US Reactor Operating Experience Data

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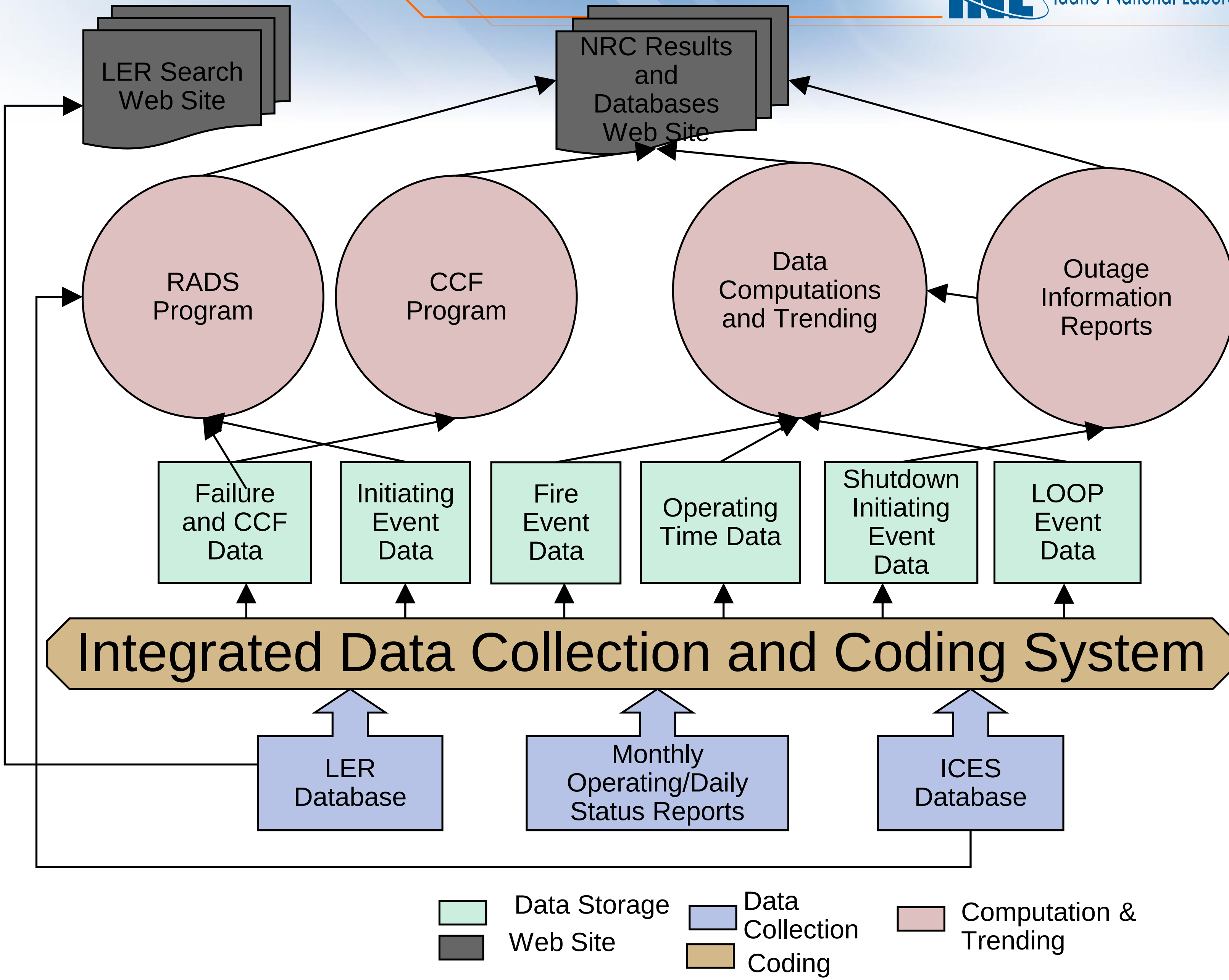
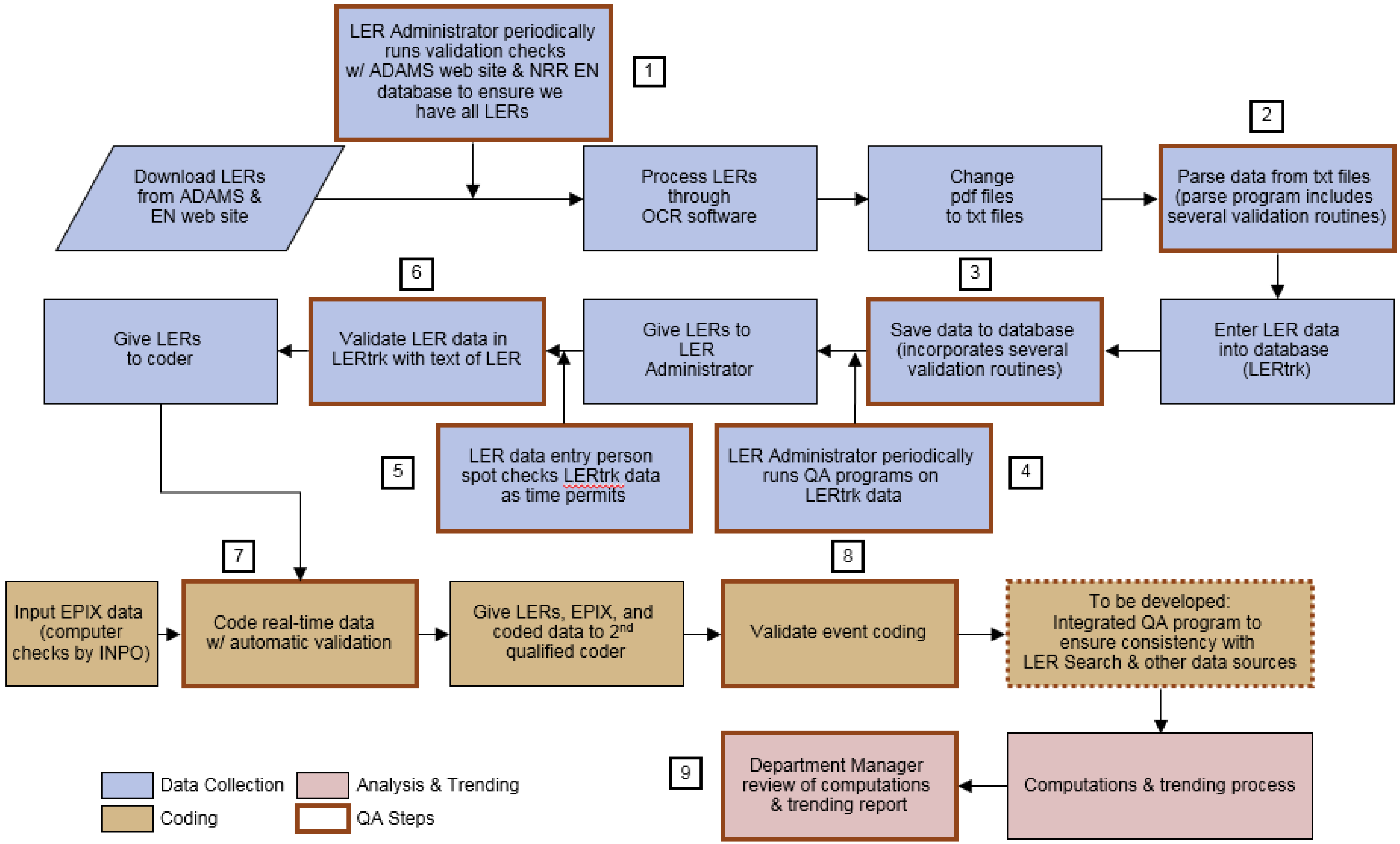
INL's Data Collection Efforts for the US NRC

