# Advancements in Technology Applications for the NuScale Power I&C Design

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# Acknowledgement & Disclaimer

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# Introduction

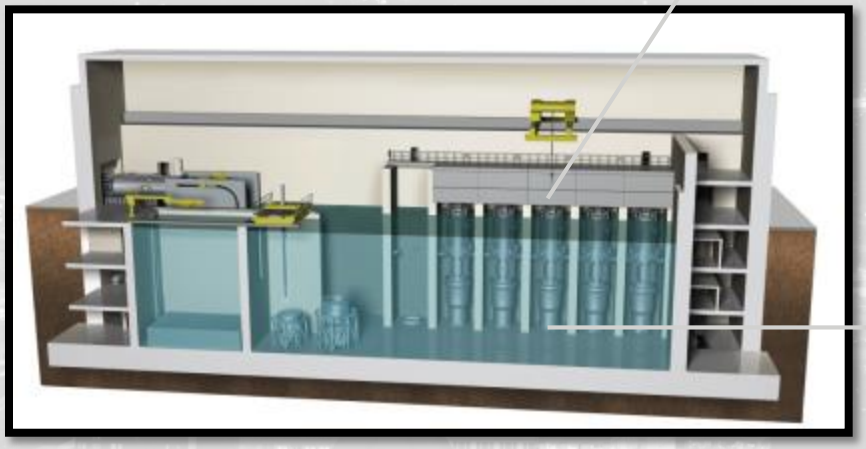


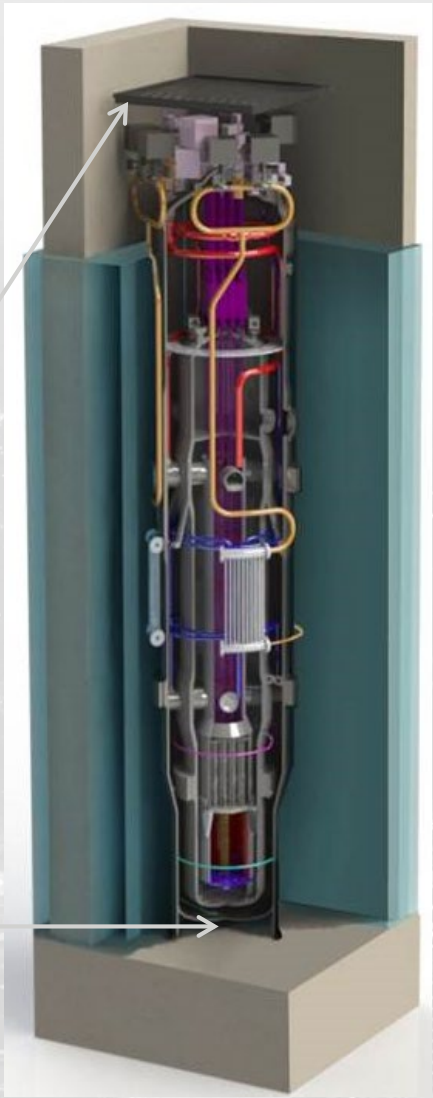
- Agenda
  - Brief Overview of NuScale Plant Design
  - Introduction to NuScale I&C Architecture
    - Unique NuScale Differences
  - First-of-a-Kind I&C Technology Application Overview
  - Future Needs and Challenges

# The NuScale Power Module



- A NuScale Power Module (NPM) includes the **reactor vessel, steam generators, pressurizer** and **containment** in an integral package that eliminates reactor coolant pumps and large bore piping (no LBLOCA)
- Each NPM is 60 MWe and factory-built for easy transport and installation
- Each NPM has its own skid-mounted steam turbine-generator and condenser
- Each NPM is installed below-grade in a seismically robust, steel-lined, concrete pool
- NPMs can be incrementally added to match load growth—up to 12 NPMs for 720 MWe gross total output

