NuScale Power™

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Enclosure 1:

"NuScale Refueling", PM-0515-14458-NP, Revision 0

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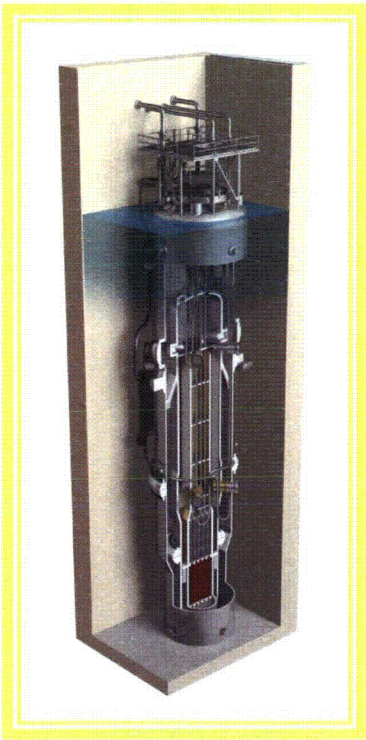
NuScale Refueling



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Acknowledgement & Disclaimer

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Purpose

- Provide a high-level overview of the NuScale refueling operations
- Identify the unique aspects of the NuScale refueling operations
- Identify technical challenges associated with the refueling process
- Review potential casualties and risks associated with the refueling process
- Answer any questions related to the refueling process

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Agenda

- Review the outage schedule
- Identify the outage windows associated with a NuScale refueling outage
- Provide a brief overview of each outage window

Introduction

Previous presentations on this topic

- April 2009 meeting with the NRC to discuss refueling operations
- October 2011 meeting with the NRC to discuss NuScale design and applicability of requirements and guidance
- October 2012 meeting with the NRC to discuss nuclear module and fuel handling
- Caveats
  - the drawings that have been provided are illustrative
  - the durations provided are estimated based on operating experience and engineering judgment
  - details of the process are subject to change pending completion of detailed design

Refueling Overview

- Two year fuel cycle
- Dedicated refueling crew separate from the Operations crew – including an SRO
- Once a module is disconnected, the refueling crew assumes primary responsibility

