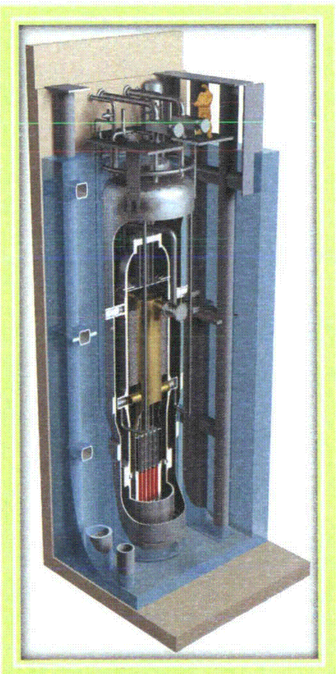
NuScale Integral Systems Test Overview – Closed Session



Bob Houser

Manager Test and Code Development

July 22, 2014

NuScale Nonproprietary

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Presenters

- Jose Reyes, Chief Technology Officer and co-founder of NuScale Power, LLC (NuScale)
- Adam Rasmussen, Testing Supervisor
- Brian Wolf, Lead Engineer Code Validation
- Bob Houser, Manager Testing and Code Development

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Meeting Objectives

- Present past and future testing conducted at NuScale Integral Systems Test (NIST) facility
- Gain alignment regarding the scope of future testing and the scope and timeline of the ongoing facility upgrades
- Identify and discuss any potential additional tests to support design certification:
  - Discuss completeness of NIST test matrix for code validation
  - Discuss relationship between the LOCA PIRT and test matrix

Agenda

Closed Session

- PIRT phenomena and NRELAP5 validation
- Overview of scaling Analysis for NIST-1 Test Facility
- NIST upgrade and capabilities
- Testing completed and planned for DCA
- RELAP5-3D NIST predictions
- Wrap-up

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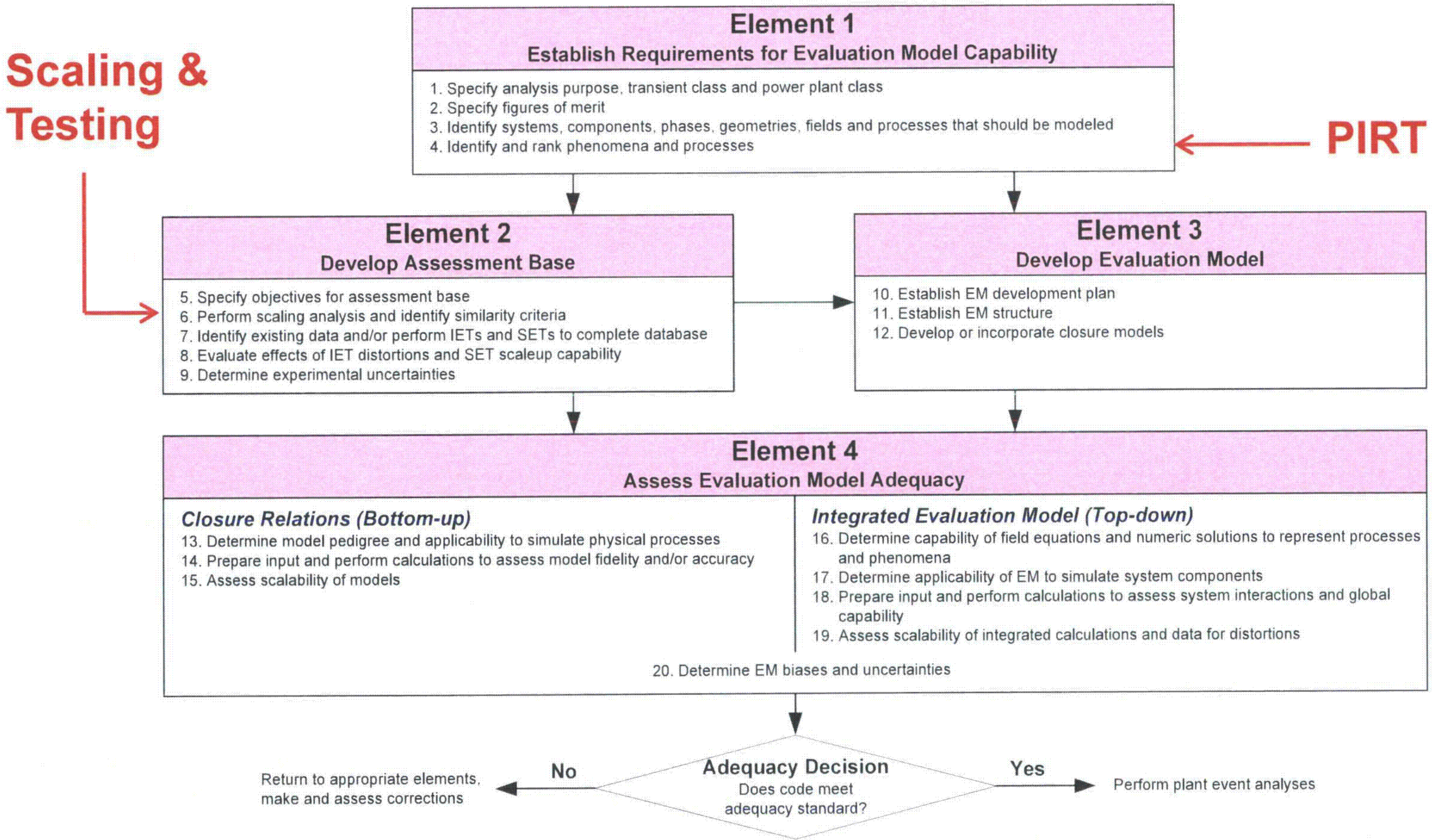
Section 4 – PIRT Phenomena and NRELAP5 Validation