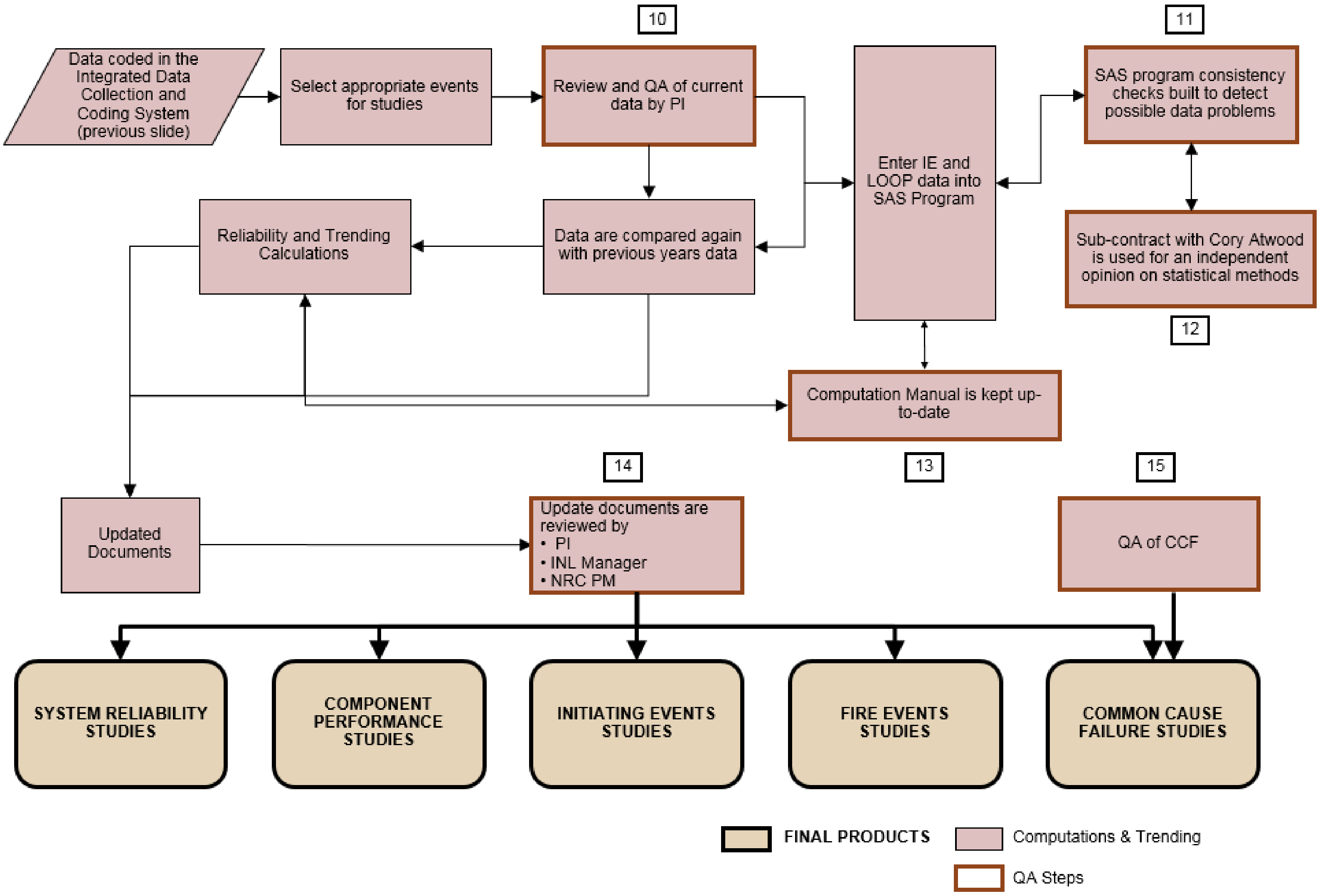
- Since 2001 INL has supported the US NRC in the collection and maintenance of operating experience data to support PRA and other risk informed applications.
- Current Project Objectives: To collect, code, assure quality of, and maintain all reactor operating experience data necessary to support various risk-associated NRC studies requiring reactor operating experience data.


