in the water pool

Dry Storage

- Cylindrical metal cask
- 8ft diameter and 16ft long
- 21 to 33 PWR assemblies (~9 to 14 t of heavy metal)
- 45 to 70 BWR assemblies (~8 to 12 t of heavy metal)
- Fully loaded weight ~ 100 to 120 t
- Walls made of iron or iron plus lead with adequate thickness to shield gamma rays

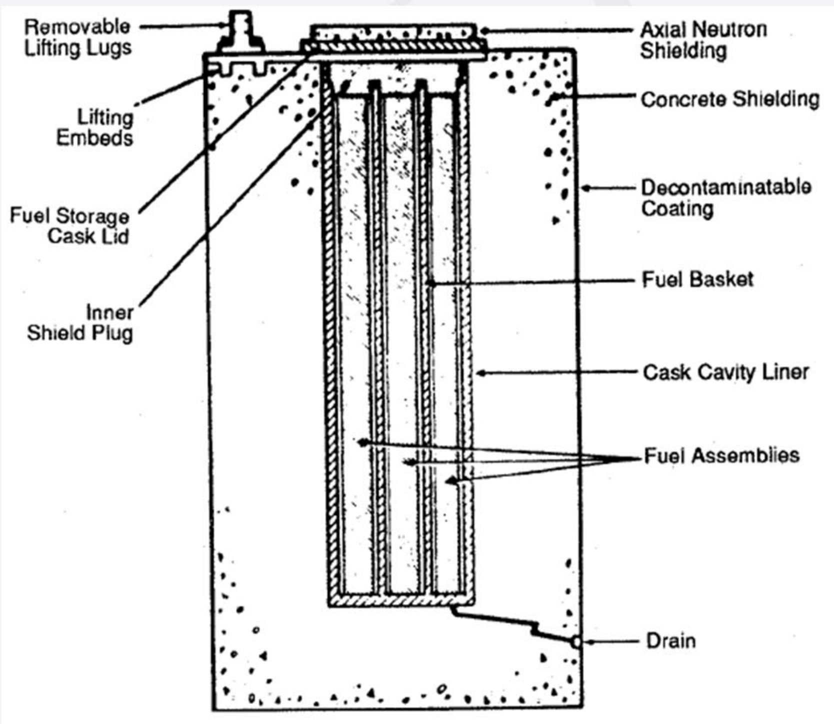


The design of a typical metal cask for dry storage of spent fuel

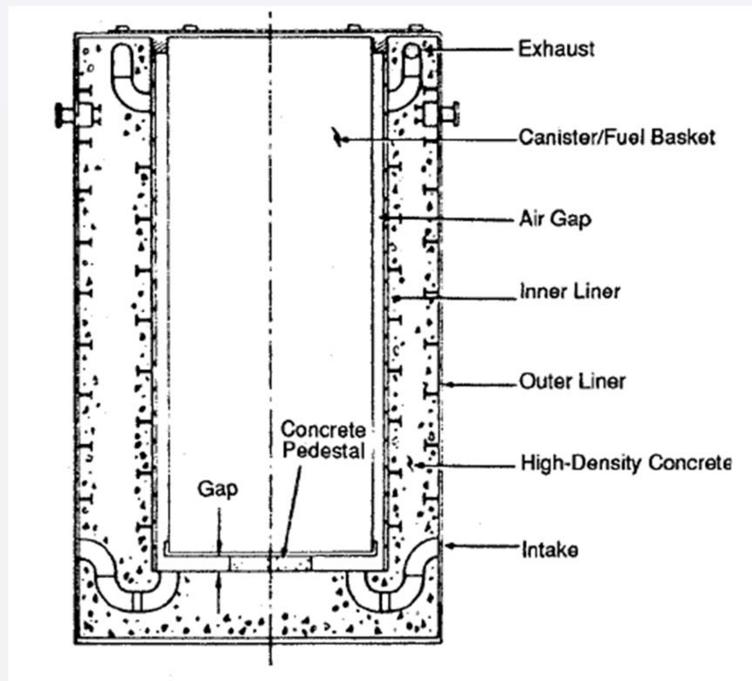
- Additional neutron absorbing material (polyethylene or resin)
- Fuel baskets made of combinations of steel, Al, Cu and B)
- External surface may have fins to enhance cooling
- 25ft^2 pad area for vertical placement

Dry Storage Concrete Cask

- Heavily reinforced concrete (~3 ft thick concrete); ventilated/unventilated
- Adequate gamma-ray shielding and a steel inner liner for concrete
- ~8.5 ft diameter and 18 ft long (unventilated-loaded weighs ~90t)
- ~12 ft diameter and 20 ft long (ventilated- loaded weighs ~125t)
- ~24 PWR assemblies in He atmosphere
- Decay heat removed by radiation/conduction/convection
- Concrete vaults

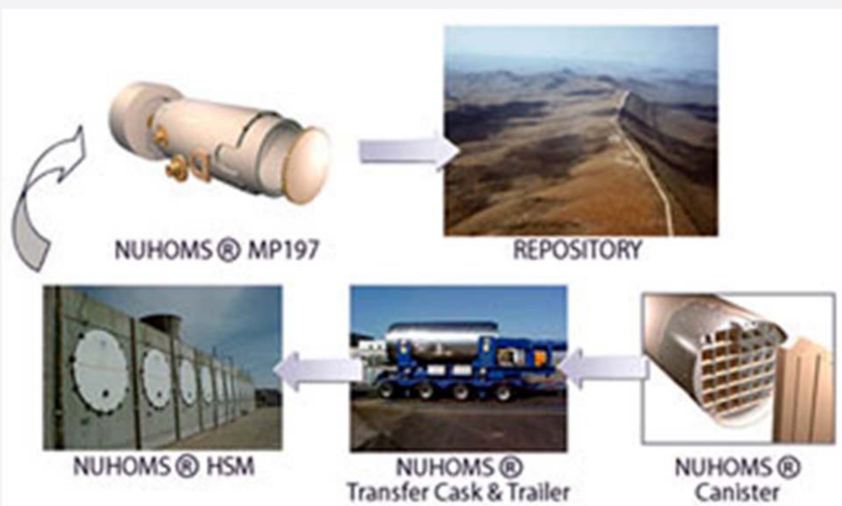


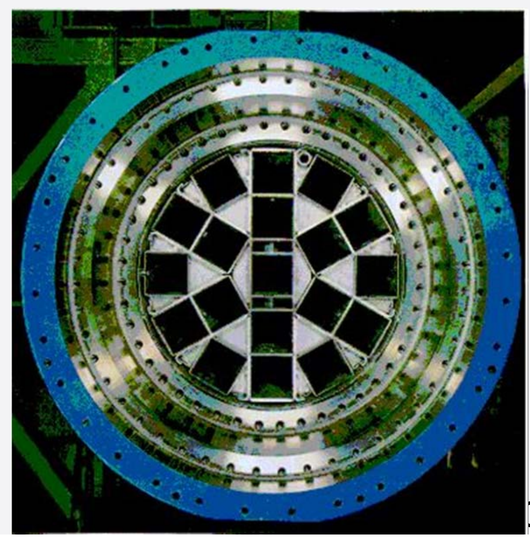
The design of an unventilated concrete cask for dry storage of spent fuel



The design of a ventilated concrete cask for dry storage of spent fuel.

Dry Storage Designs





Dry Storage Pros and Cons

- Avoids corrosion and leak potential of water pools
- Less moderation provides high density packing (8-14 MTHM)
- Shielding and thermal management more difficult
- Good for long term storage after initial cool down
- Secure and safe (typically weighs 100+ tons)
- Ventilated and unventilated designs

Spent Fuel Transport

- USDOT, NRC, US postal service within US
- IAEA; international
- Transport casks
  - Lighter casks , 25 to 40 t, holds one to seven assemblies and can be carried by trucks
  - Heavier casks, up to 120 t, can carry up to 36 assemblies and can be transported by rail
- Transport cask example
  - Fuel assemblies are sealed in a water-filled SS cylinder with walls 0.5" thick, clad with 4" of a heavy metal, usually lead, for radiation shielding
  - Further surrounded by 5" of water and encircled by a corrugated SS outer package
- NRC certification for transport casks (Transportation technology center, SNL)
  - Crash tests; Locomotive tests; Crash fire test; Drop test; Detonation test; Difficult plug; 200 mR/h on surface; 10 mR/h at any point 2m away; 2 mR/h at any normally occupied position

Transportation Casks

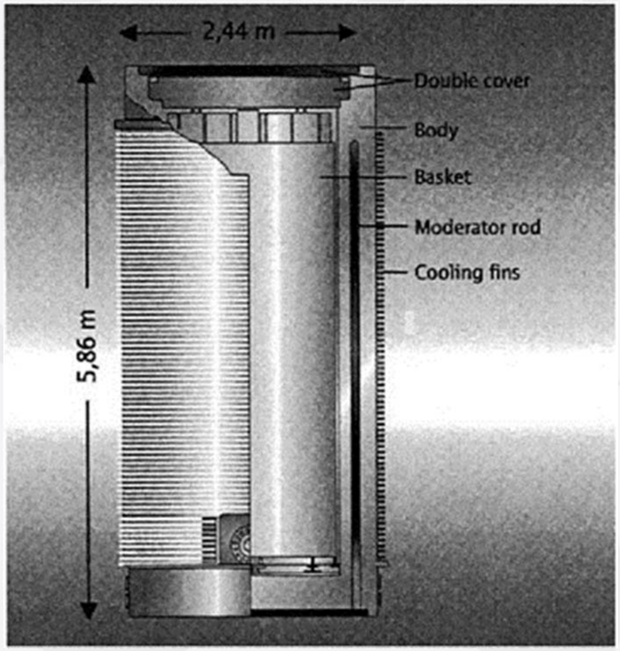
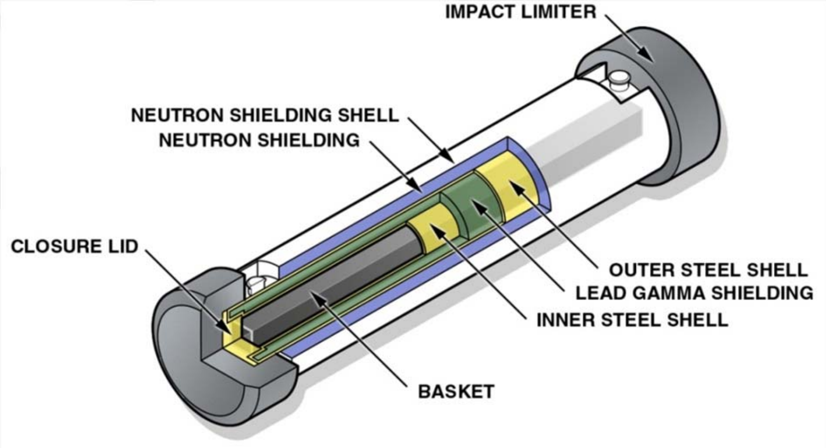


Figure 2.4: A spent fuel cask loaded on a truck for transport

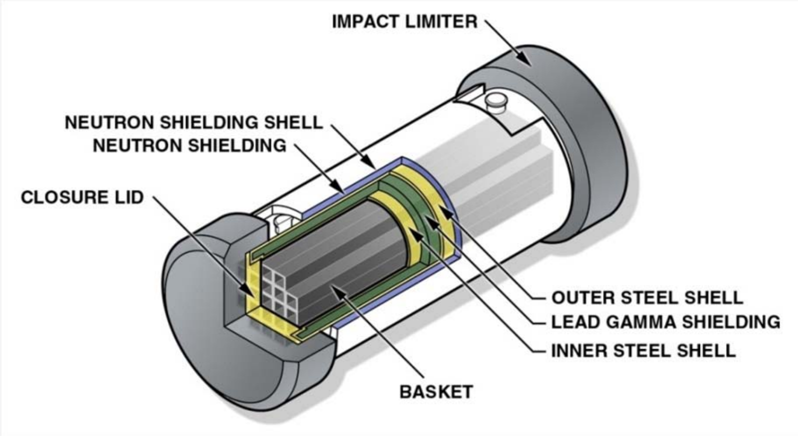
Typical Spent Fuel Transportation Casks



Generic Truck Cask for Spent Fuel

Typical Specifications

Gross Weight (including fuel): 50,000 pounds (25 tons)
Cask Diameter: 4 feet
Overall Diameter (including Impact Limiters): 6 feet
Overall Length (including Impact Limiters): 20 feet
Capacity: Up to 4 PWR or 9 BWR fuel assemblies



Generic Rail Cask for Spent Fuel

Typical Specifications

Gross Weight (including fuel): 250,000 pounds (125 tons)
Cask Diameter: 8 feet
Overall Diameter (including Impact Limiters): 11 feet
Overall Length (including Impact Limiters): 25 feet
Capacity: Up to 26 PWR or 61 BWR fuel assemblies

Summary

- Nuclear power operations encompass a wide array of activities ranging from the steady state operation to complex evolutions.
- These operations require a whole range of plant personnel.
- Documentation, Communication, and Actions
- Consideration of the 3s'

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 2)

Review of Nuclear Power Plant Systems
Nuclear Power Plant Operating Modes

3S Systems Interactions

Topic Connectivity to 3S's

- Define the key or major aspects of this week's topic as they relate to applying the topic to the 3 S's

Topic Connectivity to 3S's

- Identify Primary connections between the topic and one or more S's
- Identify Secondary connections between the topic and one or more S's
- Briefly describe your rationale for these connections

Topic Connectivity to 3S's

- Which connection(s) is (are) most important for this topic?

- Where are there confluences between S's for this topic?
  - Do these confluences allow combining of procedures, personnel, or equipment to cover both aspects?

