

Motivation



Knowledge Management and Preservation

- US operational data from reactors and test loops was feared lost after ORNL lost control of the data in the mid-1990s.
- In 2016, JAEA transferred the “flat” version of the US portion of the Centralized Reliability Data Organization (CREDO) database.

Future test complex insights

- CREDO contains failure data and operational records from the FFTF and EBR-II reactors and the WARD and ETEC loops.
- New loops will use similar physical components to those used in the historical facilities and can learn from their experiences.

Probabilistic Risk Assessment (PRA) support

- CREDO data was used to support MONJU, PRISM, and EBR-II PRAs.
- This data can be a valuable resource to future SFR PRAs.

This paper is the first in a series of papers focusing on various components in the database

Overview of the NaSCoRD Database

- Database Overview
- Types of Components
- Data Quality Efforts

Focus on Sodium Valve Insights

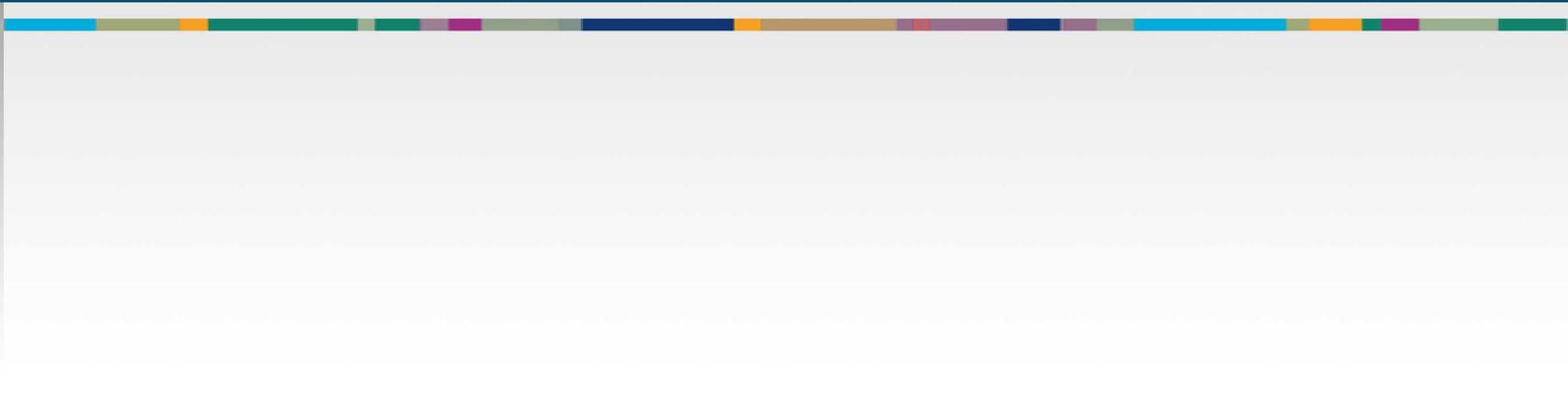
- Data Processing Method
- Prior Distribution
- Posterior Distribution

