AP1000 Nuclear Power Plant

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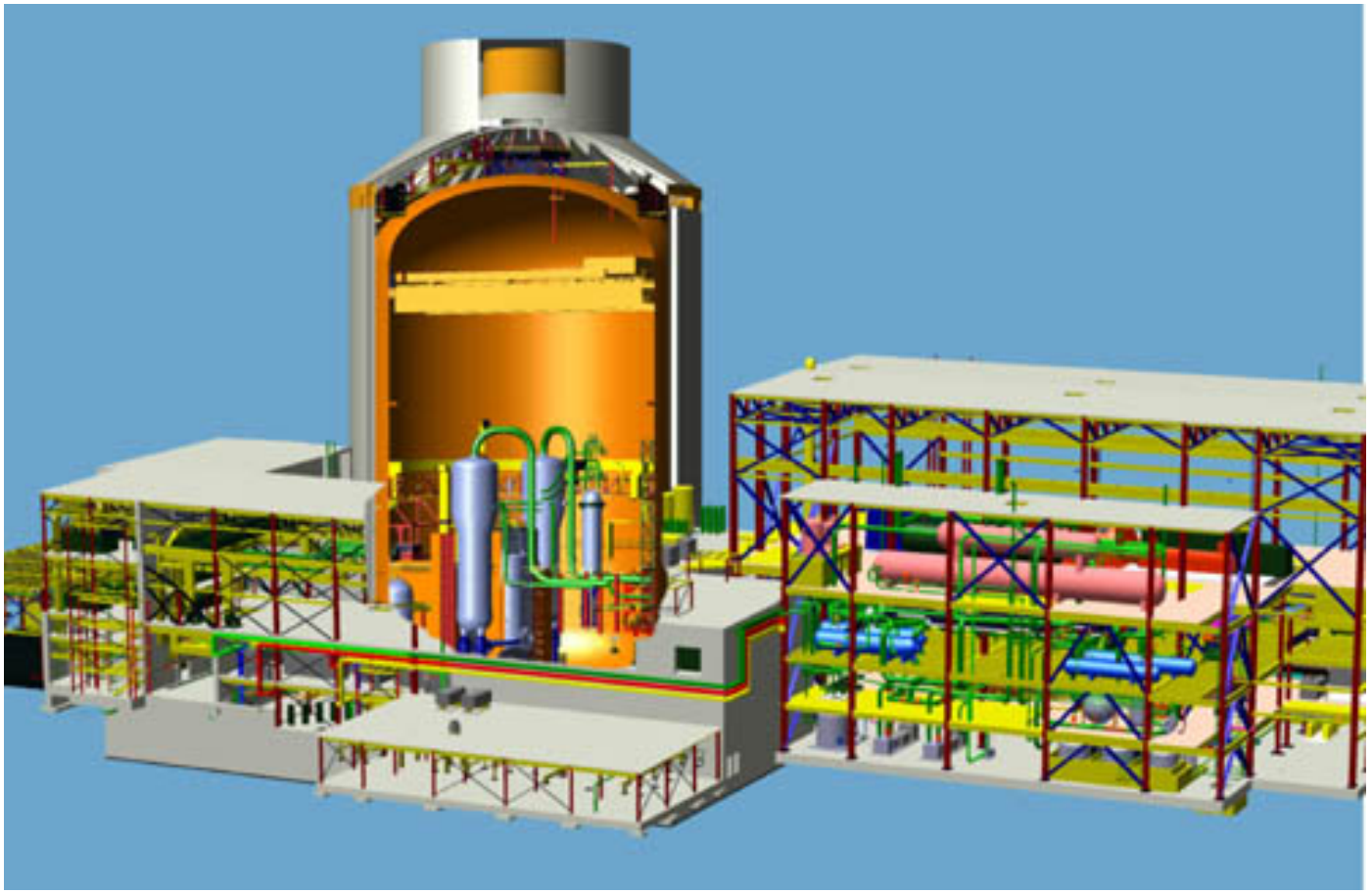
AP1000 Outline

- Introduction
- Advanced Reactor Design Background
- Overview of AP1000 Plant Design
- AP1000 Passive Safety Systems
- AP1000 Non-safety Defense-in-Depth Systems
- AP1000 Safety Analysis/PRA
- AP1000 ... Ready for Commercialization

AP1000 …
Westinghouse Standard Plant

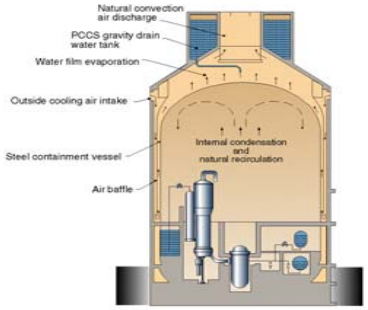
- **Simple**
- **Safe**
- **Mature**
- **Affordable**
- **Contracted**

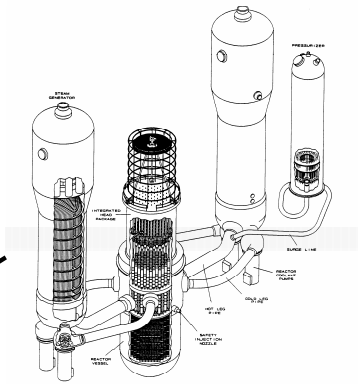


AP1000 Investment in Technology

Extensive Testing of Passive Safety Systems

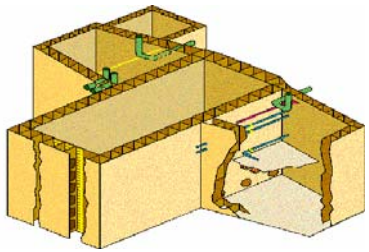
Simplified Passive Safety Systems





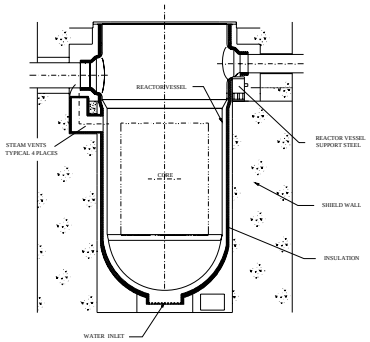
Proven Advanced Design Features

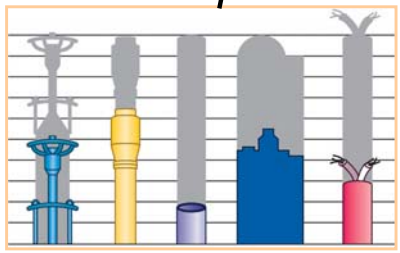
US NRC Certified



Modular Construction

PRA and Severe Accident Mitigation Features





Reduced Components and Commodities

Short Construction Schedule

AP1000 Major Uprate of AP600

- **Design Approach**
  - Increase the capability/capacity within “space constraints” of AP600
  - Retain design and regulatory bases for Advanced Passive Plants
  - Retain credibility of “proven components”
  - Retain AP600 plant design (footprint); largely preserves detailed design investment
  - Retain the basis for the cost estimate, construction schedule and modularization scheme

Comparison of Selected Parameters

Parameter	Doel 4/Tihange 3 (3 SG / RCPs)	AP1000 (2 SG / 4 RCPs)
Net Electric Output, MWe	985	1117
Reactor Power, MWt	2988	3400
Hot Leg Temperature, ^{o}F (^{o}C)	626 (330)	610 (321)
Number of Fuel Assemblies	157	157
Type of Fuel Assembly	17x17	17x17
Active Fuel Length, ft (m)	14 (4.27)	14 (4.27)
Linear Hear Rating, kw/ft	5.02	5.71
Control Rods / Gray Rods	52 / 0	53 / 16
R/V I.D., in. (m)	157 (3.99)	157 (3.99)
Vessel Flow, gpm (m^3/hr) x10^3	295.5 (67.1)	300 (68.1)
SG Surface Area ea., ft^2 (m^2) x 10^3	68 (6.3)	125 (11.1)
Pressurizer Volume, ft^3 (m^3)	1400 (39.6)	2100 (59.5)

Overview of AP1000 Plant Design

AP1000 Design Overview

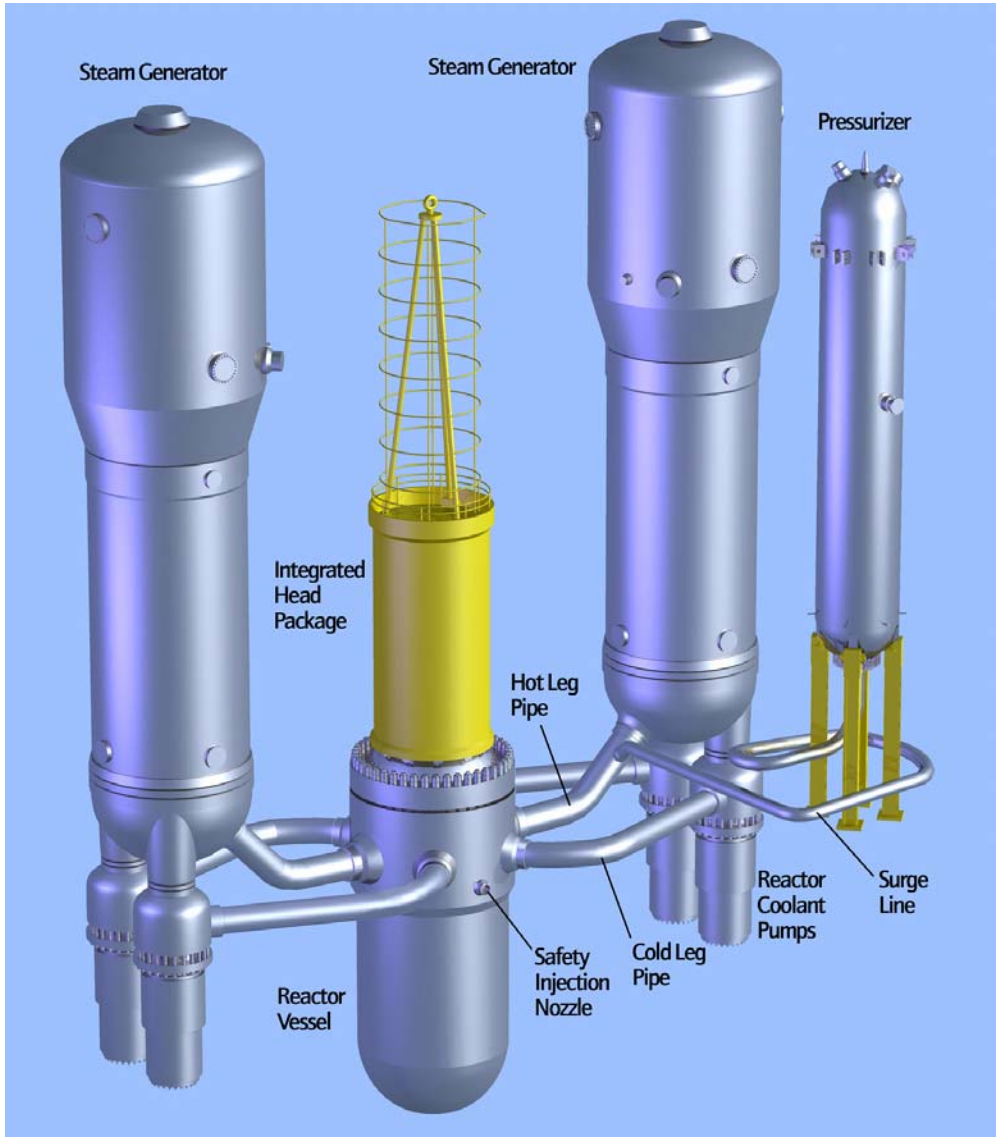
- **For the Power Generation Function, AP1000 is a typical Westinghouse PWR with advances in materials and components**
  - Fuel, Reactor Vessel, Reactor Coolant Loop
  - Steam Generators, Reactor Coolant Pumps, Turbine, Plant Controls
- **Reactor Safety Functions are achieved without using any safety-related AC power**
  - Valve Actuations (fail safe, battery powered)
  - Condensation, Natural Circulation, Evaporation, Compressed Gasses
- **Actuation of Passive Safety Systems is by simple, reliable changes in valve positions.**
- **System performance has been proven by extensive testing approved by the NRC**

