INL/XXX-XX-XXXXX
Revision X [only after initial release]

June 2021 SAPHIRE 8 Algorithm Enhancements Status Report

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Current Activities and Progress Related to the SAPHIRE Algorithm Enhancements

S. Ted Wood
Jordan T. Boyce
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Idaho National Laboratory

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ABSTRACT

Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) was developed for the Office of Nuclear Regulatory Research at the U.S. Nuclear Regulatory Commission. The U.S. Nuclear Regulatory Commission is an independent agency established by the U.S. Congress to ensure adequate protection of the public health and safety, the common defense and security, and the environment in the use of nuclear materials in the United States. SAPHIRE's purpose is to create and analyze probabilistic risk assessments, primarily for nuclear power plants. At the request of the U.S. Nuclear Regulatory Commission, this development process was started in 1987. The Idaho National Laboratory developed SAPHIRE and interfaces with the user group through training and technology transfer.

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FIGURES

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ACRONYMS

BWR	Boiling water reactors
CCF	Common cause failure
CDF	Core damage frequency
COR	Contracting Officer's Representative
DG	Diesel generators
DMZ	Demilitarized zone
E-Book	Electronic Book
ECA	Events and Conditions Assessment
FTR	Fails to run
FY	Fiscal Year
IAA	Interagency Agreement
INL	Idaho National Laboratory
JCN	Job Code Number
MAR-D	Models and Results Database
NRC	Nuclear Regulatory Commission
PRA	Probabilistic risk assessment
PRIB	Plant Risk Information e-Book
PWR	Pressurized water reactors
RAW	Risk achievement worth
RIR	Risk increase ratio
SAPHIRE	Systems Analysis Programs for Hands-on Integrated Reliability Evaluations
SDP	Significance determination process
SRA	Senior reactor analysts
SSL	Secure sockets layer
UG	User's Group

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1. INTRODUCTION

1.1 Background

The Systems Analysis Programs for Hands-on Integrated Reliability Evaluations (SAPHIRE) Algorithm Enhancements Project, Nuclear Regulatory Commission (NRC) Interagency Agreement (IAA) NRC-HQ-60-17-T-0007, is designed to enhance the features and capabilities of the SAPHIRE software. The work performed under this project is a continuation of previous projects, such as job code number (JCN) V6368, "SAPHIRE Algorithm Enhancements." This project picks up from the JCN V6368 to advance the capabilities of SAPHIRE and lays the foundation toward the future versions of SAPHIRE.
This report documents the accomplishments and recommendations for the two subtasks within this contract, SAPHIRE Algorithm Enhancements, as set forth in the NRC IAA NRC-HQ-60-17-T-0007 for the period of July 2020 through June 2021.

2. DISCUSSION

2.1 Provide Plan for SAPHIRE Enhancements

Idaho National Laboratory (INL) shall create a plan for enhancing the features of SAPHIRE. The plan shall include descriptions of each specific enhancement that may be implemented in SAPHIRE. INL shall not proceed with implementing the outlined enhancements prior to obtaining the written approval of the contracting officer's representative (COR).

Accomplishments

The Fiscal Year (FY) 2021 Implementation Plan (SAPHIRE Algorithm Enhancement Planning Report) was updated from the 2020 FY Implementation Plan. The Implementation plan was developed between the NRC COR and INL based on direct telephone conversations and multiple iterations. The updated Implementation Plan was finalized and sent to the NRC COR September 29, 2020. This Implementation Plan has been the working document for establishing the priorities of enhancements to be added to SAPHIRE, as discussed in section 2.2.

Recommendations

The Implementation Plan sent to the NRC will be revised on an annual basis and submitted to the NRC COR for review. This updated plan will continue to be used for prioritizing the work performed to enhance SAPHIRE's capabilities and features.

2.2 Implement SAPHIRE Algorithm Enhancements and Provide Report

This task involves implementing enhancements to SAPHIRE to support improved capabilities for performing model analyses and documenting results. At the direction of the COR, INL shall incorporate enhancements to the quantification and analysis capabilities of SAPHIRE. These enhancements shall be implemented to address the emerging needs of SAPHIRE's user community.

SAPHIRE enhancements may include:

- Improved capabilities in reporting and documenting analysis results
- Create enhancements to support new standardized plant analysis risk (SPAR) model features (e.g., support system initiators, Level 2 analysis, common cause failure modeling)

- Support improving SPAR model maintenance and updating its capabilities
- Make changes to accommodate large and complex models
- Implement enhancements to support SAPHIRE users' abilities to collaborate on projects and share analysis results
- Develop tools to allow users to run SAPHIRE analyses through a web browser interface
- Improve SAPHIRE's parallel processing and distributed solving (i.e., solving that is distributed over a system of networked computers) capabilities
- Expand SAPHIRE's binary decision diagram solving capabilities or other quantification and analysis enhancements to improve quantification accuracy and/or speed.
- Enhancements based on the SAPHIRE User community requests and agreed upon with the NRC COR.

Work Performed and Accomplished July 2020 – June 2021

The "SAPHIRE Algorithm Enhancement Planning Report," submitted in September 2019, was updated to add new priorities, and submitted to the NRC in September 2020. The updated "Enhancement Planning Report" contained items identified in the FY2019 report, along with new items added. The list of priorities has been identified, some of which have been worked on (finished) and others are listed as a record to address once they move up the priority list. A summary of these priority enhancements are listed and discussed in Section 4 "Review Plan."

The following is a summary list of tasks that were completed or worked on from July 2020 – June 2021. Items in this list are discussed in detail in Section 3 "Recent Tasks."

- SAPHIRE Version 8.2.3 Release
    - Initiating Event Assessments with existing Change Sets
    - Fault Tree Logic Viewer with Reports
    - Basic Event Group Editor
    - MAR-D – Load/Extract can rename basic events with a new file
- SAPHIRE Version 8.2.4 Release
    - Single MAR-D input/output file for all Standardized Plant Analysis Risk (SPAR) projects
    - SPAR 8.5 Sensitivity Report can be distributed across multiple processes
    - Plant Risk Information e-Book (PRIB) Update
    - Enhanced PRIB for specific scenarios
    - Publish of uncertainty results from View Uncertainty option for Fault trees, Event Trees, Projects, and End States
- SAPHIRE User's Group Website
    - Reconstruct user accounts & permissions with enhanced security
    - Model and Software Download & Upload Functionality
    - Restore basic administrative functionality
    - Additional and future enhancements

- Safety Portal Tasks
    - Enhance Authentication and Authorization
    - Implement new account password expiration rules
    - Future Enhancements
- Remote Solver Tasks
    - Research technologies for optimum scalability
    - Pair the Remote Solver project with the Docker technology
        - Learn more about Docker here.
    - Future enhancements

The remainder of this report contains a section for each of these tasks, followed by a review of the status of each of the FY 2021 Plan Report items. The status of each item provides a description, the accomplishments, and possible recommendations for further work. For work done in previous reporting periods, see that year's release of this report.

3. RECENT TASKS

A summary of tasks worked on this year to date contributed to the project mission during FY 2021.

3.1 SAPHIRE Related Tasks

3.1.1 SAPHIRE Version 8.2.3 Release

The following items were included in the February 22, 2021 release of SAPHIRE Version 8.2.3.

3.1.1.1 Initiating Event Assessments with Change Sets

Description

The ECA workspace now has the option to perform an Initiating Event Assessment enhanced with an existing change set like the Conditions Assessment option added in an earlier SAPHIRE release.

Accomplishments

The ability to implement a change set when performing an Initiating Event Assessment was added to the SAPHIRE Version 8.2.3 Release.

To use this new feature, double click the *New ECA* line of the "Workspaces" in the left-hand lists (see Figure 1).

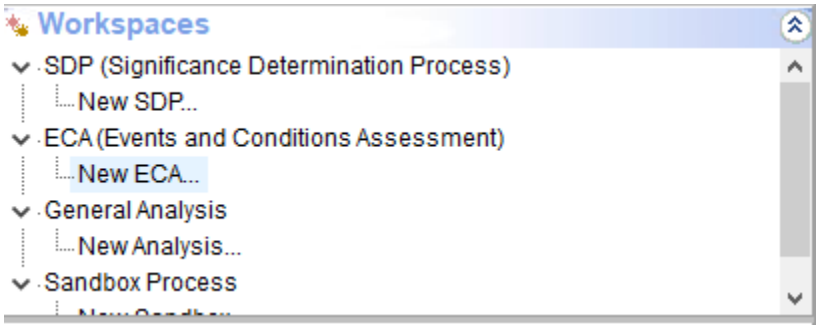


Figure 1. Create new ECA.

Clicking the *Initiating Event with Change Sets* radio button will display the "Initiating Events" and "Change Sets" lists, and the user can pick the desired initiating event(s) and the desired change set(s) (see Figure 2).

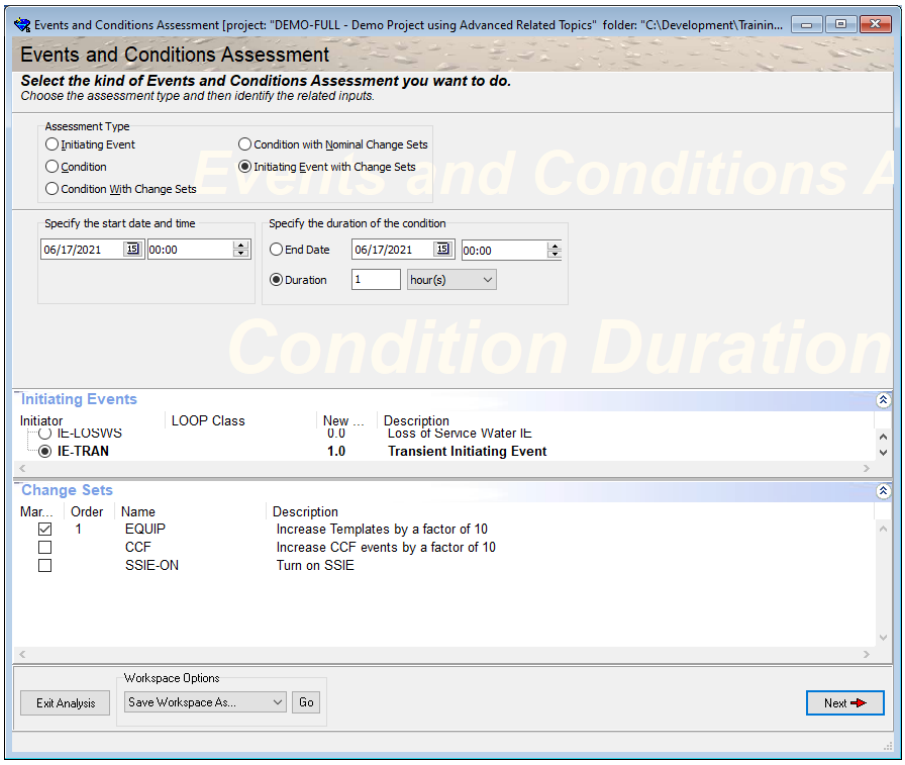


Figure 2. ECA: Initial screen.

Clicking the *Next* button displays the basic "Event" list (see Figure 3) with the appropriate initiating events checked as well as the events impacted by the selected change set(s). After the desired events have be checked on this screen, click the *Next* to continue to the next screen.".

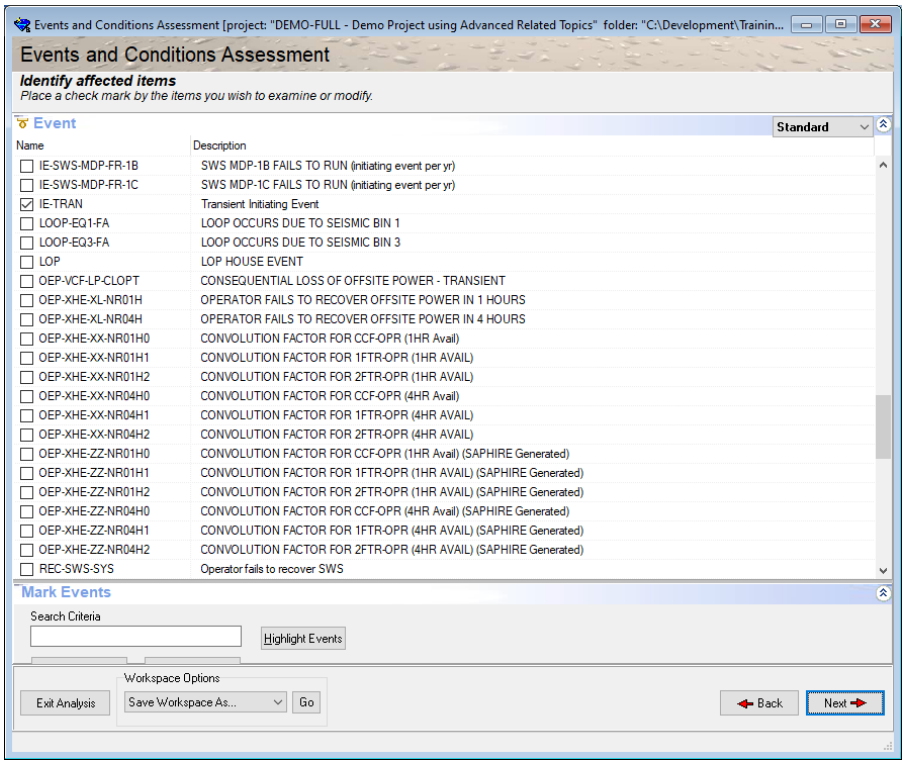


Figure 3. ECA: Select Event.

Figure 4 shows the events in the change set(s) with their updated current case failure values as well as the initiating events relating to the choices made in the previous screen. The user can update the "New Prob/Freq" entry for each event listed or retain the values as shown.

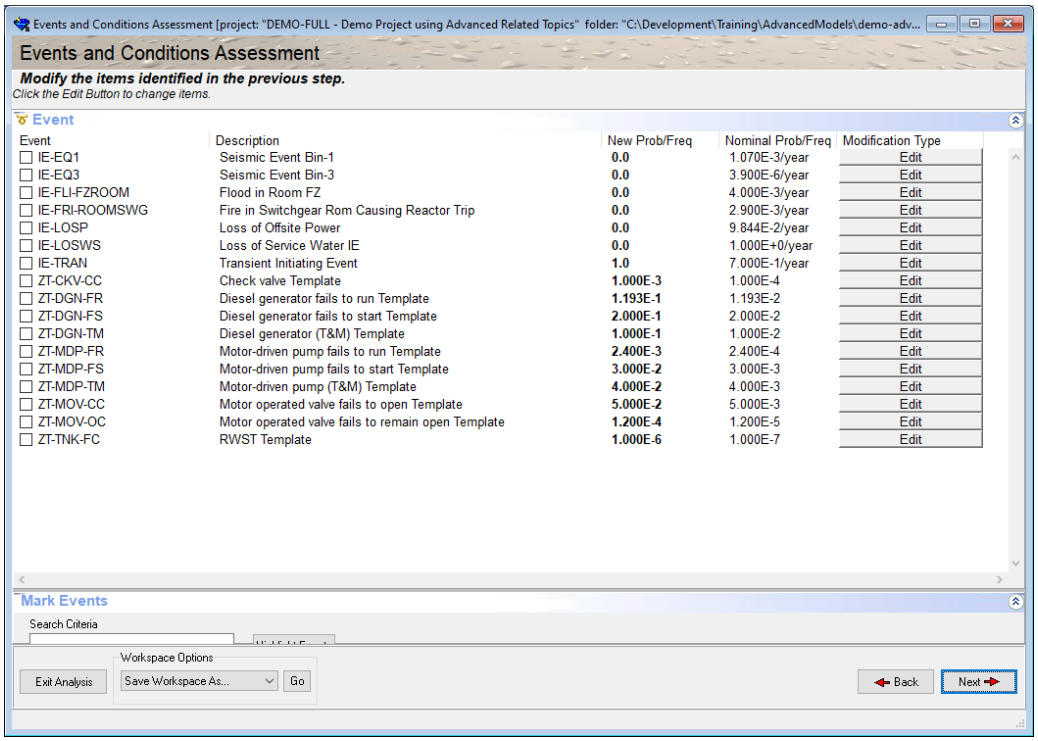


Figure 4. ECA: Edit Event.

Clicking the *Next* button moves the user to the "Solve Options" screen as shown in Figure 5.

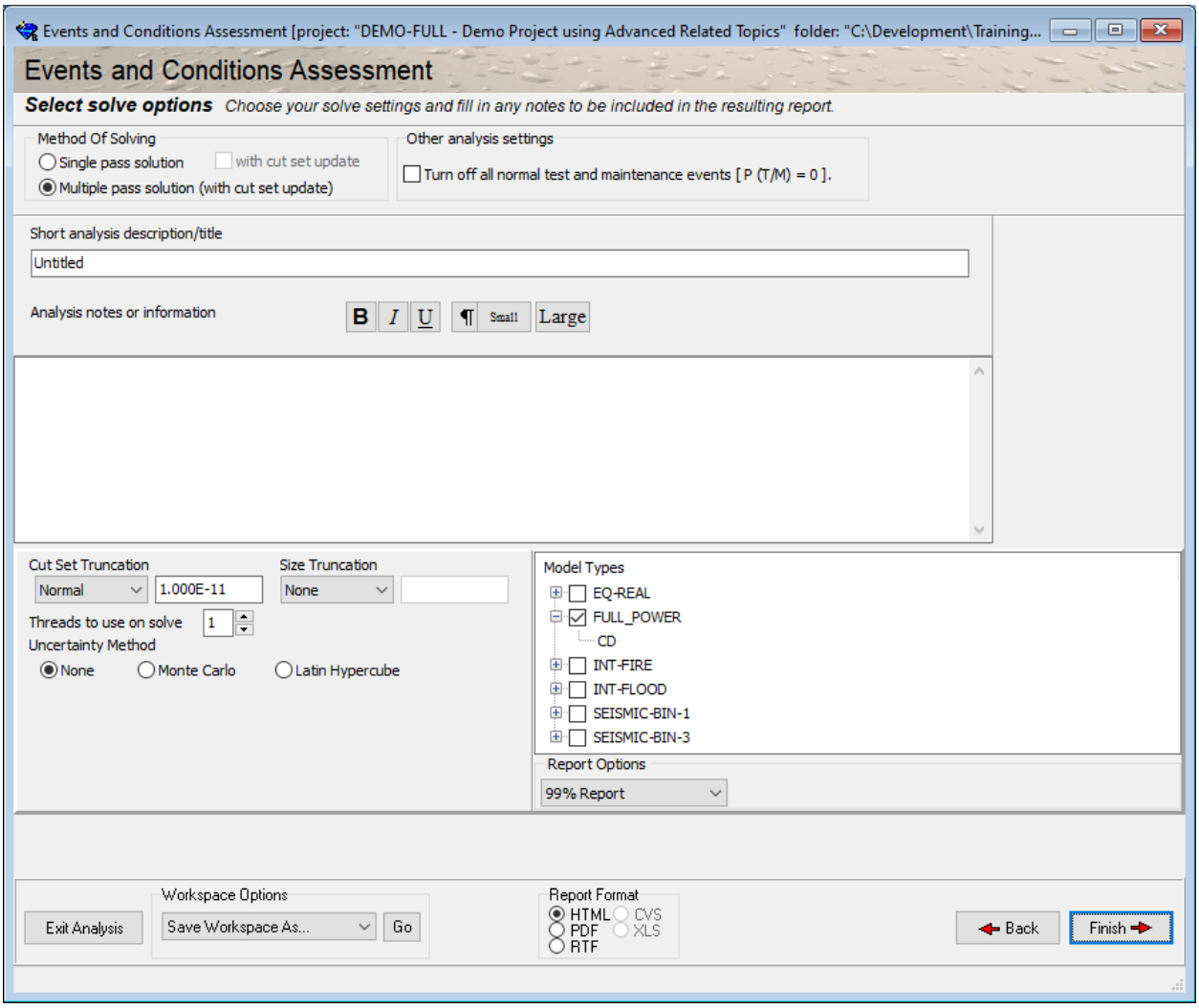


Figure 5. ECA: "Solve Options" screen.

Clicking the *Finish* button completes the Initiating Event Assessment process and then displays the results (see Figure 6). This "Initiating Event Assessment Summary" can be saved for further analysis.

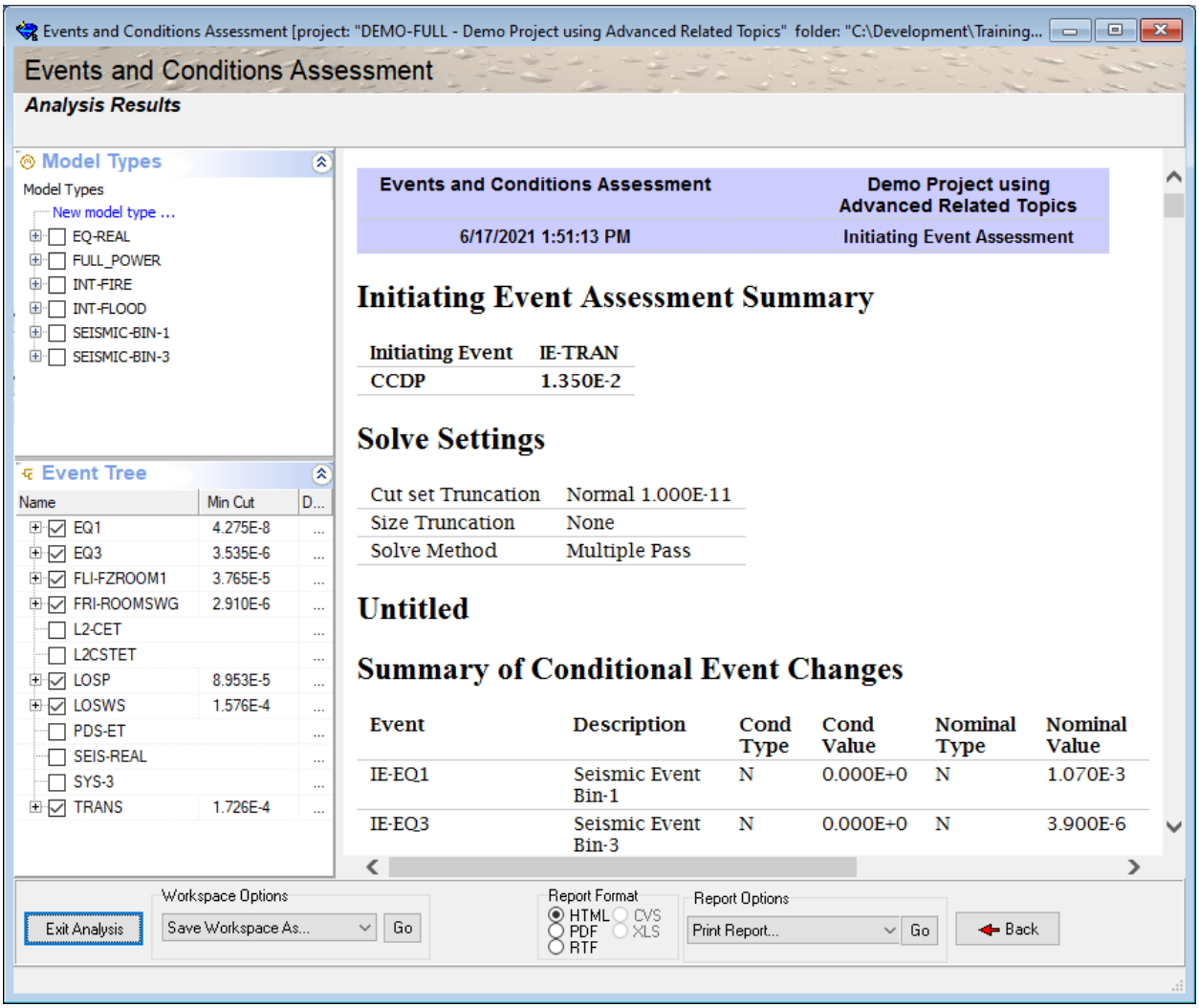


Figure 6. ECA: Final screen.

3.1.1.2 *Fault Tree Logic Reviewer with Reports*

Description

When Version 8 of SAPHIRE was released, it did not include a fault tree logic editor as in previous versions. Users expressed the need to look at the fault tree logic in a line-by-line format. The fault tree "Logic Viewer" allows the user to view a fault tree's logic and report on that logic.

Accomplishments

The Fault Tree "Logic Viewer" is displayed by highlighting the desired fault tree, right-clicking the mouse to bring up the fault tree context menu (in this example "CCS" or "Containment Cooling System"), and then left-clicking the *Review Logic* option as shown in Figure 7.

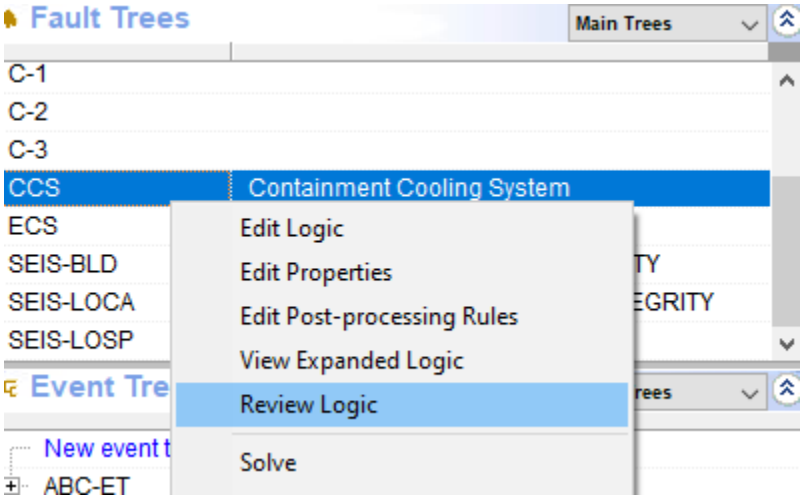


Figure 7. Review Logic.

Figure 8 below shows the logic for the highlighted fault tree for CCS in the "Logic Viewer." The default is to display all the gates and inputs expanded.

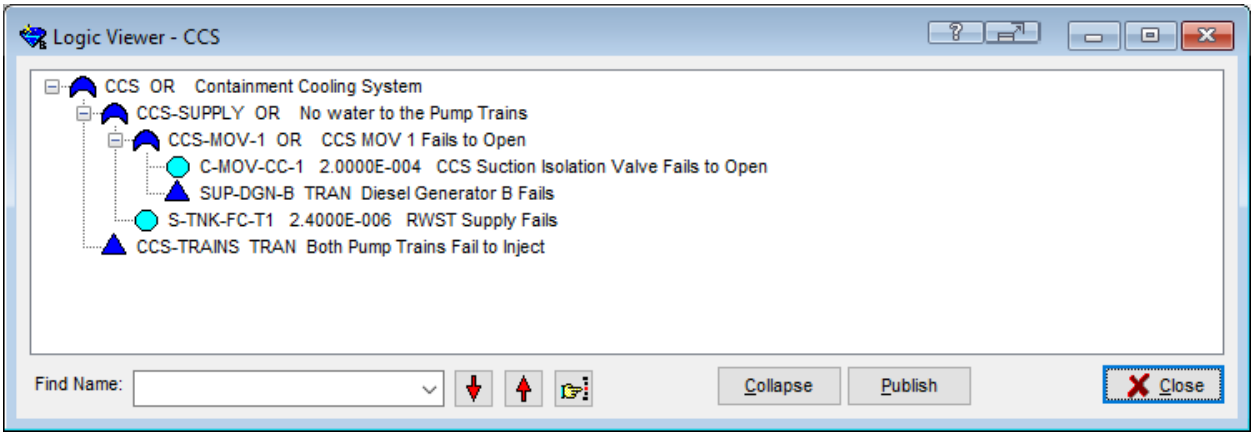


Figure 8. Logic Viewer - CCS.

Figure 9. Top gate of the CCS Tree.

Figure 9 is a representation of the top gate with its symbol, gate name, gate type, and gate description. The following symbols correspond to the gate types of Or (OR), And (AND), Transfer (TRAN), Not Or (NOR), Not And (NAND), N of M (2/3), or Delete Term (DT):

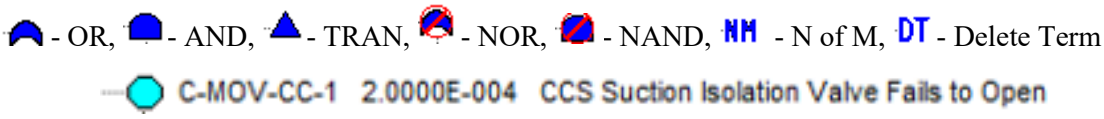


Figure 10. Basic event example.

Figure 10 shows a basic event example with its symbol , name, failure value, and description.

Double-clicking a basic event brings up the "Basic Event Editor" (see Figure 11).