Topic Connectivity to 3S's

- Where are there conflicts between S's for this topic?
  - How can you resolve the conflicts?

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Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 3)

Operation and Management of Nuclear Technologies

Gulf Nuclear Energy Infrastructure Institute – 2012 Fundamentals Course

Dr. Cable Kurwitz
Texas A&M University

Module 2/Week 5:

- **Nuclear Technology Operations**

Week 5 Learning Objectives:

- How do we manage and operate nuclear technology systems?
- How are nuclear power plants organized?
- How do we operate nuclear power plants?
- How do we show that we run a nuclear power plant correctly?
- How do we identify and fix problems?
- How can we apply these principles to new situations?

Today's Primary Learning Objective

Primary Day 3 Learning Objective:

- The operation and management of nuclear technologies.

Take away from this lecture:

- Proper communications is key to successfully operating nuclear technologies.

Module 2: Nuclear Energy Nonproliferation and Safeguards
(Week 5/Day 3)

Lecture #1: The Operation and Management of Nuclear Technologies, Part 1

Dr. Cable Kurwitz

Lecture Outline

1. The Management Responsibilities
    1. The Management Process
    2. Management Performance
2. Groups
    1. Organization Basics
    2. NPP Organization
3. NPP Key Personnel
4. Responsibilities and Training

Nuclear Organization Responsibilities

- A nuclear organization is legally and morally responsible for the safe application/use of nuclear technology
  - Minimize impact to public and environment
- A state must have an independent regulatory body to administer nuclear technology according to the 3s philosophy
- The company/agency/bureau must have management and operating functions that adhere to the 3s philosophy
- This management and operating paradigm is outlined in the operating license
  - The documents that describe the use of nuclear technology
    - Safety
    - Security
    - Safeguards

Operating License

- The operating license is issued by the regulatory authority.
  - The terms and conditions that must be met.
- Governs (Safety, Security, and Safeguards) in regard to;
  - Staffing levels
  - Staffing qualification
  - Operating practices
  - Limitation on system operation
  - Testing requirements
  - Maintenance requirements
  - Security
  - Handling of prescribed substances
  - Transportation of radioactive material
  - Reporting to licensing authority
- Operating license is predicated on acceptable risk
  - Risk = frequency * consequence
  - The license is crafted to limit risk associated with nuclear technology
- Utility must constantly evaluate the benefit/risk ratio when making decisions

Operating License

- A license serves the following purposes:
  - Authorizes a specific activity to be safely, securely performed
  - Sets out requirements and conditions which must be met to keep the license in force
  - May be procedural, technical, financial
- The typical stages of licensing, i.e., the licensing steps, are:
  - Site Identification
  - Design
  - Construction
  - Commissioning
  - Operation
  - Decommissioning

Government Role in License

- Role of government in nuclear regulation
  - Requirements for a nuclear regulatory body
  - Advisory committees and other agencies
- Regulatory body covers
  - Regulating the use of radioisotopes/radioactive material
  - Transportation of nuclear materials
  - Licensing of nuclear reactors
- Typical licensing requirements for nuclear power plants
  - Nuclear Safety
  - Security
    - Physical security of facility and of materials within facility
  - Operator certification

Role of Government

- The role of government is threefold:
  - Safety - Risk to human health and the environment
  - Security and Safeguards - To ensure the proper use of nuclear science and technology and that nuclear materials or technology are not used for nefarious purposes
- The role of government includes:
  - Laws, ordinances, or other legal mechanisms to:
    - Establish a regulatory framework including the makeup and authority
    - Provide the legal basis for how nuclear facilities are sited, designed, constructed, commissioned, operated and decommissioned
- Government may include other measures such as the following:
  - Adequate financial indemnification (catastrophic accident)
  - Framework for external relationships
  - Cost benefits associated with both capital and O&M

Role of Government

- Regulatory body practices:
  - Independence – agency requires separation from enterprise developing nuclear power and technology
  - Focused - streamlined, central location of regulatory functions – one central government agency (NRC)
  - Neutral – agency should not be seen as championing nuclear nor antagonistic toward nuclear enterprises
  - Autonomous – regulatory body should have the sole responsibility for oversight of all nuclear activities and absolute authority to regulate as specified by law
  - Resources – agency requires appropriate resources to provide the regulatory function including staffing and research needs

Regulatory Functions

- Regulatory agency capabilities and functions:
  - Review and assess safety analyses
    - Trained personnel of sufficient capability and experience
    - Resources (codes, data) to check calculations and methodology
  - Interface with domestic and international nuclear organizations and advisory committees
    - IAEA, EPRI, WANO
    - ANS, ASME, IEEE, Advisory Committee on Reactor Safeguards
  - Establish rules, guides, etc, as appropriate
  - Authority to issue, amend or revoke licenses or other approvals
  - Conduct inspections of facilities and audits of documents and records
  - Set penalties and/or corrective actions when needed

Management Process

- Management is a control function
  - Know where you are (A)
  - Know where you need to be (B)
  - Determine (C) how to move from (A) to (B)
  - Execute plan (D)
- This process is formally defined as strategic planning
  - Analysis of organizational strengths and weaknesses (A and B)
  - Analysis of goals and dangers (B)
  - Identification of appropriate response (C)
  - Define mission (C)
  - Execution of chosen response (D)
- Proper management is key to the successful operation of nuclear power plants by providing the proper leadership and instituting structures that engage all personnel and focus them on nuclear safety

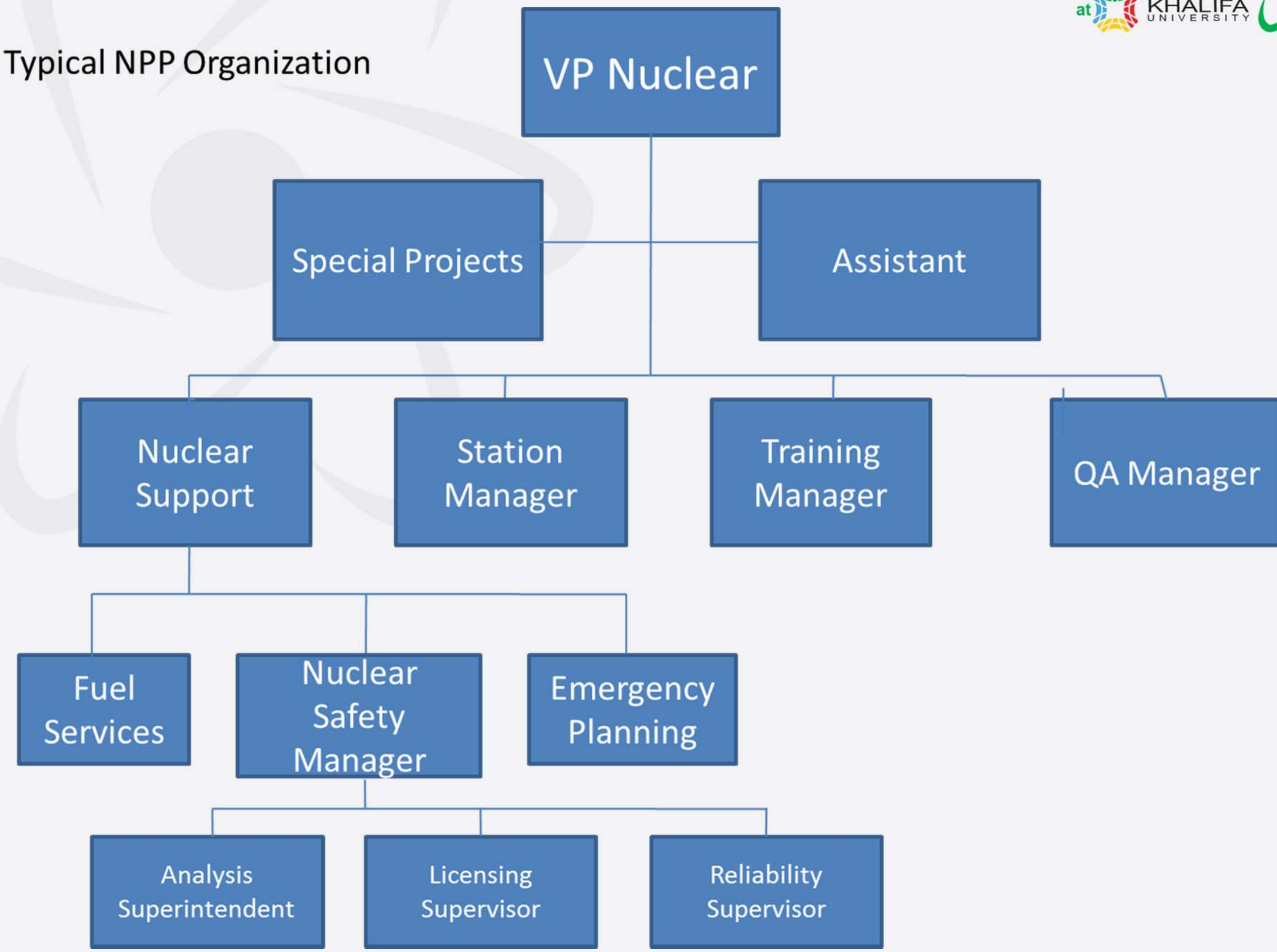
Management Performance

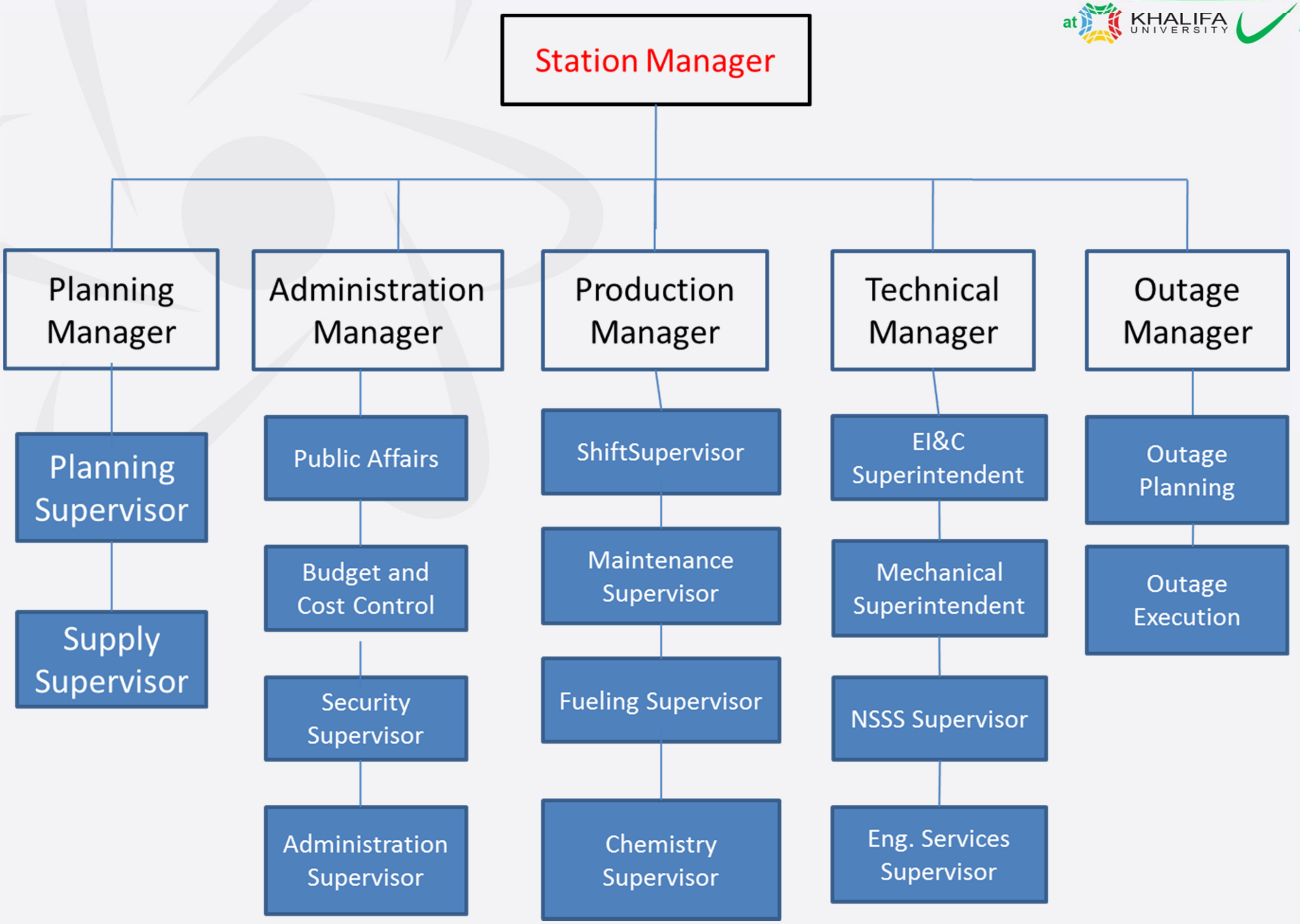
- Management performance is measured by the key result areas (KRA)
  - Safety must be the organizations overriding responsibility.
    - Employee safety - better than similar industries
    - Public safety – zero tolerance for failure both domestic and international
    - Environment – the entire environmental impact must be considered i.e. fuel cycle, radioactive wastes
  - Reliability in terms of plant material condition must be evaluated both in terms of a business case and public perception
  - Availability in terms of plant operation is the focus of the utility but must be balanced by the requirement for nuclear safety
  - Business performance
    - Business costs – actual vs. planned
      - Operating, maintenance
      - Capital improvement
    - Capacity factor/radiation exposure
    - Legal - licensing
    - Personnel
      - Hiring
      - Training
      - Retention