EMDAP for NuScale LOCA Analysis



Evaluation Model Development and Assessment Process (EMDAP)

Regulatory Guide 1.203, "Transient and Accident Analysis Methods," U.S. Nuclear Regulatory Commission, December 2005.

NRELAP5 Validation Matrix

Subsection of NRELAP5 validation matrix for LOCAs

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Testing is used to validate important PIRT phenomena and processes.

Tests are selected to cover the plant range of applicability.

}}3(a)

IET PIRT Phenomena

PIRT phenomena targeted for NIST facility

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}}3(a) and (b)

Key Points

- NIST test data plays an important role in validating NRELAP5 and providing integrated plant response information on key phenomena and processes associated with the NuScale plant:
  - natural circulation normal operation
  - natural circulation passive core cooling systems
  - reactor pressure vessel (RPV), containment (CNV), and cooling pool interactions
  - emergency core cooling system (ECCS) operation/actuation
- Instrumentation is incorporated in NIST to characterize targeted phenomena.
  - significant 3X increase in instrumentation planned for NIST-1 upgrade
- A decay heat removal system (DHRS) will be added to NIST-1 to address important PIRT phenomena and to characterize system interaction effects.
- Final LOCA PIRT rankings will be informed by testing and analysis.

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Section 5 – Overview of Scaling Analysis for the NIST-1 Test Facility

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Scaling Introduction

- NuScale has used its Dynamical System Scaling (DSS) Methodology to obtain the geometric and operating parameters for the NIST-1 facility.
- This NIST-1 scaling analysis provides an application of DSS that can be used to support the review and approval of its scaling methodology topical report.
  - *Dynamical System Scaling (DSS) Methodology, NP-TR-1010-867-P, Revision 1* was issued to the NRC in February 2011 (ML 110680401, Project 0769).
- NIST-1 Scaling Analysis report will be issued to NRC in December 2014 as a Technical Report.

NIST-1 Facility Scaling Analysis Report Objectives

To develop a properly scaled test facility, the following specific objectives must be met for each operational mode of interest.

- The thermal hydraulic processes that should be modeled must be identified.
- The similarity criteria that should be preserved between the test facility and the full-scale prototype must be obtained.
- The priorities for preserving the similarity criteria must be established.
- Specifications for the test facility design or modifications must be provided.
- Biases due to scaling distortions must be quantified.
- The critical attributes of the test facility that must be verified to meet Quality Assurance requirements must be identified.