AP1000 Design Features

- **Integrated Power Plant Design**
- **Proven Power-Producing Components** (Reactor, Fuel, etc)
- **Simplified RCS Loops with Canned Motor Pumps**
- **Simplified Passive Safety Systems**
- **Simplified Non-safety Defense-In-Depth (DID) Systems**
- **Microprocessor, Digital Technology Based I&C**
- **Compact Control Room, Electronic Operator Interface**
- **Optimized Plant Arrangement**
  - Construction, Operation, Maintenance, Safety, Cost
- **Extensive Use of Modular Construction**
  - 3-Year Construction Schedule (first concrete pour to HFT)

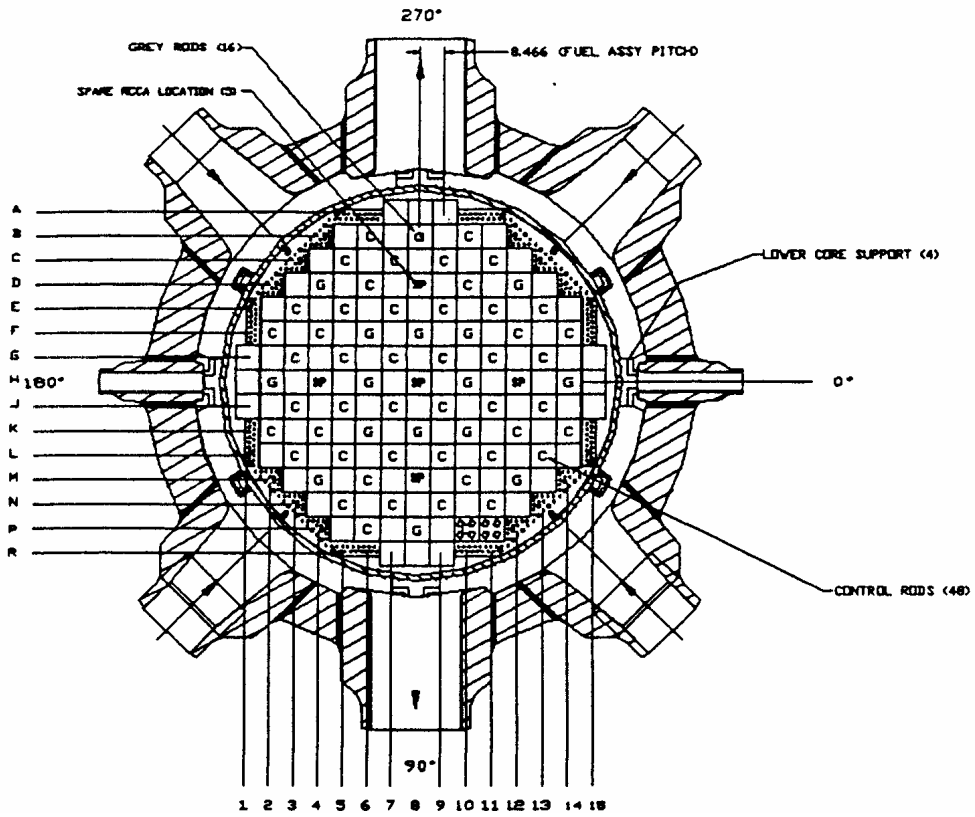
Proven AP1000 Major Components

- **Fuel, Internals, Reactor Vessel**
  - Similar to Doel 4, Tihange 3, S. Texas
  - No bottom-mounted instrumentation
  - Improved materials - 60 year life
- **Steam Generators**
  - Similar to large W/CE SGs in operation
    - System 80, ANO RSG
- **Reactor Coolant Pumps**
  - Canned motor pumps, no shaft seals
    - Early commercial reactors (Shippingport, Yankee Rowe)
- **Simplified Main Loop**
  - Reduces welds 67%, supports 90%
- **Pressurizer**
  - 50% larger than operating plants

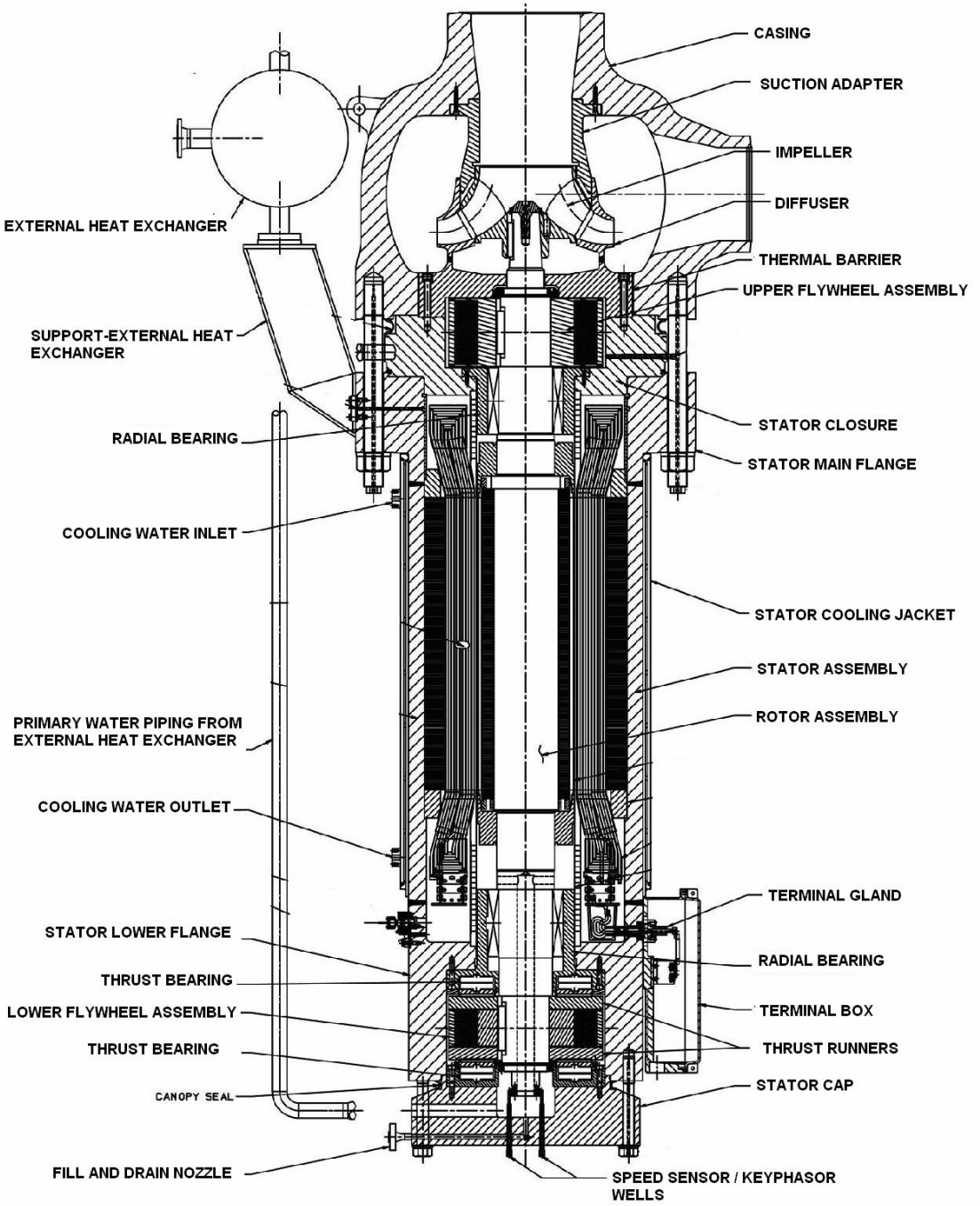


AP1000 Core Design

- **AP1000 Core Design Features**
  - Higher power density
  - 18 month cycles
  - Initial and equilibrium cycle designs presented in Design Cont Document
  - Normal BLACK rods for operation
  - New GRAY rod configuration
    - Load follow / rapid power reduction
    - No boron changes required

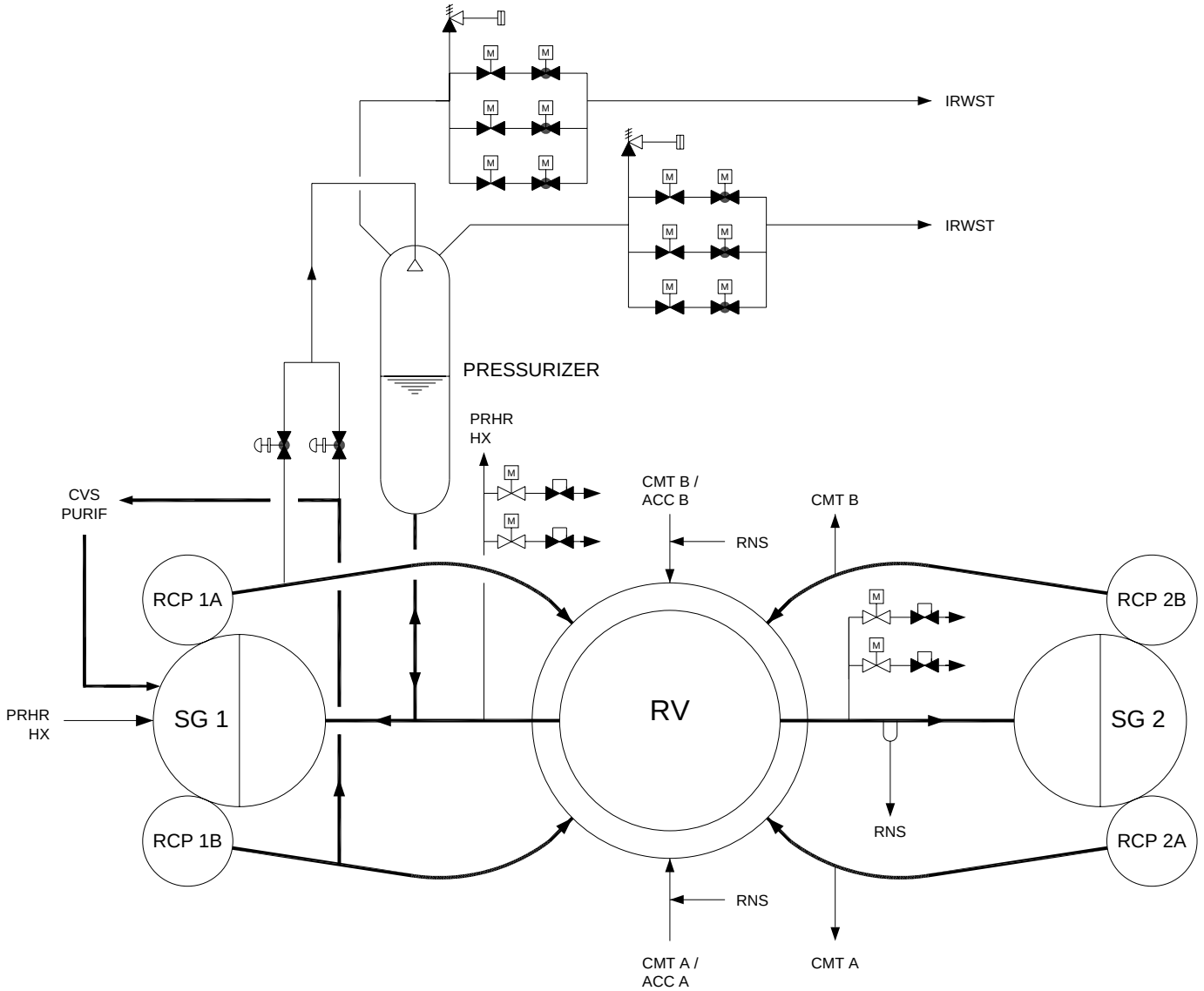


Reactor Coolant Pump



- Based on Field-Proven, Canned Motor Pumps
  - No shaft seals
    - No seal injection / leakoff system
    - No seal leakage / failure
  - Water lubricated bearings
    - No oil lubricating system
    - Eliminates fire protection issues
  - Compact, high inertia flywheels
    - Upper and lower
    - Inservice inspection not required
  - No services required in accident
    - Tripped to allow CMT operation
  - No planned maintenance