LER Search Web Site
NRC Results and Databases Web Site
RADS Program
CCF Program
Data Computations and Trending
Outage Information Reports
Failure and CCF Data
Initiating Event Data
Fire Event Data
Operating Time Data
Shutdown Initiating Event Data
LOOP Event Data
Integrated Data Collection and Coding System
LER Database
Monthly Operating/Daily Status Reports
ICES Database
Data Storage
Web Site
Data Collection
Coding
Computation & Trending

INL DATA COLLECTION AND CODING PROCESS



INL DATA COMPUTATIONS AND TRENDING PROCESS



Data Collection

- INL created the Integrated Data Collection and Coding System (IDCCS) to ensure consistent data collection, coding, and quality assurance of operating experience data.
- IDCCS uses a Microsoft Access project user interface connected to a SQL Server database (SQL Server 2008 R2).
- Source documents are loaded into IDCCS to be coded by INL staff.
- Source documents are organized by “events”, an event is defined by a plant and date: therefore when viewing an event, all documents and related records for a given plant an a given day are displayed.
- The event concept helps to prevent creating duplicate records from multiple source documents.

IDCCS Database (Example)

Field	Value	Description
System	EPS	Emergency power supply
Comp Type	GEN	Generator
Sub-Type	EDG	Emergency Diesel Generator
Failure Mode	Fail to Run	
P Value	1.00	
Number of Failures	3	
RV Dem to Failure		
Sub Component	Engine	
Piece Part	Bearing	
Cause	HM	Inadequate maintenance
Detection	Inspection	Discovered during non-demand inspection. Latent failu
Dependency	Independent	Component failure initiated within the component
Enviro Event Type		Initiator? ☐