NIST-1 Scaling Analysis Report Outline

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NuScale System Breakdown into Hierarchical Levels

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}}3(a)-(c)

Key Scale Factors for the NIST-1 Facility

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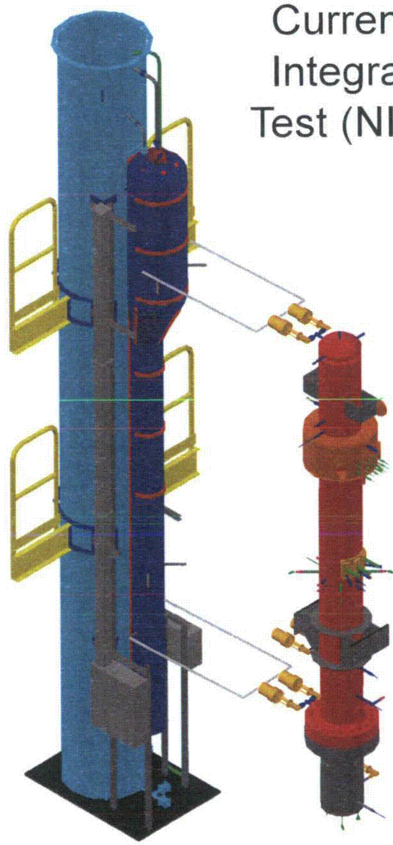
Summary and Conclusions

- DSS methodology has been applied to the design of NIST-1 facility.
- The NIST-1 Scaling Analysis report provides an application of DSS that can be used to support the review and approval of its scaling methodology topical report:
  - *Dynamical System Scaling (DSS) Methodology, NP-TR-1010-867-P, Revision 1* was issued to NRC on February 2011 (ML 110680401, Project 0769)
- The NIST-1 Scaling Analysis will be issued to the NRC in December 2014 as a technical report.
- The key scale factors have been obtained and have been applied to the test facility upgrade.

Section 6 – NIST Upgrade and Capabilities

Current Integral Systems Test Facility

- NuScale technology in development since 2000 (DOE) MASLWR program, lessons from AP1000 ¼-scale testing
- Electrically-heated, 1/3-scale integral test facility first operational in 2003
- NQA-1 program instituted in 2012
  - completed testing
    - facility characterization runs (pressure drop, heat loss, etc.)
    - LOCA runs complete
    - long-term core cooling runs complete
    - steam condensation (270 psig, separate effects)



Current NuScale Integral Systems Test (NIST) Facility

An upgraded facility will enable new types of transients, more prototypic testing, and will produce higher fidelity data.

NIST-1 Facility Upgrade

Upgrade Objective: Provide a well-scaled representation of NuScale's current reactor design that minimizes distortions and provides the measurements necessary for safety code and reactor design validation

- Replace containment and reactor pool module
- Modify portions of integral reactor vessel
- Add DHRS

