Introduction to RISE: A Digital Framework for Maintaining a Risk-Informed Safety Case for Current and Next Generation Nuclear Power Plants

FPoliSolutions, LLC

RIPB Community of Practice
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Acknowledgements

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RISE

FPoliSolutions' Vision is for RISE to become the framework of choice to enable the full benefits from a risk-informed approach for both advanced reactors and the operating fleet as envisioned by the Licensing Modernization Project (LMP) and NEI 18-04

10 CFR PART 53 ROADMAP

- A — General Provisions
- B — Technology Inclusive Safety Requirements
- C — Design and Analysis Requirements
- D — Siting
- E — Construction and Manufacturing
- F — Operations
- G — Decommissioning
- H — Licenses, Certifications, and Approvals
- I — Maintaining and Revising Licensing Basis
- J — Administrative Requirements

RISE: Risk-Informed System Engineering

RISE – Purpose

RISE

Cutting edge solution to help NPP operators and advanced reactor developers to orchestrate the complexities associated with implementing a risk-informed design process while reducing design cycle and costs like no other generic productivity tool.

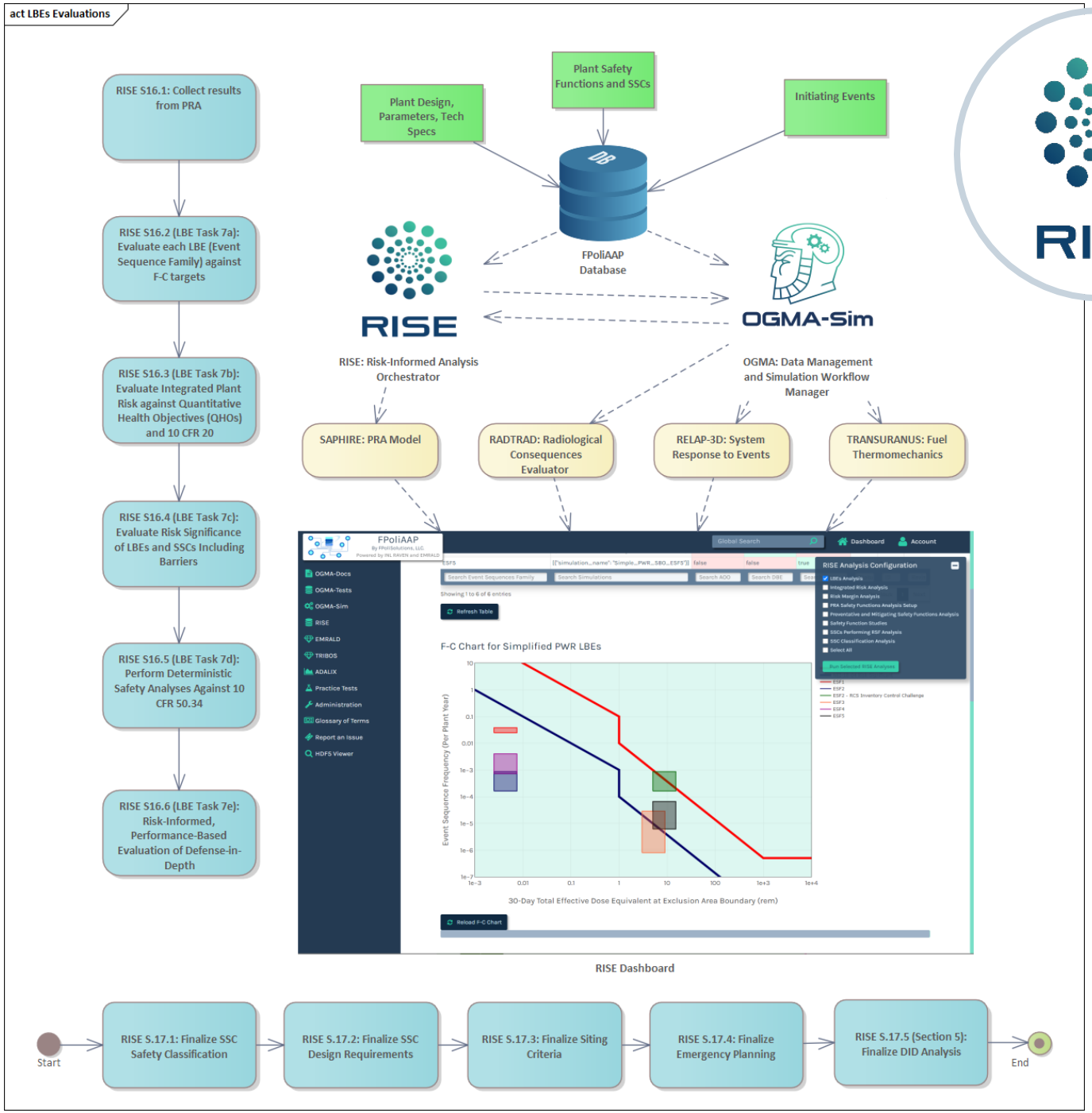
This state-of-the-art software helps to:

- Create a collaborative environment for engineering teams and stakeholders within their organization as they build the ‘safety case’ for their plant
- Digest large and complex data structures needed to characterize the engineered safety features and relationships with scenarios and events
- Optimize design to satisfy safety and economics goals.
- Guide analysts through complex workflows of simulations, data processing and qualification, analyses, and documentation.
- Maximize the value of enterprise technical data with enhanced security and process automation.
- Automate the creation of documentation and smart procedures for quality, transparency and expedited regulatory review.
- Provide a platform for maintaining the safety case throughout the life of the plant.
- Fit seamlessly within established processes of the organization.

RISE: A Smart Safety Case Builder for The Design and Licensing of Nuclear Reactors.

Development Status

- SBIR Phase I
  - Content of this presentation
- SBIR Phase II
  - Current development
- SBIR Topic is assessment of Risk Informed Methods for application to LWRs