Nuclear Organization

- Nuclear organizations and nuclear power plants (NPP) utilize a diverse workforce of technicians, operators, engineers, administrators, and managers
- NPP organization is focused on the following :
  - Operating license
    - Operating limits/qualifications/reporting requirements
  - Financial aspects and costs
    - Power production, capital repayment, plant improvements
- Nuclear organization can be structured in a number of ways and usually includes four main groups:
  - Operation
  - Maintenance
  - Technical
  - Administration
- Other elements are included to ensure the operating license and financial goals are met
  - Quality assurance
  - Training
  - Other

Typical NPP Organization




Station Manager
Planning Manager
Administration Manager
Production Manager
Technical Manager
Outage Manager
Planning Supervisor
Supply Supervisor
Public Affairs
Budget and Cost Control
Security Supervisor
Administration Supervisor
ShiftSupervisor
Maintenance Supervisor
Fueling Supervisor
Chemistry Supervisor
EI&C Superintendent
Mechanical Superintendent
NSSS Supervisor
Eng. Services Supervisor
Outage Planning
Outage Execution

Station Manager

- Responsible for the overall nuclear organization
- Responsibilities:
  - Manage NPP personnel
  - Interface with off-site management team
  - Point of contact for regulatory body
  - Demonstrate/uphold safety culture and commitment to constant improvement
  - Oversight of operating license
  - Define roles and responsibilities for each division
  - Define specific position roles to first level supervision
  - Significant event reports

Production Manager

- Responsible for Day to Day Operations
- Responsibilities:
  - Commissioning completion assurance
  - Planning and scheduling of work activities
  - Station logs (generation and archiving)
  - Significant event reports
  - Operating Manuals (Normal, abnormal ops, emergency ops)
    - Station Manager has ultimate authority
  - Procedures (Radiation protection, maintenance, other) Operating memos and interdepartmental correspondence
  - Maintenance program
  - Housekeeping
  - Audits
  - Change controls

Other Management

Maintenance Supervisor

- Responsible for the upkeep of physical plant
- Responsibilities:
  - Maintenance programs
    - Preventive maintenance
    - Specialized maintenance activities
  - Maintenance procedures
  - Spare parts
  - Maintenance training, standards, and practices
  - Identification of capital improvements

Administration Manager

- Responsible for administrative support to the nuclear organization
- Responsibilities:
  - Staff services
    - Payroll
    - Accounting
  - Information Technology
  - Material Management
    - Procurement
    - Storage and Supply
  - Security
  - Training

Technical Manager

- Responsible for adherence to the operating license through support of operations and maintenance
- Responsibilities:
  - Reporting and documentation
  - Abnormal incident reports
  - Support maintenance activities (Surveillance, testing, and inspection)
  - Audits
  - Change/configuration management
  - Oversight of operating license
  - Equipment identification
  - Qualification of safety related equipment
  - Nuclear materials control
  - Manuals (Operating, abnormal ops, emergency ops)
    - Station Manager, Production Manager
  - Operating flowcharts
  - Maintenance procedures
  - Station modifications

Quality Assurance Manager

- Responsible for oversight of nuclear organization.
- Provides an independent body to review policies, procedures, and calculations.
- Responsibilities:
  - Audit all aspects of nuclear enterprise to assure procedures are followed, relevant standards met, and license requirements are upheld
  - Specify standards for work, training, and skill sets
  - Design Control
  - Document Control
    - Procurement Document Control
    - Instructions, Procedures, and Drawings
  - Corrective Action
    - Control of Nonconforming Items
  - Prepare QA manuals and provide QA training

Work Culture

- INPO outlines the following principles of a strong nuclear safety work culture
  - Nuclear technology is recognized as special and unique.
  - Leaders within the organization must demonstrate commitment to safety.
    - Safety issues are addressed immediately
    - Decisions are transparent
    - Decision making reflects safety first
  - Organizational learning is embraced.
  - Everyone is personally responsible for nuclear safety.
    - Plant manager, electrician's apprentice, administrative clerk, security guard
  - Trust permeates the organization.
  - Nuclear safety undergoes constant examination.
  - A questioning attitude is cultivated
  - Questions must be addressed with sound engineering principles and a safety first mentality

Nuclear Organization

- Successful nuclear organizations have strong systems in place to identify, attract, and retain talented individuals.
- Improvement is made with a rigorous training program coupled with the ability to evaluate people and practices
  - Auditing – Quality Assurance
  - Peer Review and External Relationships
- Organizational improvement is realized through assessing the limits of capabilities within an organization and devising and implementing methods to extend those limits.
- The diversity of job function requires a multi-tier, integrated approach to the identification and selection of talent
- Job function requirements will set requirements for initial skill/knowledge
  - College degree - AS/BS/MS/PhD
  - Professional certification – Professional Engineer, Senior Electrician, Journeyman
- Employees must also pass background checks
- Identifying and hiring is only the start

Diversity of Job Functions

- Nuclear technology is unique and requires specialized training and qualifications
  - Reactor operator
  - Nuclear certified welder
  - Radiological safety technician
- Nuclear organizations must attract, train, and retain talented individuals to safely function
- Nuclear organizations must continually improve
  - Improve capabilities of workforce
  - Improve policies and procedures
- Nuclear technology has a wide range of job functions
  - Nuclear power
  - Nuclear medicine
  - Other industries and education
- Nuclear power plants have a wide array of job functions that must be carried out
  - Engineering – civil, electrical, mechanical, nuclear
  - Technicians – health physics, chemistry, instrumentation, information technology
  - Trades – building, machinists, warehousing, planning, drafting
- Nuclear organizations requires specific qualifications and training to meet regulatory requirements

Systematic Approach to Training

- Analysis from the station needs to the job function to the task level
  - Identify the requirements of the job/task
  - Understand how to perform the job/task and measures of performing it correctly
  - Document results and incorporate feedback
  - Rate the difficulty of the job/task to assign the level of qualification
- Design of the training takes a parallel path with the development of the course by looking at the delivery of the training objectives and how one can ensure that the employee becomes qualified to meet those objectives
  - Initial qualifications, Training setting/delivery, test objectives, assessments
- Development of the training involves the generation of training material
  - Lecture notes
  - Training aids and mockups
  - Delivery method
- Includes testing of the training plan and refinement
- May also include observation of how other organizations perform similar training tasks

Systematic Approach to Training

- Testing or implementation is the actual roll out and use of the training plan
- Conduct training
- Record feedback of training and performance of the resulting work
- Evaluate all aspects of the training
  - Delivery
  - Impact
- Document results
- Maintenance or evaluation of training involves the synthesis of feedback from all levels to provide input to improve the training
- Requires the monitoring of predetermined metrics and implementation of a predetermined
- Refinement of course includes feedback to external organizations in the form of lessons learned

Types of Training Programs

- Operator Training
  - Licensed – Reactor Operator, Senior Reactor Operator, Shift Supervisors, Specific Plant Function Operators
  - Non-Licensed – Fuel Handling, General Plant Functions
- Maintenance Training
  - Mechanical – Millwrights, Pipefitters, Machinist
  - Electrical – Electricians, Instrumentation
- Plant Support
  - Civil – Crane Operators, Building Trades
  - Chemistry – Chemical Analysts
  - Warehousing – Storekeepers, Tool Crib
- Technical Skills
  - Specific training for a host of job functions – dosimetry, scaffold, Valve packing, flux mapping, etc.
  - Covers a wide cross section of disciplines
- Radiation Protection
  - Comprehensive and multileveled instruction to provide competency to work in radiation areas
  - General to job specific
  - Usually a tiered approach corresponding to dose risk and job specification

Types of Training Programs

- Safety
  - Ongoing training ranging from briefings to classroom discussion to improve workplace safety
  - Covers a wide array of issues from shop practice and office safety to confined space and other specific safety needs
  - Covers procedures, practices, personal protection, identification
- Emergency Response Training - A comprehensive and integrated set of specifications, learning objectives, and courses for training a person to be a qualified member of the station emergency response team.
  - Requires frequent training and simulations usually involves non-plant personnel from external bodies

Qualification

- Qualification is the set of requirements and milestones needed to perform a job/task
  - Reactor Engineer, field Operator, Station Chemist
  - Calibrate Core Exit Thermocouples, Replace Main Panel Breaker, Perform flux map
- Qualification requires training and evaluation
- Requalification may be required
- Qualifications can be independent or sequential
- Qualifications are part of job record and are documented
- Qualifications are typically localized may may take the form of industry standards or nationalized requirements
  - Professional engineer
  - Nuclear or N-stamp certification

Training Documentation

- Documentation of training and qualification is critical to ensure that jobs/tasks are carried out by the appropriate personnel
- Computerized training and qualification records allow station management to:
  - Ensure jobs/tasks are carried out by appropriate personnel
  - Meet License requirements
  - Track station personnel training needs
  - Quality assurance
  - Properly guide/mentor/promote individuals
- Documentation typically includes
  - Education - Diploma
    - AS, BS, etc.
  - Specialized training certificates – training that includes education and other requirements
    - Nuclear welding, Certified electrician, Professional engineer
  - Training records – usually classroom or mockup training
    - Radiation worker training, Self-contained breathing apparatus, office safety, scaffold training, security
  - Qualification records – Check offs on ability to perform job/task/procedure
    - Ability to perform flux map, butterfly valve maintenance, Core exit thermocouple calibration,

External Relationships

- Nuclear organization strives to develop relationships to strengthen own operation and ensure the positive reception of the profession
  - "All hostages to each other" – Industry is dependent on other nuclear organizations for public support. A mistake by one will affect all
- Relationships allow the all members to learn from mistakes, encourage best practices, and develop cost effective approaches to nuclear operation.
- Each organization is independent and must be able to identify, evaluate, and implement each practice as they see fit.

Conclusion

- Nuclear organizations require a unique management approach
  - Adherence to the license to adhere to the 3s
- Proper management is critical to the safe, effective operation of a nuclear power plant
  - Know where you are (A)
  - Know where you need to be (B)
  - Determine (C) how to move from (A) to (B)
  - Execute plan (D)
- Management requirements and balancing influences
- Understand the broad scope of talent and skills needed to successfully run a NPP
- Development of skills and talents
- Documentation of education and training of station staff
- Station Organization
- Key Personnel and Responsibilities
- Work Culture

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 3)

Lecture #2: The Operation and Management of Nuclear Technologies, Part 2

Dr. Cable Kurwitz

Lecture Outline

1. Operation organization &administration
2. Conduct of operators
3. Operating procedures & documentation
4. Operator knowledge & performance

Introduction

- The operation of a nuclear power plant must be focused on safely producing power
  – Public safety must be paramount
  – The plant license must be viewed as the mechanism to minimize risk to the public
- The design of the organization places limits on authority of supervisor positions and strengthens all personnel in regards to safety
  – Strong defense in depth
  – Identification of faults to safety analysis are dealt with immediately
  – Recognize good operating and maintenance practices
  – Strong operating procedures and administration

Introduction

- Operational procedures and administration (OP&A) provide policies that encompass the actions of operations
- OP&A are made up of the following:
  - Management
    - Proper operating standards are reinforced
    - Nuclear excellence is expected
    - Support for plant and personnel improvement is recognized for successful operation
  - Training
    - Provide operators and staff the needed qualifications to operate the NPP
    - Additional training and requalification maintain a professional staff
    - Peer evaluation and quality assurance ensure plant management that training is meeting station needs
  - Procedures
    - Provide trained operators with the proper actions to take to safely operate the NPP
    - Procedures are rehearsed through training simulators to ensure the intent is carried out properly
      - Feedback to training and technical staff
    - Procedures allow operators to evaluate changes to the plant

Introduction

- Safe operations require OP&A violations must never occur
  - Intentional
  - Unintentional
- Violations must follow strict sequence of actions:
- When an OP&A violation is discovered:
  - The affected system is to be placed in known safe state
    - Using approved procedures approved by the Manager
    - May require shutting reactor down
      - Safety – unknown state
      - Inadequate procedures
  - Violations must be reported to regulatory body
    - Event significance
  - Analysis of violation
    - Root cause analysis
    - Unanalyzed condition
  - Application of proposed solution
    - Procedure
    - Modification

Operator Duties

- Operations in a NPP is defined as the activities associated with the manipulation and observation of components to have systems perform in a coordinated manner to produce electric power safely
  - Place equipment and systems in and out of services.
  - Monitor to ensure systems conditions are within the specified operation range
    - License requirements
    - Other requirements
  - Take action to avoid/mitigate abnormal conditions that may violate the license

OP&A Standards

- Operator conduct
  - Safety is foremost consideration
  - Operator adhere to procedures
  - Clear, concise, and effective communication
  - Station equipment is effectively monitored
  - Well defined role
    - Accountability
    - Clear job expectations
  - Self-checking
- Management conduct
  - Safety is foremost consideration
  - Hierarchy of control over plant condition
    - Shift supervisor – SRO – RO
    - Changes in capacity or redundancy to the configuration of safety related systems without appropriate approval of the Shift Supervisor
  - Conservative operation
    - Always operate to maximize safety margin
  - Minimize radiation exposure
    - "As low as reasonably achievable" (ALARA)

OP&A Management

- The plant manager maintains standards of performance that ensure safe and economical operation of plant
- Plant manager is responsible for building and developing nuclear organization
- Coordinates with the regulatory body to ensure plant operations are in compliance with the requirements stated in the operating license.
- Plant manager must be able to interface with industry and peers to establish and enforce standard plant operations and procedures.
- Shift Supervisor Responsibilities
  - Ensure strict OP&A compliance
  - Communicate his expectations to the crew
  - Bear OP&A in mind when authorizing O&M
  - Ensure safety features credited in safety report are disabled only with compensating, AECB approved safeguards
  - Know & observe the limits of shift supervisor authority

OP&A Management

- Senior Reactor Operator (SRO) duties include:
  - Licensed to manipulate the controls of a nuclear reactor and direct others to manipulate controls.
  - Senior watch stander in a control room and is responsible for directing the operation of the nuclear reactor as desired (within regulatory requirements).
  - SROs also are licensed to perform fuel movement/core alterations within the reactor.
- A senior reactor operator licensee is authorized by law to depart from regulations during emergencies.
  - 10CFR50.54(x) states they may "take reasonable action that departs from a license condition or a technical specification (contained in a license issued under this part) in an emergency when this action is immediately needed to protect the public health and safety and no action consistent with license conditions and technical specifications that can provide adequate or equivalent protection is immediately apparent."
  - 10CFR50.54(y) "Licensee action permitted by paragraph (x) of this section shall be approved, as a minimum, by a licensed senior operator, or, at a nuclear power reactor facility for which the certifications required under Sec. 50.82(a)(1) have been submitted, by either a licensed senior operator or a certified fuel handler, prior to taking the action."

