LWRS Newsletter
Light Water Reactor Sustainability
Issue 8 • July 2012

Meet the LWRS Program Managers

Kathryn A. McCarthy
Director, LWRS Program
Technical Integration Office

Some of the Light Water Reactor Sustainability (LWRS) Program managers have changed; therefore, I would like to provide a brief introduction to all of the LWRS program managers: the LWRS Federal Program Manager, the Technical Integration Office, and the Pathway Leads.

Richard A. Reister
U.S. Department of Energy, Office of Nuclear Energy

Mr. Reister manages the Department of Energy's LWRS Program in the Office of Nuclear Energy. He previously managed the NP2010 program to expand the contribution of nuclear power to the nation's energy portfolio and the International Nuclear Safety Program that improved the safety of Soviet-designed reactors in the wake of the Chernobyl accident. He has worked on nuclear matters within the Department of Energy for over 20 years. Prior to this, he served in the U.S. Navy's nuclear submarine program. Mr. Reister is a member of the American Nuclear Society.

Donald L. Williams
Oak Ridge National Laboratory

Mr. Williams is the Deputy Director of the LWRS Program Technical Integration Office. He has 38 years of combined experience at the Tennessee Valley Authority and Oak Ridge National Laboratory.

Mr. Williams' responsibilities at Tennessee Valley Authority included design, pre-operational testing, licensing, and management activities affecting 17 nuclear reactors either in operation or under construction at seven commercial nuclear power plant sites. Since joining Oak Ridge National Laboratory in 1989, Mr. Williams has supported a number of nuclear technology and nonproliferation programs for U.S. government agencies. As Deputy Director of the Technical Integration Office, Mr. Williams provides technical and project management leadership in collaboration with the Department of Energy's Office of Nuclear Energy, the U.S. Nuclear Regulatory Commission, other national laboratories, and industry to establish the scientific and technical basis for extending commercial nuclear power plant operations beyond 60 years.

Mr. Williams is a member of the American Nuclear Society and the Society for Standards Professionals. He served on the American National Standards Institute's Executive Standards Council (1993 - 1994), and he received a "Hammer Award" in 1997 under the Federal Government's National Performance Review Program led by Vice President Al Gore.

Cathy J. Barnard
Idaho National Laboratory

Ms. Barnard is the Operations Manager for the LWRS Program Technical Integration Office. She has 25 years of program management experience. She has successfully managed projects ranging from $50 to $180 million. Previously, Ms. Barnard worked at the Lawrence Livermore National Laboratory where she conducted physical and mechanical experiments on plutonium and its alloys and managed the plutonium chemistry laboratories. Ms. Barnard is a member of the American Nuclear Society.

Jeremy T. Busby
Oak Ridge National Laboratory

Dr. Busby leads the Materials Aging and Degradation Pathway for the LWRS Program. Dr. Busby's research is focused on materials performance and development of materials for nuclear reactor applications. While at Oak Ridge National Laboratory, Dr. Busby has participated

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in materials research efforts for space reactors, fusion machines, advanced fast reactors, and light water reactors.

In 2010, Dr. Busby received the Presidential Early Career Award for Science and Engineering, for "excellence in research leading to the development of high performance cast stainless steels, a critical part of the U.S. Contributions to the International Thermonuclear Experimental Reactor project, and for his mentoring of students both as an Adjunct Assistant Professor at the University of Michigan and at Oak Ridge National Laboratory." In 2011, he was awarded a Secretary of Energy Achievement Awards for contributions to the Department of Energy's response to Fukushima. The American Nuclear Society presented Dr. Busby with the Landis Young Member Achievement award in 2006 and, in 2007, he received the Oak Ridge National Laboratory Early Career Award for Engineering Accomplishment for his leadership in the cast stainless steel effort.

He is an Adjunct Assistant Professor of Nuclear Engineering and Radiological Sciences at the University of Michigan and has developed and taught his own graduate level course in materials degradation and performance for fission and fusion reactors.

Bruce P. Hallbert
Idaho National Laboratory

Dr. Hallbert leads the Advanced Information, Instrumentation, and Controls Systems Technologies Pathway for the LWRS Program. He has a broad background in the international nuclear industry, having worked over 20 years with national and international agencies on issues that include human reliability analysis and probabilistic risk assessment; advanced reactor control room design and staffing; advanced alarm systems; emergency operating procedures, accident management; management and organizational factors; safety culture; and the risk impact of operational accidents.

Dr. Hallbert currently serves as the President of the International Association of Probabilistic Safety Assessment and Management; he is a member of the board of external advisors to the Ohio State University and the University of Tennessee departments of Nuclear Engineering. In the past, he has served as U.S. representative to the International Atomic Energy Agency technical working group on instrumentation and controls for nuclear power plants. He is a member of the Institute of Electrical and Electronics Engineers' Power Engineering Society.

LWRS Program Managers

Richard A. Reister

Kathryn A. McCarthy

Donald L. Williams

Cathy J. Barnard

Jeremy T. Busby

Bruce P. Hallbert

Curtis L. Smith

Shannon M. Bragg-Sitton

Curtis L. Smith
Idaho National Laboratory

Dr. Smith leads the Risk-Informed Safety Margin Characterization Pathway for the LWRS Program. Dr. Smith is a risk and reliability expert with over 20 years of experience and both national and international recognition. Within the probabilistic risk assessment community, he is recognized as an expert in complex system modeling methods and associated tools development, Bayesian inference techniques, advanced quantification approaches, and course development and instruction on probabilistic risk assessment issues. Most recently, he has been involved in Fukushima Event Reconstruction activities.