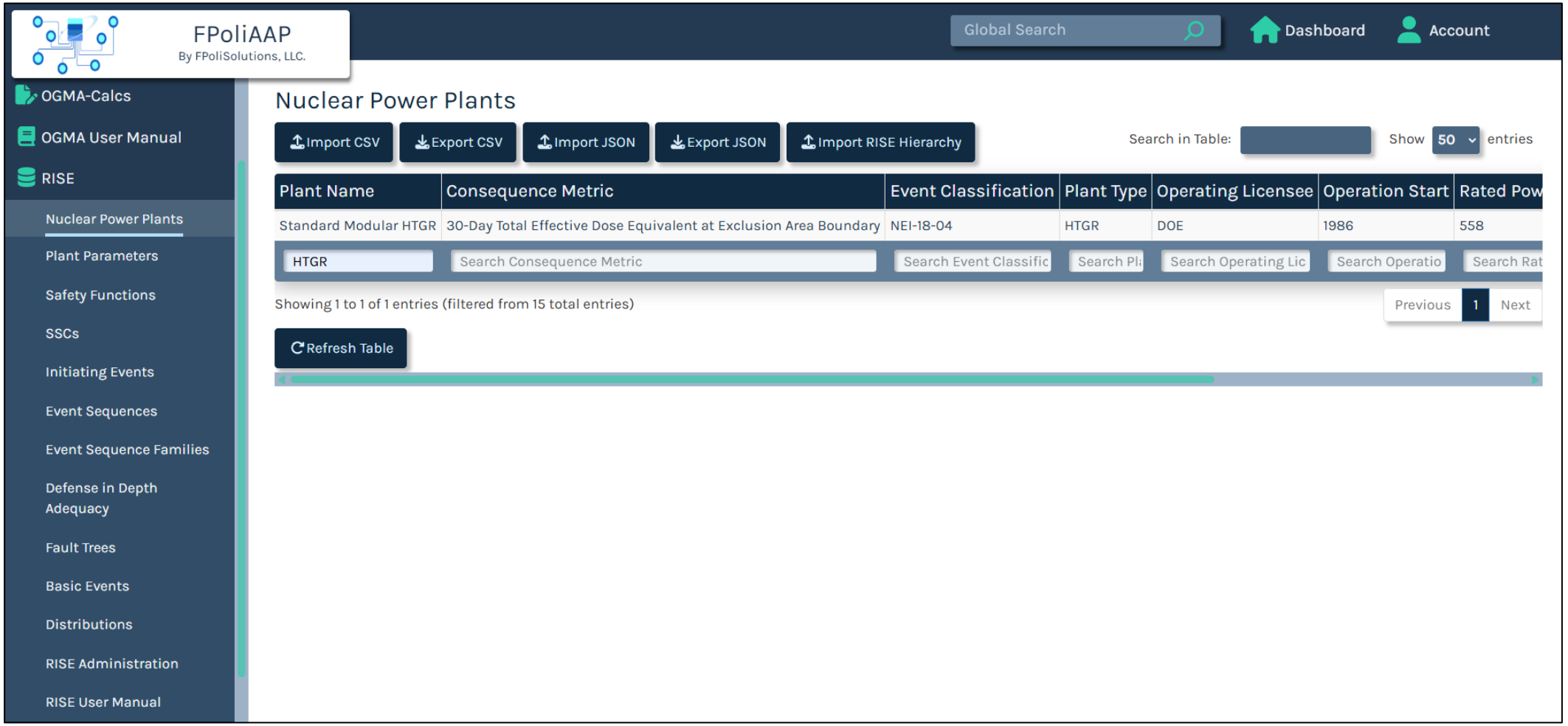


RISE

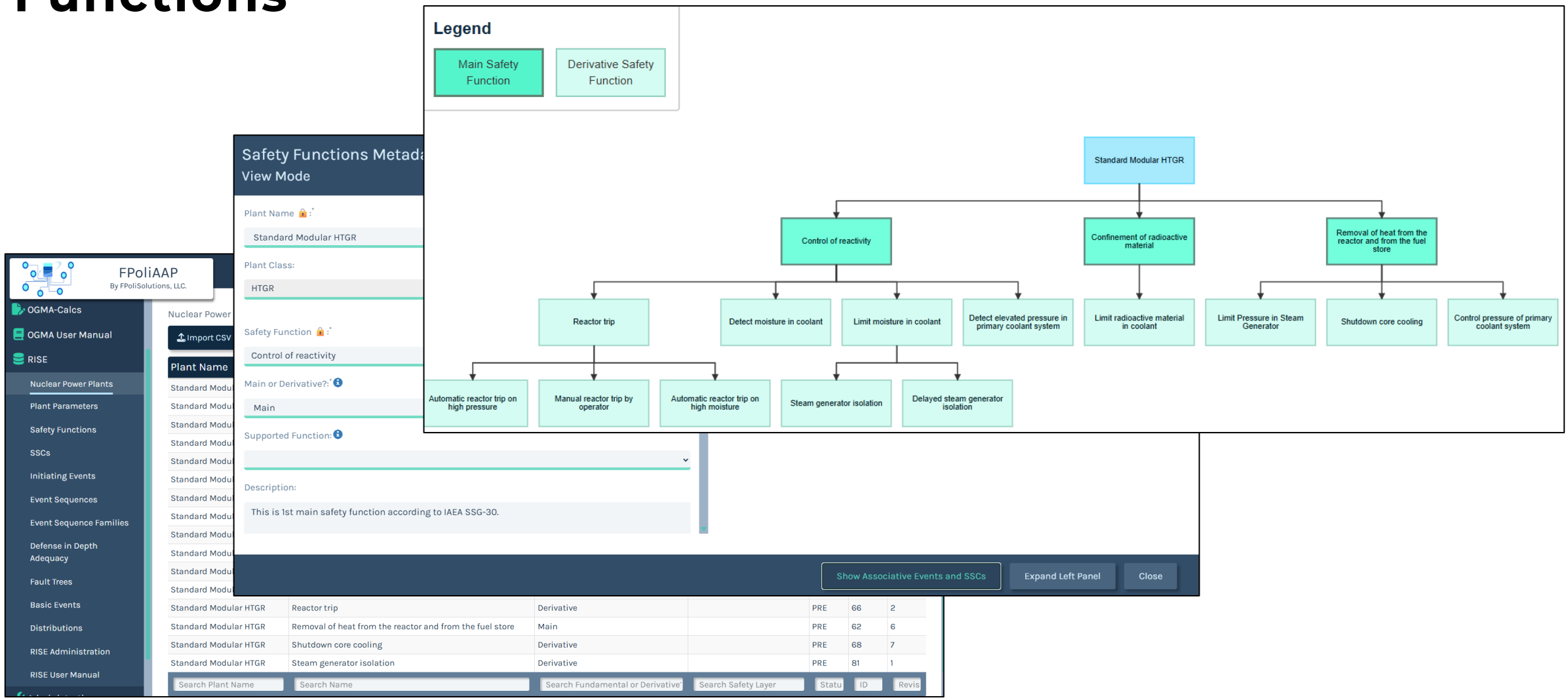
- RISE project was motivated by the LMP and NEI 18-04 which was directed to facilitate licensing of Advanced Reactors.
- FPoli extended the LMP methodology to the current operating LWRs fleet
- RIPB paradigm can uncover safety margin still embedded in the NPP operating fleet safety case
- *A parallel can be drawn with the introduction of Best-Estimate Plus Uncertainty (BEPU) methodologies starting from the 1990's to replace the conservative Appendix-K methods:*

BEPU methods made extended power uprates possible in the US NPP fleet during the 2000's for a total of 8 GW added to the grid without a single power plant built in the same time period