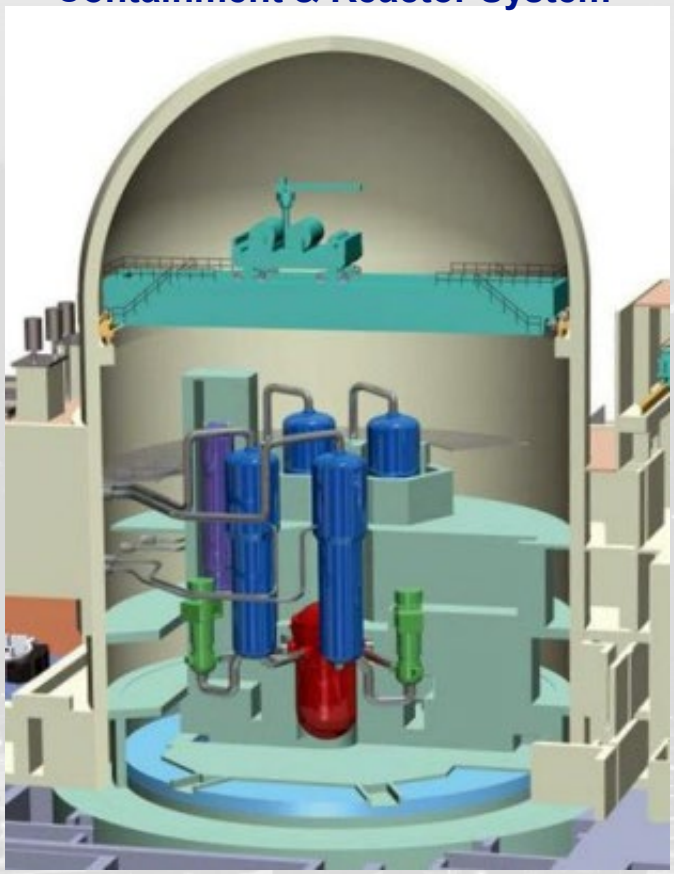




# Size Comparison



**Typical Pressurized-Water Reactor**
**Containment & Reactor System**

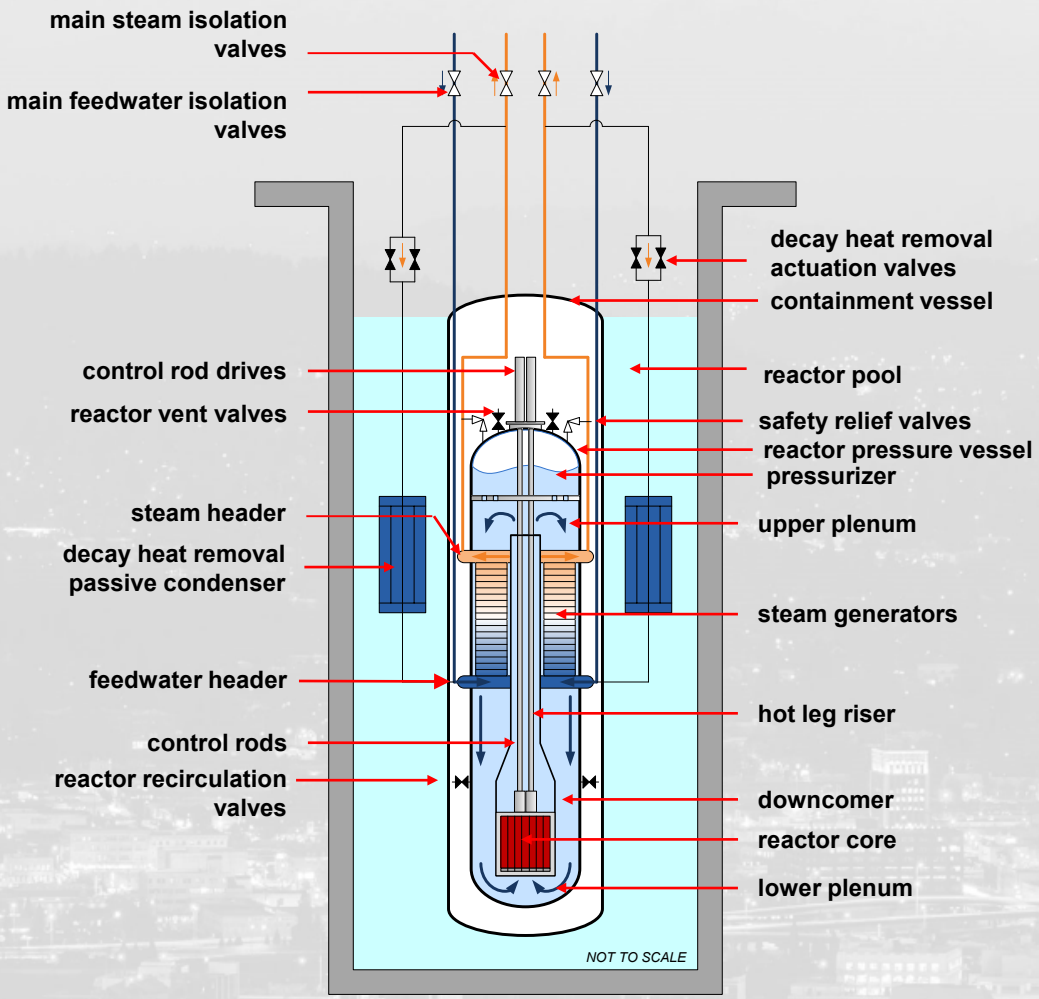


*Source: NRC

**NuScale Power Module**
Combined Containment Vessel and
Integral Reactor System

# Simplified NSSS Protection Design



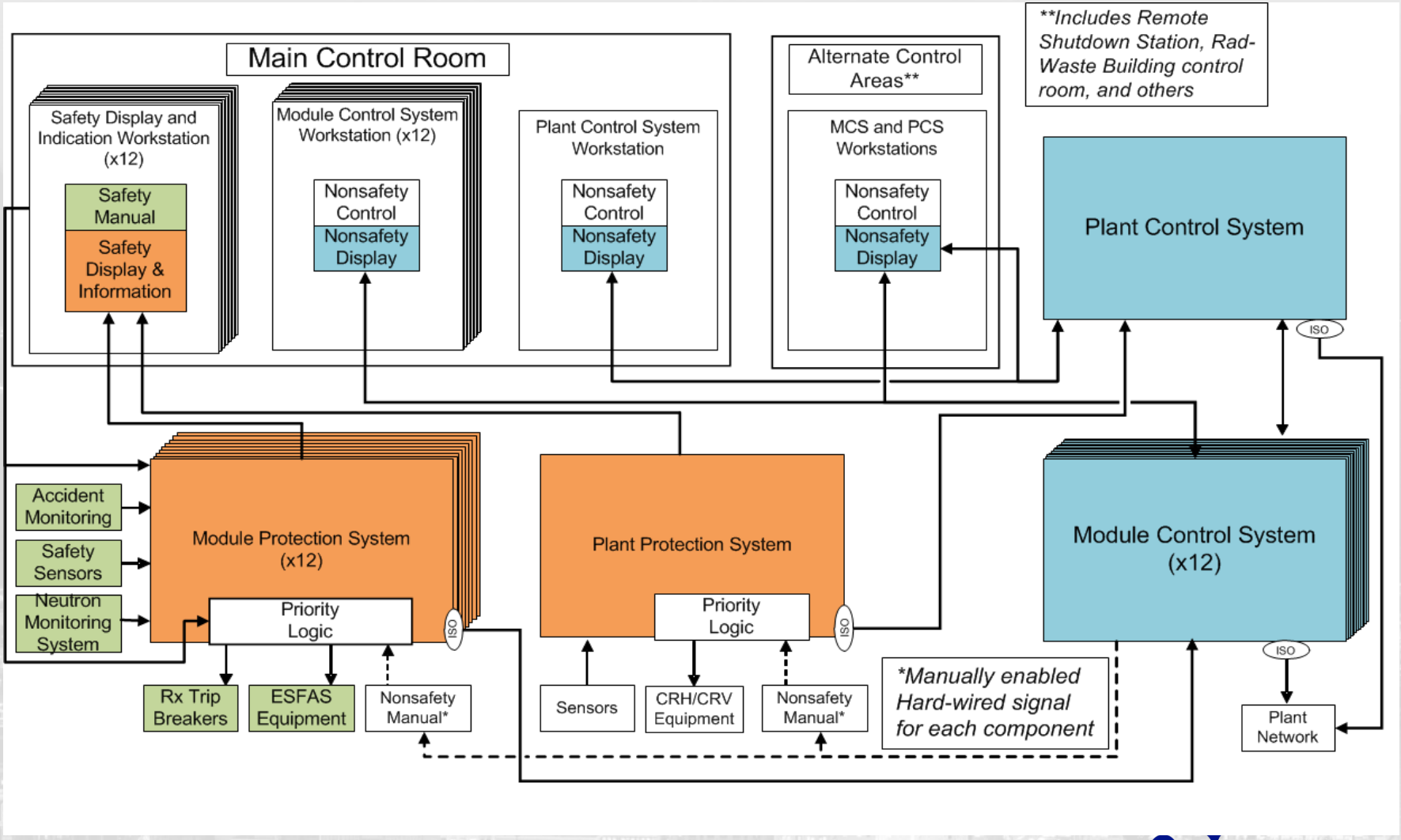



## Safety I&C Platform

- Digital I&C System
- Use of FPGAs allows for diversification within the safety I&C platform
