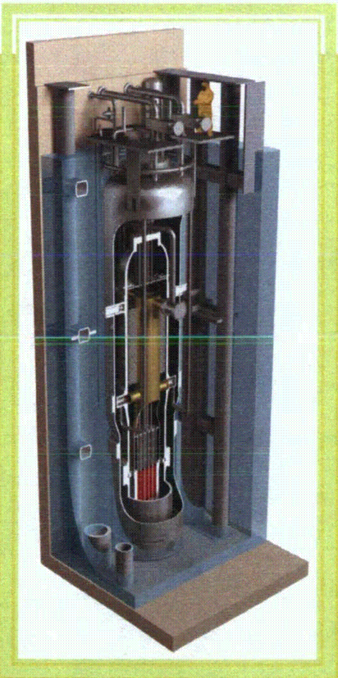
Nonproprietary

Class 1E Power System Design



Ted Hough

December 04, 2012

Nonproprietary

NuScale Power™

Agenda

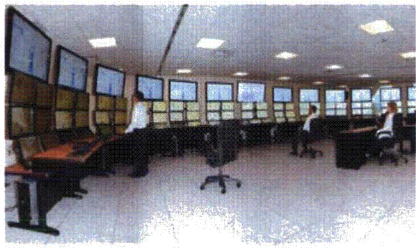
- Purpose
- Plant overview
- Background
- Class 1E power system design overview
- Effects on other plant design aspects
- Regulations and related guidance
- Feedback
- Next steps

NuScale Power™

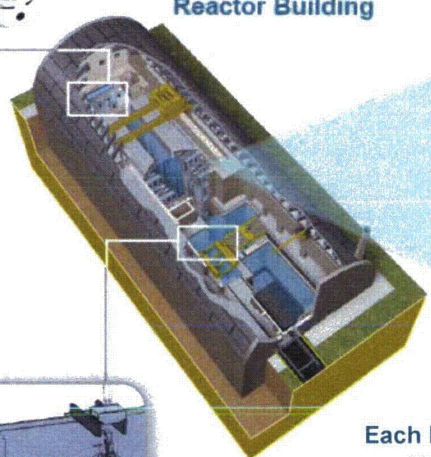
Purpose

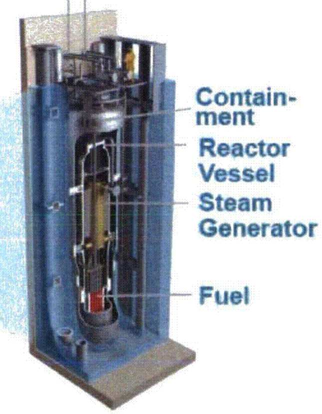
- Demonstrate that the NuScale class 1E power system design ensures public health and safety
- Demonstrate that the NuScale class 1E power system design is consistent with the existing regulatory framework
- Allow opportunity for NRC feedback and questions
- Discuss path forward

Plant Overview



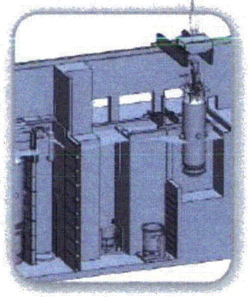
Below-Ground Control Room provides enhanced security and state-of-the-art controls





Each Module is refueled underwater while the remainder of the plant produces power