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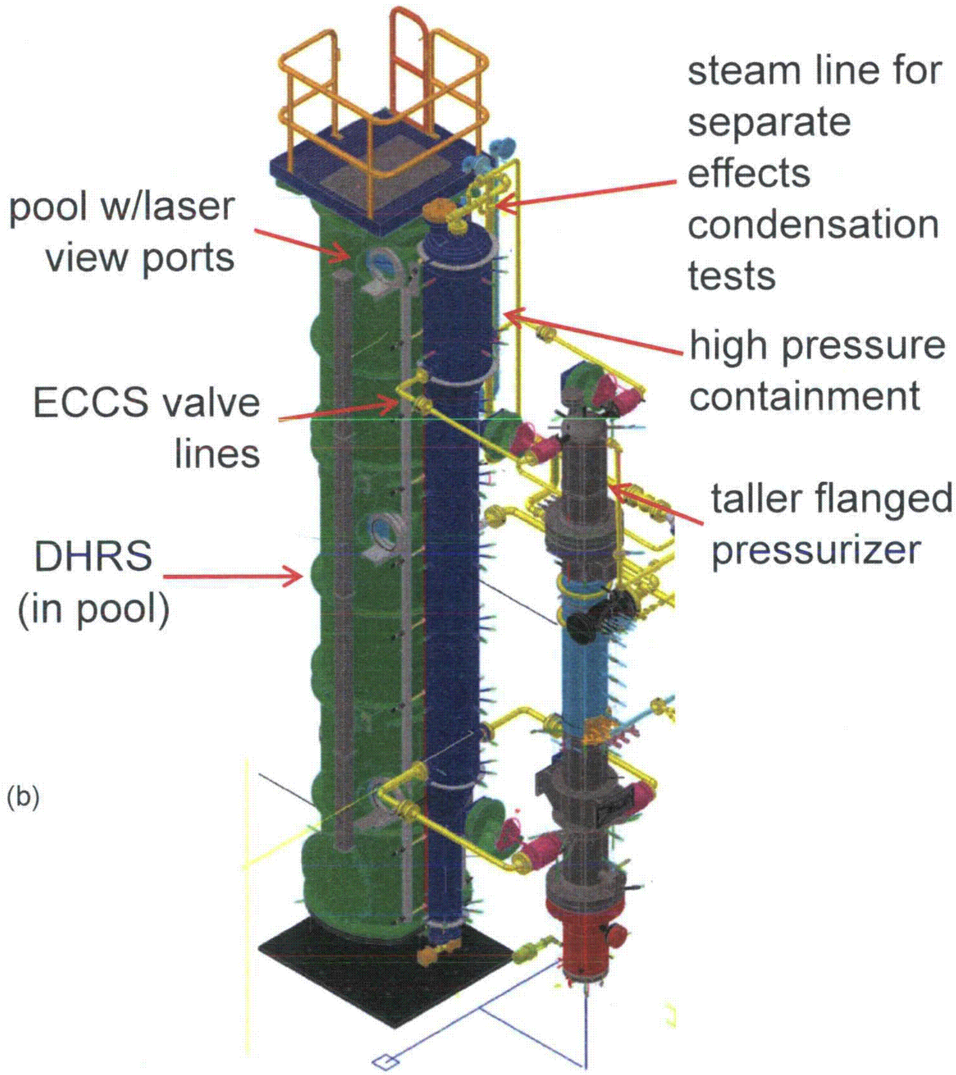
}}3(a) and (b)

- Increase (3X) instrumentation for phenomena capture and validation
- New control room & data acquisition and control system (DACS)



New Containment and Cooling Pool

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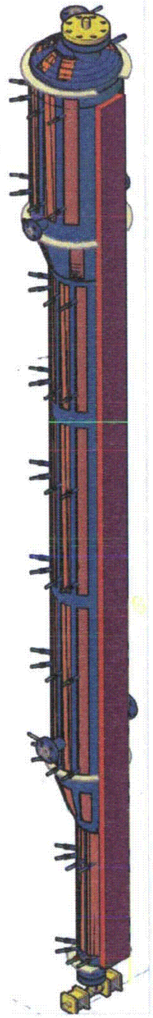
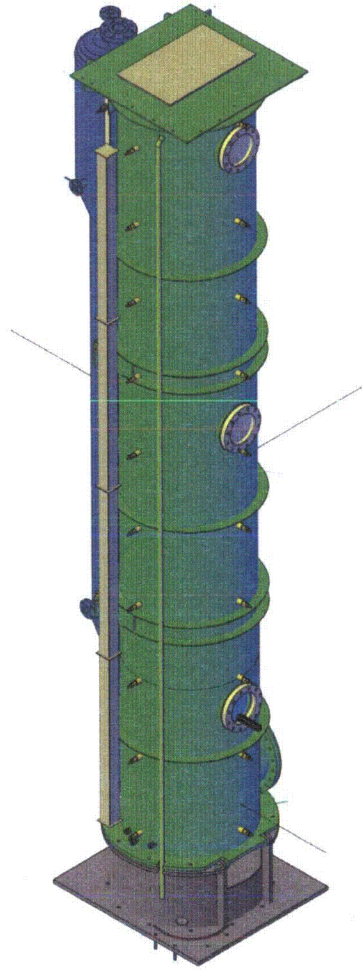
- Highly instrumented heat transfer plate
  - increase instrumentation used to characterize heat transfer from containment to pool



- Cooling pool view ports
  - allow Particle Image Velocimetry (PIV) measurements to characterize local velocities near the heat transfer plate
- DHRS
  - add ability to characterize the DHRS performance under varied DHRS and pool inventories