Recovery
- (●) Non-Recoverable
- ( ) Recoverable
- ( ) Long Term

Recovery Duration

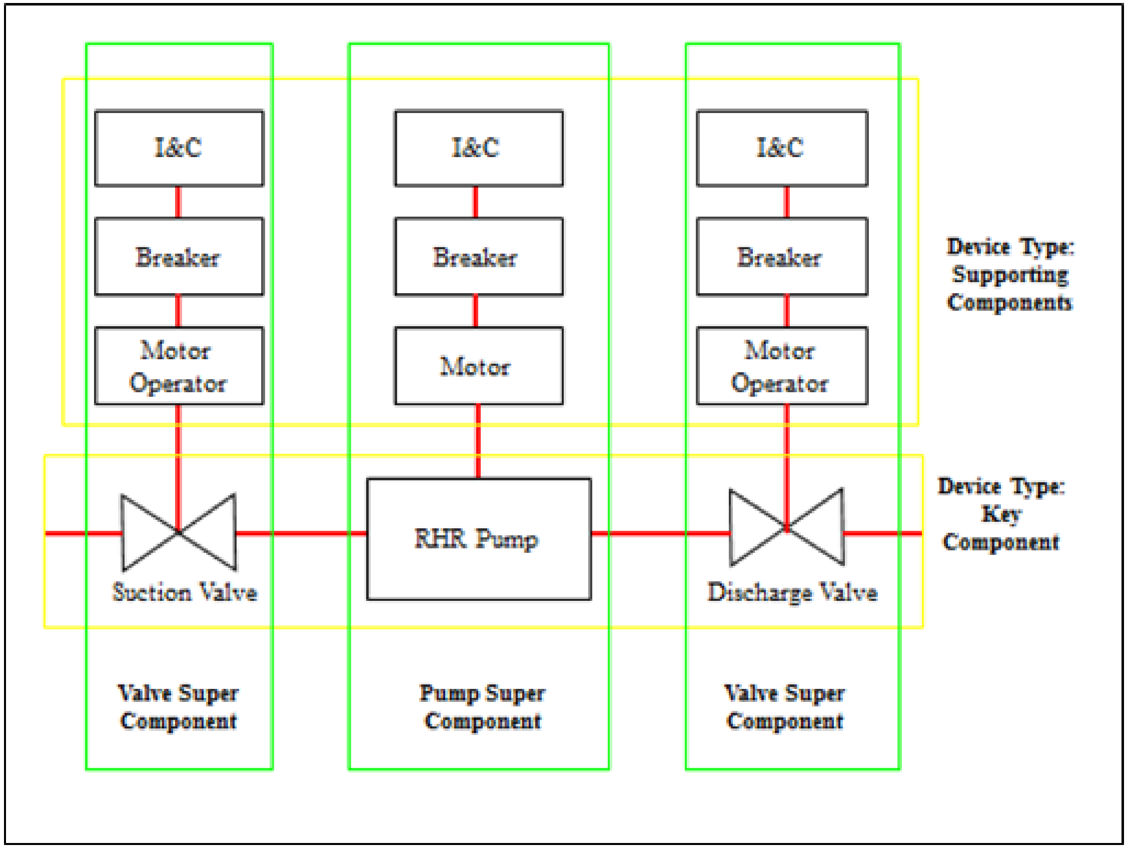
Data Quality Controls

- A user's guide describes each study and provides guidance for filling out each field in the IDCCS.
- The IDCCS program utilizes numerous lookup tables and automated checks to ensure data consistency.
- Records are entered by qualified coding engineers.
- Each record is independently checked by a second qualified coding engineer.
- The IDCCS software randomly selects a sample of records for an independent quality review semi-annually.

Equipment Reliability Data

- Primary source is the INPO Consolidated Events Database (ICES), formerly the Equipment Performance Exchange System (EPIX).
  - Supports the Maintenance Rule, Mitigating Systems Performance Index (MSPI) and Reactor Oversight Process (ROP).
  - Data is considered proprietary, only accessible by INPO members. The NRC is allowed to publish industry average data derived from the INPO provided data, but not publish the plant specific failure information
  - Data is input by each utility in the US.
  - The amount of data provided varies by utility. All provide required MSPI data, but some provide significantly more.
  - INL codes failure records into the IDCCS database to support the various reliability studies.
  - The raw failure records in ICES can be inconsistent, INL engineers evaluate the failure records against a consistent failure mode definition
  - Also includes demand and run time data.