Dr. Smith is involved in the professional community, including serving on the American Society of Mechanical Engineers Safety Engineering and Risk Analysis Executive Committee, the Idaho State University College of Engineering Advisory Council, a Lifetime member and published author for the Idaho Academy of Sciences, and is a steering committee member for the ELEUSI Research Center – University of Bocconi, Italy.

Shannon M. Bragg-Sitton
Idaho National Laboratory

Dr. Bragg-Sitton leads the Advanced Light Water Reactor Nuclear Fuels Pathway for the LWRS Program. In addition to leading the Advanced Light Water Reactor Nuclear Fuels Pathway, Dr. Bragg-Sitton is responsible for development of tungsten-uranium dioxide cermet fuel for nuclear thermal propulsion engines for Space Reactor Technology Development; she works with both the Department of Energy and National Aeronautics and Space Administration team members on space reactor design and analysis for nuclear thermal propulsion and for lunar or Martian surface power.

Dr. Bragg-Sitton has received numerous awards, including the National Aeronautics and Space Administration Exceptional Engineering Achievement Award (2007), the Outstanding Paper Award, Space Technologies and Applications International Forum (2006), and the Craig C. Brown Senior Achievement Award, Texas A&M University (1997). She is a member of the American Nuclear Society and is a founding member of the North American Young Generation in Nuclear organization. She has been extensively involved in organizing both national and international conferences for the space nuclear community and for young professionals in nuclear.

Prior to joining the Idaho National Laboratory, Dr. Bragg-Sitton was an Assistant Professor at Texas A&M University in the Department of Nuclear Engineering. She currently is an adjunct faculty member and assistant research engineer at Texas A&M University.

Zhili Feng

Materials Aging and Degradation Pathway

Oak Ridge National Laboratory

Fellow Announcement

The American Welding Society has elected the Materials Science and Technology Division's Dr. Zhili Feng to its 2012 class of Fellows. Dr. Feng leads the Materials Joining group. The American Welding Society recognized his outstanding contributions in several important areas such as computational welding mechanics, friction-stir welding and processing, characterization of weld by advanced neutron and synchrotron scattering, and novel solid-state joining processes of dissimilar metals. He has published over 120 journal publications and conference proceedings and holds three U.S. patents. Dr. Feng will be inducted at the American Welding Society annual business meeting in November 2012.

Dr. Feng will present recent research results on welding residual stress modeling and measurement at the ASME Pressure Vessel and Piping Conference. This research was conducted for the LWRS Program and in collaboration of Electric Power Research Institute and Nuclear Regulatory Commission.

Computer-Based Procedures: A Realistic Path Forward for Field Workers in Nuclear Power Plants to Support Enhanced Human Performance

Johanna H. Oxstrand
Advanced Instrumentation, Information, and Control Systems Technologies Pathway

The introduction of advanced technology in existing nuclear power plants may help to manage the effects of aging systems, structures, and components. In addition, the advanced technology may ensure the technology base of the future workforce at nuclear power plants is one with which people are familiar. Advantages are being sought by developing and deploying technologies that offer improvements in safety and efficiency. One significant opportunity for existing plants to increase efficiency is to phase out the paper-based procedures currently used at most nuclear power plants and replace them, where necessary and feasible, with computer-based procedures (CBPs).

Although CBPs have been investigated as a way to enhance operator performance on procedural tasks in the nuclear industry for almost 30 years, they currently are not widely deployed at U.S. utilities. One barrier to this wide-scale deployment is the lack of operational experience with CBPs within the nuclear utilities. Utilities are hesitant to adopt CBPs because of concerns over both potential costs of implementation and potential regulatory concerns. Regulators require a sound technical basis for the use of any procedure at the utilities; without operating experience to support the use of CBPs, it is difficult to establish such a technical basis.

The LWRS Program's Advanced Instrumentation, Information, and Control Systems Technologies Pathway is partnering with industry in conducting research, development, and deployment in the following four pilot projects:

- Pilot Project 1: Advanced Outage and Control Center
- Pilot Project 2: Digital Control Room Upgrades
- Pilot Project 3: Improved Plant Operator Performance in Plant Configuration Control
- Pilot Project 4: Improved Operator Performance with Computer-Based Procedures.

The research effort for Pilot Project 4 was started early in Fiscal Year 2012 and is the newest of the four pilot projects. In Pilot Project 4, Advanced Instrumentation, Information, and Control Systems Technologies Pathway researchers are working with the nuclear industry to explore CBPs with the objective of defining requirements for CBPs and developing an industry-wide vision and path forward for the use of CBPs.

The research effort in Pilot Project 4 utilizes the findings from Pilot Project 3. Pilot Project 3 demonstrated, through a series of studies at Catawba Nuclear Station, that human performance could be improved by using CBPs on handheld devices out in the field (Figure 1). The CBP pilot project is leveraging these findings and focusing on how to design the user interface and user experience to enhance human performance, increase operator efficiency, and reduce the risk of errors by streamlining and distilling the information in the paper-based procedures.