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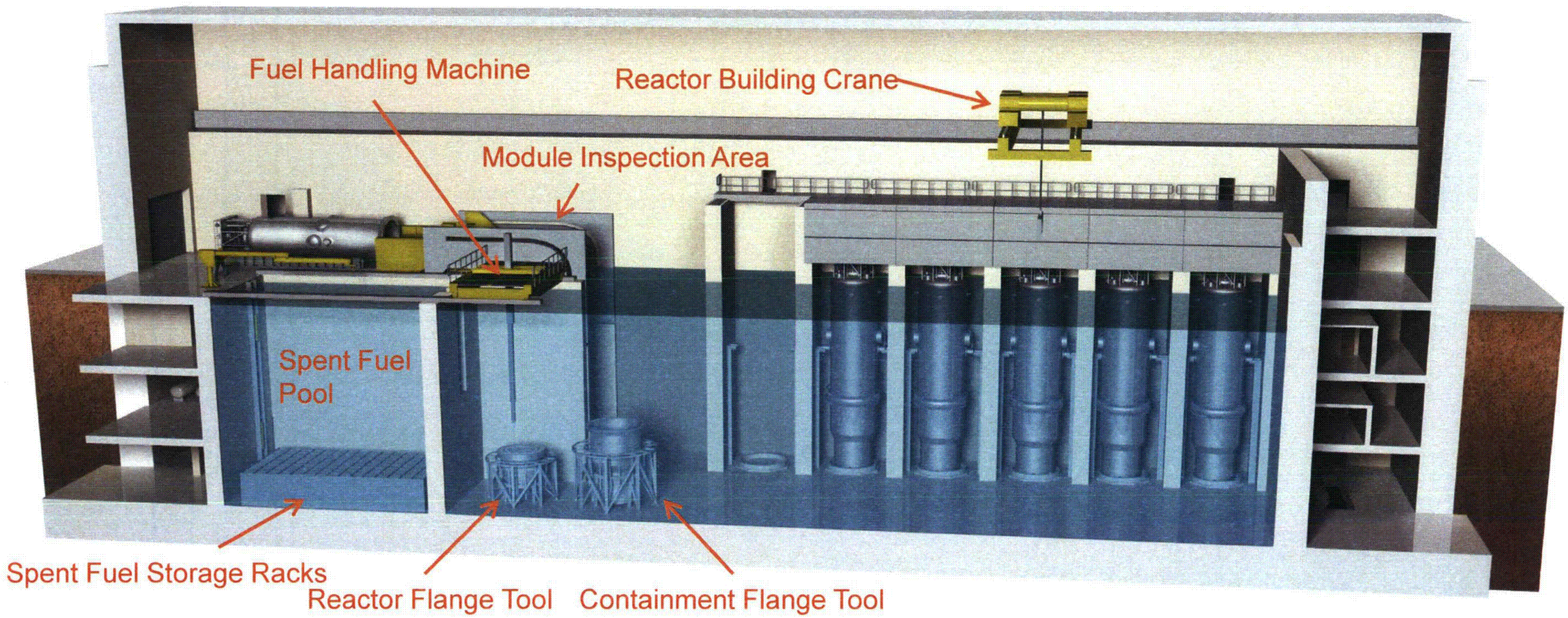
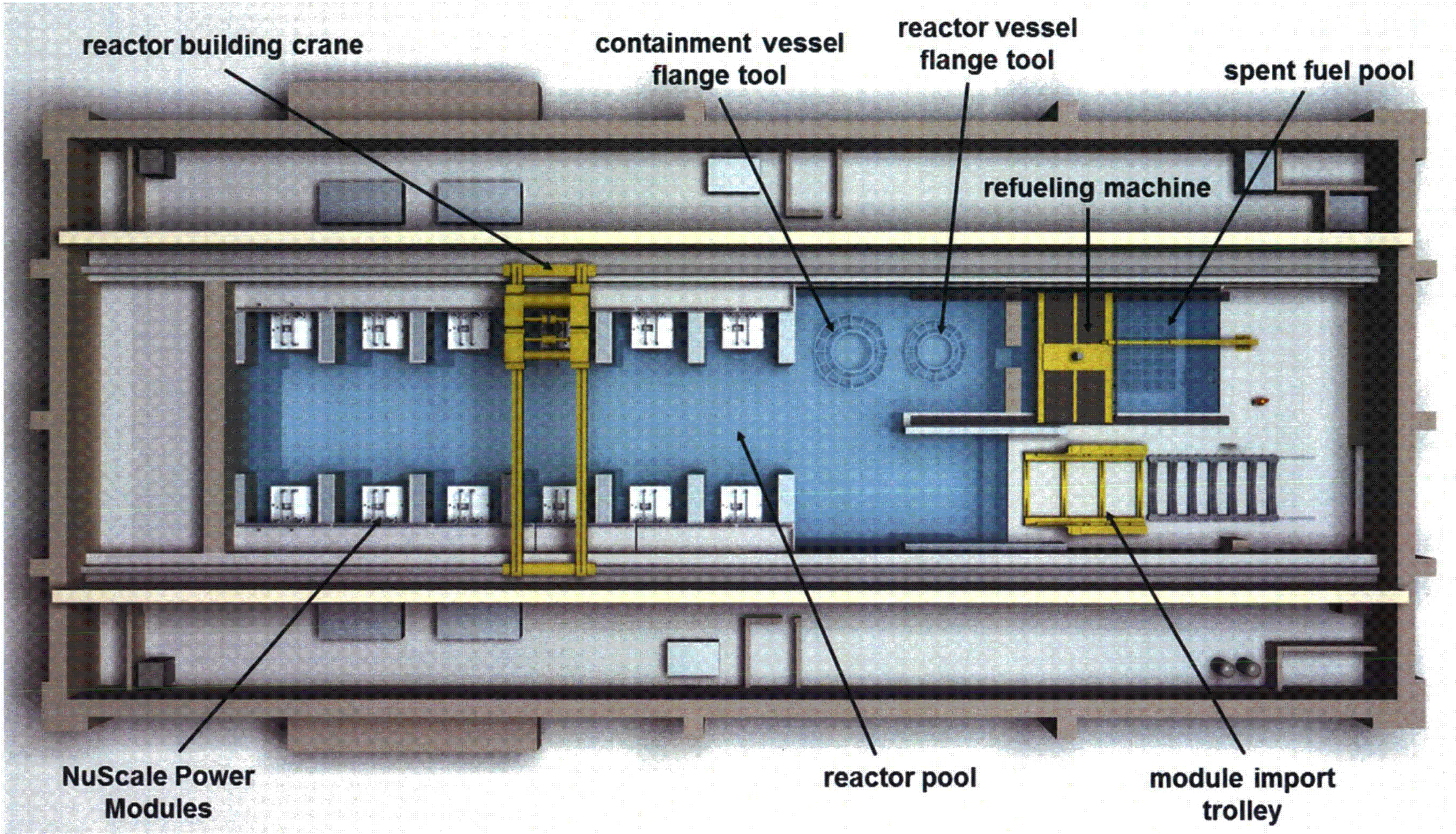
Module Assembly and Spent Fuel Storage



- Spent fuel pool has capacity to store:
  - 10 years of spent fuel
- Spent fuel storage racks
  - Seismic Category I
  - high density design
  - neutron absorber material for criticality control

- Module assembly equipment
  - reactor module assembly/disassembly
  - refueling core
  - loading dry storage cask

Reactor and Refueling Pool Overhead View



Mode Table Comparison

NuScale Draft Mode Table

Mode	Title	k_{eff}	Reactor Coolant Average	Module Position
1	Operations	≥ 0.99	N/A	Operating
2	Hot Shutdown	< 0.99	≥ 300 F	Operating
3	Safe Shutdown	< 0.99	< 300 F	Operating
4	Transition[a]	< 0.95	< 200 F	Connected to the overhead crane
5	Refueling[b]	< 0.95	< 200 F	Other

Current PWR Mode Table

Mode	Title	k_{eff}	% Power[a]	T_{ave} (°F)
1	Power Operation	≥ 0.99	> 5	NA
2	Startup	≥ 0.99	≤ 5	NA
3	Hot Standby	< 0.99	NA	≥ 350
4	Hot Shutdown	< 0.99	NA	350 > Tavg > 200
5	Cold Shutdown	< 0.99	NA	≤ 200
6	Refueling	NA	NA	NA

(a) All CVC connections to MODULE isolated.
(b) One or more reactor vessel head closure bolts less than fully tensioned.