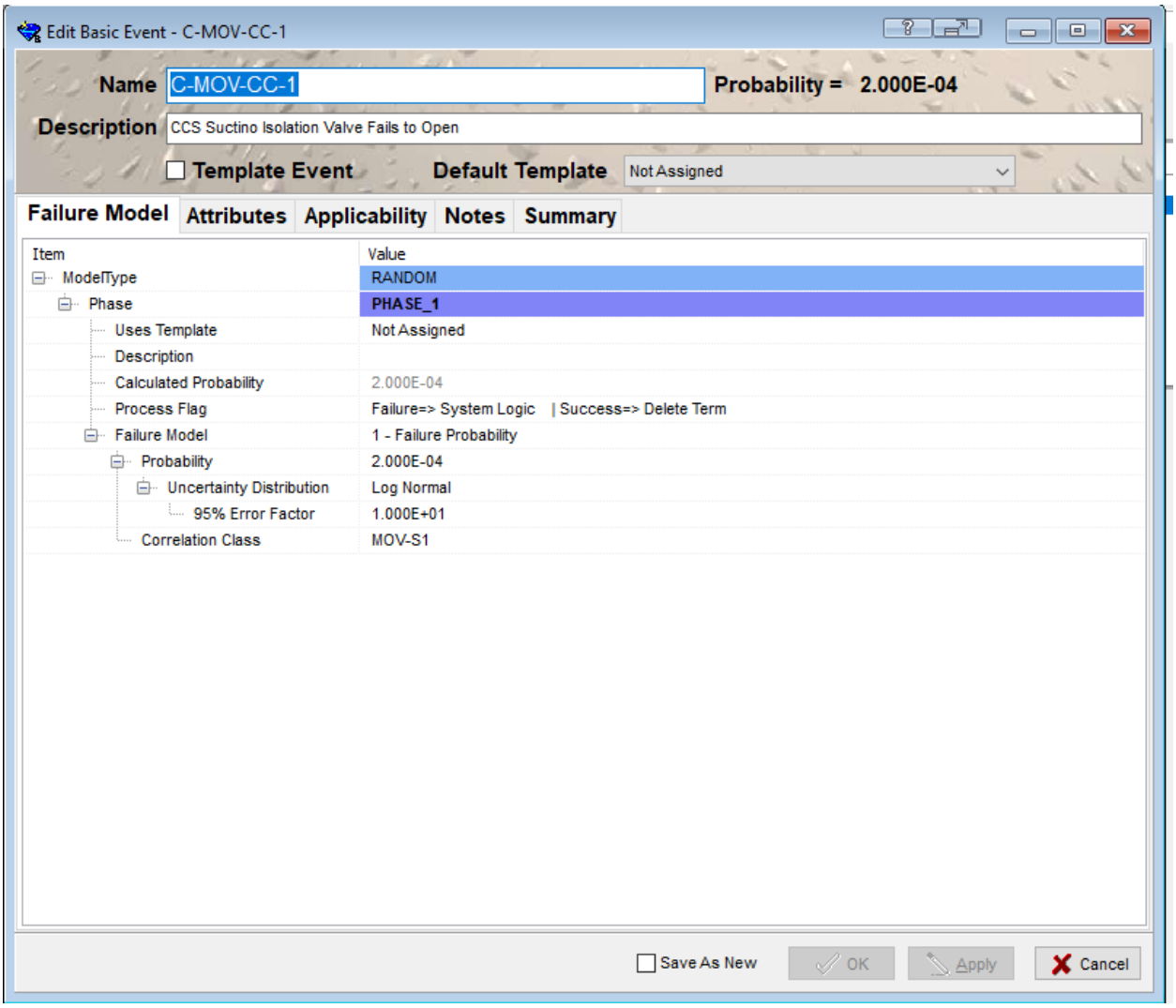


Figure 11. Basic Event Editor.

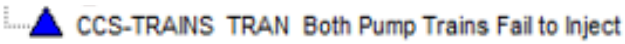


Figure 12. Transfer gate example.

Double-clicking a transfer gate (see Figure 12) will open another "Logic Viewer" for the selected transfer fault tree (see Figure 13).

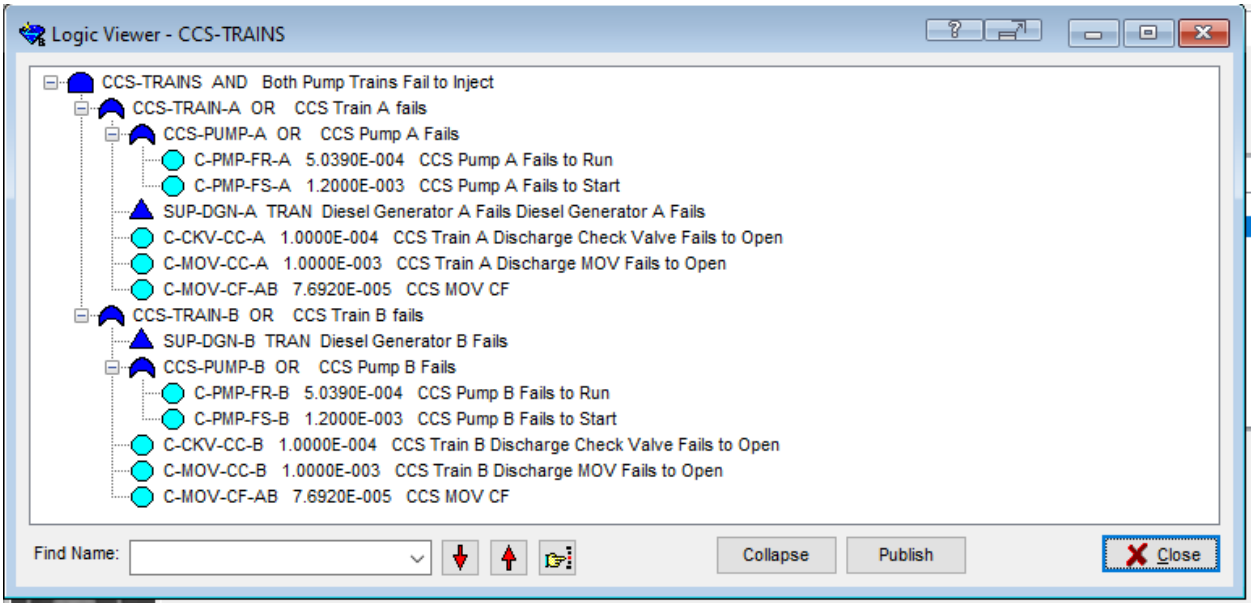


Figure 13. CCS Trains fault tree logic.

Right-clicking on any line in the "Logic Viewer" will display the context menu (see Figure 14).

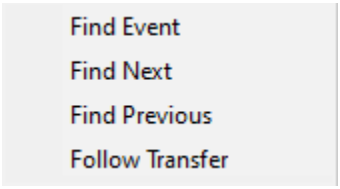


Figure 14. Context menu.

Find Event will look for the name in the *Find Name* text box (see Figure 15) and highlight the first gate or event with that name. (The Find Event functionality will find any gate or event, so the name, "Find Event" is not correct.)

Figure 15. Find Name text box.

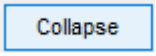
Find Next will look for the next instance of the *Find Name* below the found input.

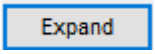
Find Previous will look for a previous instance of the *Find Name* above the found input.

Follow Transfer will open a new "Logic Viewer" window for the highlighted transfer gate. If the highlighted line is not a transfer gate, no action will be performed.

The three buttons to the right of the *Find Name* area correspond to *Find Next*, *Find Previous*, and *Find Item* functions:

 - *Find Next*,  - *Find Previous*, and  *Name Find*.

Clicking the  button will collapse all the expanded gates and then rename the button to *Expand*.

Clicking the  button will expand all the gates and rename the button to *Collapse*.

Clicking the  button will leave the "Logic Viewer."

Clicking the  button will bring up a subset of "Fault Tree Logic Reports" options (see Figure 16).

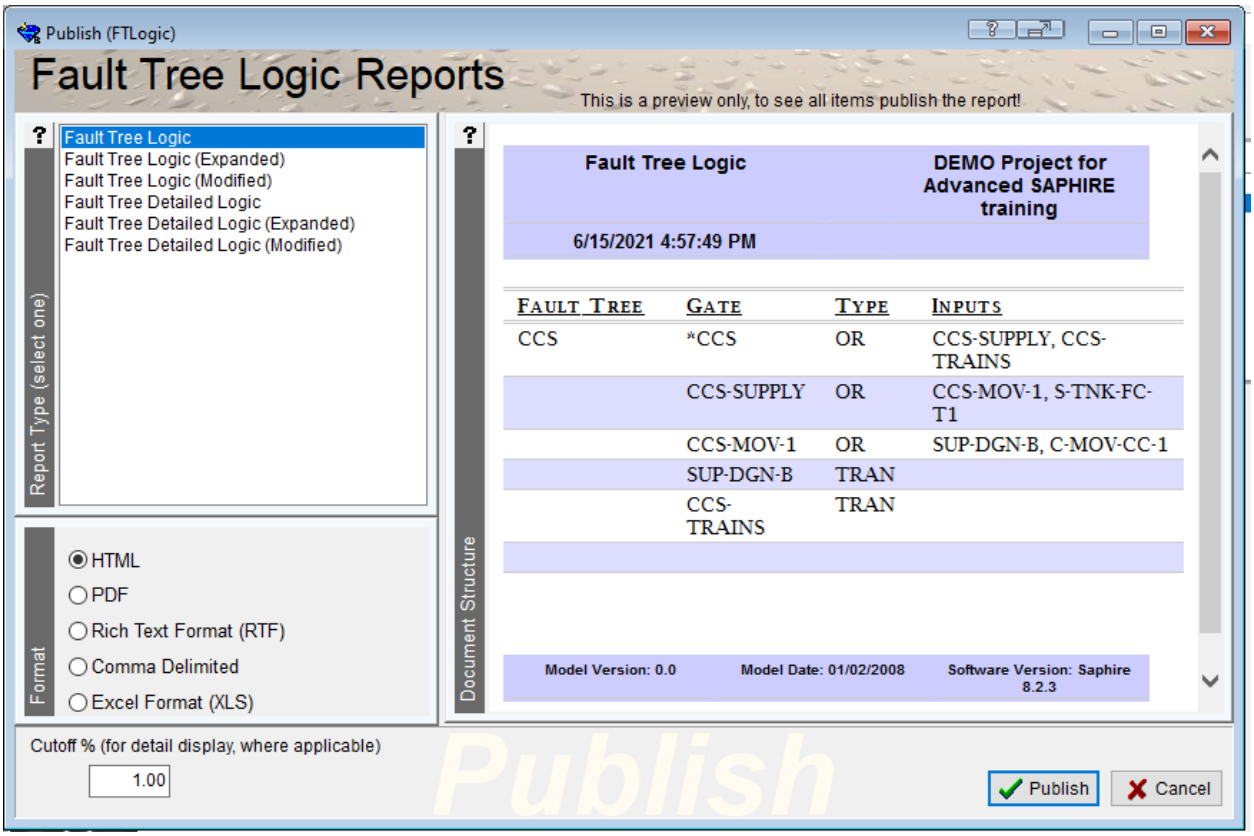
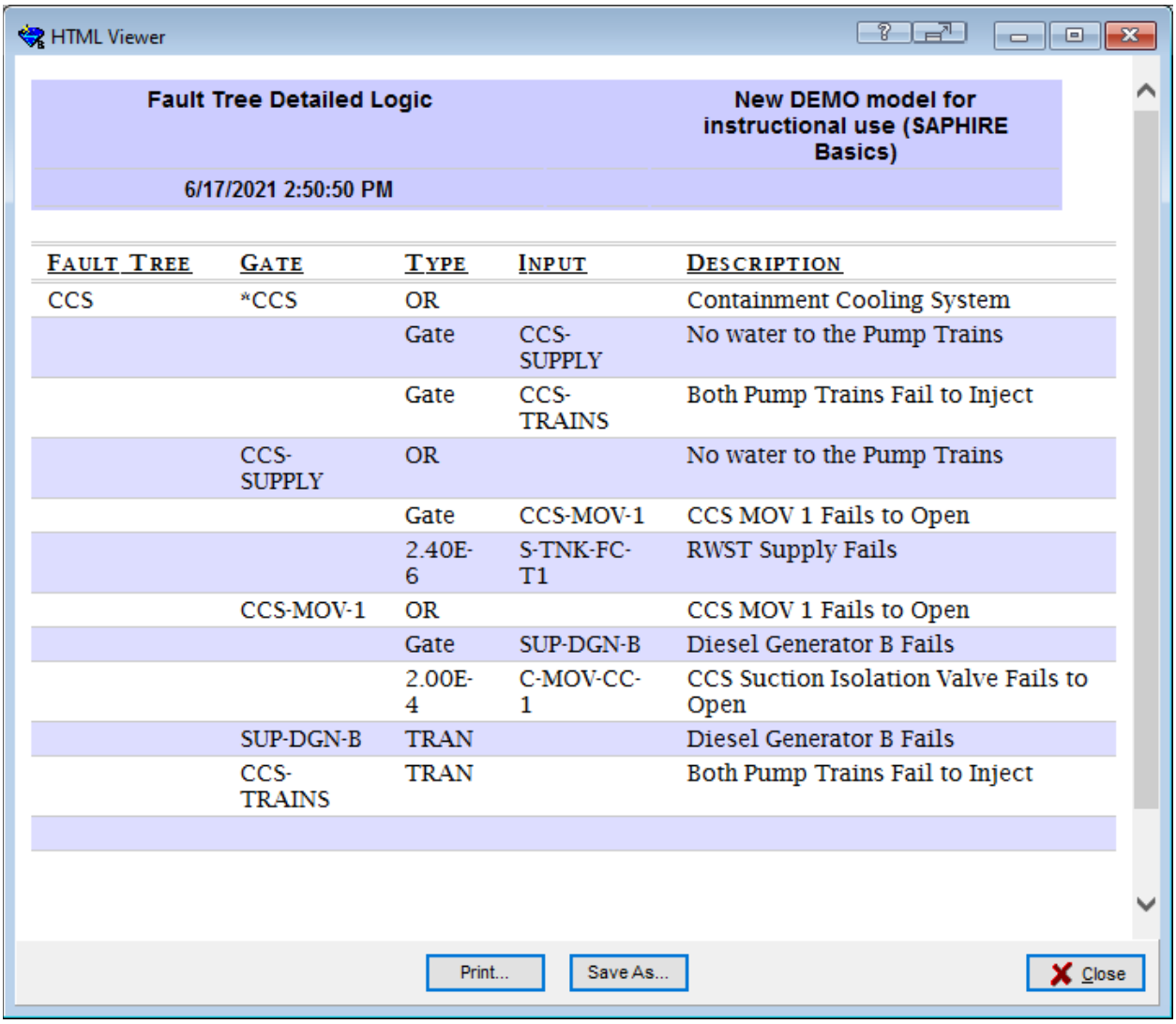


Figure 16. "Fault Tree Logic Reports."

The first three reports have been in SAPHIRE 8 since its release. Three "Fault Tree Detailed Logic" reports were added for this release.

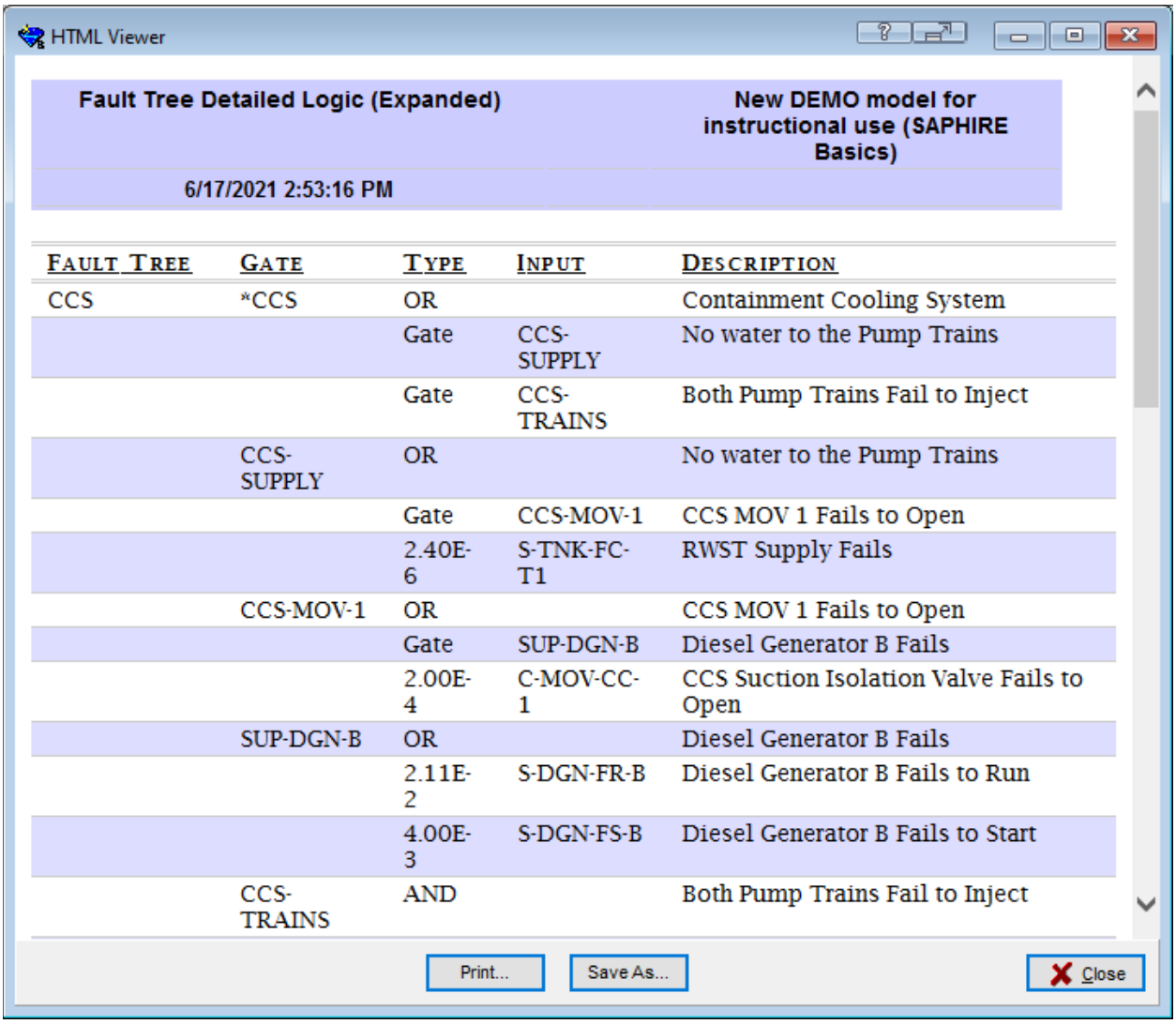
Figure 17 shows an HTML example of the “Fault Tree Detailed Logic” report screen.



Fault Tree	Gate	Type	Input	Description
CCS	*CCS	OR		Containment Cooling System
		Gate	CCS-SUPPLY	No water to the Pump Trains
		Gate	CCS-TRAINS	Both Pump Trains Fail to Inject
	CCS-SUPPLY	OR		No water to the Pump Trains
		Gate	CCS-MOV-1	CCS MOV 1 Fails to Open
		2.40E-6	S-TNK-FC-T1	RWST Supply Fails
	CCS-MOV-1	OR		CCS MOV 1 Fails to Open
		Gate	SUP-DGN-B	Diesel Generator B Fails
		2.00E-4	C-MOV-CC-1	CCS Suction Isolation Valve Fails to Open
	SUP-DGN-B	TRAN		Diesel Generator B Fails
	CCS-TRAINS	TRAN		Both Pump Trains Fail to Inject

Figure 17. “Fault Tree Detailed Logic.”

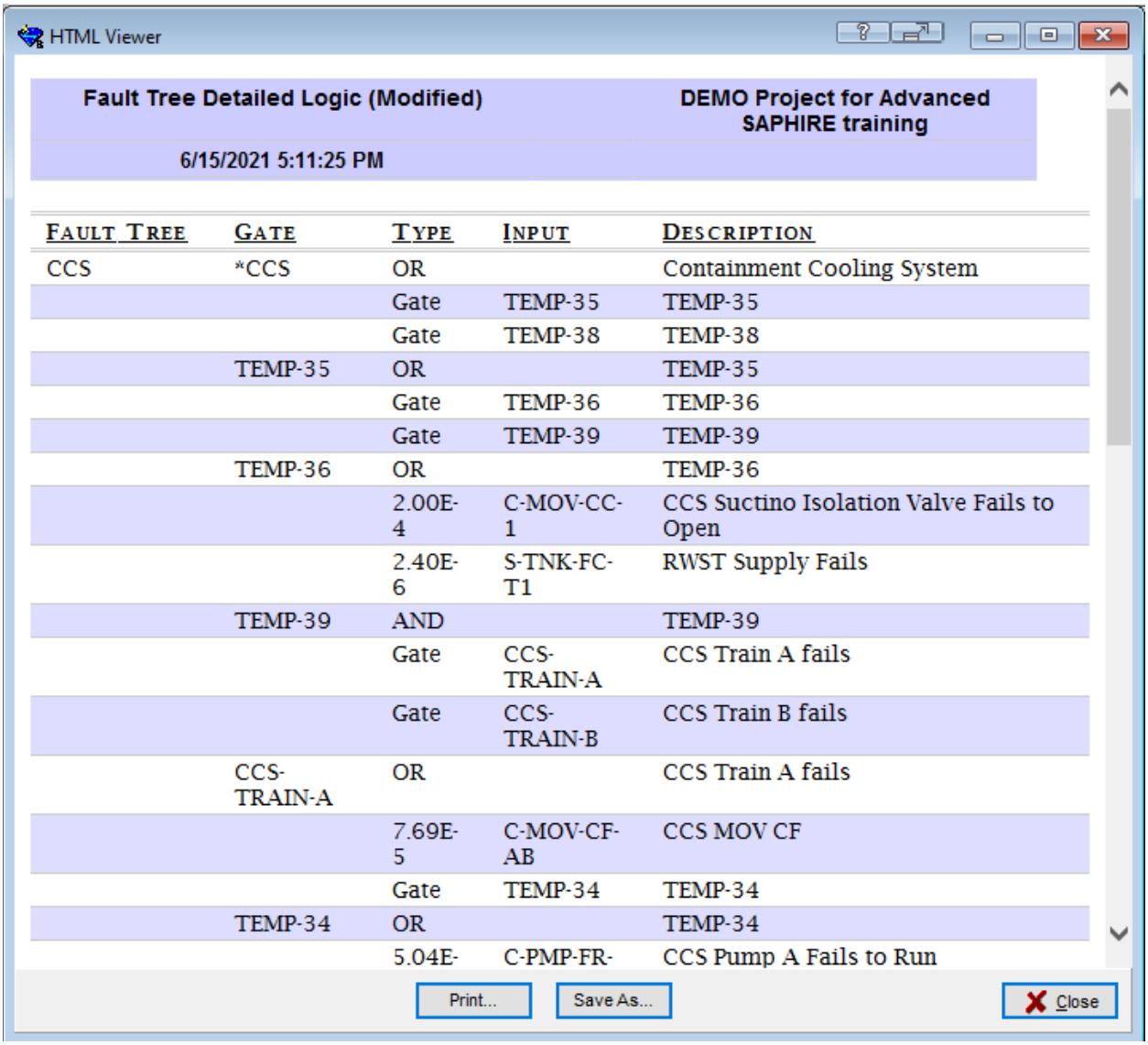
Figure 18 shows an HTML example of the "Fault Tree Detailed Logic (Expanded)" report screen.



FAULT TREE	GATE	TYPE	INPUT	DESCRIPTION
CCS	*CCS	OR		Containment Cooling System
		Gate	CCS-SUPPLY	No water to the Pump Trains
		Gate	CCS-TRAINS	Both Pump Trains Fail to Inject
	CCS-SUPPLY	OR		No water to the Pump Trains
		Gate	CCS-MOV-1	CCS MOV 1 Fails to Open
		2.40E-6	S-TNK-FC-T1	RWST Supply Fails
	CCS-MOV-1	OR		CCS MOV 1 Fails to Open
		Gate	SUP-DGN-B	Diesel Generator B Fails
		2.00E-4	C-MOV-CC-1	CCS Suction Isolation Valve Fails to Open
	SUP-DGN-B	OR		Diesel Generator B Fails
		2.11E-2	S-DGN-FR-B	Diesel Generator B Fails to Run
		4.00E-3	S-DGN-FS-B	Diesel Generator B Fails to Start
	CCS-TRAINS	AND		Both Pump Trains Fail to Inject

Figure 18. "Fault Tree Detailed Logic (Expanded)."

Figure 19 shows an HTML example of the "Fault Tree Detailed Logic (Modified)" report screen.



FAULT TREE	GATE	TYPE	INPUT	DESCRIPTION
CCS	*CCS	OR		Containment Cooling System
		Gate	TEMP-35	TEMP-35
		Gate	TEMP-38	TEMP-38
	TEMP-35	OR		TEMP-35
		Gate	TEMP-36	TEMP-36
		Gate	TEMP-39	TEMP-39
	TEMP-36	OR		TEMP-36
		2.00E-4	C-MOV-CC-1	CCS Suctino Isolation Valve Fails to Open
		2.40E-6	S-TNK-FC-T1	RWST Supply Fails
	TEMP-39	AND		TEMP-39
		Gate	CCS-TRAIN-A	CCS Train A fails
		Gate	CCS-TRAIN-B	CCS Train B fails
	CCS-TRAIN-A	OR		CCS Train A fails
		7.69E-5	C-MOV-CF-AB	CCS MOV CF
		Gate	TEMP-34	TEMP-34
	TEMP-34	OR		TEMP-34
		5.04E-	C-PMP-FR-	CCS Pump A Fails to Run

Figure 19. "Fault Tree Detailed Logic (Modified)."

3.1.1.3 Basic Event Group Editor

Description

Many users have asked for the ability to highlight a group of related basic events and update their information with one editor. The Basic Event Group Editor provides that capability.

Accomplishments

This Basic Event Group Editor has been added to the SAPHIRE Version 8.2.3 Release. After highlighting more than one event in the "Basic Event" left-hand list, right-click the mouse to show the pop-up menu (see Figure 20). Click the *Edit Group* option to bring up the Basic Event Group Editor (see Figure 21).

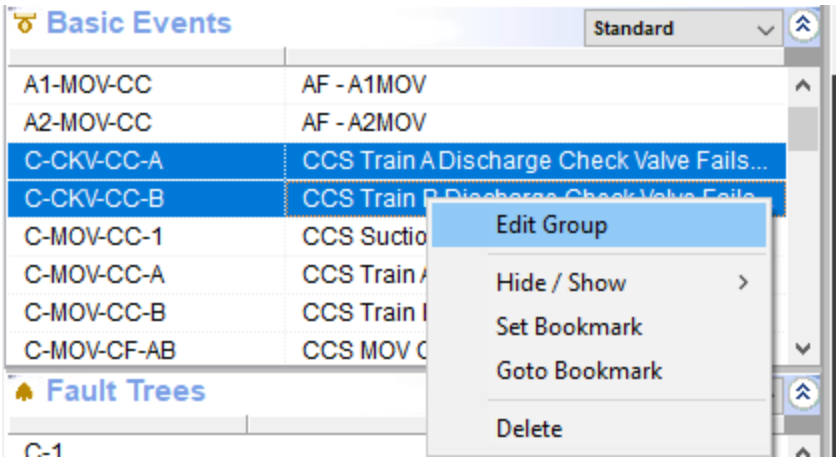


Figure 20. "Basic Event" pop-up menu.

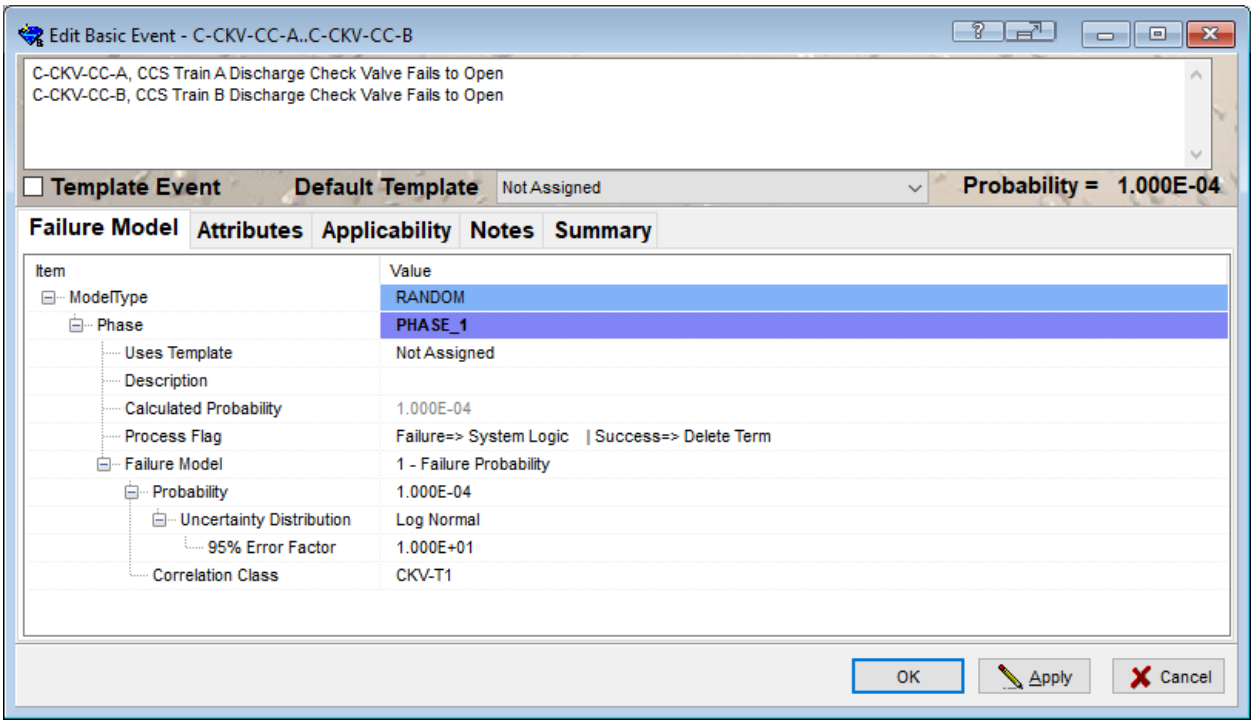


Figure 21. Basic Event Group Editor.

The basic events being edited are shown in the list with the familiar "Edit Basic Event form beneath the list. Whatever changes made in the "Failure Model" tab and other tabs will be saved to the listed basic events when the *OK* or *Apply* button are clicked. Clicking the *Cancel* button will leave the form without saving the changes.

WARNING: If the user selects a non-congruent (unrelated) group of events, the first event's information will be displayed and if any changes are made and saved, all of the events in the upper list will be updated with the entered changes.

3.1.1.4 MAR-D Load/Extract can rename basic events with a new file

Description

SPAR modelers have requested a new function be added to the MAR-D Load/Extract of basic events giving the user the ability to rename basic events in a batch mode. The user can extract a basic event rename file with a .BERN extension, and using Notepad or an equivalent text editor, the user can enter a new name for any number of basic events and then load that file back into the project.

Accomplishments

The MAR-D Load/Extract Basic Event Rename function has been added to the SAPHIRE Version 8.2.3 Release. To extract a BERN file, highlight the desired basic events and then select the File-> Load/Extract option from the "Main Menu" toolbar. Check the *Rename* check box in the "Basic Event" listing of the Load/Extract form as shown in Figure 22. The extract rename generates a file with a .BERN extension that contains three columns: "Name," "New Name," and "Project." An example of this process is given below.