Researchers take an iterative approach to defining the requirements. The research team began by working closely with industry partners to identify the real issues that utilities are having with procedural use. The team conducted an initial literature review to identify gaps in research on CBPs, specifically looking for empirically based research that provides a sound basis for a transition to CBPs. The research team conducted a user needs analysis to gain a better understanding of the nuclear power plant utilities' current plans for implementing CBPs, the current infrastructure in place to support CBPs, and the perceived or real barriers to implementing CBP systems. Finally, researchers conducted a qualitative study aimed at identifying how operators interact with procedures in the field. Field operators and maintenance technicians from four nuclear power plant utilities participated in the study.

Results from the research activities were incorporated into a model of procedure usage, which is a detailed description of how the operator interacts with a procedure (see Figure 2). The purpose of the model is to identify the physical and cognitive actions involved in the execution of one procedure step, as well as potential error traps and factors affecting the risk of these human errors. The research team, in the process of identifying the requirements, used the model of procedure usage for CBPs and in the prototype development process. It is critical that the error traps identified in the model are adequately addressed and the cognitive load on the operator reduced.

Based on the results from the research activities and the model of procedure usage, a set of general requirements was defined and was based on two selection criteria: (1) a clear and attainable solution for the potential error identified in the model of procedure usage, and (2) no negative consequences identified related to the specific requirement. This set of general requirements is listed as follows and should be viewed as the minimum requirements needed to address the specific challenges identified in the research activities:

1. Guide operators through the logical sequence of the procedure. The CBPs should be designed so they automatically take the operators through the specified procedure path based on initial conditions and operator input.
2. Ease the burden of place keeping for the operator. CBPs should keep track of where the operator is in the procedure, should mark steps as completed, and should highlight the current step.
3. Make the action steps distinguishable from information gathering steps. CBPs should use some method to differentiate steps for which an operator must actually manipulate the plant versus when he/she must simply check a condition or value.
4. Alert operator to dependencies between steps. Typically, the operator has to rely on previous experience or on a caution or warning in order to identify the situations in which he/she needs to read ahead in the steps. CBPs should alert the operator when he/she reaches a step with dependencies, rather than relying on him/her to read ahead (or remember from previous experience) to detect the dependency. Additionally, if a CBP system has access to real-time plant data, the system should alert the operator when the plant status changes in a manner that affects the operator's task.
5. Ease the burden of correct component verification for the operator. CBPs should employ some method to automate correct component verification (e.g., include barcode scanning or text recognition functionality).
6. Ease the identification and support assessment of the expected initial conditions. Some method of illustrating the expected initial conditions in a simple and easy to understand manner should be available to the operator through the CBPs. For example, a schematic or piping and instrument diagram of the relevant equipment could be available on demand.
7. Ease the identification and support assessment of the expected plant and equipment response. Some method of illustrating the expected equipment and plant response in a simple and easy to understand manner should be available to the operator through the CBPs. For example, a schematic or piping and instrument diagram of the relevant equipment could be available on demand.

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Figure 1. Field operators testing the technology prototype during the human performance pilot project demonstration at Catawba Nuclear Station, August 2011.

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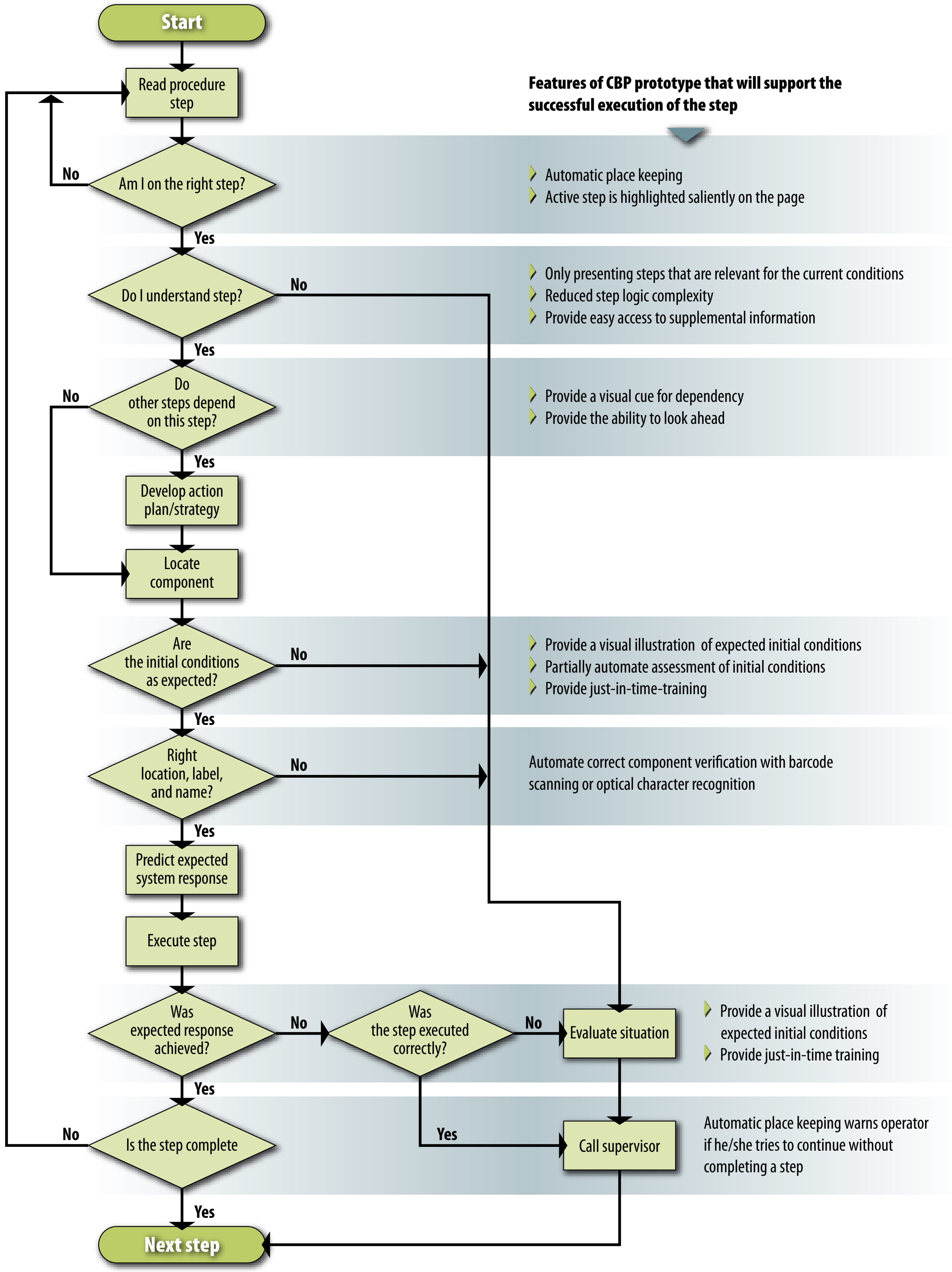