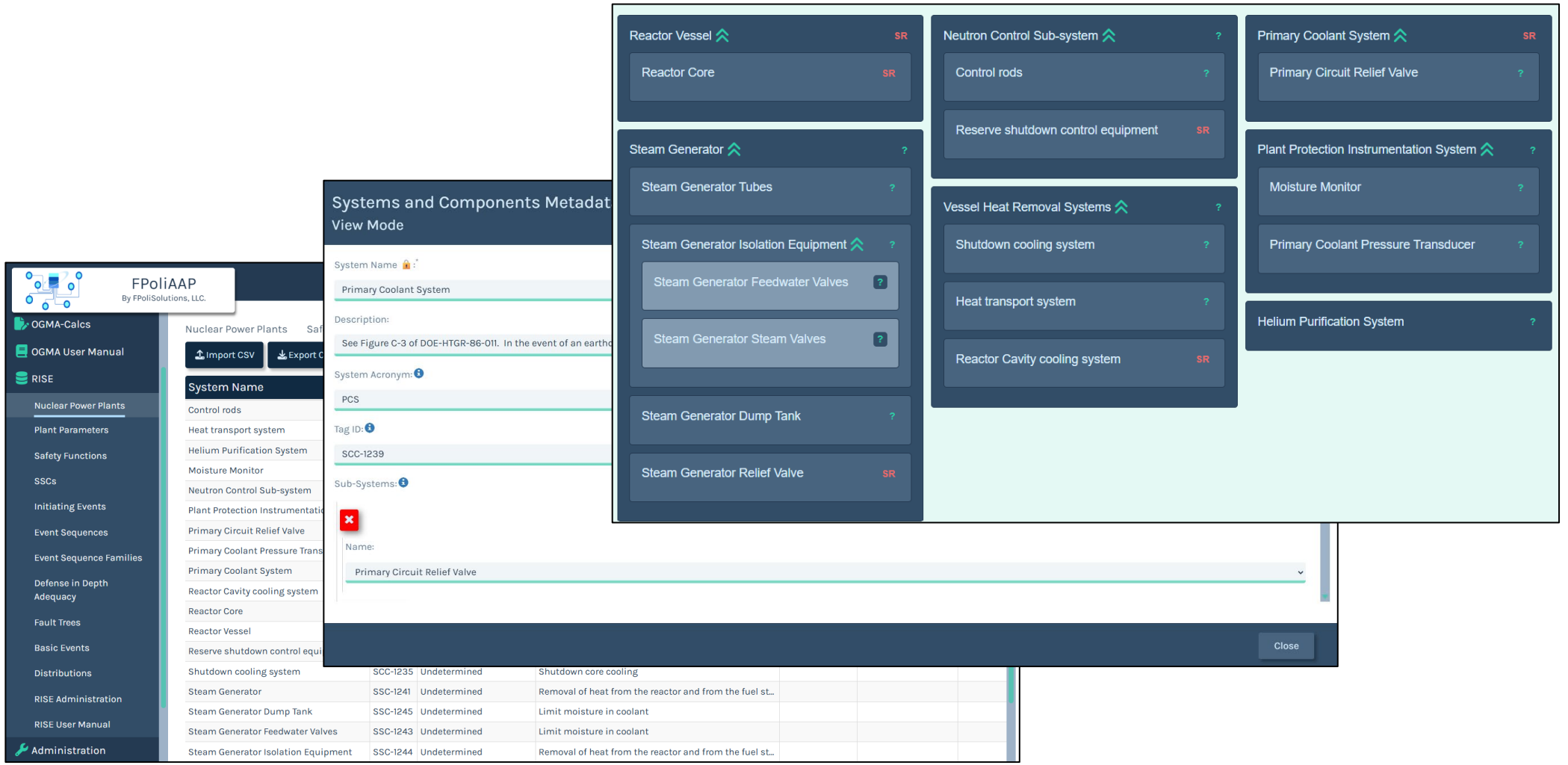
RISE Plant Entry



Defining Safety Functions



Plant SSC Entry and Visualization



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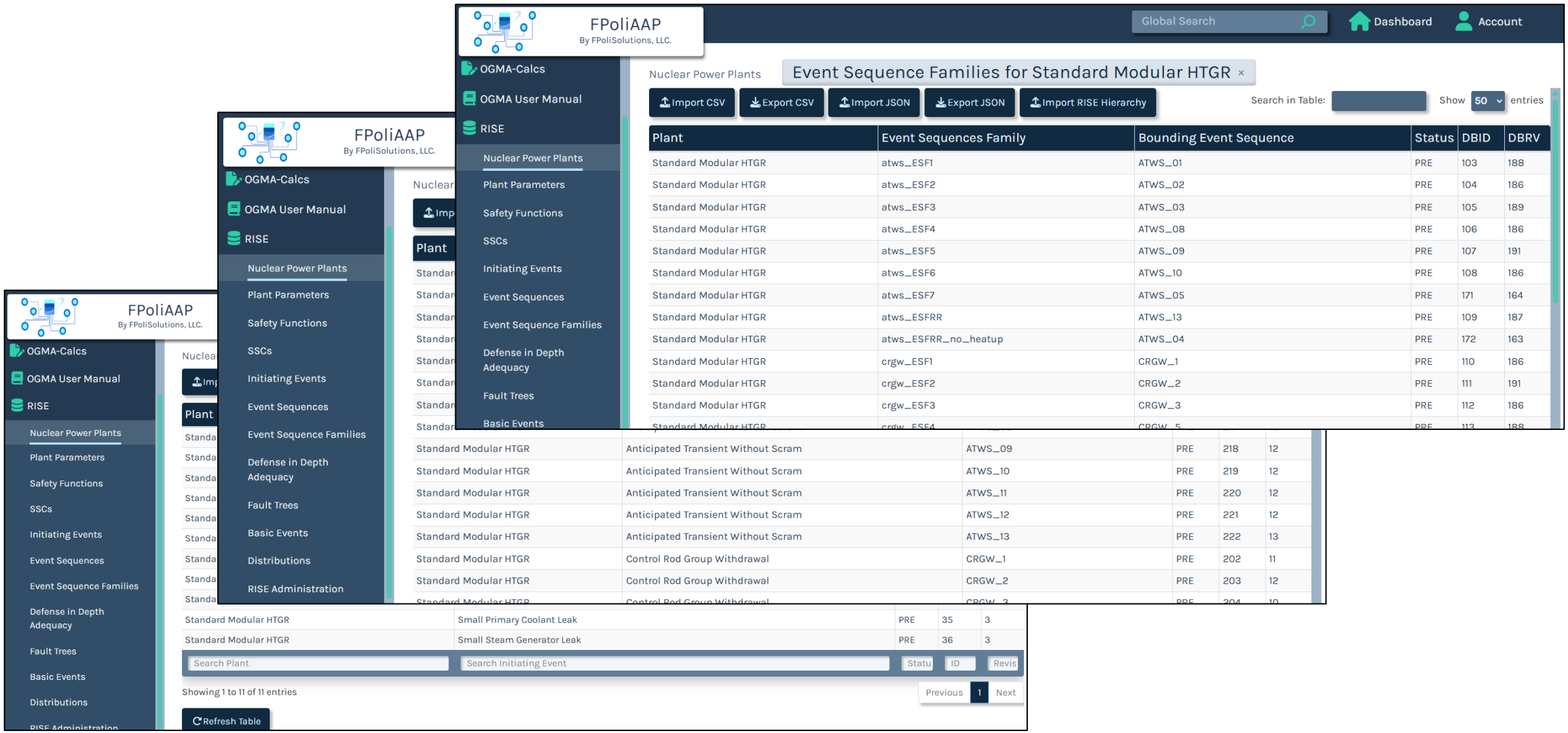
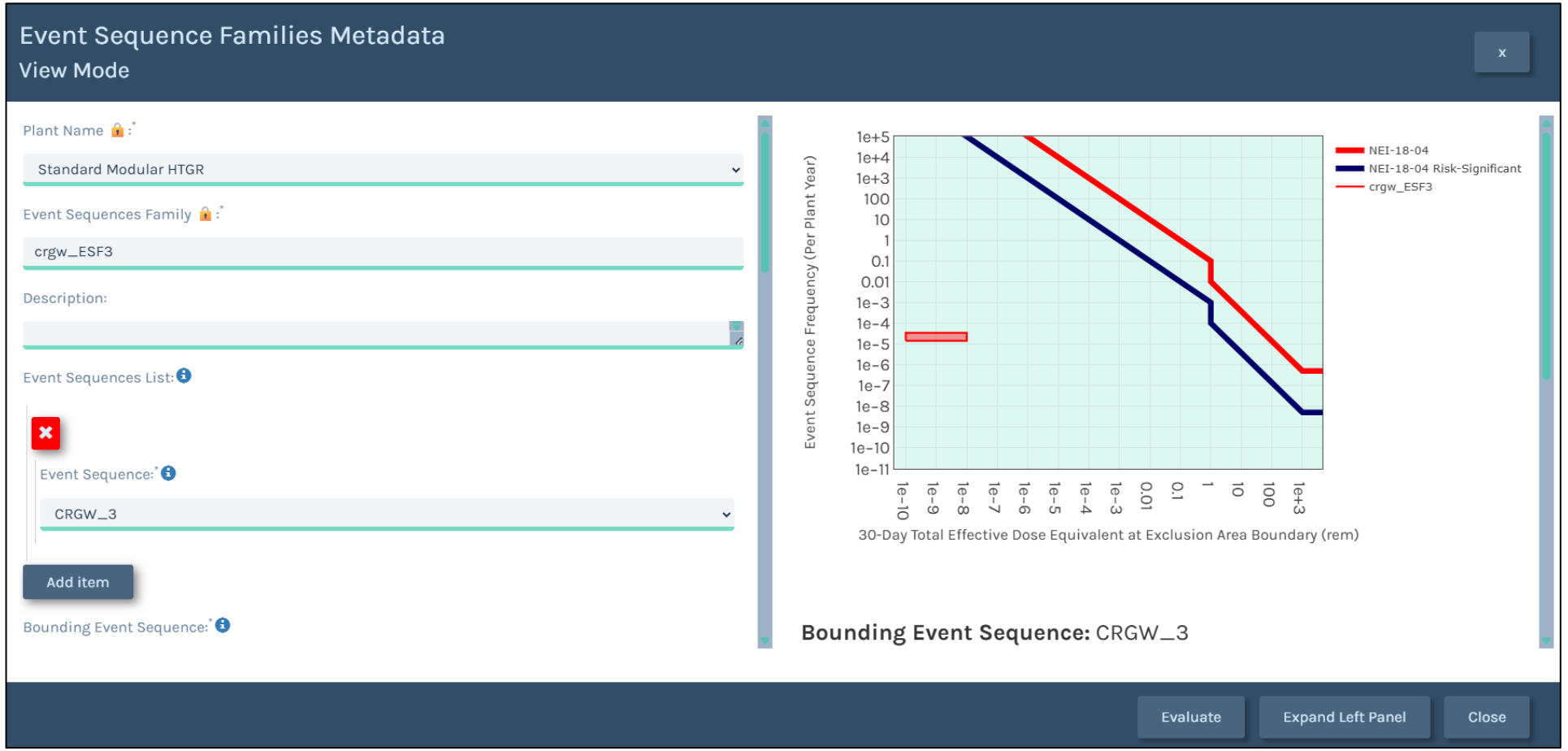
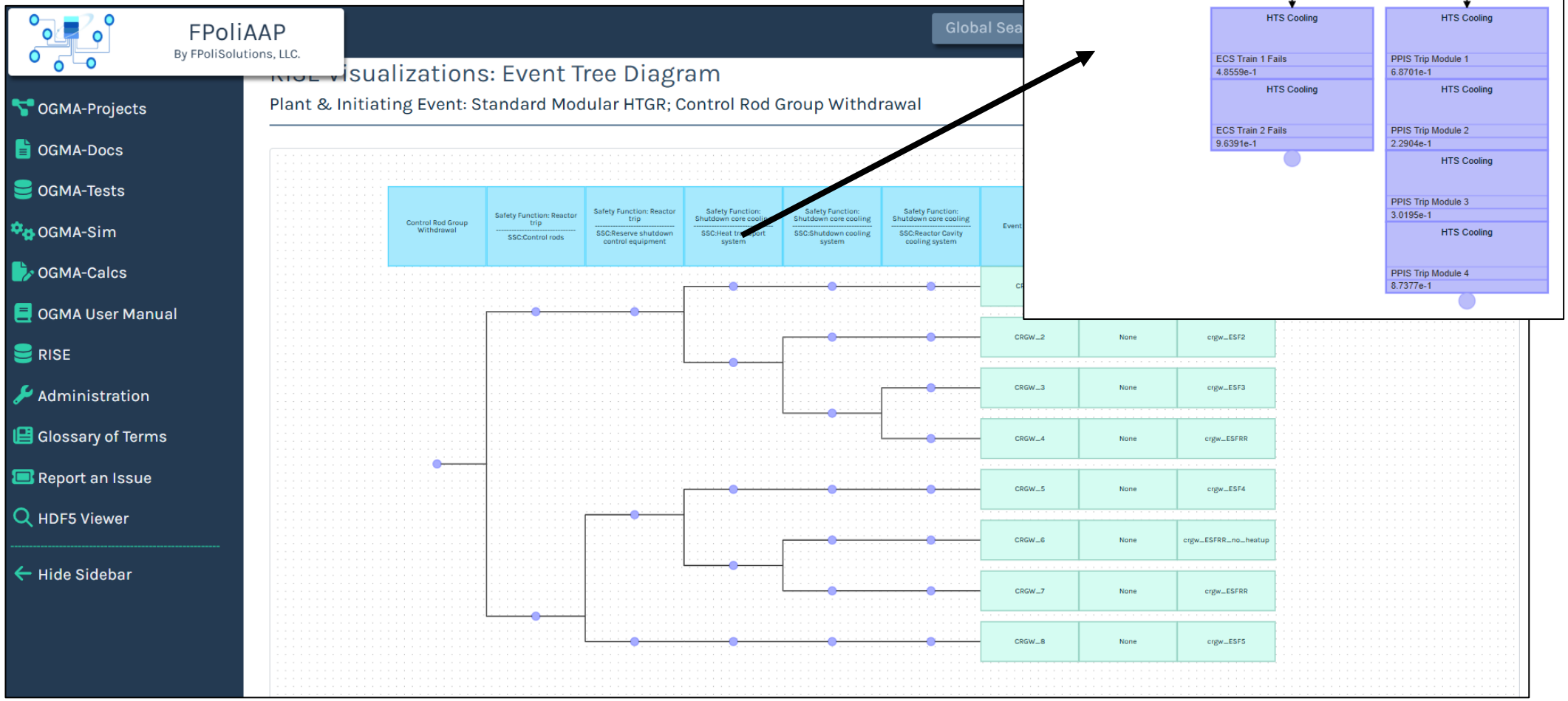
Initiating Events, Event Sequences, and Event Sequence Families