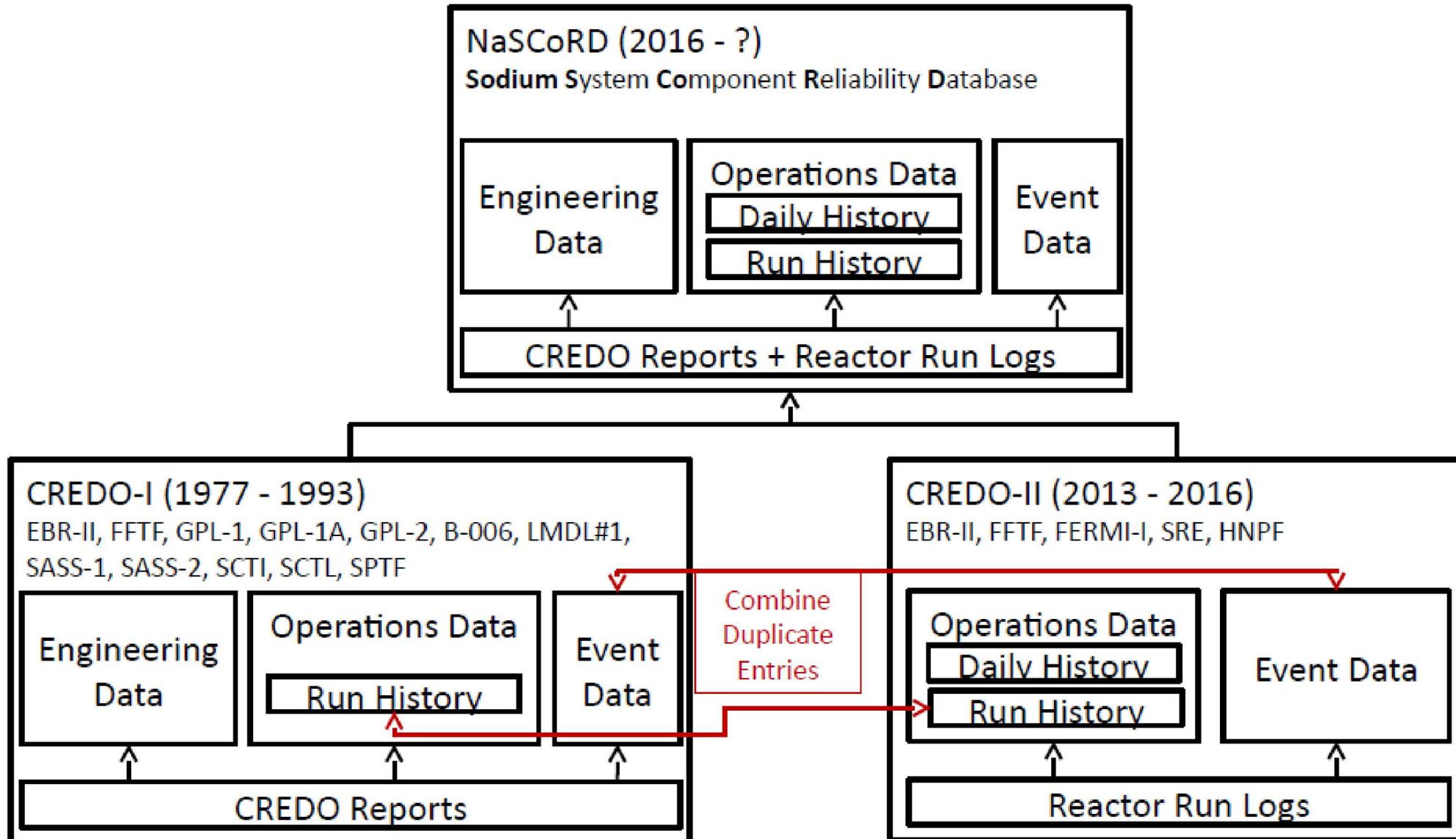
Path Forward

- Temperature Dependency
- Other Components (e.g., Pump, Pipes, and I&C)
- Requesting Access