Figure 2. The model of procedure usage.

8. Include functionality that improves communication. In the event that an operator encounters a situation that he/she needs to contact a supervisor to resolve, he/she needs to be able to efficiently and accurately describe the problem. Tools (such as texting, capturing photographs, and streaming video) have all been identified as highly desirable to build into any device that displays CBPs.

The research team complemented the set of general requirements with a list of specific CBP requirements for field operators. The CBP list of specific requirements was developed based on a review of existing CBP guidance. Examples of this list include the following field CBP-specific requirements:

1. Be designed so the operator controls the procedure pace.
2. Make calculations when necessary information is available.
3. Alert users when procedure steps or conditions have been violated.
4. Alert users when conditions require transitioning to another procedure.
5. Evaluate step logic when necessary information is available.
6. Be designed so it is easy for the user to "undo" an unintended or incorrect action (an error of commission).
7. Allow the operator to look ahead and look back in the procedure.

The next step in this research effort is to design prototypes of CBPs based on both sets of initial requirements. Together, with industry partners, the research team will select one specific procedure to implement as a CBP. In August 2012, an evaluation study will be conducted at Palo Verde Nuclear Generating Station (see Figure 3), focusing on the use of both the CBP and the current paper-based procedure version of the selected nuclear power plant procedure and a comparison of the two. Field workers at the plant will be observed using both versions of the procedure. The purpose of the evaluation study is to compare the use and execution of the CBP to the current use and execution of the paper-based procedure version. The CBP's user interface design also will be evaluated in terms of usability, acceptability, and potential increased process efficiency. The results of the evaluation study will support a refined set of requirements and inform the design of a refined CBP prototype, which will then be tested and evaluated again. The research team plans to conduct the next evaluation study at Catawba Nuclear Station in October 2012.

Throughout the process, the research team will work closely with industry to ensure the guidance developed is relevant to existing and future needs, provides realistic solutions, and is presented so that it can be effectively implemented by utilities.

Figure 3. Palo Verde Nuclear Generating Station.

RELAP-7 Strategy and Status

Within the LWRS Program, the purpose of the Risk-Informed Safety Margin Characterization Pathway is to develop and deploy approaches to support the management of uncertainty in safety margins quantification to improve decision making for nuclear power plants. Management of uncertainty implies the ability to (a) understand and (b) control risks related to safety. Consequently, the Risk-Informed Safety Margin Characterization Pathway is dedicated to improving both aspects of safety management.

Curtis L. Smith
Risk-Informed Safety Margin Characterization Pathway Lead

Richard C. Martineau
Risk-Informed Safety Margin Characterization Pathway

To support decision-making regarding plant life extension, we are developing advanced methods and tools for safety assessment that enable more accurate characterization of the plant's safety margins. One of the key elements to understanding these margins is the ability to determine the plant's physical response as a function of off-normal conditions. Accordingly, this pathway will use an improved plant physics code called RELAP-7 (under development in the Department of Energy (DOE) Nuclear Energy Advanced Modeling and Simulation Program in coordination with the LWRS Program) that addresses the representation of the fluid and thermal phenomena found in a nuclear power plant

RELAP-7 Goal

The goal of the RELAP-7 development is to use advanced computational techniques to simulate the behavior of a nuclear power plant in a way that develops more comprehensive safety insights and enables a more useful risk-informed analysis of plant safety margin. RELAP-7 is a systems-level code. Consequently, it will represent physical behavior at the plant level by simulating a range of phenomena for systems, structures, and components at an applicable level of detail.