OP&A Management

- A reactor operator (RO) is licensed to manipulate the controls of a nuclear reactor which may alter reactivity and change the power level.
  - Observe OP&A constraints featured in operating instructions
  - Notify the shift supervisor immediately upon discovering OP&A non compliance
  - ROs also are licensed to perform fuel movement/core alterations within the reactor.
- Shift Technical Advisor (STA) was established to provide additional on-shift technical support and knowledge to the shift supervisors
  - Operational event evaluation and accident assessment
- The primary duties of the STA include:
  - Provide technical and engineering advice in assuring safe operations of the plant.
  - Review and evaluate operating events and accident and incident assessments
  - Provide advice and/or recommendations to the shift supervisor on the safety significance and reportability of these events as they occur.

OP&A Training

- Experience required to properly perform a specific job–founded upon:
  - Knowledge
    - Fundamental Process Understanding
    - Skills
    - Procedural Training, Practical Skills, Achieved through Practice
    - Behavior
    - Composure, Trained Response, Reflexive Under Pressure
  - Experiment – although related, you wouldn’t want to do it in production
- Expertise
  - Skills, understanding, knowledge possessed by expert
- Personnel
  - Possess Reliable Expertise, confident understanding

OP&A Training

- Operators must have specific qualifications required to perform certain tasks
- For a nuclear station operating staff, qualifications are specified by law and the license is dependent upon demonstration of the qualifications
- Training philosophy is dictated upon active, multilevel, varying types of learning.
- Training should include:
  - Classroom training
    - Fundamentals, reactor theory, component manuals
  - On-the-job training
    - Field work, shadowing, working in other disciplines/trades
    - Peer training, industry exchange
  - Simulator training
    - Standard operating procedures (SOP), emergency operating procedure (EOP)

OP&A Training

- An example is the qualifications for a reactor operator. In the US, the Code of Federal Regulations 10 CFR 55 and NUREG-1021 list the following requirements:
  - A high school diploma
  - At least 3 years of power plant experience with at least 1 year of experience at the nuclear power plant where the individual is licensed (not including time spent as a control room operator).
  - At least 6 months of experience performing plant operational duties at the nuclear power plant where the individual is licensed
  - At least 3 months of experience as a control room operator at the nuclear power plant where the individual is licensed
  - Completion of the nuclear power plant's reactor operator training program
  - Supervised manipulation of the controls of the nuclear reactor for certain operations affecting reactor power level
  - A successful medical examination meeting NRC requirements
  - Passing the NRC Generic Fundamentals Examination
  - Passing the nuclear power plant's reactor operator test
  - Passing the nuclear power plant's Operating Test (approved by the NRC) which covers knowledge of the nuclear power plant components, knowledge of casualty response, and responses to simulated causalities and plant evolutions in an approved simulator.

OP&A Training

- Classroom Training, Reading Exercise
  - Allows for broad base of knowledge to be conveyed
  - Conveys process knowledge without practical operating skills
  - No test of ability to act under pressure Startup with experienced operators from other sites
- On-the-Job Training (OJT)
  - Reduced Curriculum – focus tends to be familiarization at normal conditions
  - Much more costly to learn from mistakes
  - Industry exchange
    - Expand knowledge base – reduce group think
    - Reduces costs for unique training
    - High travel costs to train in similar corporate facilities
- Simulator Training
  - Allows for classroom training to be expanded in a near real environment
  - Able to perform actions not typically performed in operating plant
    - Startups, transient operation, emergency ops
    - Reduces time to capture experience

OP&A Procedures

- Procedures are the vehicle by which proper operation occurs
- Properly constructed procedures provide a quality methodology to accomplish station tasks
- A well defined process to develop operating procedures
  - Involvement by all parts of the organization
    - Well written
    - Accurate
    - Understand impact to license, plant, and organization
    - Safety
  - A specific holder/owner for procedure
    - Quality
    - Accurate
  - Training over procedure
    - Ensure proper implementation
    - Feedback
  - Use of controlled procedures
    - Current/correct version
    - Accurate for plant condition
  - Quality assurance
- Procedure adherence is a key factor in station performance

OP&A Procedures

- Procedures have a number of important features
  - Well defined entry conditions
  - Well defined exit conditions
    - Completeness – no missing steps
    - Quantified requirements
  - Design basis information
- Procedures usually have a number of elements
  - Version and approval information
  - Text instructions (Step list)
    - Entry/Exit conditions
    - Process steps
  - Diagrams
    - Flow charts
    - Logic diagrams
  - Sign offs
    - Step
    - Completion

OP&A Procedures

- Standard operating procedures (SOP) are used in the normal operating activities of the NPP
- Cover the spectrum of normal operating activities
  - Power operations
  - Refueling
  - Startup/shutdown
- SOPs must:
  - Guide the user
  - Standardize procedures
  - Reduce errors and variability
  - Set the standards
  - Be understood by experienced and inexperienced laboratory personnel
- SOP scope
  - Scope and limitations of the SOP
  - Apparatus, chemicals and equipment required for the operation
  - Description of the procedure
  - Appendices or annexes (records and logbooks, figures, photos, graphs, etc.)
  - Determine critical steps
  - Determine QA/QC criteria

OP&A Procedures

- Temporary Procedures are used under specific conditions when plant safety is not jeopardized but an no existing procedure is available to cover the desired task/job
  - Measurements of EAB room temperature
  - Removal of tool from spent fuel pool
- Must use same process as regular procedures
  - Writing and approval
- Increased oversight
- Must not become dependent upon temporary procedures
  - Convert to SOP if needed
  - Technical staff evaluate why needed and propose modification

OP&A Procedures

- Emergency operating procedures are procedures that are entered into under specific conditions when operations move outside the design basis OR can lead to operations outside the design basis
- EOPs may include:
  - Station staff safety
    - First Aid – broken arm, heart attack
    - Rescue - confined space, elevated rescue
  - Plant safety
    - Fire/explosion
    - Radiation release
  - Plant Security
    - Breach of controlled access
    - Security of control room/controlled equipment
  - Common mode incident effect multiple aspects
    - Environment – floods, earthquake
    - Terrorism

OP&A Procedures

- Emergency operating procedures can utilize different philosophies
  - Event oriented
    - Operator identification of specific event or class of events causing the transient or accident
    - Determine optimum response to mitigate the consequences of the transient or accident
    - Typically, increases the number of procedures to cover the scope of possible events
  - Symptom oriented
    - In this approach the entire safety of a nuclear power plant is assumed to be controlled by a certain number of safety-related plant parameters, which (as in medicine) can be called "symptoms"
    - As long as all safety-related symptoms are within pre-determined safety limits, plant safety is maintained
    - If any symptoms exceed safety limits, operators have to initiate actions in accordance with the appropriate symptom-oriented procedure in order to return to acceptable conditions
  - Function oriented
    - Function oriented EOPs assure NPP safety is achieved by controlling a determined number of safety functions
    - Operators focus on verification of proper operation and restoration of important safety functions
  - State oriented
    - State oriented procedures can be considered holistic in that this approach values all parameters related to all safety functions
    - State values are combined by logical equations that define the state of the plant
    - Each possible state has a well defined course of action to transfer the plant to a long-term safe condition

OP&A Noncompliance

- Noncompliance of OP&A procedures may result in operation outside design basis and in violation of license
  - Plant in unanalyzed, unsafe state
  - Transients might cause accidents
  - Mitigation capability may be impaired
- Loss of “control of the plant”
  - Decreased defense in depth
  - Not dictating plant operation but responding
- Not exhibiting leadership in nuclear safety
  - Allow continuation of bad habits

Operating Performance Indicators

- Several performance indicators are used to rate operations of nuclear power plants
- Safety related
  - Reactor trips
  - Operating errors – deviate from procedures
  - Work place injuries
  - Lit annunciators or alarms
- Performance related
  - NPP capacity factor
  - OP&A costs
- Other
  - Training program results
  - Qualification status
  - Use of temporary operating procedures

Operator Functions

- Operations in made up of routines
- Routines have several characteristics
  - Clear line of authority
  - Set procedures and policies
  - Adherence to a strict professionalism
  - Communication
- Routines are used to:
  - Meet station objectives safely through staying within license requirements
  - Eliminate abnormalities in plant configuration
    - Identification
    - Control or containment
    - Eliminate
    - Document

Operating Functions

- Operations are run from the station control room
  - Control room environment
    - Professional, disciplined work environment
    - Clear lines of authority
    - Communication
  - Control of plant configuration
    - Knowledge of component/equipment/system configuration and its impact to nuclear safety
    - Hierarchy of plant activities
  - Communications
    - Logs
    - Shift turnover reports
    - Event reporting
    - Operator aids

Operating Functions

- Control of plant configuration
  - Understand current plant status
    - Known analyzed state
    - Correspondence of component/equipment/system configuration with operating mode
      - Planned work for the upcoming shift
      - Current annunciator/alarm status
    - Hazard and hazard levels - recent changes
    - Unusual events that have occurred
      - During the last 24 hours
    - Unit/plant status
      - Changes in state that are in progress or planned
      - Current annunciator/alarm status

- Control of plant configuration (cont)
  - Understand current plant status (cont)
    - Equipment configuration
      - Unusual lineup, faults, isolations, etc.
      - Current annunciator/alarm status
    - Documentation changes
      - which impact on the completion of routines
      - Authorization of change
      - Shift turnover
  - Maintenance interaction
    - Ensure deficiencies are identified and corrected
    - Pre-maintenance alignments
    - Post-maintenance testing
  - Independent verification

Conclusions

- Operations cover the activities that allow the plant to carry out the desired function
- Management of operations require a strong commitment to OP&A compliance
- Operator Duties
- Operator Standards
- OP&A Management
- OP&A Training
- OP&A Procedures
- OP&A Noncompliance
- Operator Performance Indicators
- Operator Functions

Module 2: Nuclear Energy Nonproliferation and Safeguards
(Week 5/Day 3)

Operation and Management of Nuclear Technologies

3S Systems Interactions

Topic Connectivity to 3S's

- Define the key or major aspects of this week's topic as they relate to applying the topic to the 3 S's

Topic Connectivity to 3S's

- Identify Primary connections between the topic and one or more S's
- Identify Secondary connections between the topic and one or more S's
- Briefly describe your rationale for these connections

Topic Connectivity to 3S's

- Which connection(s) is (are) most important for this topic?

- Where are there confluences between S's for this topic?
  - Do these confluences allow combining of procedures, personnel, or equipment to cover both aspects?

Topic Connectivity to 3S's

- Where are there conflicts between S's for this topic?
  - How can you resolve the conflicts?

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Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 4)

Operation and Management of Nuclear Technologies

Gulf Nuclear Energy Infrastructure Institute – 2012 Fundamentals Course

Dr. Cable Kurwitz
Texas A&M University

Module 2/Week 5:

- **Nuclear Technology Operations**

Week 5 Learning Objectives:

- How do we manage and operate nuclear technology systems?
- How are nuclear power plants organized?
- How do we operate nuclear power plants?
- How do we show that we run a nuclear power plant correctly?
- How do we identify and fix problems?
- How can we apply these principles to new situations?

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 4)

Lecture #1: Configuration Management and Maintenance

Dr. Cable Kurwitz

Today's Primary Learning Objective

Primary Day 4 Learning Objective:

- The importance of configuration management and maintenance.

Take away from this lecture:

- If you don't know the condition of your plant, you cannot run it properly.