AP1000 Reactor Coolant System



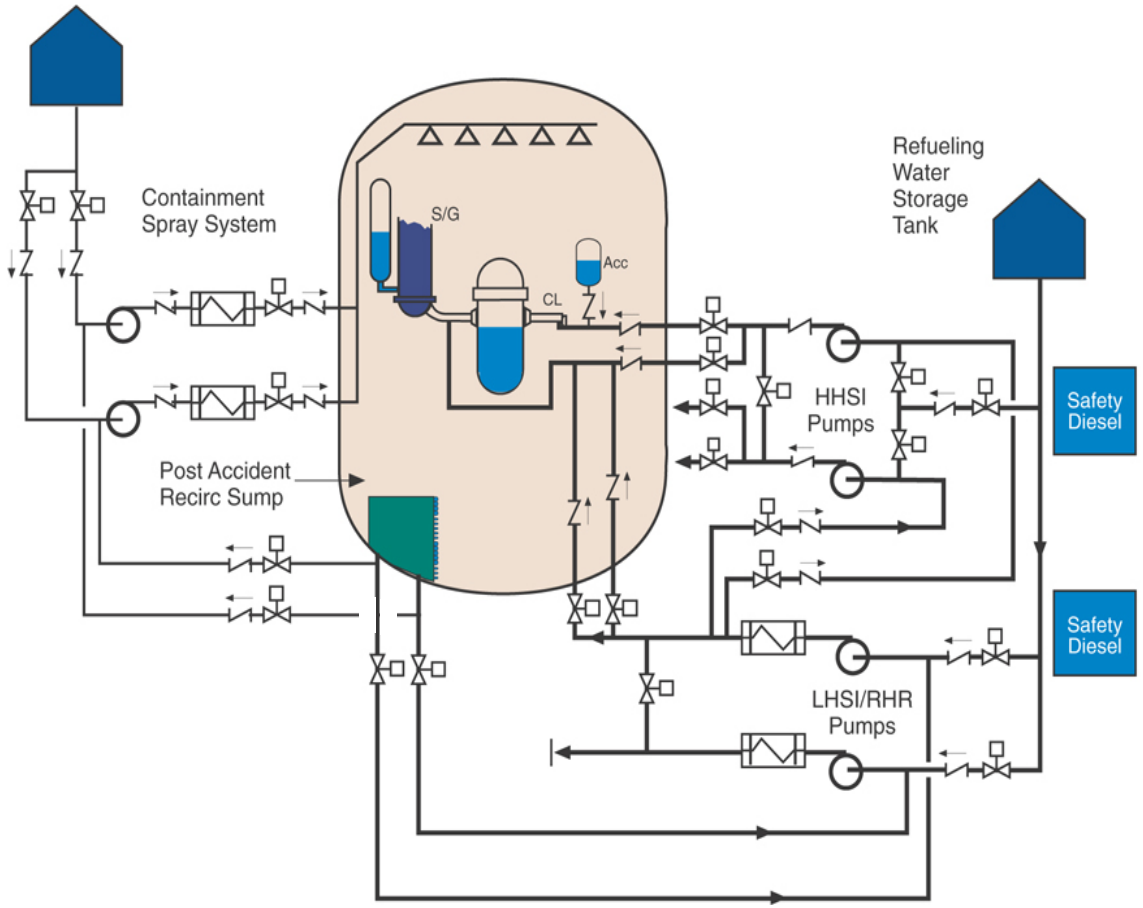
AP1000 Passive Safety Systems

AP1000 Approach to Safety

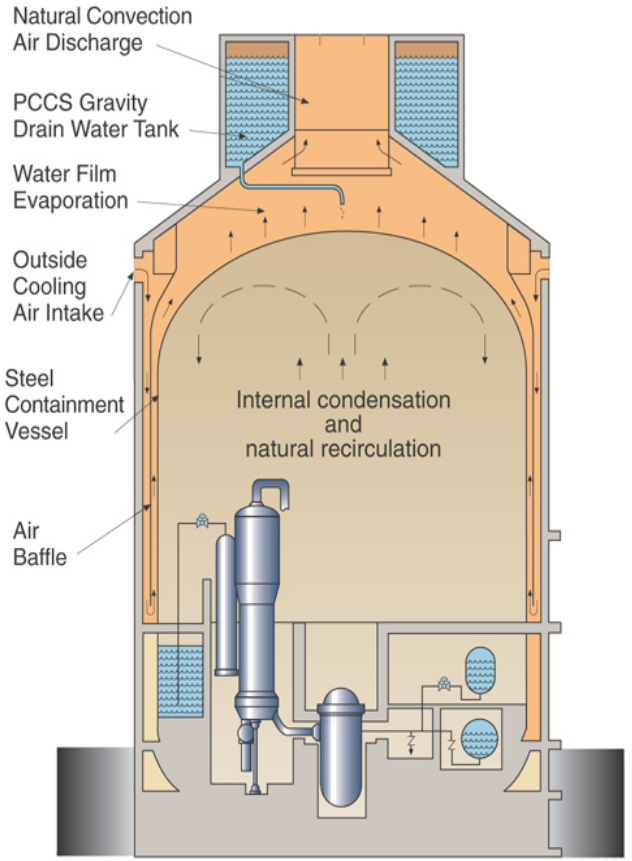
- **Passive Safety-Related Systems**
  - Use “passive” process only, no active pumps, diesels, ….
    - One time alignment of valves
    - No support systems required after actuation
      - No AC power, cooling water, HVAC, I&C
  - Greatly reduced dependency on operator actions
  - Mitigate design basis accidents without nonsafety systems
  - Meet NRC PRA safety goals without use of nonsafety systems
- **Active Nonsafety-Related Systems**
  - Reliably support normal operation
    - Redundant equipment powered by onsite diesels
  - Minimize challenges to passive safety systems
  - Not required to mitigate design basis accidents

Passive Systems Greatly Simplify Safety Systems

Standard PWR



AP1000



Passive Safety Features

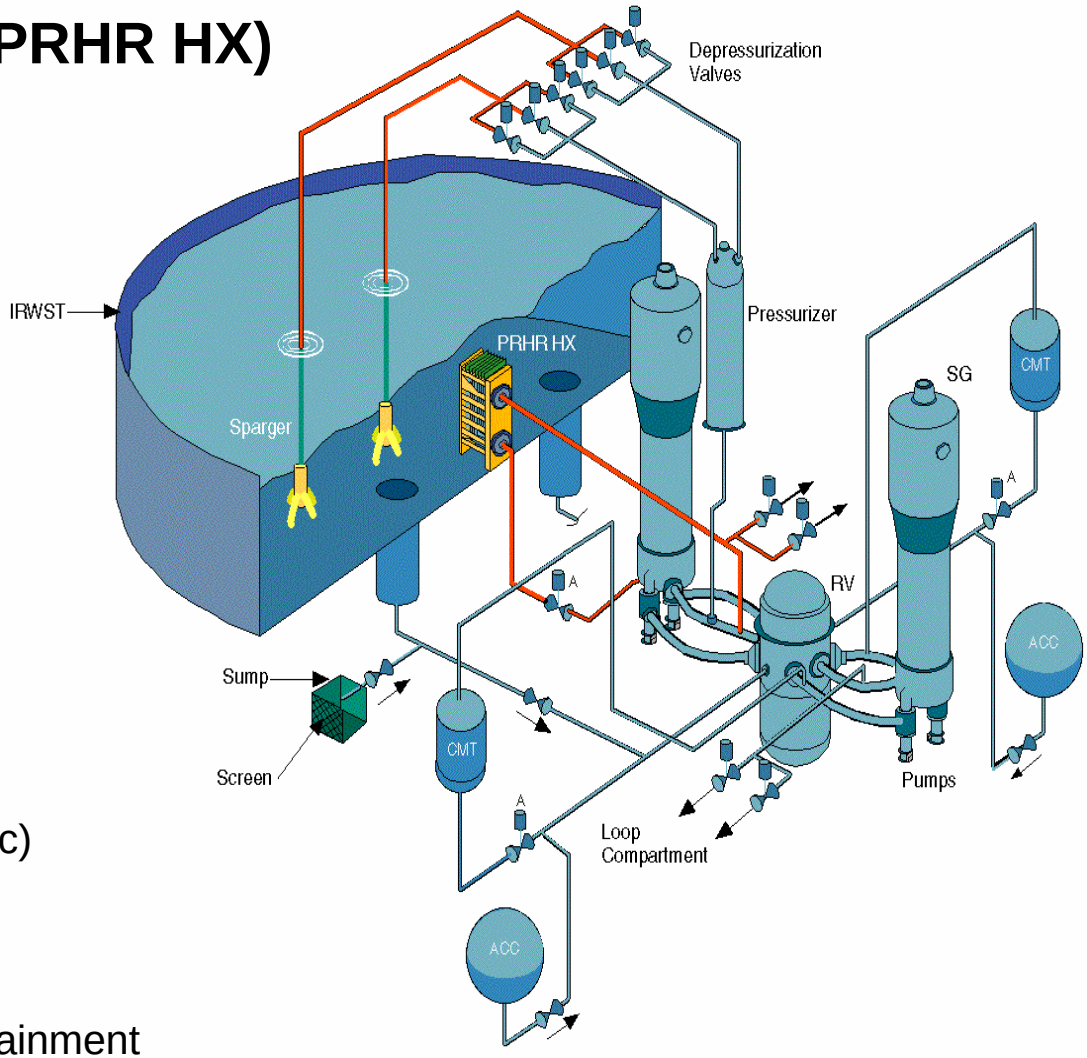
- **Passive Residual Heat Removal**
  - Natural circulation HX connected to RCS
- **Passive Safety Injection**
  - Natural circulation / gravity drain core makeup tanks (RCS pres)
  - N_2 pressurized accumulators (700 psig)
  - Gravity drain refueling water storage tank (containment pres)
  - Automatic depressurization valves, Pressurizer and RCS hot leg
- **Passive Containment Cooling**
  - Natural circulation of air / evaporation of water on outside surface of steel containment vessel

Passive Safety Features (cont'd)

- **Passive Radiation Removal from Containment Atm.**
  - Natural circulation / removal mechanisms
- **Passive Main Control Room Habitability**
  - Compressed air pressurization of MCR
- **Passive MCR / I&C Room Cooling**
  - Natural circulation to concrete walls / ceiling
- **Passive Containment pH Control**
  - Baskets of TSP flooded by accident

AP1000 Passive Core Cooling System

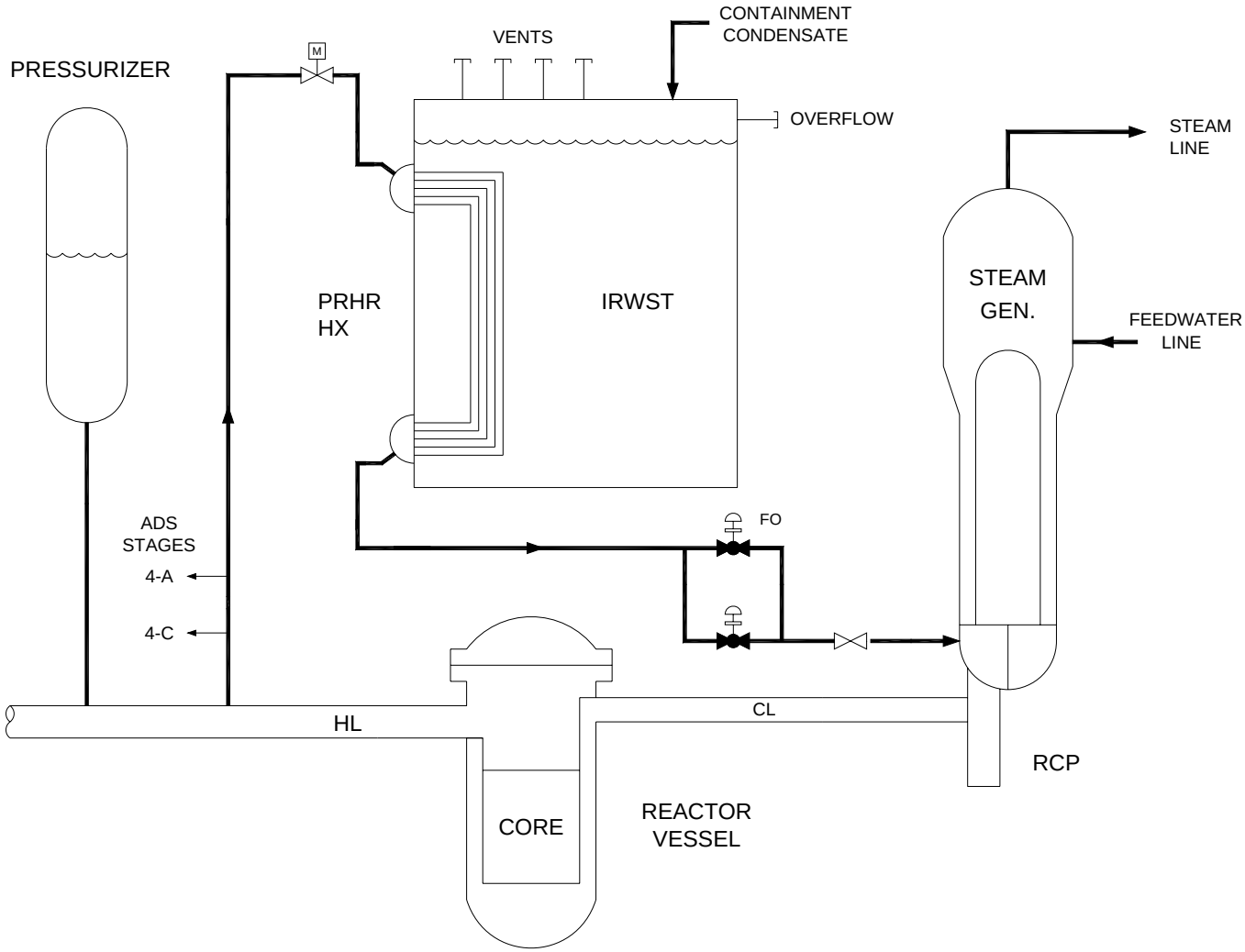
- **Passive RHR Heat Exchanger (PRHR HX)**
  - Natural circ. heat removal
- **Passive Safety Injection**
  - Core Makeup Tanks
    - Full RCS pres, natural circ. inject
    - Replaces HHSI pumps
  - Accumulators
    - Similar to current plants
  - IRWST Injection
    - Low pressure (replaces LHSI pumps)
  - Containment Recirculation
    - Gravity recirc. (replaces pumped recirc)
  - Automatic RCS Depressurization
    - Staged, controlled depressurization
    - Stages 1-3 to IRWST, stage 4 to containment



