Constructing the "Best" Reliability Data for the Job

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Abstract:

Modern business and technical decisions are based on using the results of analyses, which are only as good as the data used. When considering "reliability data", the concern is how long a system will continue to operate as designed. Ideally, a large set of pass/fail tests or observations to estimate the probability of failure of the item under test would produce the best data. However, this would be a costly endeavor if used for every analysis and every design.

Developing specific data is costly and time consuming. Instead, analysts rely on available data to assess reliability. Finding data relevant to the specific use and environment for any project is difficult, if not impossible. Instead, we attempt to develop the "best" or composite analog data to support our assessments.

One method used incorporates processes for reviewing existing data sources and identifying the available information based on similar equipment, then using that generic data to derive an analog composite. Dissimilarities in equipment descriptions, environment of intended use, quality and even failure modes impact the "best" data incorporated in an analog composite. Once developed, it can be used to support early trades, models to establish the predicted reliability data points. Those data points may be used as a prior and updated based on observations during development, test and operations.

The better and more project specific the data, the more accurate the analysis and hopefully the better the final decision.

Introduction:

Data is information in a raw or unorganized form that represents facts, condition or ideas. In the reliability arena it is usually in the form of facts or statistics that can be analyzed and used to provide addition information for system operations or improvement. Interpreting raw data and manipulating it into a form which provides the most useful input into the analysis is crucial for deriving the most realistic and effective analysis.

For many computing and data processing models, the data is often represented in a tabular structure (rows and columns), a tree (nodes with parent-child relationship), or a graph (connected nodes). Data can be the result of observations, measurements or research. Generally, large sets of data are more easily visualized using graphs and charts.

Raw or unprocessed data refers to a collection of numbers or characters. Data processing commonly occurs by stages, and the "processed data" from one stage may be considered the "raw data" of the next. Field data refers to raw data that is collected without rigorous procedural control in a normal working environment as part of operational measurements, verification of meeting specifications or data reporting requirements. Experimental data is generated as part of a specific study with a defined purpose, and recorded using rigorous processes and procedures within the context of a scientific study.

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Knowing how the data was generated can assist the data analyst if questions arise regarding differences in values for the same or similar components. The general preference is to locate data that is similar to the specific project or system under review. This is more likely to be more representative of observed operations providing more accurate analysis, and a better decision.

The topics discussed in this paper include: Where do we find data, source selection, taxonomies, data development protocols, development of generic datasets, using generic data composites to influence design and operations and deriving a composite generic failure rate supporting the quantification of early design risk and reliability models. Once we have a number, we need to address is it "good enough".

Finding the Data:

Reliability performance data is critical to quantifying a system or product risk, identifying the reliability of systems and equipment, defining cost effective maintenance cycles, and providing accurate information for logistics support. Identifying data sources is one of the challenges the analyst faces.

There are a number of common complaints about data. When asked, most people will state that data sources do not exist for their specific needs, systems, components or whatever it is they are looking at. If they are aware that something exists, the assertion is that it is not relevant to their needs, or the data is unusable because it is not an exact fit with their component or system or environment. Although this is sometimes true, the arguments are based on biased assumptions. Often there is useful information available. The analyst needs to seek out potential sources.

Federal agencies, national and international consortia, industry groups and commercial entities develop, publish and maintain risk and reliability data based on observed operations, test, failures, warranty, and expected life.

Reliability data and associated technical reports are generated by and in support of numerous federal agencies. A great deal of the information is available for public access. Legal considerations and constraints preclude full access to all federal agency datasets and reports. Information of a sensitive nature or with limited distributions normally requires special access. Those that are available for public distribution may be located using internet search capabilities or may be purchased from the agency technical publications libraries. Several federal agency web sites include technical report libraries. One source of government funded studies is maintained by the Defense Technical Information Center (DTIC).

National laboratories are also a good source to find available data. Most work performed by the laboratories is in support of federal agencies. The generated reports are often available from supported agency technical report libraries with unlimited or public access distribution. A number of the national laboratories provide access to their technical report libraries.

