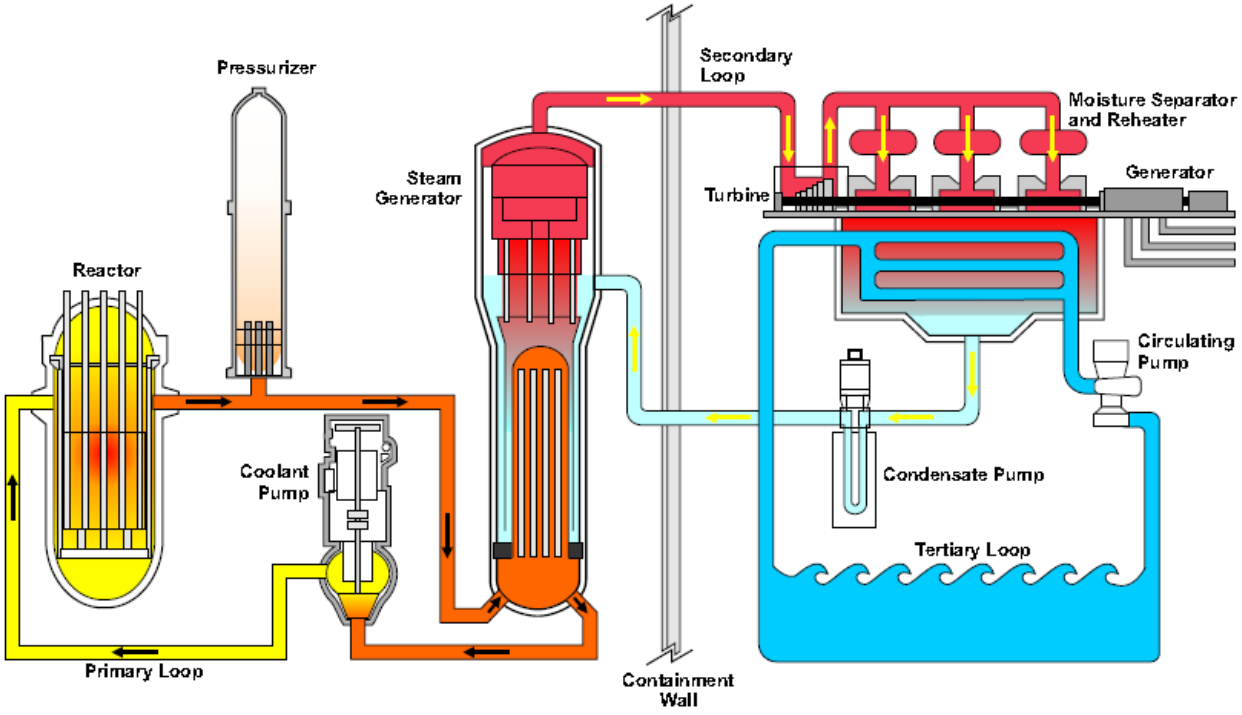
RELAP5-3D: The Path Forward

2019 International Users Group Seminar
April 18, 2019

James Wolf, Rich Martineau, George Mesina



www.inl.gov

Idaho National Laboratory

RELAP5-3D Going Forward

- Anything that remains stagnate and does not continue to evolve will eventually disappear.
- This applies to all computer codes as well as RELAP5-3D.
- The RELAP series of codes have been have been developed at the INL for more than 30 years.
- There are currently over 100 active RELAP5-3 licenses.
- This customer base and the huge world wide investment in plant models, training and analyses make it imperative that RELAP-3D continue to be available for the foreseeable future.
- RELAP5-3D will be developed as long as there is a customer base that needs its capability.

What is the current status of RELAP5-3D software?

- It is still the flagship of nuclear reactor systems analysis tools.
- It is exactly what it was designed to be and quite successful at it.
- Infrastructure is becoming dated and difficult to maintain.
- However, commercial FORTRAN compilers are rapidly disappearing. DEC, Microsoft, G95, and Lahey have disappeared. Intel and NAG FORTRAN compilers are healthy and actively maintained. Others, are sporadically updated and/or maintained.
- RELA5-3D relies on unmaintained libraries, primarily the Parallel Virtual Machine (PVM) for parallel networking. Last release, February 2, 2009.
- The main issue with unsupported libraries and ever increasingly hard to find compilers is that they may not work properly, or at all, on future hardware platforms.
- RELAP5-3D's range of applicability has not kept up with current industry and regulatory needs, such as 10 CFR 50.46c and uncertainty quantification. Modern capabilities and features, such as more rigorous fuel analysis and uncertainty quantification, are unavailable.

INL Strategy

- Continue to make strategic improvement in RELAP5-3D to insure its viability for the next 15 years or so.
- Continue development of RELAP-7 so when it is completed, code users will have an alternative if the choose.
- It is likely that a Version 1.0 of RELAP-7 will be delivered to the community in the FY-2021 timeframe.
- Transition from RELAP5-3D to RELAP-7 will take several years for the nuclear power industry to make this transition perform the necessary validation, software quality procedures, and leveraging decades of reactor analysis with various versions of RELAP5.