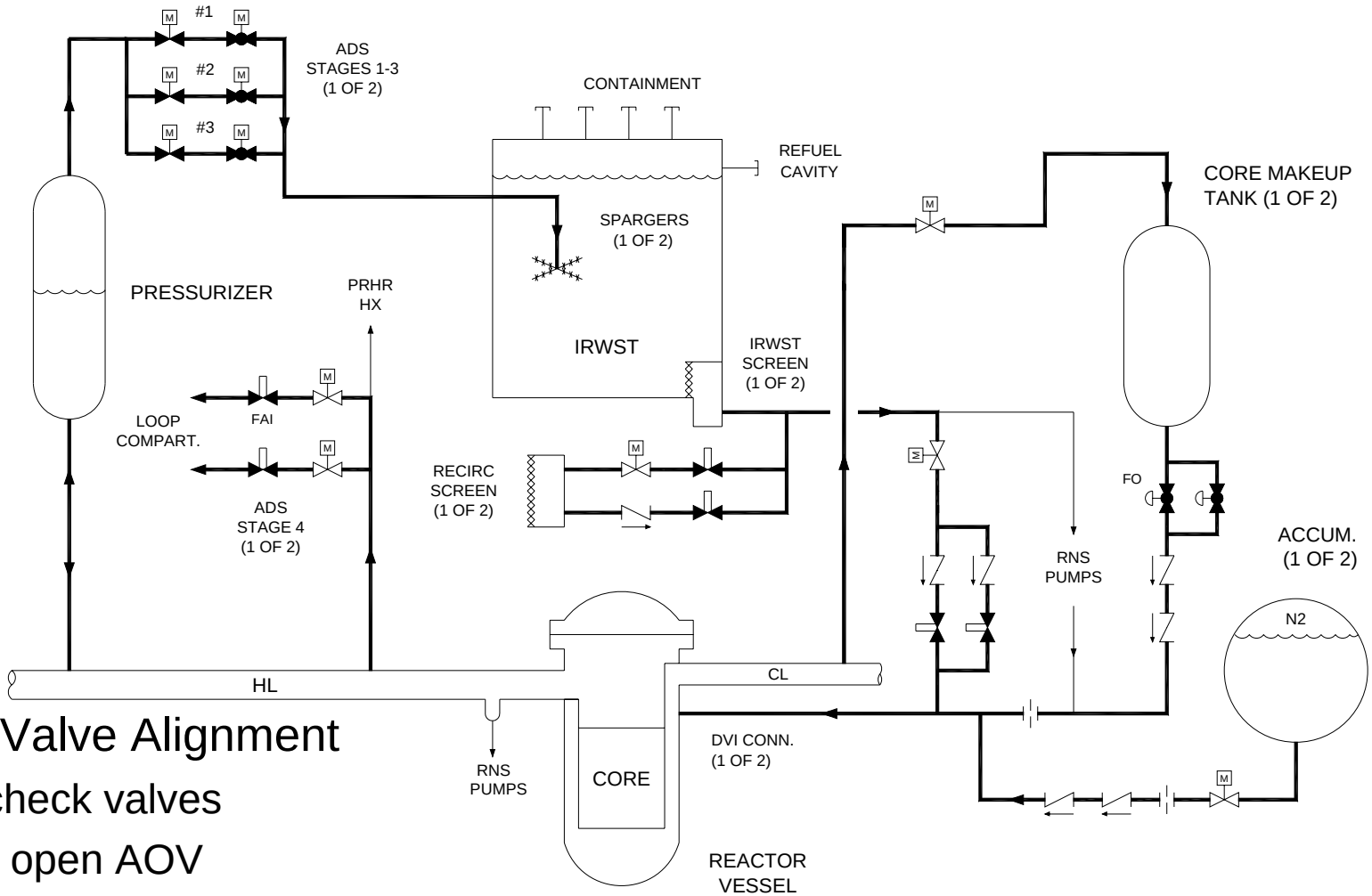
Passive Core Cooling System at Work

Passive Decay Heat Removal

- Normally Isolated By Two AOV, Fail Open
  - Opening 1 AOV actuates RCS cooling via natural circulation
  - AOVs actuated by PMS and by DAS
- IRWST Absorbs Heat
  - Takes ~ 2 hr to heat up to saturated
  - Steam is condensed by PCS and returned to IRWST by gutter



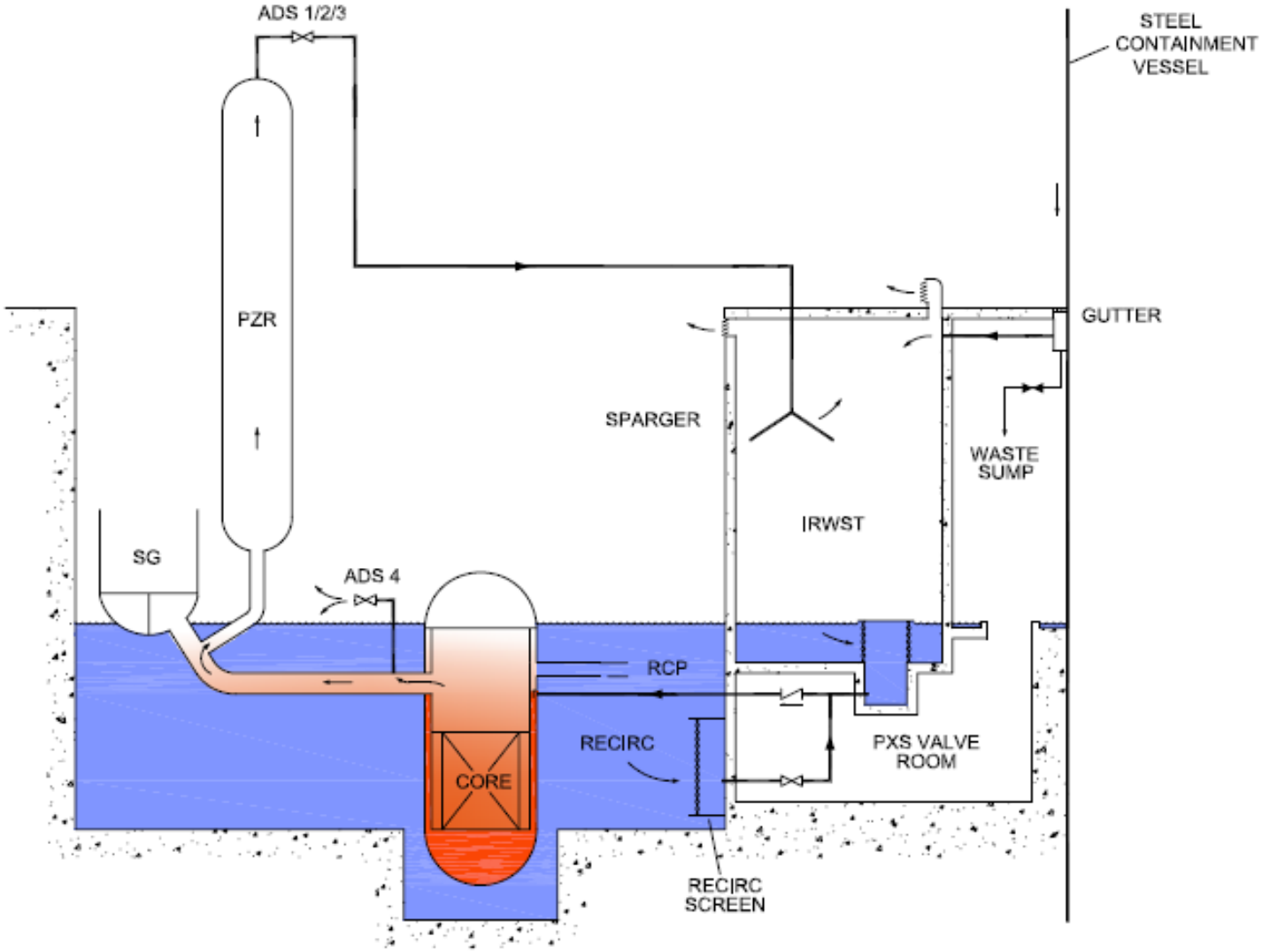
Passive Safety Injection



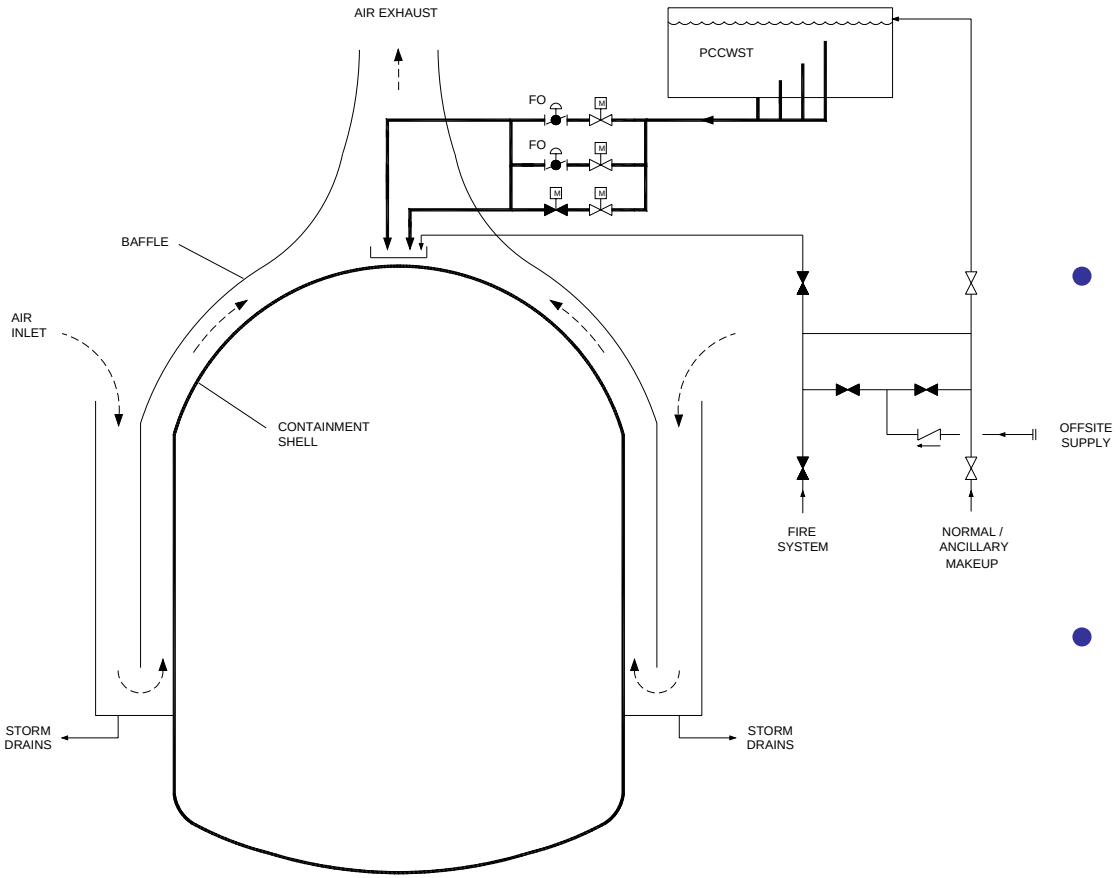
- Uses One Time Valve Alignment
  - Accum uses check valves
  - CMT uses fail open AOV
  - ADS uses MOV for 1/2/3 & Squibs for 4
  - IRWST uses Squibs and check valves