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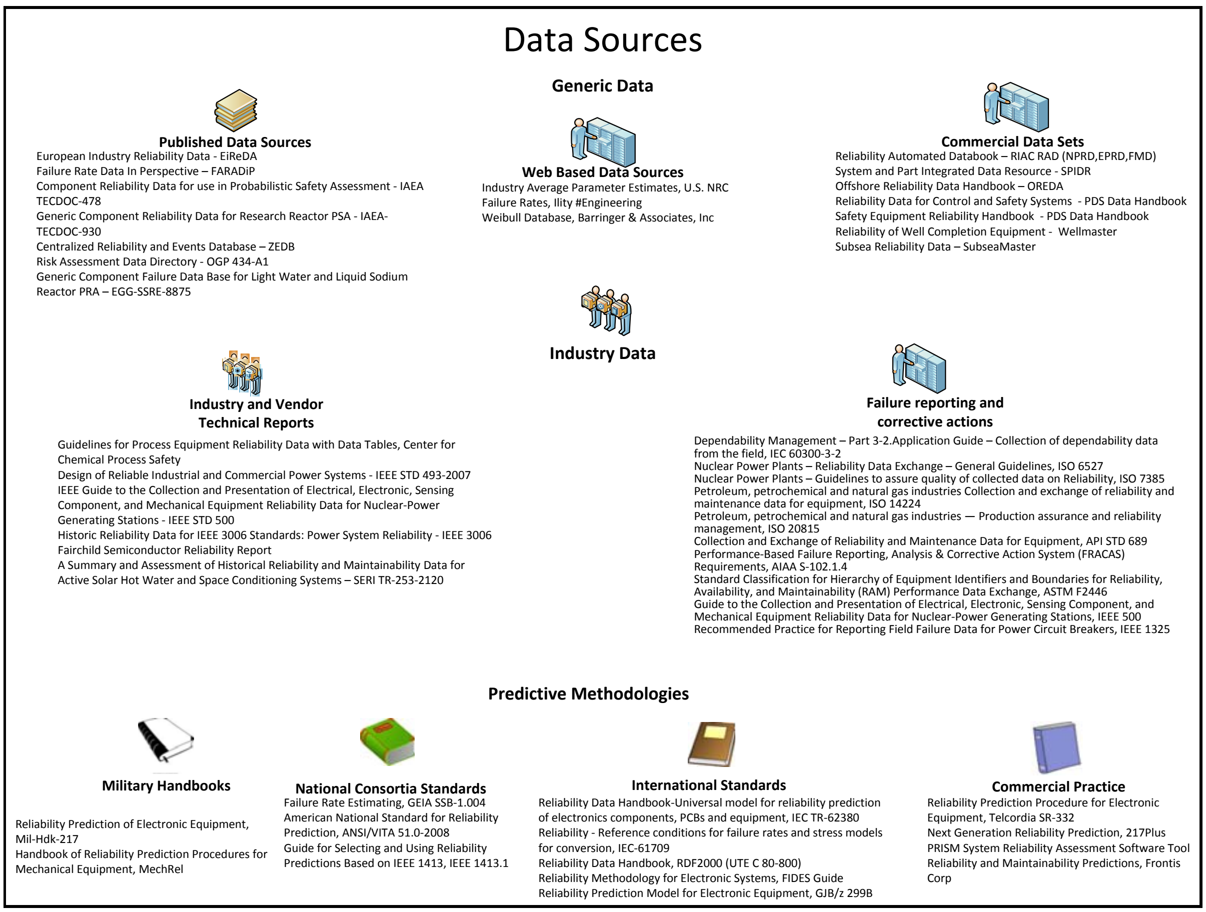
An alternative to searching various federal agency technical libraries is to access the National Technical Reports Library under the National Technical Information Service run by the Department of Commerce. They provide an extensive library of published historic government reports.

In addition to federal agencies, national and international professional organizations develop and maintain technical documents, reports and datasets. Criteria to access those reports differ between organizations.

Finally, commercial activities provide access to datasets, technical reports, and applications that document reliability performance parameters.

Examples of the data sources and the types of documents available are shown below.



A general knowledge of industry data sources is a central key for data collection and aggregation efforts. Canvasing different industries and technical organizations provides a wealth of information. Individuals, companies, research organizations, technical organizations and industry wide efforts have all identified and collected data. Examples of these sources include the Center for Chemical Process Safety (CCPS) a function of the American Institute of Chemical Engineers (AiCHE) and their "Industry Process Equipment Reliability Database", the Institute of Electrical and Electronics Engineers (IEEE) "Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems" and the Oil and Gas industry's " Offshore Reliability Data Handbook" . Other alternative published data sources include the Department of Defense (DOD) Reliability Information Analysis Center and their published Databooks as well as published European datasets like Failure Rate Data in Perspective (FARADIP) and the European Industry Reliability Data Bank (EIReDA).