For a simple project, the user needs to rename all the basic events used in the B Train to be used in the C Train. First step, the user highlights all the basic events ending with a -B and extracts the Rename file as shown in Figure 22.

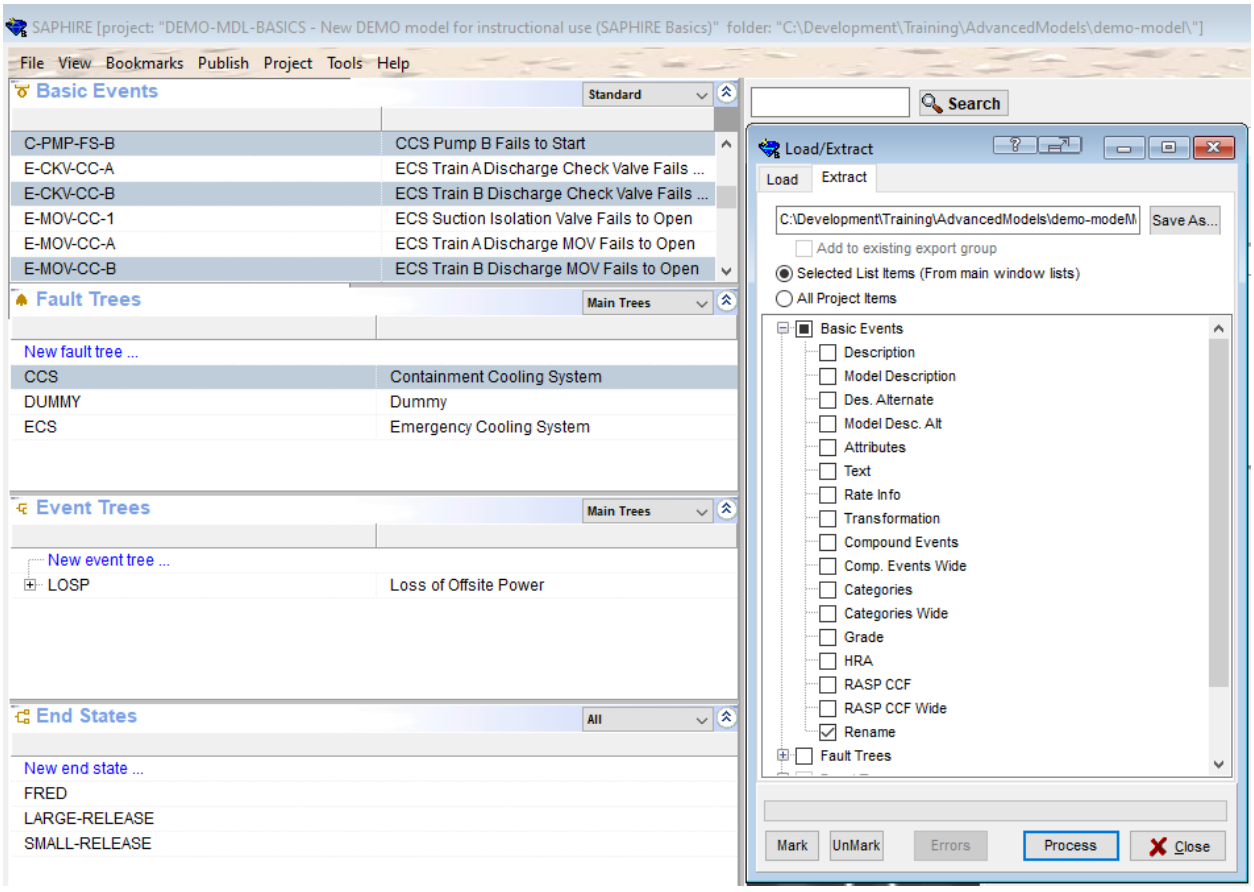


Figure 22. Load/Extract rename basic events.

Click the *Process* button and wait for the confirmation form (see Figure 23).

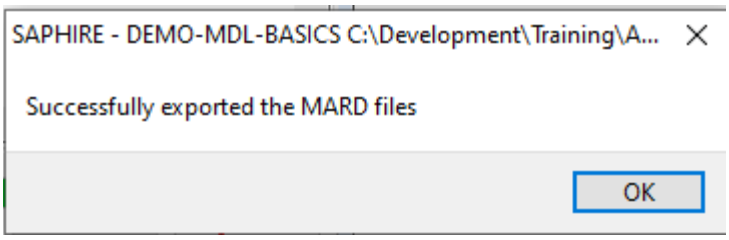


Figure 23. Confirmation form.

Figure 24 shows the DEMO-MDL-BASICS.BERN file as it was extracted. Figure 25 shows the user can do a search and replace of all the -B in the “New Name” column to make them -C events.

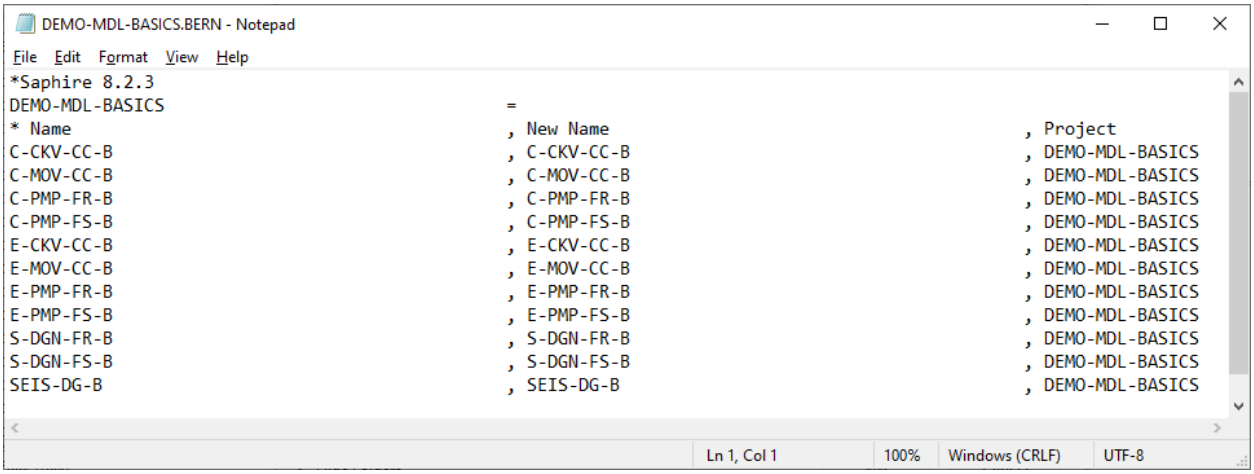


Figure 24.Original BERN file.

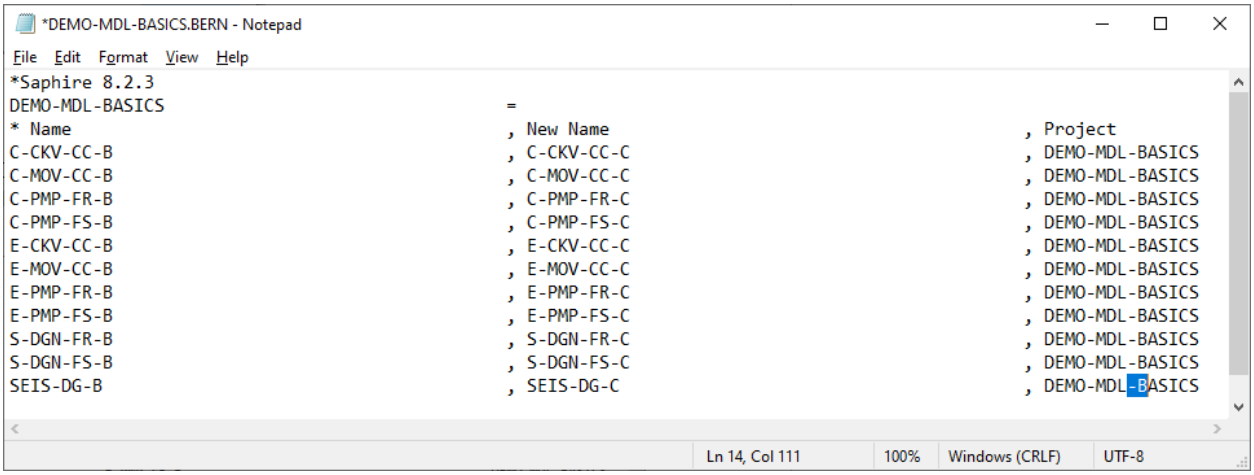


Figure 25. Modified BERN file.

Import the modified file (see Figure 26) by clicking the *Process* button. Wait for the confirmation form (see Figure 27).

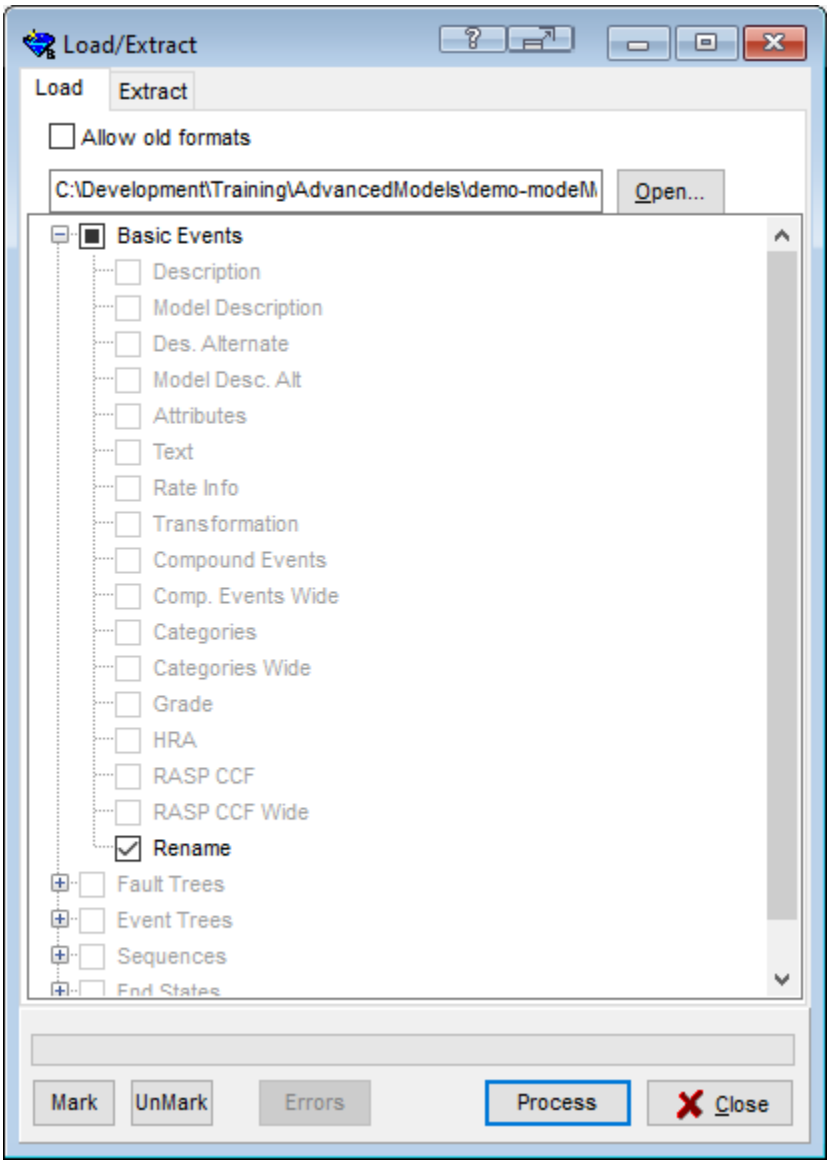


Figure 26. Load Rename.

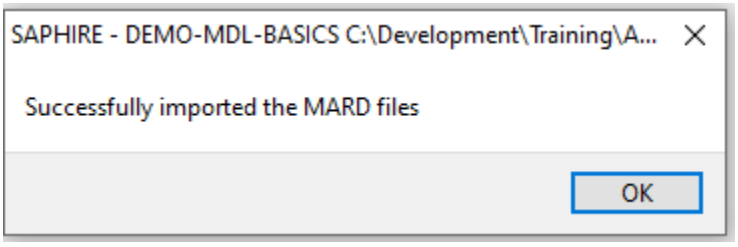


Figure 27. Load confirmation.

The report shown in Figure 28 shows the impact of the .BERN file load. The descriptions can now be updated through a .BED file if necessary.

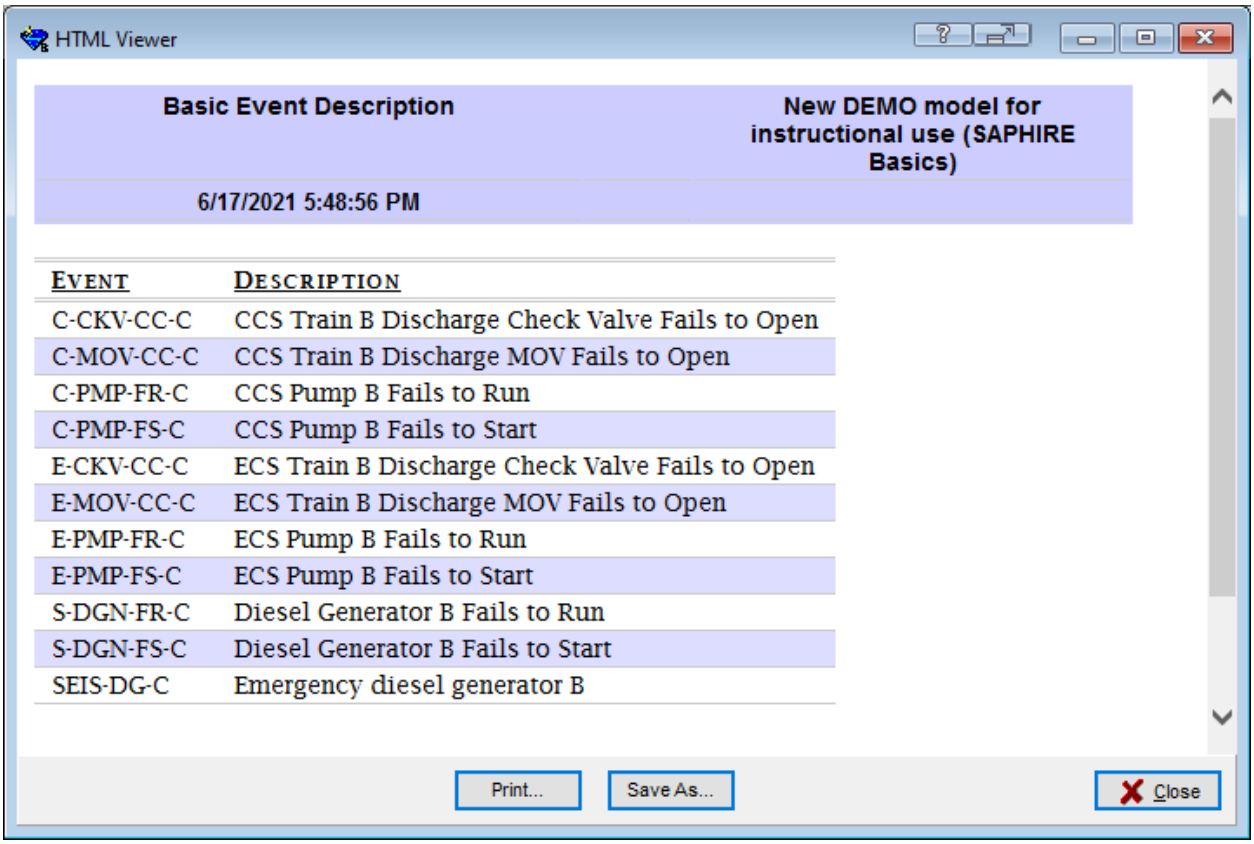


Figure 28. Basic event description report.

3.1.2 SAPHIRE Version 8.2.4 Release

The upcoming June/July release of SAPHIRE, Version 8.2.4, will have following new features described in detail in Sections 3.1.2.1–3.1.2.6:

- Single MAR-D input/output file for all SPAR projects
- SPAR 8.5 Sensitivity Report can be distributed across multiple processes
- PRIB Changes
- PRIB for selected scenarios
- Reports for NRC Dashboard
- Ability to publish Uncertainty from View Uncertainty

3.1.2.1 Single MAR-D input/output file for all Standardized Plant Analysis Risk projects

Description

Earlier releases of SAPHIRE 8, added a project name to each MAR-D output format. This project identifier provided sortable information to the SPAR modelers to help them identify the source project for each basic event as well as other data items. This allowed the SPAR modelers to separate the MAR-D files into files related to specific SPAR projects. This was a workable solution, but the bookkeeping activities of taking a master basic event file and separating out the events to each project basic event file caused some data errors to pop-up in the SPAR projects. The solution proposed was to change the Load operation to load only basic events belonging to the current project. Because some basic events need to be

loaded into all models, or just boiling water reactors (BWR), or just pressurized water reactors (PWR), specific keywords have been defined to inform the Load process of the correct activity. Those keywords are listed below:

SPARALL – always load this basic event,

SPARBWR – if the project is a BWR, load this basic event, or

SPARPWR – if the project is a PWR, load this basic event.

If one of the special keywords defined above are not in the project column, the Load algorithm will ensure the name of the project is equivalent to the project column entry.

The default operation of the Load process is to disregard the project column and load every basic event in the file. To override this default action, a special marker must be added to the standard opening line of a MAR-D file. This marker text is "!ProjectField!" In a most basic event MAR-D files, it would be placed as shown below:

*SAPHIRE 8.2.2 – Version tag on MAR-D output.

MASTER-DATA-LOAD !ProjectField! =.

Accomplishments

This capability has been added to SAPHIRE Release 8.2.4. The SPAR modelers have used a pre-release version of SAPHIRE to test this functionality and accepted this capability functional.

3.1.2.2 SPAR 8.5 Sensitivity Report can be distributed across multiple processes

Description

Before any SPAR model is released, a series of SPAR reports are produced and included with that model. The SPAR report "Table 8-5 Results from Sensitivity Analyses" uses a group of special change sets called sensitivity change sets to generate event tree cut sets and results for each change set and then produces a report. This process is time consuming, so the SPAR modelers requested this process be parallelized like the "Convergence Report" or "PRIB" preparation.

Accomplishments

This capability has been added to SAPHIRE Release 8.2.4. To use multiple processes to create a SPAR Report Table 8-5, select "SPAR Reports" and ensure the check box to the left of Table 8-5 is checked (see Figure 29). Set the "Number of Processes" (bottom left of the pop-up form) to an appropriate value using the up and down arrows. For this example, the number of processes was set to two (2).

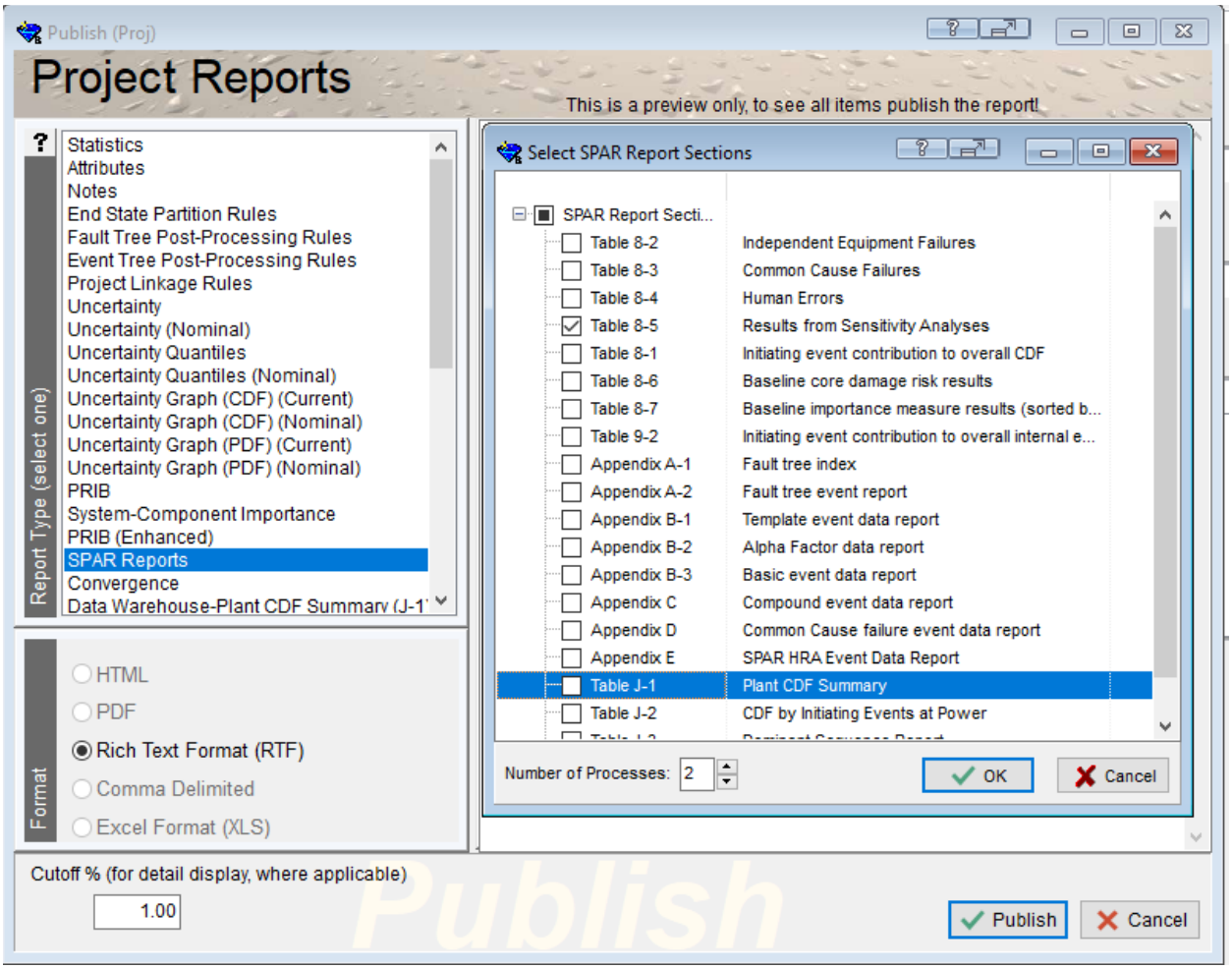


Figure 29. SPAR reports.

Clicking the *OK* button will display the reports selected prompting a confirmation dialog box (select *Yes* or *No*) in a possibly lengthy process before proceeding (see Figure 30). Clicking the *Yes* button will perform the sensitivity analysis with the desired number of processes.

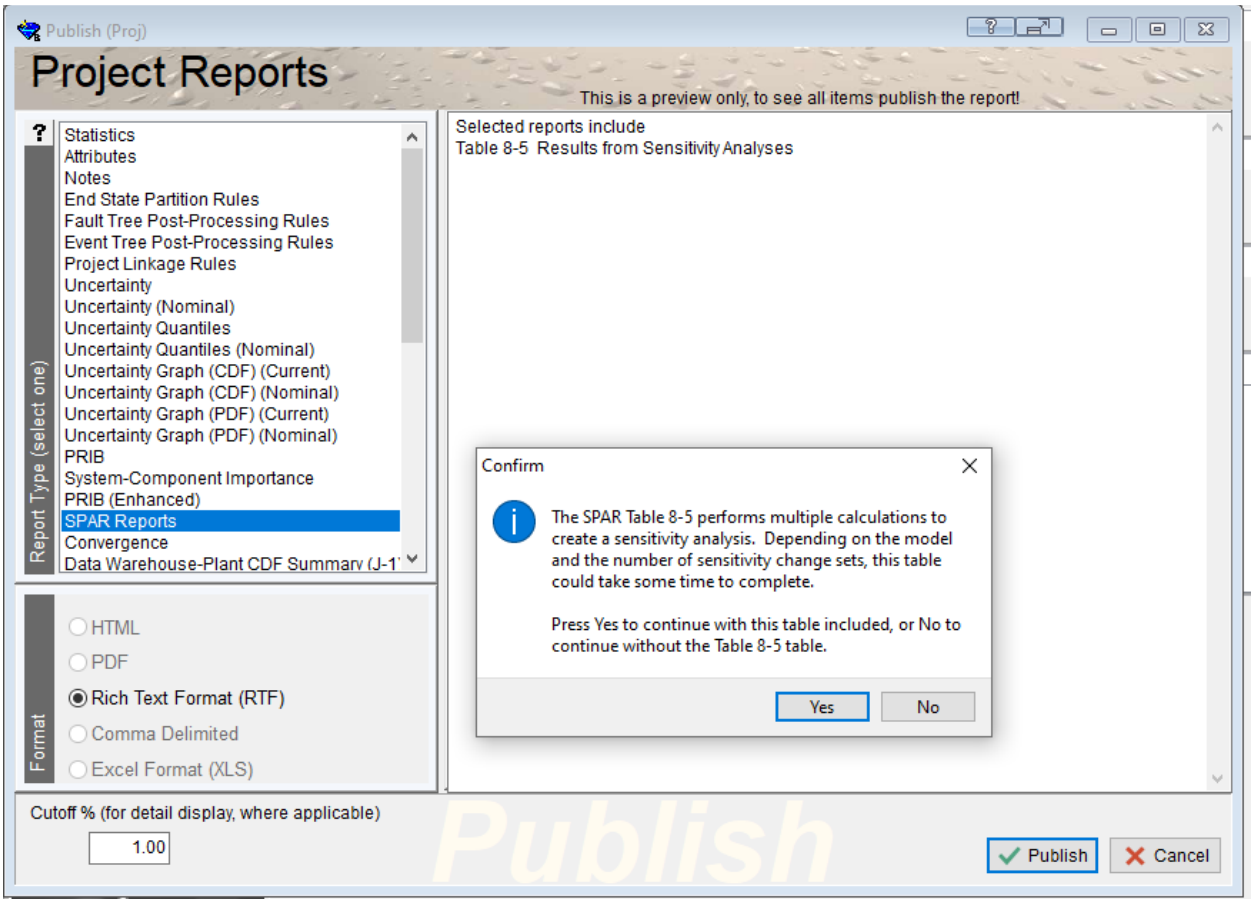


Figure 30. Confirmation.

Figure 31 shows a screen shot of an actual sensitivity report being produced using four processes. This is similar to producing a Convergence Report or PRIB. Figure 32 shows a sample.

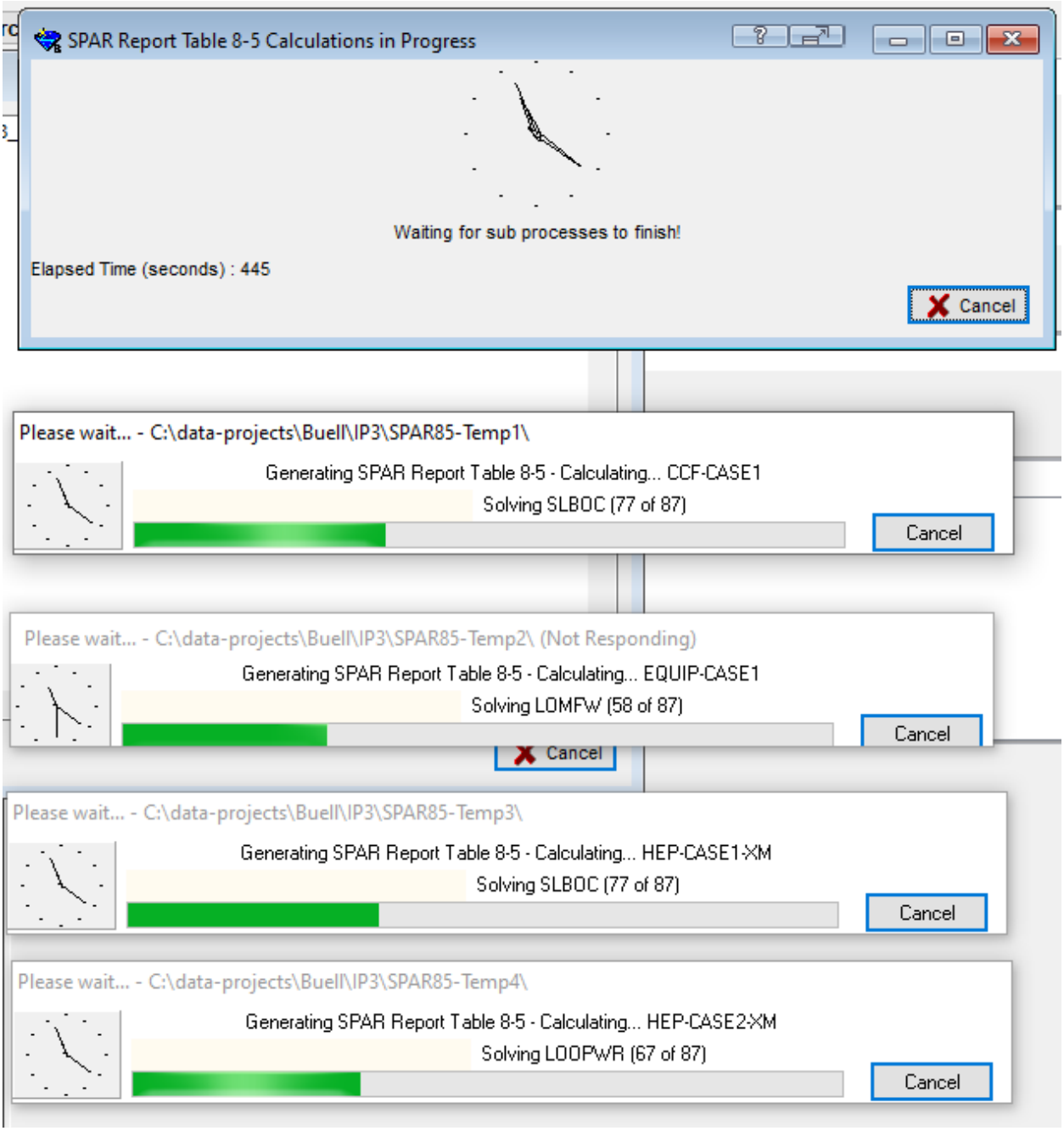


Figure 31. Actual working screen shot.