Objective of the RELAP-7 Development

One feature of the Risk-Informed Safety Margin Characterization method is that it can be used to find vulnerabilities that affect safety margins. In general, a margins analysis approach for carrying out simulation-based studies of safety margin uses the following generic process steps:

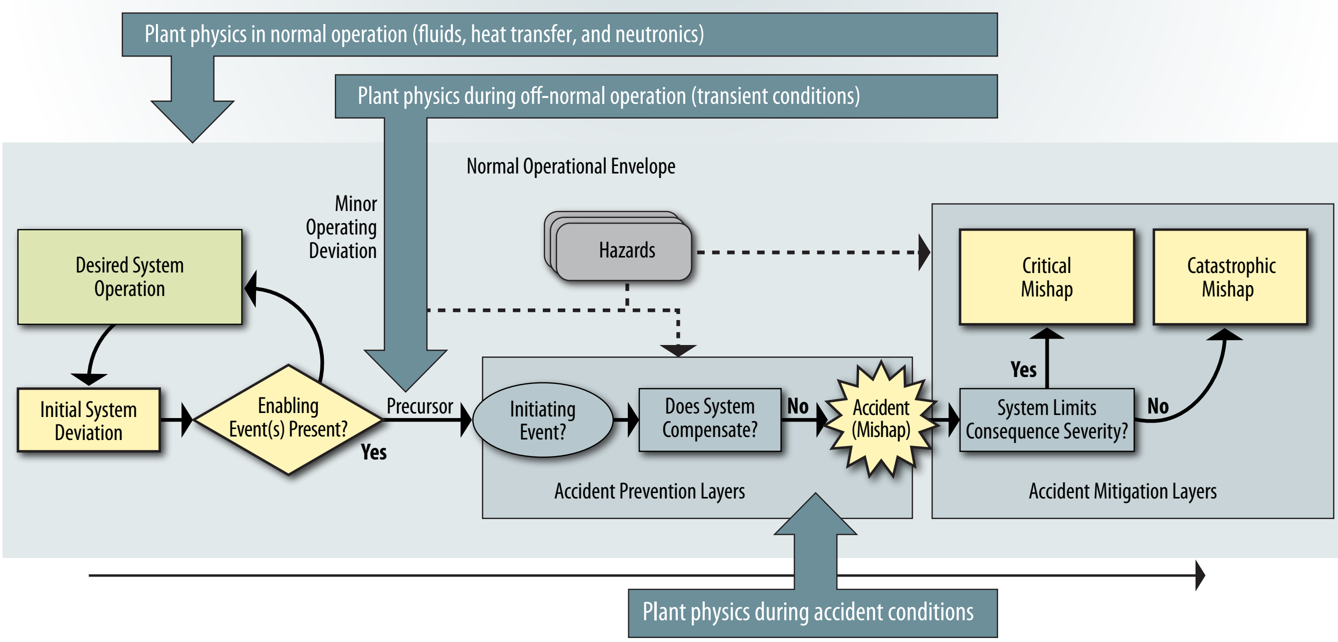

Figure 4. Characteristics of the accident scenario simulation for the RELAP-7 calculations.

1. Determine issue-specific, risk-based scenarios and accident timelines.
2. Represent plant operation probabilistically using the scenarios identified in Step 1.
3. Represent plant physics mechanistically using RELAP-7.
4. Quantify probabilistic load and capacity relating to safety to determine the margin.
5. Identify and characterize the factors and controls that determine safety margin within this issue to determine the safety case.

As indicated in the steps above, RELAP-7 is a critical technology in safety margins characterization. As we evaluate off-normal situations using RELAP-7, the calculations that are required for plant simulation become complex. For example, Figure 4 shows some of the types of mechanistic calculations that would be required as part of the safety margins approach. Ultimately though, the merging of accident scenarios with RELAP-7 will allow us to integrate the mechanistic methods of system processes with the probabilistic methods of risk assessment to provide a complete, consistent, and comprehensive characterization of safety margins in a nulcear power plant.

The objective of the RELAP-7 development is to provide capabilities for a next-generation nuclear reactor system safety analysis code that will be able to support safety margins characterization calculations. These capabilities will support integration with industry needs and requirements (for example, as described in the Electric Power Research Institute's report titled "Desired Characteristics for Next Generation Integrated Nuclear Safety Analysis Methods and Software" [EPRI 2010]). In addition to enhanced capabilities, RELAP-7 will retain and extend the RELAP5-3D functionality (Idaho National Laboratory 2012).

To carry out the objective of RELAP-7, several capabilities will be needed. RELAP-7 is based on the Idaho National Laboratory Multi-physics Object-Oriented Simulation Environment (MOOSE) development framework. (Gaston, Hansen and Newman 2009). Further, it will be nearly backward compatible with the RELAP-5 input format; it will include improved semi-implicit algorithms for short duration transients; it will use full implicit coupling algorithms for long duration transients; it will represent all-speed ($0 \leq \text{Mach} \leq 1$) and all-fluid (two-phase, gas, liquid metal) flow; and it will be second-order accurate temporal and spatial discretization in order to eliminate traditional numerical errors.