Empirical data, often centered on observation or experience, may be based on historical facts or raw field data. Data sources might include test documents and field data of electronic, electro-mechanical, and mechanical systems, assemblies, and parts. Field data is often based on identical, similar or equivalent items. Sources for empirical data include the commercial compendiums as well as industry technical reports. Details from maintenance records are also a source of observed empirical data. The value of the detail is predicated on robust maintenance data collection efforts. Best practices and standards pertinent to field data collection are available and should comprise core protocols as part of and organizations failure reporting and corrective action system (FRACAS).

Other data sources include predictive methodologies; using mathematical models to make predictions about inherent reliability. Although the results tend to be conservative, these methodologies are often used for new technologies as well as continued use in various commercial reliability analysis applications. These models include both the national and international standards as well as models incorporated into various reliability program applications.

Another alternative is to address reliability is the use of physics of failure models. This approach to reliability uses models and simulations to design-in reliability by understanding system performance, reduce decision risk during design and improve equipment reliability in the field. The simulation includes modeling the root causes of failure such as environmental factors, wear and material characteristics. If physics-based models are to be employed information needed includes: defect rates, material properties (e.g., functional characteristics), defect (flaw) distributions, material variation quantification (e.g., purity, yields, dimensions).

Source Selection:

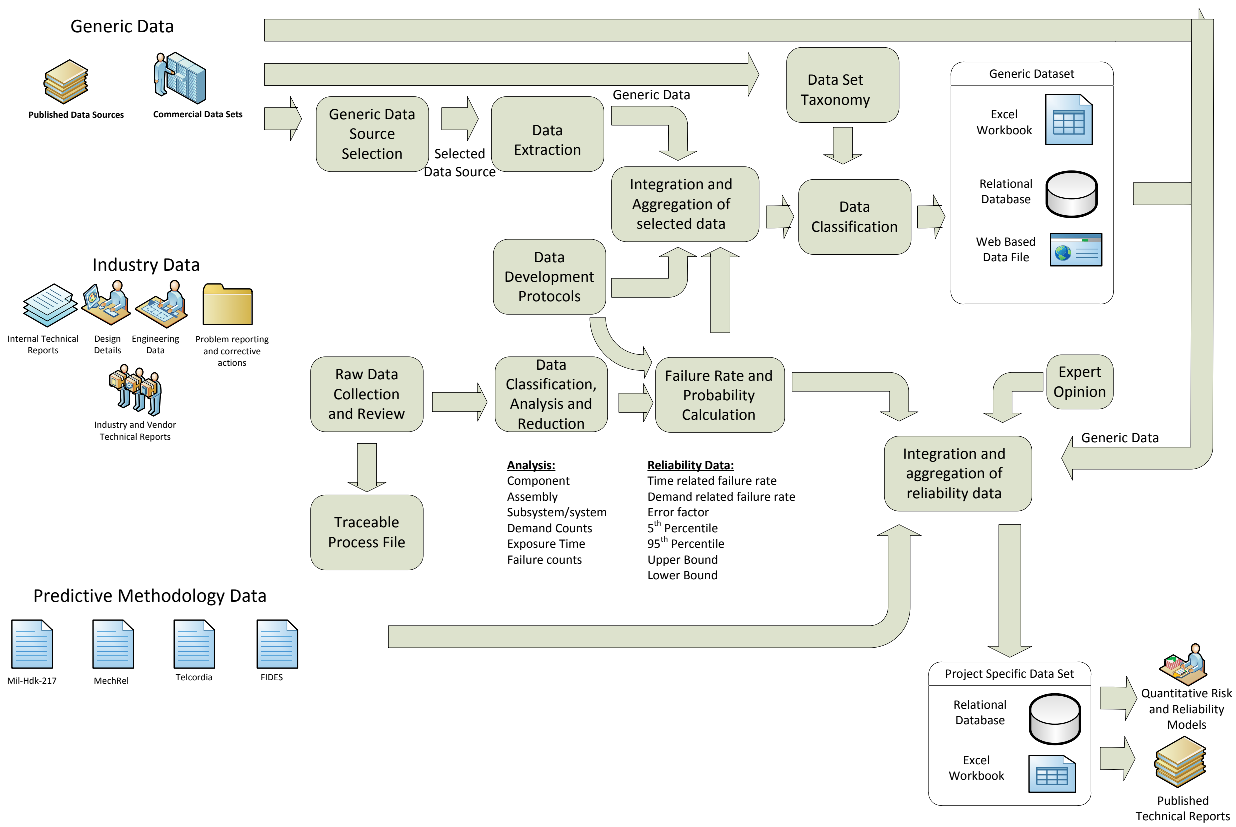
In general, it is best to use data sources pertinent to the specific industry, since these will be similar in specifications, design requirements, environmental conditions and operational characteristics. Corporate, industry and various standards consortia should influence any developed protocols that will be used to support the data source selection. Selection criteria should consider:

- Data validity
- Suitability
- Maintenance of Data
- Recognition of data source
- Usability
- Cost

Ultimately source selection will be based on availability of source datasets, the viability of the reported data and its applicability to the intended use. All of which will be influenced by corporate policies and professional best practice.

Process Flow:

A critical effort for developing internal data processing protocols is defining the documentation needed for each decision. These decision points will have an impact on how data is captured, processed, and reported. The example data process shown below is modified from the CCPS process flows and defined in their text "CCPS Guidelines for Chemical Process Quantified Risk Analysis", 1996.



Data Development:

The development of composite analog data requires the identification of the dataset taxonomy. This taxonomy, or method of classification identified, is influenced by the data analysis protocols used to derive an aggregated reliability performance parameter based on similar equipment types and failure modes from multiple data sources.

The data collection and reporting taxonomy should be clearly defined early in the data collection process. Industry taxonomy best practice is a good resource for developing the look and feel of the collection record based on indentured levels. Setting up this taxonomy early, will save time and effort by precluding the need to revisit multiple sources in order to capture details that were missed or overlooked. The indenture level and boundary should be clear to both the developer and the user. Example sources available to assist in defining taxonomies include the Center for Chemical Process Safety's Process Equipment Reliability Database (PERD) Taxonomies and the International Organization for Standardization (ISO) Standard 14224: Petroleum, petrochemical and natural gas industries - Collection and exchange of reliability and maintenance data for equipment.

Data development protocols are the corporate or industry best practice describing how composite data records will be collected, aggregated and reported. As a minimum, it includes the data required, and how the details will be combined or aggregated to develop the resulting generic performance parameter. Considerations should include:

- Limited observations (operating time, number of demands or cycles)
- Zero failures (estimate performance parameter)
- Use of adjustment factors (referred to as Pi-factors or logistic performance factors)
- Environmental conditions of observed failures
- Quality level of the part or item under study
- Duplicate records
- Minimum number of records needed
- Rationale for inclusion and exclusion of records
- Confidence level or uncertainty bounds
- Use of models to derive performance measures:
- Aggregation of failures and observed time, cycles or miles
- Wiebull analysis
- Bayesian analysis
- Use of logistic performance parameters (Pi-factors) to convert quality and environment factors to a common known level.

Capturing observed operational hours and failure data from multiple sources allows the development of industry and generic composite failure rates. Inclusion of industry protocols should be clearly defined, to address the variance of environment and quality as well as record exclusions necessary to provide requisite refinement of the composite failure rate that will reflect an expected quality level and environment.

The development of composite analog data will only be as good as the consistent implementation of the data processing protocols.

Data Composites and Design:

Generic data aggregation provides an initial predictive reliability estimation of equipment types, assemblies, parts or components. The data processing protocols provide the means to derive and refine the predictive measures. Dataset architecture (planning, designing, and constructing how to format the datasets) controls the level of detail based on the data taxonomy and industry or developed protocols. Good data collection is critical to the effective process for utilizing data. The dataset architecture needs to include:

- Equipment type identification
- Failure statistics (i.e., failure rate, observed operational time, and failures)
- Application information (i.e., environment, quality level)
- Failure modes and distributions
- Additional data is needed when a composite failure rate is to be applied to a model or incorporated into a Project specific data set. Elements needed would be:
- System information (Parts breakout or master equipment list
- Number of systems
- Dates fielded for each system
- Location of operation
- Unique identifier for each system
- Environment of intended use

Data acquired from tests and field surveillance should be used to update the generic data. Field data is probably the most valuable type of data for this purpose since it represents the actual product or system in the intended use environment.

Validating the aggregate

Reliability performance measurements are not easy to find. However, data and useful details for analyzing the data do exist. Industry datasets, technical documents and maintenance records are a viable source to develop quantitative reliability factors. With data source information documented and the data appropriately developed, their use in quantitative models produces effective measurements of risk. These risk and reliability models also support the quantitative logistics parameters associated with maintenance planning, spares acquisitions and provisioning.