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Refueling Animation

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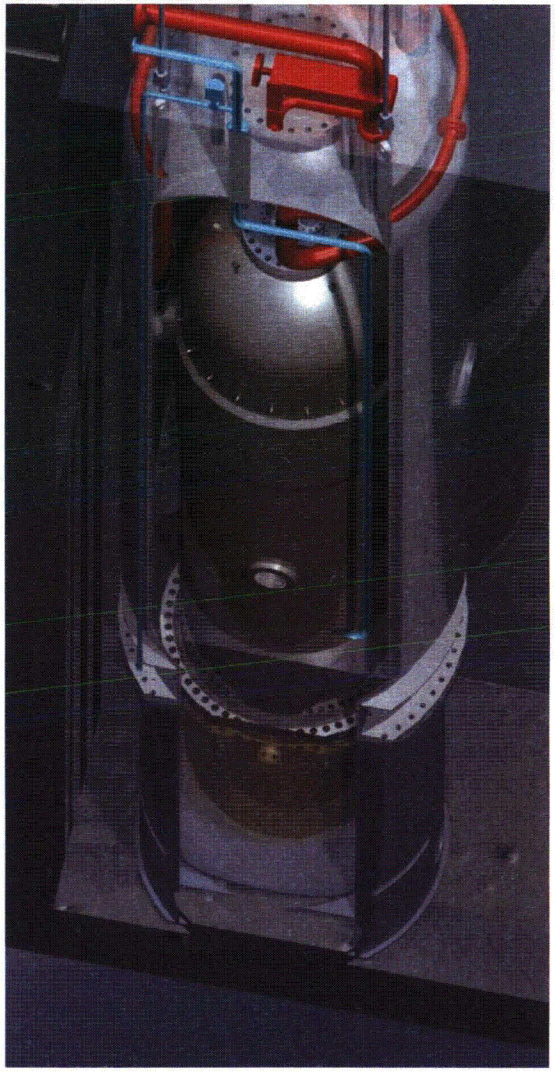
Module refueling

Windows

1) Shutdown/cooldown
2) Transition preparation and disconnection
3) Transition (to containment flange tool)
4) Disassembly
5) Upper module work window
6) Refueling
7) Lower containment vessel work window
8) Reassembly
9) Transition (to operating bay)
10) Reconnection
11) Module heat up
12) Reactor startup and ramp to full power



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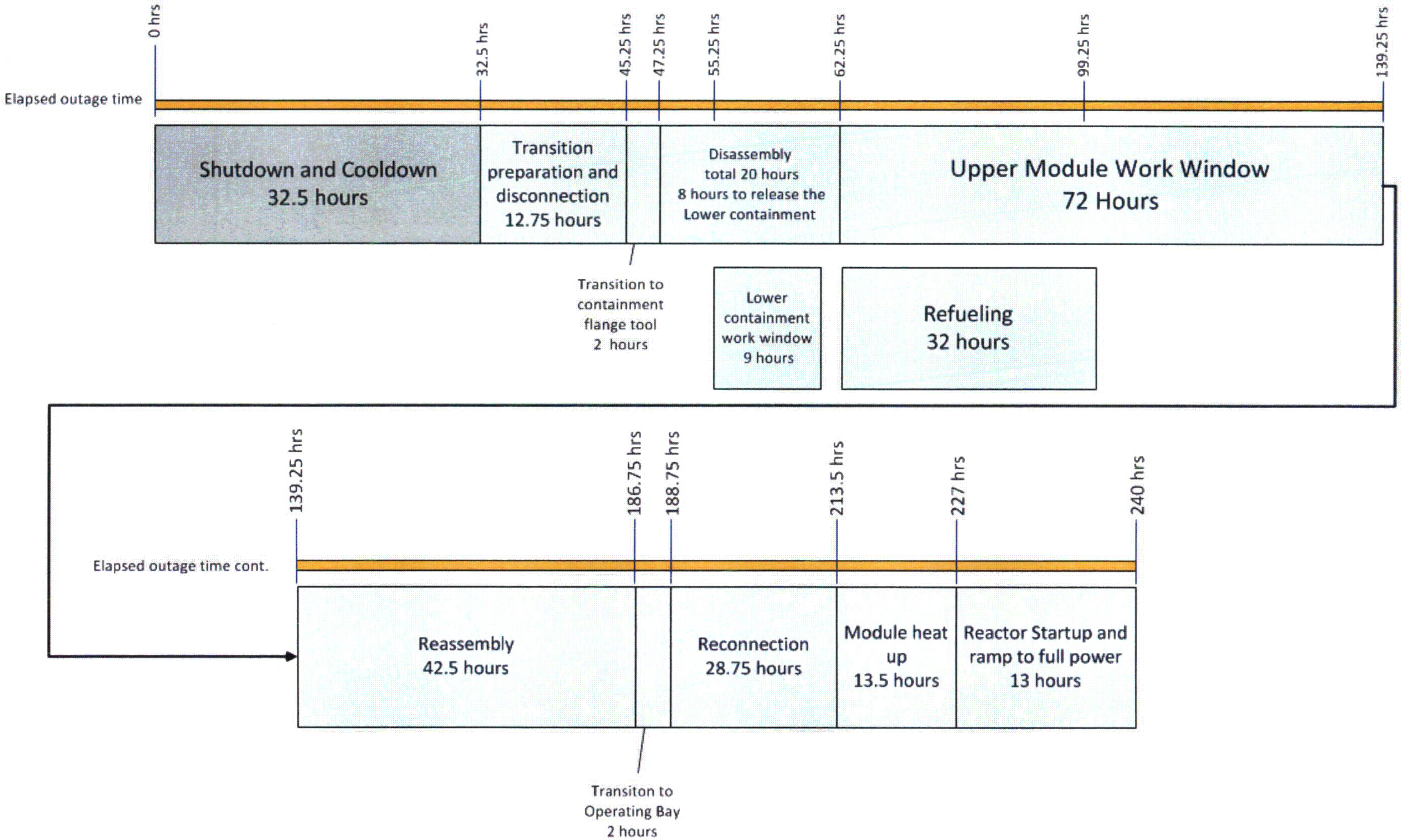
10 Day (240 hr) Refuel Schedule



