Reliability Data Collection and Analysis

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Component failure rate data have many uses

- A primary use of component failure rate data is to quantify a probabilistic safety assessment (PSA), which we believe will be requested by the US Nuclear Regulatory Commission for licensing prototype fusion power facilities in the US.
  - ITER used failure rate data to set accident frequency categories for its "Reference Accidents" in its safety analysis report
- Another important use of component failure rate data is to support Reliability, Availability, Maintainability (RAM) analyses
  - The ITER team is very interested in RAM to demonstrate that ITER can reach 25% availability
  - The IFMIF designers are interested in RAM to demonstrate that the IFMIF accelerator can reach 70% availability
- A third use is to support facility operations, including spare parts planning & maintenance intervals

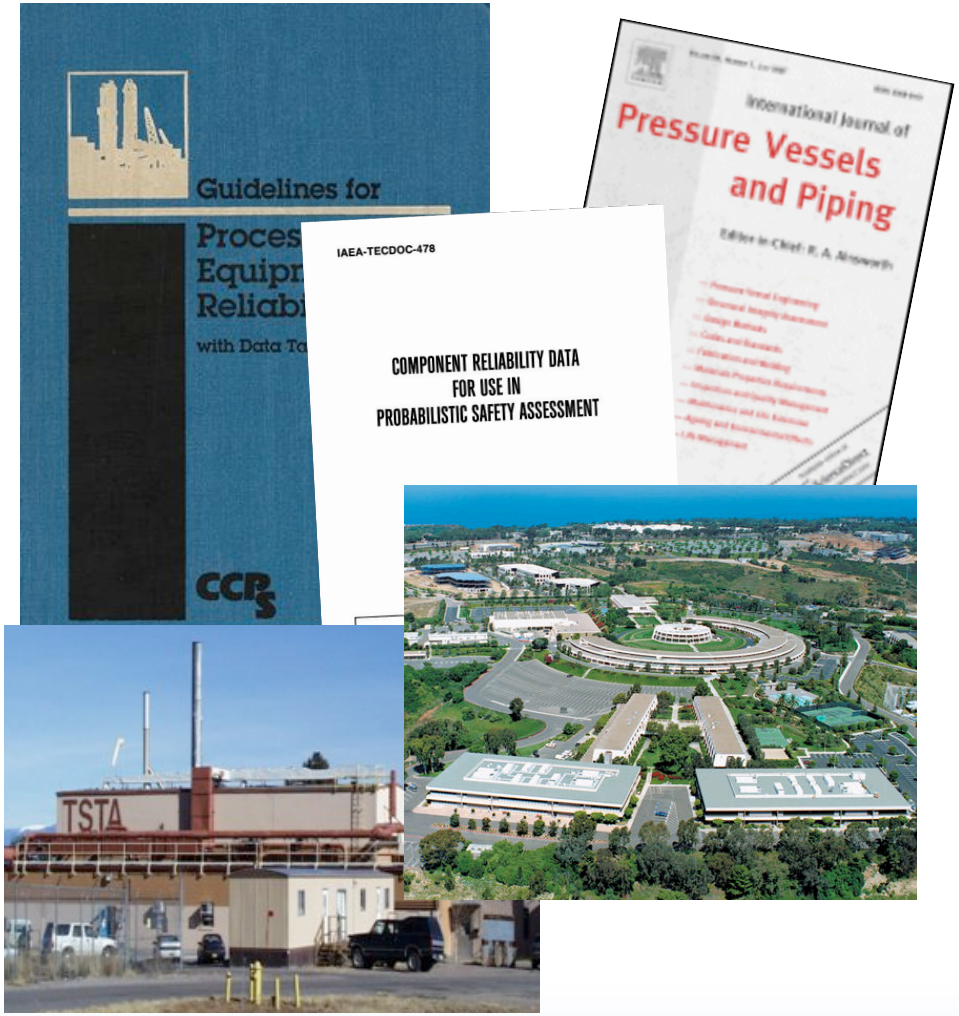
There are two long-standing criticisms of fusion component reliability data

- "Existing machine experiences tell us little about reliability performance of future designs"
  - In any endeavor, the existing technology performance is the best indicator of the performance of the next incremental step forward. Fortunately, ITER is not a huge step forward in most technologies.
  - ITER shifted the public safety burden from experimental components, e.g. FW/BKT and DIV, to proven industrial components, e.g., the vacuum vessel and other confinement systems, detritiation systems. This shift reduced the need for reliability data on experimental components. Data on ITER safety components and in-vessel components will be valuable to stair step up to future designs.
- "No data base exists to properly quantify a PSA on a fusion design"
  - We've come a long way in building a data base. We collect the most relevant data possible from the existing generation of fusion machines to apply to the next generation. We now have some component failure rate data specific to fusion.