Event Sequence Families



Event and Fault Trees



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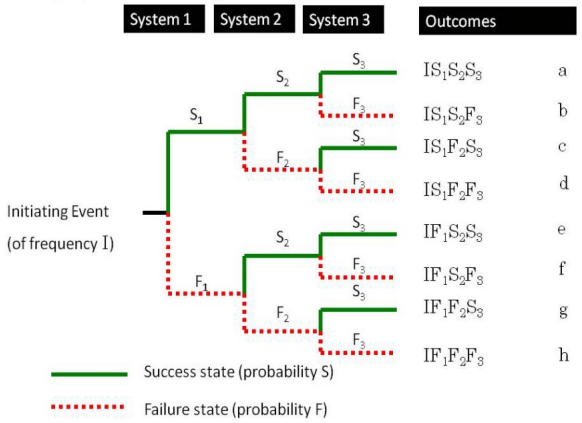
Frequency Distributions

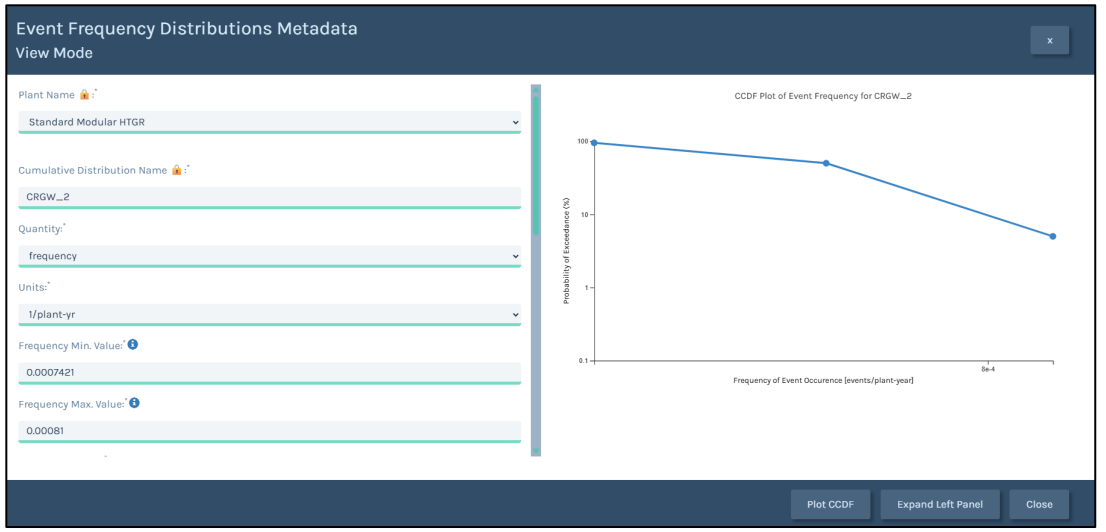
- Manual Input of PRA Artifacts
- Automated Importation of PRA data
  - API for import

PRA Model: Event Trees and Event Frequencies

SAPHIRE

CAFTA





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Consequence Distributions

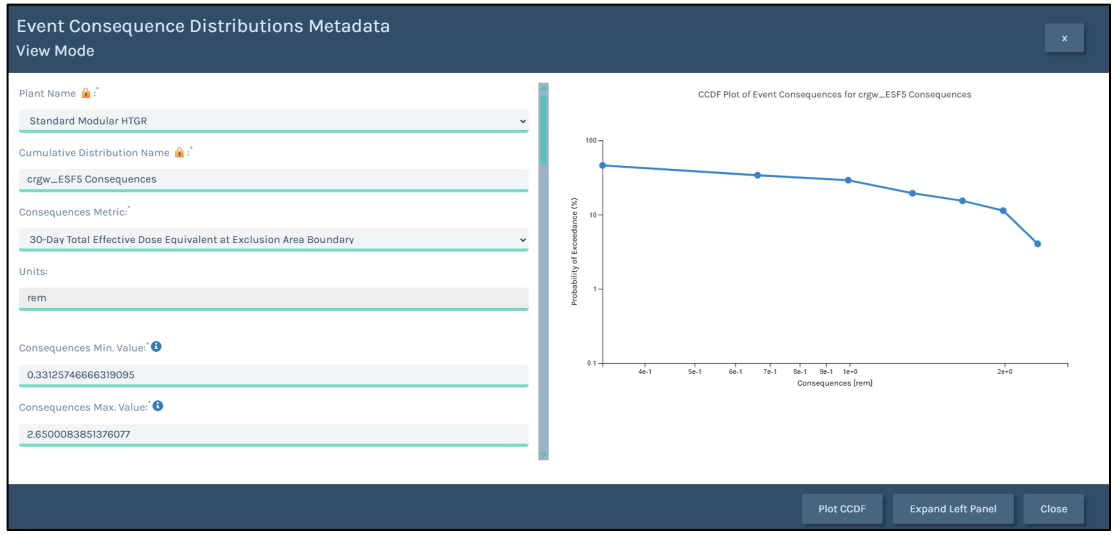
- Manual Input of Dose Values
- Calculation of Dose Values through OGMA Simulation Manager RAVEN
  - External Couplings
  - Uncertainty Propagation