- Refueled once every 24 months
- 10 Day Refueling Target



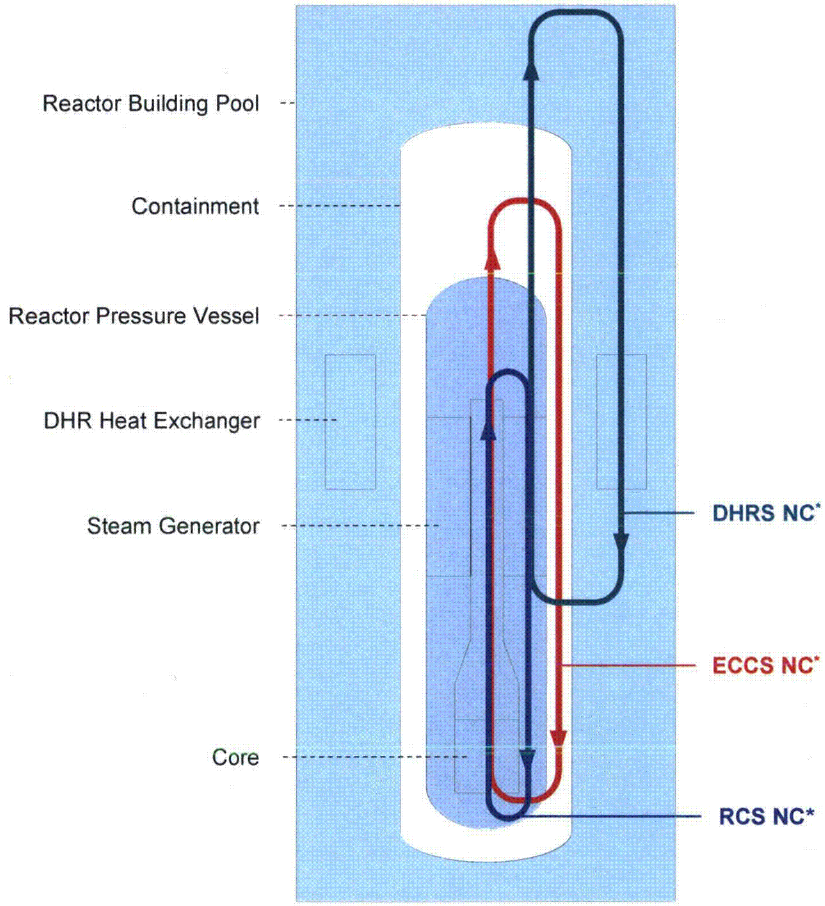
Each Module installed in its own isolated bay

- **Natural Circulation**
  (No Reactor Coolant Pumps
- **Standard 17x17 PWR Fuel**
- **Standard Magnetic Jack Control Rod Drives**
- **Internal Steam Generator and Pressurizer**
- **45 MWe Net Power**

Nonproprietary

NuScale Power™

Plant Overview – Natural Circulation



* NC: Natural Circulation

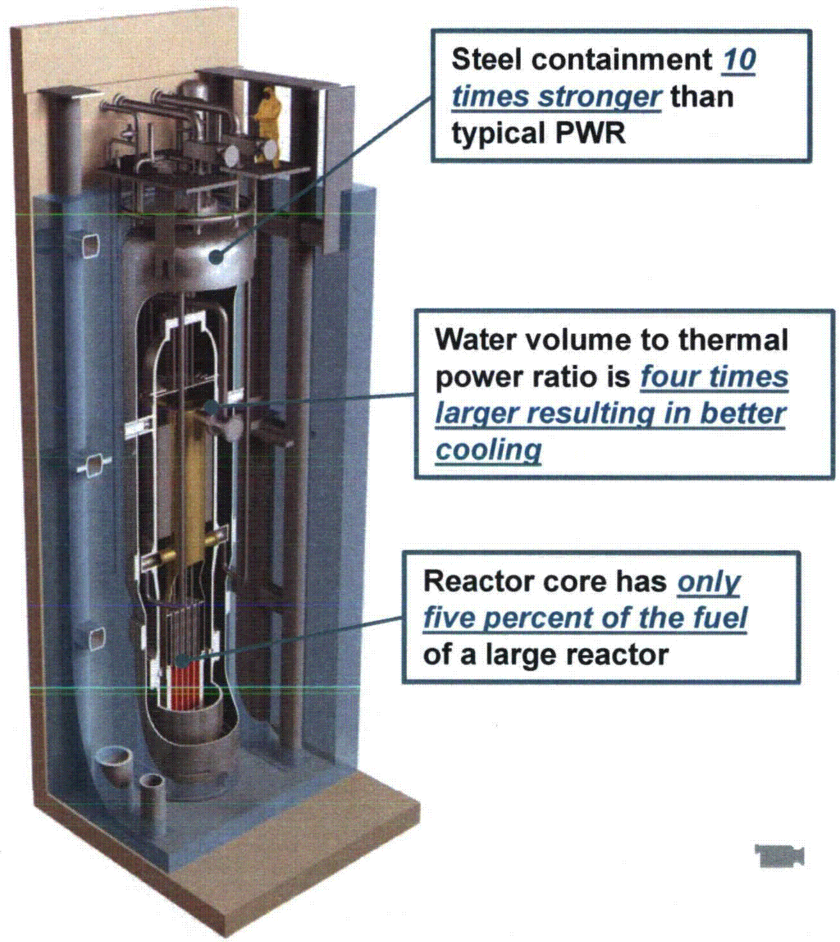
- **Natural circulation in the reactor coolant system (RCS)**
- **Natural circulation in the decay heat removal system (DHRS)**
- **Natural circulation in the emergency core cooling system (ECCS)**