- Passive safety features result in a simpler safety I&C platform
- A simpler and more diversified design results in a more reliable safety I&C platform
- No safety related pumps or fans to control
- Provide Reactor Trip Breaker and Pressurizer Heater Breaker trip signals
- Provide trip signals to solenoid operated valves
- On “loss of power” solenoids de-energize and associated valves fail in the “safe” position and Reactor Trip and Pressurizer Heater breakers open

# I&C Architecture Overview





# NuScale Main Control Room



**NuScale 12-Module**
**Control Room Simulator**



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# Challenges



- Unique NuScale Power Module Design
- Use of Technology in First-of-a-Kind Applications of Sensors and Instrumentation
- Testing, Calibration and Maintenance of I&C components
  - 12 modules – need for efficient maintenance strategies based upon quantity of I&C components

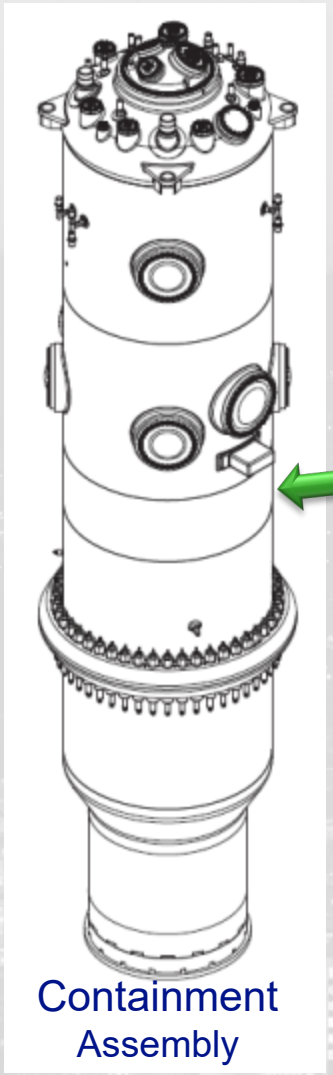
# Unique NuScale Design Features Differences