Severe Accident Progression and Radiological Consequence Dose Assessment

RELAP5-3D Reactor Excursion & Leak Analysis Program + RADTRAD

MELCOR + MACCS Accident Consequence Model

Custom Python Scripts for Dose Assessment

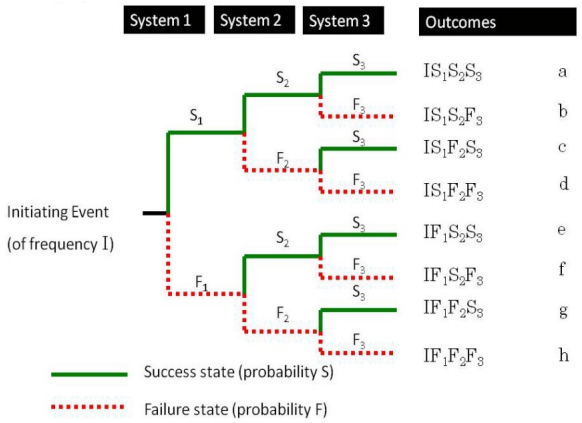


Risk Informed Decision Making

PRA Model: Event Trees and Event Frequencies

SAPHIRE

CAFTA



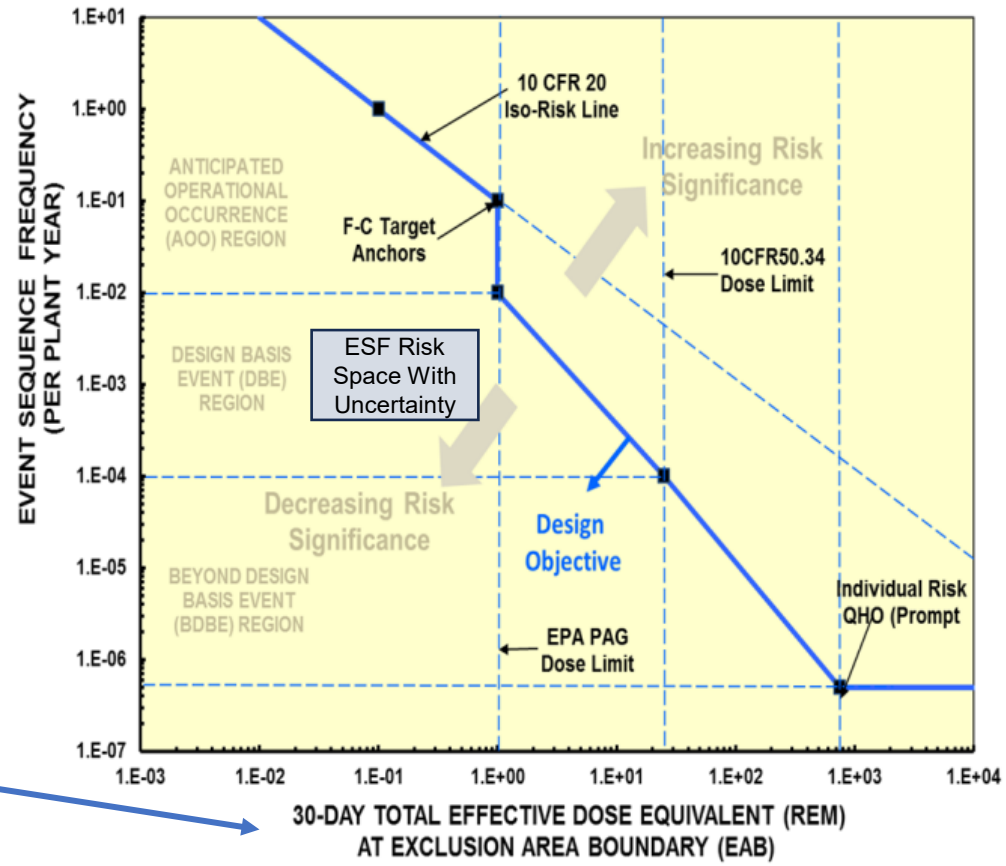
Severe Accident Progression and Radiological Consequence Dose Assessment

RELAP5-3D Reactor Excursion & Leak Analysis Program + RADTRAD

MELCOR + MACCS Accident Consequence Model

Custom Python Scripts for Dose Assessment

Frequency – Consequence (FC) Chart



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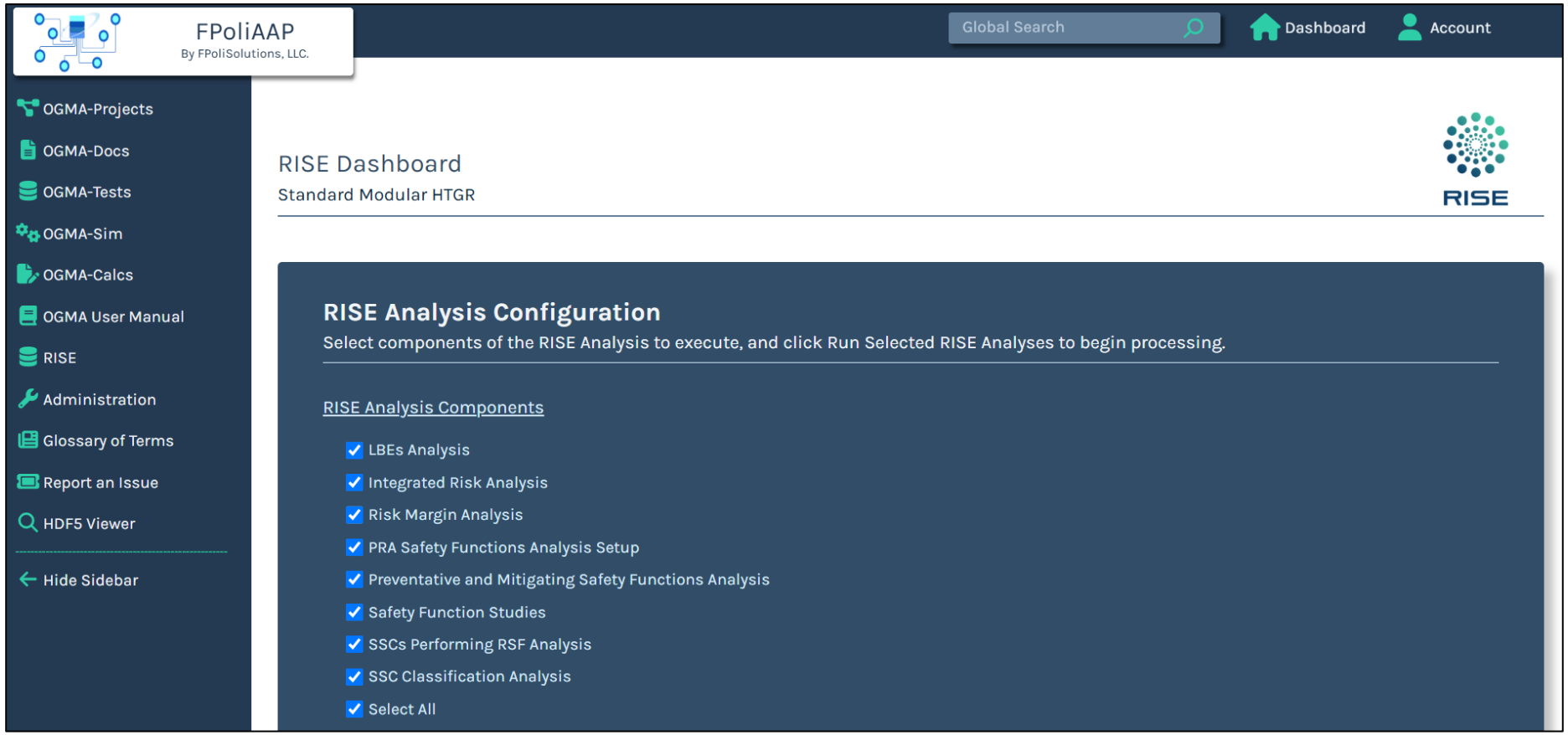
RISE Analysis Dashboard



RISE Dashboard – LBE Classification

Event Sequences Family	Simulations	AOO	DBE	BDBE	Status	DBID	DBRV
atws_ESF1		true	false	false	PRE	93	184
atws_ESF2		true	false	false	PRE	95	184
atws_ESF3		true	false	false	PRE	96	184
atws_ESF4		false	true	false	PRE	98	184
atws_ESF5		false	true	true	PRE	100	184
atws_ESF6		false	false	true	PRE	101	184
atws_ESFRR_no_heatup		false	false	true	PRE	151	162
crgw_ESF1		true	false	false	PRE	105	184
crgw_ESF2		false	true	false	PRE	107	184
crgw_ESF3		false	false	true	PRE	109	184
crgw_ESF4		false	false	true	PRE	111	184
crgw_ESF5		false	false	true	PRE	155	134
leq_ESF1		false	false	true	PRE	165	112
lomlc_ESF1		true	false	false	PRE	116	184
lomlc_ESF2		true	false	false	PRE	118	184
lomlc_ESF3		false	false	true	PRE	120	183
lomlc_ESF4		false	false	true	PRE	122	184
lomlc_ESFRR_no_heatup		false	false	true	PRE	152	163
losp_ESF1		false	true	false	PRE	126	184
losp_ESF2		false	false	true	PRE	128	184
lpcl_ESF1		false	true	false	PRE	131	184
lpcl_ESF2		false	true	false	PRE	133	184