NuScale Power™

Reactor Module Overview

- Natural Convection for Cooling
  - Passively safe, driven by gravity, natural circulation of water over the fuel
  - No pumps, no need for emergency generators
- Seismically Robust
  - System submerged in a below-ground pool of water in an earthquake resistant building
  - Reactor pool attenuates ground motion and dissipates energy
- Simple and Small
  - Reactor is 1/20th the size of large reactors
  - Integrated reactor design, no large-break loss-of-coolant accidents
- Defense-in-Depth
  - Multiple additional barriers to protect against the release of radiation to the environment

45 MWe Reactor Module



NuScale Power™

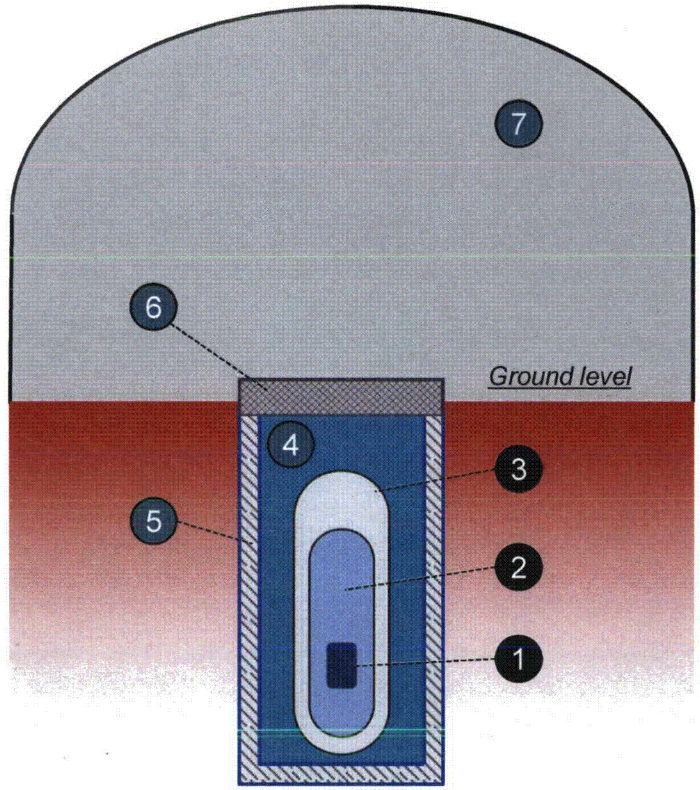
Barriers between Fuel and Environment

Conventional Designs

1. Fuel pellet and cladding
2. Reactor vessel
3. Containment

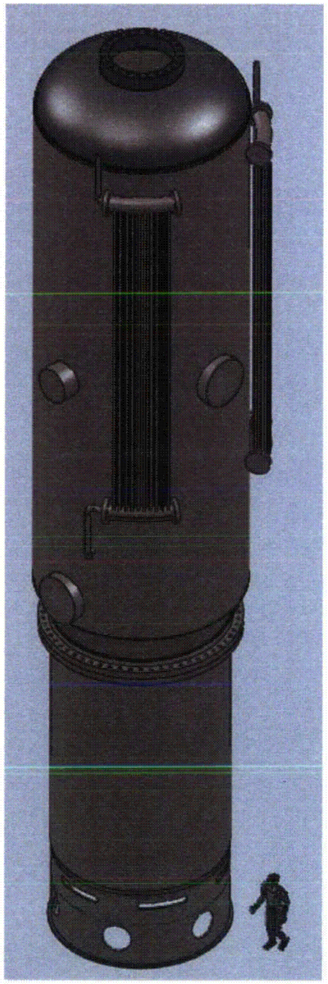
Additional Features in NuScale Design

4. Water in reactor pool (10 million gallons)
5. Stainless steel lined concrete reactor pool
6. Biological shield covers each reactor
7. Reactor building (Seismic Category I)