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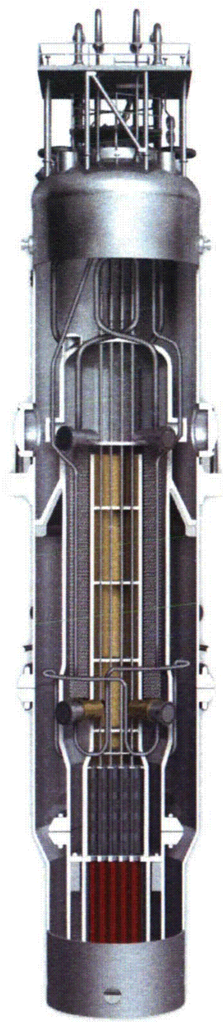
Shutdown/Cooldown

- Unit is ramped down to 20% and tripped
- Primary system is borated to refueling concentration
- Cooldown to 300 degrees F using feedwater and turbine bypass
- Depressurize the RCS to 200 psia using pressurizer spray
- Containment flooded to continue cooldown below 200 degrees F
- Steam generators placed in wet layup
- Crud burst and cleanup performed
- DHRS is not used in a normal shutdown and cooldown



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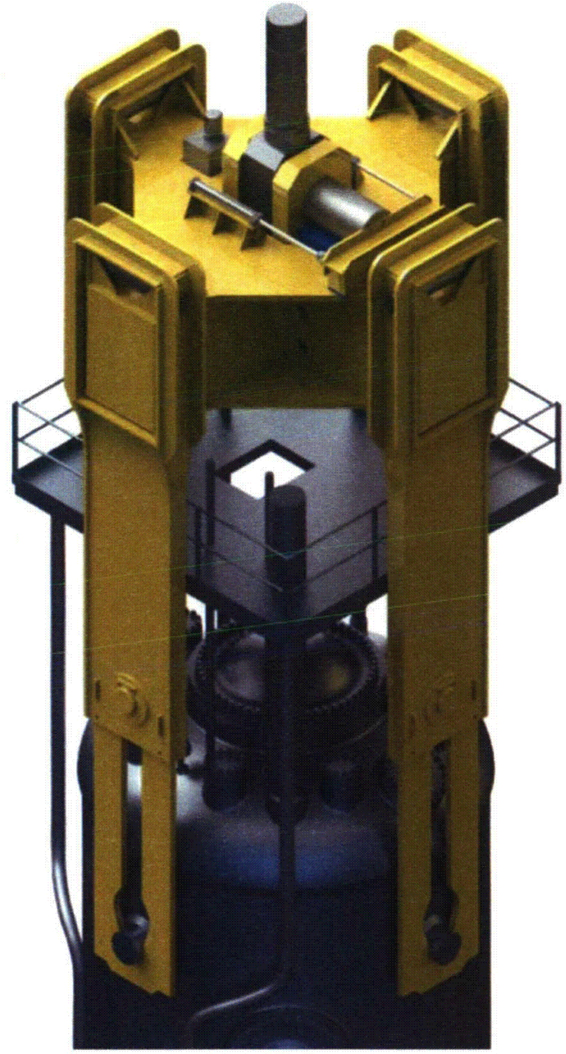
Transition Preparation and Disconnection

- Shutdown CVCS
- Fully depressurize RCS
- Open ECCS valves
- Remove bioshield
- Close all containment isolation valves
- Electrical and I&C disconnections performed
- Containment is pressurized to prevent water from coming over the top of the RPV head when the CNV flange is separated
- Mechanical disconnections completed
- Crane and lifting device connected