Current Development Status

First Alpha Version

The development of RELAP-7, based on the MOOSE framework, started in the fall of 2011. The first beta version is scheduled for release at the end of 2014, with incremental "alpha" versions provided (as shown in Figure 5). Recently (May 15, 2012), the Risk-Informed Safety Margin Characterization Pathway completed the α-0.1 deliverable (Anders et al. 2012).

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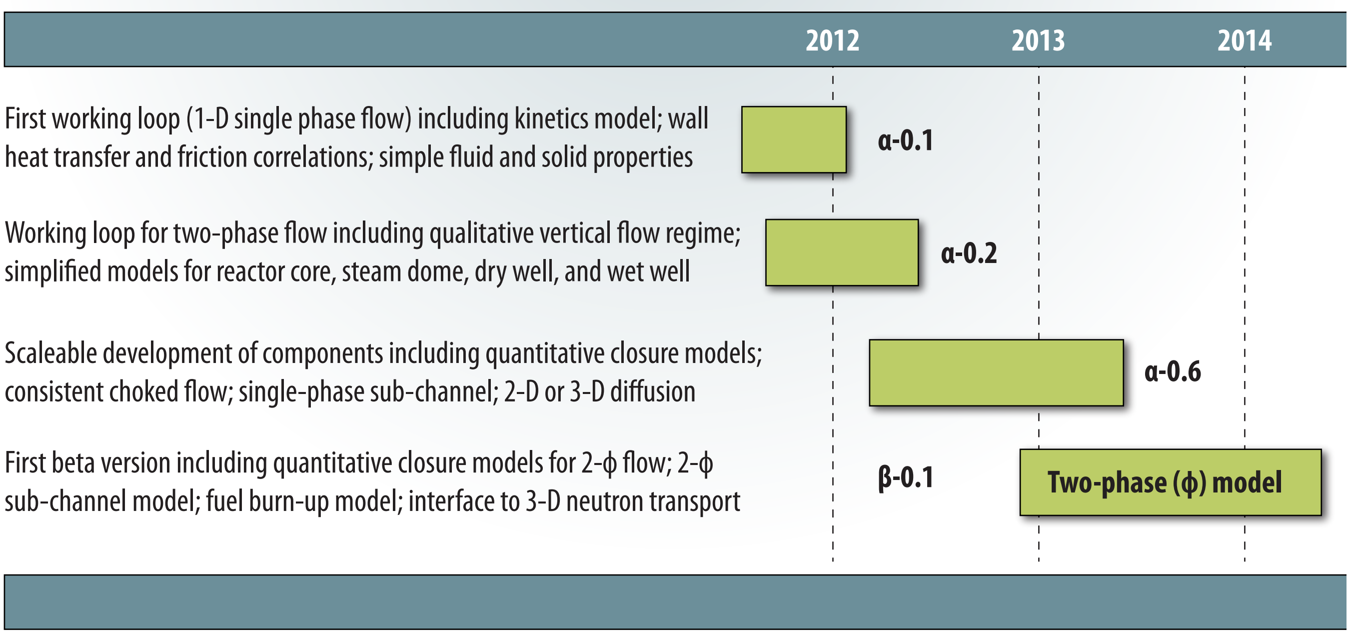

Figure 5. RELAP-7 development time table.

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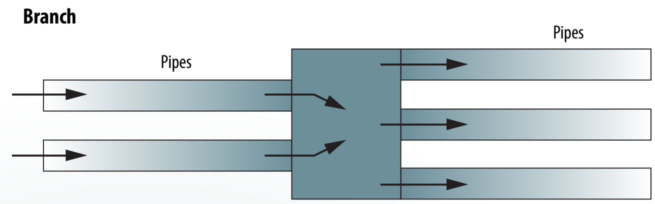
This version of RELAP-7 includes physical models such as partial differential equations, ordinary differential equations, and experimental based closure models. RELAP-7 will eventually use well-posed governing equations for multi-phase flow, which can be strictly verified. Note that the closure models used in RELAP5-3D and newly developed models will be reviewed and selected to reflect the progress in developing two-phase flow models during the past three decades.

RELAP-7 uses modern numerical methods, which allow implicit time integration, higher order schemes in both time and space, and strongly coupled multi-physics simulations. RELAP-7 is written with the object-oriented programming language C++. The preliminary RELAP-7 software structure has been designed inside the MOOSE framework; key highlights for the α-0.1 version include the following:

- Numerical stability schemes for single-phase flow have been developed.
- Several major components have been completed (designed and tested):
  - One-dimensional components, including pipe, core channel, and heat exchanger
  - Zero-dimensional components for setting boundary conditions, including time-dependent volume, time-dependent junction, and time-dependent mass flow rate
  - Zero-dimensional components for connecting one-dimensional components, including junction/branch and pumps.
- User input interfaces have been designed to facilitate model creation.

Examples of the represented components include branches and pumps.



Branch
A branch is a general-purpose junction with multiple inlets and outlets in order to agregate fluid flow. A branch has one to many inlets and outlets. Each connection in a branch has an individual form loss coefficient K pressure loss.