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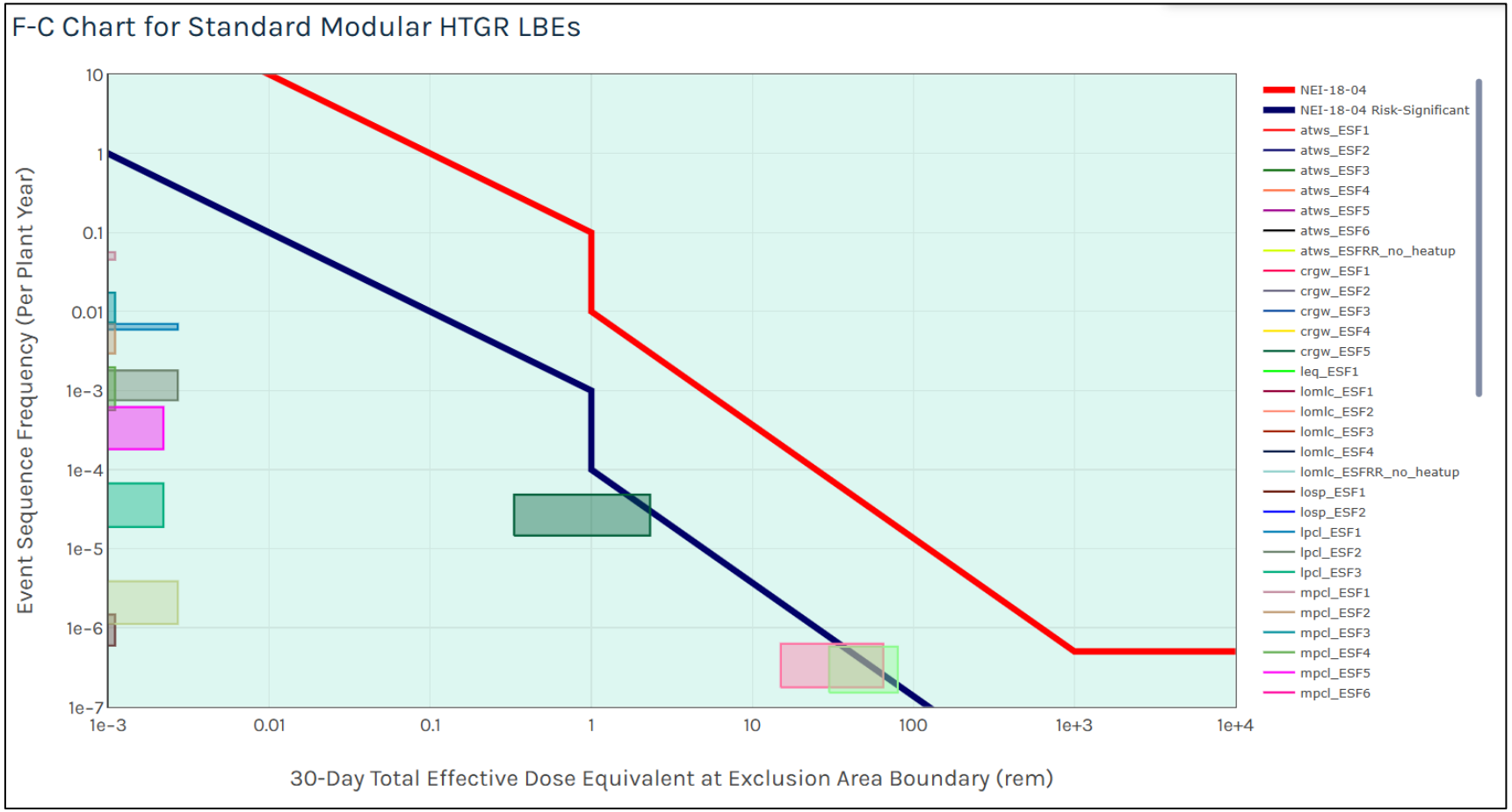
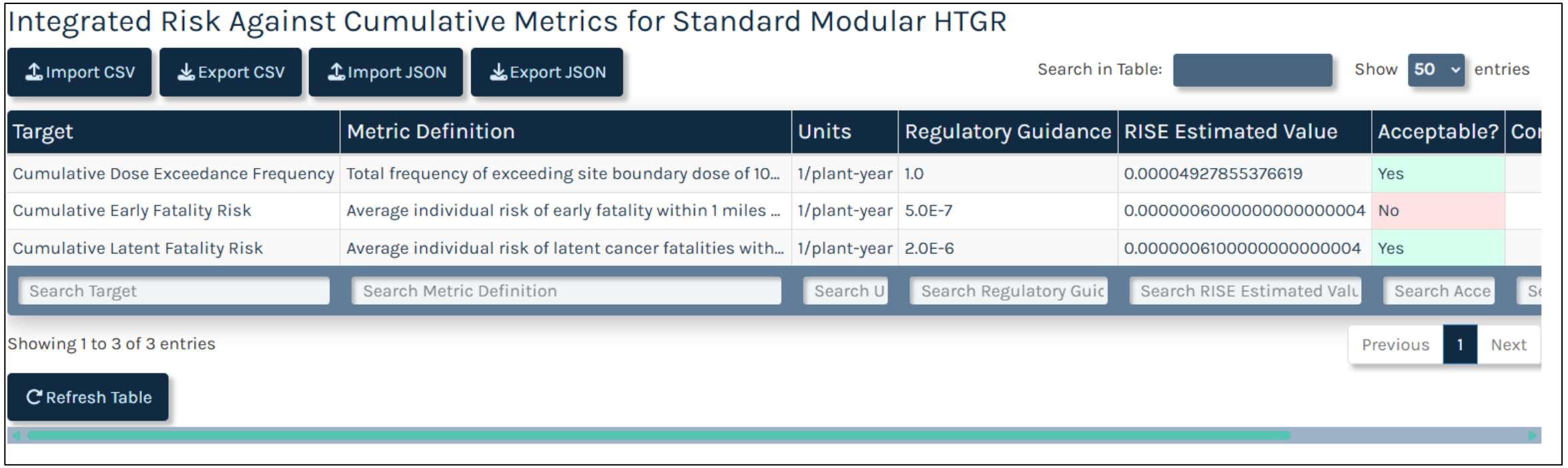
RISE Dashboard – FC Chart



RISE Dashboard – Integrated Risk Metrics



Integrated Risk Against Cumulative Metrics for Standard Modular HTGR

Import CSV | Export CSV | Import JSON | Export JSON

Search in Table:

Show 50 entries

Target	Metric Definition	Units	Regulatory Guidance	RISE Estimated Value	Acceptable?	Co
Cumulative Dose Exceedance Frequency	Total frequency of exceeding site boundary dose of 10...	1/plant-year	1.0	0.00004927855376619	Yes	
Cumulative Early Fatality Risk	Average individual risk of early fatality within 1 miles ...	1/plant-year	5.0E-7	0.0000006000000000000004	No	
Cumulative Latent Fatality Risk	Average individual risk of latent cancer fatalities with...	1/plant-year	2.0E-6	0.0000006100000000000004	Yes	