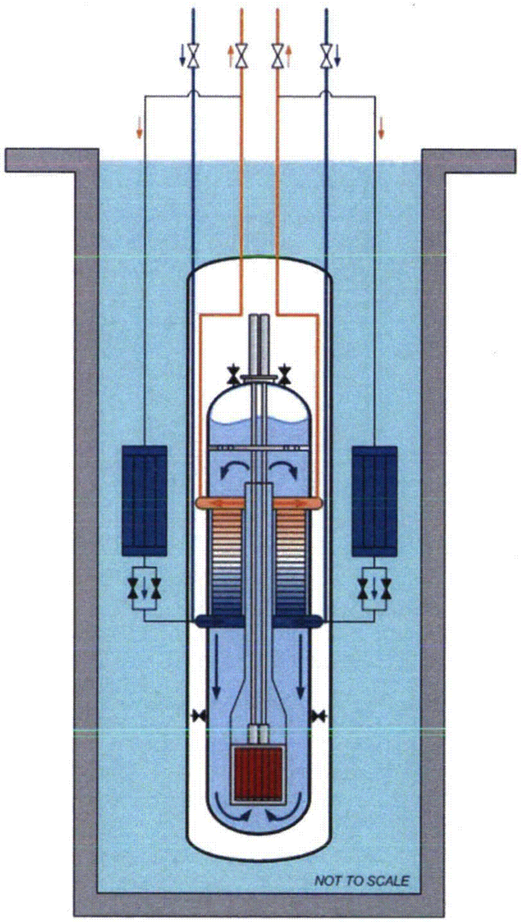


NuScale Power™

Passive Decay Heat Removal System



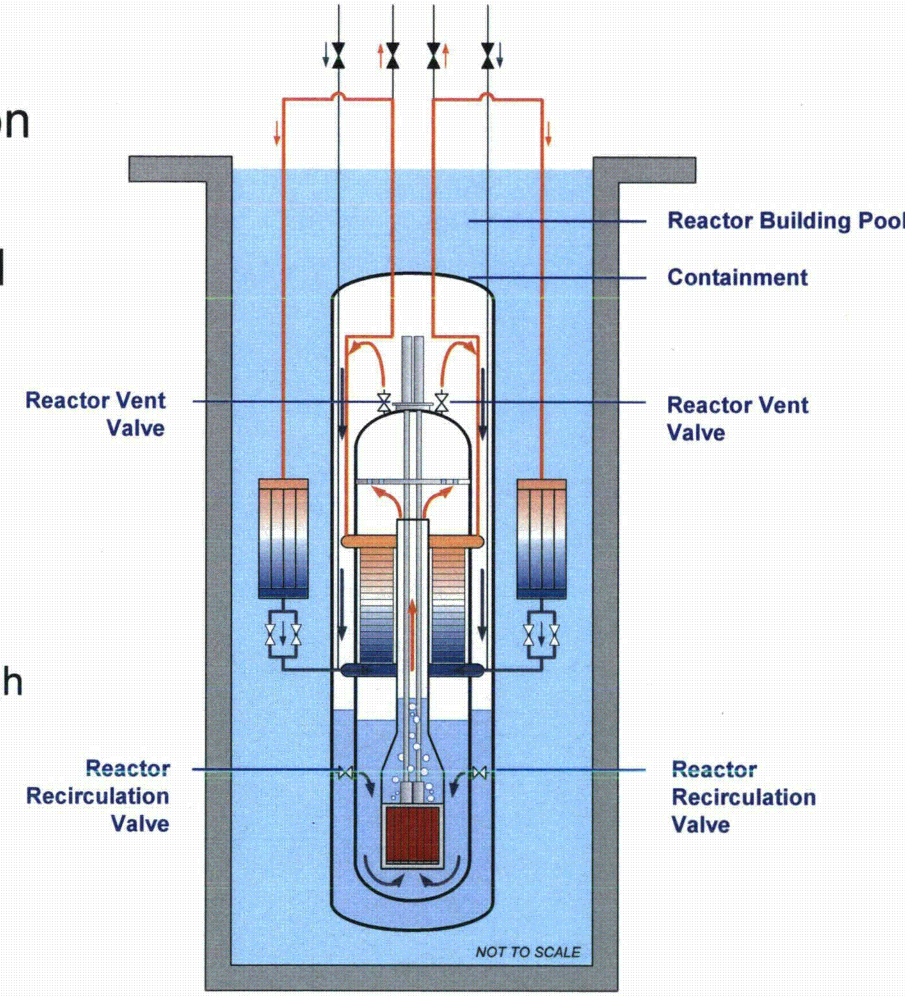
- Main steam and main feedwater isolated
- Decay heat removal (DHR) isolation valves opened
- Decay heat passively removed via the steam generators and DHR heat exchangers to the reactor pool