Table 8-5 Results from Sensitivity Analyses Sensitivity Analysis

Nominal Case CDF = 1.31E-05

Sensitivity Case	New CDF	Change in CDF	RIR/RAW
Increase HEP values to 1.0 (XHE-XM)	3.3E-02	3.3E-02	2.5E+03
Increase equipment failure by a factor of 10	3.0E-03	3.0E-03	2.3E+02
Increase HEP values by a factor of 10 (XHE-XM)	1.4E-04	1.3E-04	1.1E+01
Increase CCF events by a factor of 10	5.5E-05	4.1E-05	4.2E+00
Decrease HEP values to 0.0 (XHE-XM)	1.1E-05	-2.2E-06	8.3E-01

Figure 32. Table 8-5 example.

3.1.2.3 Plant Risk Information e-Book Updates

Description

A PRIB is part of each SPAR model. Each PRIB provides insights into important aspects of its corresponding SPAR model. After the NRC's review, it was determined the PRIB needed to have more explanatory text and three additional tables. The explanatory text helped define the several importance measures calculated in the PRIB. The updated PRIB will contain three new tables based on component importance. The first, Table 8, will provide a list of components with a Fussell-Vesely importance of greater than 0.005 sorted by their Fussell-Vesely importance value. The second, Table 9, will provide a list of components with a risk increase ratio (RIR) or risk achievement worth (RAW) importance of greater than 2.0 sorted by their RAW, and the third, Table 10, will provide a list of components with a Birnbaum importance of greater than 1.0E–6 sorted by their Birnbaum importance value.

Accomplishments

SAPHIRE Release 8.2.4 will produce an updated PRIB meeting the requirements described in the above description. Given the sensitive nature of each PRIB, an example PRIB has been sent to the COR and received approval. It is not necessary to include a PRIB in this document.

3.1.2.4 Enhanced plant risk information e-book for selected scenarios

Description

In discussions with senior reactor analysts (SRAs) and SPAR modelers, it was requested the SPAR modelers prepare several PRIB-like reports detailing the impact of various scenarios on each project. These Enhanced PRIBs will enable the SRAs to quickly see the relative importance of different systems and components given the failure of important components. The SPAR modelers have developed special change sets representing these dominant scenarios used to produce an Enhanced PRIB specific to that scenario. These Enhanced PRIBs will be named after the name of the change set defining the scenario. These change sets are given the special type of "Enhanced." They can be added to a SPAR model by a user or through the MAR-D Load of change sets (.CSD, .CSI, and .CSA files).

Accomplishments

SAPHIRE Release 8.2.4 will produce several Enhanced PRIBs meeting the requirements described above. An Enhanced PRIB was developed to enable special change sets to be applied, and the model to be solved using them. The output will provide importance measures and other results conditional on these specific conditions. At this time, the Enhanced PRIB is not completely implemented but will function as described in the below details.

Figure 33 shows the "Change Set Editor" has been updated to allow the "Enhanced" change sets to be defined.

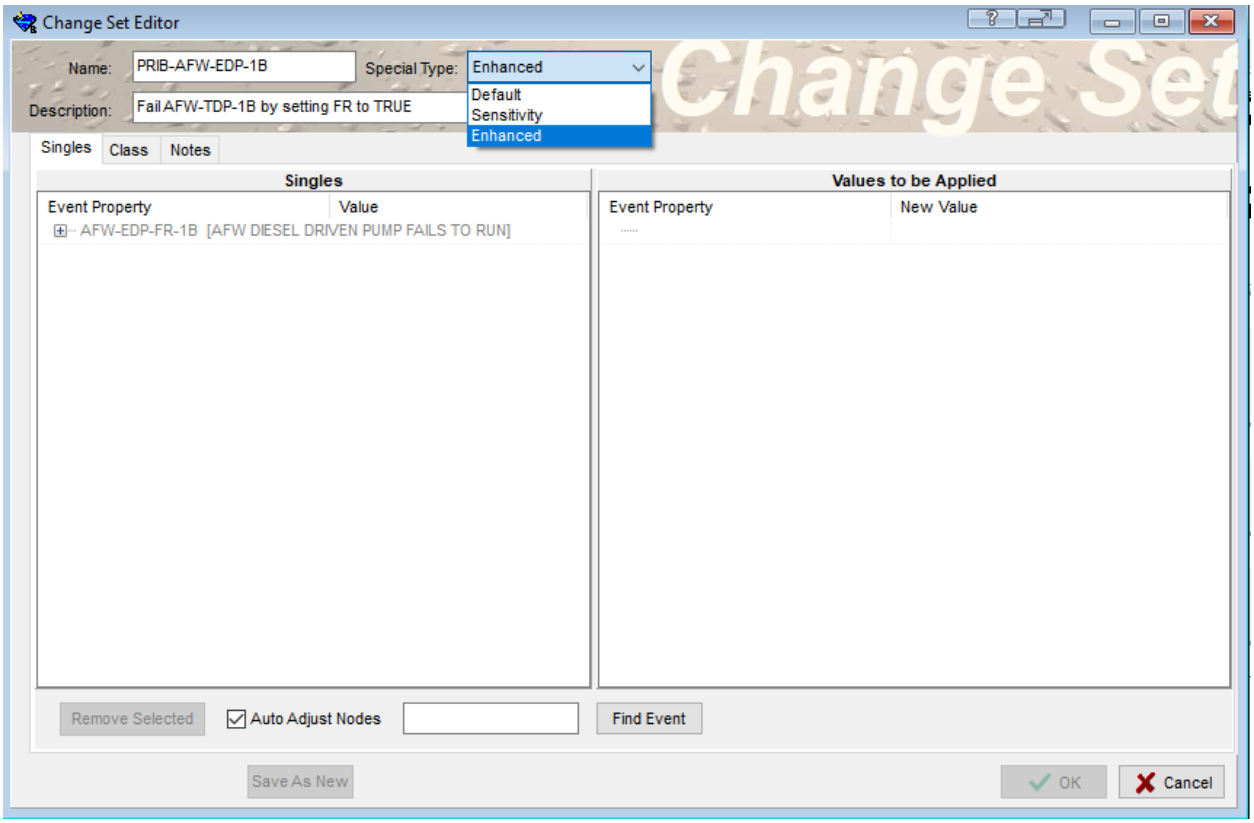


Figure 33. Change Set Editor.

Figure 34 illustrates how once the *PRIB (Enhanced)* is selected as the "Report Type," the enhanced change sets are displayed in the "Change Set Reports" pop-up menu. The user can create an Enhanced PRIB for all the enhanced change sets or use the check boxes to limit which Enhanced PRIBs are produced. Clicking the *Ok* button will show the Enhanced PRIB – Systems with Reportable Components form (not displayed) allowing the users to update the various importance measures of the systems and components.

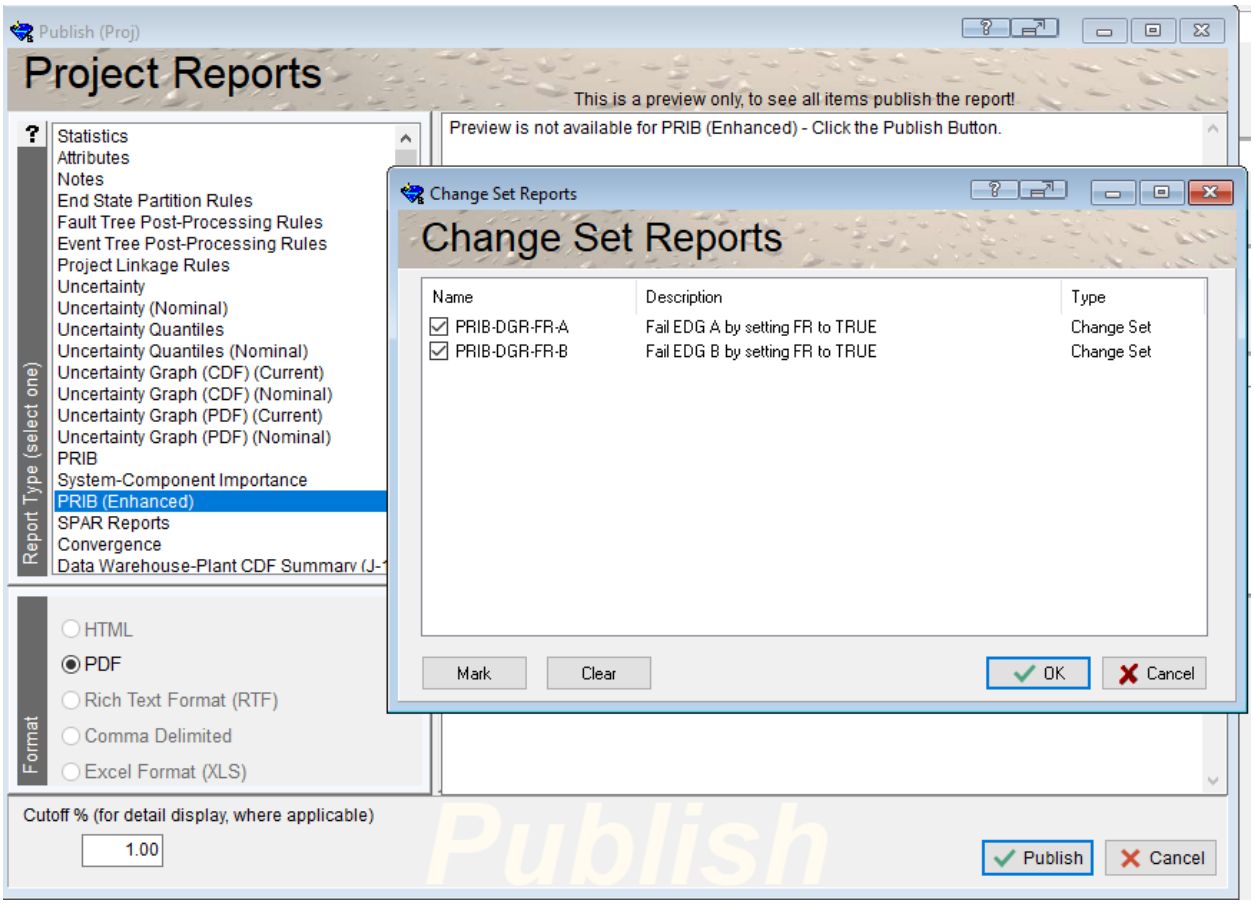


Figure 34. Project Reports - PRIB (Enhanced).

The “PRIB (Enhanced) Project Report” does not contain all the PRIB sections but does contain the following:

- PRIB Figure 1 - Initiating Event Percent Contribution to CDF. The contribution to the baseline CDF per initiating event is presented.
- PRIB Figure 2 - Risk Important Systems. The increase in the baseline CDF due to failure of an individual plant system is ranked from highest to lowest. The top 10 systems with the largest increase are included and color-coded.
- PRIB Figure 3 - Risk Important Operator Actions. The top 10 operator action contributors to the baseline CDF are listed from highest to lowest according to percent reduction in CDF.
- PRIB Table 1 - Component Importance (grouped by system). This is for each system listed in PRIB Figure 2. The most significant contributors to the baseline CDF (based on Birnbaum importance) are listed from highest to lowest following the same color code as in PRIB Figure 2.
- PRIB Table 2 - Operator Action Importance (grouped by system). For each system listed in PRIB Figure 2, the most significant operator action contributors to the baseline CDF (Birnbaum importance) are listed from highest to lowest following the same color code as in PRIB Figure 2.
- PRIB Table 3 - Common Cause Component Importance (grouped by system). For each system listed in PRIB Figure 2, the most significant common cause contributors to the baseline CDF (based on Birnbaum importance) are listed from highest to lowest following the same color code as in PRIB Figure 2.

- PRIB Table 7 - Component Risk Importance Measures. Ranks all components and operator actions first by system and then by the Birnbaum importance measure with respect to the baseline CDF.

As mentioned above, the Enhanced PRIB is not completely implemented or tested but will be completed and tested before the SAPHIRE Release 8.2.4 is released. This section will be updated in the next series of this report.

3.1.2.5 Reports for NRC Dashboard

Description

The NRC has requested several report outputs be produced from SAPHIRE so they can import them into databases and produce data-driven dashboards to promote a better understanding of the SPAR models.

Accomplishments

Six new project reports have been added to SAPHIRE Release 8.2.4. Two of these reports contain similar information to two of the SPAR Tables:

- Table J-1 - Plant CDF Summary J-1
- Table J-2 - CDF by Initiating Events at Power.

Four of these reports contain similar information to parts of the PRIB:

- PRIB Table 7 - Component Risk Importance Measures
- PRIB Table 8 - Component Risk Importance FV > 0.005
- PRIB Table 9 - Component Risk Importance RAW > 2.0
- PRIB Table 10 - Component Risk Importance Birnbaum.

These new reports are named:

- Data Warehouse - Plant CDF Summary (J-1)
- Data Warehouse - CDF by Initiating Events (J-2)
- Data Warehouse - PRIB Table 7 Complete
- Data Warehouse - PRIB Table 8 F-V exceeds 0.005
- Data Warehouse - PRIB Table 9 RAW exceeds 2.0
- Data Warehouse - PRIB Table 10 Birnbaum exceeds 1.0E–6.

To identify the source of these data reports, the NRC docket number and four-character NRC plant name were added to each SPAR model. These may be entered through the “Edit Project” form on the “SPAR” tab (see Figure 35). Please note the “NRC Plant Name” and “Docket #” displayed here (DEMO and #05XX9999 respectively) are fictitious and for demonstration purposes only.

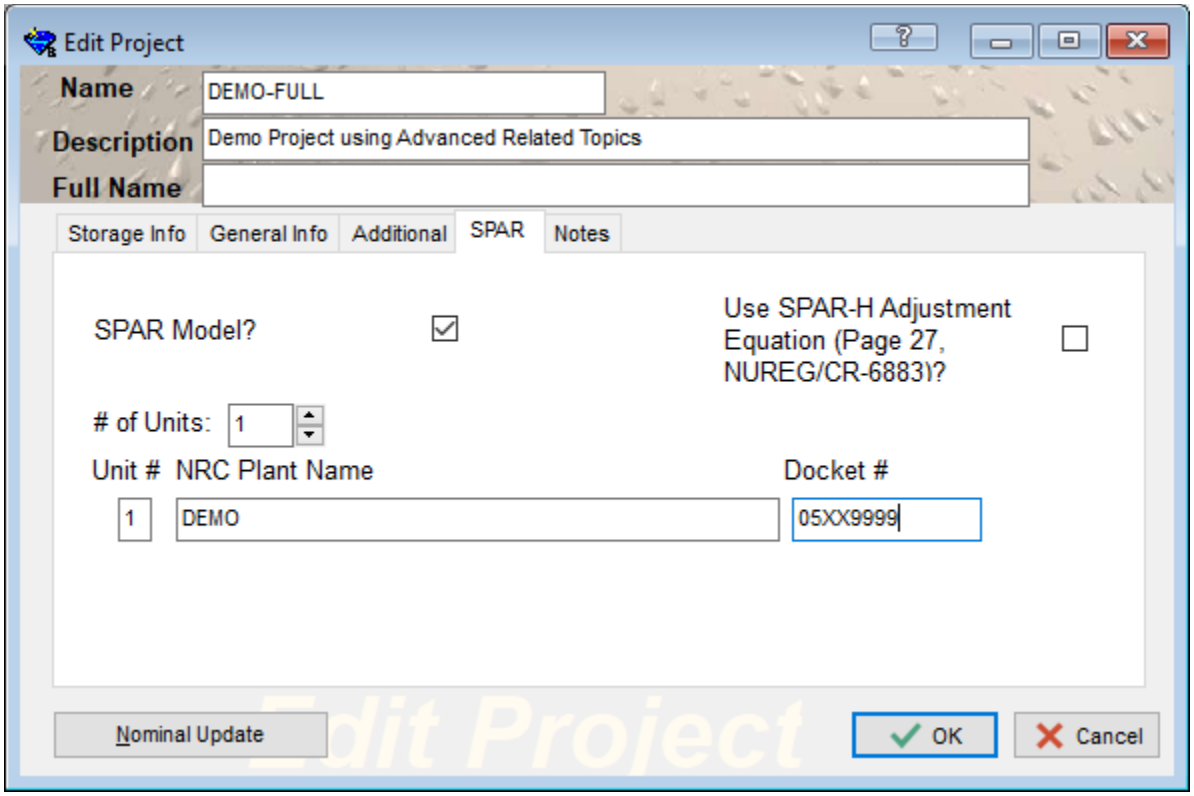


Figure 35. Edit Project.

Figure 36 displays these new project reports in the "Publish" form. Each report is provided in five report formats (HTML, PDF, RTF, CSV, and Excel). Figure 37–Figure 42 shows examples of the six *Data Warehouse* report types in HTML format.

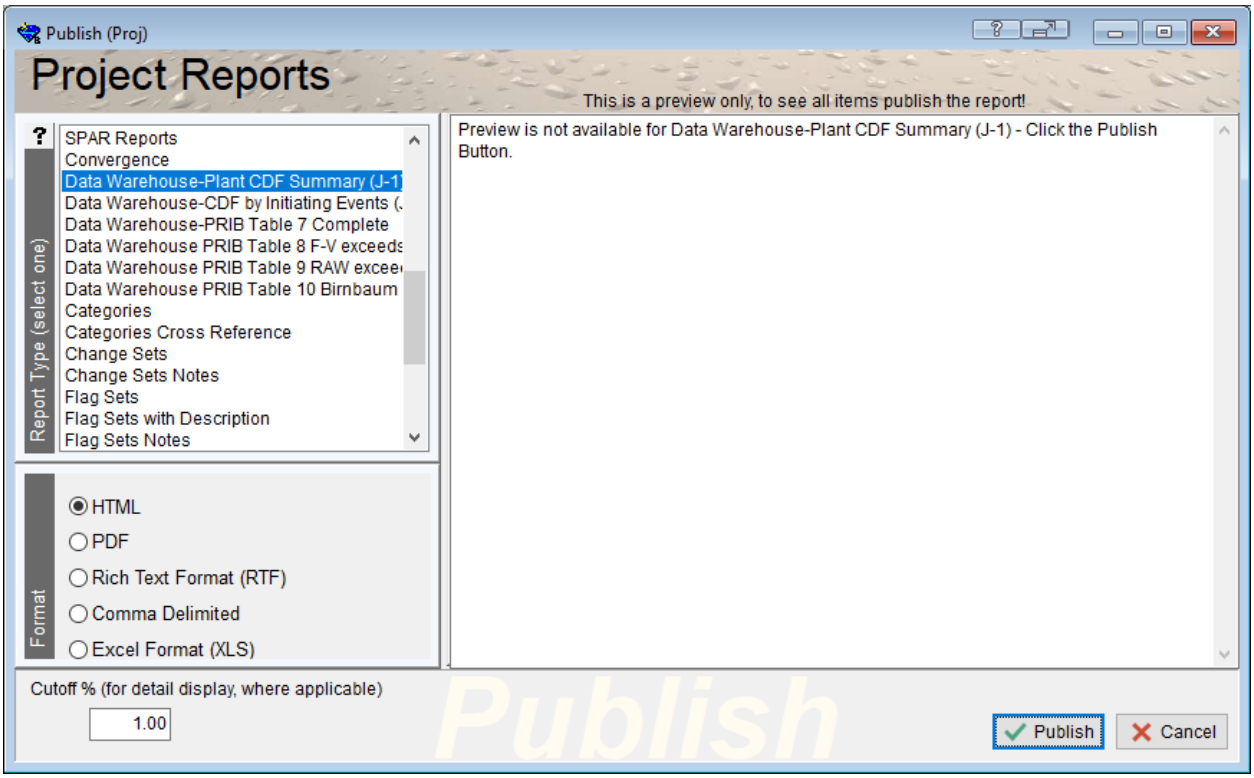
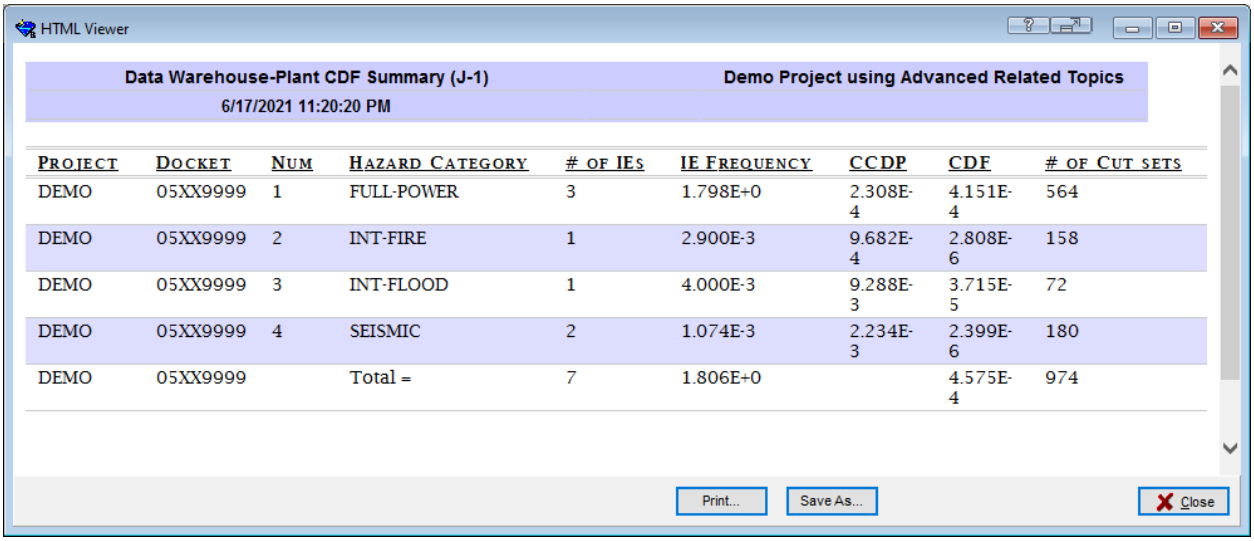
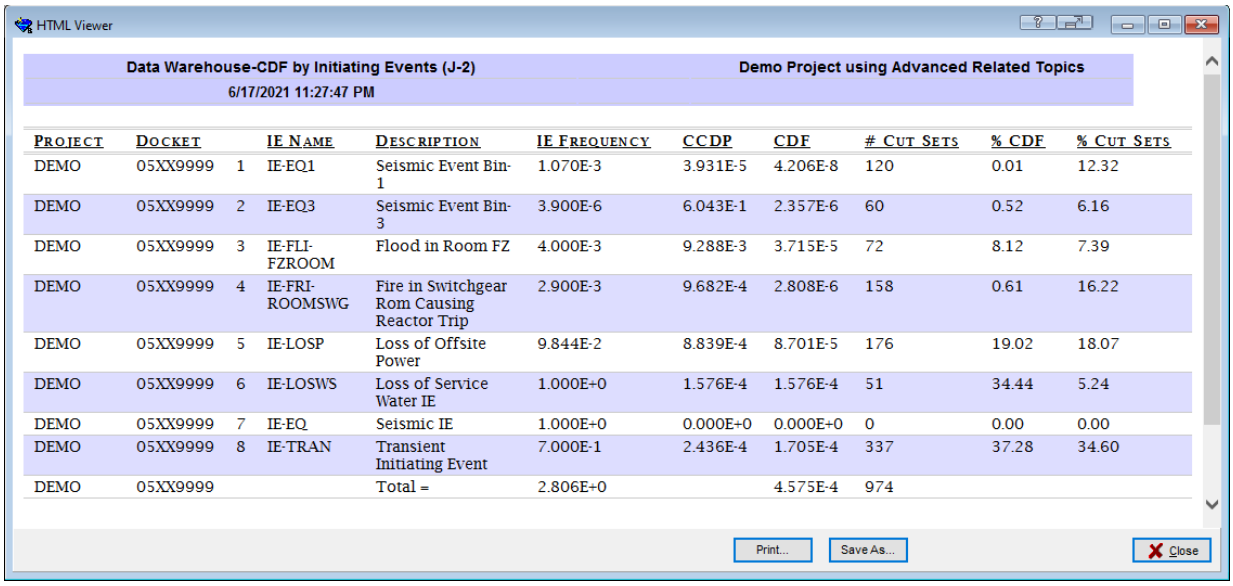


Figure 36. Project Reports.



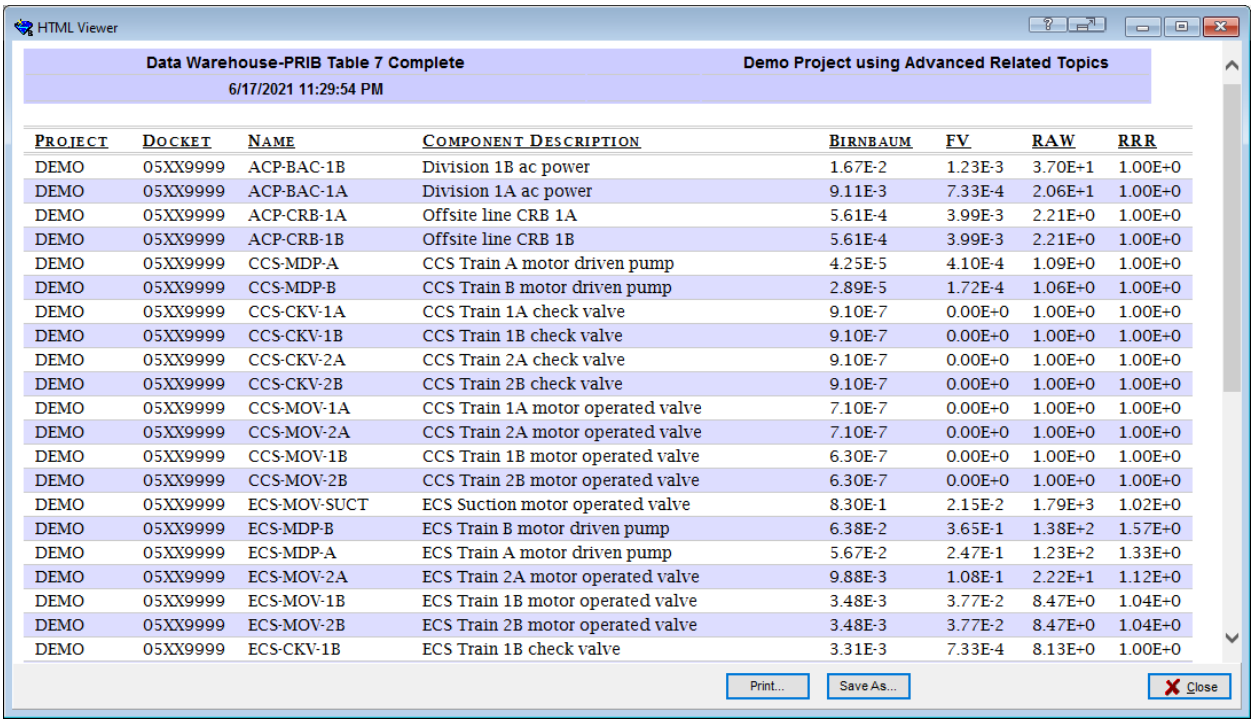
PROJECT	DOCKET	NUM	HAZARD CATEGORY	# OF IES	IE FREQUENCY	CCDP	CDF	# OF CUT SETS
DEMO	05XX9999	1	FULL-POWER	3	1.798E+0	2.308E-4	4.151E-4	564
DEMO	05XX9999	2	INT-FIRE	1	2.900E-3	9.682E-4	2.808E-6	158
DEMO	05XX9999	3	INT-FLOOD	1	4.000E-3	9.288E-3	3.715E-5	72
DEMO	05XX9999	4	SEISMIC	2	1.074E-3	2.234E-3	2.399E-6	180
DEMO	05XX9999		Total =	7	1.806E+0		4.575E-4	974

Figure 37. Data Warehouse-Plant CDF Summary (J-1).



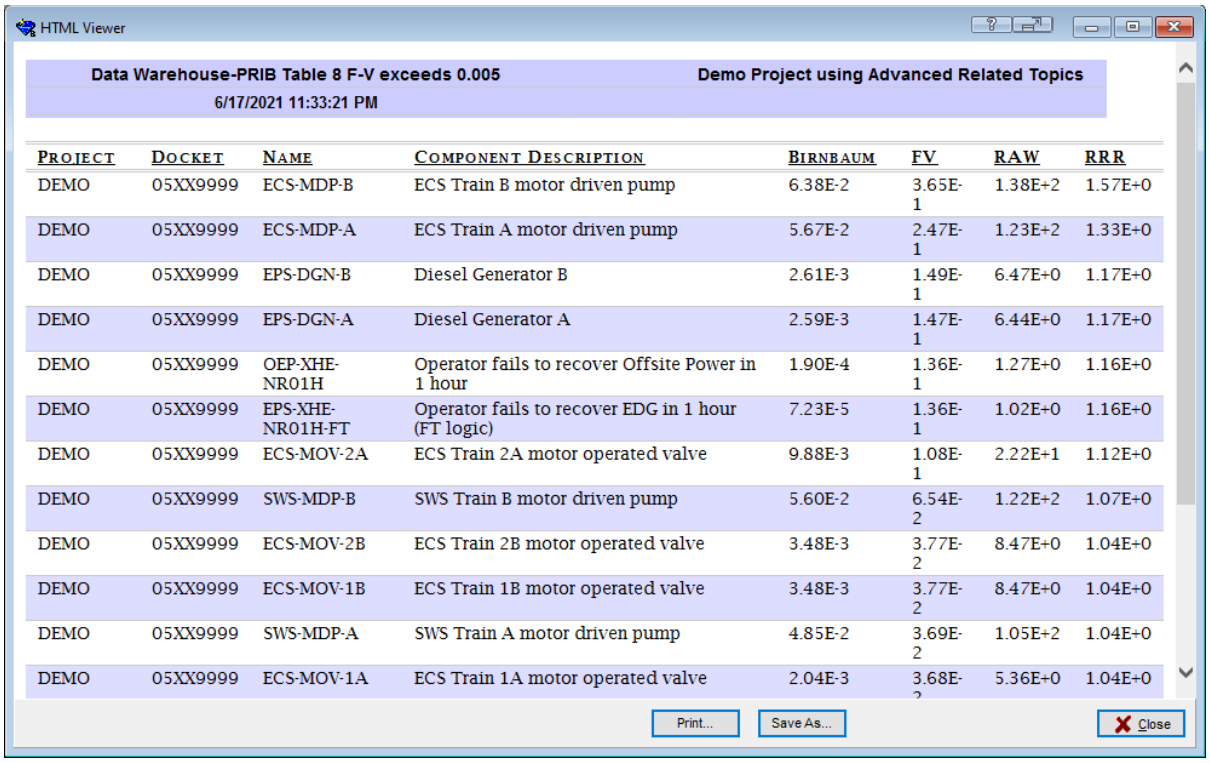
Project	Docket		IE Name	Description	IE Frequency	CCDP	CDF	# Cut Sets	% CDF	% Cut Sets
DEMO	05XX9999	1	IE-EQ1	Seismic Event Bin-1	1.070E-3	3.931E-5	4.206E-8	120	0.01	12.32
DEMO	05XX9999	2	IE-EQ3	Seismic Event Bin-3	3.900E-6	6.043E-1	2.357E-6	60	0.52	6.16
DEMO	05XX9999	3	IE-FLI-FZROOM	Flood in Room FZ	4.000E-3	9.288E-3	3.715E-5	72	8.12	7.39
DEMO	05XX9999	4	IE-FRI-ROOMSWG	Fire in Switchgear Rom Causing Reactor Trip	2.900E-3	9.682E-4	2.808E-6	158	0.61	16.22
DEMO	05XX9999	5	IE-LOSP	Loss of Offsite Power	9.844E-2	8.839E-4	8.701E-5	176	19.02	18.07
DEMO	05XX9999	6	IE-LOSWS	Loss of Service Water IE	1.000E+0	1.576E-4	1.576E-4	51	34.44	5.24
DEMO	05XX9999	7	IE-EQ	Seismic IE	1.000E+0	0.000E+0	0.000E+0	0	0.00	0.00
DEMO	05XX9999	8	IE-TRAN	Transient Initiating Event	7.000E-1	2.436E-4	1.705E-4	337	37.28	34.60
DEMO	05XX9999			Total =	2.806E+0		4.575E-4	974		

Figure 38. Data Warehouse-CDF by Initiating Events (J-2).