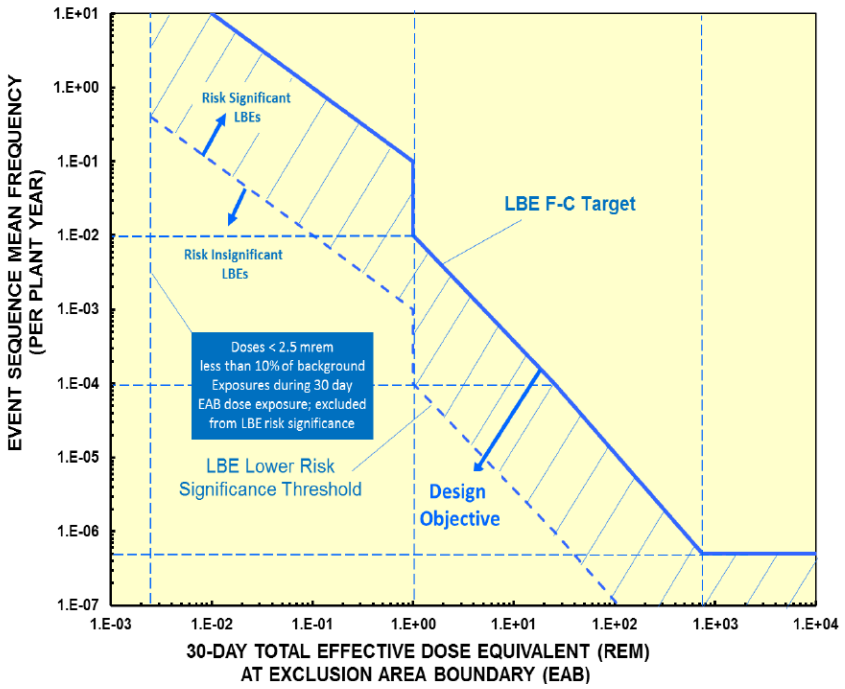
Search Target | Search Metric Definition | Search U | Search Regulatory Guic | Search RISE Estimated Valu | Search Acce | Se

Showing 1 to 3 of 3 entries

Previous 1 Next

Refresh Table

RISE Dashboard – Risk Margin Quantification



Risk Margin Quantification

Import CSV | Export CSV | Import JSON | Export JSON

Search in Table:

LBE	Mean Frequency Margin [-]	Mean Consequence Margin [-]	95th Percentile Frequency Margin [-]	95th Percentile Consequence Margin [-]	Risk Significant?
atws_ESF1	2.43e-07	2.43e-07	2.54e-06	2.54e-06	No
atws_ESF2	2.58e-08	2.58e-08	3.64e-07	3.63e-07	No
atws_ESF3	1.34e-09	1.34e-09	2.19e-08	2.19e-08	No
atws_ESF4	7.29e-12	1.60e-10	7.74e-11	1.67e-09	No
atws_ESF5	7.66e-13	3.32e-11	1.08e-11	4.23e-10	No
atws_ESF6	4.09e-14	4.32e-12	6.66e-13	6.07e-11	No
atws_ESFRR_no_heatup	4.36e-15	0.00e+00	7.24e-14	1.29e-11	No
crgw_ESF1	9.92e-10	1.00e-09	9.92e-09	1.00e-08	No
crgw_ESF2	7.76e-12	1.67e-10	8.10e-11	1.73e-09	No
crgw_ESF3	2.40e-13	1.48e-11	3.39e-12	1.89e-10	No
crgw_ESF4	9.90e-15	1.61e-12	1.41e-13	2.06e-11	No
crgw_ESF5	9.86e-05	5.70e-03	1.60e-02	5.57e-02	Yes
leq_ESF1	1.18e-13	9.01e-12	1.19e-12	9.07e-11	No
lomlc_ESF1	2.47e-08	2.47e-08	2.52e-07	2.52e-07	No
lomlc_ESF2	1.31e-09	1.31e-09	1.84e-08	1.84e-08	No
lomlc_ESF3	4.94e-13	2.45e-11	5.17e-12	2.53e-10	No
lomlc_ESF4	2.59e-14	3.14e-12	3.65e-13	3.99e-11	No

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RISE Dashboard –Safety Function Classification

LBEs Associations and Safety Functions for Standard Modular HTGR

PRA Safety Functions | Preventative Safety Functions | Mitigating Safety Functions | **Safety Function Studies** | Required Safety Functions

Import CSV | Export CSV | Import JSON | Export JSON

Search in Table: | Show 50 entries

DBE	Safety Function Challenged	Are FC Targets Met?	Status	DBID	DBRV
atws_ESF4	Control pressure of primary coolant system	Yes	PRE	17	37
atws_ESF4	Manual reactor trip by operator	Yes	PRE	15	37
atws_ESF4	Reactor trip	No	PRE	14	37
atws_ESF4	Shutdown core cooling	Yes	PRE	16	37
atws_ESF5	Control pressure of primary coolant system	Yes	PRE	13	37
atws_ESF5	Manual reactor trip by operator	Yes	PRE	11	37
atws_ESF5	Reactor trip	No	PRE	10	37
atws_ESF5	Shutdown core cooling	Yes	PRE	12	37
crgw_ESF2	Reactor trip	Yes	PRE	40	37
crgw_ESF2	Shutdown core cooling	Yes	PRE	41	37
losp_ESF1	Reactor trip	Yes	PRE	83	37
losp_ESF1	Shutdown core cooling	Yes	PRE	84	37
lpcl_ESF1	Control pressure of primary coolant system	Yes	PRE	66	37

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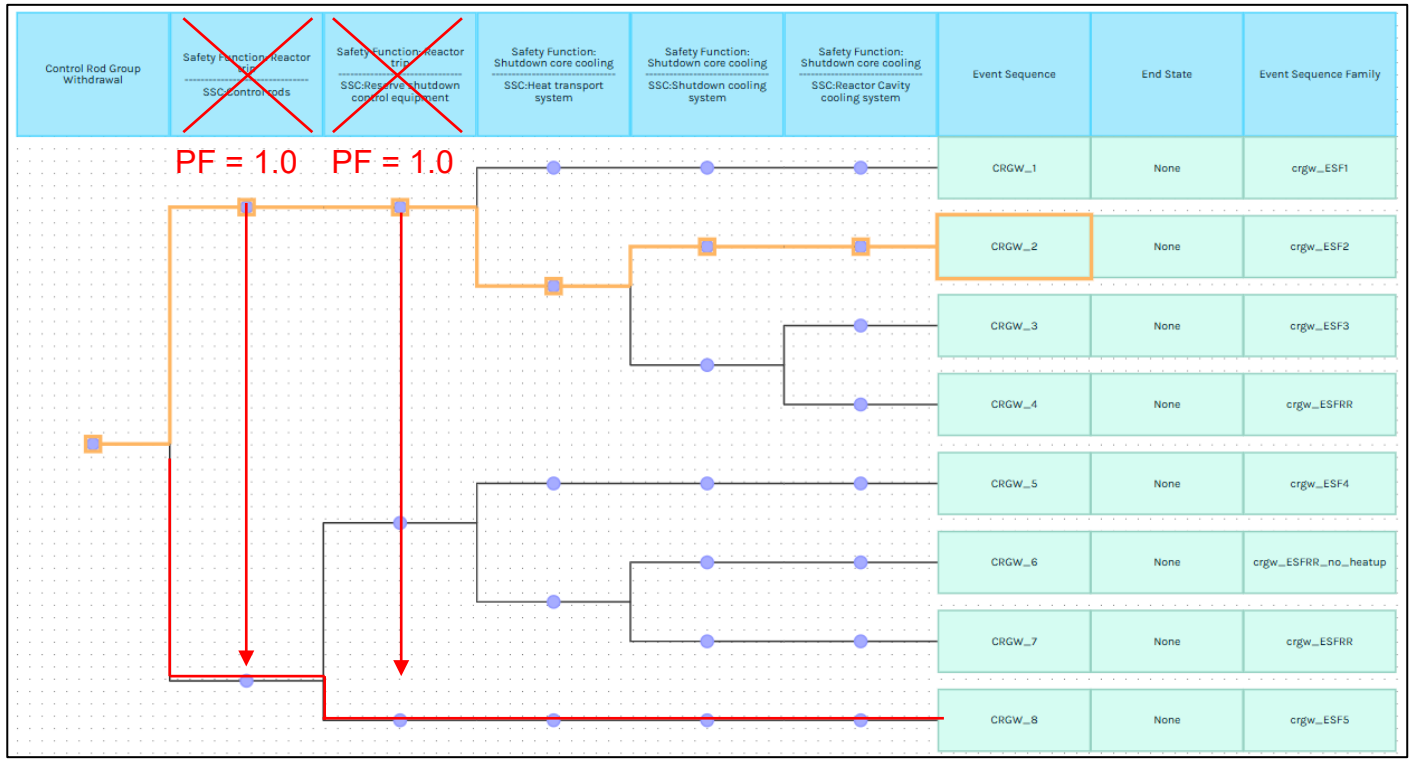
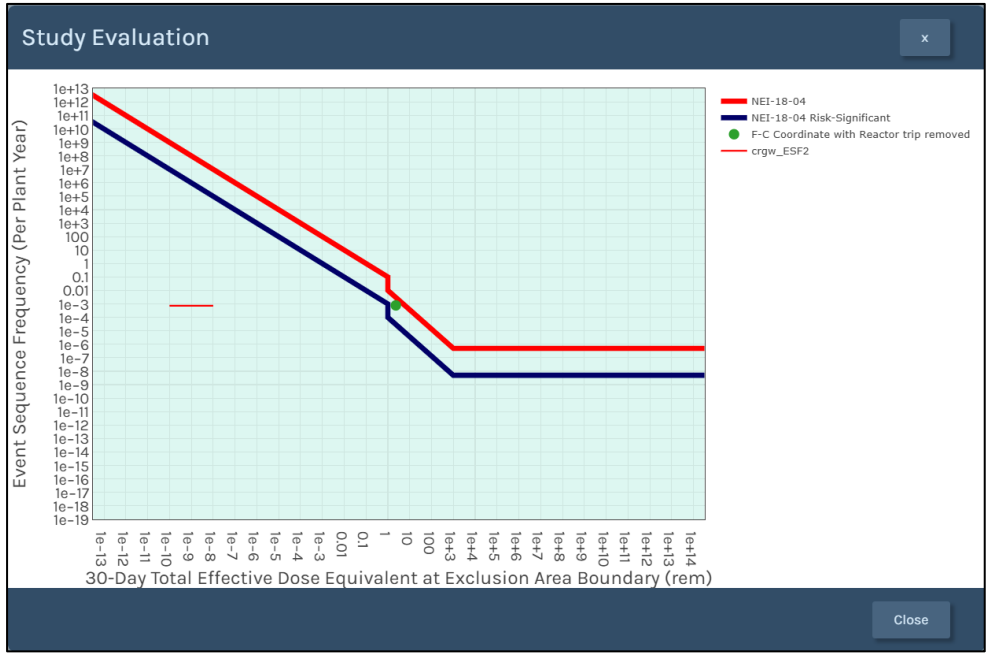
RISE Dashboard – Safety Functions Studies