NUSCALE POWER™

ECCS/Containment Heat Removal

- Reactor vent valves opened on safety signal
- When containment liquid level is high enough, reactor recirculation valves open.
- Decay heat removed:
  - condensing steam on inside surface of containment vessel
  - convection and conduction through liquid and both vessel walls

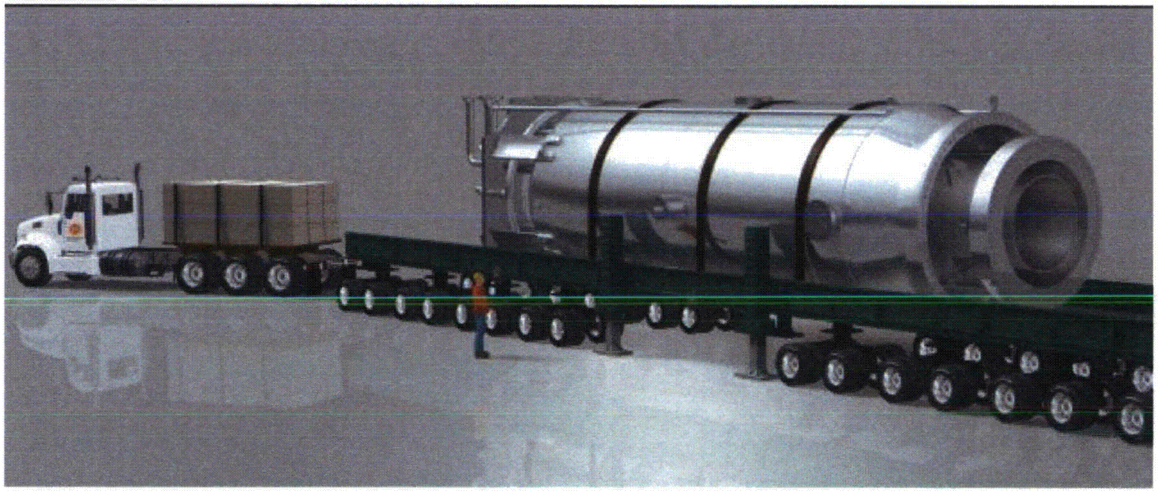


Nonproprietary

NUSCALE POWER™

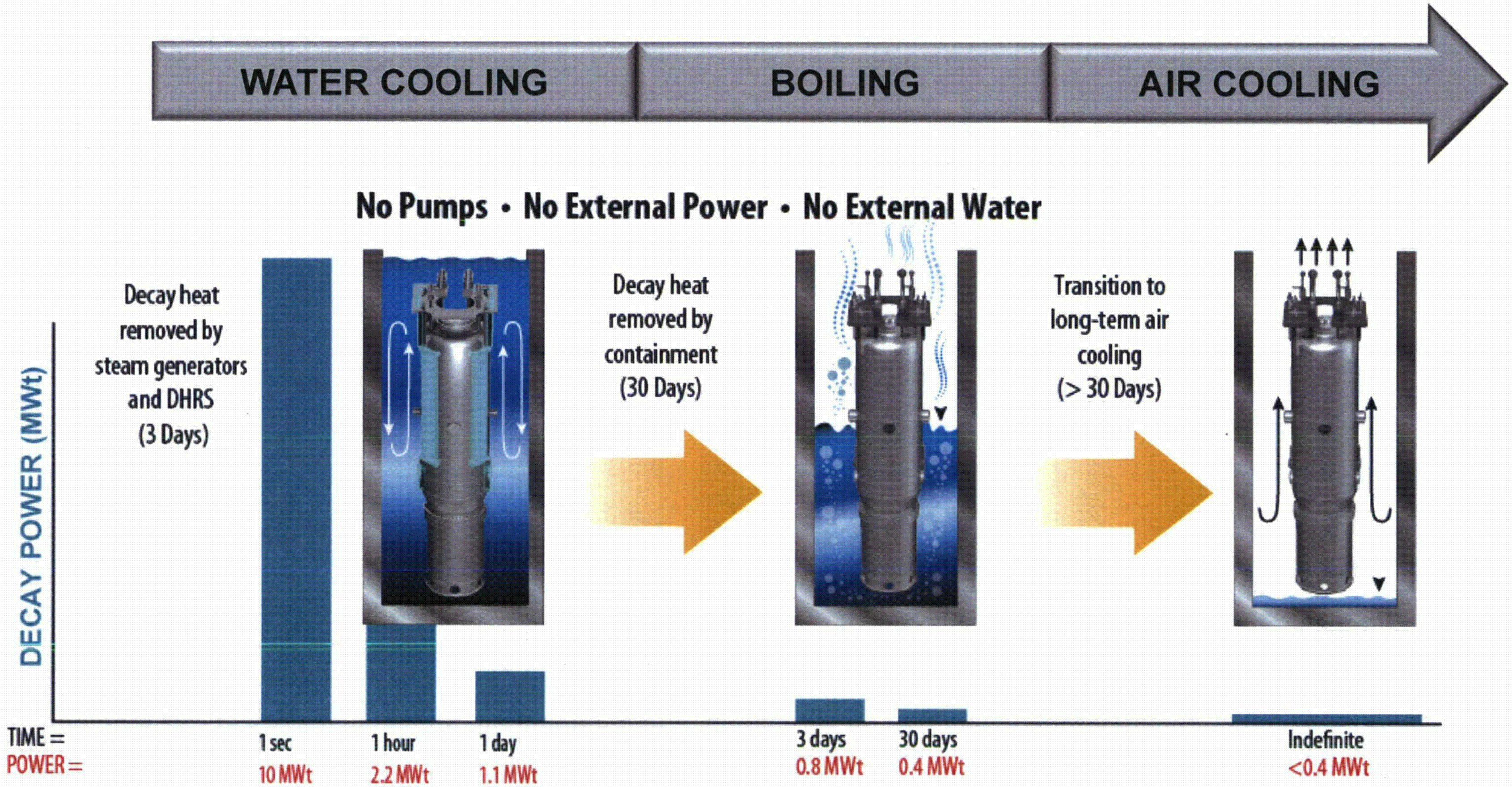
Ship by Truck, Rail, or Barge

- Integrated reactor module
- Factory manufactured
- Transportable by truck, rail, or barge
- 15 meters x 4.5 meters