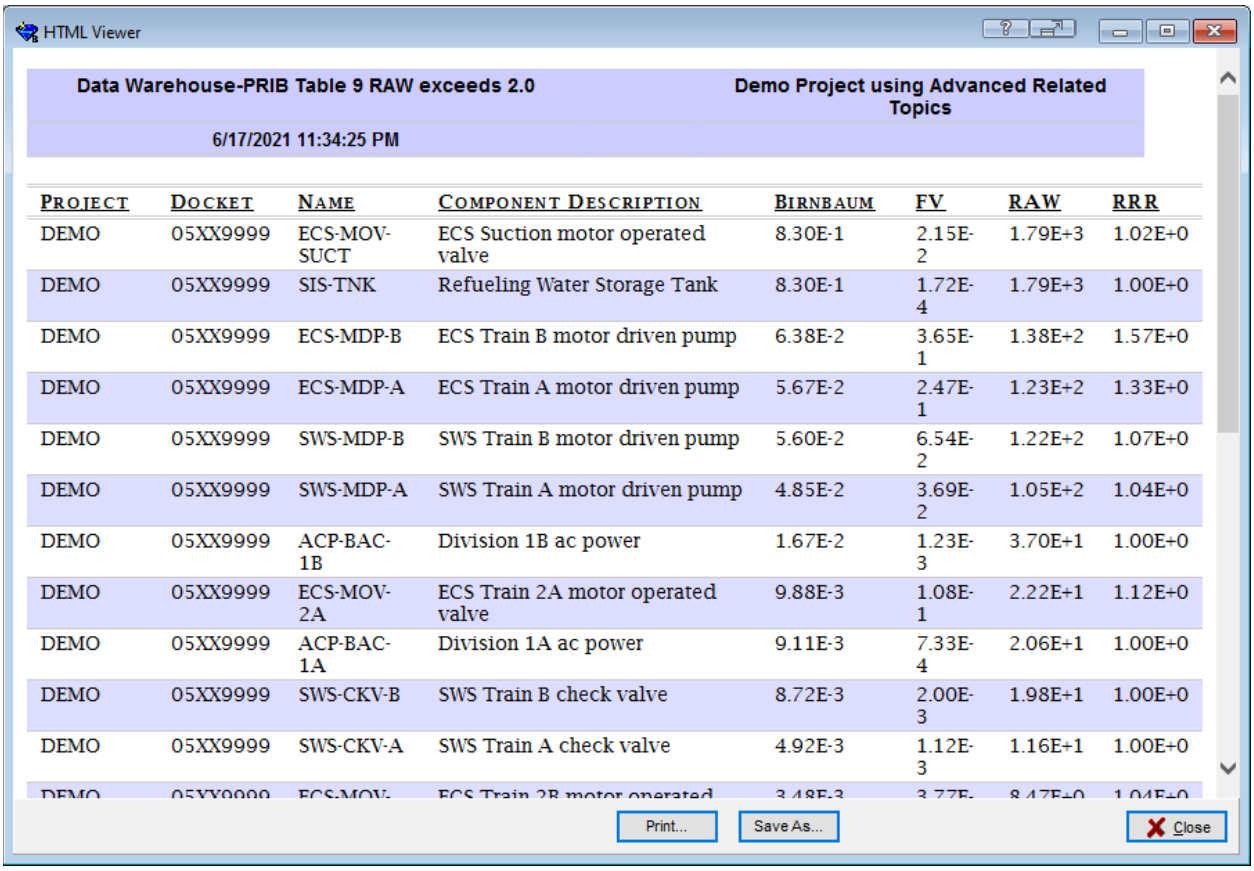
Project	Docket	Name	Component Description	Birnbaum	FV	RAW	RRR
DEMO	05XX9999	ACP-BAC-1B	Division 1B ac power	1.67E-2	1.23E-3	3.70E+1	1.00E+0
DEMO	05XX9999	ACP-BAC-1A	Division 1A ac power	9.11E-3	7.33E-4	2.06E+1	1.00E+0
DEMO	05XX9999	ACP-CRB-1A	Offsite line CRB 1A	5.61E-4	3.99E-3	2.21E+0	1.00E+0
DEMO	05XX9999	ACP-CRB-1B	Offsite line CRB 1B	5.61E-4	3.99E-3	2.21E+0	1.00E+0
DEMO	05XX9999	CCS-MDP-A	CCS Train A motor driven pump	4.25E-5	4.10E-4	1.09E+0	1.00E+0
DEMO	05XX9999	CCS-MDP-B	CCS Train B motor driven pump	2.89E-5	1.72E-4	1.06E+0	1.00E+0
DEMO	05XX9999	CCS-CKV-1A	CCS Train 1A check valve	9.10E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-CKV-1B	CCS Train 1B check valve	9.10E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-CKV-2A	CCS Train 2A check valve	9.10E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-CKV-2B	CCS Train 2B check valve	9.10E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-MOV-1A	CCS Train 1A motor operated valve	7.10E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-MOV-2A	CCS Train 2A motor operated valve	7.10E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-MOV-1B	CCS Train 1B motor operated valve	6.30E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	CCS-MOV-2B	CCS Train 2B motor operated valve	6.30E-7	0.00E+0	1.00E+0	1.00E+0
DEMO	05XX9999	ECS-MOV-SUCT	ECS Suction motor operated valve	8.30E-1	2.15E-2	1.79E+3	1.02E+0
DEMO	05XX9999	ECS-MDP-B	ECS Train B motor driven pump	6.38E-2	3.65E-1	1.38E+2	1.57E+0
DEMO	05XX9999	ECS-MDP-A	ECS Train A motor driven pump	5.67E-2	2.47E-1	1.23E+2	1.33E+0
DEMO	05XX9999	ECS-MOV-2A	ECS Train 2A motor operated valve	9.88E-3	1.08E-1	2.22E+1	1.12E+0
DEMO	05XX9999	ECS-MOV-1B	ECS Train 1B motor operated valve	3.48E-3	3.77E-2	8.47E+0	1.04E+0
DEMO	05XX9999	ECS-MOV-2B	ECS Train 2B motor operated valve	3.48E-3	3.77E-2	8.47E+0	1.04E+0
DEMO	05XX9999	ECS-CKV-1B	ECS Train 1B check valve	3.31E-3	7.33E-4	8.13E+0	1.00E+0

Figure 39. Data Warehouse-PRIB Table 7 Complete.



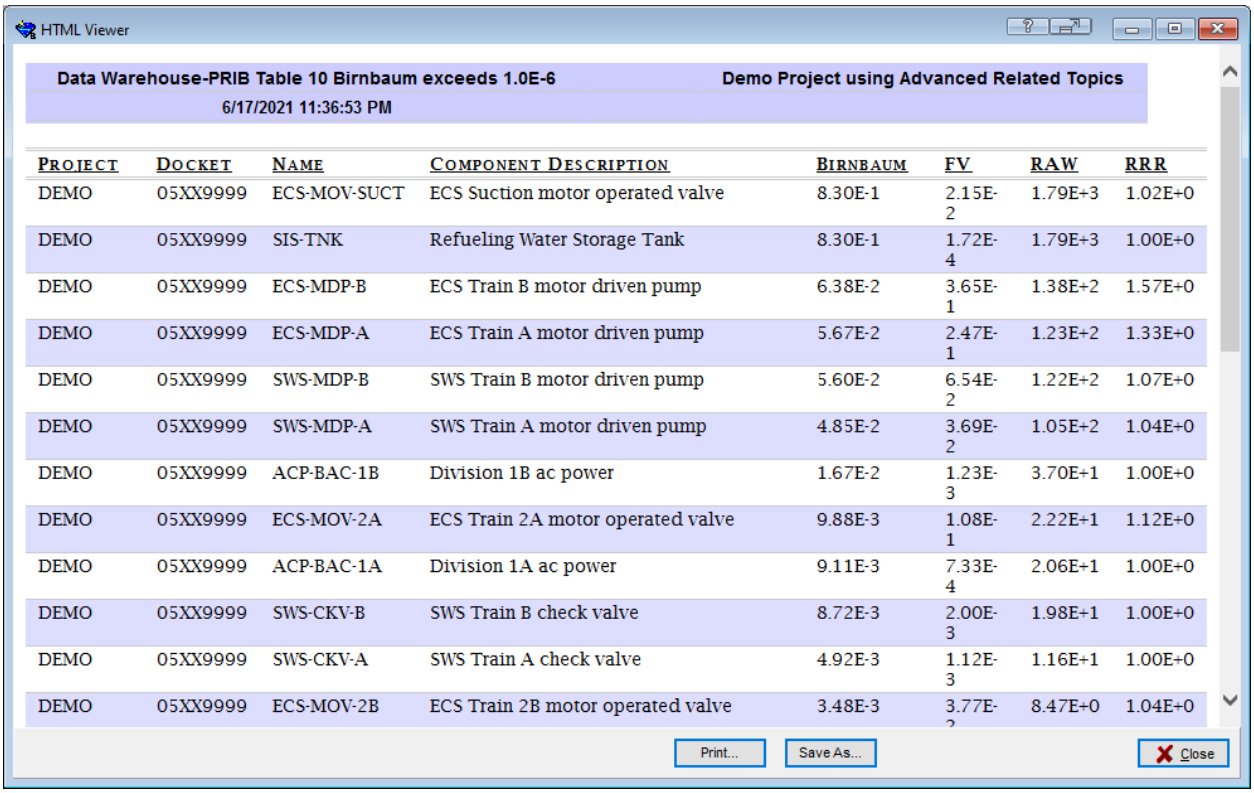
PROJECT	DOCKET	NAME	COMPONENT DESCRIPTION	BIRNBAUM	FV	RAW	RRR
DEMO	05XX9999	ECS-MDP-B	ECS Train B motor driven pump	6.38E-2	3.65E-1	1.38E+2	1.57E+0
DEMO	05XX9999	ECS-MDP-A	ECS Train A motor driven pump	5.67E-2	2.47E-1	1.23E+2	1.33E+0
DEMO	05XX9999	EPS-DGN-B	Diesel Generator B	2.61E-3	1.49E-1	6.47E+0	1.17E+0
DEMO	05XX9999	EPS-DGN-A	Diesel Generator A	2.59E-3	1.47E-1	6.44E+0	1.17E+0
DEMO	05XX9999	OEP-XHE-NR01H	Operator fails to recover Offsite Power in 1 hour	1.90E-4	1.36E-1	1.27E+0	1.16E+0
DEMO	05XX9999	EPS-XHE-NR01H-FT	Operator fails to recover EDG in 1 hour (FT logic)	7.23E-5	1.36E-1	1.02E+0	1.16E+0
DEMO	05XX9999	ECS-MOV-2A	ECS Train 2A motor operated valve	9.88E-3	1.08E-1	2.22E+1	1.12E+0
DEMO	05XX9999	SWS-MDP-B	SWS Train B motor driven pump	5.60E-2	6.54E-2	1.22E+2	1.07E+0
DEMO	05XX9999	ECS-MOV-2B	ECS Train 2B motor operated valve	3.48E-3	3.77E-2	8.47E+0	1.04E+0
DEMO	05XX9999	ECS-MOV-1B	ECS Train 1B motor operated valve	3.48E-3	3.77E-2	8.47E+0	1.04E+0
DEMO	05XX9999	SWS-MDP-A	SWS Train A motor driven pump	4.85E-2	3.69E-2	1.05E+2	1.04E+0
DEMO	05XX9999	ECS-MOV-1A	ECS Train 1A motor operated valve	2.04E-3	3.68E-2	5.36E+0	1.04E+0

Figure 40. Data Warehouse-PRIB Table 8 F-V exceeds 0.005.



PROJECT	DOCKET	NAME	COMPONENT DESCRIPTION	BIRNBAUM	FV	RAW	RRR
DEMO	05XX9999	ECS-MOV-SUCT	ECS Suction motor operated valve	8.30E-1	2.15E-2	1.79E+3	1.02E+0
DEMO	05XX9999	SIS-TNK	Refueling Water Storage Tank	8.30E-1	1.72E-4	1.79E+3	1.00E+0
DEMO	05XX9999	ECS-MDP-B	ECS Train B motor driven pump	6.38E-2	3.65E-1	1.38E+2	1.57E+0
DEMO	05XX9999	ECS-MDP-A	ECS Train A motor driven pump	5.67E-2	2.47E-1	1.23E+2	1.33E+0
DEMO	05XX9999	SWS-MDP-B	SWS Train B motor driven pump	5.60E-2	6.54E-2	1.22E+2	1.07E+0
DEMO	05XX9999	SWS-MDP-A	SWS Train A motor driven pump	4.85E-2	3.69E-2	1.05E+2	1.04E+0
DEMO	05XX9999	ACP-BAC-1B	Division 1B ac power	1.67E-2	1.23E-3	3.70E+1	1.00E+0
DEMO	05XX9999	ECS-MOV-2A	ECS Train 2A motor operated valve	9.88E-3	1.08E-1	2.22E+1	1.12E+0
DEMO	05XX9999	ACP-BAC-1A	Division 1A ac power	9.11E-3	7.33E-4	2.06E+1	1.00E+0
DEMO	05XX9999	SWS-CKV-B	SWS Train B check valve	8.72E-3	2.00E-3	1.98E+1	1.00E+0
DEMO	05XX9999	SWS-CKV-A	SWS Train A check valve	4.92E-3	1.12E-3	1.16E+1	1.00E+0
DEMO	05XX9999	ECS-MOV-	ECS Train 2B motor operated	3.48E-3	3.77E-	8.47E+0	1.04E+0

Figure 41. Data Warehouse-PRIB Table 9 RAW exceeds 2.0.



PROJECT	DOCKET	NAME	COMPONENT DESCRIPTION	BIRNBAUM	FV	RAW	RRR
DEMO	05XX9999	ECS-MOV-SUCT	ECS Suction motor operated valve	8.30E-1	2.15E-2	1.79E+3	1.02E+0
DEMO	05XX9999	SIS-TNK	Refueling Water Storage Tank	8.30E-1	1.72E-4	1.79E+3	1.00E+0
DEMO	05XX9999	ECS-MDP-B	ECS Train B motor driven pump	6.38E-2	3.65E-1	1.38E+2	1.57E+0
DEMO	05XX9999	ECS-MDP-A	ECS Train A motor driven pump	5.67E-2	2.47E-1	1.23E+2	1.33E+0
DEMO	05XX9999	SWS-MDP-B	SWS Train B motor driven pump	5.60E-2	6.54E-2	1.22E+2	1.07E+0
DEMO	05XX9999	SWS-MDP-A	SWS Train A motor driven pump	4.85E-2	3.69E-2	1.05E+2	1.04E+0
DEMO	05XX9999	ACP-BAC-1B	Division 1B ac power	1.67E-2	1.23E-3	3.70E+1	1.00E+0
DEMO	05XX9999	ECS-MOV-2A	ECS Train 2A motor operated valve	9.88E-3	1.08E-1	2.22E+1	1.12E+0
DEMO	05XX9999	ACP-BAC-1A	Division 1A ac power	9.11E-3	7.33E-4	2.06E+1	1.00E+0
DEMO	05XX9999	SWS-CKV-B	SWS Train B check valve	8.72E-3	2.00E-3	1.98E+1	1.00E+0
DEMO	05XX9999	SWS-CKV-A	SWS Train A check valve	4.92E-3	1.12E-3	1.16E+1	1.00E+0
DEMO	05XX9999	ECS-MOV-2B	ECS Train 2B motor operated valve	3.48E-3	3.77E-2	8.47E+0	1.04E+0

Figure 42. Data Warehouse-PRIB Table 10 Birnbaum exceeds 1.0E–6.

3.1.2.6 Publish of Uncertainty from View Uncertainty

Description

Uncertainty analysis can be performed on a project, its fault trees, event trees, sequences, and end states. The results of these uncertainty analyses have not been reportable for groups of these items. Specifically, groups of one or more event trees, groups of sequences, and groups of end states did not have a way to publish their uncertainty results. Therefore, a publish function needed to be added allowing the user to create a report of the last uncertainty analysis performed.

Accomplishments

SAPHIRE Release 8.2.4 will be able to publish the various group uncertainty results. A publish function was added to the "View Uncertainty" form as shown in Figure 43. The *Publish* button was placed to the right of the *Calculate* button as shown in Figure 44. The sample process shown was created by highlighting the three event trees ("LOSP," "LOSWS," and "TRANS"), right-clicking the mouse to bring up the pop-up menu, selecting *View Uncertainty*, and then selecting the *Group by Event(s)* option (see Figure 43).

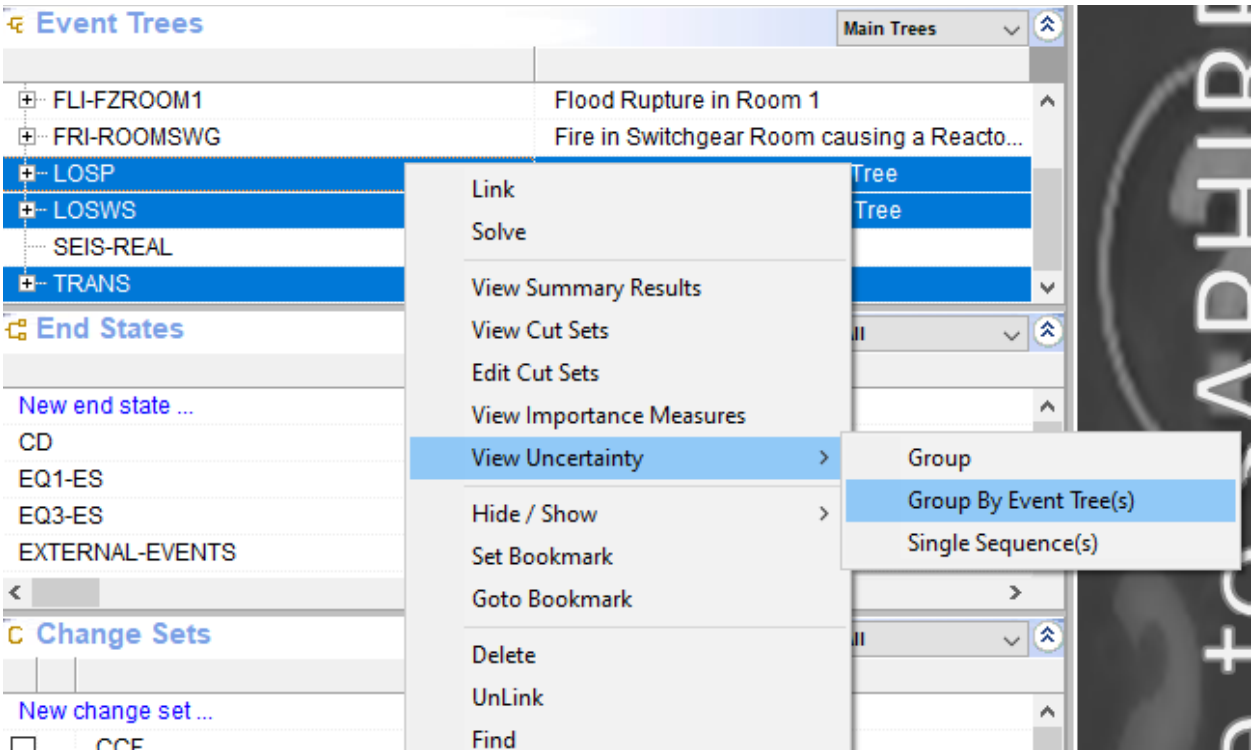


Figure 43. View Uncertainty selection.

Clicking the *Calculate* button on Figure 44 after setting the desired seed ("Random # Seed"), sample size ("Number of Samples"), and "Uncertainty Method" yields the whisker plots displayed in Figure 44.

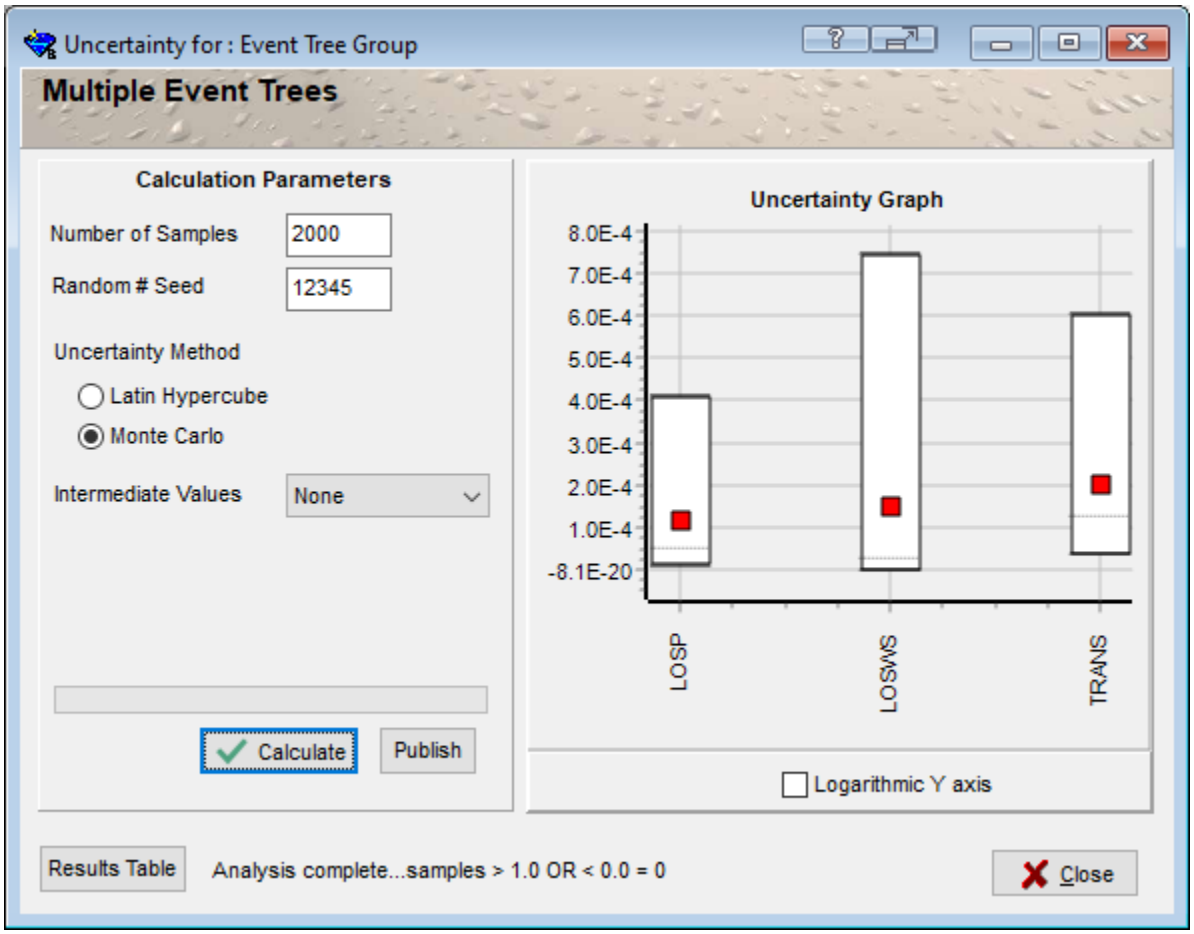


Figure 44. Uncertainty results.

Clicking the *Publish* button displays the "Publish" form with a subset of reports for publishing different uncertainty reports (see Figure 45–Figure 48).

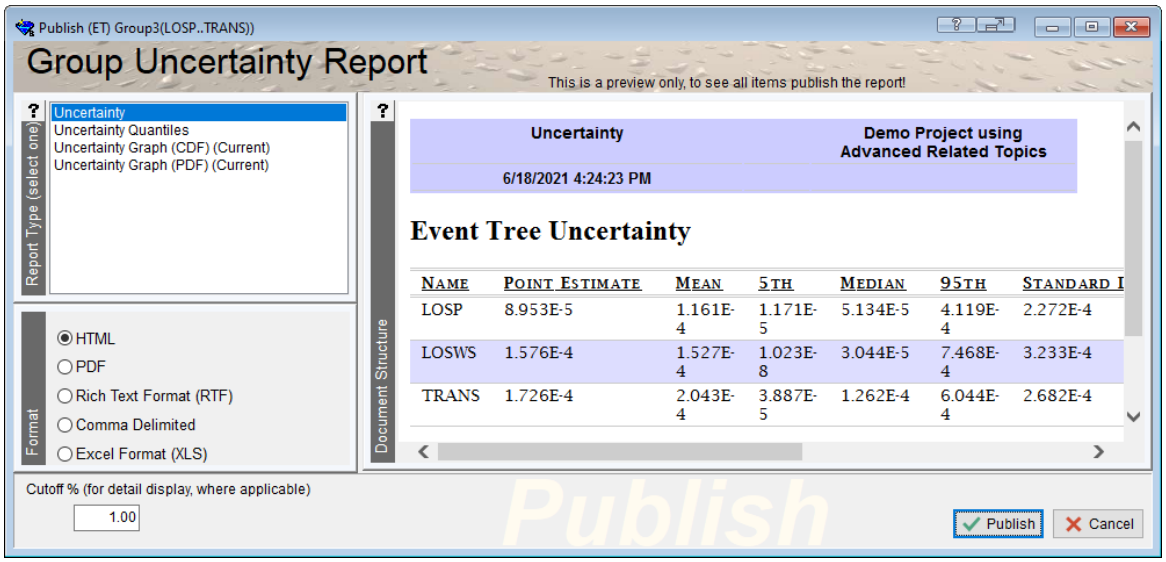


Figure 45. Uncertainty report.

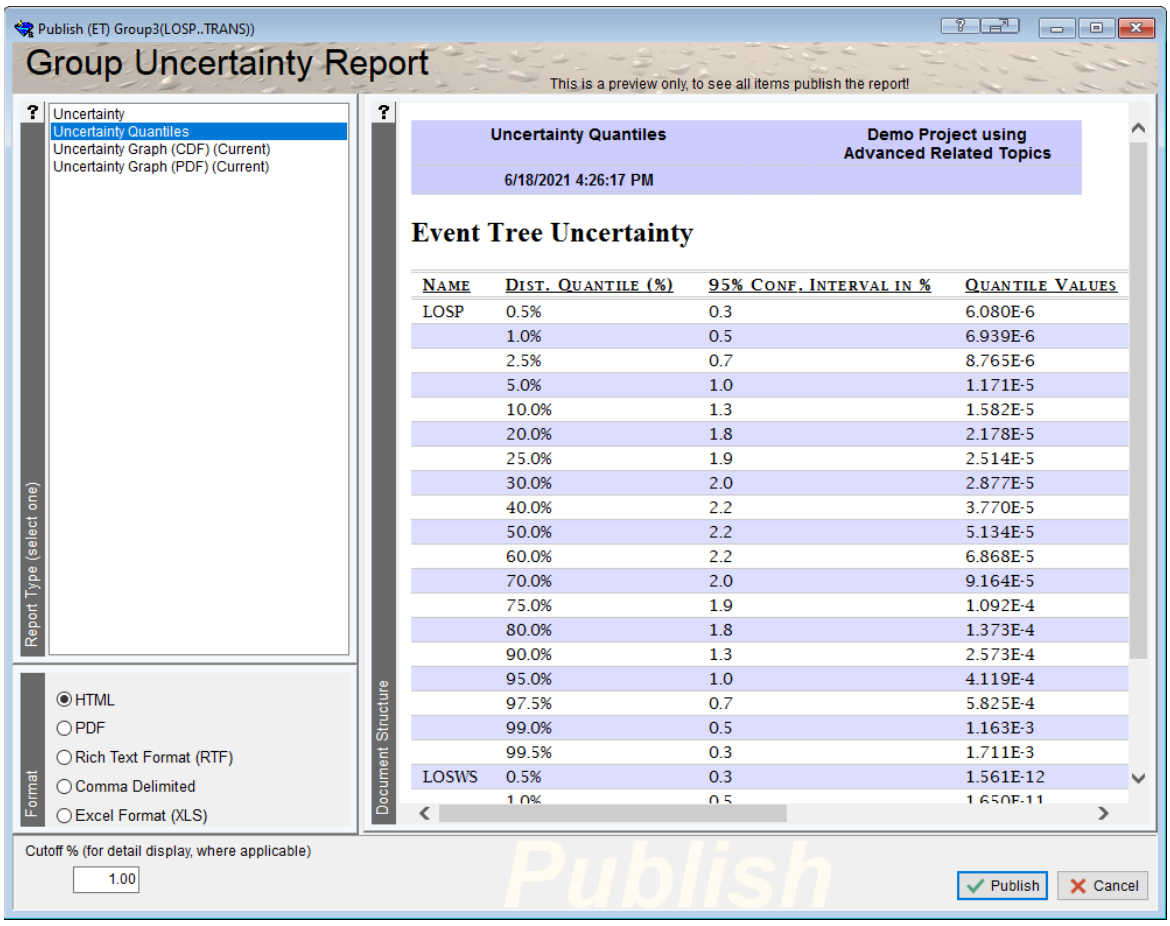


Figure 46. Uncertainty Quantiles report.