LOCA Long Term Cooling

- Uses No Pumps
- Addresses Debris Head Loss Issues
  - No fiber generation
  - Large advanced design screens
    - Demonstrated by test
  - Low flows, deep flood up
    - Low velocities
  - Delayed start of recirculation



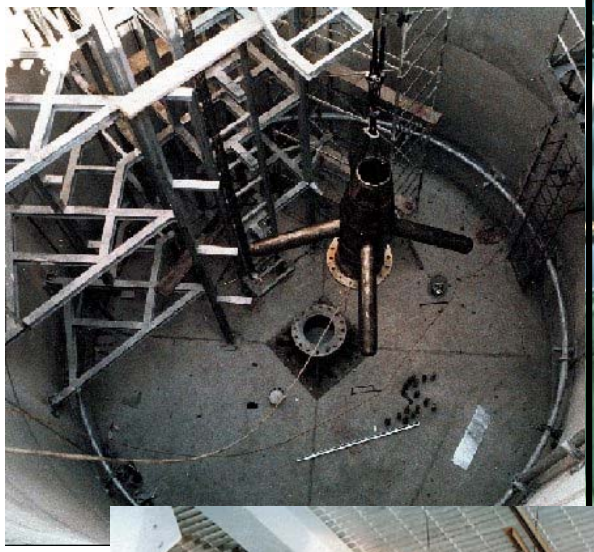
Passive Containment Cooling System

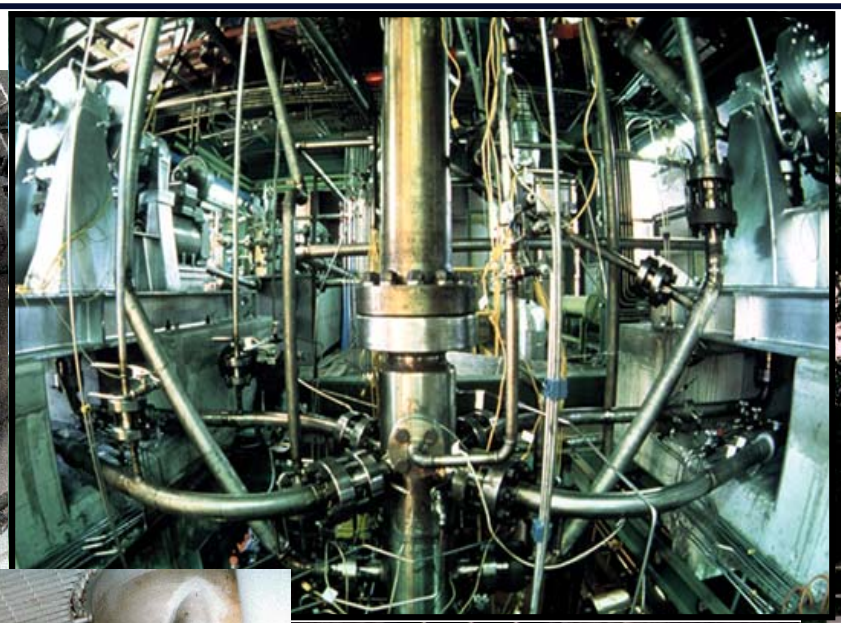


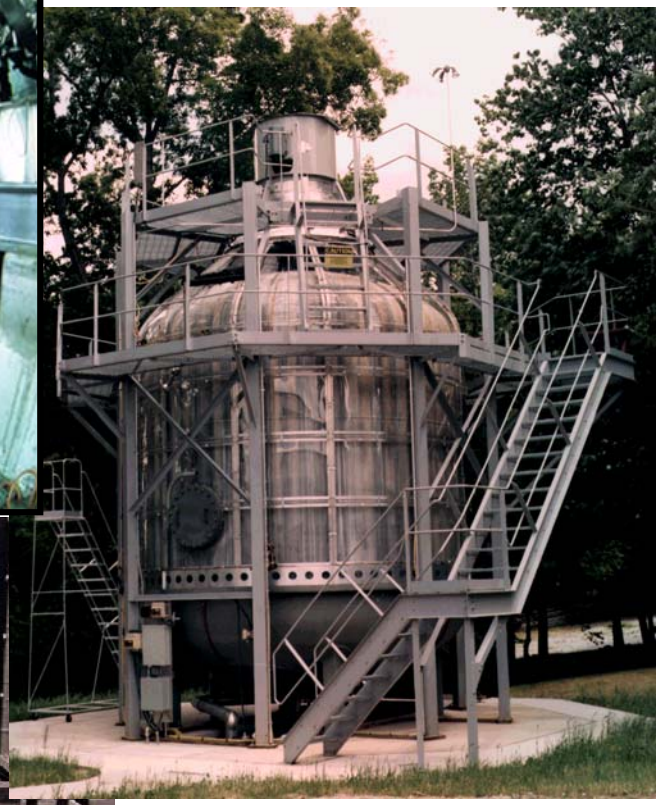
- PCS Water Storage Tank
  - Provides 72 hr drain
    - Afterwards use on/offsite water
    - Air only cooling prevents failure
  - Flow decreases with time
    - 4 standpipes control flow
- PCS Flow Rates
  - High initial flow
    - Rapidly forms water film
    - Effectively reduces cont pressure
  - Later flows match decay heat
- 3 Redundant Drain Paths
  - 2 AOV, 1 MOV
  - Improves PRA reliability
    - T&H uncertainty of cont cooling without water drain

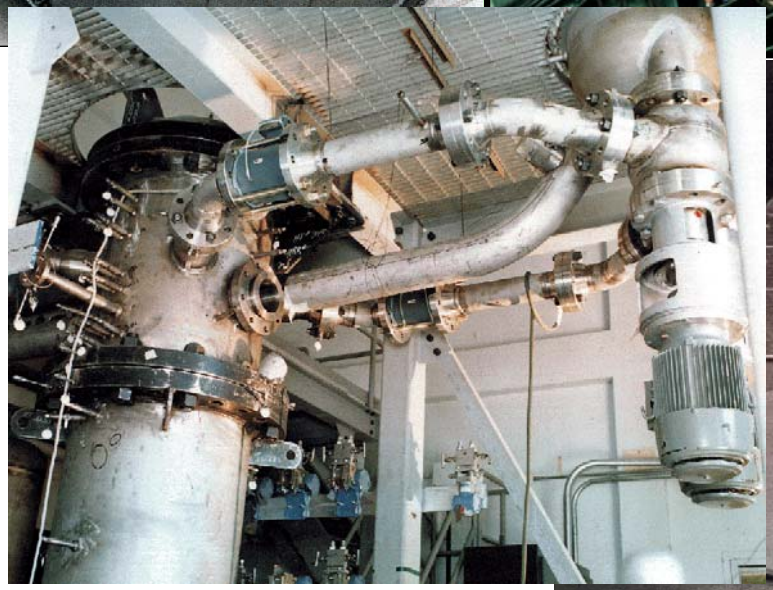
Passive Containment Cooling System at Work

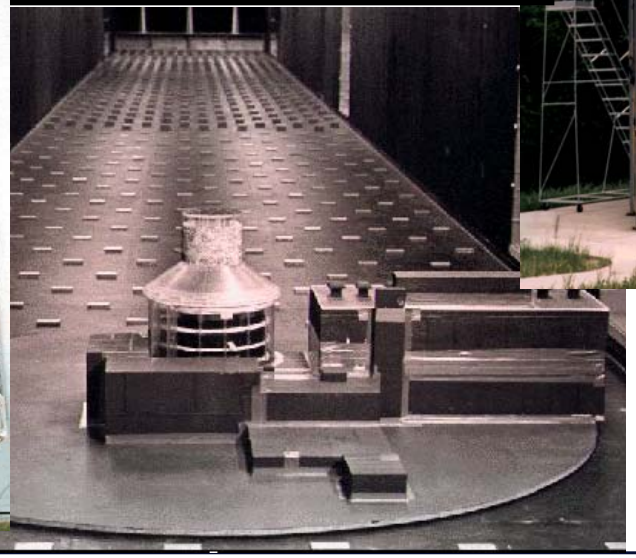
AP1000 Most Tested Reactor











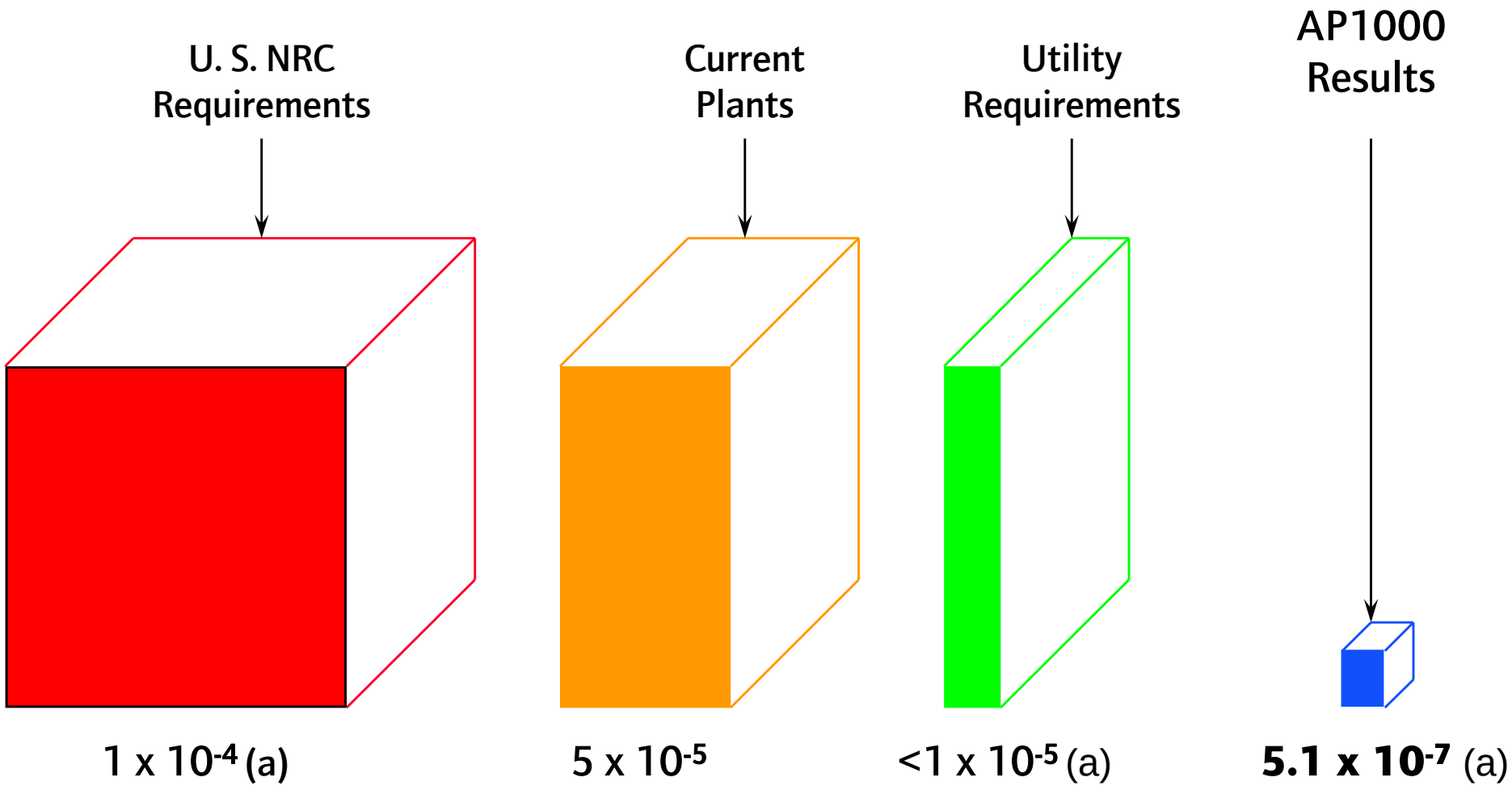
AP1000 Safety Analysis

- **Safety Analysis Performed**
  - Computer codes were verified
    - Adequate to model passive systems
    - Verified against extensive AP600 tests
      - Tests well scaled for AP600 and AP1000
    - NRC / ACRS reviewed tests and computer code verification
  - Extensive accident analysis were performed
    - Range of Design Basis Accident conditions, single failures
    - NRC / ACRS reviewed and approved results