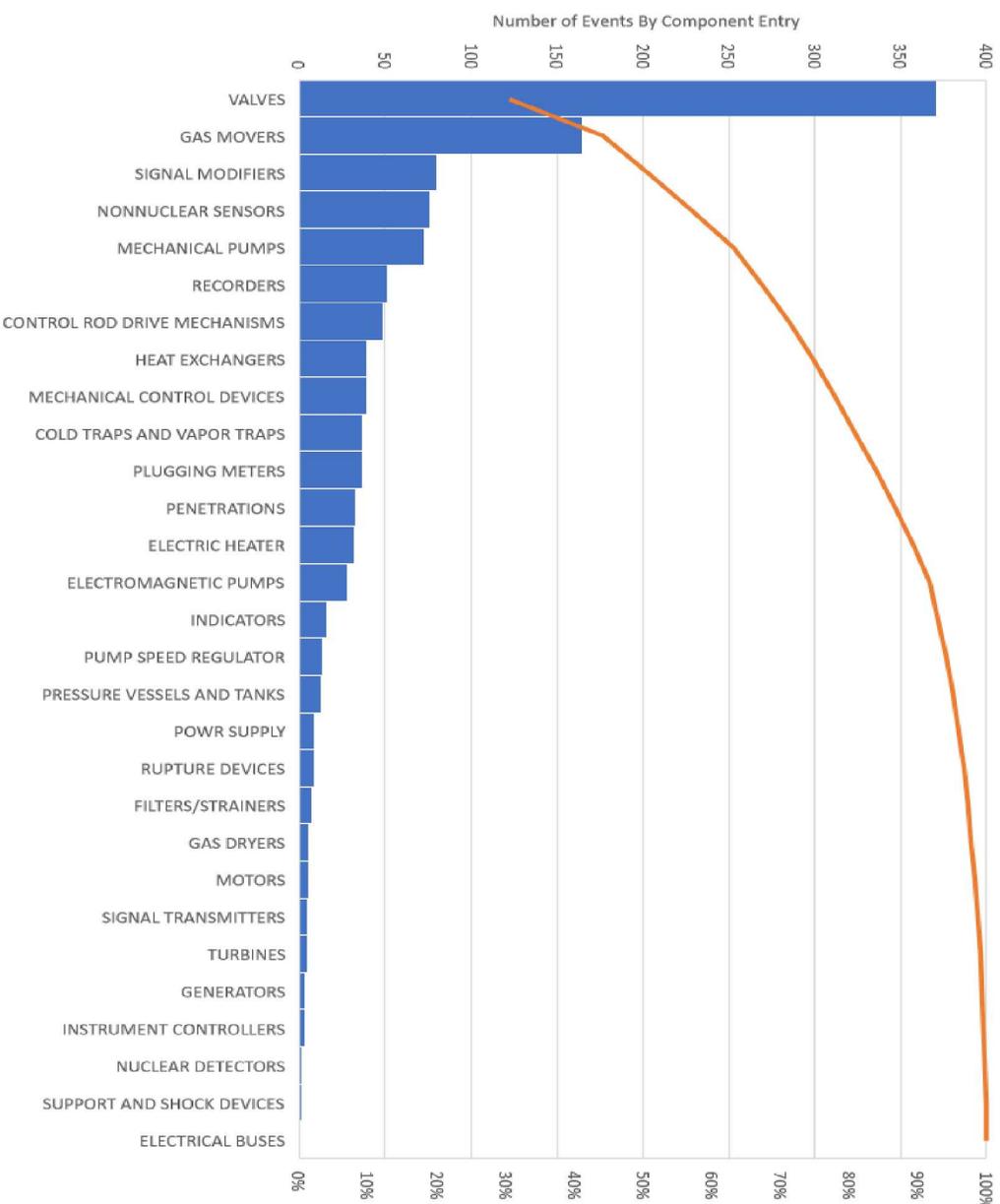


Overview of the NaSCoRD Database

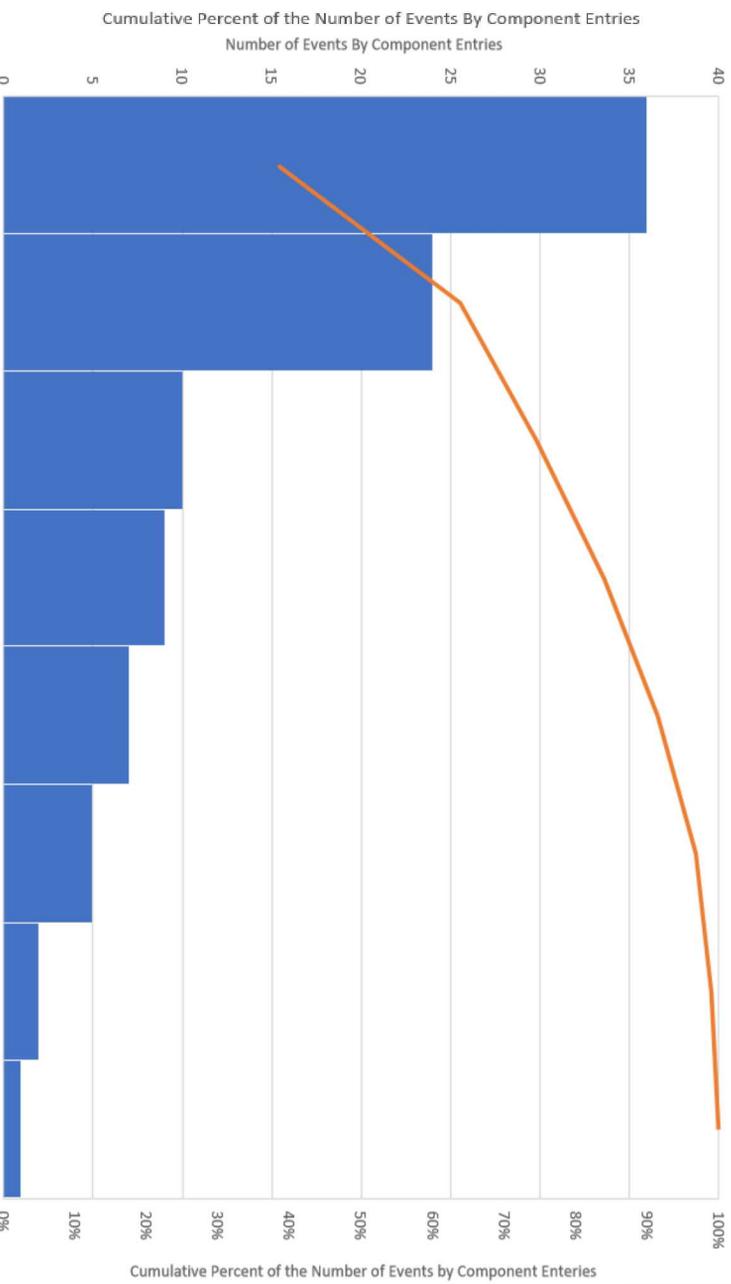




Number of Events Recorded in NaSCoRD



Reactor