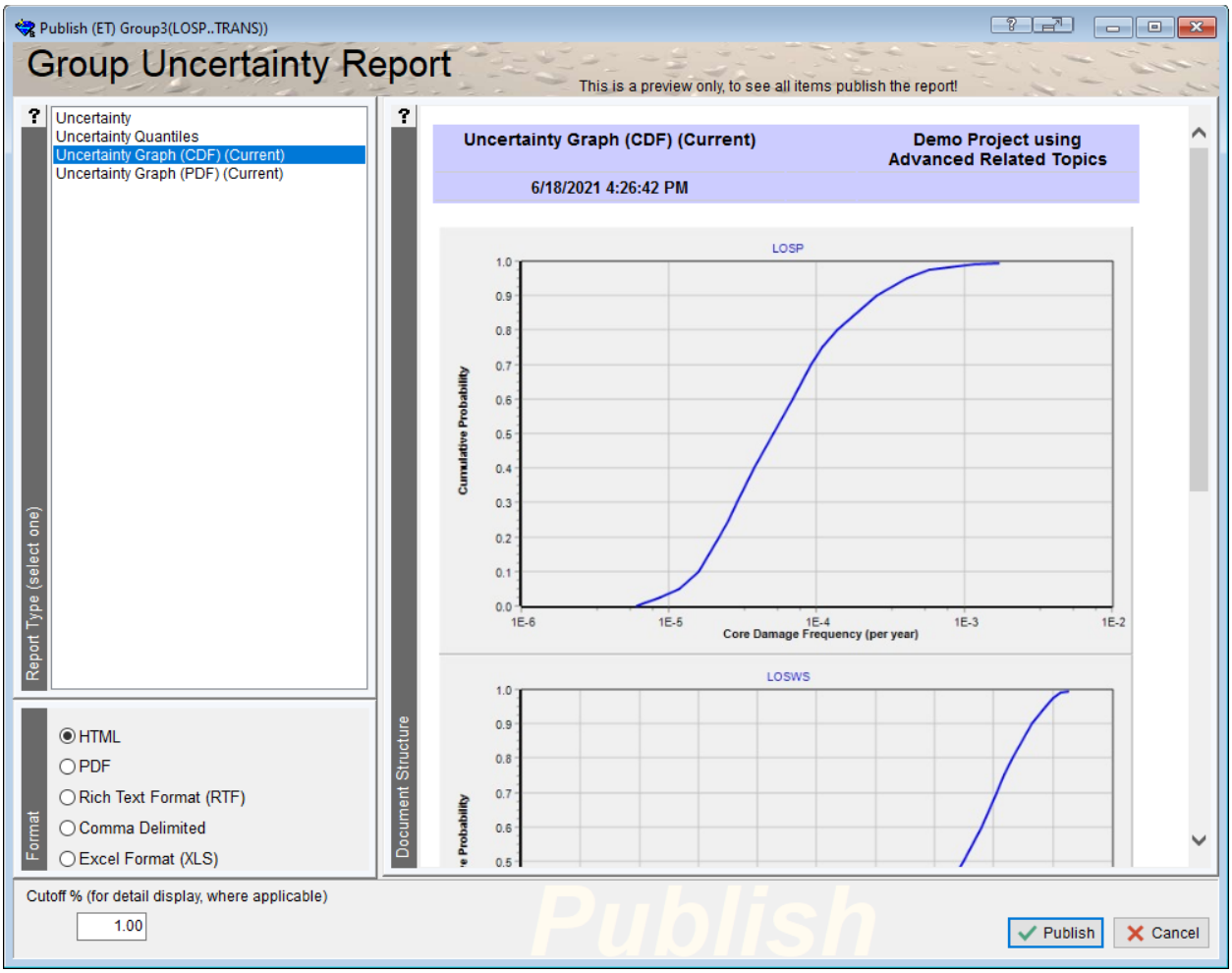


Figure 47. Uncertainty Graph (CDF) (Current) report.

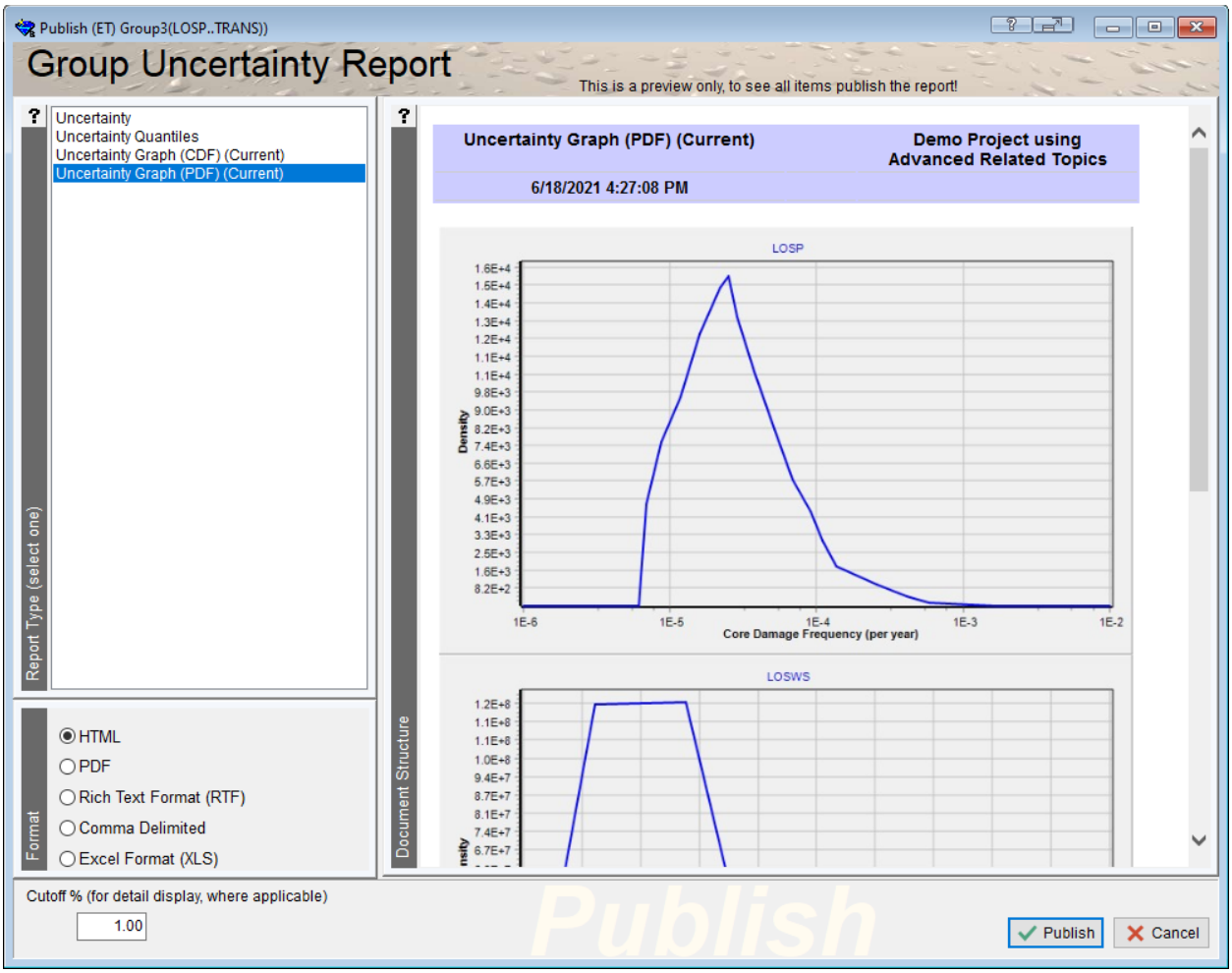


Figure 48. Uncertainty Graph (PDF) (Current) report.

The Uncertainty and Uncertainty Quantiles reports are available in the five report formats (HTML, PDF, RTF, CSV, and Excel). The Uncertainty Graph reports are not available in the CSV format.

3.2 SAPHIRE User's Group Website Rebuild

The SAPHIRE UG website was completely rebuilt this FY due to the INL demilitarized zone (DMZ) network outage which occurred in August 2020. In the wake the DMZ outage, the INL cyber security team implemented new security requirements for all INL-hosted applications. Instead of fixing the old and otherwise outdated SAPHIRE UG website, it was decided time would be better spent constructing a new website with more modern technologies.

3.2.1 Reconstruct user account/permissions with enhanced security

Description

As per the new cyber security requirements, all the users of the SAPHIRE UG website were required reset account passwords to meet the new INL cyber complexity requirements. In addition to the new password rules, SAPHIRE UG passwords now expire every 180 days, users will be forced to reset passwords if they have not logged into the SAPHIRE UG website in 180 days, and users will not be allowed to reuse any previously used passwords. A new and secure account recovery process was implemented that guides the users in setting a secure and new password. Upon a successful password reset, users will be redirected to the login view to enter their new password. See Figures 49, 50, and 51.

Accomplishments

First time users of the new SAPHIRE UG website are instructed to click the *Forgot Password?* option to recover access to their account. This process is soon to be renamed to, "Can't Login?" as this wording is more fitting to the process.

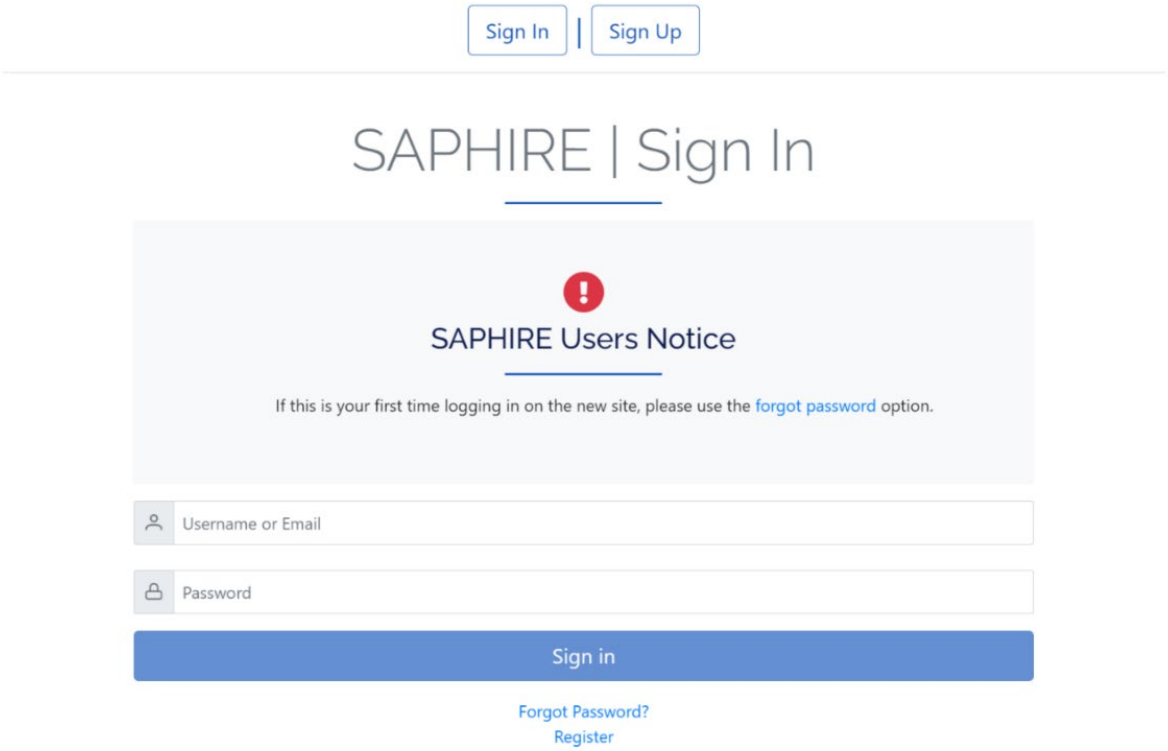


Figure 49. SAPHIRE UG login view.

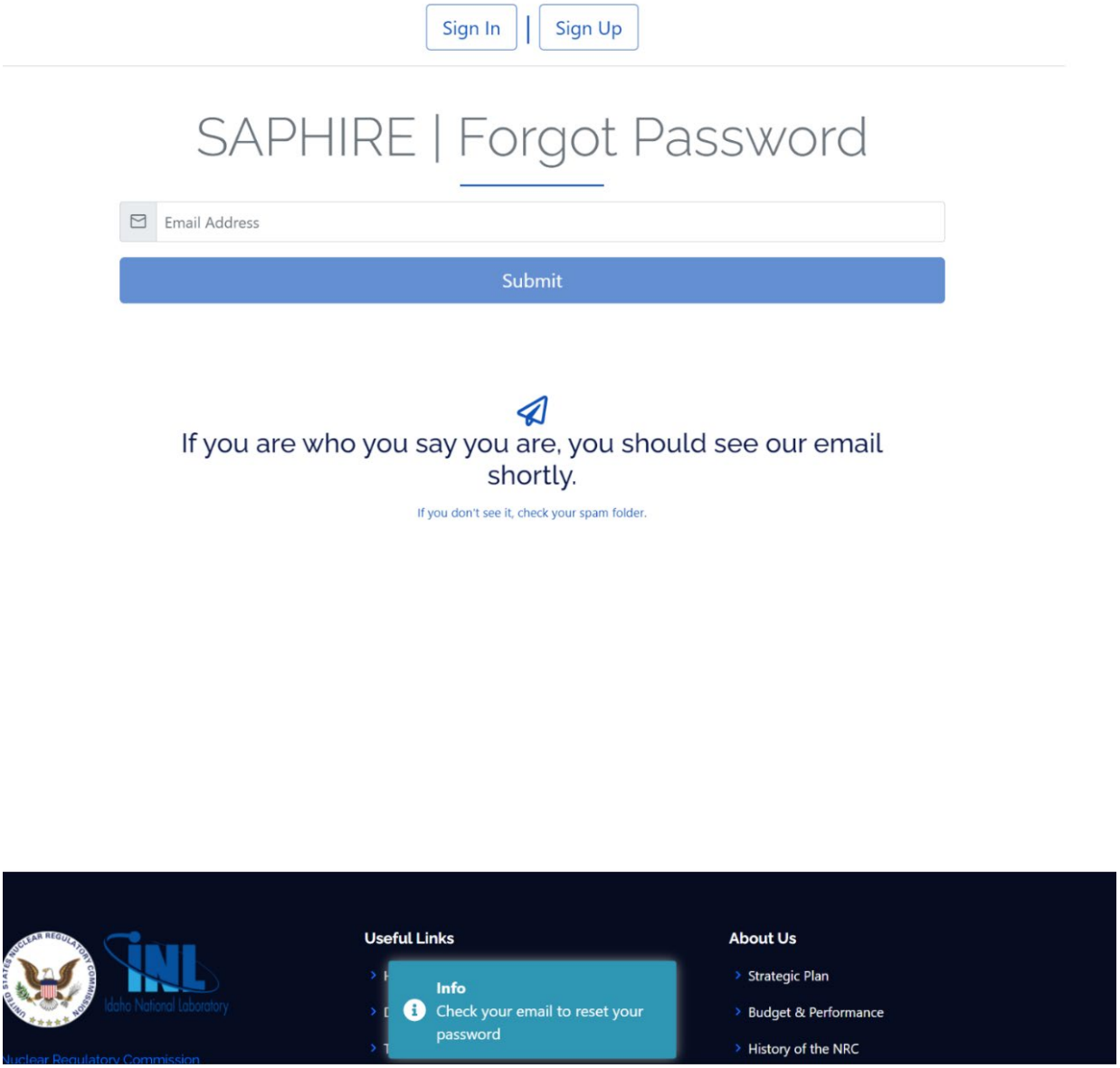


Figure 50. SAPHIRE UG forgot password view.

Upon entering the email address associated with your SAPHIRE UG account, you will receive an email with a secure link to reset your password. The password reset link will be valid for 30 minutes.

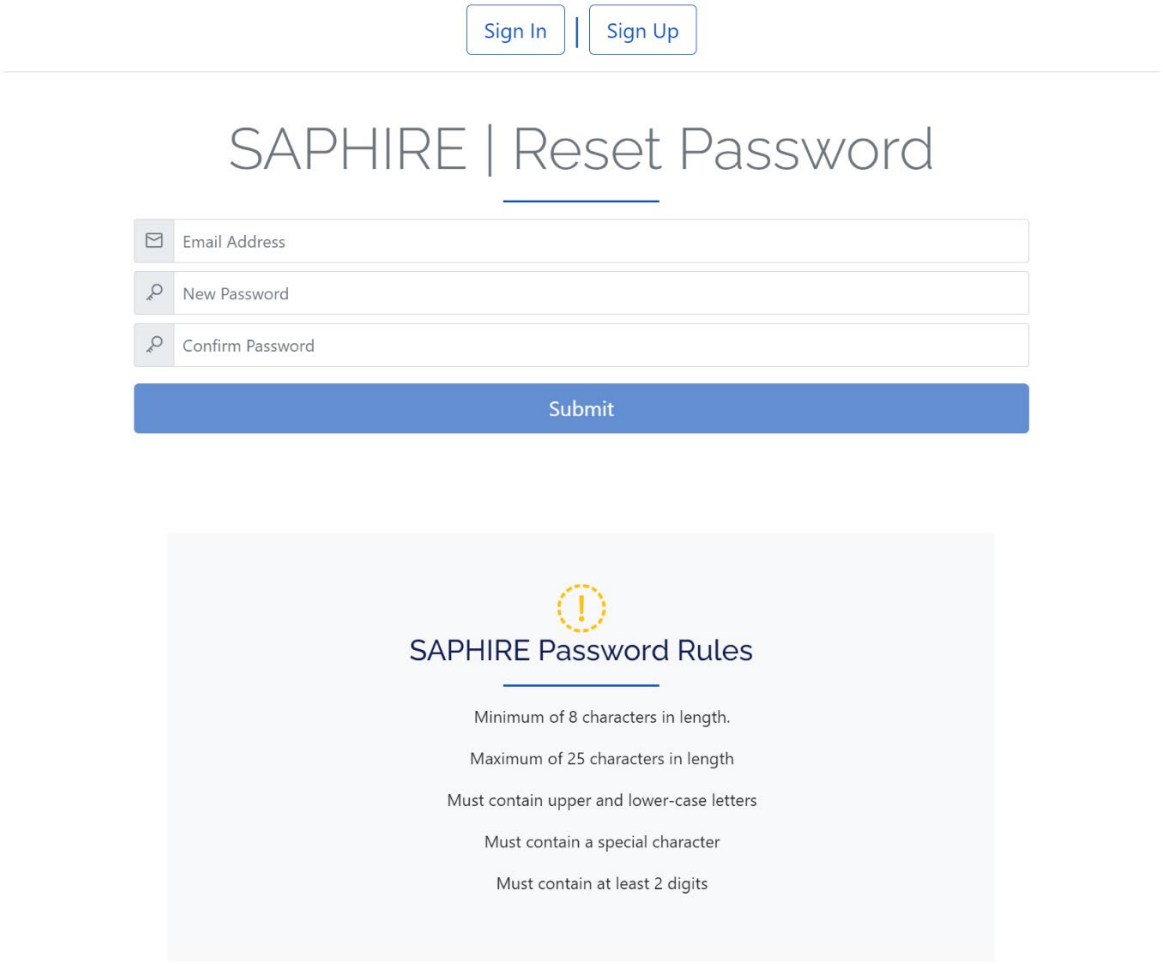


Figure 51. SAPHIRE UG secure password reset view.

Figure 51 shows the view users see upon clicking the link sent via the "Forgot Password" form. For enhanced security, users are asked to re-enter the email address associated with the generated reset link.

3.2.2 Implement model and software download and upload functionality

Description

The SPAR model view in the SAPHIRE UG website has been restored and updated with added security and a better user experience. Depending on the user's level of access, they can create, read, update, or delete model data.

Accomplishments

Depending on the user's level of access, they can edit, view, or download models. Note not all SAPHIRE UG organizations have access to this view.

Figure 52 shows the “Green Pencil” icon available to users with SPAR model edit privileges.

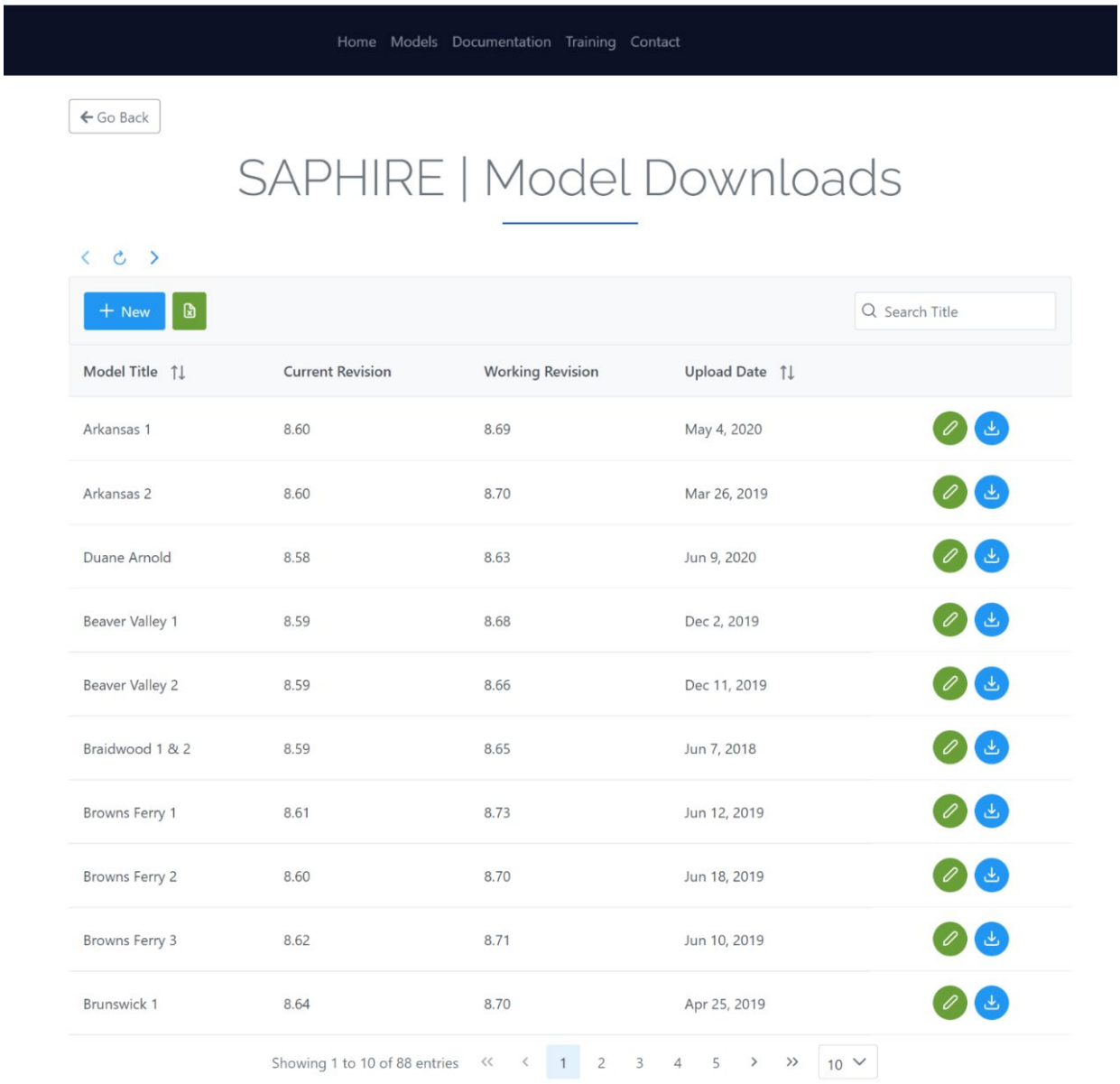


Figure 52. UG SPAR Model view.

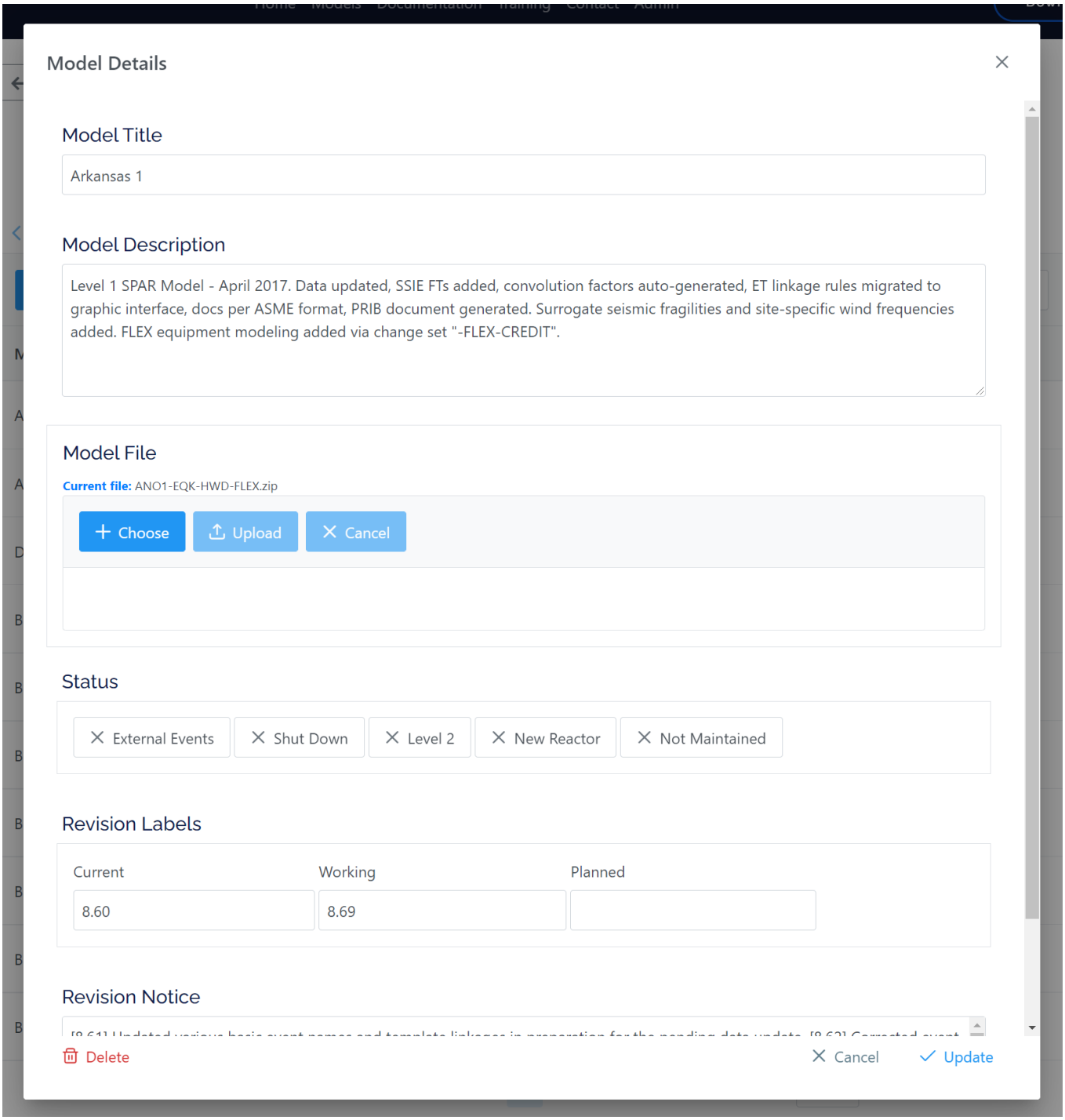


Figure 53. SAPHIRE UG edit SPAR model view.

This view (see Figure 53) is only available to users with specified access and privileges.

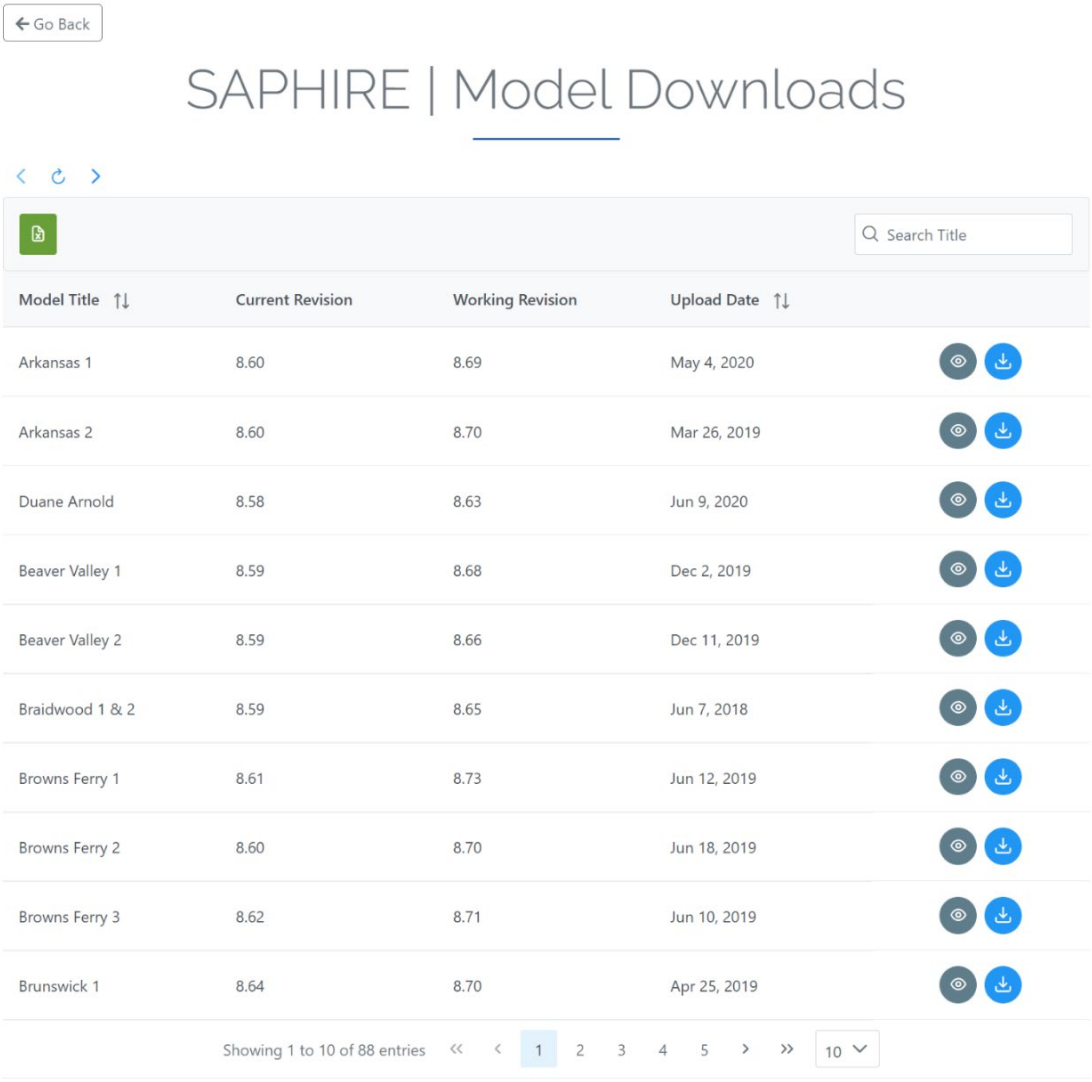


Figure 54. SAPHIRE UG SPAR Model view.