ICES Device Types

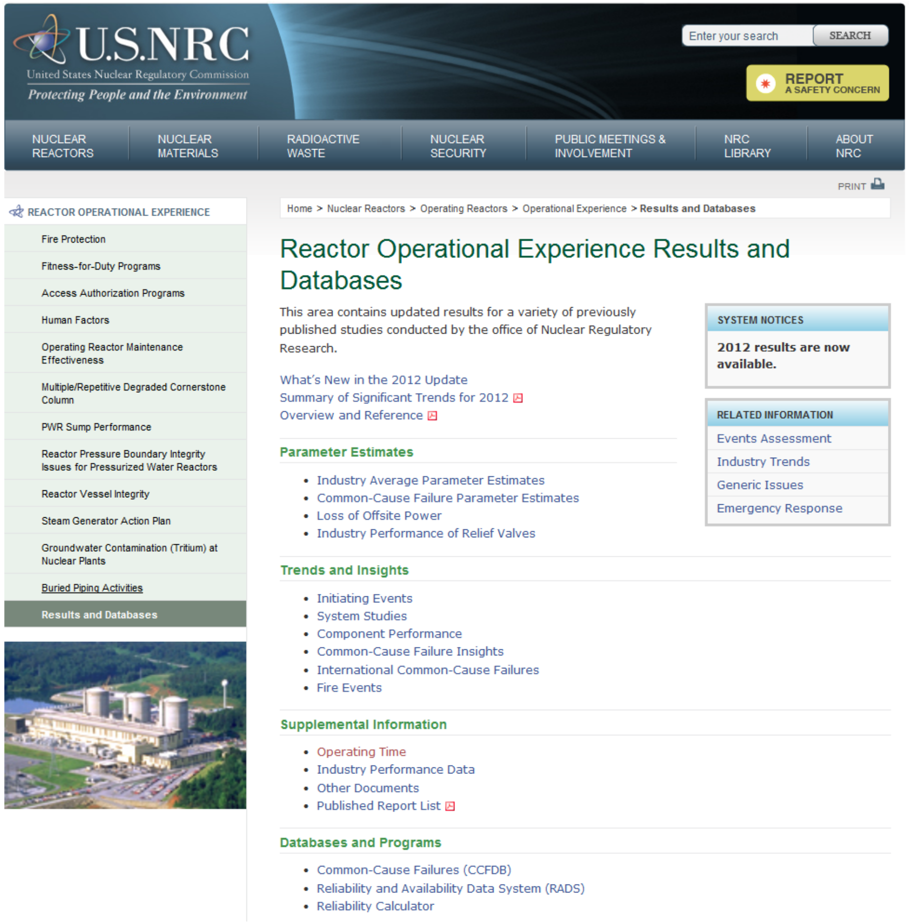


Event Data

- US Nuclear Regulatory Commission (NRC)
  - Licensee Event Reports (LERs).
    - Reports required to be submitted to the NRC per 10CFR50.73.
    - Event Report Guidance provided in NUREG-1022 rev3.
    - Primary source of initiating events information.
    - Significant safety system failures are reported.
  - Event Notification Reports.
  - Inspection Reports.
  - Monthly Operating Reports.
    - Primary source of operating time data.
    - Required by NRC Generic Letter 97-02.
  - Daily Morning Reports.

Uses of NRC Reactor Operating Experience Data

- Reactor Operational Experience Results and Databases http://nrcoe.inl.gov/resultsdb
- Industry Average Parameter Estimates.
- Common Cause Failure Parameter Estimates.
- Loss of Offsite Power Study.
- Initiating Events Study.
- System Studies.
- Component Performance Studies.
- Fire Events Studies.
- Industry Trends Program.



Industry Average Parameter Estimates

- Rather than revising NUREG/CR-6928, updated results are published on the NRC website periodically, currently 2010.
- The INL maintains component failure data for the NRC in a database, the Integrated Data Collection and Calculation System (IDCCS).
- Contains unreliability data for components grouped by valves, pumps, generators, relief valves, electrical equipment, strainers, reactor protection, control rods and heating & ventilation.

Group	Component Failure Mode	Description	Data Source	Data				Industry-average Failure Probability or Rate Distribution (note a)					
				Failures	Demands or Hours	d or h	Components	Distribution (note b)	Analysis Type	Mean	α	β	Error Factor
Valves	AOV ELS	Air-Operated Valve (AOV) External Leak Small	EPIX	64	1171601352	h	10283	Gamma	JNID/IL	5.51E-08	64.500	1.172E+09	1.2
	AOV ELL	Air-Operated Valve External Leak Large	EPIX			h		Gamma (ELS*0.07, LL)		3.86E-09	0.300	7.778E+07	18.8
	AOV FC	Air-Operated Valve (AOV) Loss of Function / Fail to Control	EPIX	266	1171601352	h	10283	Gamma	EB/PL/KS	2.49E-07	1.421	5.719E+06	2.7
	AOV FTO/C	Air-Operated Valve (AOV) Fail to Open/Close	EPIX	146	173117	d	2207	Beta	EB/PL/KS	9.51E-04	1.112	1.168E+03	2.9
	AOV ILS	Air-Operated Valve (AOV) Internal Leak Small	EPIX	113	1171601352	h	10283	Gamma	JNID/IL	9.69E-08	113.500	1.172E+09	1.2
	AOV ILL	Air-Operated Valve Internal Leak Large	EPIX			h		Gamma (ILS*0.02, LL)		1.94E-09	0.300	1.548E+08	18.8
	AOV SOP	Air-Operated Valve (AOV) Spurious Operation	EPIX	140	1171601352	h	10283	Gamma	EB/PL/KS	1.31E-07	0.680	5.211E+06	3.4

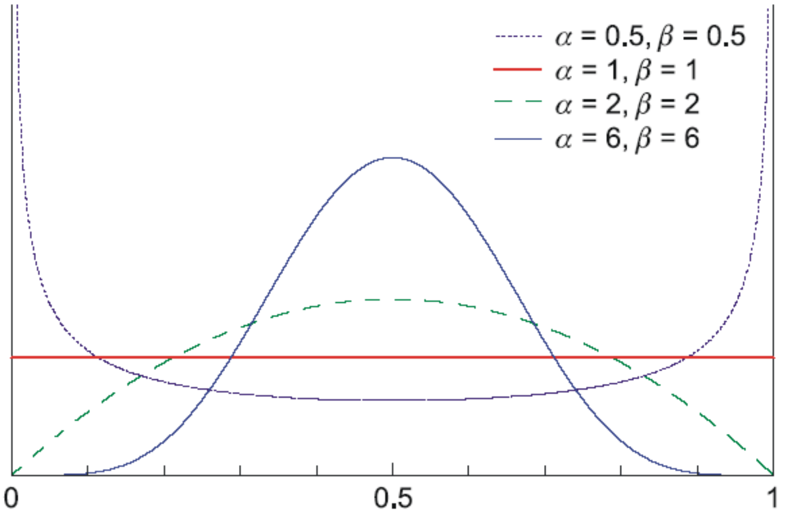
Bayesian Parameter Estimation

- The general procedure is:
  1. Begin with a prior distribution about parameter, quantifying uncertainty, i.e., quantifying degree of belief about the possible parameter values
  2. Observe data
  3. Obtain the posterior distribution for the parameter
  4. Model validation (sanity checks)
- Follow this process to determine probability that a hypothesis is true, conditional on **all** available evidence
  - This approach is fundamentally different from the classical statistics methods