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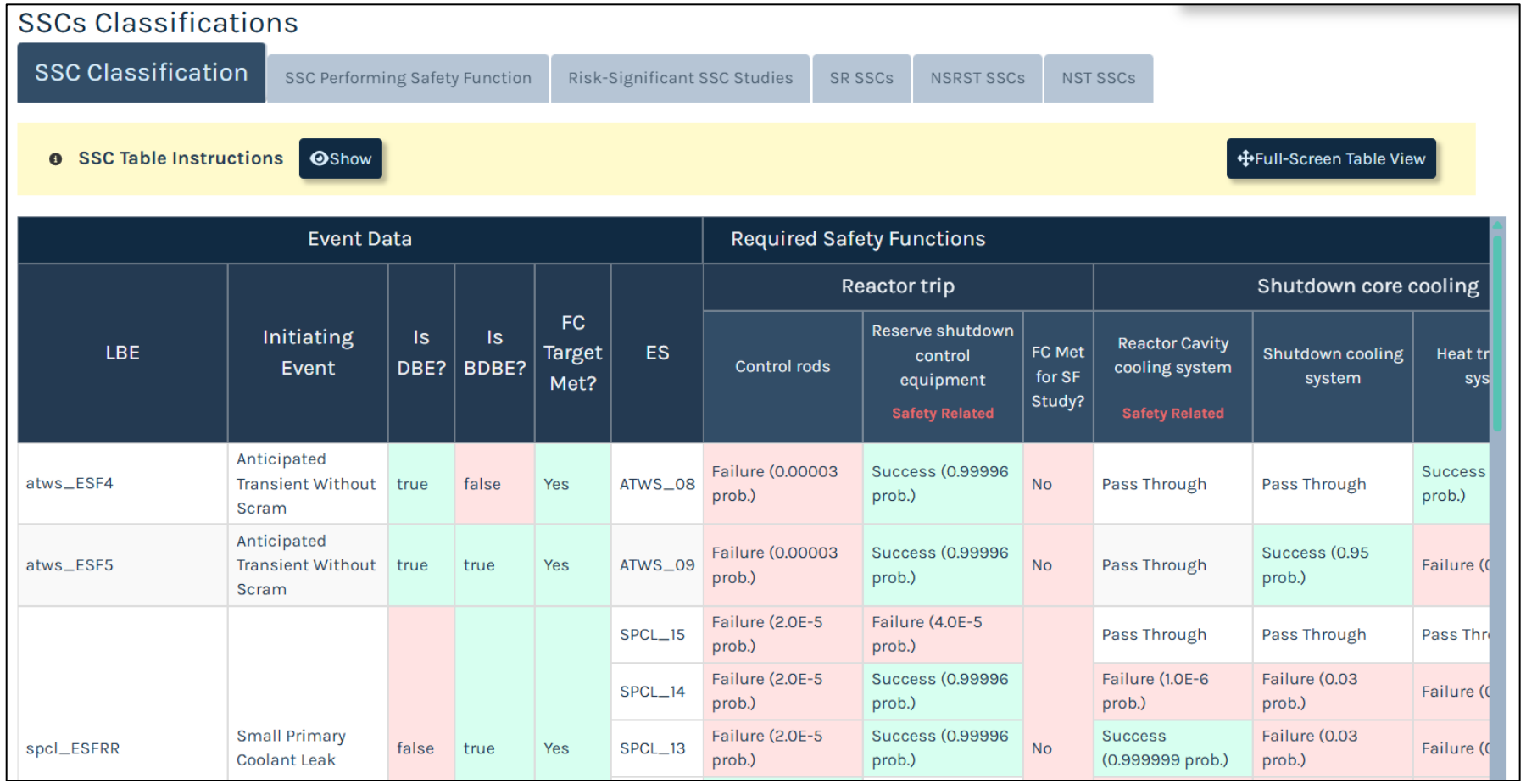
RISE Dashboard – SSC Classification



SSCs Classifications

SSC Classification | SSC Performing Safety Function | Risk-Significant SSC Studies | SR SSCs | NSRST SSCs | NST SSCs

SSC Table Instructions Show

Full-Screen Table View

Event Data						Required Safety Functions					
						Reactor trip			Shutdown core cooling		
LBE	Initiating Event	Is DBE?	Is BDBE?	FC Target Met?	ES	Control rods	Reserve shutdown control equipment Safety Related	FC Met for SF Study?	Reactor Cavity cooling system Safety Related	Shutdown cooling system	Heat tr sys
atws_ESF4	Anticipated Transient Without Scram	true	false	Yes	ATWS_08	Failure (0.00003 prob.)	Success (0.99996 prob.)	No	Pass Through	Pass Through	Success prob.)
atws_ESF5	Anticipated Transient Without Scram	true	true	Yes	ATWS_09	Failure (0.00003 prob.)	Success (0.99996 prob.)	No	Pass Through	Success (0.95 prob.)	Failure (
spcl_ESFRR	Small Primary Coolant Leak	false	true	Yes	SPCL_15	Failure (2.0E-5 prob.)	Failure (4.0E-5 prob.)	No	Pass Through	Pass Through	Pass Thr
					SPCL_14	Failure (2.0E-5 prob.)	Success (0.99996 prob.)		Failure (1.0E-6 prob.)	Failure (0.03 prob.)	Failure (
					SPCL_13	Failure (2.0E-5 prob.)	Success (0.99996 prob.)		Success (0.999999 prob.)	Failure (0.03 prob.)	Failure (

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RISE OPPORTUNITIES

ADVANCED REACTOR LICENSING

Generate the **RIPB safety case**

Provide **transparency, scrutability, and collaboration**

Provide risk insights for design changes

Maintain safety case through plant lifetime

Guide analysts through complex workflows

Automate documentation

OPERATIONAL MARGINS AND FLEXIBILITY for LWRs

Challenge/remove artificial surrogate safety limits while maintaining safety-in-depth

Improve fuel utilization

Facilitate **management of operational incidents/issues**/non-compliance

Commoditize fuel supply (reduce fuel product transition costs)

Streamline safety analysis methods and enhanced transparency for safety determinations

Risk insights (F-C) for SSC safety classification

Expand benefits from **10 CFR 50.69 programs**

PROMOTE INNOVATION AND PUBLIC ACCEPTANCE

Enable deployment of **Highly Enriched-High burnup and/or Accident Tolerant Fuel** products

Siting and Emergency Planning Zone (EPZ) Management activities

Facilitate disposition Generic Safety Issues (GSI)

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Questions

Risk-Informed Systems Engineering (RISE)

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