Lecture Outline

1. Understand the breadth, depth, and interdependence of configuration management

2. Why configuration management is needed

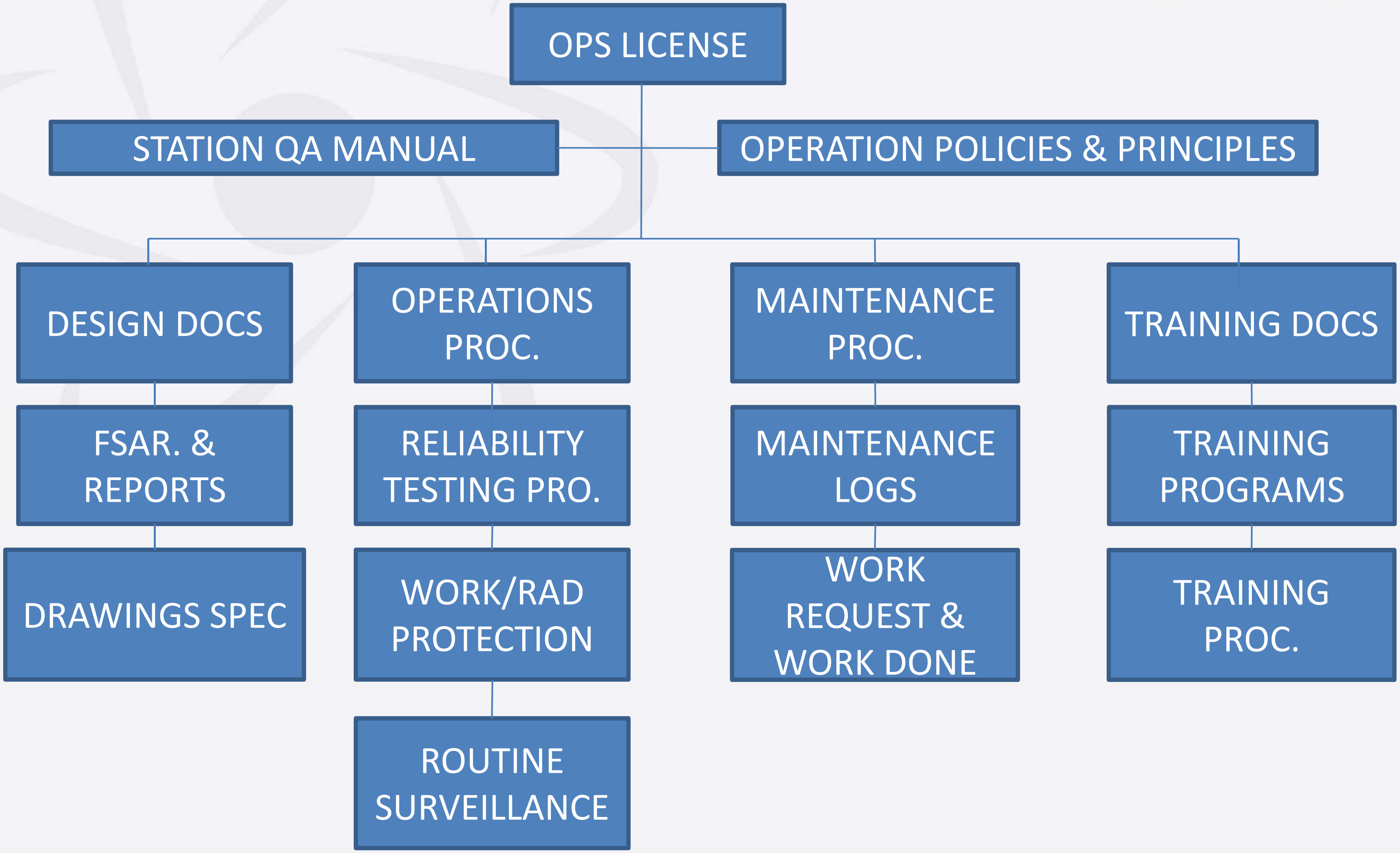
3. How configuration management is achieved

4. To understand the consequence of not achieving configuration control

Overview

- Configuration management is the control of the plant configuration to demonstrate that the organization is meeting the license requirements
    - Documentation as built
    - Examination or surveillance of configuration
    - Implications of plant changes
        - Operational
        - Design
    - Engineering/maintenance/operating documents
    - Staffing qualifications/capabilities
    - Material condition
    - Feedback

Managing Operations and Maintenance



- Configuration management covers:
  - Documents
    - Procedures
    - Drawings
    - Technical documents – logs, reports, data sheets, analysis
    - Personnel records – Training, education, qualifications
  - Plant condition
    - Materials
    - Component/system performance
  - Software
    - Analysis codes
    - Engineering support codes
    - Security

Document Management

- Engineering Documents
  - Process and Instrumentation (P&ID) diagrams, Piping CAD drawings
  - Electrical wiring diagrams, field drawing for instrument/pressure transmitter racks
  - Control equipment room instrument layout
  - Core Operating License Report (COLR)
  - Computer network diagrams, software lists, specialized software settings, PLC codes
  - Valve lists, pump lists, etc.
  - Radiographs, fuel inspection reports, special nuclear material inventory
- Safety Analysis Documents
  - Final Safety Analysis Report
    - Addendums
  - Stress and Reliability analysis
  - Seismic qualification report
  - Over pressure protection report
  - Responses to regulatory inquiries, reports to regulatory agencies

- Plant Condition
  - Equipment specification, procurement, warehousing
  - Obtain manufacturers manuals
- Material management:
  - Specification, purchase order, receiving, inspection, certification
  - Equipment compliance documentation
  - Warehousing/inventory control
  - Material list – inventory/fire control/radioactive material, Material Safety Data Sheets (MSDS)

- Requirements documents
- Software specification and development process
- Validation and Testing program
  - Test program to ensure correct installation
  - Software provides the correct result
  - Program testing program results are documented
- Installation and control of revisions
  - Software revision control and data management

Organization Group Responsibilities

- Operations
  - Operating documents
    - Normal procedures
    - Abnormal procedures
  - Operating capabilities
    - Operating staff qualifications
    - Operating staff work actions
    - Station radiation exposure
- Maintenance
  - Maintenance documents
    - Maintenance procedures
    - Calibration records
    - Surveillance logs
  - Maintenance capabilities
    - Maintenance qualifications
    - Maintenance staff work actions
    - Station radiation control

Organization Group Responsibilities

- Technical staff
  - Technical documents
    - FSAR and addendums
    - FSAR analysis
    - Licensing notifications
    - Fuel documents – Core operating license report (COLR), foreign material exclusion (FME)
    - Fire loading, material record keeping
  - Analysis of plant activities
    - Configuration changes
    - Material condition of plant
    - Fuel loading and design

Change Control

- In order to maintain proper plant configuration, a rigorous process for controlling change is utilized
  - A change is any alteration to systems, procedures, work practices, or station organization.
    - Temporary changes – valve lineups, instrumentation channel
    - Permanent changes – replacement rod position indicators
- Change control is the process by which changes are proposed, evaluated to be safe, approved, scheduled, implemented and documented.

Surveillance Activity

- Surveillance is performed to measure and record plant parameters to ensure the safe operation of the plant within the specifications of the license
  - Design basis accidents
  - Component/equipment performance within technical specifications
- Surveillances also provide information that indirectly affects the plant license
  - Material condition
  - Document control
  - Qualifications

Surveillance Activity

- Surveillance is driven by the technical staff
  - System Engineer – are technical staff responsible for a particular component or system. A subject matter expert, the system engineer defines the surveillance program to ensure the appropriate data is logged
  - The system engineer evaluates data and initiates corrective action to improve system performance
- Operations staff execute the field activities
- Maintenance staff carry out the required repairs or maintenance on system and components

Surveillance Activity

- Surveillance is carried out at times in plant operation
  - Planned periodic activities
    - Change lubricant, perform radiation sweeps
  - Special activities
    - Ageing effects, Reactor Coolant Pump bearing inspection, Reactor vessel material tests
  - Critical maintenance
    - Occurs after breakdown and is used to ensure that proper operation has been restored
    - Follow up radiation surveys following a contamination event

Nuclear Maintenance Philosophy

- Concerted effort to constantly improve plant condition
  - Goals
    - Keep NPP availability high
    - Prevent degradation and failures
    - Clearly defined objectives with known performance indicators
    - Identify root causes of failure
  - High Standards
    - Assessment
      - Multiple levels of assessment from self to external professionals
    - Training
    - Positive reinforcement of job well done

Nuclear Maintenance Philosophy

- Must have complete devotion of all station personnel
  - Management Involvement
    - Support from plant management to supervisors
    - Leadership by example and access to resources
  - Cooperation between departments
  - Appropriate staffing and training
- Focus on preventive maintenance rather than corrective maintenance

- Maintenance involves actions that sustain or restore a component/system to a predetermined state needed to carryout the component/system's function(s).
- Two types of maintenance concepts utilized in the nuclear industry
  - Corrective –
    - equipment failed – operator discovers pump does not start
  - Preventive
    - Understand failure mechanisms – maintenance sees abnormal wear on thrust bearing, pump filter plugs after 1000 hours of operation

Corrective Maintenance

- Corrective maintenance covers the jobs/tasks that are required to return equipment/components/systems from a failed state to normal operation.
  - Occurs after a failure or break down
  - Typically more expensive due to the loss of functionality impacting other systems and worn or failed equipment can damage other equipment

Preventative Maintenance

- Preventive maintenance involves jobs/tasks that are carried out on equipment/components/systems prior to a failure
  - Has a predetermined criteria that may be based on time (periodic), performance (conditional), or administrative (regulatory) criteria
    - Outage, periodically; temperature, vibration; manufacturer warning, regulatory mandate
  - Involves a number of specific actions
    - Monitoring – recording of important data through time
    - Evaluating – tracking of performance and analyzing trends. Usually involves comparison to industry data and manufacturer data.
    - Execution – determining the proper job/tasks to perform to address failure mechanism

Preventative Maintenance

- Periodic preventive maintenance (PM) is the simplest and is based on predetermined fixed intervals
  - Outage, monthly, 10 years performed regardless of the condition
  - Increased costs of supplies/components when they may not be needed
  - Decreased costs associated with manpower associated with monitoring and analysis
- Conditional maintenance is a more sophisticated approach based on input from inspections or predictions based on models
- Predictive maintenance utilizes models developed to predict the time to failure of a component
  - Inputs – monitored performance i.e. bearing temperature, shaft vibration, decibels, differential pressure
  - Output – generally a probability based value that is linked to a predetermined action

Reliability Centered Maintenance

- Reliability Centered Maintenance (RCM) is utilized by almost all nuclear power plants to establish of the required levels of maintenance, operating strategies, and organization commitment to capital improvements through modifications.
  - Improved cost effectiveness
  - Improved capacity factor
  - Reduced unplanned reactor trips
  - Greater understanding of the level of risk associated with plant operation
- Goal of RCM
  - Avoid or reduce failure CONSEQUENCES
  - Not necessarily to avoid failures
- Failure Consequences are the effects of failure on:
  - Safety – Public, Personnel
  - Environmental Health/Compliance
  - Operations/Availability
  - Economics

RCM History

- In the past, preventive maintenance was associated with periodic maintenance (change oil filter, overhaul engine)
- Airlines discovered that overhauls had little or no effect on overall reliability or safety and in many cases the costs associated with periodic maintenance were unsustainable
  - What the airlines discovered
    - Statistical analysis showed, in most cases, no change in safety or reliability when overhaul limits changed.
    - Initial overhaul limits were not analytically based.
    - High repair costs for little or no benefits.
  - Facts about overhauls
    - Many failure modes do not support overhaul philosophy- have no 'right' overhaul time.
    - Lose considerable component life.
    - Overhauls re-introduce infant mortality failures.

- SAE JA1011 “Evaluation Criteria for RCM Processes” defines seven questions for RCM:
  - What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?
  - In what ways can it fail to fulfill its functions (functional failures)?
  - What causes each functional failure (failure modes)?
  - What happens when each failure occurs (failure effects)?
  - In what way does each failure matter (failure consequences)?
  - What should be done to predict or prevent each failure (proactive tasks and tasks intervals)?
  - What should be done if no suitable proactive task can be found (default actions)?

RCM Management

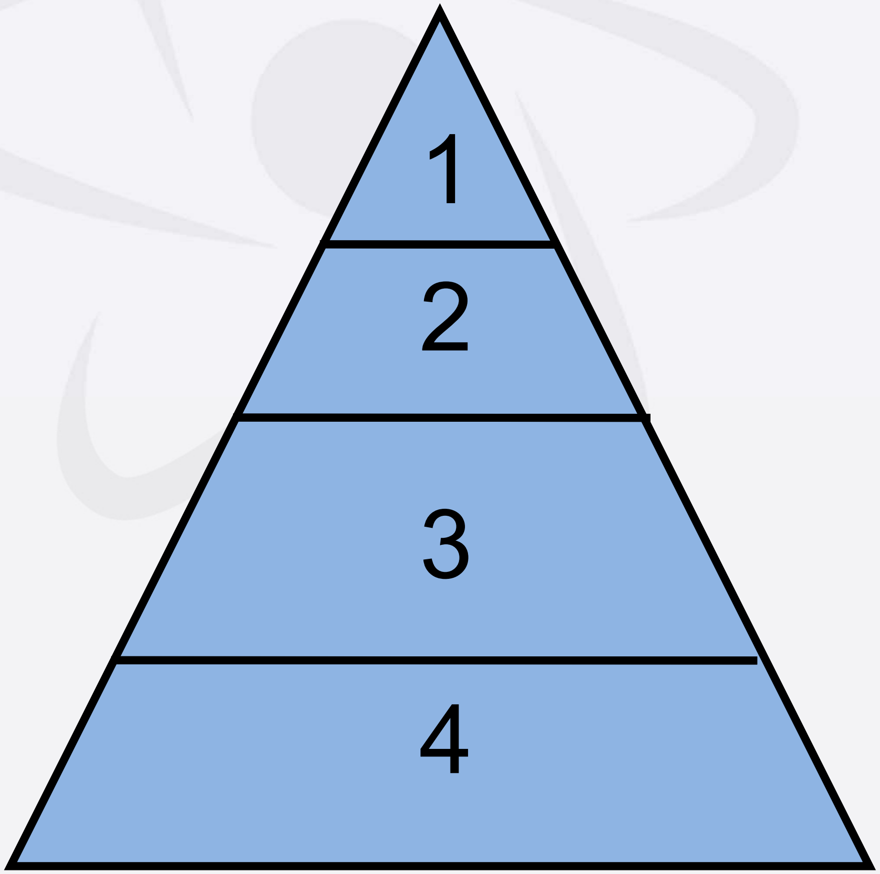
- Maintenance is a total team effort – operations, maintenance, technical, training
- RCM is not equipment oriented but system oriented
  - Integrated effects
  - Common mode failures
  - Failure consequences
- Design directs failure consequences and impacts RCM program
  - Redundancy
  - Instrumentation
  - Layout
- Ideally, the order of failure discovery should be:
  - Technical (proper design of system – design away the problem)
  - Maintenance (proper maintenance – discover a potential problem)
  - Operation (proper operation – do not produce a problem)