Binomial Likelihood – Beta Conjugate Prior

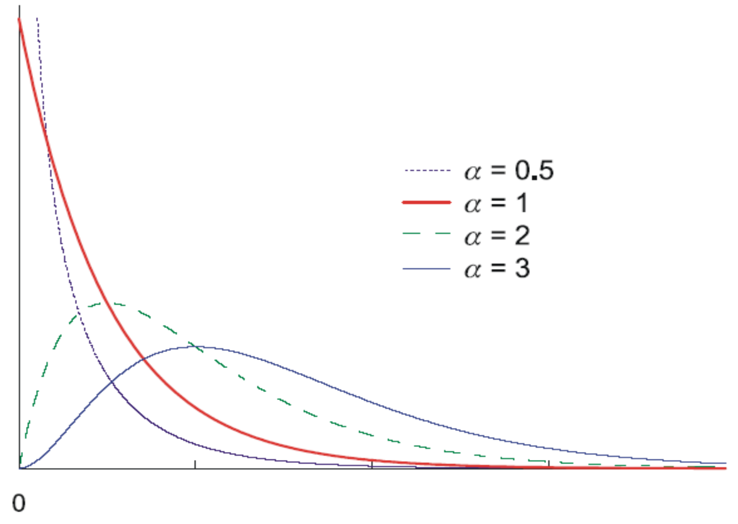
- Facts about ***beta*(α, β)** distribution
  - beta(α, β) density is: $g(p) = C\, p^{\alpha-1}(1-p)^{\beta-1}$
  - mean = $\alpha / (\alpha + \beta)$
  - variance = mean(1 – mean)/$(\alpha + \beta + 1)$
  - Example beta distributions →
  - Use BETAINV in Excel:

  100p percentile = BETAINV(p, α, β)
  - SAPHIRE uses mean and β



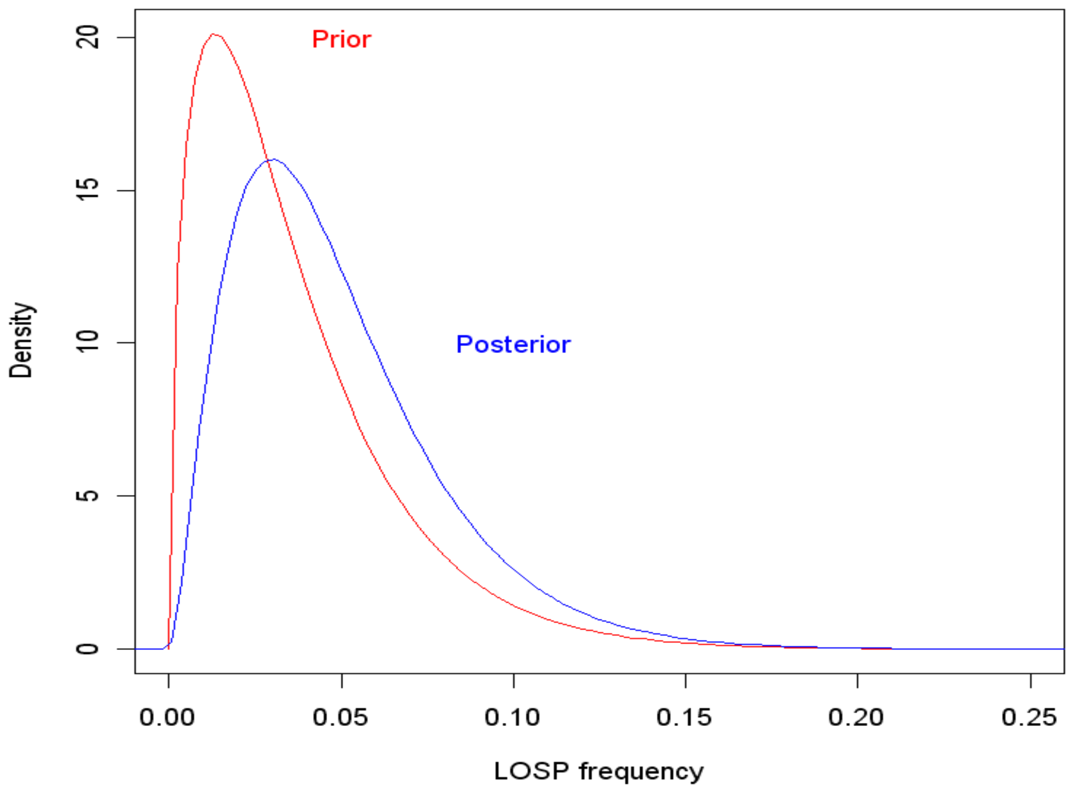
Poisson Likelihood – Gamma Conjugate Prior

- Facts about ***gamma*(α, β)** distribution
  - gamma(α, β) density is $g(\lambda) = C \lambda^{\alpha-1} e^{-\lambda\beta}$
  - mean = α / β
  - variance = α / β^2
  - 100p percentile = GAMMAINV(p, α, 1/β) or GAMMAINV(p, α, 1)/β
  - Excel uses 1/ β instead of β as the second parameter
  - SAPHIRE uses mean and α (called “r” by SAPHIRE)