"Any Number – Is not good enough"

When proposing to use a number to quantify a risk or reliability model from alternative industry or commercial sources, we need to determine if the number "makes sense". Before using "just any number", compare available parameters documented in multiple sources to provide correlation of reported data as an aid in determining if the recommended parameters are "In-family" or "Out of expected range".

The details used to quantify risk and reliability models include the failure rate, based on time or cycles, and error factors or uncertainty, used to generate the upper and lower failure rate constraints at a predetermined percentile.

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Comparing the reported performance measures from multiple data sources allows the determination of "in-family" or "out of expected range". By creating the data records used in the data comparison, the details can be used to validate the predictive or aggregated values. The comparison supports the data selection process used in the quantification of risk and reliability models. It supports conclusions and recommendations when the model output or result does not meet reviewer or decision maker expectations. The reliability measures needed for the comparison should include:

- Time related failure rate
- Demand related failure rate
- Error factor
- 5th Percentile
- 95th Percentile
- Upper Bound
- Lower Bound

Not all industries use the same models and distribution parameters, knowing how the reported parameters are calculated is important if the data represented must be modified or normalized as part of the comparison process.

Comparing multiple sources

Implementing our data collection and data processing protocols allows the generation of worksheets showing the level of detail available from each source. Consistency in implementing protocols to include all conversions to normalize details across multiple originating sources allows the analyst to compare the results as apples to apples. Data sources from various industries will have different operating conditions, quality levels, and different processes to identify and assess performance. The protocols should address how the variances are to be handled.

Comparing the reported data from multiple sources provides insight and validity to the model when those results are used to quantify risk and reliability models. An example that shows the variance noted between the various data sources is easily seen when comparing details for Valves. Different industries, and even different reports within an industry, use different formats and report results differently.

ALTERNATIVE FAILURE RATE DATA:			Reg1Bot		
Dataset 1:					
λ	Variance	EF	Source	Equivalent Component	Comment
2.76E-05	1.57E-09	5.70	**Summary composite Reliability Analysis Information Center's Reliability Auto**	**Valve,Manual**	
Dataset 2:					
λ	Variance	EF	Source	Equivalent Component	Comment
4.66E-08	**1.80E-14**	**11.67**	**Summary composite based on total hours and total failures**	**Valve,Manual**	**Observed operational time: 100961448; Observed Failures: 47**
2.62E-07		1.34		Valve,Manual, External Leak Small	Observed operational time: 100961448; Observed Failures:26
1.34E-07		1.49		Valve,Manual, Internal Leak Small	Observed operational time: 100961448; Observed Failures: 13
8.42E-08		1.63		Valve,Manual,Spurious Operation	Observed operational time: 100961448; Observed Failures: 8
Dataset 3:					
λ	Variance	EF	Source	Equivalent Component	Comment
1.03E-06	**3.63E-06**	**6.18**	**Idaho Chemical Processing Plant Failure rate database, INEL-95/0422**	Valve, All	
2.52E-07	1.79E-06	12.80		Valve, Leak	
6.58E-08	9.17E-07	28.22		Valve, Plug	
7.53E-07	3.10E-06	7.24		Valve, Other	
Dataset 4:					
λ	Variance	EF	Source	Equivalent Component	Comment
3.00E-07			**Generic Component Reliability Data for Research Reactor PSA, IAEA TECDOC-**	Valve, manual, Failure to function	**Uper Control Limit: 1.0E-06 Lower Control Limit:**
4.60E-06				Valve, manual, Degraded	Uper Control Limit: 6.2E-06 Lower Control Limit: 7.0E-07
5.50E-06				Valve, manual, Degraded	Uper Control Limit: 1.31E-05 Lower Control Limit: 1.10E-06
1.35E-05				Valve, manual, Failure to function	Uper Control Limit: 3.2E-05 Lower Control Limit: 2.40E-06
1.35E-05				Valve, manual, Leakage	Uper Control Limit: 3.2E-05 Lower Control Limit: 2.40E-06