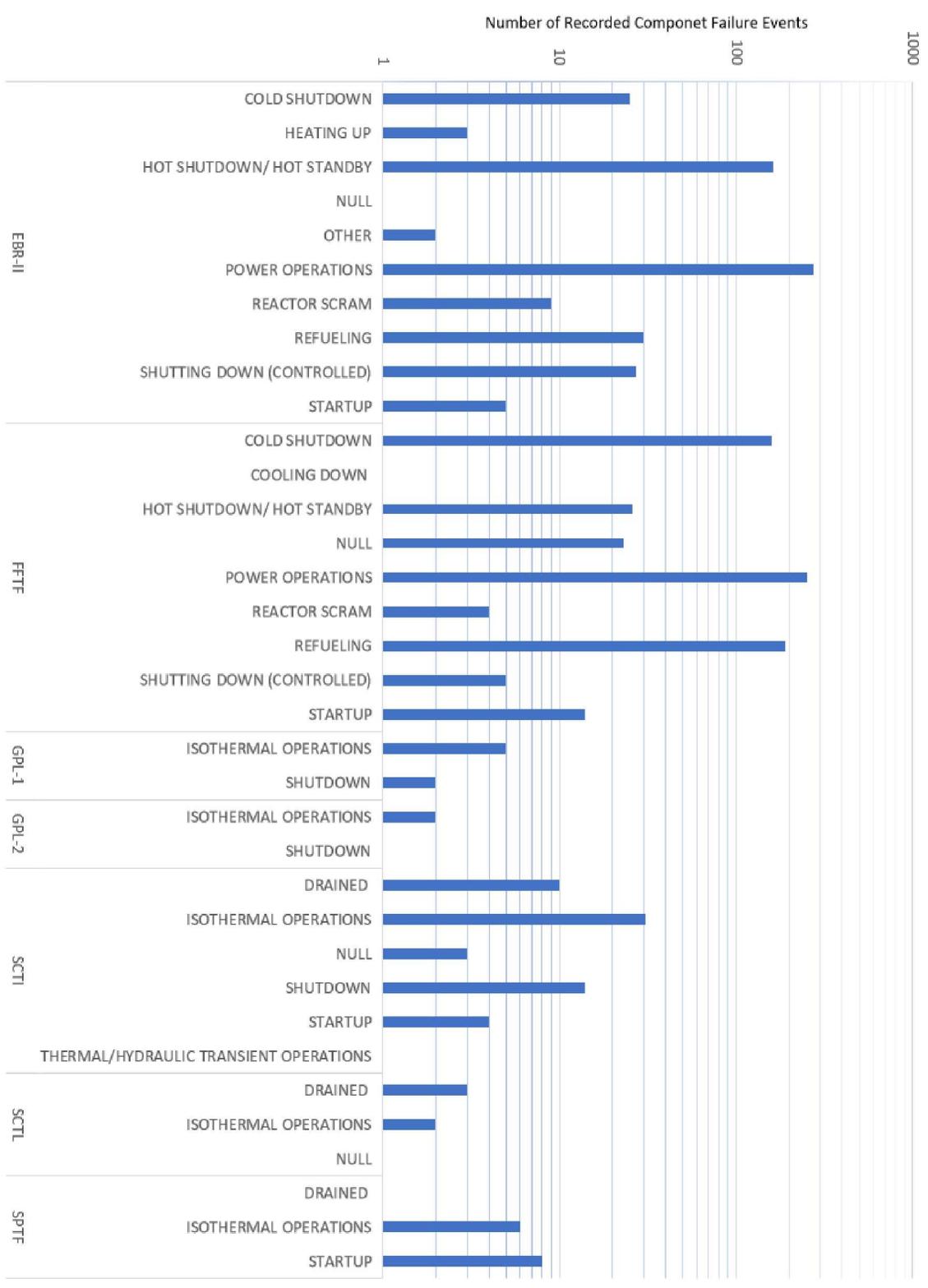
Test Loop

Cumulative Percent of the Number of Events by Component Entries

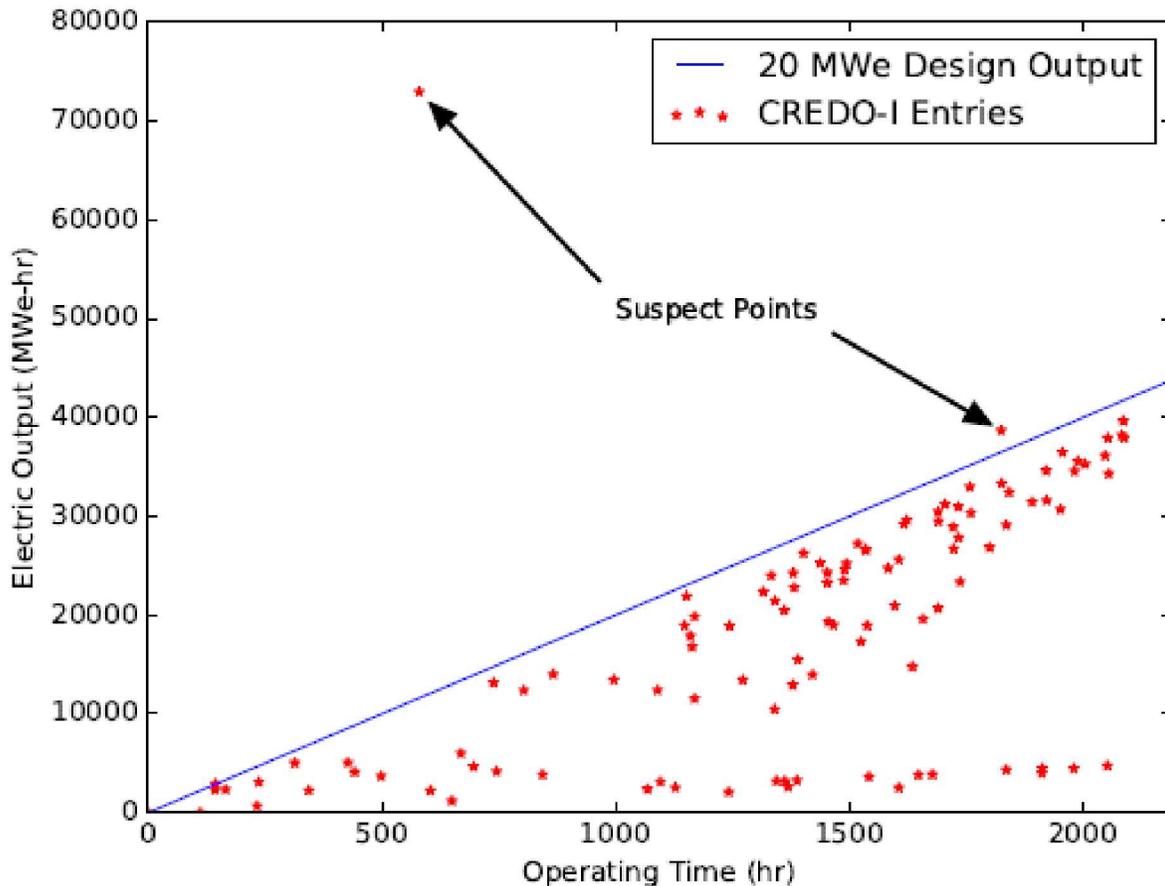
NaSCoRD Provides a Rich and Multifaceted Database