Westinghouse Uses PRA as Design & Licensing Tool

- 7 Major PRA Quantifications Performed on AP600
  - First in 1987, final in 1997
  - Extensive interaction with plant designers
    - Changes were made to analysis, procedures and design
    - Used to guide severe accident design, ensures reliability
  - Extensive NRC review / comment
- 4 Major PRA Quantifications Performed on AP1000
  - Started with AP600 models / analysis
  - Benefited from AP600 development and NRC review
  - Modified models to account for the few changes from AP600
  - Extensive NRC review / comment

AP1000 Provides Safety and Investment Protection

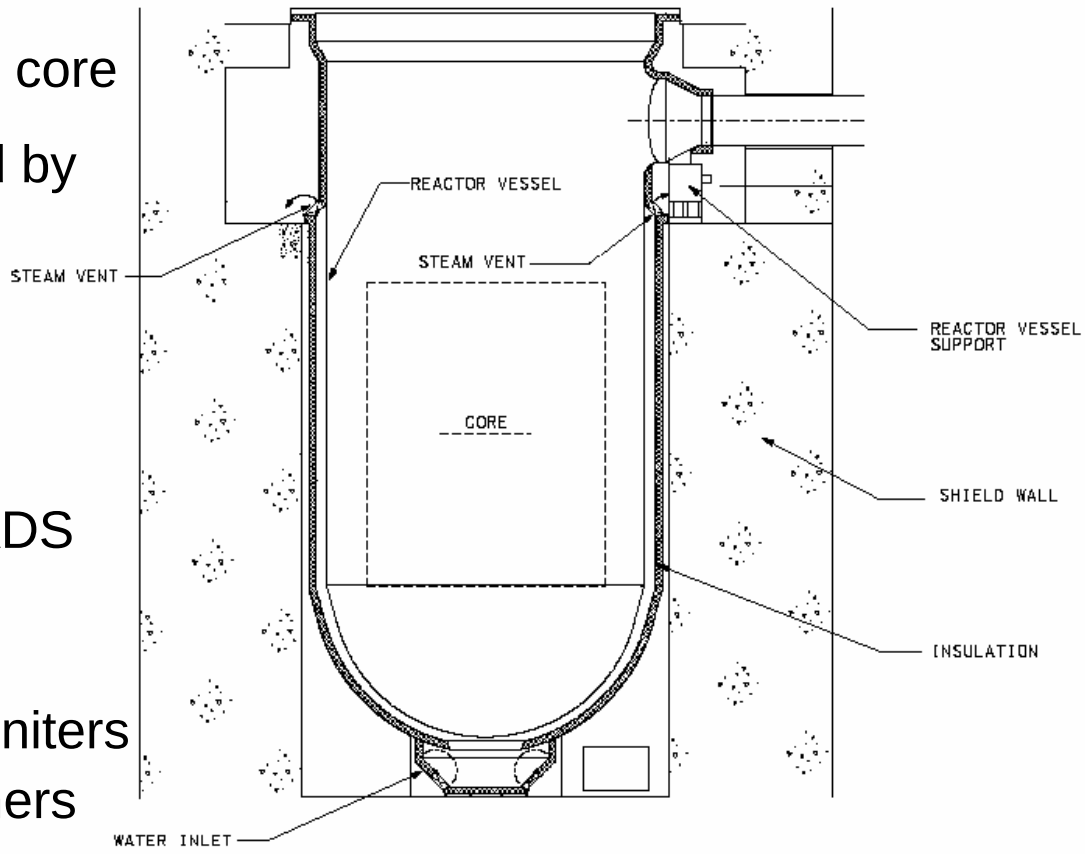


Core Damage Frequency per Year

Note (a) CDF includes random and internal hazard events from at-power and shutdown conditions.

Severe Accidents Addressed

- Core-Concrete Interaction
  - Ex-vessel cooling retains damaged core
  - Tests and analysis of IVR reviewed by U.S. NRC
  - Prevents core-concrete interaction
- High Pressure Core Melt
  - Eliminated by redundant, diverse ADS
- Hydrogen Detonation
  - Prevented by redundant, diverse igniters and passive autocatalytic recombiners
- Steam Explosions
  - Prevented by IVR



Severe Accident Design at Work

AP1000 Non-Safety Defense-In-Depth Systems

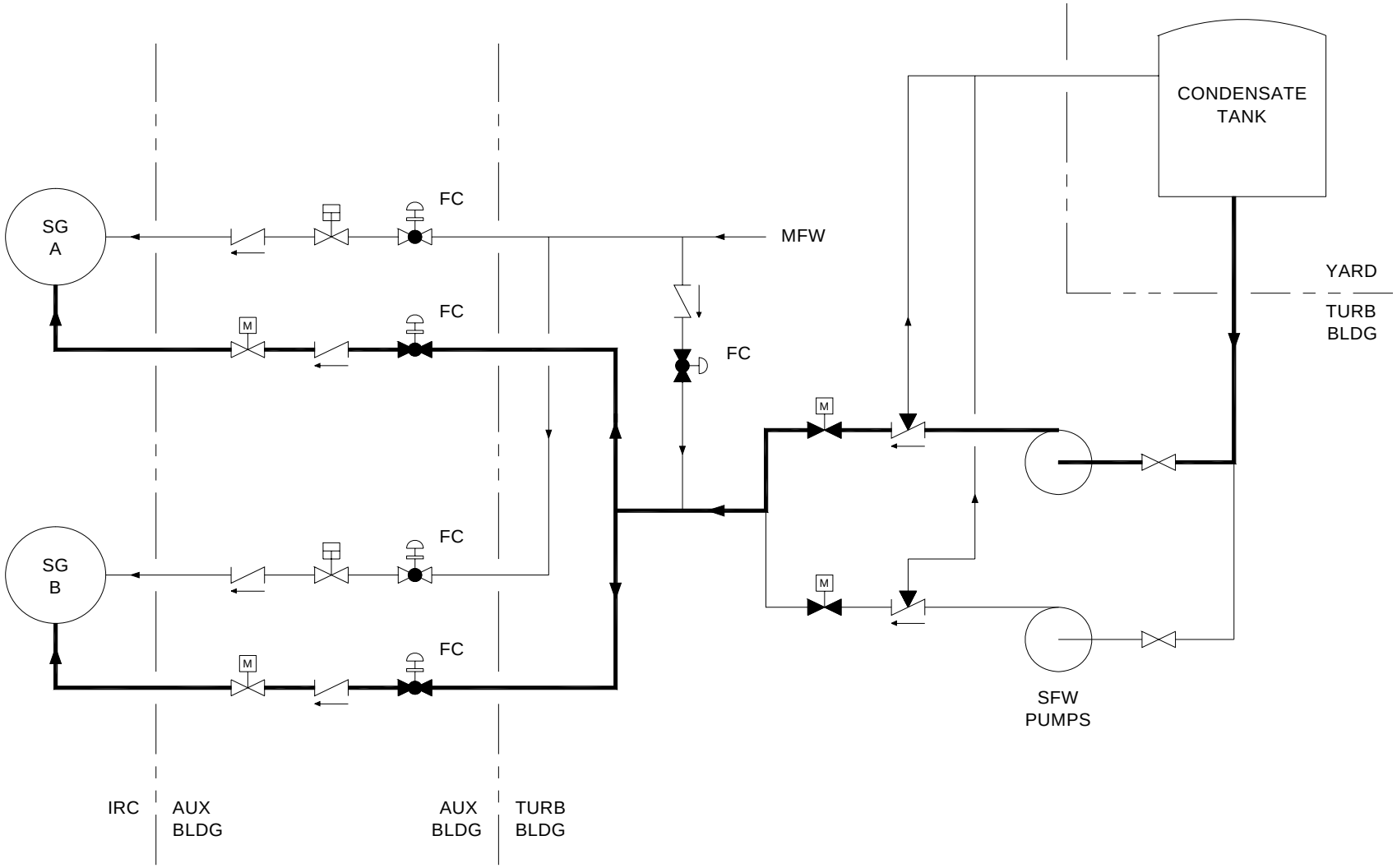
AP1000 Active Nonsafety Features

- **Active Nonsafety Functions**
  - Reliably support normal operation
  - Minimize challenge to passive safety systems
  - Not required to mitigate design basis accidents
  - Not required to meet NRC safety goals
- **Active Nonsafety Design Features**
  - Simplified designs (fewer components, separation not required)
  - Redundancy for more probable failures
  - Automatic actuation with power from onsite diesels
- **Active Nonsafety Equipment Design**
  - Reliable, experienced based, industrial grade equipment
  - Non-ASME, non-seismic, limited fire / flood / wind protection
  - Availability controlled by procedures, no shutdown requirements
  - Reliability controlled by maintenance program

Startup Feedwater System

- **Simplified, Reliable Non-Safety System**
  - Auto start on low SG level with auto SG level control
    - Same flow if one or two pumps start
    - Operation does not cause excessive RCS cooldown or SG overfill
  - Auto load on non-safety DG
  - Simple reliable system design
    - Two electric motor pumps, no steam turbine driven pumps
    - No physical separation requirements
  - PRHR HX not actuated if SFW works as designed

AP1000 Startup Feedwater System



System Defense In Depth

- **AP1000 Provides Multiple Levels of Defense**
  - First actuation is usually nonsafety active system
    - High quality industrial grade equipment
  - Second actuation is safety passive system
    - Provides safety case for SSAR
    - Highest quality nuclear grade equipment
  - Other passive features provide additional levels of defense
    - Example; passive feed/bleed backs up PRHR HX
  - Available for all shutdown conditions as well as at power
  - More likely events have more levels of defense