There is an IEA task to collect failure rate data

- The International Energy Agency in Paris hosts an implementing agreement on the Environmental, Safety and Economic Aspects of Fusion Power (IEA-ESE/FP)
- The agreement was formed in 1989 and ratified in 1992
- Most of the countries researching magnetic fusion energy are members of the IEA
- One of the IEA-ESE/FP tasks is to create a component failure rate data base for safety use

Task 5 in the IEA-ESE/FP implementing agreement is assembly of a component failure rate data base



- **We use a dual approach:**

  - Data harvesting from generic data sources to apply to balance of plant systems

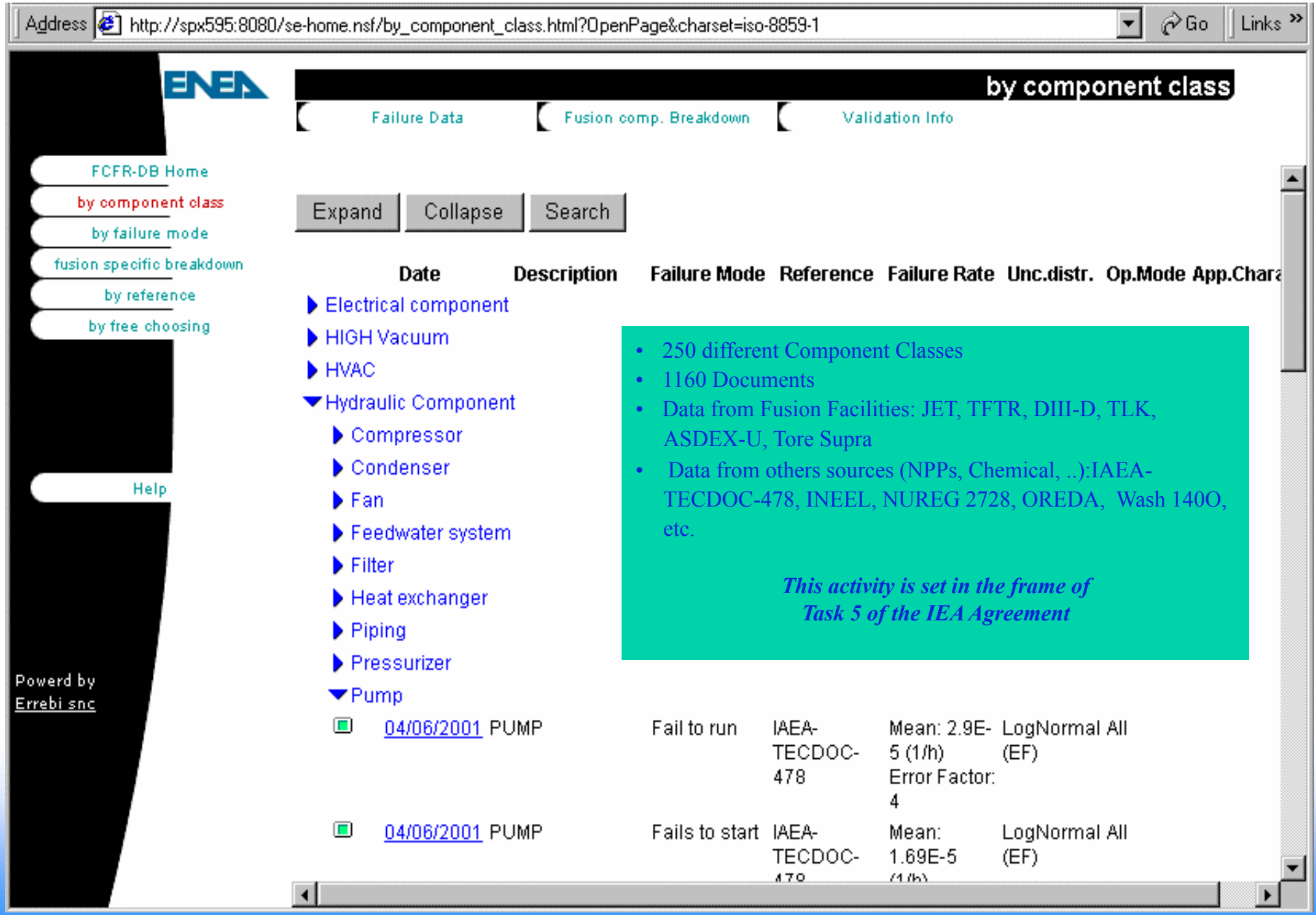
  - Operational data analysis from fusion facilities to apply to fusion-specific components

  - Our data set resides in a computerized data base

Failure rate data harvesting from existing sources

- The farther from the tokamak vessel you are, the more “industrial” or conventional - and less high-tech - a fusion experiment looks
- For industrial components, we have taken applicable failure rate data from the literature published by these communities
  - Fission power industry
  - Particle accelerator community
  - Military
  - NASA / aerospace
  - Chemical process industry
- These data, and fusion-specific data, reside in a data base created by Tonio Pinna, an IEA Task 5 participant. The data base resides at ENEA-Frascati. Task participants have internet access to the data base.