Maintenance Performance

- Maintenance performance indicators used for internal and external assessment
  - Quality of maintenance (Training)
    - Repeat work
    - Time to complete maintenance task/job
    - Plant upset from maintenance job/task
  - Plant material condition (Technical and Maintenance)
    - Backlog of maintenance work
    - Ratio of corrective maintenance to preventive maintenance
    - Safety system out of service (Technical specification)
  - Maintenance management (Administrative, Planning, Maintenance)
    - Ratio of corrective maintenance to preventive maintenance
    - Control room annunciators out of service
    - Worker accident rate
    - Unplanned trips or license events
    - Safety system out of service (Technical specification)

Maintenance Performance

- Jobs/tasks require feedback regarding if the job/task was performed correctly
- Assessments are used and integrated into the entire process
  - Want mutually supportive approach to eliminate mistakes not penalize maintenance worker
  - Integrates organization into maintenance
  - Multi-leveled approach based on the complexity of the system and its associated risk



Assessment Pyramid

1. Independent External Assessment – INPO, IAEA
2. Independent Internal Assessment – QA
3. Management Assessment – Direct line supervisor, Maintenance supervisor, Training personnel
4. Individual Assessment – worker or coworker

Verification and Assessment

- Verification and assessment is important for a number of reasons
  - To ensure the job/task is performed correctly
    - Correct procedure, correct unit/system/component
  - To ensure the job/task will not impact the plant
    - In the correct operating mode, pressure boundary, system interface
  - To ensure proper training
    - Prior to job – mockups, training, pre-job briefs
    - After the job – Evaluation of procedures, tools, personnel
  - Interaction with other plant personnel
    - Operations
    - Technical
- Verification occurs before the activity, Assessment occurs afterward

Specialized, Unique, or External Maintenance

- A nuclear power plant is an unique work environment that requires special attention when compared to other similar industrial situations
  - Radiation
    - Fixed vs. Dispersed
  - Special tooling
  - Restrictive work practices and Special qualifications (required)
- Special tooling is required to:
  - Provide a safer work environment
    - Remote manipulators, robots, remote video imagery
    - Reduce radiation exposure
  - Provide specialized measurements
    - Eddy current inspection, Radiographs. Ultrasonics, Radiation detectors

Specialized, Unique, or External Maintenance

- A number of activities are closely controlled within the NPP
- These activities involve hazardous tasks, work in radiation areas, and work that may impact plant safety
- These activities must have:
  - Well defined procedures to perform work as well as get it approved
    - Exhaustive review from multiple groups within organization
    - Once approved NO changes are allowed
  - Jobs in many cases must be rehearsed on mock ups
  - Strict provisions to stop and make safe work areas ('back-out') must be built into planned work.
  - Limit dose to individuals.

Specialized, Unique, or External Maintenance

- The nuclear power industry relies on a network of external or outside contractors to provide additional labor during outage activities or for specialized tasks
- The NPP organization must have in house expertise to properly specify, supervise, and assess the work performed by external contractors
- Management of external contractors presents challenges across the entire NPP organization
  - Knowledge and expertise
  - Record keeping – qualifications, dose, etc.
  - Security

Maintenance Work Process

- Maintenance has a well characterized set of steps to ensure the job is done properly, timely, efficiently, and safely.
- Elements of the work process
  - Problem Identification (what)
    - Walk downs
    - Predictive – high bearing temperature
    - Problem identification forms
    - Industry report
  - Evaluation (why)
    - Preventive maintenance
    - Plant modification
    - License
    - Resources
  - Scheduling (when)
    - Operating mode (full power, hot standby, refueling outage, etc.)
    - Prioritization

- Elements of the work process (cont)
  - Planning (who)
    - Which work group performs the task/job
    - What training is needed
    - Assessment (supervisor, QA)
    - Tooling, spare parts, and supplies
    - Other plant support - operations support, technical staff input, scaffolding, fuel handling, security
  - Implementation (how)
    - Perform the job
    - Testing and validation
    - Assessment
  - Package closure (Review)
    - Return to service
    - documentation

Outage Management

- Modern station management emphasizes stand alone outage management
  - Separate outage manager
    - Planning staff
    - Elements of entire organization
  - All work must be identified and scheduled
  - A similar, separate maintenance process is carried out in parallel to station activities
  - Outage management challenges
    - Nuclear fuel
    - Increased job activities require external staffing
      - Work leveling
      - Training
      - Security
    - Activities not performed consistently
      - Training
      - Documentation

Outage Management

- Outage management is usually focused on duration
  - Scheduling is used to determine critical path
  - Optimization strategies are used to balance work load
  - Main projects typically drive project
    - Refueling
    - Steam generator maintenance
    - Plant modifications
    - Staffing
- Lessons learned from previous outages play critical role
  - Better planning
  - Focus of outage team can utilize past experience
  - Outside experts

Outage Management

- Proper planning is key – must handle scheduled activities as well as activities that may arise during the outage
  - Delays or expanded scope of normally scheduled activities
  - New work activities that emerge during the outage
- Planning must be able to support these activities
  - Staffing
  - Equipment and spare parts
- Contingencies must be planned and supported before the outage
- New work must be evaluated with station safety paramount

Outage Management

- Planning must include the positioning of tooling, parts, and supplies
  - Availability of material to complete tasks
    - Requisitioning
      - Short lead vs. long lead items
      - Transportation
    - Storage
      - Verifying correct parts
      - Storing (safety, legal, security, environment)
      - Inventory "Tools", means tools and equipment such as cranes, lifting slings, jacks
    - Disposal
      - How to dispose of old hardware, contaminated components, etc.
  - Training
    - How to use/install/test
    - Requalification
  - Specialized equipment/tooling

- External personnel, contractors, are typically used to provide the needed work leveling
- Utilization of external personnel must include:
  - Integration with internal staff
  - Included in pre-outage activities
  - Scope of work must be clearly defined to ensure the proper skill set of external contractors
  - Training requirements and qualifications
  - Supervision using station personnel

- Outage team must analyze performance to improve next outage
  - Lessons learned
    - What worked well – what did not
    - Critical path / schedule
  - Identify work for next outage
  - Preparation regarding maintenance work process
  - Performance of different organization elements
    - Health physics, engineering, security
  - Reconfigure outage team based on results

Conclusions

- Configuration Management enables safe, economical operation of the plant
  - Document Management
  - Plant Condition
  - Software Management
- Organization Responsibilities
  - Operations
  - Management
  - Technical
- Failure to control plant configuration may lead to undesirable performance and regulatory violations
- Change Control
- Surveillance Activity

Conclusions

- A proper maintenance program enhances the bottom line by safely increasing availability while lowering the operating costs
- Principles of maintenance
- Types of Maintenance
  - Corrective
  - Preventive
- Reliability based maintenance
- Maintenance Performance
  - Verification and assessment
- Specialized, unique, or external maintenance

Conclusions

- Maintenance Work Process
  - Identification
  - Evaluation
  - Scheduling
  - Planning
  - Implementation
  - Package Closeout
- Outage Management

Module 2: Nuclear Energy Nonproliferation and Safeguards
(Week 5/Day 4)

Lecture #2: Human Performance Housekeeping

Dr. Cable Kurwitz

Lecture Outline

1. Operator Performance
   1. Communication
   2. Assessment

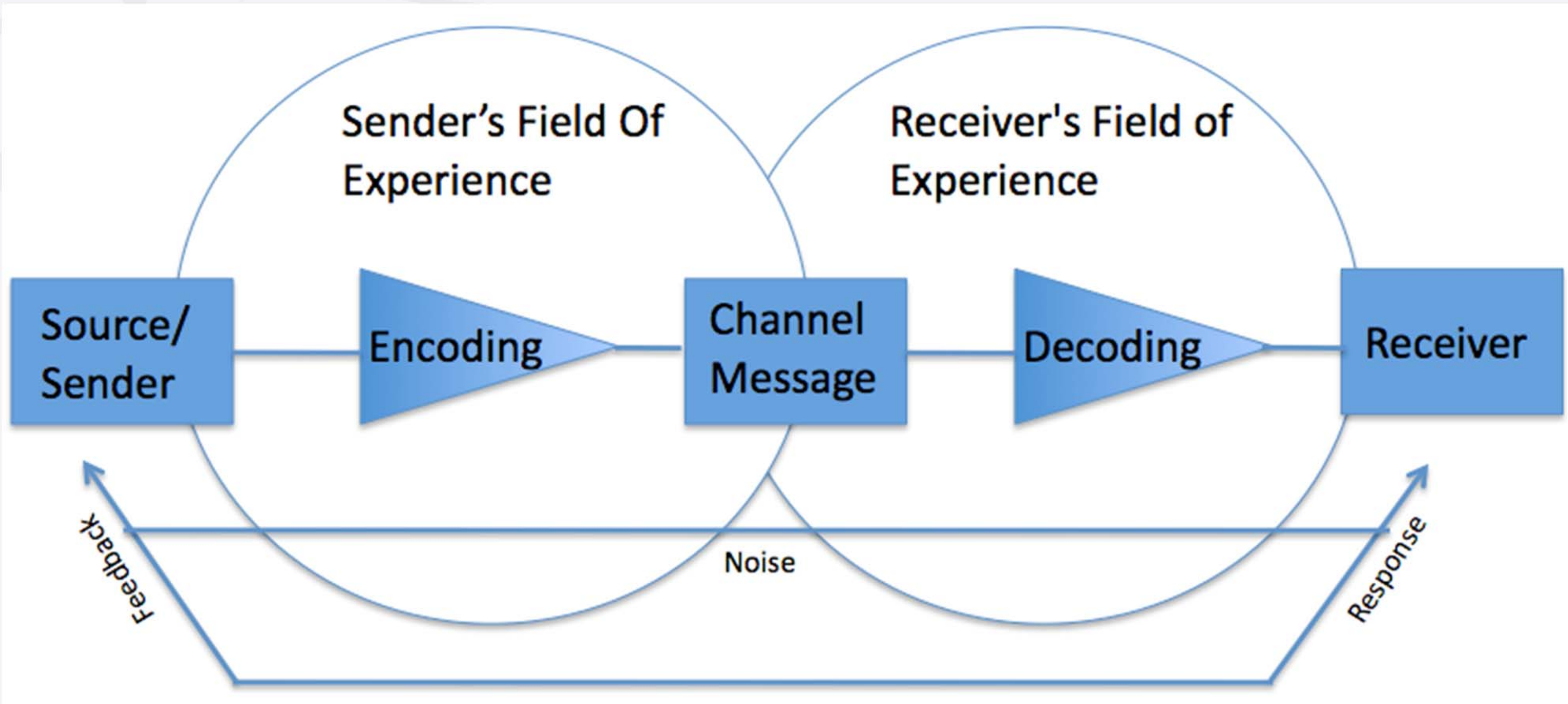
2. Safety Culture

3. Housekeeping

Operator Communications

- Operations require clear, concise, and effective communication
  - Established formal procedure
    - Alpha-phonetic alphabet
    - Proper identification of components/systems
    - Proper sequence
      - Send (Sender)
        - » Concise, descriptive message
          - "Move control rod bank alpha in two steps"
      - Acknowledge (Receiver)
        - » Acknowledge transmission with playback
          - "Understand. Move control bank alpha in two steps"
      - Respond (Sender)
        - » Execute message
          - "Correct. Move control bank alpha in two steps"
      - Acknowledge
        - » Execute message with feedback
          - "Moving control bank alpha in two steps. Complete"
      - Respond (Sender)
        - » Acknowledge feedback
          - "Understand. Movement of control bank alpha in two steps completed"

Operator Communications



Operator Assessment

- Self- Assessment
  - **S**TOP
    - Pause before acting
    - Focus on what to do
    - Confirm what one is to do
  - **T**HINK
    - Consider the actions that are to occur
    - Identify the component/equipment/system to be acted upon
    - Consider the current state of component/equipment/system
    - Project the change in state of component/equipment/system
  - **A**CT
    - Maintain focus
    - Confirm that the components what is to be acted upon
    - Carryout action while monitoring indicators
  - **R**EVIEW
    - Verify response is what was expected
    - If response is not expected, announce response
    - Take appropriate action

Operator Assessment

- Assessment carried out by various levels within the organization and from elements outside organization
- Several programs available for international participants
  - Operation safety review team (OSART) program IAEA
    - Long term operation
    - Probabilistic safety assessment
    - Accident management

Operator Assessment

- Self Assessment is used when performing procedural steps and to evaluate the proper state for the given tasks
- Evaluation of act
  - Verification of state
    - Correct unit, train, equipment, and component
    - Correct procedure
    - Correct tools
    - Correct plant state
  - Pre-job briefing
    - Review all steps of procedure
    - Identify critical steps
    - Determine exit/back out steps
- Execution of act
  - Manipulate plant control or component as directed by a plant procedure or work instruction
  - Proper communication prior to, during, and after act
  - Documentation of step

Safety Culture

- A strong safety culture is made up of the following principles
  - Strong technical basis
    - Limits of safety analysis/license are understood and observed
      - Procedures up to date
      - Technical documentation matches plant configuration
      - Discrepancies in design basis or unanalyzed conditions are promptly addressed
      - Risks are clearly understood and used in operations
  - Operator Expectations
    - Highly qualified and experienced
    - Operate from a conservative stance
    - Strict adherence to following procedures
    - Committed to good communications and teamwork
    - Support - RESOURCES