The NaSCoRD database records:

- State of the system or facility (operational, standby, maintenance, ...)
- Component Descriptions, Operating Conditions, Design Levels
- Human interactions with components
- Links to additional records (if still available)



Some Data Quality Issues Remain



EBR-II

Original data collection efforts occurred in the early days of PRA

- Failure boundaries were not always well defined
- Data was passed back and forth from ORNL and JAEA
- Data quality issues remain but should be resolvable when NaSCoRD is combined with other data sources.



Focus on Sodium Valve Insights





EG&G (INEL) took an initial attempted at evaluating failure probabilities for sodium components in the early 1990s.

- CREDO data was examined but was not used exclusively in their recommendations
- EG&G suggested changes to the CREDO data given current best practices.
- This report was used as our primary source for a diffuse informed prior

GENERIC COMPONENT FAILURE DATA BASE

FOR LIGHT WATER AND LIQUID SODIUM REACTOR PRAS

Steven A. Eide

Stefan V. Chmielewski

Tammy D. Swantz

February 1990

EG&G IDAHO, INC.

IDAHO FALLS, IDAHO 83415

Table 2. Mechanical component (sodium working fluid) recommended failure rates

COMPONENTS	COMPONENT TYPE	FAILURE MODES	MECHANICAL COMPONENT (SODIUM WORKING FLUID) FAILURE RATE COMPARISON																	
			RECOMMENDED (A)			LAEC			LYON			PIPING SURVEY			CBBR-4			GEFR 0054		
			MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES	MEAN	ERROR FACTOR	NOTES
VALVES	MANUAL	FAIL TO OPEN/CLOSE	3.0E-04 /D	5	-	-	-	2.0E-07 /H (B) OR 1.0E-06 /H (B)	1	-	-	-	-	-	-	-	-	-	-	-
		PLUG	5.0E-08 /H	10	-	-	-	-	-	-	1.0E-07 /H	10	1	-	-	-	-	-	-	-
		INTERNAL LEAKAGE	5.0E-08 /H	10	-	-	-	-	-	-	1.0E-07 /H	10	1	-	-	-	-	-	-	-
		INTERNAL RUPTURE	1.0E-08 /H	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EXTERNAL LEAKAGE	2.0E-07 /H	10	0	2.8E-06 /H	1	-	-	-	1.0E-08 /H	10	1	5.9E-08 /H OR 4.4E-08 /H	10	2	-	-	-	-
		EXTERNAL RUPTURE	1.0E-08 /H	10	0	-	-	-	-	-	-	-	-	7.0E-14 /H	10	3	-	-	-	-
	MOTOR-OPERATED	FAIL TO OPEN/CLOSE	1.0E-03 /D	5	1.2E-04 /H (B)	2	1.0E-05 /H (B)	3	-	-	-	-	-	-	-	-	-	-	-	-
		SPURIOUS OPERATION	5.0E-07 /H	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		PLUG	5.0E-08 /H	10	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		INTERNAL LEAKAGE	5.0E-07 /H	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		INTERNAL RUPTURE	5.0E-08 /H	10	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EXTERNAL RUPTURE	5.0E-07 /H	10	0	2.8E-06 /H	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	PNEUMATIC/HYDRAULIC	FAIL TO OPEN/CLOSE	3.0E-03 /D	5	1.2E-04 /H (B)	2	-	-	-	-	1.0E-03 /D	10	1	3.1E-04 /D	10	4	-	-	-	-
		SPURIOUS OPERATION	3.0E-07 /H	10	-	-	-	-	-	-	1.0E-07 /H (B)	10	1	-	-	-	-	-	-	-
		PLUG	5.0E-08 /H	10	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		INTERNAL LEAKAGE	1.0E-07 /H	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		INTERNAL RUPTURE	3.0E-08 /H	10	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		EXTERNAL RUPTURE	1.0E-06 /H	10	0	2.8E-06 /H	1	-	-	-	1.0E-08 /H	10	1	3.3E-07 /H	10	5	-	-	-	-
SOLENOID	FAIL TO OPEN/CLOSE	3.0E-03 /D	5	1.2E-04 /H (B)	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	SPURIOUS OPERATION	3.0E-07 /H	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	PLUG	3.0E-08 /H	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	INTERNAL LEAKAGE	1.0E-07 /H	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	INTERNAL RUPTURE	3.0E-08 /H	10	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	EXTERNAL RUPTURE	1.0E-06 /H	10	1	2.8E-06 /H	1	-	-	-	-	-	-	-	-	-	-	-	-	-	
CHECK	FAIL TO OPEN	1.0E-04 /D	5	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	PLUG	5.0E-07 /H	10	0	-	-	-	-	-	-	-	-	6.1E-08 /H	10	-	-	-	-	-	
	FAIL TO CLOSE	1.0E-04 /D	5	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	INTERNAL LEAKAGE	5.0E-07 /H	10	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	INTERNAL RUPTURE	5.0E-07 /H	10	0	-	-	-	-	-	-	-	-	5.7E-08 /H	10	7	5.7E-06 /H	10	7		
	EXTERNAL RUPTURE	5.0E-07 /H	10	0	-	-	-	-	-	-	-	-	7.0E-15 /H	10	8	-	-	-		
RUPTURE DISC	FAIL TO OPEN	5.0E-07 /H	10	0	-	-	-	-	-	-	-	-	-	-	-	5.0E-07 /H OR 1.3E-06 /H	10	9		
	IRREGULAR OPENING	1.0E-05 /H	10	0	3.1E-04 /H	-	-	-	-	-	-	-	-	-	-	-	-	-		