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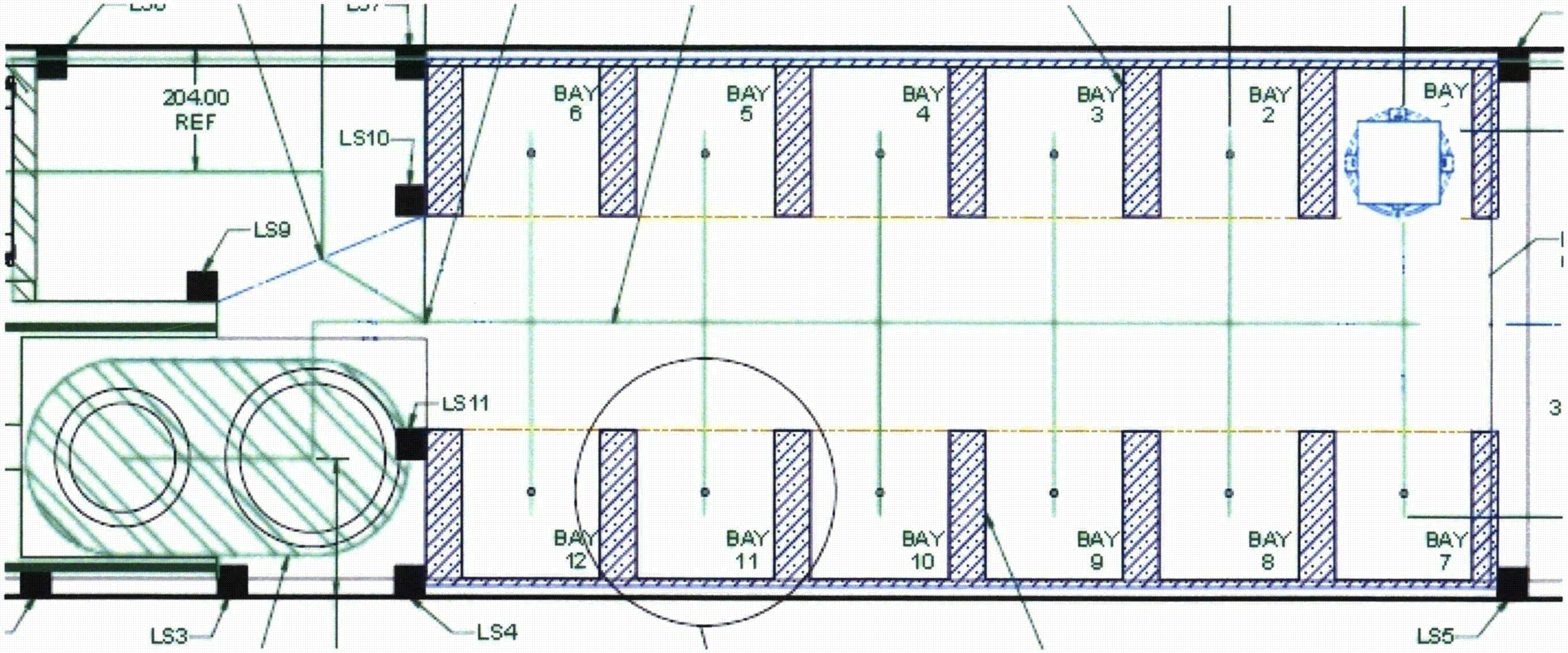
Transition to the Containment Flange tool

Module configuration during transition

- ECCS vent and recirculation valves are open
- Module is flooded to the pressurizer baffle plate
- All penetrations are isolated and disconnected

Transition to the Containment Flange tool

1) Module is raised enough to clear the pool floor
2) Crane trolleys to the centerline of the pool
3) Crane travels to the lift point (just past bay 6 and 12)
4) Module is lifted to clear the containment flange tool
5) Crane travels along the centerline until it is lined up with the containment flange tool
6) Crane trolleys until the module is directly over the containment flange tool
7) Module is placed into the containment flange tool



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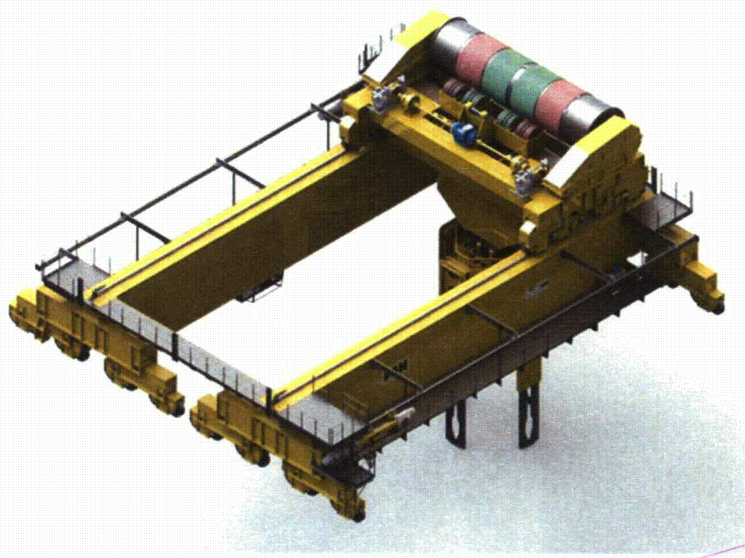
Crane Events