Safety Culture

- A strong safety culture is made up of the following principles (cont)
  - Constantly Focused on safety
    - Constant improvement
    - Awareness of what could go wrong and understanding and what to do in the event that something does go wrong
    - Accountability for actions and pride in performance at the plant and personnel level
  - Assessment
    - Internal and independent review
    - Accountability for actions and pride in performance at the plant and personnel level
    - Deficiencies are addressed in a timely manner

- Performance Indicators
  - Radiation safety
    - Station/individual dose
      - Dose reduction program
      - Goals and measurements
      - Work in radiation areas
      - Worker contamination events
    - Contamination
      - % area and change in % area of plant contaminated
      - Contamination reduction goals

- Performance indicators (cont)
  - Public safety
    - Operating performance indicators
      - Event reports
      - Reactor trips
      - Abnormal operating events
    - Impact to environment
      - Outside exclusion boundary monitoring
      - Spent fuel, mixed waste. and low level waste volume
  - Problem resolution
    - Root cause analysis
    - Repeat events

Defense in Depth

- Prevent accidents – limit consequences
  - Multiple barriers to the release of radioactivity
    - Require staged protection to support integrity of barrier
    - Focused on the design of the plant
  - Protection of boundaries
    - Reduce interaction of operations that may upset boundaries
    - Focused on the procedures for operating and maintaining the plant
- Defense in depth principles
  - Protect from abnormal operation
  - Control abnormal events to limit progression
  - Mitigate consequences of accident
- Defense in depth characteristics
  - Redundancy
  - Specified Probability criteria
  - Separate
  - Multiple types

Operator Fitness for Duty

- Since operators are instrumental to nuclear safety, their fitness for duty must be unimpeachable
- Substance abuse
  - Drugs, alcohol
  - Testing program
- Medical fitness
  - Physical
  - Mental
- Training
- Work load
  - Work hours
  - Call ins
  - Staffing levels

Housekeeping

- Plant housekeeping is defined as the process by which plant work conditions are maintained at optimum for operation and maintenance
- Housekeeping covers a array of topical areas:
  - Cleanliness standards
  - Plant material conditions
  - Workplace safety
  - Good practices in nuclear power
- A station housekeeping program consists of the following elements:
  - Policy
  - Housekeeping program
    - Training
    - Expectations
    - Procedures
    - Resources and support
  - Work group/individual participation
  - Quality assurance

Housekeeping

- The plant material condition is defined as the current maintenance condition of components/equipment and systems
  - Ability to carryout intended function
  - Current state to be operated or maintained
    - Cleanliness
    - Labeling
    - Contamination
    - Foreign material
    - Accessibility
- Housekeeping refers to the degree to which the plant is safely accessible and operable
  - Micro to macro level

- The importance of housekeeping:
  - Visibility to station personnel and external peers/regulators
    - Indication of the standards enforced by the plant
  - Creates a safe, efficient work environment
  - Allows for more efficient maintenance of plant material condition
    - Identification
    - Ability to repair in a timely, safe fashion
  - Allows for better evaluation of plant state in regards to deterioration and potential problems

Housekeeping Standards

- Housekeeping standards are culturally dependent
  - Japan – 5S
  - Germany
  - US
- Should be clearly understood
  - Must be visibly reinforced by plant management
  - Training
    - Demonstration
    - Peer review – plant visits/interchange
  - Sufficient resources
    - Equipment
    - Materials
    - Personnel
    - Time
  - Monitoring and feedback
- Station personnel must understand that a clean and organized plant will outperform a poorly kept plant
  - Both station and personnel should benefit for an effective housekeeping program
    - Station goals
    - Competition/reward

Housekeeping Requirements

- Housekeeping must be considered throughout the organization
  - The design of equipment must consider maintenance
  - Operations must understand housekeeping as a tool for performance improvement and plan accordingly
  - Maintenance considers housekeeping as an integral part of everyone's duties
  - Management exhibits leadership and commitment to housekeeping
- Station must have a simple to use, accurate reporting system to report housekeeping issues
  - Responsive work planning fixes small problems before they become chronic
  - Operations must consider housekeeping in the day to day operations
  - An effective tracking process
  - Quality assurance
- Housekeeping program must be robust
  - An appropriate stock of spare parts
  - Good maintenance procedures
  - Housekeeping should interface with preventive maintenance program

Housekeeping Examples

- Cleanliness and order throughout the plant
  - Tools, safety equipment, scaffolding stored properly
    - Identified, specific location
    - Clean, ready to use
  - Work locations are clean and organized
  - Equipment clean with proper guards
    - Proper labels
    - Special coatings
- Plant equipment is accessible and can be maintained or operated properly
  - Warning placards
  - Free from debris or obstructions
  - Special tooling/equipment to work on difficult to reach equipment
- Refuse containers well marked, clean, and routinely emptied
- Proper use of tool management
  - Tool cribs
  - Check out/check in and work site storage
- Equipment is free of leaks
  - Steam, water, oil
  - Seals
  - Filters
- Radiation areas are clearly defined and clear of clutter

Performance Indicators

- Maintenance backlog of housekeeping items is small and handled in a timely fashion
- Reporting system captures housekeeping items effectively
- Internal reviews - Walk-downs
  - Visible signs of poor housekeeping
    - Leaks
    - Very few annunciaters out of service
    - Painting, labels, plant condition
    - Storage
    - Tool crib
- External reviews
  - Peer visits
  - Regulatory inspections
- Number of industrial accidents

Performance Indicators

- A walk down is an effective method for evaluating housekeeping
  - Examples may include:
    - Cleanliness of floor, equipment, rest rooms, work areas
    - Leaks (oil, steam, water, seals)
    - Work air quality, noise
    - Rotating equipment guards
    - Protection from environment (Dust guards, drains)
    - Electrical connections (oxidation, connection, wire management)
    - Fasteners (proper engagement, corrosion)
    - Labels, placards, signage
    - Coatings
    - Personnel behavior

Conclusion

- Work Assessment
- Prioritization and Constraints
- Materials and Tooling
- Supporting Personnel

Module 2: Nuclear Energy Nonproliferation and Safeguards
(Week 5/Day 4)

Operation and Management of Nuclear Technologies

3S Systems Interactions

Topic Connectivity to 3S's

- Define the key or major aspects of this week's topic as they relate to applying the topic to the 3 S's

Topic Connectivity to 3S's

- Identify Primary connections between the topic and one or more S's
- Identify Secondary connections between the topic and one or more S's
- Briefly describe your rationale for these connections

- Which connection(s) is (are) most important for this topic?

Topic Connectivity to 3S's

- Where are there confluences between S's for this topic?
  - Do these confluences allow combining of procedures, personnel, or equipment to cover both aspects?

- Where are there conflicts between S's for this topic?
  - How can you resolve the conflicts?

*Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. **SAND2012-2384C**

Module 2: Nuclear Energy Nonproliferation and Safeguards
(Week 5/Day 5)

Operation and Management of Nuclear Technologies

Gulf Nuclear Energy Infrastructure Institute – 2012 Fundamentals Course

Dr. Cable Kurwitz
Texas A&M University

Module 2/Week 5:

- **Nuclear Technology Operations**

Week 5 Learning Objectives:

- How do we manage and operate nuclear technology systems?
- How are nuclear power plants organized?
- How do we operate nuclear power plants?
- How do we show that we run a nuclear power plant correctly?
- How do we identify and fix problems?
- How can we apply these principles to new situations?

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 3)

Lecture #1: Corrective Action and Quality Assurance

Dr. Cable Kurwitz

Today's Primary Learning Objective

Primary Day 5 Learning Objective:

- The operation and management of nuclear technologies.

Take away from this lecture:

- Proper communications is key to successfully operating nuclear technologies.

Lecture Outline

1. Corrective Action Program

2. Quality Assurance

Corrective Action

- Corrective action is the action taken to eliminate the causes of an existing nonconformity, defect, or other undesirable situation in order to prevent recurrence (NELAC 2003 Glossary)
- Correction vs. Corrective Action
  - Correction-The quick fix
    - Get it out the door
    - May cause other problems
  - Corrective Actions-The thoughtful fix
    - Correct the underlying cause
    - Do not cause other problems

Corrective Action Request Form

QS-14001 Controlled Document	QS-14001 Element: 4.5.2 Non-conformance CAR and PAR EMS-F 4.05.002 Corrective & Preventive Action Request	Revision Level: Release

Audited Area / Department:		Audit Date:	
Auditee(s):		Auditor:	
CAR / PAR Number:		Date Due:	
Audit Question #:		ISO-14001 Element	

Description of Non-conformance
Root Cause Analysis:
CAR Interim action: Date of Implementation:
CAR Long range action: Date of Implementation:
Preventative action: Date of Implementation:
Verification: Date of Verification

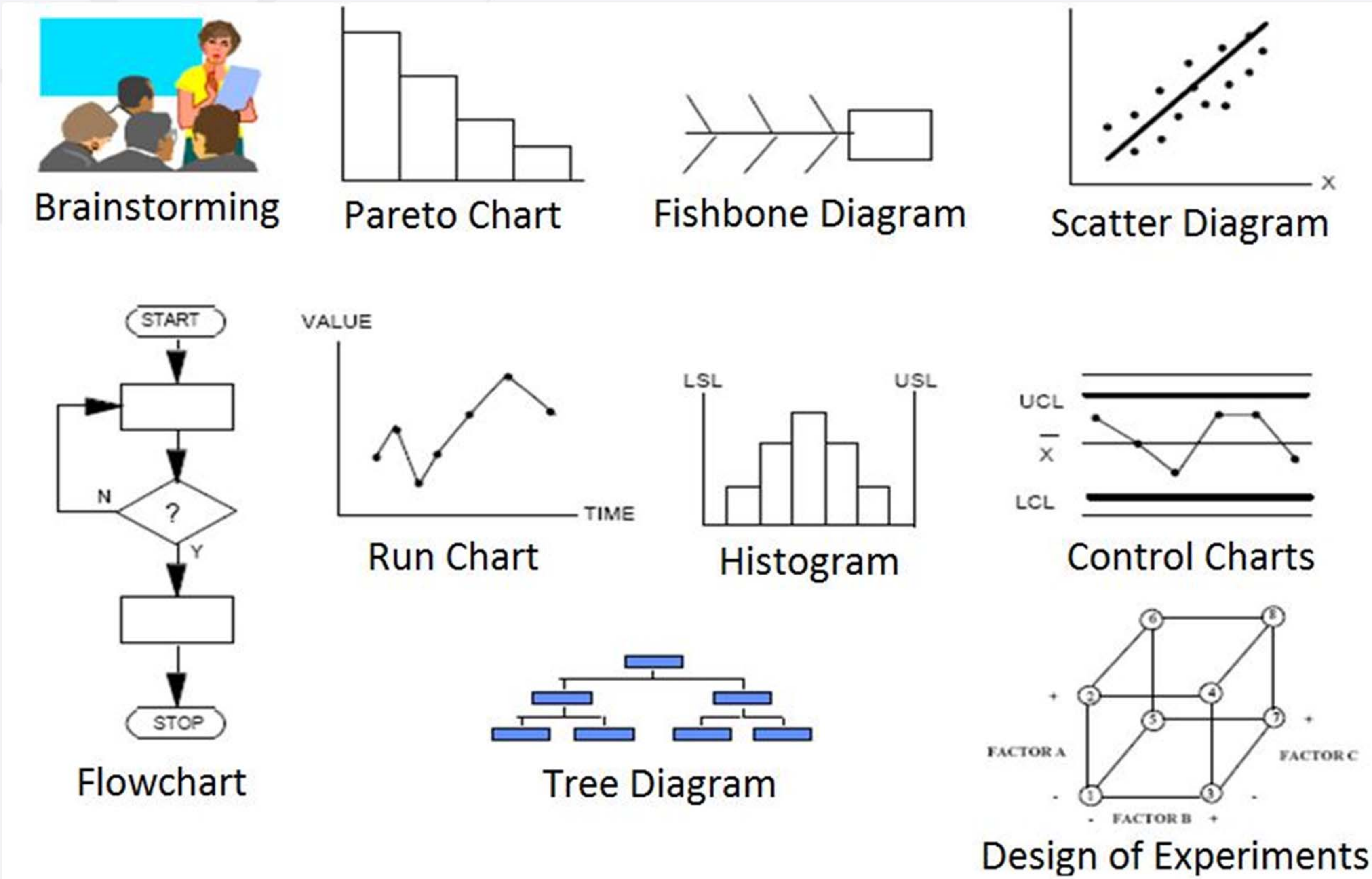
Auditor (signed)	*Date*

Note: This form shall be retained as required per EMS Procedure EMS-013 (Environmental Records)