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Upgrade Instrumentation

- Increased thermocouple (T/C) density to capture thermal profiles and gradients
- New ECCS flow measurements
- Additional and enhanced pressure drop measurements to characterize losses
- New measurement capabilities to capture additional phenomena and processes (PIV in pool, DHRS)

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}}3(a) and (b)

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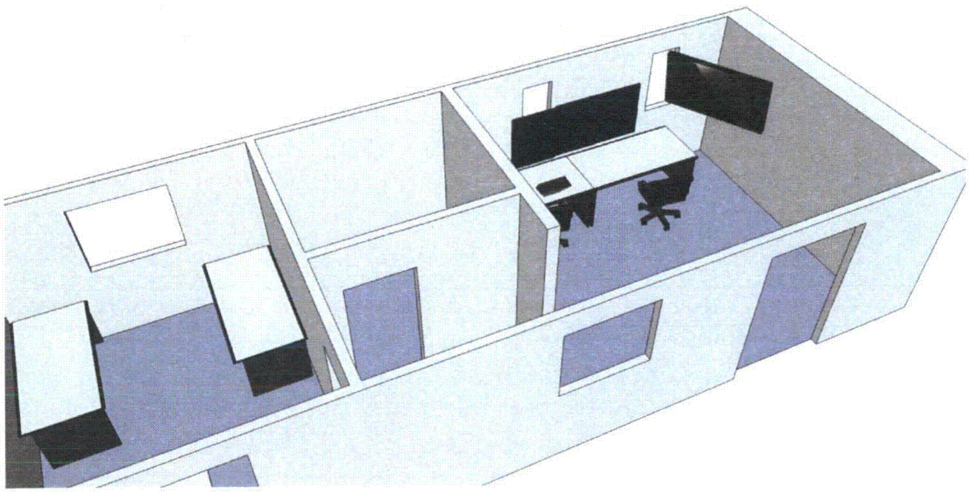
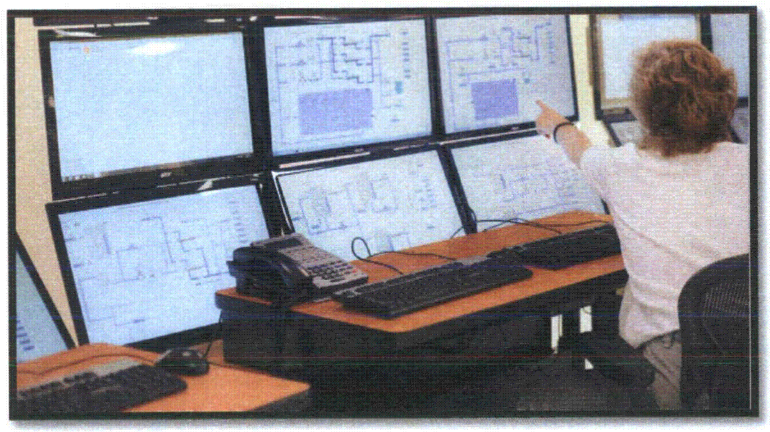
Data Acquisition and Control System

- State of the art data acquisition and control system
  - log all actions and events affecting the facility
  - ability to perform precisely timed and sequenced control actions during test operations
  - multi-display interface for users to monitor and control operation of the NIST facility
  - interface with almost 500 instruments
  - visual indications of alarm conditions
  - automatically initiate control actions (trips) to prevent unsafe operations
  - initiate facility shutdown actions if an emergency stop button is actuated

New Control Room

- Dedicated control room for NIST-1 operations
  - current control room is shared space with APEX control room
- Multi-display interface for users to monitor and control operation of the NIST-1 facility
- Data analysis, evaluation, and reporting stations
- Secure access and controls for NuScale Proprietary Class I data





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Upgrade Project Schedule

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Section 7 - Testing Completed and Planned for DCA

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Tests Completed – Current Facility

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NIST-1 Testing after Upgrade

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NIST-1 Test Matrix (Subject to Change)

Test Identifier	Test Title

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}}3(a)-(c)

ECCS Valve Fails Open - Objectives and Description

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All ECCS Valves Fail Open - Objectives and Description

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}}3(a)-(c)