- Reactor building crane single failure proof and Seismic Class 1 (ASME NOG-1, Type 1)
- PRA analysis has been performed for a module drop
- Analysis was done with MELCOR for a module laying horizontally at the bottom of the pool
- Results – no core damage as long as the control rods remain in the core



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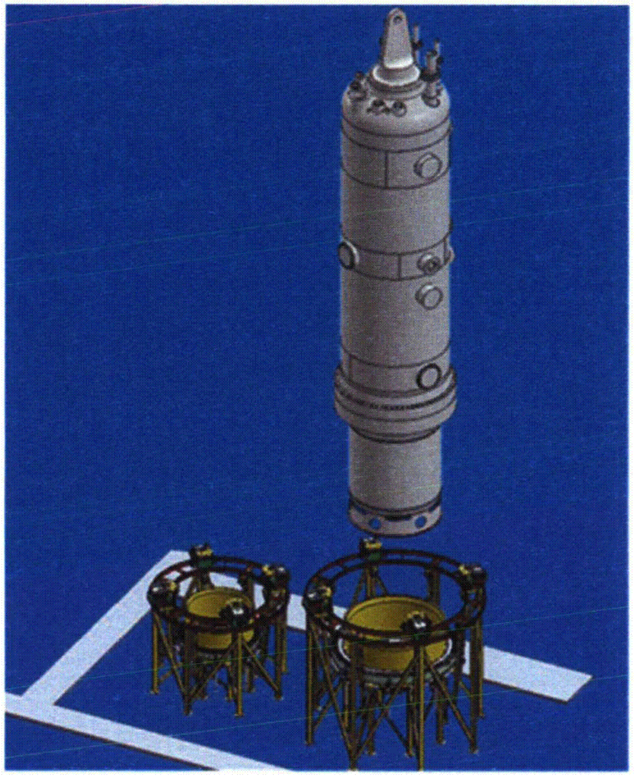
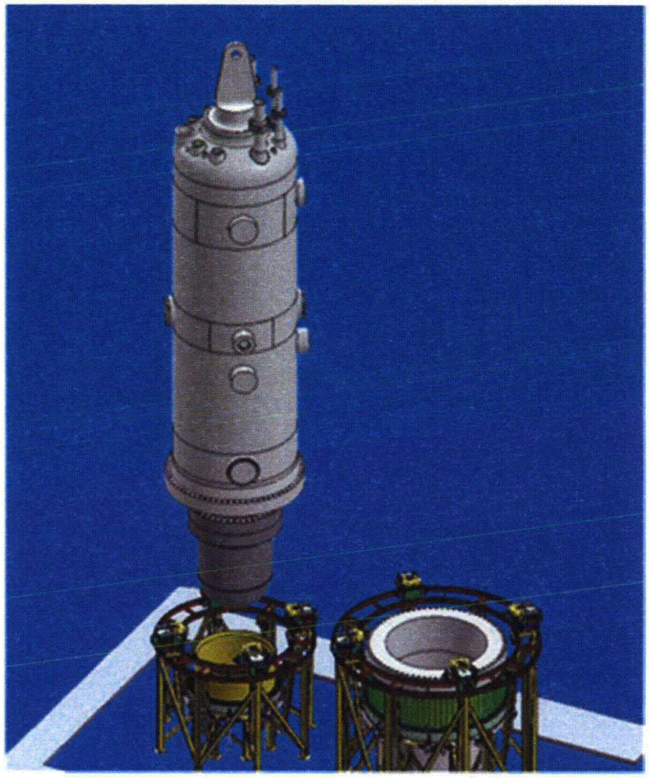
Disassembly

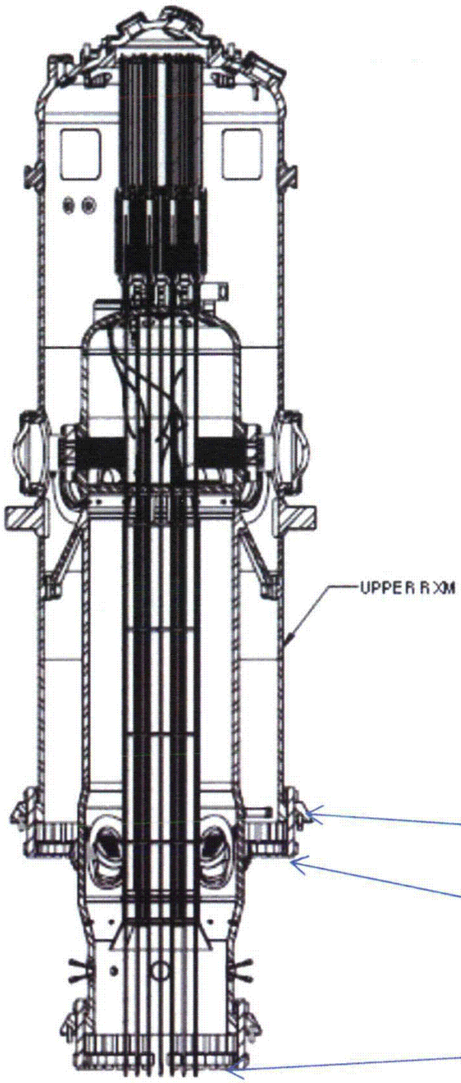
The containment flange tool detensions the containment flange studs and provides a stand for the containment lower vessel