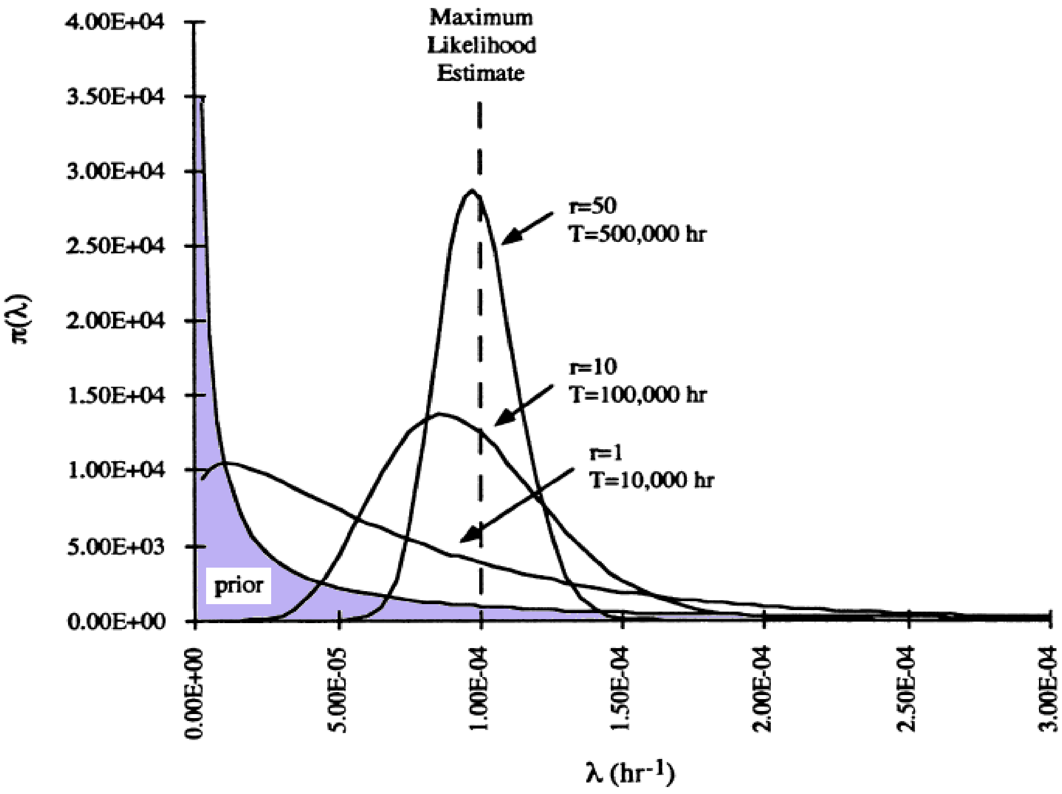
Overlay of Posterior and Prior: LOSP

- λ_{LOSP}



Influence of Data On Prior Distribution

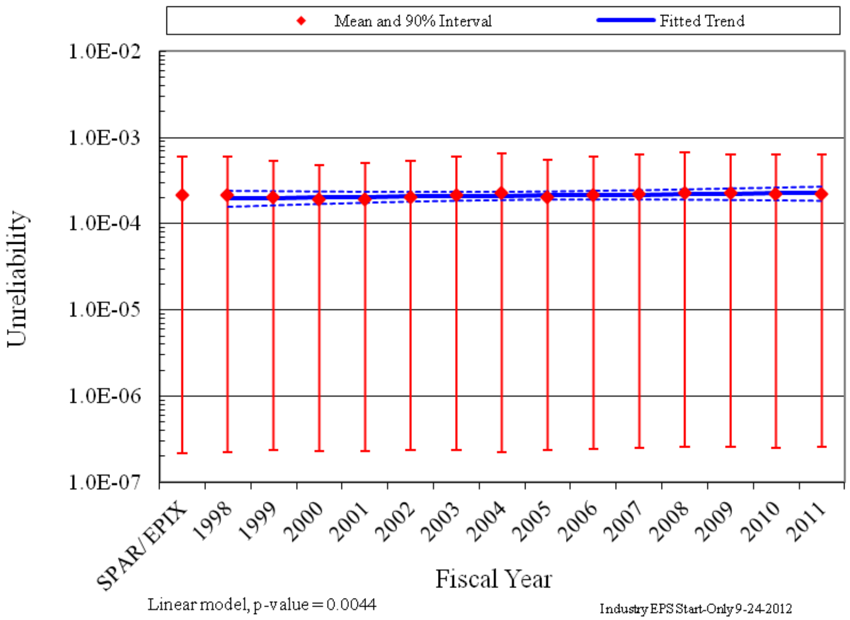
- As amount of data increases, prior becomes less important