The “Dark Blue Eye” icon is available to users with SPAR model read access.

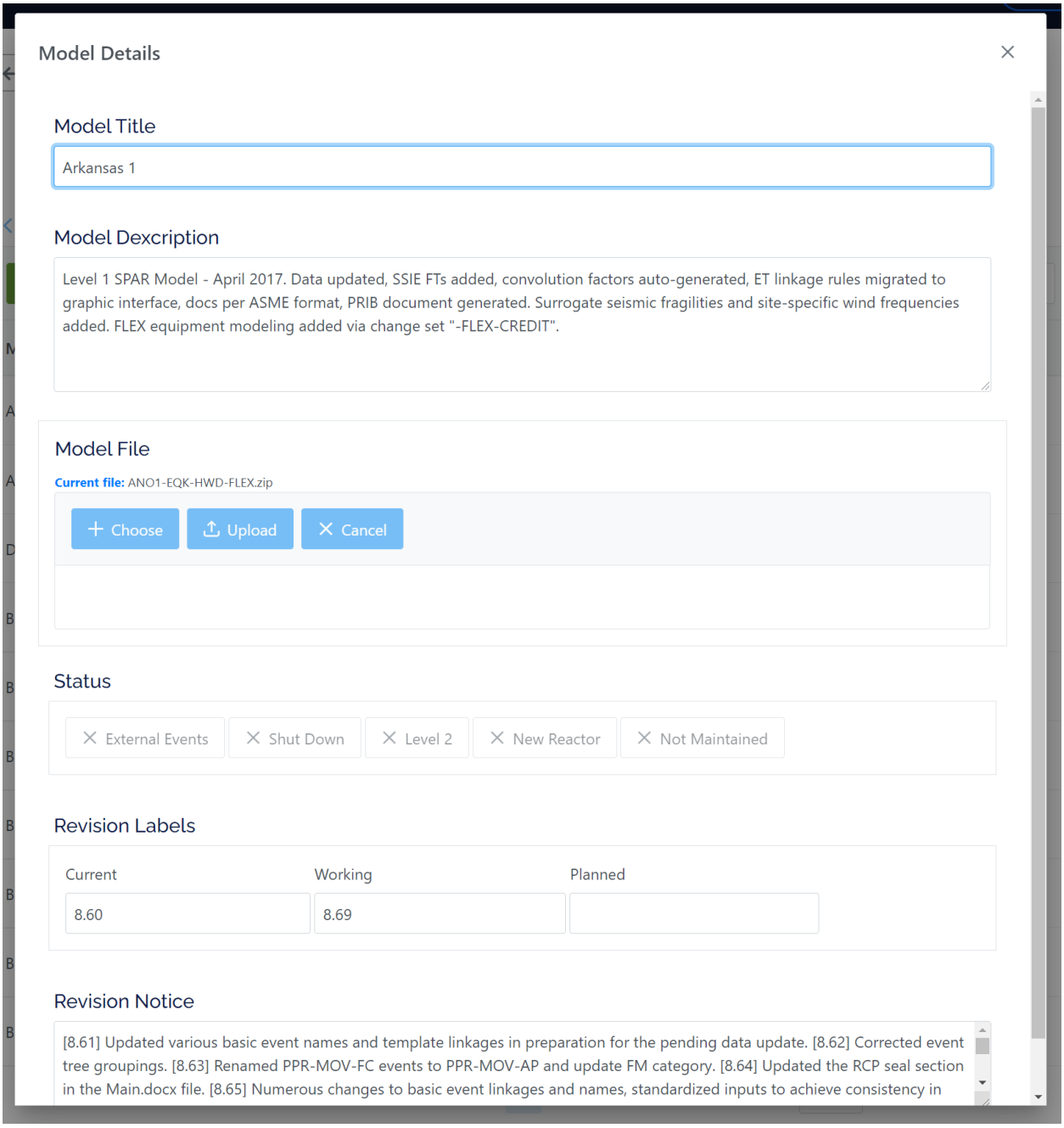


Figure 55. SAPHIRE UG SPAR model view.

This modal view (see Figure 55) is read-only to users with read-only access. All actions associated with editing this information have been removed or disabled.

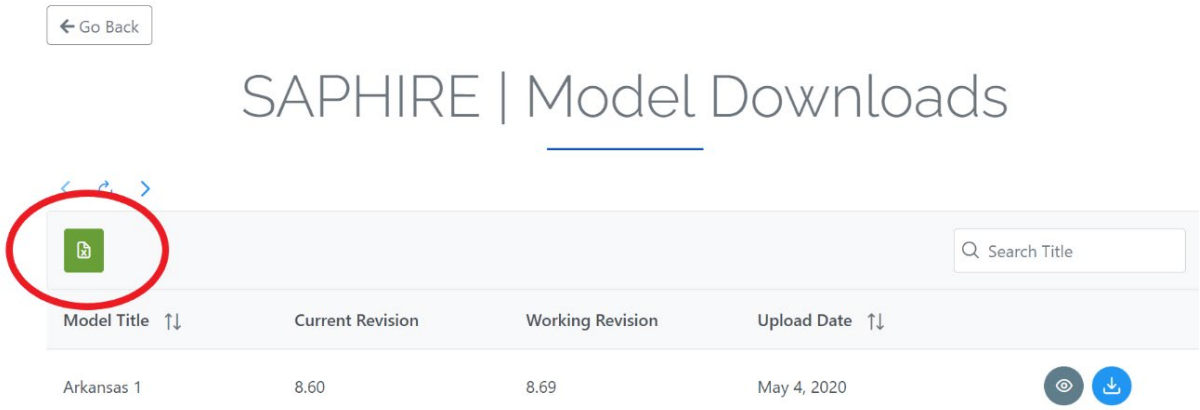


Figure 56. Export model data to Excel.

As a requested feature, the ability to export all SPAR models into an Excel file has been added for user convenience (see Figure 56).

3.2.3 Implement basic administrative functionality

Description

As part of one of the initial phases of the SAPHIRE UG website restoration, the ability to manage user data and their level of access has been implemented into the new website. Additionally, the ability to create, read, update, and delete SAPHIRE organizations has been fully restored.

Accomplishments

There are many more administrative abilities yet to be implemented, but below are a few critical, high-priority pieces for website functionality.

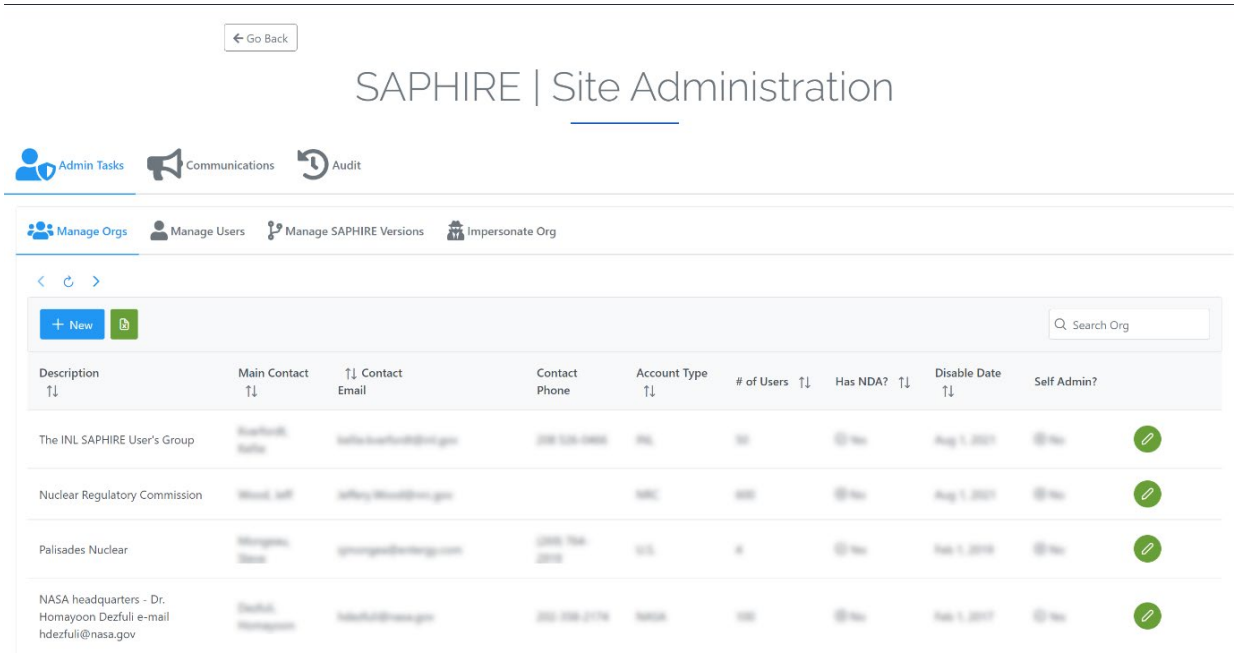


Figure 57. SAPHIRE UG administer organizations view.

All admin table views have the added functionality of being able to search and sort by all columns in the table. Upon clicking the “Green Pencil” icon , administrative users will see a modal to edit organization details.

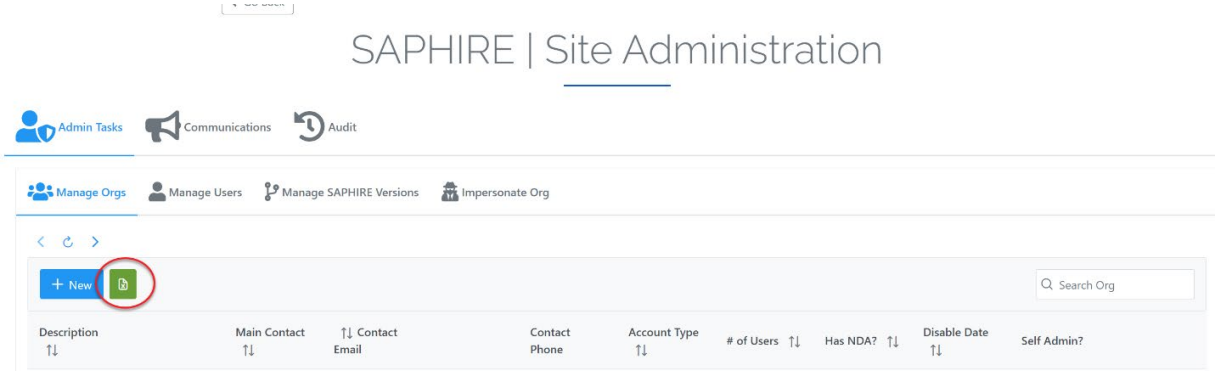


Figure 58. SAPHIRE UG administer organizations view.

Just as with the SPAR models, administrative users can export organizational data to an Excel spreadsheet.

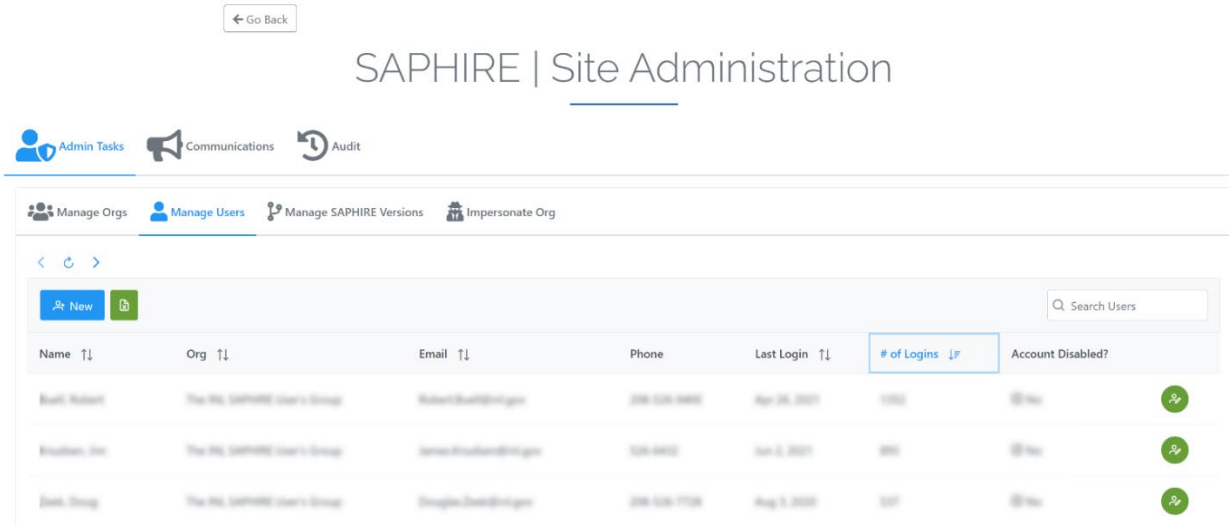


Figure 59. SAPHIRE UG administer users view.

Just as with the manage organizations view, upon clicking the “Green Pencil” icon , a modal will appear to edit user details and permissions.

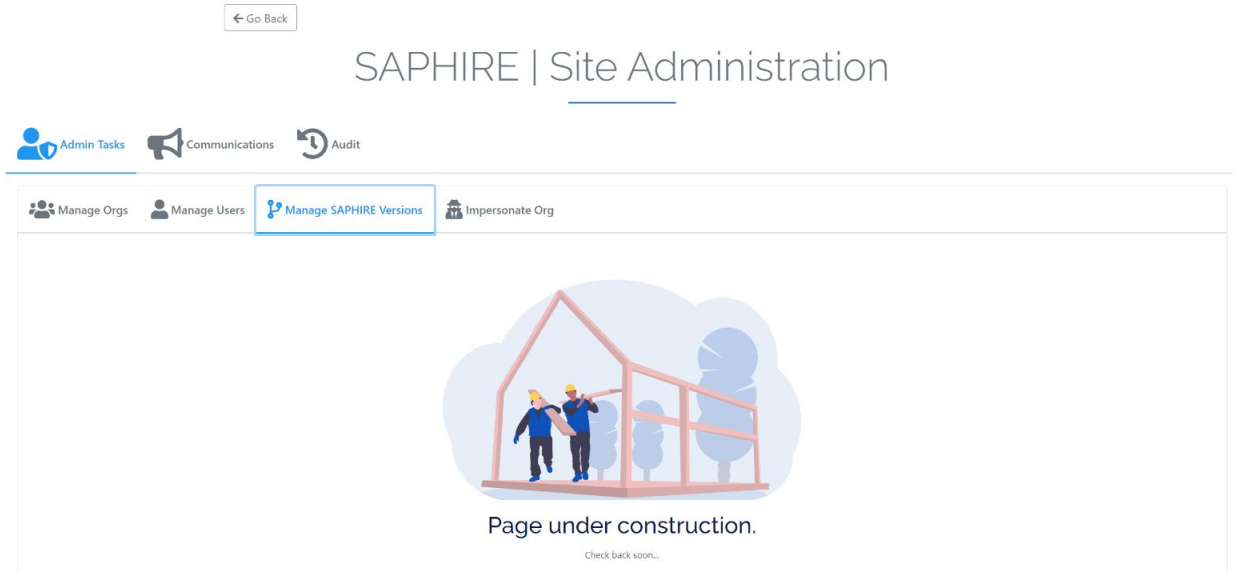


Figure 60. All other administrative features.

All other administrative features are currently under construction and are slated for future releases of the website.

3.2.4 Additional and future enhancements

Description

Upon a successful login, users have access to an array of options to manage their account information and password. Additionally, a user will receive a notification if their password is expiring within a 15 day time window.

Accomplishments

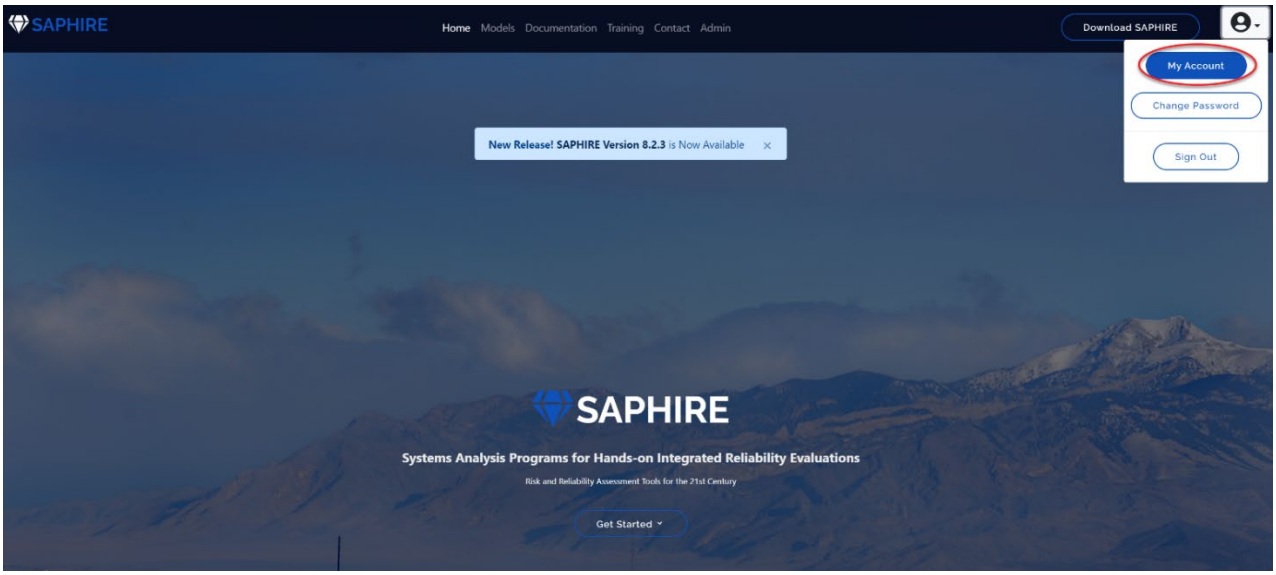


Figure 61. SAPHIRE UG home screen view with authenticated user options expanded.

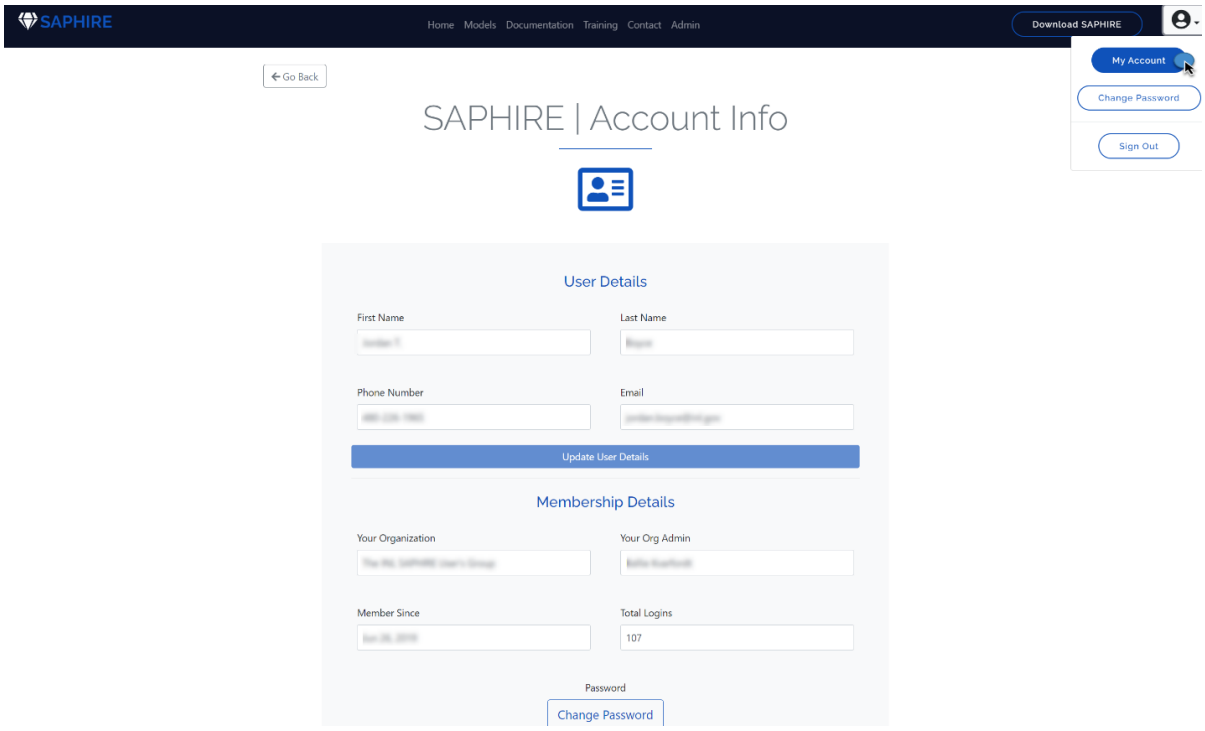


Figure 62. SAPHIRE UG authenticated user details view.

Upon clicking the *My Account* option from the user dropdown menu in the navigation bar (see Figure 62), authenticated users can update their personal data and manage their password.

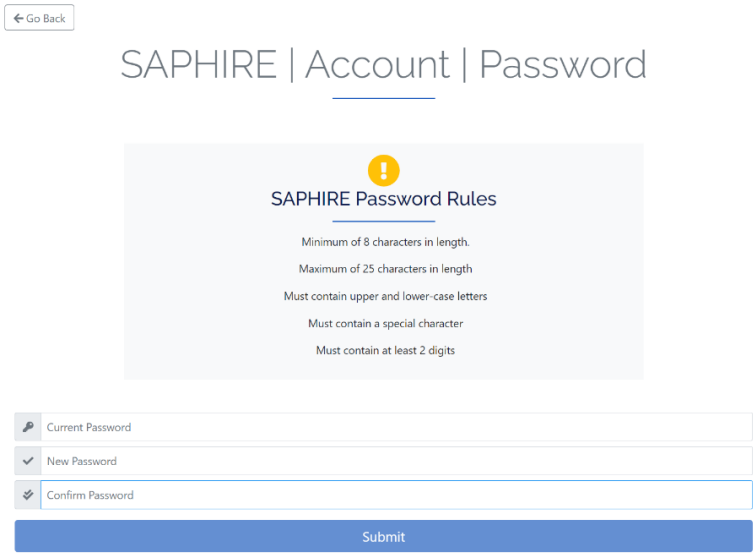


Figure 63. SAPHIRE UG authenticated change password view.

Authenticated users can change their password at any time as long as the new password meets the complexity requirements and does not match the current password or a previously used password.

3.3 Safety Portal Tasks

All enhancements to the Safety Portal are intended to facilitate moving towards web-based methods for SAPHIRE and any requirements necessary for future work in solving, security, reporting, and graphical display.

3.3.1 Enhance Safety Portal authorization and authentication

Description

As per new INL cyber security requirements, users of any platform hosted on INL platforms must adhere to specific password and authorization requirements.

Accomplishments

Passwords must be at least a minimum of eight-characters to a maximum of 25 characters in length. Users who enter a new password without meeting these specific requirements will receive an error message (see Figures 64 and 65 for examples).

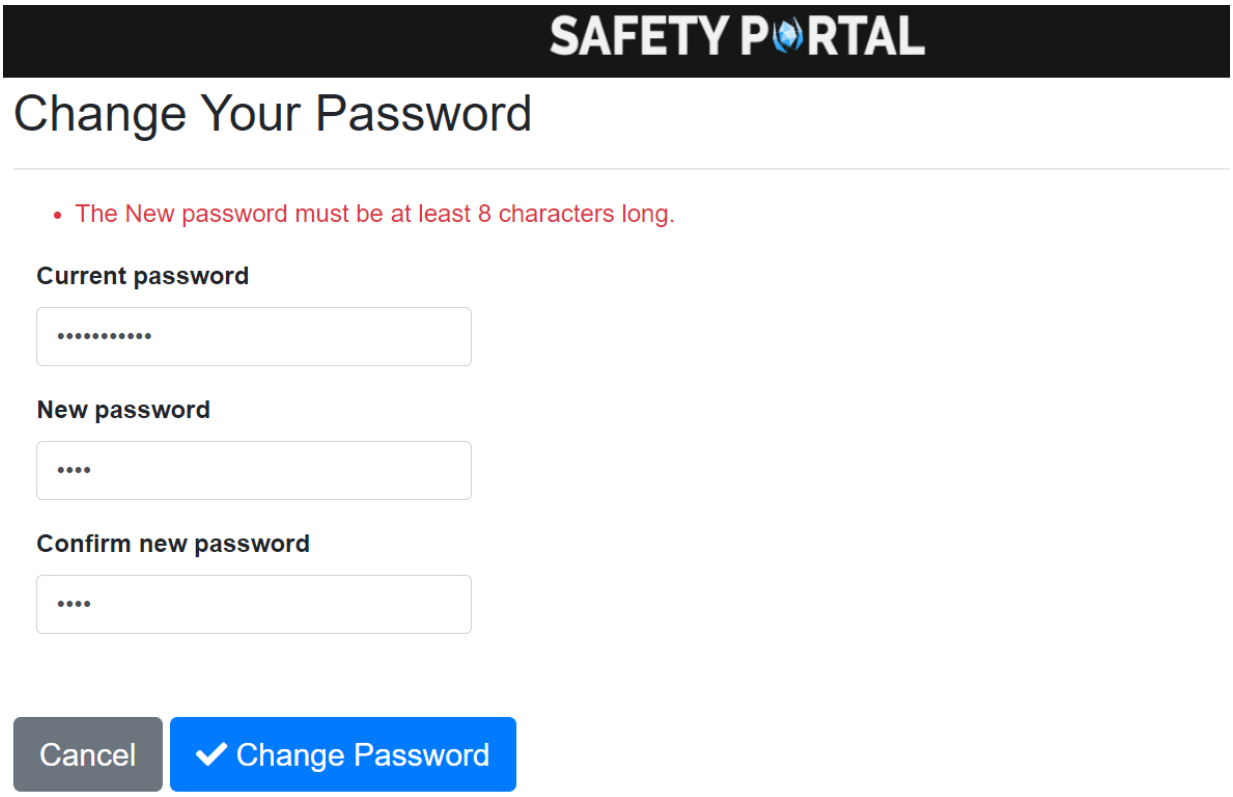


Figure 64. Safety Portal Change Password View.

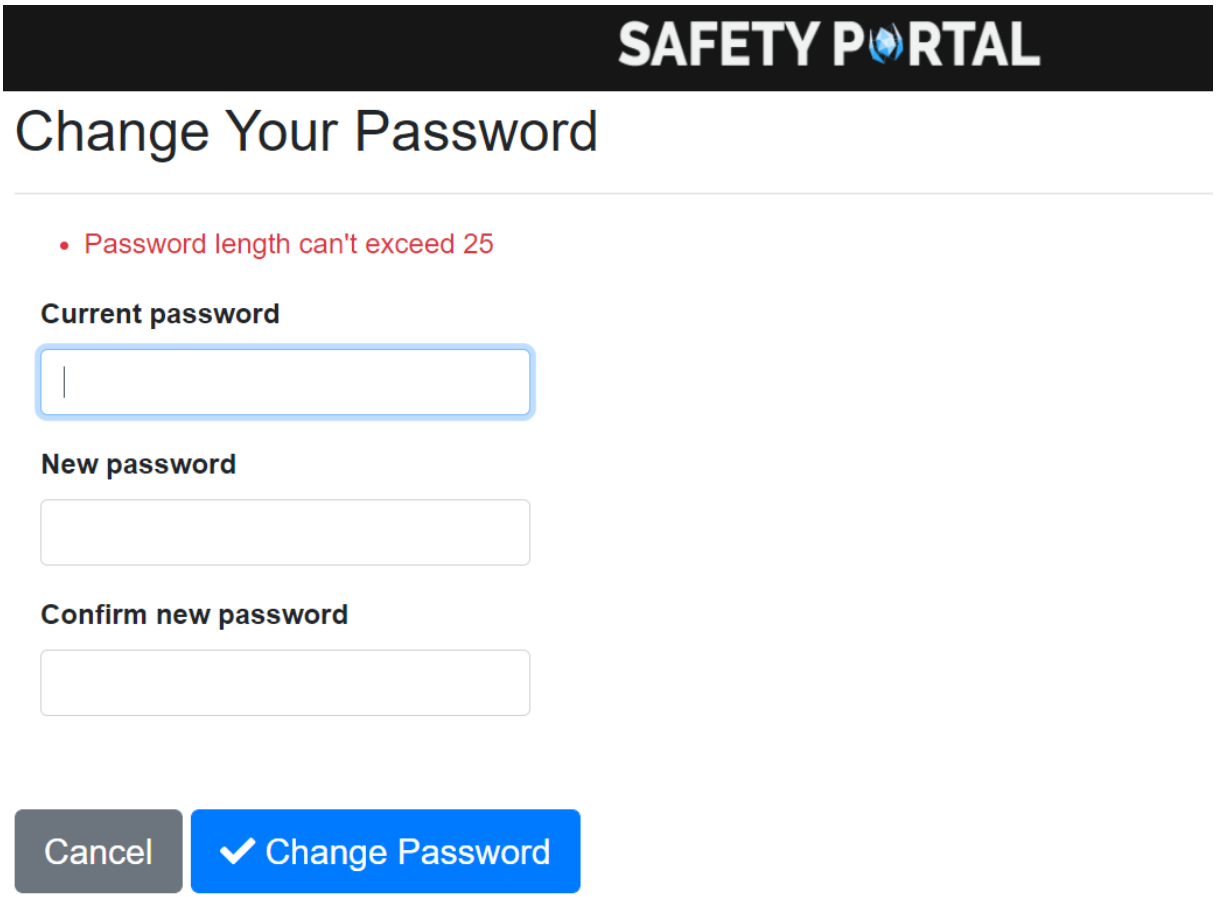


Figure 65. Safety Portal Change Password View.