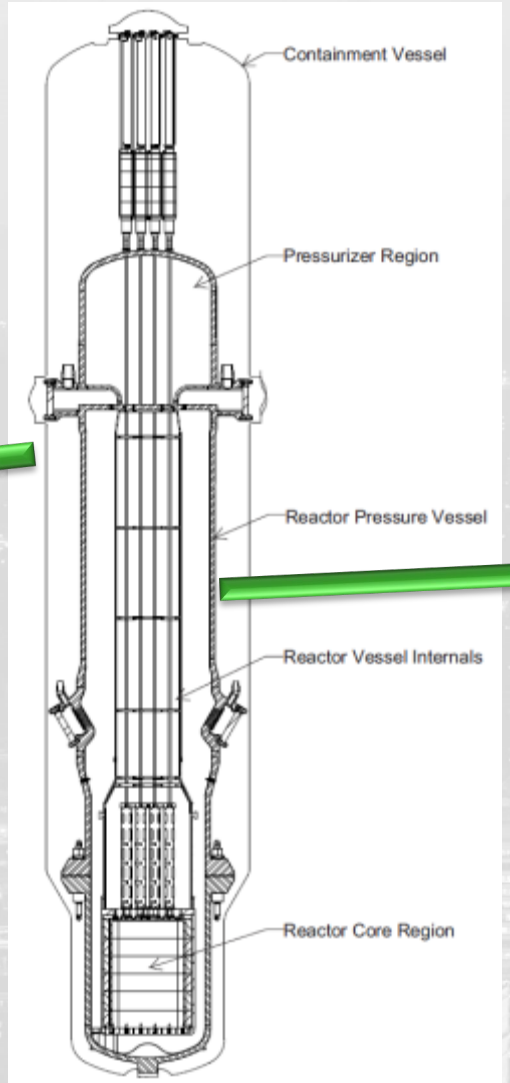
- Natural circulation as a function of power level
  - Testing during changing flow conditions between shutdown and power operations.
- most of the reactor module is under water during normal operation and during most of the refueling evolution
- containment is flooded during refueling
- vacuum conditions in containment during normal operation
- volume of containment is significantly smaller than typical PWR containment
- no reactor coolant system piping
- higher containment temperatures during normal operation and higher containment design-basis event (DBE) temperatures and pressures
- higher containment radiation levels during normal operation and higher containment DBE radiation levels