Stable Long-Term Cooling Under All Conditions

Reactor and nuclear fuel cooled indefinitely without pumps or power

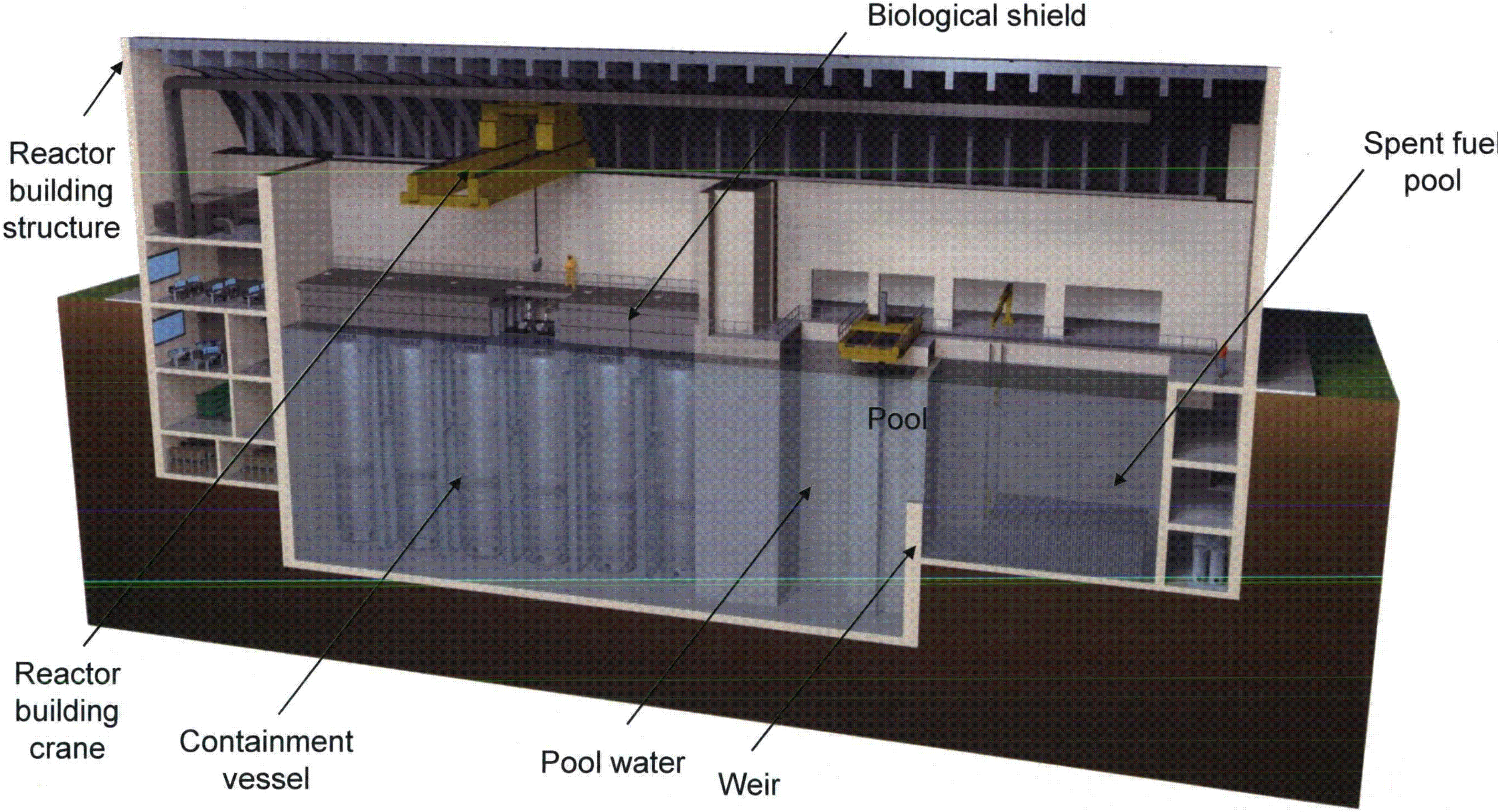


** Based on conservative calculations assuming all 12 modules in simultaneous upset conditions and reduced pool water inventory.