Characteristics of Root Causes

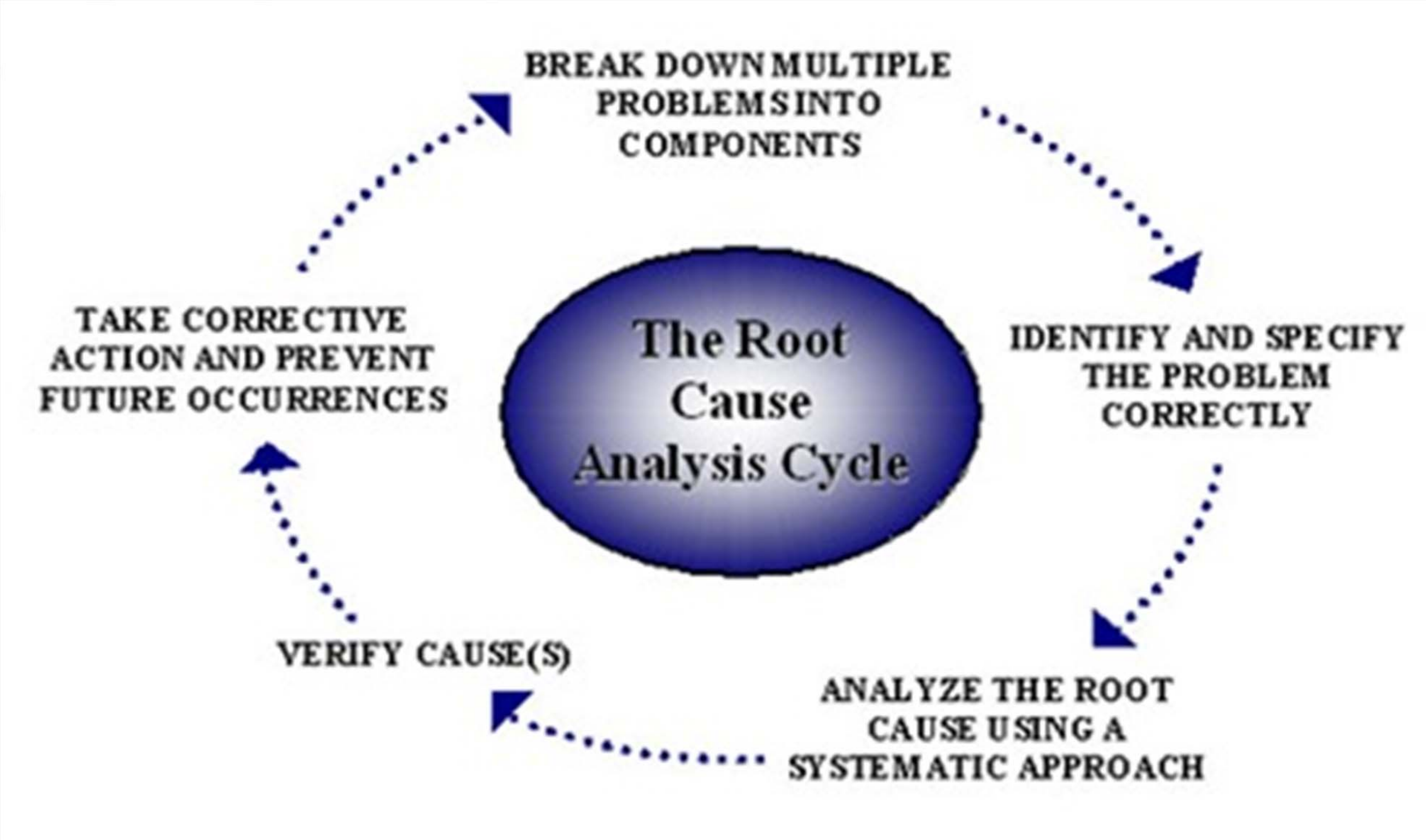
- Root causes are specific underlying causes
- Root causes are those that can reasonably be identified
- Root causes are those management has ability to fix
- Root causes are those for which effective recommendations for preventing occurrences can be generated

Quoted from "Root Cause Analysis for Beginners", Rooney and Vanden Heuvel, Quality Progress, July, 2004


Brainstorming
Pareto Chart
Fishbone Diagram
X
Scatter Diagram
START
N
?
Y
STOP
Flowchart
VALUE
TIME
Run Chart
LSL
USL
Histogram
UCL
X
LCL
Control Charts
Tree Diagram
FACTOR A
FACTOR C
FACTOR B
Design of Experiments

Conducting a Root Cause Analysis

- Aim corrective measures at cause
  - Not merely treating symptoms
- Perform systematically
  - Back conclusions by evidence
    1. Assemble Team and Fact Finding
    2. Analyze Data to Determine Cause
    3. Develop Corrective Actions
    4. Document the RCA
    5. Monitoring Corrective Actions for Effectiveness and Sustainability
- Management support for corrective action program


BREAK DOWN MULTIPLE PROBLEMS INTO COMPONENTS
IDENTIFY AND SPECIFY THE PROBLEM CORRECTLY
ANALYZE THE ROOT CAUSE USING A SYSTEMATIC APPROACH
VERIFY CAUSE(S)
TAKE CORRECTIVE ACTION AND PREVENT FUTURE OCCURRENCES
The Root Cause Analysis Cycle

Assemble Team, Gather Data

- The RCA Team Leader provides a briefing to the RCA Team
  - Defines the scope of the Fast Track or Formal RCA.
  - Establishes deadline for completing the Fast track or Formal RCA
  - Assigns duties to each team member
  - Experience Facilitator
    - External for more complex problems
    - No More Than 8 - 10 per Group
- RCA Form started
  - A description of the incident
  - Data gathered for analysis (ongoing process)

WHO - WHEN – WHERE - WHAT

Problem Definition

- 4W:
  - What was affected
  - Where did the problem take place
  - When was the problem discovered
  - Who Discovered the problem
- 2H:
  - How much was affected
  - How often has the problem occurred
- 1C:
  - What is the consequence

Correct, Prevent, Improve

Ask why this happened !

Apply root cause analysis problem solving techniques to the incident to identify contributing factors.

After review of findings, identify the Root Cause(s)

Basic Elements

- Materials
  - Defective raw materials
  - Wrong type for job
- Machine/Equipment
  - Incorrect instrument selection
  - Poor maintenance or design
- Person
  - No or poor management activity
  - Inattention to task
  - Task hazards not guarded properly
  - Other - Skill set not defined - Not trained for task
  - Stress demands or undue pressure
    - Results in improper practice
- Environment
  - Workplace cleanliness/clutter
  - Layout of work area
  - Maintenance of work area
  - Techniques or demands of task
  - Forces of nature
- Methods
  - No or poorly written procedure
  - Practice not same as written procedure
  - Poor communication
- Management System
  - Training or education lacking
  - Poor personnel involvement
  - Poor recognition of hazard
  - Previous unidentified hazard or skill set not handled properly

Develop Corrective Actions

- Corrective actions should:
  - Be specific to address the root cause(s) of the incident.
  - Be measurable to assure their effectiveness and sustainability.
  - Be achievable from operational and budgetary view
- Interim and long range actions
- Document results using a predetermined form that outlines the team, problem, corrective actions, etc.
- Distribute report with findings to groups within plant
  - Management
  - Training
- Documentation, Reporting, and Actions

Monitoring Corrective Actions

- Corrective actions are monitored by the quality assurance program
  - Documentation
    - Reports
  - Reporting
    - Responsible group/owner
    - Those impacted
  - Actions
    - Time
    - Resources
- Monitor the status of the corrective action(s) to assure their effectiveness
  - Document and report

Summary

- Corrective Action Program
- Root Cause
  - Systematic approach to problem solving
- Removes the problem
  - If cause is really identified
- Allows focus of organization on preventive actions
  - Reduces number of corrective actions

Quality Assurance Introduction

- Quality assurance is a planned and systematic pattern of actions designed to provide confidence in station processes
  - Safety
    - Mandatory for work on safety related systems
    - Permeated through all aspects of nuclear organization
  - Known - Properly defined
    - Detail in the QA Manual
    - Training and implementation
  - Complete
    - Design
    - Procurement
    - Construction
    - Operation
  - Grounded in legal and industry standards
    - NUREG, CFR, CSA Standard N286

Quality Assurance Introduction

- Quality assurance is integral to the design, procurement, construction, operation and maintenance of plant structures and equipment
  - Ensure the quality of the physical plant
  - Examples:
    - Code compliance
      - Fire code
      - ASME code for boilers & pressure vessels
      - ANSI code for pressure piping
      - Code for Seismic design
    - Operations
      - Reactor control
      - Safety related operations
    - Maintenance
      - Impact safety related systems and instrumentation
    - Manufacturing
      - N-stamp
      - ISO9000
      - Counterfeit items
    - Software
      - Verification and validation
      - Controlled use

Quality Assurance Tenets

- Well defined
  - Goals, objectives and policies, procedures
  - Specify roles and responsibilities
  - Specify and communicate results to be achieved
  - Plan and control work
- Well understood
  - Training
  - Procedures
  - and ensure they are understood
- Well supported
  - Identify and allocate resources
  - Ensure the competent personnel
  - Correct information in timely manner
- Accountable
  - Hold individuals accountable
  - Known expectations
  - Management leadership

QA Manual

- The station QA Manual describes the program for achieving and assuring quality work on safety related systems, whether performed by station personnel or by contractors.
- At Management's discretion, the QA program may be extended to other work at the station.
- The OP&A require that QA activities be carried out according to the station QA manual.
- Implementation of the QA program is integrated into station procedures.

Definitions

- Quality:
  - The condition achieved when an item, service or process meets or exceeds the users' requirements or expectations.
- Quality Assurance (QA):
  - All those actions that provide confidence that quality is achieved.
- Quality Assurance Program (QAP):
  - A management system established to assign responsibilities and authorities, define policies and requirements, and provide for the performance and assessment of work.
- Graded Approach
  - The process of ensuring that actions used to comply with a requirement are commensurate with:

Standards

- ASME NQA-1, Quality Assurance Requirements for Nuclear Facility Applications
  - Key national consensus standard for nuclear quality & safety
  - Unique focus on nuclear facilities & activities
  - Single most rigorous and comprehensive standard
  - First choice for DOE nuclear facility applications
  - Supports compliance with DOE QA Requirements
  - Establishes criteria for the performance of work
- ISO 9001, Quality Management System
  - Applies to all types of organizations that are involved in non-nuclear activities
  - Based on 8 quality management principles
  - ISO chose these principles because they can be used to improve organizational performance and achieve success
- ANSI/ASQ Z1.13, Quality Guide for Research
  - Applies to non-nuclear research activities
  - This document can be used in the development of a quality system for basic and applied research.
  - Consensus Standards must be used to develop and implement the QA Program

QA Structure

Management	Performance	Assessment

• Organization
• Training
• Improvement
• Documentation
	• Work Process
	  • Operation
	  • Maintenance
	• Design
	• Procurement
		• Self Assessment
		• Management Assessment
		• Independent Assessment

- Organization
  - Establish management structure
    - Responsibilities
    - Lines of responsibility
    - Delineation of authority
    - Communication
    - Policies and procedures for those managing, performing, and assessing work
  - Establish management processes
    - Planning
    - Scheduling
    - Resources
- Key Elements
  - Ownership and support
  - Clear performance objectives
  - Focus on nuclear safety
  - Use of graded approach to assessment

- Training
  - Train and qualify personnel to be capable of performing assigned work
  - Provide continuing training to personnel to maintain job proficiency.
- Key Elements
  - Affects all personnel
  - Stimulate professional development
  - Designed to address specific needs
  - Maintain proficiency and promote improvement
  - Conduct on-going review of training effectiveness

Quality Assurance Principles

- Improvement
  - Establish mechanisms to detect and prevent quality problems
  - Correct plant and process deficiencies
    - Identify
    - Evaluate
    - Correct
  - Identify the causes of problems
    - Root cause analysis
    - Recurring issues
    - Performance indicators
- Key Elements
  - Standards and measures for performance
  - Problem identification, control, resolution, and follow-up
  - Continuous improvement
  - Prevent problems before they occur

Quality Assurance Principles

- Documentation
  - Utilize proper document sequence
    - Prepare, review, approve, issue, use, and revise documents
  - Maintain proper document retention
    - Logs
    - Records
    - Communications
- Key Elements
  - Level of detail for documents and records defined
  - Key documents identified and controlled
  - Controlled document retrieval

- Work Processes
  - Perform work in a consistent safe manner
    - Meet the legal, regulatory, administrative, and technical standards
    - Use approved instructions, procedures, etc.
  - Identify and control items to ensure their proper use.
  - Maintain proper plant material condition
  - Preventive maintenance program integrated into organization
- Key Elements
  - Management provides training, resources, and direction
  - Employees are responsible for their work
  - Review and improve processes

Quality Assurance Principles

- Design
  - Use correct engineering principles
  - Meet the appropriate standards
  - Modification to plant must have significant support
  - Identify barriers and control design interfaces
- Key Elements
  - Design based on sound engineering/scientific principles
  - Validation of design changes using internal and external groups

Quality Assurance Principles

- Procurement
  - Maintain proper documentation over item specification and procurement
  - Evaluate/test equipment
  - Maintain proper storage and control
  - Verify suppliers capability to deliver acceptable equipment
- Key Elements
  - Procured items and services must perform as specified and meet requirements
  - Use qualified suppliers
  - Acceptance of procured items and services in accordance with specified methodology

Quality Assurance Principles

- Self Assessment
  - Review work processes to ensure proper implementation
    - Plant state
    - Supporting actions
    - Testing and validation
- Key Elements
  - Inspection
  - Nuclear safety

Quality Assurance Principles

- Management Assessment
  - Ensure that management assess processes
    - Identify – problems in meeting goals
    - Evaluate – how problems are affecting goals
    - Correct – Fix problems to meet goals
- Key Elements
  - Across organization
    - Operations
    - Technical
    - Maintenance
    - Quality assurance
  - Leadership

- Independent Assessment
  - Plan and conduct independent assessments to measure item and service quality and the adequacy of work performance & to promote improvement.
  - Establish sufficient authority and freedom from line management for independent assessment teams.
  - Ensure that persons conducting independent assessments are technically qualified and knowledgeable in the areas to be assessed.
- Key Elements
  - Implemented by independent organization representing senior management
  - Performance-based approach
  - Technically knowledgeable personnel
  - Focus on improving performance
  - Scheduling based on performance

Conclusion

- Introduction
- Quality Assurance Tenets
- Definitions
- Standards
- Quality Assurance Principles

Module 2: Nuclear Energy Nonproliferation and Safeguards (Week 5/Day 5)

Operation and Management of Nuclear Technologies

3S Systems Interactions

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