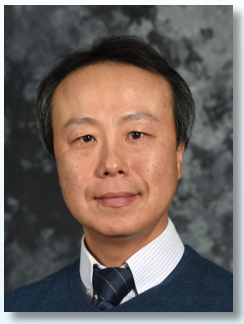
Technical Capability Assessment of RAVEN (Risk Analysis Virtual ENvironment)



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Risk-Informed Systems Analysis Pathway

The LWRS Program has developed software tools that need to achieve a high technical maturity in order to be utilized by the nuclear industry. Therefore, the software needs a comprehensive capability assessment based on their potential use.

The Risk-Informed Systems Analysis (RISA) Pathway performed an assessment of software to be used in risk-informed margin management. The assessment process includes three items:

1. Developing the software capability requirements;
2. Evaluating the importance (i.e., high, medium, or low) of the requirements; and
3. Assessing the Technology Readiness Level (TRL) of each requirement.

Technical Capability Assessment of RAVEN

Developed by the U.S. National Aeronautics and Space Administration, the TRL is a method for estimating the maturity of technologies during the development and acquisition phase of technology deployment as shown in Figure 10. A total of nine levels are set from low level (1 to 4) to high level (5 to 9), which represents a range from research and development status to readiness for industrial use.

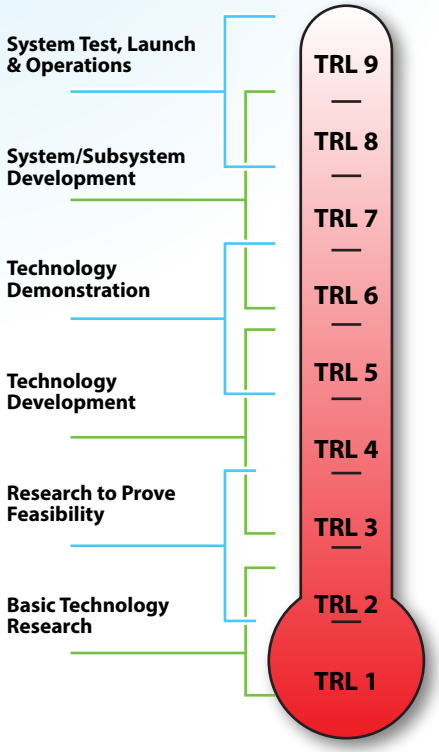
The RAVEN software developed by LWRS Program researchers at INL [2] is used by the RISA Pathway for uncertainty quantification, regression analysis, probabilistic risk assessment, data analysis, and model optimization. One of the purposes of RAVEN is to support system-analysis code application for risk-informed analysis.

The RAVEN development philosophy is to construct a capability of analysis from calculation flow to interpreting the user-defined instructions and then assembling the different analysis tasks following a user specified scheme. The Python programming language was used to maximize flexibility and accelerate development. Flexible code coupling capability is one of the strong features found in RAVEN. It was designed to couple many of the computer codes in the field of thermal-hydraulics, safety analysis, neutronics, probabilistic risk assessment, and Multiphysics Object Oriented Simulation Environment (MOOSE) based-applications. This coupling works even with code generated with different program languages such as FORTRAN, C++, and Python.

RAVEN was designed as a non-physics application (it does not solve partial differential equations for example); therefore, no specific validation is necessary. However, RAVEN automatically performs a regression test to confirm that the code works correctly. A total of 733 regression tests are available in the RAVEN framework and tests are continuously added as needed.

During the assessment, 14 requirements were considered, including: the code development level, capability and features, quality assurance program, developer/independent verification and validation (V&V) record, separate/integral tests history, user documents, and user feedback. Table 1 summarizes the result of the assessment, including the importance of each requirement and the assessed TRL. RAVEN has been used for uncertainty quantification, dynamic probabilistic risk analysis, automated sensitivity studies, and extensive data mining. It has a strong capability of coupling with various computer software packages used in the nuclear industry. An open source policy, its plotting capability, and detailed output

Figure 10. Technology Readiness Levels (TRL) [1].



Requirements	Level of Importance	Results	TRL
Code development level	High	Fundamental development for RAVEN technology is mostly finalized. Coupling capability with external software is fully demonstrated. Need platform for VERA-CS, FRAPCON/FRAPTRAN, CFAST, FDS, and GOTHIC. More industrial use and V&V is needed.	7
Use of proven technology	High	Python used. No specific issue was found.	9
Probabilistic Risk Assessment capability/applicability	High	Demonstrated for classical and dynamic probabilistic risk assessment purpose. Risk-weighted optimization method could improve quality.	8
Documentation	Medium	Set of manual includes theories, user guide, and verification activities. Thorough revision and proof reading is necessary.	6
System requirements	Low	Linux, Windows, and Mac OsX with various versions are tested. Operating system comparison study was not performed.	7
Easy installation	Medium	Installation method is well described in software package.	9
Graphic user interface (GUI)	Medium	No official GUI is currently available. Plotting capability is included. GUI will facilitate coupling capability.	5
Version control	Medium	New version includes all features of previous version and updates. Developer's version is also available. No version comparison study.	7
V&V history	Low	No validation activity is needed for RAVEN. Verification is extensive.	9
Quality Assurance (QA) program	High	Follows development company's QA program (NQA-1 compliance).	9
Web page	High	Both GitHub and conventional style web pages are functioning. However, general information should be updated.	7
User support	High	GitHub web page is main method for user support. Reported issues management is well controlled. However, sustainable resource is necessary for continuous support to RAVEN development team.	7
Training program	Medium	Training program is organized by development team as needed.	8
License	Medium	RAVEN is open source. Contributor license agreement is needed for participating development.	9

Table 1. Results of the technical capability assessment of RAVEN.

data management are also notable features. As an element of the RISA Toolkit, RAVEN has proven capable of generating various dynamic probabilistic risk assessments and coupling capability with the RELAP5-3D thermal-hydraulics software. In addition, new capabilities are added as needed, extending this framework to support LWRS Program projects.

The RISA Pathway evaluated both RAVEN and RELAP5-3D in 2019. From these analyses, we identified areas for future focus. In summary for RAVEN, the TRL is quite high indicating a mature software package. Next, we will evaluate the INL-developed HUNTER (human reliability simulation) and EMRALD (dynamic risk simulation) using this assessment approach.

References

1. Technology Readiness Level https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html
2. C. Rabiti, et. al., RAVEN User Manual, INL/EXT-15-34123 Rev. 7, 2019.