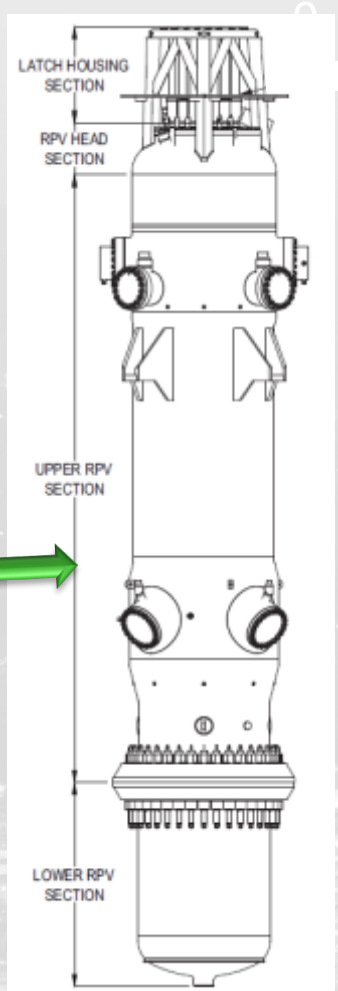
# NuScale Power Module View





Containment Assembly




Reactor Pressure Vessel Assembly



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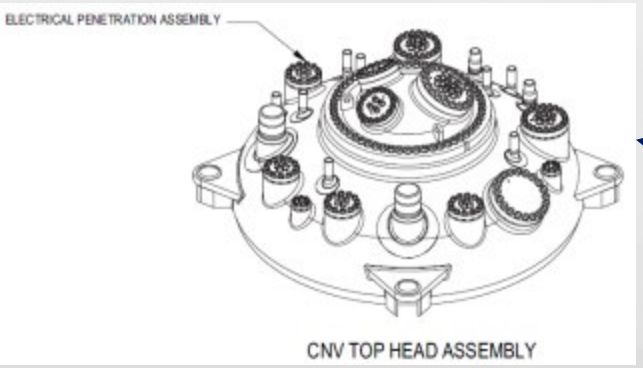
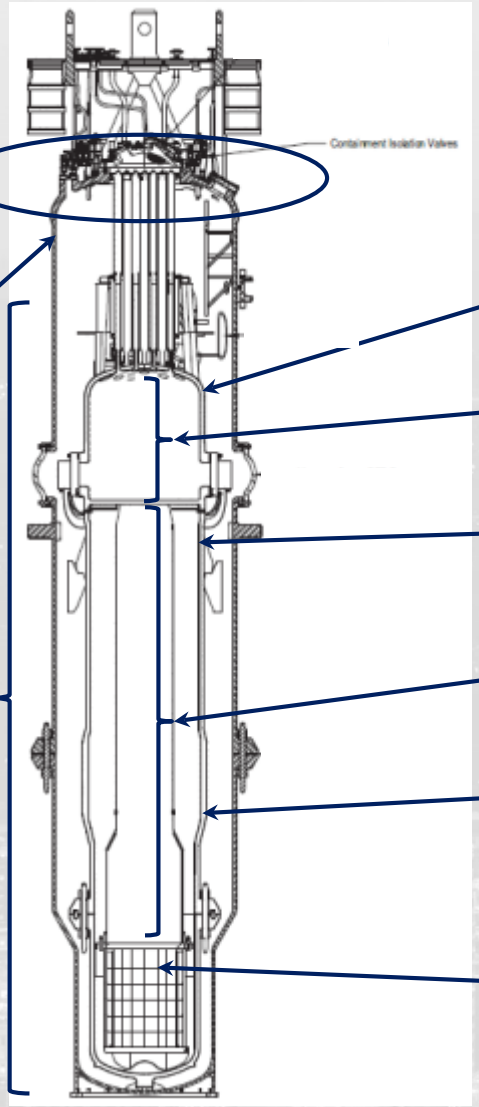
# NuScale Power Module Sensor Locations






Containment Pressure Sensors

Containment Level Sensors

Reactor Coolant Pressure Sensor

Pressurizer Level Sensors

RCS Temperature Sensors

RPV Riser Level Sensors

Reactor Coolant Flow Sensors

Incore Neutron Flux and Temperature Sensor Assemblies

# Sensor Environment



- Development of environmental conditions
  - collaborated with multiple vendors to evaluate sensor technologies and associated environmental conditions
- Example environmental conditions

| | Normal | Design Basis |
|---|---|---|
| Temperature | 295°F<br>(CNV surface temperature) | ~550°F<br>(CNV surface temperature) |
| Pressure | -14.6 psig | 958 psig |
| Radiation | $6.00 \times 10^7$ rads – neutron<br>$3.01 \times 10^6$ rads - gamma | $6.38 \times 10^6$ rads – beta<br>$1.20 \times 10^7$ rads - gamma |

*NuScale Power, LLC, "Final Safety Analysis Report, Chapter 3," Revision 2.*

# First-of-A-Kind Applications



- The NuScale Power Module utilizes both conventional and application of First-of-A-Kind Technologies to Light Water Reactors
- First-of-a-Kind Reactor Protection System
  - Prototype completed in April, 2017.
  - https://newsroom.nuscalepower.com/press-release/nuscale-power-llc-announces-highly-integrated-protection-system-hips-platform
- First-of-a-Kind FPGA-based Display System
  - Prototype completed December, 2018.
  - https://newsroom.nuscalepower.com/press-release/company/nuscale-and-ultra-electronics-energy-unveil-new-digital-display-system-enhance
- First-of-a-Kind Sensor Applications
  - Pressure, Level, Flow

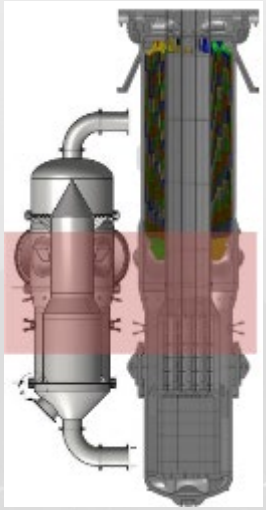
# I&C Sensor Development Focus Areas



- Prototype Development
  - Completed
    - RPV Prototype and Flow Sensor testing completed in 2017.
    - Incore Instrumentation Stringer Assembly prototype completed in 2018.
  - In Development
    - Prototype Sensors for Key Process Variables for Pressure, Level
  - Testing and qualification of sensor applications in unique environments
    - In situ calibration and testing
    - Testing during refueling (module movement)