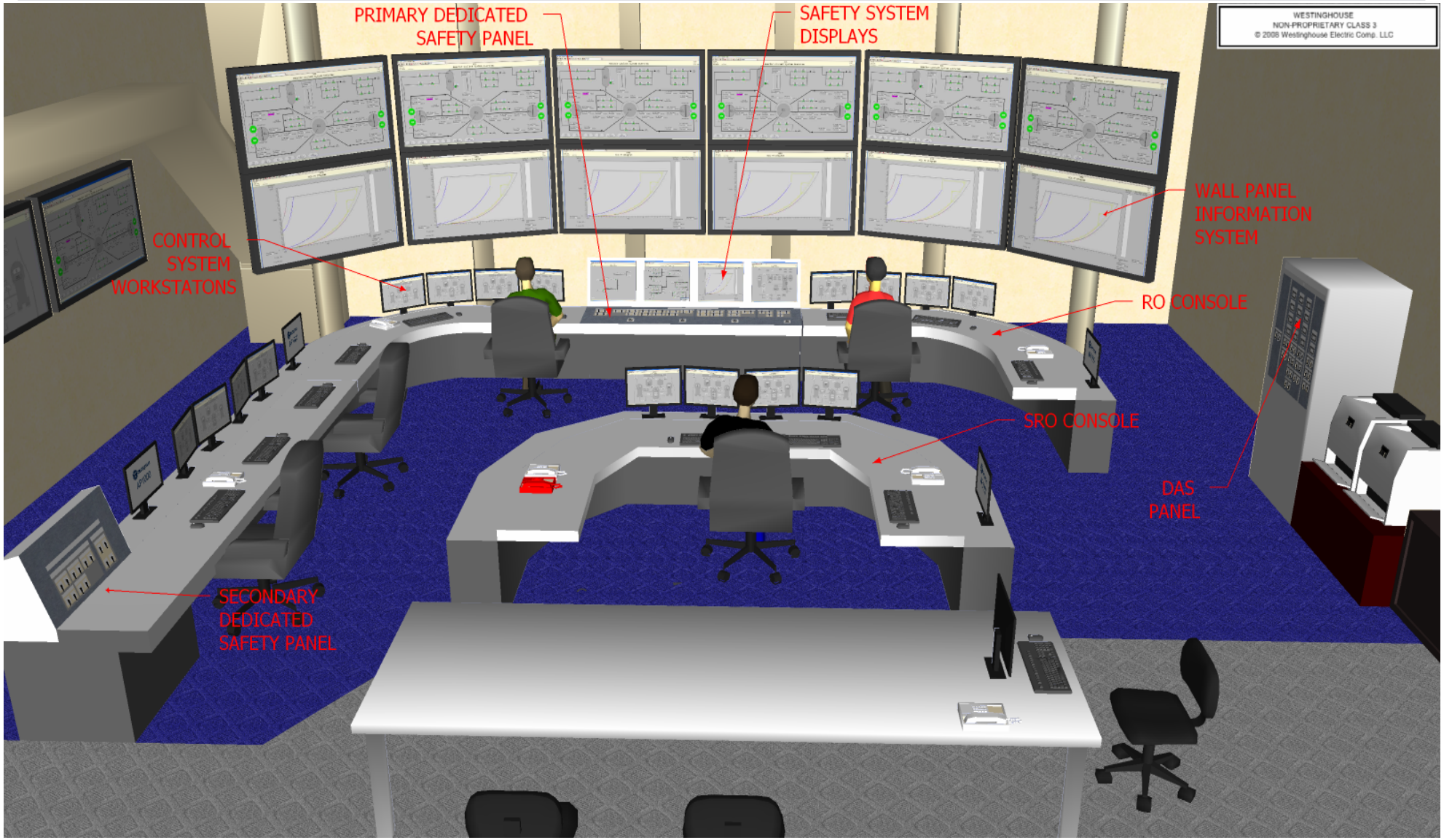
AP1000 I&C Systems

- **Control System**
  - Plant wide non-1E system for all normal displays & controls
  - Microprocessor / software based, multiplexed communications
- **Safety System**
  - Reduced size 1E system for all safety displays & controls
    - Use of passive systems eliminates many safety components
  - Microprocessor / software based, multiplexed communications
  - May use same hardware / software as Control I&C
- **Diverse System**
  - Limited scope non-1E system, PRA based displays & controls
    - Backs up Safety I&C where common mode failure a risk
  - Different microprocessor & software than Safety I&C
    - No multiplexing

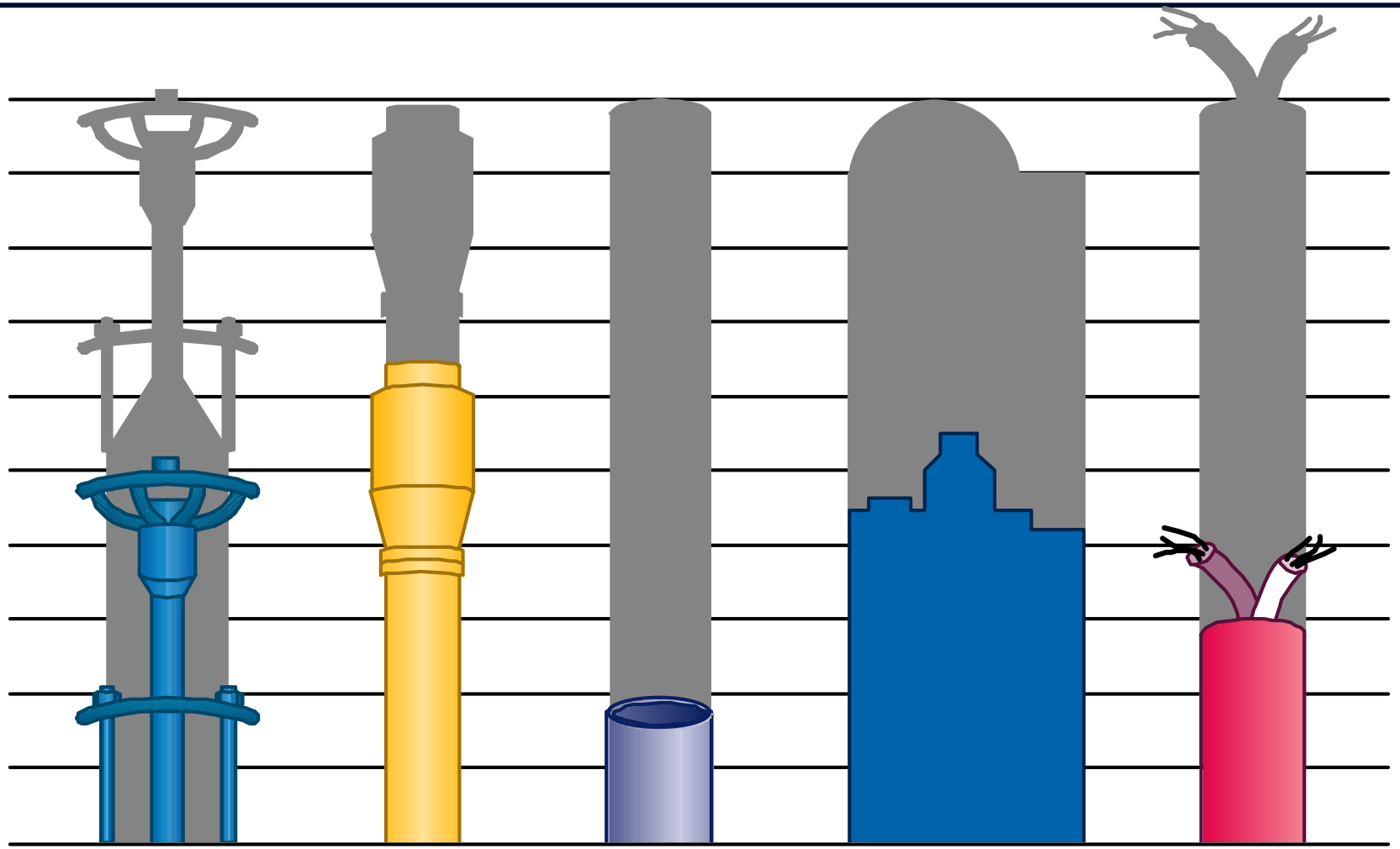
AP1000 Human-Machine Interface

- **Compact Control Room**
  - Designed for 1 Reactor Operator and 1 Supervisor
- **Displays**
  - Plant status / overview via wall panel (non 1E)
  - Detail display via workstation video displays (non 1E)
  - Small number dedicated displays; safety (1E) & diverse (non 1E)
- **Controls**
  - Soft controls (non 1E) for normal operation
  - Small number dedicated switches; safety (1E) & diverse (non 1E)
- **Advanced Alarm Management**
- **No Paper Procedures**