Pump
A pump can be treated as a single junction connecting two pipes and provides a momentum source into the fluid system. For steady-state positive flow, the pump provides a nominal pump head. For reverse flow, it provides a flow resistance. More realistic pump models such as those found in RELAP5-3D will be developed later.

Pressurized Water Reactor Case Study

An example case study selected for initial demonstration of RELAP-7 is the simulation of a two-loop, steady-state pressurized water reactor. The model contains two parallel loops and multiple reactor core flow channels (see Figure 6). The reference design for this

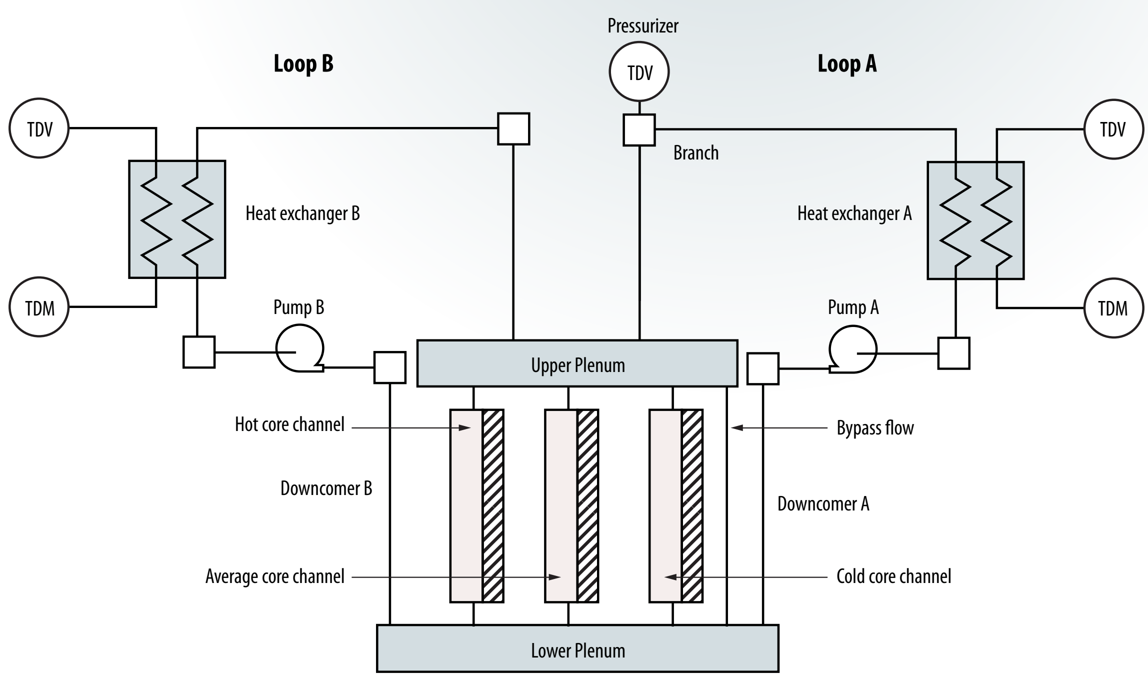


Figure 6. Schematic of the pressurized water reactor case study plant.

case study was based on the Organization for Economic Cooperation and Development (OECD) main steamline break benchmark problem nuclear power plant (NRC and OECD 1999). The simulation begins as a transient and progresses toward a converged steady state.

RELAP-7 α-0.1 was used to represent the case study plant to obtain steady-state results. These results were compared to the benchmark report calculations (NRC and OECD 1999), looking at energy conservation. The benchmark report indicated a 27 K core coolant temperature rise while RELAP-7 calculated the core temperature rise to be 26.9 K. In addition to the core temperature comparison, RELAP-7 calculated fluid temperatures in the entire system as shown in Figure 7. Other results of the calculations for the case study are found in (Anders et al. 2012).

Summary

The RELAP-7 code development is a significant step change in systems code development. Built within the MOOSE framework, a case study single-phase pressurized water reactor problem has been successfully simulated to steady state. The next stage of development is to demonstrate two-phase modeling capability through a simplified boiling water reactor station black-out analysis, which will be reported in the next demonstration simulation report as part of the α-0.2 version slated for November 2012.

Acknowledgements

We would like to recognize the members of the RELAP-7 development team:

Project Manager: Richard Martineau

Reactor Simulation Team: Haihua Zhao (PI), Ling Zou, and Hongbin Zhang

Software Design Team: Derek Gaston (lead), David Anders, and John Peterson

Theory Team: Ray Berry (lead), Richard Martineau, Samet Kadioglu, and Brandon M. Blackburn