In addition to the new Safety Portal password length requirements, users are required to follow these additional password requirements:

- Two digits
- At least one uppercase letter
- At least one special character.

Figure 66 shows an example error message received for a password not meeting these requirements.

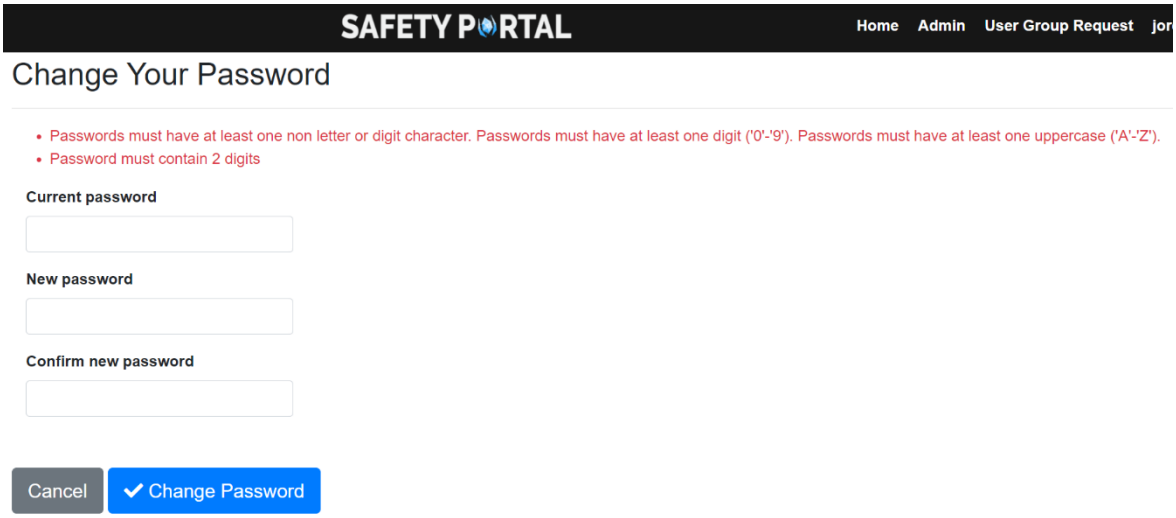


Figure 66. Safety Portal Change Password View.

3.3.2 Implement Safety Portal account password expiration rules

Description

As per the new INL cyber security account management rules, users are required to change their passwords every 6 months. Additionally, a Safety Portal user account will be locked if a user has not logged into the Safety Portal platform in 180 days.

Accomplishments

Passwords must be reset on accounts idle for 6 months or more. In this context, idle is defined as a user who fails to successfully login within a 6-month period. Figure 67 shows an example error message for a user whose account has been idle for too long.

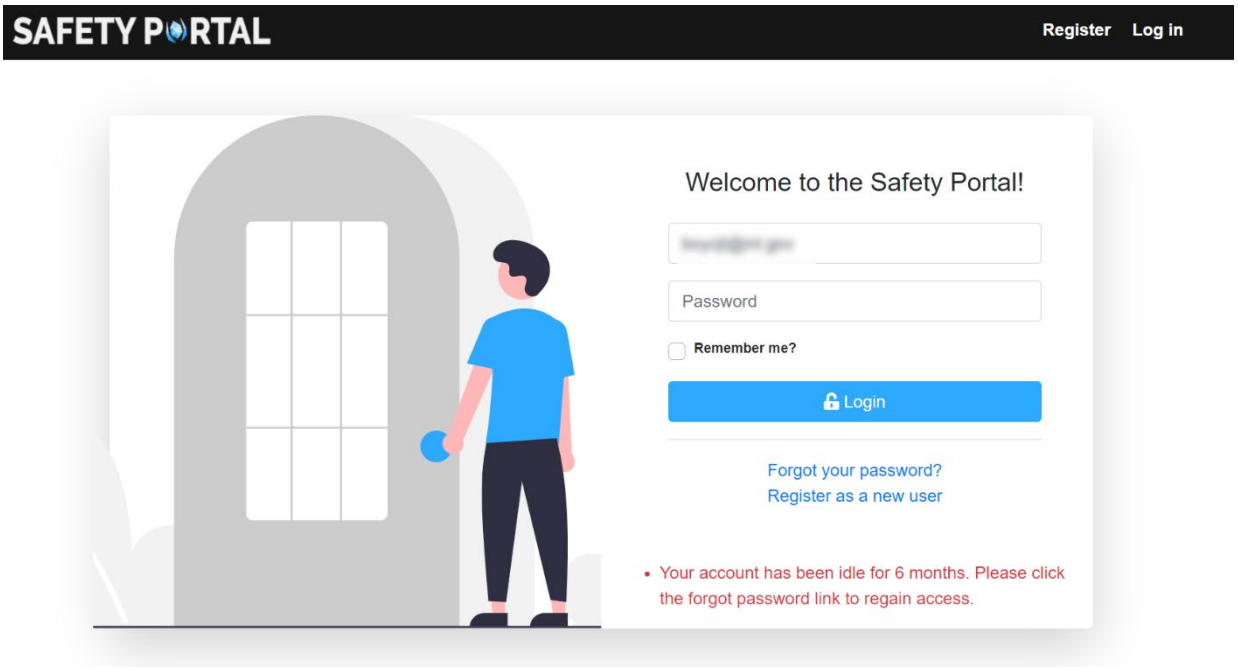


Figure 67. Safety Portal login view.

Passwords now must be reset if they have not been changed withing a 6-month time window. Users will see the error message in Figure 68 if their account password has expired.

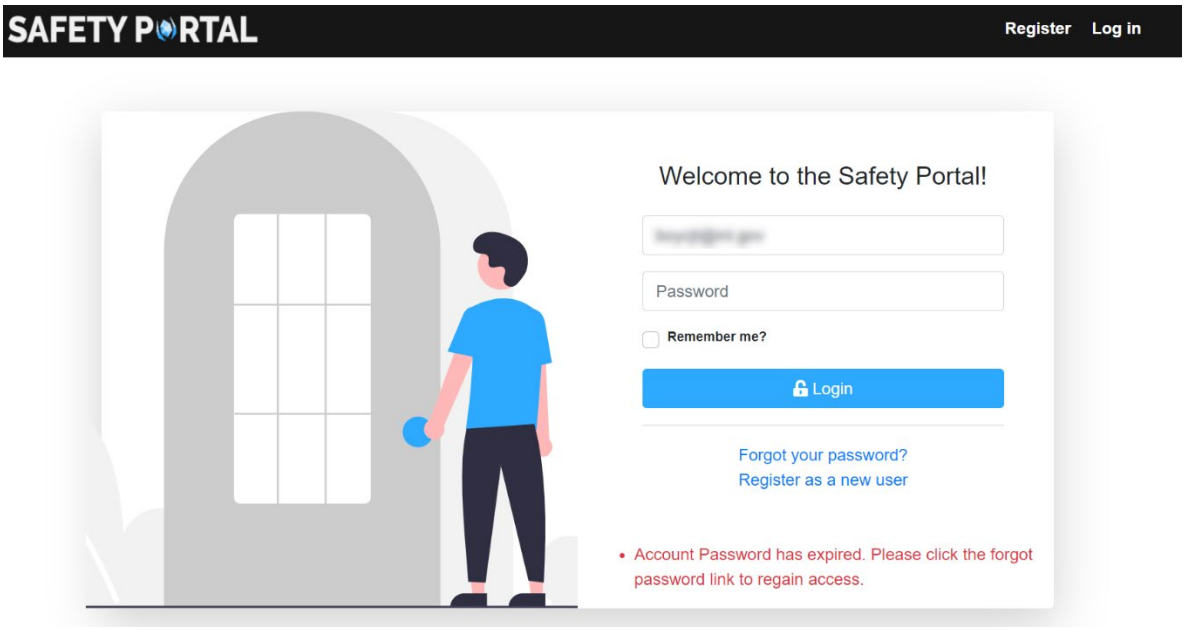


Figure 68. Safety Portal Login view.

3.3.3 Safety Portal future enhancements

Description

Several features needed to be addressed in the Safety Portal to enable the remote solving and SAPHIRE Version 9's development. The data management, allowing users to be group admins, and the

one time sharing of a publication are examples of items done the previous years. The following items are currently the only identified items, but more will be added as development continues.

- Scalability - As users receive access to multiple files, some calls to the Safety Portal start to slow down.
- Test/Debug features - Testing and debug features were added to the Safety Portal production to simplify maintenance and support issues.

Accomplishments

Due to the DMZ outage and the Safety Portal being down, no progress was made on the scalability issue.

3.4 SAPHIRE Remote Solve Tasks

As a proof of concept, the "Remote Solve (Cloud Solve)" option was added to SAPHIRE (see Figures 69 and 70). This year, research and development efforts have been dedicatedly working to create the best design for the remote solve option moving forward.

3.4.1 SAPHIRE 8 user interface options for remote solve

Description

User interface settings/options for remote solving have been added to several forms on SAPHIRE 8. These changes have been made to allow for a similar workflow for the user. Details on setting up and solving using these options can be found in the "SAPHIRE 8 Remote Solve Options" design document.

Accomplishments

The options to set up for remote solving have been added to the "External Solvers" section in the "User Settings" form. Here the user specifies and names a connection to the cloud for solving. The user can also set this remote solver ("External Solvers") as the default option under the "Analysis Options."

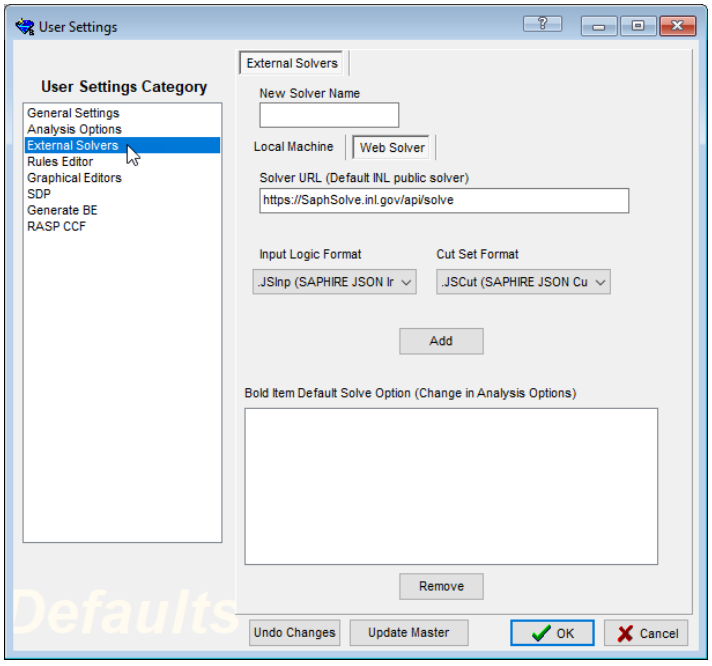


Figure 69. User settings form for remote solve options.

Whenever the user selects an item to solve, the "Solve Options" form that normally shows up will now have the user-named remote solve option under "Cut Set Solve Package" dropdown menu. If the user

assigned it as the default option, it will automatically be selected; otherwise, the user will have to select it from the dropdown menu.

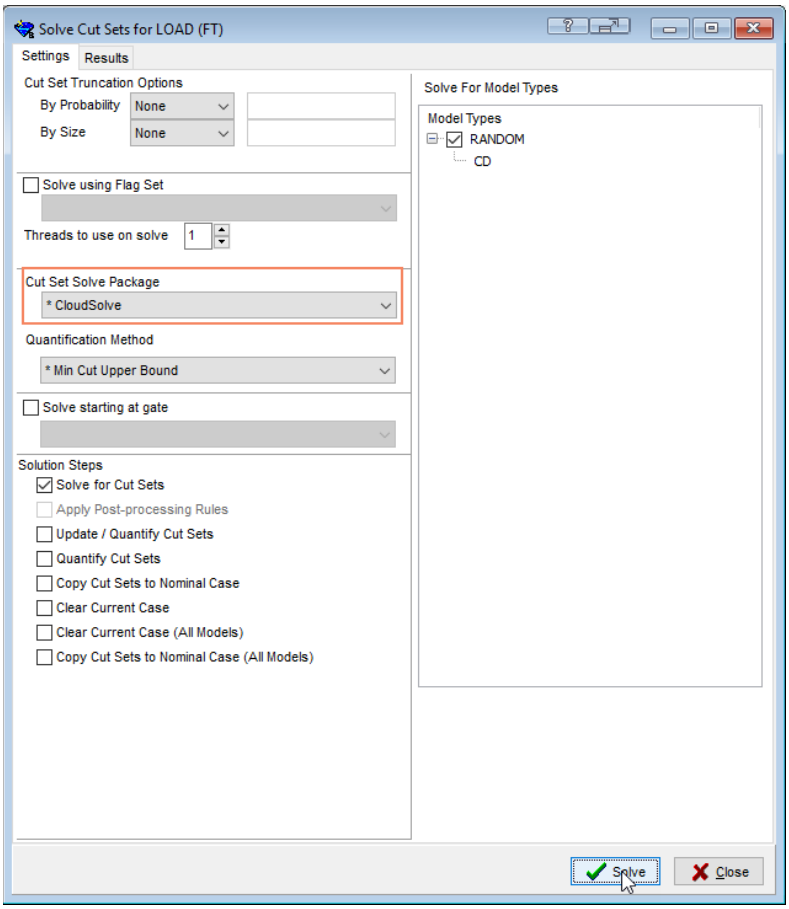


Figure 70. “Cut Set Solve” form with the remote solve package selected.

If they have not recently logged into the Safety Portal, when the user clicks *Solve*, they will be required to log in. Results will be returned from the cloud solve and shown as normal.

3.4.2 API solve protocol

Description

To perform remote solves, a gateway for sending and receiving data between the desktop application and the solve engine needs to be set up. There were several options tried and challenges encountered with the differing methods. The final design chosen was a Web API call on a load balancer, which forwarded calls onto available servers. Options and details of the final process are described below.

Accomplishments

Initially, a secure messaging protocol called Extensible Messaging and Presence Protocol (XMPP) and outlined in the initial design was tried. While the concept and methods for this were ideal, a limitation on message size made this option impossible for many larger items to be sent for solving. Other secure messaging options were also looked at but had similar issues.

The methodology settled upon was using a single Web API call behind a virtual load balancer that then connected to other servers (see Figure 71). This provided a built-in method to distribute the work between resources enabling scalability through manually adding servers. To use this method, the

SAPHIRE application creates a new thread for every solve-piece item. This allows the user to continue to use SAPHIRE, and after the remote solve is finished, this thread updates the results and exits.

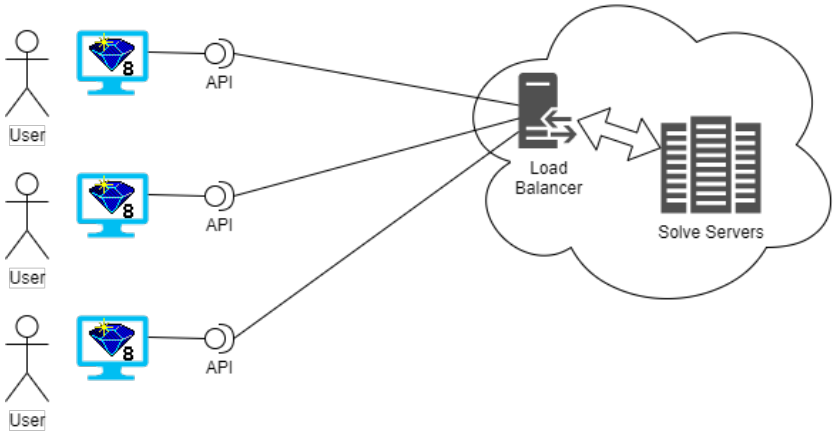


Figure 71. Cloud solve flow (version 1).

This setup was implemented for testing purposes inside INL's network where we have several servers available for our department's use attached to an internal load balancer used for testing. This process was being duplicated for all users using a few test servers in INL's DMZ before the DMZ outage. Since the 2020 DMZ outage, INL changed to the Azure architecture using more maintainable and modern cloud technologies. The latest revision of the remote solve option will utilize a Docker and Kubernetes pipeline and is structured as shown in Figure 72.

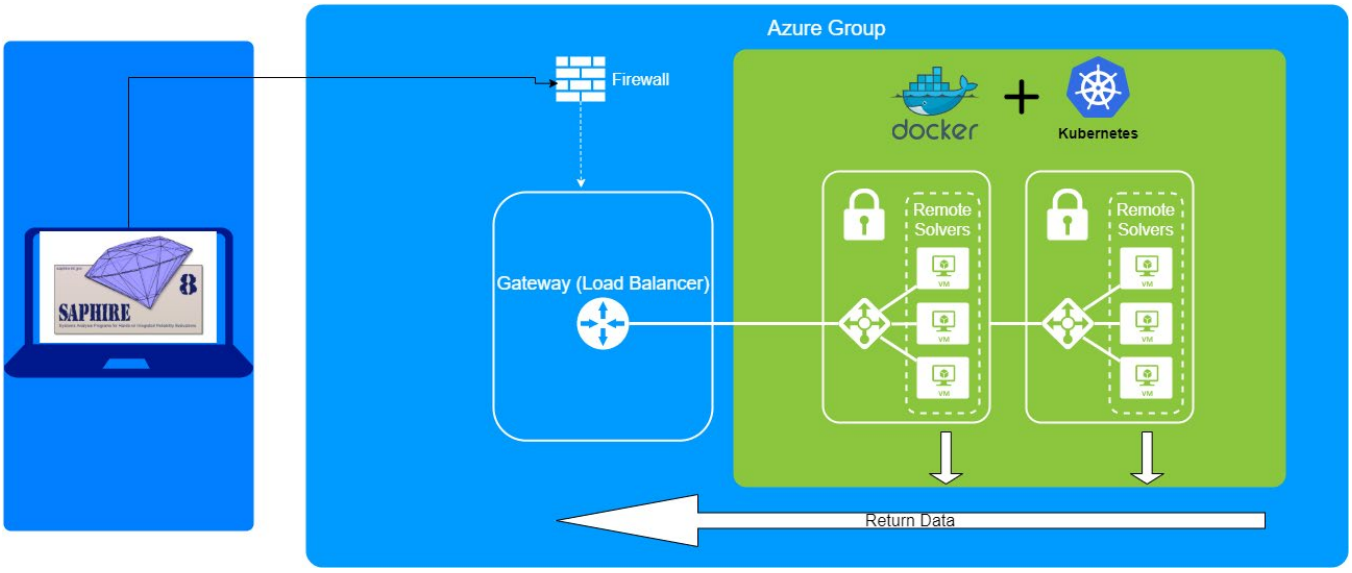


Figure 72. New cloud solve flow.

With this new architecture in place, the SAPHIRE team is more confident with the future of remote solving capabilities. With the addition of Docker and Kubernetes frameworks, remote solving capabilities can be scaled up or down as needed very quickly whereas the old setup would require manually adding new virtual machines to increase computing capabilities. The cloud solve option is a pivotal building block to the future of SAPHIRE. Even in initial plans the feature of auto scaling was desired but was not

available on the previous INL platform so using the Docker and Kubernetes frameworks provides the perfect long-term solution.

Preliminary research was done into using other cloud service options for solving. With INL's move to Azure, there is currently no approved option for INL to deploy developed software to other cloud services. However, under the new architecture, each software deployment is in its own isolated block, so a security breach or attack on one should not affect the availability of others.

3.4.3 SAPHIRE solve engine

Description

To make a workable remote solver, the existing SAPHIRE solve engine had to be extracted from the SageRisk API, and the necessary inputs to the solve engine and outputs from the solve engine needed to be defined. Only the minimal subset of the function in the SageRisk API was used. Given the power of the various servers, Our team decided was decided to create a 64-bit solve engine. The solve engine needed to be tested to ensure the results (generated cut sets) matched the results from the internal integrated solver. Extensive testing needs to be done to ensure the remote solver's fidelity to the cut set generation process. An input file format was reviewed, and a JavaScript Object Notation (JSON), which is a lightweight data-interchange format, was determined to meet the remote solver's requirements. JSON is also used for the output format.

Accomplishments

A 64-bit SaphSolver.dll has been created and tested extensively. The SaphSolver.dll takes two files as its parameters: 1) An input file containing the necessary logic and basic event failure data to produce cut sets and 2) an output file containing the cut sets and other information that make it possible to store the cut sets and results back into the SAPHIRE project model. The cut set results process will be described in Section 3.4.4.

The input file has a JSInp file extension. All the information necessary to identify the fault tree or event tree sequences to be solved is contained in this file. A JSInp file contains the information for one fault tree if it is a fault tree solve. An event tree JSInp file contains all the fault tree(s) logic, sequence(s) logic based on the fault tree combinations required to specify the event tree accident sequence(s), and the basic event information required to generate cut sets. The truncation levels are also contained in these JSInp files. Last year's summary report (June 2020 SAPHIRE 8 Algorithm Enhancements Status Report) shows the JSInp files for the simple CCS tree and the LOSP event tree of the DEMO project. Rather than pass in multiple flag sets to the solver, it was determined to apply the necessary flag sets to the input data before it is sent to the solver. This required that some event trees be split up into multiple JSInp files so that only one flag set was applied per JSInp file.

3.4.4 Cut set results

Description

The remote solver generates cut sets for the input file passed into it. It sends those cut sets back in a JSON based JSCut file. This file contains information about the source of the cut sets and the various truncation parameters used to generate the cut sets. It has the overall number of cut sets and the overall failure value of the cut sets for each fault tree or each sequence of an event tree.

Accomplishments

When SAPHIRE is made aware the remote solver is done, it reads the JSCut file and loads the truncation values and flag set used (if any) into the corresponding fault tree or sequence results. It then places the cut sets into the proper fault tree or sequence results. Last year's report shows the JSCut file for the simple CCS fault tree and the JSCut file for the LOSP event tree.

3.4.5 SAPHIRE post-processing engine

Description

To make a workable remote post-processing engine, the existing SAPHIRE post-processing engine (post-processor) is being extracted from the SageRisk API, and the necessary inputs to the post-processor and outputs from the post-processor are being defined. Only the minimal subsets of the function in the SageRisk API will be used. Given the power of the various servers being used, it was decided to create a 64-bit post-processor. The post-processor needs to be tested to ensure the answers (processed cut sets) matched the answers (processed cut sets) from the internal post-processor. Extensive testing needs to be done to ensure the remote post-processor's fidelity to the cut set generation process. An input file format was reviewed, and a JSON was determined to meet the requirements of the remote solver and is also used for the output format.

Accomplishments

A 64-bit SaphPPE.dll is being created by extracting the functionality from the SageRisk API. The SaphPPE.dll takes three files as its parameters: 1) an input file containing the necessary rules and basic event data to understand the post-processing rules, 2) an input file containing the cut sets and other information defining the cut sets, and 3) an output file containing the cut sets and other information making it possible to store the cut sets and results back into the SAPHIRE project model. The cut set results process will be described in the previous section. INL is currently developing the format of the rule input file. It might be necessary to have two input rule files to accommodate project level and event tree level rules.

3.4.6 SAPHIRE remote solver security

Description

There are several levels of security for access to and protection of data when using the remote solve option. The remote solver is inserted within an ASP.NET Core API endpoint. ASP.NET Core contains features for managing authentication, authorization, data protection, HTTPS enforcement, app secrets, anti-request forgery protection, and CORS management. These security features allowed us to build a robust yet secure feature.

Accomplishments

The remote solve option requires a Safety Portal user account for access. When the user selects a remote solve option, they are required to log into the Safety Portal. This provides SAPHIRE with a token. This token is sent along with the solve item and verified using current Safety Portal protocol. This prevents unauthorized access to the resources.

The main protection of user data from infiltration is the secure sockets layer (SSL) encryption for Web API calls. Currently, TSL 1.2 is being used but will be updated to TSL 1.3 shortly. To protect against unknown security flaws, all data being sent across the network to the servers will be stripped of names, descriptions, or general identifiable features. Only internal numerical IDs will be used for solving with the sending machine, knowing the correct association.

4. REVIEW PLAN

The SAPHIRE enhancements have driving principles that need to be a priority. The work must advance the SAPHIRE software to keep pushing the state of practice and meet the changing needs within the probabilistic risk assessment (PRA) community. The following areas are the focus for future SAPHIRE enhancements:

- Improved capabilities in reporting and documenting analysis results
- Enhancements to support new Standardized Plant Analysis Risk (SPAR) model features (e.g., support system initiators, Level 2 analysis, common-cause failure modeling)

- Support to improve SPAR model maintenance and update capabilities
- Changes to accommodate large and complex models
- Continued enhancements to support SAPHIRE users' abilities to collaborate on projects and share analysis results
- Development of tools to allow users to run SAPHIRE analyses through a web browser interface
- Improvements to SAPHIRE's parallel processing and distributed solving (i.e., solving that is distributed over a system of networked computers) capabilities
- Expansion of SAPHIRE's binary decision diagram solving capabilities or other quantification and analysis enhancements to improve quantification accuracy and/or speed.
- Enhancements based on the SAPHIRE User community requests and agreed upon with the NRC COR.

The "SAPHIRE Enhancement Plan Report," which started in FY-2017 and continues to be the guiding document with annual updates (the latest for FY 2021 is from September 2020), details the items that need to be added to SAPHIRE to enhance its capabilities and meet user needs. These items are listed below to provide the status and based on approval from the NRC COR:

- Tier 1: Top priority enhancements for the near term.
  - Online/offline data model design and testing.
  - Processing engines–Finish this enhancement for SAPHIRE 8 to speed up solving and developing the PRIB report. This process will transition from SAPHIRE 8 to SAPHIRE 9 (Cloud Version).
  - Remote/commercial solve servers–Finish setting up INL remote solver servers, and research commercial cloud options.
  - Single MAR-D input/output file for all SPAR projects–Completed.
  - Convolution factor calculations:
    - Needs to be updated for common cause failure (CCF) of diesel generators (DG).
    - Needs to be able to handle the system generated expansion CCF events.
  - Develop multiple processer operations when solving sensitivity change sets–Completed.
  - Change set options:
    - Add the ability of apply a change set to the system generated CCF terms.
    - Add the ability to back calculate a DG fails to run (FTR) probability into lambda*mission time.
  - Research and potentially implement the ability to handle success sequence information in the sequence cut sets without slowing down the solving and quantification–In process.
  - Increased solving and quantification speed–Continuing.
  - Error message for uncertainty analysis with large probability events and if the sampled probability is greater than 5% of the samples.
  - Safety Portal–Make changes to prepare for online editing.
  - Basic event data connection–Build a system to link template basic events within SAPHIRE to the data collection database stored on the Safety Portal.

- Tier 2: These enhancements will be addressed after Tier 1 or if directed by the NRC COR. Most of these enhancements would have near-term benefits to SAPHIRE users and SPAR model analysts.
  - Finalize Safety Portal enhancements.
  - Note semi-graphic fault tree viewer (Logic Viewer)–Completed in SAPHIRE Release 8.2.4.
  - Implement External Report Generation Tool–This tool would be beneficial to the SPAR modelers and external users for setting up different parts of a document and then letting this tool collate the information together in a single document.
  - Improve report options when viewing delta CDF.
  - Update the "Project Check" functionality:
    - "Fault Tree Top Issues" function needs updated based on SPAR modelers inputs.
    - Filter out CCF events from "BE Probabilities" tab with "Uncertainty is not defined" error.
    - Filter out all "OEP-XHE-*" events from unused.
  - Populate the "Basic Event Category" fields from the "Basic Event" name.
  - Rethink/update the multiple pass option in the significance determination process (SDP) and ECA workspace modules.
  - Feature to fail all recovery of offsite power in ECA/SDP workspaces.
  - Develop a search option within each list panel to highlight those basic events, fault trees, and/or event trees within the search criteria. This would make highlighting specific groups very easy for reporting or MAR-D outputs.
  - Add the ability to place branching on the event tree by selecting the node and then simply right-clicking and selecting either the up or down branching.
  - For operator actions that use the SPAR-H method, have this form available when performing an ECA and these operator actions need adjusted.
  - Add large early release factors to the ECA workspace.
  - Note change sets in ECA–Completed and change sets in General Workspaces–In process.
- Tier 3 – These are good suggestions for enhancements but have a lower priority. These should be pursued as schedule and resources permit.
  - Develop new technology research and testing.
  - Implement SAPHIRE Improved Reports.
  - Provide user with a visual cue that a sub-gate is being viewed as the top gate of a fault tree.
  - Alphabetize the basic events within the SDP systems by name and not description.
  - Gray out the other Model types when solving in the ECA\SDP workspace. Only the Model type that was used to solve the base results should show up.
  - Create cut set slice options:
    - when cut sets are sliced and reported, provide slice criteria.
    - provide percent contribution of sliced cut sets to overall cut sets, similar to the total number of sliced cut sets to overall total number of cut sets.

Several of these identified enhancements are intended to expand the capability of SAPHIRE 8 while paving the way for SAPHIRE 9 (Cloud Version). This approach will provide some of SAPHIRE 8's advanced capabilities earlier for users and the developers with user feedback. These identified enhancements are listed by priority based on the NRC COR and INL's ranking. Some of these enhancements may be worked on concurrently.

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Appendix A
Schema

See previous FY report for the Schema or SAPHIRE Data Dictionary as it has not been modified this FY.

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