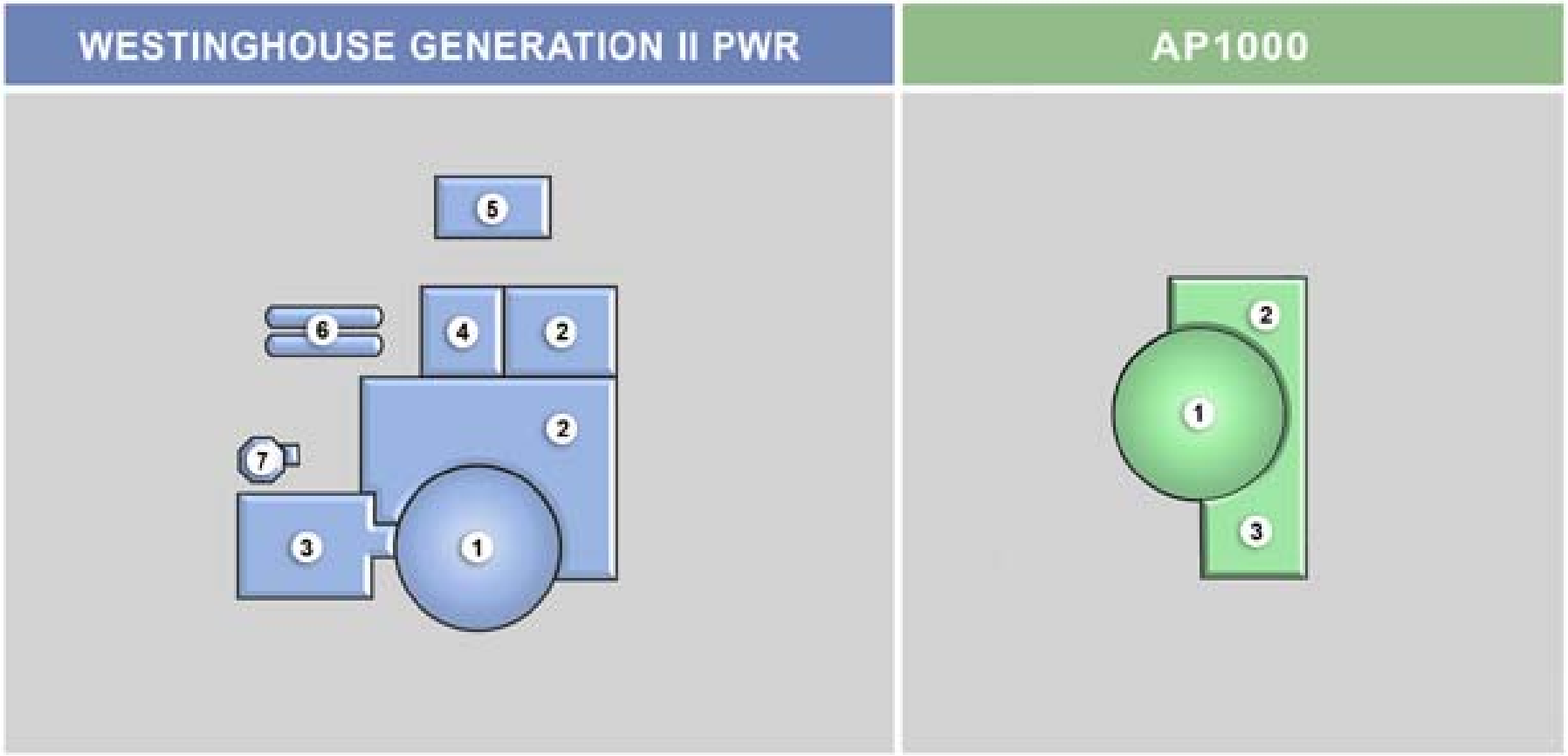
Main Control Room 3D Model



AP1000 Passive Safety System Design Improves Economics and Construction Schedule

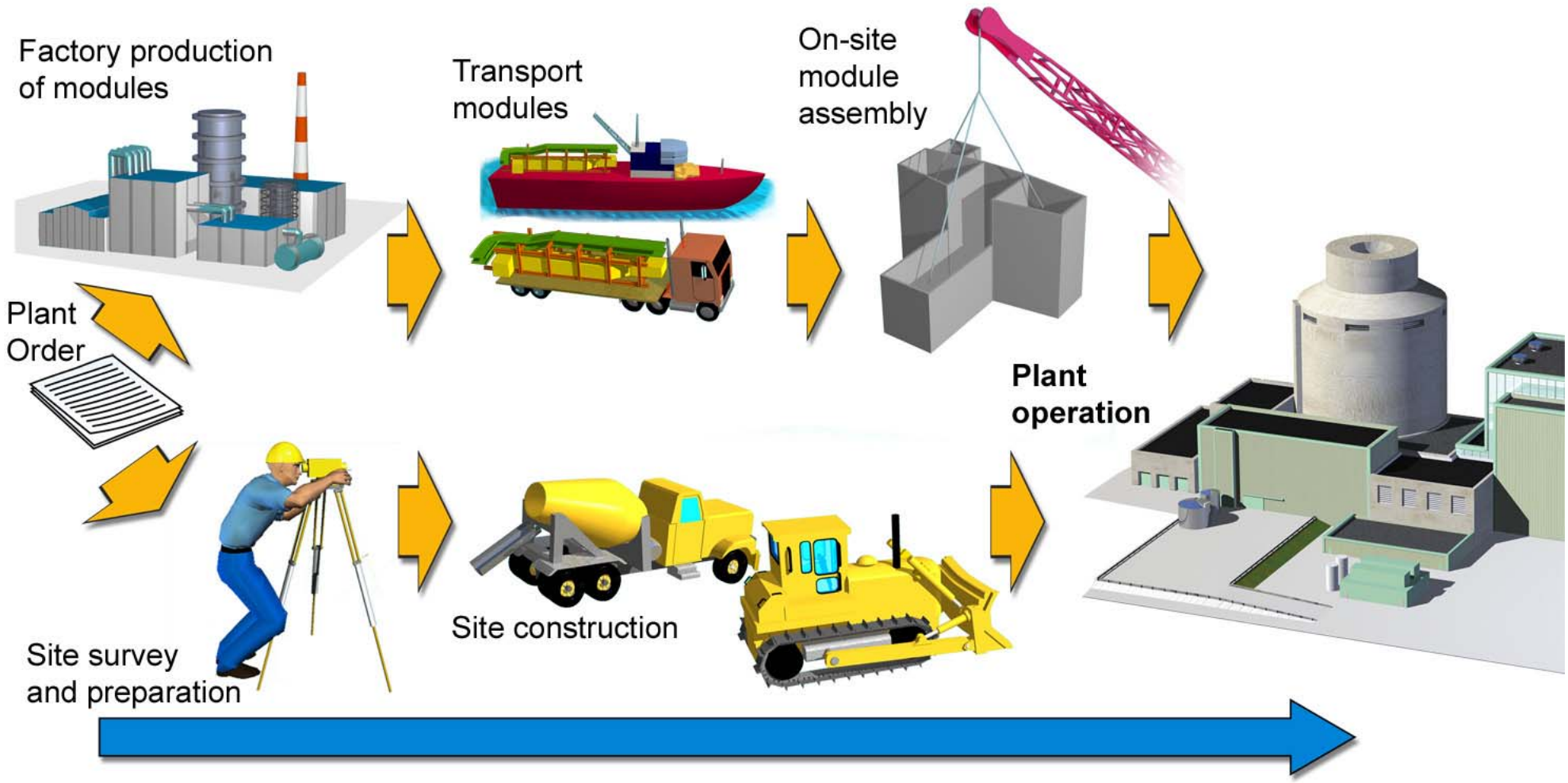


Comparison of Seismic Category I Buildings



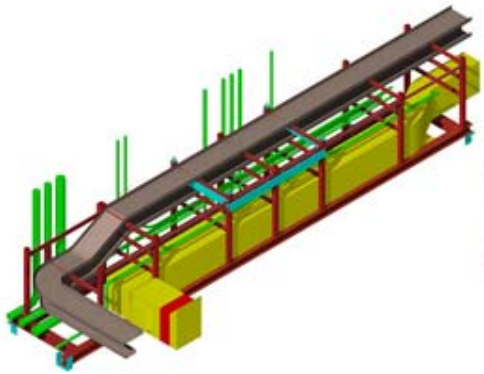
1. Shield / Containment
2. Auxiliary Building
3. Fuel Area
4. Diesel Generators
5. Essential Service Water Pumphouse
6. Emergency Fuel Oil Storage
7. Refueling Water Storage Tank

Modular Construction Allows More Tasks To Be Done in Parallel
Result: Shorter Construction Schedule

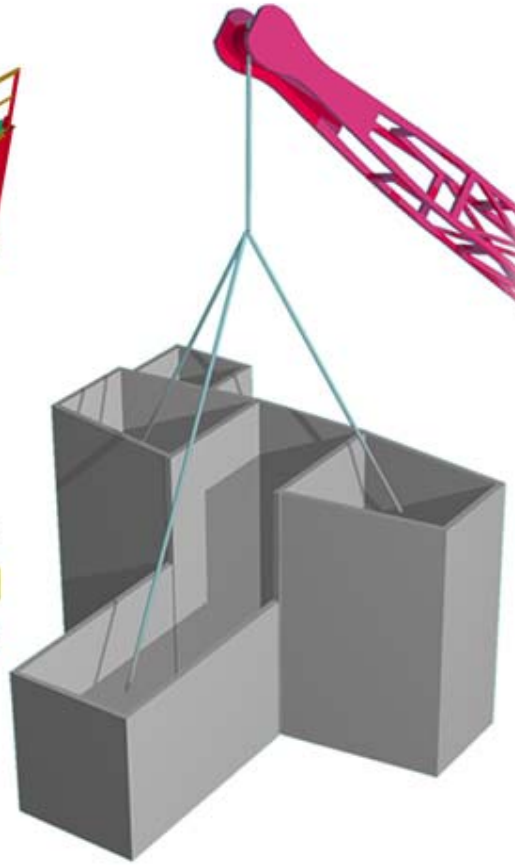


Modules Designed into AP1000 from the Beginning

Pump/Valve Module



Raceway Module

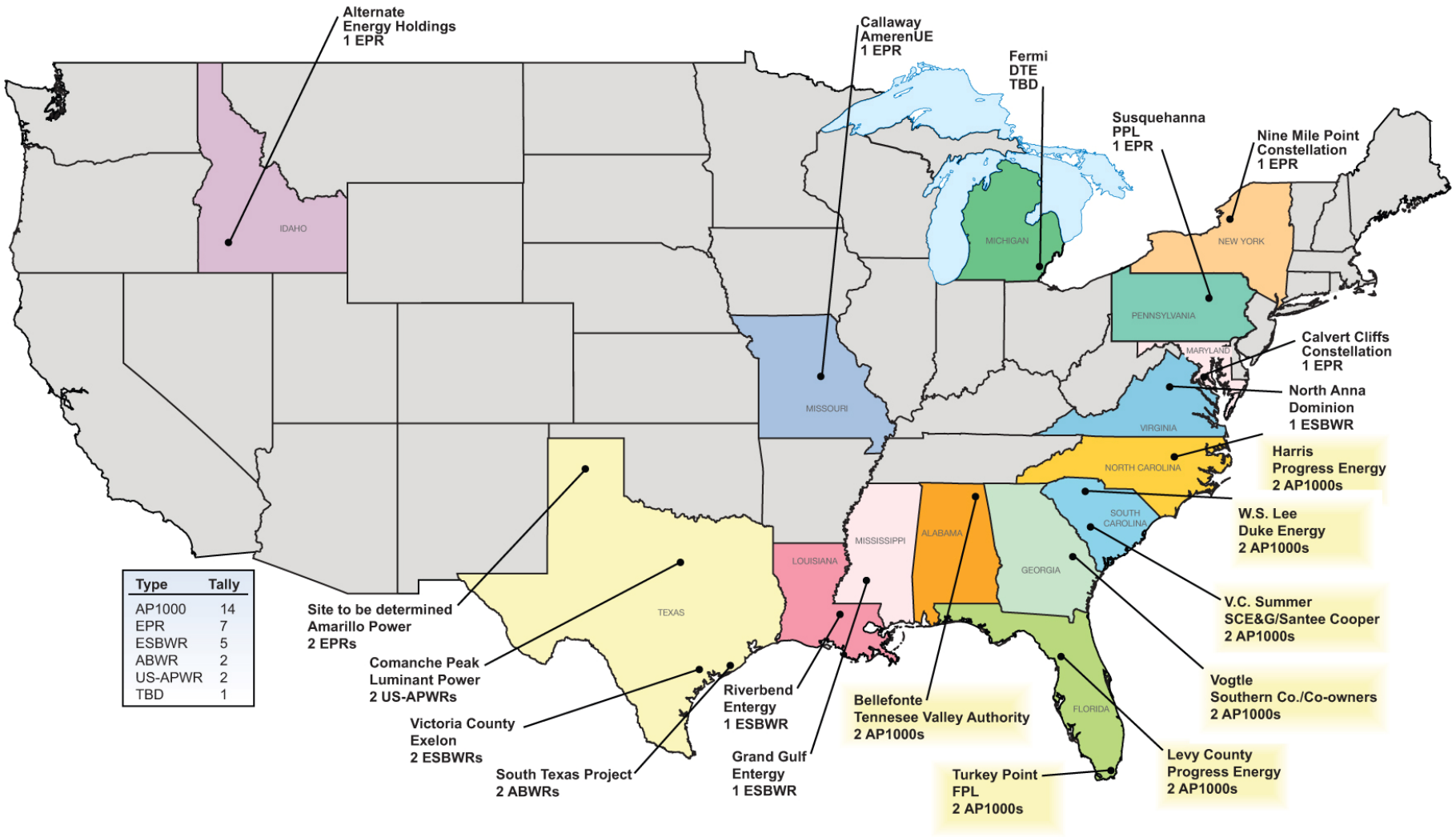


Structural Module

Depressurization Module

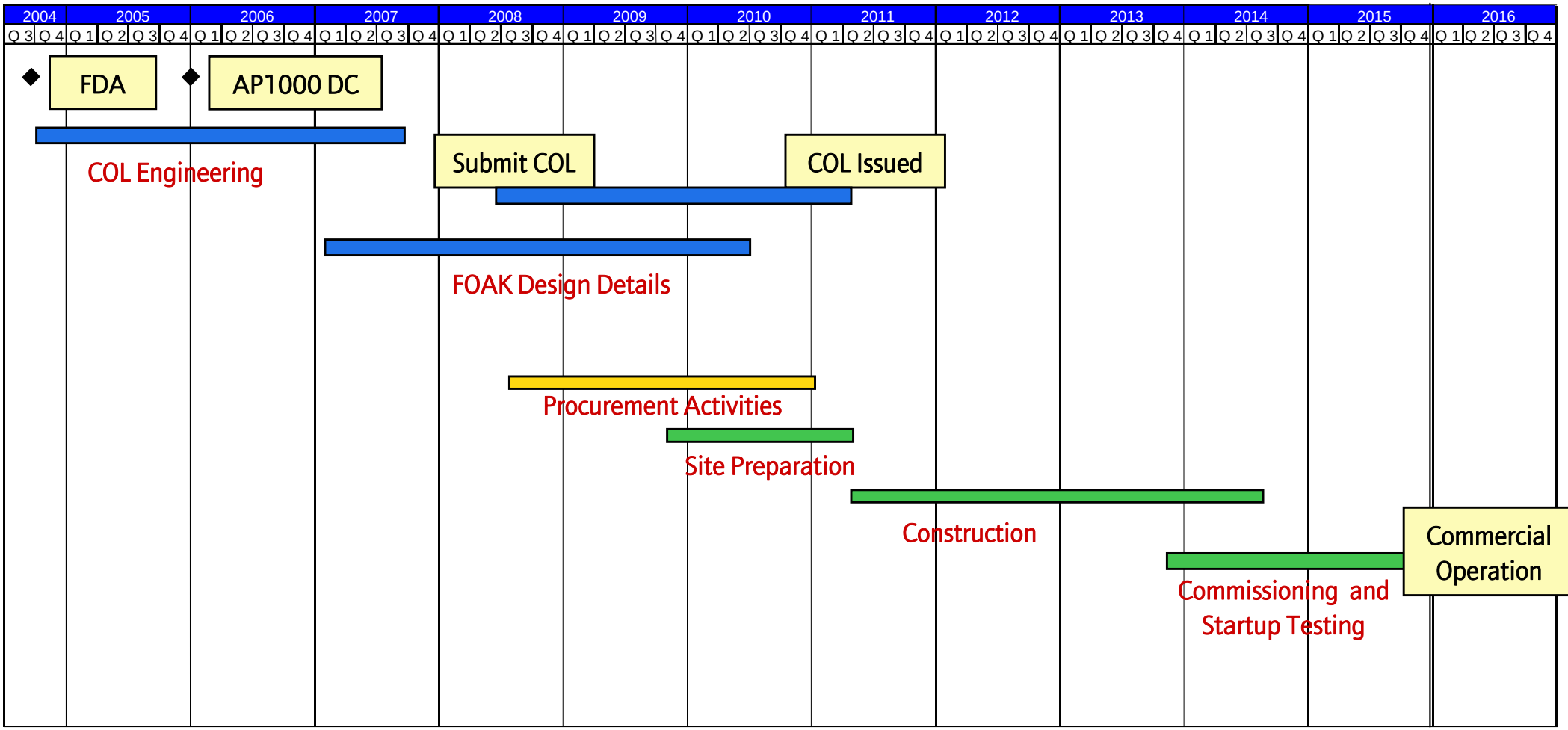
Module Type	Number
Structural	122
Piping	154
Mechanical Equipment	55
Electrical Equipment	11
TOTAL	342

New Reactor License Applications in U.S. (31 Currently Planned)



Type	Tally
AP1000	14
EPR	7
ESBWR	5
ABWR	2
US-APWR	2
TBD	1

The Steps to Bring a New Plant On-line in 2016 (United States)



How AP1000 Reduces Risk

AP1000 … Ready for Commercialization

- **Meets Utilities' Needs**
  - **Satisfies U.S. Utility Requirements**
- **Provides New Standard of Safety**
  - **Simplified Passive Safety features**
- **Major Simplifications Achieved**
  - **Construction, operation, maintenance**
- **Licensing Certainty**
  - **Design Certification in Dec 2005**
- **More economical to build**
- ***Four units in construction in China, 2013 startup***
- ***Two units contracted by Southern Co***
- ***Two units contracted by SCANNA***

Ground Breaking of AP1000 in China

Questions