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Prior

$$EG\&G : p(\lambda|\sigma^2, \mu) = \frac{1}{\lambda\sqrt{2\pi\sigma^2}} \exp\left(\frac{-(\ln \lambda - \mu)^2}{2\sigma^2}\right) \text{ for } \lambda > 0$$

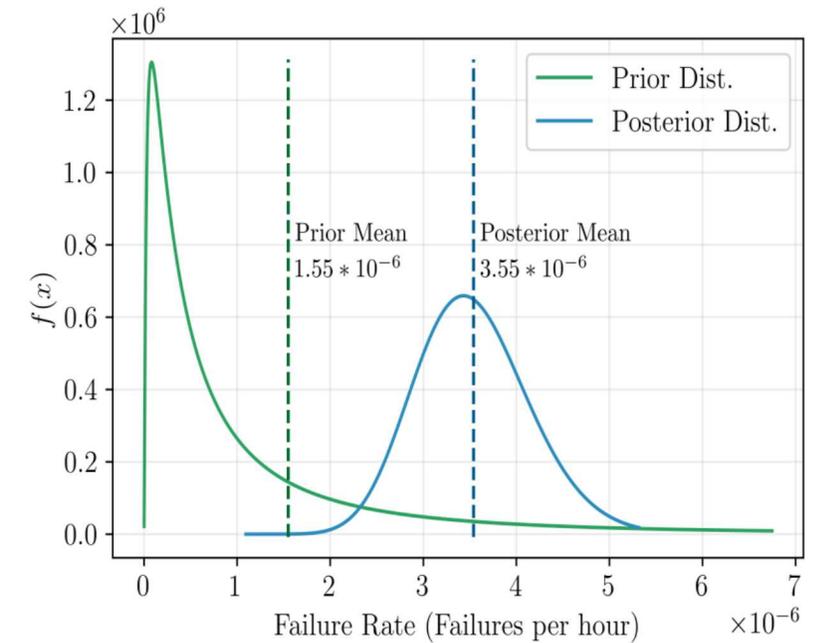
$$\text{Noninformative} : p(\lambda|\alpha = 0, \beta = 0) = \frac{\beta^\alpha \lambda^{\alpha-1} e^{-\beta\lambda}}{\Gamma(\alpha)} = \lambda^{-1} \text{ for } \lambda > 0$$

Likelihood – NaSCoRD Data

$$f(\underline{y} | \lambda) = \prod_{i=1}^n \left(\frac{1}{\lambda} \exp\left(-\frac{y_i}{\lambda}\right)\right) \prod_{j=1}^m \left(\exp\left(-\frac{y_j}{\lambda}\right)\right) \text{ for } \lambda, y_i, y_j > 0$$

Posterior – Calculated via Bayesian Updating

$$p(\lambda | \underline{y}) \propto f(\underline{y} | \lambda) p(\lambda)$$



Impact of EG&G Revised Failure Modes on the Results



SNL has updated NaSCoRD's reported failure modes based upon EG&G's recommendations.

- Did these changes significantly impact the final results?
- Was there enough data to overwhelm and EG&G recommendations?