RELAP5-3D Software Modernization and Capability Upgrade

- Integrate RELAP5-3D into the MOOSE environment:
  - "MOOSE-wrap" RELAP5-3D so that it runs under a single executable.
  - Create a GIT repository on INL's GitLab server for RELAP5-3D source, scripts, and auxiliary files.
  - RELAP5-3D under the MOOSE test harness provides an automated means to run standard and verification test cases (revealing bugs earlier), automates syntax checking, and checks lines of source code coverage during testing.
  - Integrated MOOSE/RELAP5-3D provides an automated path to NQA-1 compliance for RELAP5-3D.
  - The test harness leverages the MOOSE build infrastructure to ensure solution repeatability.
  - Coupling with advanced core physics, MC21, PARCS, Serpent, BISON, Marmot, etc.
  - MOOSE wrapping RELAP5-3D is non-intrusive inside the RELAP5-3D source code. Thus, RELAP5-3D may be run with or without MOOSE.

RELAP5-3D Software Modernization and Capability Upgrade(Cont.)

- Leverage the NRC TRACE-BISON coupling tightly couple RELAP5-3D to BISON:
  - The NRC can maintain its regulatory independent analysis capability using the TRACE code as the systems codes will be different. Thus, separate validation of RELAP5-3D/BISON will be compared with a validated TRACE/BISON capability.
  - Industry will be in a better position to address new regulatory requirements.
  - The NRC and Industry will have better tools to evaluate and design ATF concepts for performance, evaluation of coping times for LOCA events, etc.

Additional RELAP5-3D Code Development Areas (Cont.)

- During the transition, a number of key developmental improvements will be made to both RELAP5-3D and RELAP-7. For RELAP5-3D, most new developments will require funding be identified so they are not tied to a specific date.
- Best Estimate Plus Uncertainty capability. The Best-Estimate Plus Uncertainty (BEPU) methodology has become the de-facto standard in the nuclear industry to perform safety analysis of NPPs. The key aspect of BEPU methodology is to quantify uncertainties in the calculations. As a Best Estimate state-of-the-art reactor systems safety analysis code, RELAP5-3D plays an important role in the nuclear industry to perform reactor safety analysis. However, the current capability of the RELA5-3D code to support BEPU analysis is limited. Many of the models built into the RELAP5-3D code are not accessible to the users and hence would require code enhancements and modifications to render the models accessible to the users such that uncertainties can be quantified to support BEPU analysis.

Additional RELAP5-3D Code Development Areas (Cont.)

- Improved Code Robustness. This area includes:
  - Expand Verification to cover more code features. The ability to accept changed answers based on percentage of change should be added.
  - Improve Developmental Assessment, the application of engineering judgment to determine goodness of fit of code calculations to data, by applying statistical methods to rigorously define it. This will allow automation of validation judgment.
  - Fluid property consistency improvements. Inconsistencies cause issues with extra timestep advancements and code backup.
  - Examine limits. Many cutoff limits in the code have no justification and should be reconsidered based on the extensive test cases now available. This is very important to mass error reduction.
  - Deep Backup. Normal backup must record the exact information in the right place, and this causes serious maintenance issues, particularly when multiple backup conditions occur on the same advancement. A simplified, deep backup that saves whole derived type arrays, backup-conditions info, and retreats to near the beginning of the time advancement would solve these issues. It also allows multi-step backups to be developed.

Additional RELAP5-3D Code Development Areas (Cont.)

- Improve the Nearly-Implicit Modeling for 3-D applications and modify the switching from nearly- to semi-implicit time advancement.
- Increase code speed by activities such as enhance vector and OpenMP parallel coding in the hydrodynamics and heat structures.
- Improve long term code maintenance by refactoring, elimination of obsolete constructs, remove all non-ANSI conditional coding for machines and compilers that no longer exist, removal of memory leaks.
- Comparison of RELAP5-3D code manuals to actual coding to insure consistency.

INL's Combined RELAP5-3D/RELAP-7 Systems Analysis Effort

- More closely integrate the RELAP5-3D, RELAP-7 and MOOSE teams to leverage existing resources and staff.
- Managed by DOE Center of Excellence for Thermal Fluids Applications in Nuclear Power
  - Center of Excellence is a NEAMS funded effort located at INL
  - It is a joint collaborative effort between INL, ANL, and LANL.
  - The goal is to conduct research in thermal fluids applications of current interest to nuclear power, for both the current fleet of LWRs and the new Advanced Reactor Concepts.
  - The technical focus of the Center of Excellence is in three areas:
    1. *Multi-phase flow*
    2. *Coolant Flow Damage and Corrosion* Effects
    3. *Advanced System/Plant Analysis*
- Jim Wolf will continue to lead the RELAP5-3D team and the new RELAP5-3D extended software development effort.
- Rich Martineau, will continue to lead the RELAP-7 team through the end of its algorithmic development.
- As M&S Director, Rich Martineau will still be responsible for the overall mission
- The Center of Excellence will be located in INL's new computational science facility, the Collaborative Computing Center, C3.

Conclusion

- RELAP5-3D, as any code, has challenges ahead over the next several years. However, if software modernization and capability upgrades continue, the code will continue to be the workhorse of the nuclear industry.