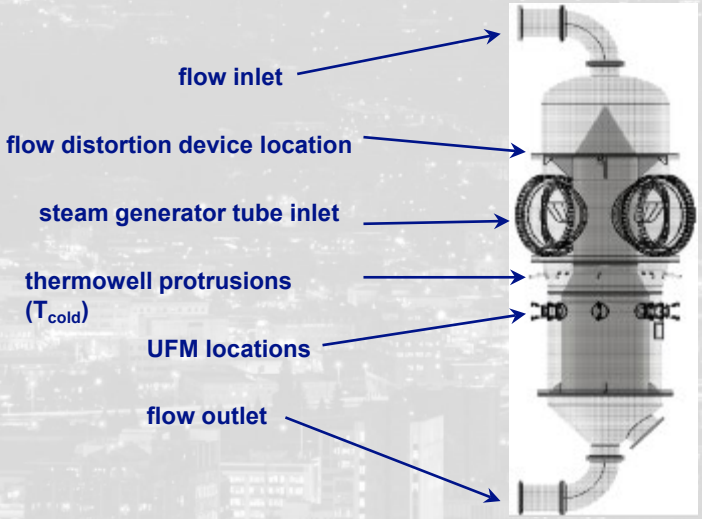
# RCS Flowmeter Model Prototype





Concept → Design

- Completed Phase 2 prototype development testing with NuScale RPV test model
- Confirmed initial technology selection and performance characteristics




Prototype Test Hardware

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# In-Core Instrumentation General Arrangement



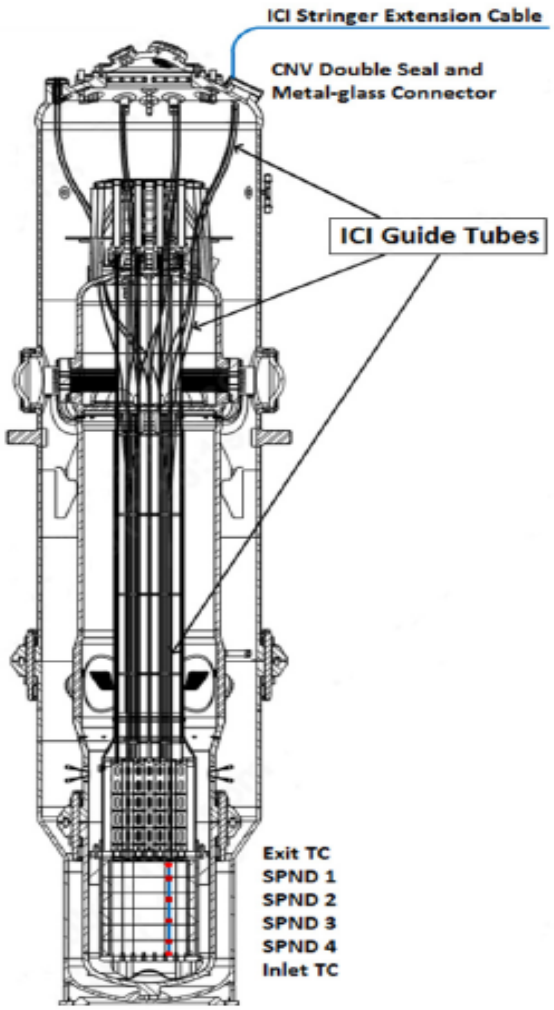


Figure 1 - An overview of the NuScale SMR design and the ICI guide tubes [5].

# In-Core Instrumentation Prototype




# Conclusions



- A phased approach has been used to select the sensor technologies to meet the NuScale design and performance requirements to support commercialization
- Proof of concept work is on-going
  - Completed prototype development for flow sensors and incore instrumentation
  - Key near-term focus areas:  pressure and level sensors
- NSSS sensor design documented in technical report NuScale Power, LLC, "Nuclear Steam Supply Systems Advanced Sensor Technical Report," TR-0316-22048.

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