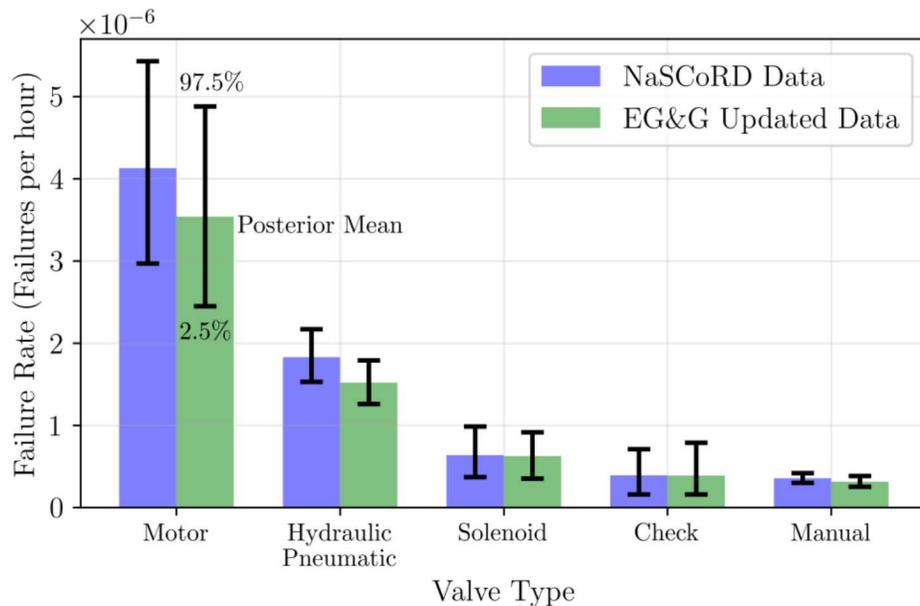


Table A-1. (continued)

No.	Event	Failure Mode	Revised Failure Mode	Include?
23.	FF800083	SPURIOUS	NOMOVE	YES
24.	FF800035	NOMOVE		YES
25.	FF850058	ABNORMOP		NO
26.	SL730003	NOMOVE		YES
27.	SL770007	LEAK(small)		YES
28.	SG770001	LEAK(small)		YES
29.	SG770006	ABNORMOP	NOMOVE	YES
30.	SG770007	ABNORMOP	NOMOVE	YES
31.	SG770008	ABNORMOP	NOMOVE	YES

The EG&G estimates are fairly reflective of the NaSCoRD Dataset



Valve	Failure Mode	EG&G Prior Mean	Evidence (Hours, Failures)	Posterior Mean	95% Probability Interval
Check	External Leakage	5.0E-07	(7.7E06, 2)	2.5E-07	(7.1E-08, 5.3E-07)
	Internal Leakage	5.0E-07	(7.7E06, 1)	1.5E-07	(3.4E-08, 4.3E-07)
	Plug	5.0E-07	(7.7E06, 0)	5.8E-08	(3.4E-09, 2.1E-07)
	Total	1.5E-06	(7.7E06, 3)	3.9E-07	(1.6E-07, 7.9E-07)
Hydraulic/ Pneumatic	External Leakage	1.0E-06	(1.6E07, 12)	7.0E-07	(5.4E-07, 8.7E-07)
	Internal Leakage	1.0E-07	(1.6E07, 1)	2.3E-07	(1.4E-07, 3.8E-07)
	Plug	3.0E-08	(1.6E07, 0)	6.0E-09	(3.9E-10, 1.4E-08)
	Spurious Operation	3.0E-07	(1.6E07, 6)	1.1E-07	(4.3E-08, 1.9E-07)
	Total	1.4E-06	(1.6E07, 21)	1.5E-06	(1.3E-06, 1.8E-06)
Manual	External Leakage	3.0E-07	(2.4E07, 3)	1.1E-07	(7.4E-08, 1.4E-07)
	Internal Leakage	5.0E-08	(2.4E07, 2)	5.9E-08	(3.6E-08, 8.2E-08)
	Plug	5.0E-08	(2.4E07, 2)	4.9E-08	(3.3E-08, 6.9E-08)
	Total	4.0E-07	(2.4E07, 9)	3.1E-07	(2.5E-07, 3.9E-07)
Motor	External Leakage	5.0E-07	(7.4E06, 2)	1.3E-07	(2.4E-08, 4.6E-07)
	Internal Leakage	5.0E-07	(7.4E06, 4)	4.8E-07	(1.8E-07, 9.4E-07)
	Plug	5.0E-08	(7.4E06, 1)	5.8E-08	(8.2E-09, 2.1E-07)
	Spurious Operation	5.0E-07	(7.4E06, 3)	1.4E-07	(1.2E-08, 4.3E-07)
	Total	1.6E-06	(7.4E06, 24)	3.5E-06	(2.5E-06, 4.9E-06)
Solenoid	External Leakage	1.0E-06	(4.7E06, 0)	6.0E-08	(2.7E-09, 1.9E-07)
	Internal Leakage	1.0E-07	(4.7E06, 2)	2.7E-07	(1.2E-07, 4.4E-07)
	Plug	3.0E-08	(4.7E06, 1)	4.3E-08	(1.6E-09, 1.2E-07)
	Spurious Operation	3.0E-07	(4.7E06, 0)	3.2E-08	(3.2E-09, 1.1E-07)
	Total	1.4E-06	(4.7E06, 3)	6.3E-07	(3.5E-07, 9.1E-07)

Impacts of Prior Information on the Results were Minimal but Increased when Examining Failure Modes