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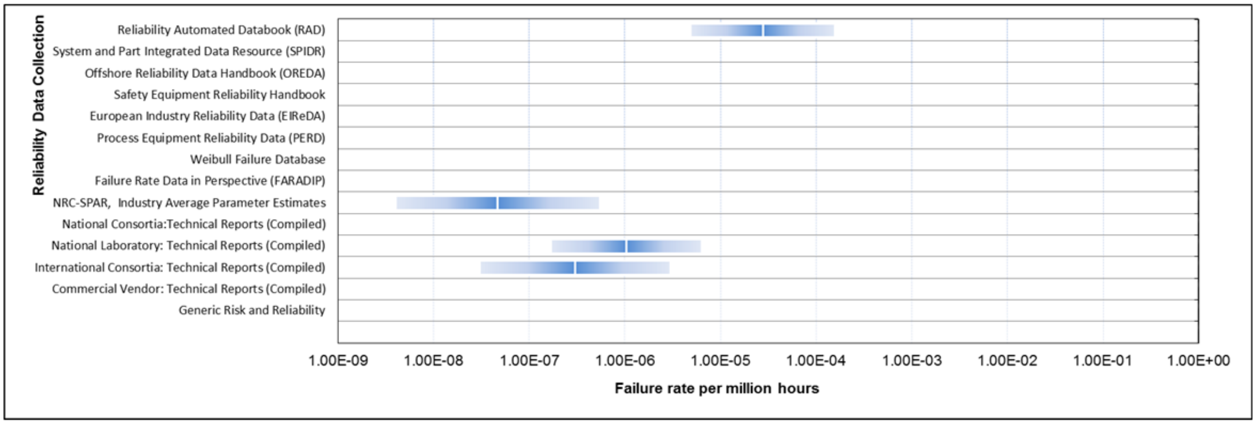
Using a summary worksheet shows the reported failure rate and allows for the calculation of upper and lower bounds. This also shows the specified or assumed quality level and environment.

Component Type Name:						
Failure rate per million hours						
Dataset Source	**Original Qlty Level**	**Original Environment**	**Mean**	**95%**	**5%**	**EF**
Reliability Automated Databook (RAD)	Military	Aviation	2.76E-05	1.57E-04	4.85E-06	5.70
System and Part Integrated Data Resource (SPIDR)						
Offshore Reliability Data Handbook (OREDA)						
Safety Equipment Reliability Handbook						
European Industry Reliability Data (EIReDA)						
Process Equipment Reliability Data (PERD)						
Weibull Failure Database						
Failure Rate Data in Perspective (FARADIP)						
NRC-SPAR, Industry Average Parameter Estimates	Commercial	Ground Fixed	4.66E-08	5.43E-07	3.99E-09	11.67
National Consortia:Technical Reports (Compiled)						
National Laboratory: Technical Reports (Compiled)	Commercial	Ground Fixed	1.03E-06	6.37E-06	1.67E-07	6.18
International Consortia: Technical Reports (Compiled)	Commercial	Ground Fixed	3.00E-07	3.00E-06	3.00E-08	10.00
Commercial Vendor: Technical Reports (Compiled)						
Generic Risk and Reliability						
Selected Failure Rate						

The original failure rate, as processed using our data protocols, are captured and then used to calculate the upper and lower bounds based on the known or assumed error factor. The resulting chart is a graphic depiction that allows the reliability analyst to consider values to be used to quantify risk and reliability models.



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By comparing the reliability records of multiple data sources, the analyst can evaluate the applicability of specific failure rate data to quantify the risk and reliability models. Comparing the numbers provides a basis for decisions to use or discard proposed failure data. Acceptance/rejection rationale can be developed supporting the use of specific data sources and failure rates used to quantify the model or verify the range of data submitted by a vendor or contractor.

When responding to critics, it is evident the numbers used are "In-family" with reported data reflecting operational conditions.

Summary and conclusions:

The reliability analyst is often tasked to determine the probability of failure or success of a system based on a new or incomplete design using state of the art equipment with little or no failure history. To accomplish that task requires planning and effort. Modeling the system is one part of the solution, but to quantify the model requires data. Developing data that is supportable, traceable, documented, and makes sense takes time and effort. And, someone will disagree with the results. By using available data sets and comparing the observed operational reliability the analyst can determine if the recommended performance parameters used to quantify the model make sense. Establishing the means and methods to derive and validate data supports the conclusions and recommendations reported to decision makers.

References:

Reliability Information Analysis Center (RIAC) System Reliability Toolkit, SRKIT, 2006

Reliability Information Analysis Center (RIAC) Reliability Modeling – The RIAC Guide to Reliability Prediction, Assessment and Estimation

CCPS Guidelines for Chemical Process Quantified Risk Analysis", 1996.