*

NUSCALE POWER™

Reactor Building

Reactor building houses reactor modules, spent fuel pool, and reactor pool



NuScale Power™

Background

{{

}}3(a)

Roadmap to Solution

{{

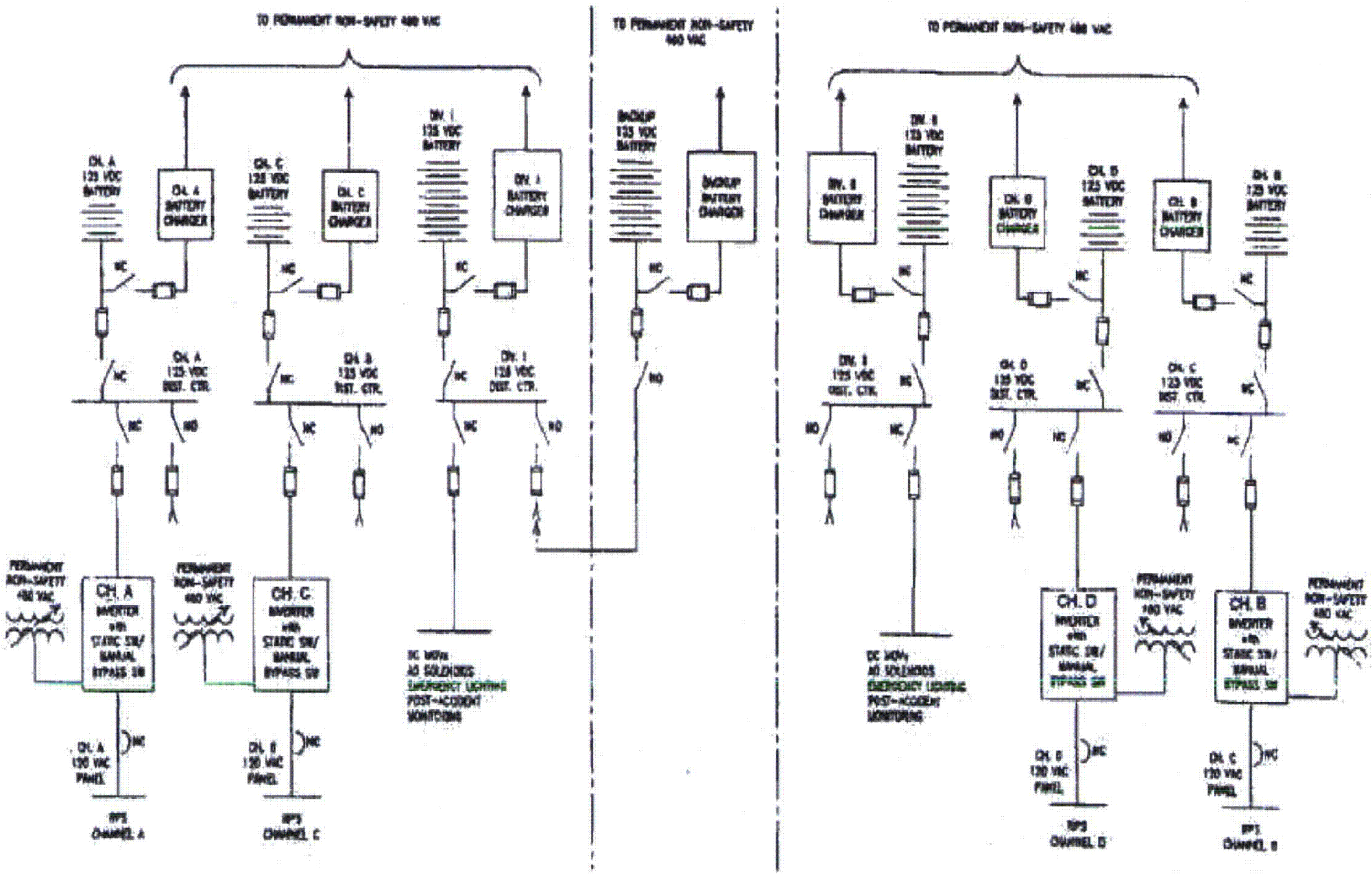
}}3(a)