Long-Term Cooling - Objectives and Description

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}}3(a)-(c)

High Pressure Condensation - Objectives and Description

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}}3(a)-(c)

Cooling Pool Convection - Objectives and Description

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}}3(a)-(c)

Non-LOCA Transients Under Consideration - Objectives and Description

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Section 8 – RELAP5-3D NIST Predictions

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Lessons Learned

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Lessons Learned continued

- No core uncovery measured in test or predicted for any LOCA scenarios
- Steam condensation in the containment is not of high importance relative to core cooling figures of merit
  - 2X change in HTCO value changes peak pressures by ~5%
- RELAP5-3D is an appropriate tool in predicting the integral system behavior of NIST
  - contains the essential models and correlations to represent the important phenomena and processes occurring in NIST
  - limited code development needed for NIST
  - few special process models required (i.e., no accumulators, no separators, no primary pump)

NIST RELAP5-3D Model Nodalization

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Comparisons

- Primary pressure drop characterization
- RVV fails open, no ECCS activation
- RVV fails open, with ECCS activated
- All ECCS valves fail open simultaneously

Primary Pressure Drop Test Initial Conditions

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Primary Pressure Drop Test

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}}3(a) and (b)

Primary Pressure Drop Test

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}}3(a) and (b)

Primary Pressure Drop Test

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}}3(a) and (b)

RVV Open / No ECCS Test Initial Conditions

Parameter	NIST Instrument	Unit	Steady-State Value from Data	Steady-State Value from RELAP5-3D

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}}3(a) and (b)

RVV Open/ No ECCS Test Sequence of Events

Event	Time (s)

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}}3(a) and (b)

RVV Open/No ECCS Test

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RVV Open/No ECCS Test

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}}3(a) and (b)

RVV Open with ECCS Test Initial Conditions

Parameter	NIST Instrument	Unit	Steady-State Value from Data	Steady-State Value from RELAP5-3D

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}}3(a) and (b)

RVV Open with ECCS Test Sequence of Events

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Event	Time (s)

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RVV Open with ECCS Test

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}}3(a) and (b)

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RVV Open with ECCS Test

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}}3(a) and (b)

RVV Open with ECCS Test – {{ }}3(a)-(c)

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}}3(a) and (b)

All ECCS Valves Open Test Initial Conditions

Parameter	NIST Instrument	Unit	Steady-State Value from Data	Steady-State Value from RELAP5-3D

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}}3(a) and (b)

All ECCS Valves Open Test Sequence of Events

Event	Time (s)

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}}3(a) and (b)

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All ECCS Valves Open Test

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}}3(a) and (b)

All ECCS Valves Open Test – {{ }}3(a) and (b)

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}}3(a) and (b)

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Section 9 - Wrap-up

Key Points

- A major test facility upgrade is in progress that will be complete at the end of this calendar year with testing resuming in February 2015.
- This upgrade aligns the NIST test facility with the NuScale reactor design.
- Additional instrumentation will be included to characterize those phenomena and processes identified as important in the LOCA PIRT and targeted for evaluation in the NIST facility.
- NuScale's proprietary Dynamical System Scaling methodology was used to
  - obtain the scaling factors used to design the NIST upgrade
  - provide similitude for key LOCA phenomena and processes
  - identify and minimize testing distortions
- Final LOCA PIRT rankings will be informed by NIST testing and analysis.

Insights and Lessons Learned

- RELAP5-3D contains the essential models and correlations necessary to represent the important phenomena and processes observed at NIST that influence integral system behavior.
- One-dimensional test facility modeling using RELAP5-3D captures the test data trends and magnitude.

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}}3(a) and (b)

- Core uncovery has not occurred for any design basis LOCA scenarios tested nor has it been predicted. Accordingly, core heat-up for LOCAs is not anticipated.
- Steam condensation heat transfer in the containment is well predicted by the existing RELAP5-3D correlation up to 270 psig.

NRC Feedback

- Questions and comments?
- Gain alignment regarding the scope of future testing and the scope and timeline of the ongoing facility upgrades
- Identify and discuss any potential additional tests to support Design Certification:
  - discuss completeness of NIST test matrix for code validation
  - discuss relationship between LOCA PIRT and test matrix

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