Siu and Kelly, 1998

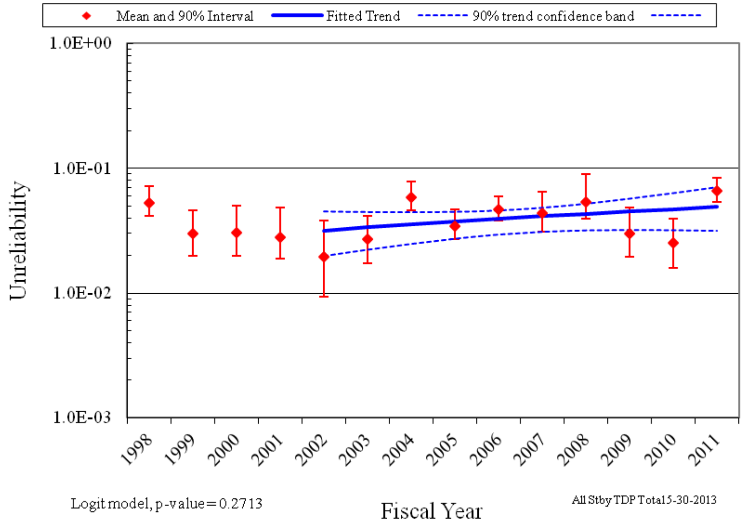
Systems Studies

- Provides system reliability trending and insights for select safety systems.
- Results originally published in NUREG/CR-5500 series reports, now updated annually on the NRC website.
- Data provided for High Pressure Coolant Injection, High Pressure Core Spray, Isolation Condenser, Reactor Core Isolation Cooling, Auxiliary Feedwater, High Pressure Safety Injection, Emergency Power and Residual Heat Removal Systems.



Component Performance Studies

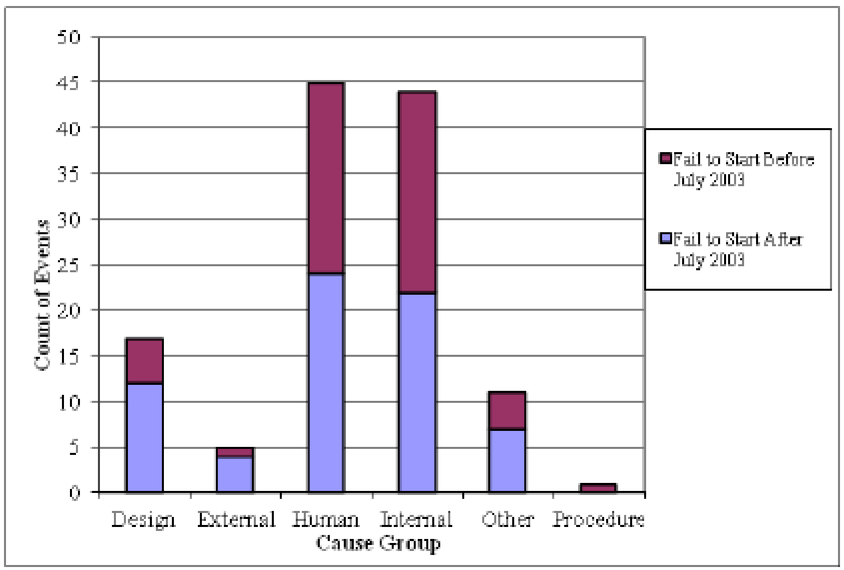
- An analysis of the performance of safety-related components in risk-important systems.
- Provides a risk-based analysis of the operating data and an engineering analysis of trends.
- Studies include Emergency Diesel Generators, Turbine-Driven Pumps, Motor-Driven Pumps, Air-Operated Valves and Motor-Operated Valves.



Component Performance Studies(example)

Table 4. Summary of TDP failure counts for the FTS failure mode over time by system.

System Code	*TDP Count*	*TDP Percent*	*FY 98*	*FY 99*	*FY 00*	*FY 01*	*FY 02*	*FY 03*	*FY 04*	*FY 05*	*FY 06*	*FY 07*	*FY 08*	*FY 09*	*FY 10*	*FY 11*	*Total*	*Percent of Failures*
AFW	74	42.8%	1	6	5	3	2	5	4	4	3	4	3	10	4	3	57	41.9%
HCI	28	16.2%		4	5		3	1	1	2	1	3	1	3	2	2	28	20.6%
RCI	31	17.9%	1	9	7	2		2	5	2	2	2	4	2	3	1	42	30.9%
MFW	40	23.1%	1	3		1				2		1		1			9	6.6%
Total	173	100.0%	3	22	17	6	5	8	10	10	6	10	8	16	9	6	136	100.0%



Insights from Risk Data Inform:

- Maintenance rule prioritization and inspection
- Risk-informed testing and tech specs
- Reactor oversight process
- Significance determination process
- Risk-informed engineering programs
- Accident sequence precursor program
- Plant risk monitors for configuration control
- All plant PRAs

Conclusion

- This paper provided a summary of operating experience data collection efforts performed by Idaho National Laboratory for the U.S. Nuclear Regulatory Commission. The results of this ongoing work were generally provided to the public through a series of NUREGs and currently through periodic web reports on the NRC's website. Several databases and data analysis tools are also provided for specific purposes. The operating experience data and data analysis tools provided by the NRC are available to support various PSA modeling needs.