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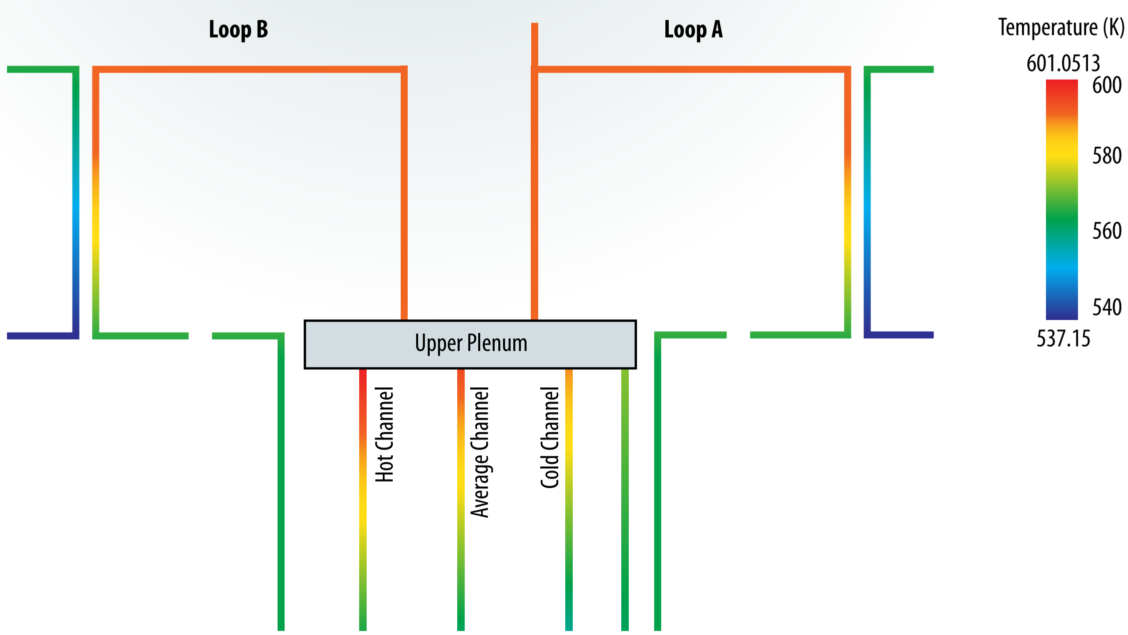

Figure 7. Pressurized water reactor case study plant-calculated fluid temperatures from RELAP-7.

Joint Research and Development Plan Update

The DOE Office of Nuclear Energy (NE) and the Electric Power Research Institute (EPRI) have established separate but complementary research and development programs (DOE NE's LWRS Program and the EPRI's Long-Term Operations Program) to develop the technical bases from which decisions can be made regarding extended nuclear power plant operation, which may include continued operation past 60 years. Because of the complementary nature of both research and development programs, it is important that the work be coordinated to the benefit of both organizations. An integrated approach to the planning and execution of this research and development enables both DOE-NE and EPRI to more efficiently establish and fund research and development activities and avoid unnecessary duplication of efforts.

Sherry L. Bernhoft
Program Manager,
EPRI Long-Term
Operations Program

Donald L. Williams
Deputy Director
LWRS Program
Technical
Integration Office

To ensure that a proper linkage is maintained between the programs, DOE-NE and EPRI executed a Memorandum of Understanding in late 2010 to "establish guiding principles under which research activities (between LWRS Program and Long-Term Operations Program) could be coordinated to the benefit of both parties." The Memorandum of Understanding calls for DOE-NE and EPRI to provide and annually update a coordinated plan for the LWRS and Long-Term Operations Programs. The first update to the joint plan (INL/EXT-12-24562, Revision 1, April 2012) has been completed and is now available on the LWRS website (https://inlportal.inl.gov/portal/server.pt/document/102497/inl-ext-12-24562_lwrs-lto_joint_plan_rev_1_final_4-12-12_pdf). The joint plan describes the coordinated and collaborative research and development activities of both programs and identifies key milestones for delivering research and development results. Both DOE-NE and EPRI intend to use the joint plan to guide program-specific initiatives and ensure that information derived from the research and development investments serves to strengthen this unique public-private sector collaboration.

Recent LWRS Reports

- ***Report on Prevention Analysis Trial Method and Case Study Improvements***

  https://lwrs.inl.gov/RisckInformed%20Safety%20Margin%20Characterization/Report_on_Prevention_Analysis_Trial_Method_and_Case_Study_Improvements-April_2012.pdf

- ***Reactor Pressure Vessel Task of Light Water Reactor Sustainability Program: Letter Report on Metallurgical Examination of the High Fluence RPV Specimens From the Ringhals Nuclear Reactors***

  https://lwrs.inl.gov/Materials%20Aging%20and%20Degradation/Milestone_Ltr_Report-Ringhals.pdf

- ***Assessment of Opportunities for Acquiring Plant Materials to Aid in Model Validation***

  https://lwrs.inl.gov/Materials%20Aging%20and%20Degradation/FY12_Q3_Milestones-White_Bernstein.pdf

- ***A Review of Stress Corrosion Cracking/Fatigue Modeling for Light Water Reactor Cooling System Components***

  https://lwrs.inl.gov/Materials%20Aging%20and%20Degradation/Environmental_Fatigue.pdf

- ***Use Computational Model to Design and Optimize Welding Conditions to Suppress Helium Cracking during Welding***

  https://lwrs.inl.gov/Materials%20Aging%20and%20Degradation/Weld_model_suppress_stress_2012-6-22%20v2.pdf

- ***Digital Full-Scope Mockup of a Conventional Nuclear Power Plant Control Room, Phase 1: Installation of a Utility Simulator at the Idaho National Laboratory***

  https://lwrs.inl.gov/Advanced%20IIC%20System%20Technologies/LWRS_Simulator_Buildout_Milestone_Report_.pdf

Editor: Teri Ehresman
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