The remainder of the module is picked up and moved to the reactor flange tool – where the reactor flange studs are detensioned and then the upper module is lifted and transported to the dry dock, leaving the lower reactor vessel and the core for refueling





Upper Module Work Window



- Upper module is secured in the module upender and the crane and lifting rig is removed
- Steam generator eddy current
- Instrument testing, repair, and calibration
- Upper reactor flange inspection
- Upper containment flange inspection
- Inspect 20% of ISI welds, forgings, and surfaces
- Inservice testing (SRVs, RRVs, RVVs and check valves)
- Appendix J Type B and C testing

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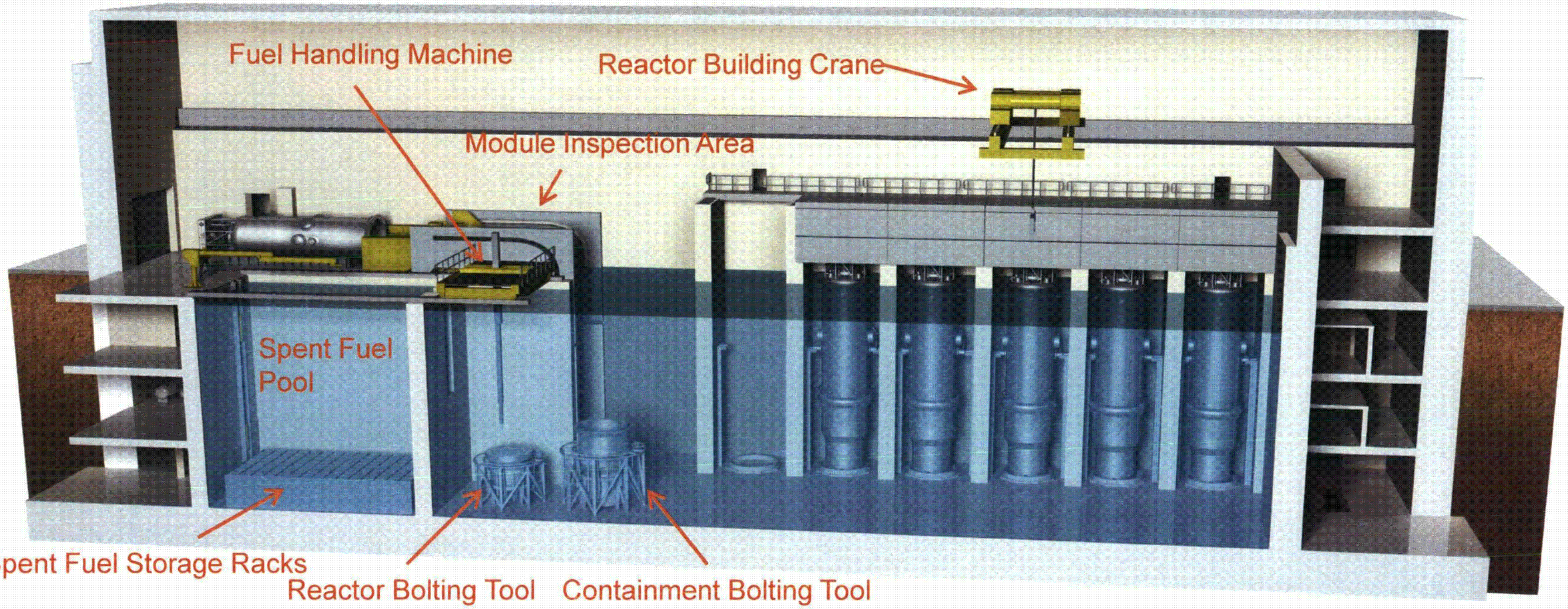
Refueling



The 37 fuel assemblies in the lower reactor vessel can be taken directly from the core with the refueling machine and placed in the spent fuel pool.

Each assembly only requires a single handling event to take it from the core to the spent fuel storage location.

Lower reactor vessel inspections would also be performed in this window.

Refueling can be completed either as a partial core offload and fuel shuffle, or full core offload and reload.