Fusion component failure rate data base



- 250 different Component Classes
- 1160 Documents
- Data from Fusion Facilities: JET, TFTR, DIII-D, TLK, ASDEX-U, Tore Supra
- Data from others sources (NPPs, Chemical, ..):IAEA-TECDOC-478, INEEL, NUREG 2728, OREDA, Wash 140O, etc.

This activity is set in the frame of Task 5 of the IEA Agreement

Some representative data in the data base

- **The data base contains over 800 failure rate values for mechanical, electrical, and electronic components**

Circuit breaker	Specific fuses	Fuses	Fail to function	WASH 1400	1.25E-5	1/D	LogNormal (Md-U95-L5)	Median Value	1.00E-05	Upper Bound 95%
Circuit breaker	Specific fuses	Fuses	Spurious open	WASH 1400	1.25E-6	1/h	LogNormal (Md-U95-L5)	Median Value	1.00E-06	Upper Bound 95%
Circuit breaker	Various	Circuit Breaker	Spurious function	INEEL-EGG-FSP-7922	1.0E-5	1/h				
Circuit breaker	Various	Circuit Breaker	Fail to function	WASH 1400	1.25E-3	1/D	Undefined (M-m-EF)	Max		Minimum
Circuit breaker	Various	Circuit Breaker	Spurious function	WASH 1400	1.25E-6	1/h	Undefined (M-m-EF)	Max		Minimum
Conductors	Busbars	Buses	All Failure Mode	INEEL-EGG-FSP-7922	1.0E-8	1/h				
Heaters	Various	Heat Tracing Pipe Heater	Fail to function	IAEA-TECDOC-478	5.6E-7	1/h	Undefined (R-M-m)	Recommended	5.60E-07	Max
Heaters	Various	Heater Air Heater General	Fail to function	IAEA-TECDOC-478	1.6E-5	1/h	Undefined (R-M-m)	Recommended	1.60E-05	Max
Heaters	Various	Heater Air Heater General	Overheated	IAEA-TECDOC-478	2.5E-7	1/h	Undefined (R-M-m)	Recommended	2.50E-07	Max
Blowers and fans		Fan	Global failure	OREDA	6.0E-5	1/h	Chi-square	lower	4.20E-05	upper
Specific tritium blowers and fans	Blower, tritium	Fusion facility D	failure	INEEL/CON-2000-0034	1.95E-6	1/h	point estimate			
Valves	Without operator and rupture disk	Check Valve	Fail to close	T-BOOK	2.8E-7	1/h	point estimate			

Fusion-specific data collection and analysis

- LANL/INL collected and analyzed reliability data from TSTA in the 90's
  - N_2 gas handling & cleanup system, gloveboxes, T room air monitors, and the room air detritiation system
- Japan has analyzed TPL safety system operating experience data and the EU has analyzed TLK components and the JET AGHS system
  - These failure rate values have agreed fairly well across sites
- We have collected and analyzed data from DIII-D, the longest-lived US large tokamak, in the 2000's, courtesy of Peter Petersen at General Atomics
  - DIII-D has matured its way into becoming a provider of valuable engineering experience data
  - Vacuum leak experiences, large power supply operations, and oxygen monitors have been analyzed
  - The DIII-D plasma heating systems (NBI, ICH, ECH) and plasma diagnostic devices (primarily Thomson Scattering) are being analyzed now
  - Future plans are to examine the DIII-D vacuum system, plant instrumentation and controls, and computer systems

Fusion-specific data collection and analysis, con't

- Through the IEA-ESE/FP task, we compare failure rates from independent data sets, which helps validate the data analysis results
  - Tonio Pinna has analyzed the JET vacuum system, ICRH, NBI, magnet and NBI power supplies, as well as the AGHS to obtain component failure rates
- More machines are interested in reliability data collection and analysis
  - TJ-II stellarator has had a reliability analysis performed on its power supplies and water cooling systems
  - ASDEX-U has had a reliability analysis of its vacuum system
  - Tore Supra has performed a reliability analysis of its magnets and cryogenic systems, and PFC cooling circuits
  - NSTX has granted INL access to its Trouble Report data base and engineering records for reliability analyses

Conclusions

- These data are valuable for immediate and longer term reasons – RAM analyses, operations support, and PSA quantification
- The US will continue working in the IEA-ESE/FP collaboration to build a component failure rate data base to support these needs
- With more and more data being analyzed from several tritium facilities and tokamak experiments, we are close to having the essential data set needed to quantify a PSA for a fusion experiment