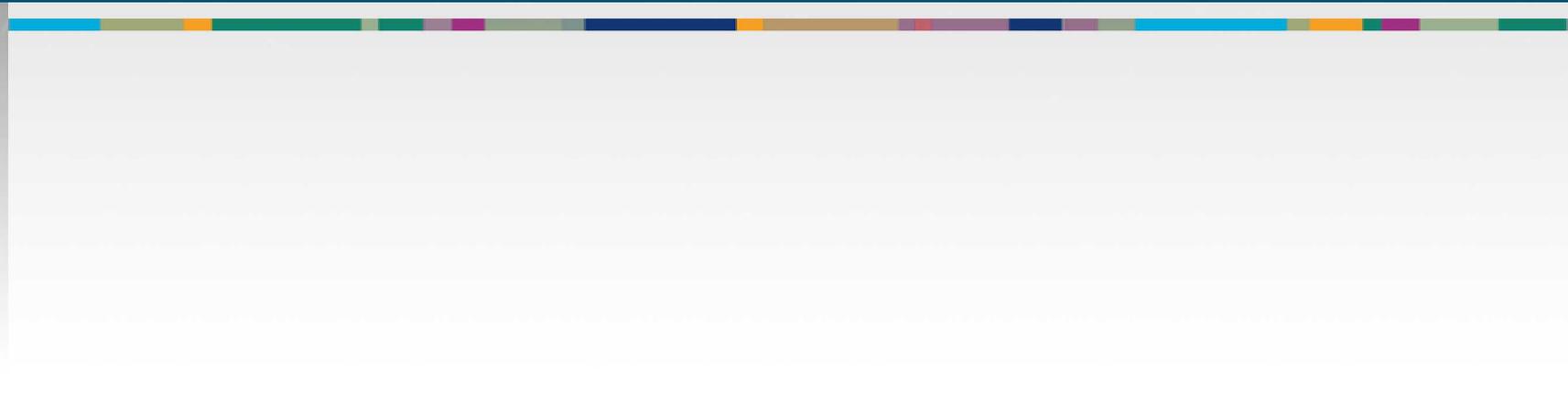
The reduced total amount of data in the NaSCoRD data when compared to the CREDO data forces caution when looking at specific categories since there is a greater potential for insufficient failure data.

- In many of the valve type and failure mode combinations there were categories that had few to no recorded failure events.
- The estimated rates were predictably sensitive to the choice of prior.
- The biggest impacts of the prior distribution occur when there were less than two observed events in a valve type and failure mode combination.
- The choice of prior dominated the posterior in nine instances. Most of the combinations were in the check valve and solenoid valve categories because there were one or fewer recorded failure events.

When studying specific failure modes, it is recommended that the analyst considers how many failures are present. A small number of failures may affect the reliability of the data.



Wrapping Up



Requesting Access to the NaSCoRD Database



NaSCoRD is access controlled

- To request access, go to www.sandia.gov/nascord
- DOE and SNL approvals are required before access is granted.
- NaSCoRD access is provided to external users via Microsoft SQL HTML reports.

Yesterday Informing Tomorrow

Introduction

This database was developed as part of a United States DOE Nuclear Energy Advanced Reactor Technologies program. The project's mission is to re-create the capabilities of the legacy Centralized Reliability Database Organization (CREDO) database. The CREDO database provided a record of component design and performance documentation across various systems that used sodium as a working fluid but was lost by its US custodian in the 1990s. Raw data of US origin was only recently recovered from the Japan Atomic Energy Agency (JAEA) with whom the US had established a joint database. This NaSCoRD database uses reconstructed CREDO data (CREDO-I) with reliability information sourced from operational documents, unusual occurrence reports, and design documents, called CREDO-II.

Capabilities

CREDO-I, CREDO-II, and Sodium System Component Reliability Database (NaSCoRD) will immediately benefit sodium system designers who can extract engineering, operational, and safety insights from these data sets. The ability to examine the failure modes for sodium components and the environments that led to multiple and repeated component failures will allow for future sodium loop and sodium reactor designers to leverage the expansive legacy of domestic sodium reactor operations. The future expansion of NaSCoRD to new facility data sources provides the domestic industry with the best opportunity to develop a broad database to support future Probabilistic Risk Assessment (PRA) applications.

Contact

NaSCoRD
NaSCoRD@sandia.gov

Database Access

To allow the domestic sodium industry access to this data, Sandia has established a controlled access website for users to directly explore SQL reports. Access to NaSCoRD can currently be requested through the DOE-NE ART sodium reactor program manager. Request access by e-mailing NaSCoRD@sandia.gov.

Resources



[NaSCoRD SAND Report](#)
 Creation of the NaSCoRD Database.
 (3.97 MB PDF)

The posterior failure rates for sodium fast reactor valves produced in this analysis were consistent with failure rates produced from the CREDO data prior to 1990.

- Many factors were tested that could have potentially changed inferences regarding the valve failure rates such as prior assumptions and cleaning recommendations from SNL and EG&G.
- Despite these differences, the inferred failure rates were consistent for each valve type and even the different failure modes within each valve type.
- This suggests that the current NaSCoRD data is robust not only to different reasonable prior assumptions but also slight changes due to data cleaning.
- The information lost due to the absence of the JAEA data does not seem to have changed the conclusions regarding average valve failure rates.

Prior assumptions had a greater impact when subdividing valve failure rates such as for specific failure modes within specific valve types.

- Certain subdivisions of data do not have enough observed failure data to overwhelm a diffuse prior distribution.
- Conclusions based off such data will not be as robust to different prior distributions.