Define the Problem

Need for 1E Power

- Engineered safety feature actuation system (ESFAS)
  - Systems designed to provide automatic protective functions
  - ESFAS is an active power demand for existing fleet
- Post-accident monitoring (PAM)
  - PAM is a power demand and must be available post-accident

Typical Class 1E System



Regulatory Requirements

- GDC 5 "Sharing of Structures, Systems, and Components"
- RG 1.81 "Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants"
  - Shortly after GDC-5, **no shared 1E DC between units**
- RG 1.32 "Criteria for Power Systems for Nuclear Power Plants"
  - Endorses IEEE Standard 308, Criteria for 1E Power Systems
  - Takes exception to sharing DC and refers back to RG 1.81
- RG 1.97 "Criteria for Post-Accident Monitoring"
  - Endorses IEEE Standard 497, Criteria for Post-Accident Monitoring
  - PAM is 1E load for type A, B, and C variables
  - Silent on sharing DC
- NUREG-0800 Standard Review Plan
  - Reiterates use of RG 1.81
- IEEE Standard 946 "Design of DC Auxiliary Power Systems"
  - Requires 4 channels of independent battery for a 4 channel reactor protection system RPS/ESFAS

Regulatory Requirements

{{

}}3(a)

Vented Lead Acid Batteries

- Stationary Battery Technology
  - IEEE Standard 535 "Qualification of Class 1E Lead Storage Batteries"
  - Vented lead acid is the only qualified battery for nuclear applications
- The Cell

- 17" L x 15" W x 27" H
- Approximately 2 volts per cell
- Need 60 cells in series to make 120 VDC battery
- Typical 2 high rack results in 5' x 24' area for a bank
- Parallel install for demand

NuScale Power™

{{ }}3(a)

{{

}}3(a)

Design Decision Background

{{

}}3(a)

Dedicated versus Shared System

{{

}}3(a)

NuScale Power Solution

NuScale Power™

NuScale 1E Design (ESF)

{{

}}3(a)

NuScale 1E Design (ESF)

{{

}}3(a)

NuScale 1E Design (ESF)

{{

}}3(a)

NuScale 1E Design (ESF)

{{

}}3(a)

NuScale 1E Design (ESF)

{{

}}3(a)

NuScale 1E Design (ESF)

{{

}}3(a)

NuScale 1E Design (PAM)

{{

}}3(a)

NuScale 1E Design (PAM)

{{

}}3(a)

Summary

Summary of NuScale Solution

{{

}}3(a)

Summary of NuScale Solution

{{

}}3(a)

Summary of NuScale Solution

{{

}}3(a)

Regulations and Related Guidance

- RG 1.32 and RG 1.81 address active ESF functions only
- Monitoring functions (PAM) not affected by RG 1.81

{{

}}3(a)

NuScale Power™

Overall Summary

- Achieves enhanced safety
- Complements the inherent safety aspects of the NuScale design (i.e., simple and passively safe)

{{

}}3(a)

- Maintains regulatory compliance

NRC Feedback and Next Steps

- Comments and questions
- Propose regular engagement meetings to provide the increasing level of detail regarding the NuScale class 1E power system design
- Discuss potential Design-Specific Review Standard aspects

NuScale Power™

Probabilistic Risk Assessment Status and Update