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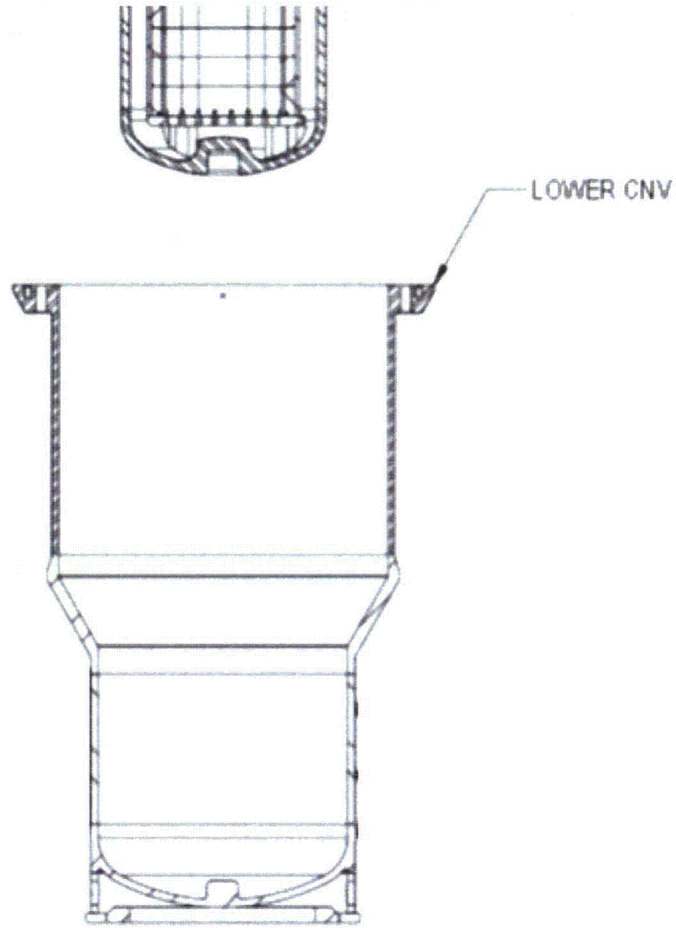
Lower Containment Vessel Work Window

- Inspect 20% of ISI welds, forgings, and surfaces
- Lower containment flange inspection
- Inspect or replace containment flange bolts



LOWER CNV REMOVED

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Reassembly

- Prerequisites
  - lower containment work window complete
  - upper module work window complete
  - refueling work window complete
- Align, inspect sealing surfaces, and tension reactor flange
- Connect and test rod control
- Latch and stroke test control rods (one at a time)
- Disconnect rod control and instrumentation

Reassembly

- Leak test reactor flange
- Move module to the containment tool
- Align and inspect sealing surfaces, and tension containment flange
- Leak test containment flange

Reconnection

- Prerequisites
  - CVCS operating on recirculation
  - feedwater and condensate on long cleanup
- Connect power, instrumentation and controls
- Verify instrumentation and control operability
- Place excore power / intermediate range NIs in their operating position
- Insert in-core instrumentation
- Connect CES and begin containment and RCS degas
- Complete the remainder of the mechanical connections
- Shut ECCS vent and recirculation valves
- Pressurize the RCS to with N2 to provide NPSH for CVCS recirculation pumps

Module Heat Up

- Establish normal CVCS recirculation
- Place module heat up system in service to establish 10% core flow
  - the module heatup system is a steam heater that raise the temperature of the CVCS return flow to heat up the module
- Restore feedwater to and main steam from the SG
- Perform SG flush
- Verify containment is operable
- Drain containment
- Install bioshield

Module Heat Up

- Perform first dilution to approach critical boron concentration
- Draw a vacuum on containment
- Draw a steam bubble in the pressurizer
- Continue dilution to critical boron concentration
- Stabilize RCS temperature at 430 degrees F
- Stabilize RCS pressure at 1850 psia

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Start Up

- Withdraw rods to criticality
- Perform physics testing
- Withdraw rods to raise power to 15% and Tave to 546 degrees F
- Remove the CVCS heater from service
- Place the main turbine in service
- Synchronize turbine generator to the grid
- Ascend to 100% power

NuScale Plant Refueling

Benefits of NuScale refueling design

- Dedicated refueling area
  - shortened outages, improved predictability, and reduced workforce requirements
- Design simplicity and modularity
  - on-line maintenance, fewer systems, smaller components, skid mounted equipment, spare module
- Refueling outage staffing
  - in-house staff, eliminate staff augmentation, improved quality of work
- Refueling outage frequency and flexibility

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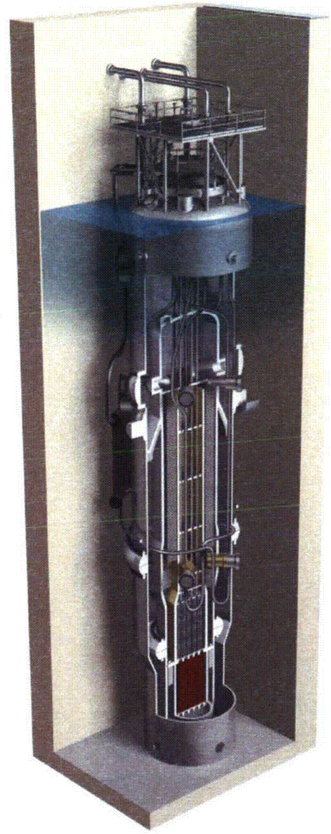

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