Setting the Standard for Automation™

Comparing Failure Rates for Safety Devices

FMEDA Prediction vs OREDA Estimation

Standards
Certification
Education & Training
Publishing
Conferences & Exhibits

Iwan van Beurden, exida

- Vice President Product Development, Chief Technology Officer
- Supports exida's End-user services, exida's Manufacturer services, and exida certification activities.
- Responsible for exida end-user software, including exSILentia®, SILStat™, SILAlarm™, and CyberPHAx™
- Member ISA S84 committee
- Performs
  - IEC 61508 development support
  - Functional Safety Assessments, Audits
  - Variety of reliability analyses
  - SIL Selections
  - SIL Verifications
  - exida and ISA instructor

Contents

INTRODUCTION

Introduction

- Functional Safety Standards provide safety lifecycle framework for E/E/PES systems
- IEC 61511 addresses SIFs in Process Industry applications

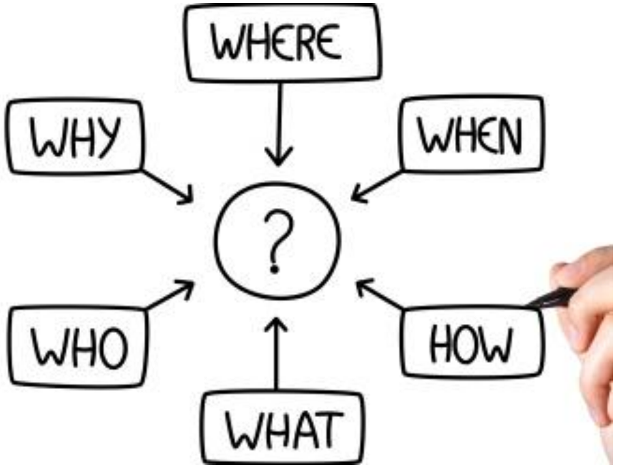
Probabilistic Analysis

- SIF conceptual design is evaluated through probabilistic analysis
- Inputs are performance parameters including failure rates for all devices

FAILURE RATE ESTIMATION

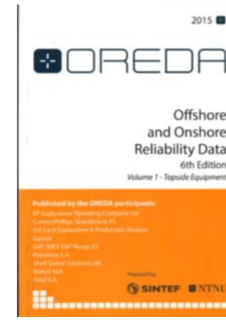
Failure Rate Sources - Estimation

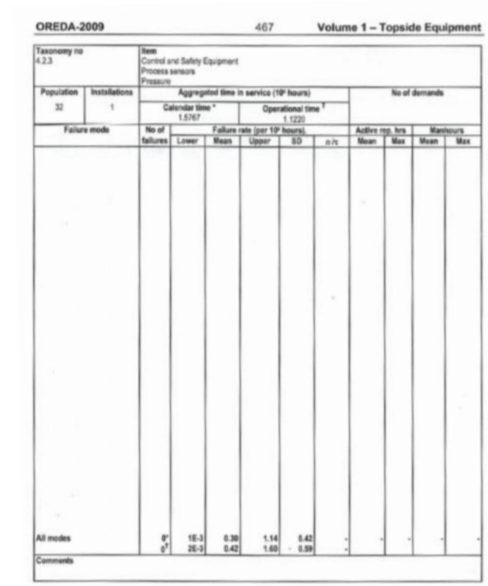
- Industry Databases
- Committee Estimates
- Manufacturer Warranty Analysis
- End User Field Failure Data Studies



Industry Databases

- Field failure data gathered from variety of sources
- Aggregated results published
- For example
  - OREDA
    - Operated by DNV, Data Analysis by SINTEF
    - Useful data on process equipment
    - Latest public release in 2015
    - Failure rates based on given population and recorded operating hours
  - OREDA Example
    - Pressure transmitter
    - Total mean failure rate 0.42E-6/hr
    - Population 32 units





OREDA-2009 467 Volume 1 – Topside Equipment

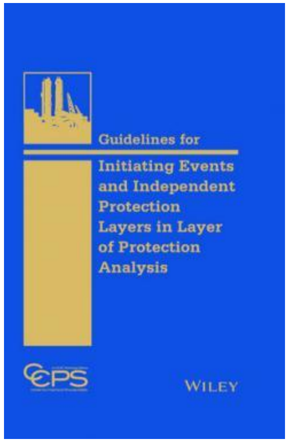
Taxonomy no 4.2.3	Item: Control and Safety Equipment, Process sensors, Pressure

Population	Installations	Aggregated time in service (10^6 hours): Calendar time *	Operational time †	No of demands
32	1	1.5767	1.1220	

Failure mode	No of failures	Failure rate (per 10^6 hours): Lower	Mean	Upper	SD	n/τ	Active rep. hrs: Mean	Max	Manhours: Mean	Max
All modes	0*	1E-3	0.30	1.14	0.42	-	-	-	-	-
	0†	2E-3	0.42	1.60	0.59	-				
Comments										

Committee Estimates

- Failure rates estimated based on committee member experience
- Methods rarely published
- Data good for comparison
- For example
  - AIChE, CCPS Guideline documents



Manufacturer Warranty Analysis

- Real Data!

- Calculation methods vary widely
- Don’t know what percentage of actual failures are returned
  - Operational hours sometimes estimated based on shipping records while assuming that all failures are returned (very optimistic)
- Narrow definition of “Failure”
  - Many manufacturers classify returned items as a “Failure” only if a manufacturing defect is found
  - Many returned items are marked “No Problem Found” or “Systematic Failure”

- Data can be valuable to identify root causes and compare to establish lower bounds on failure rate

End User Field Failure Data Analysis

- Excellent source for site specific data
- Many existing data gathering systems are weak
  - Different definitions of “Failure” / not all “Failures” recorded
  - Variations of amount of data collected
  - Categorizing and Merging Technologies
  - Lack of fault isolation
- Data collection process can vary by an order of magnitude or more!
  - When is a failure report written?
  - What is the definition of failure?
  - Are "as found" conditions recorded during a proof test?
  - What were the operating conditions?

FAILURE RATE PREDICTION

Problems with Estimation

- One problem with all failure rate estimation techniques is product obsolescence
- Number of failures recorded per end-user site relatively low, i.e. statistical analysis not viable
- No information available on new product designs

Failure Rate Sources – Prediction

- B10d / HALT
  - Highly Accelerated Life Test
- FMEDA
  - Failure Modes, Effects, and Diagnostic Analysis

B10d (Cycle Test) Failure Data

- Cycle test for mechanical / electro-mechanical products
  - Test until 10% of units under test fail (B10 Point)
  - Convert number of cycles until failure to time period
  - Failure rate calculated by dividing 10% failure count by time period
  - λ_D is assumed 50% of total failure rate, λ_S is 50%, no other failure modes are assumed to exist
- Assumptions
  - All failures due entirely to *premature wear-out*
  - Application has *constant dynamic* operation

Failure Modes, Effects, and Diagnostic Analysis (FMEDA)

- A predictive failure rate method developed by exida engineers
- Study of each component and how the component failure will affect the product
- Estimate (or test) how well automatic diagnostics and proof test will detect the component failure
- Uses a component database that accounts for design strength versus a predefined environment

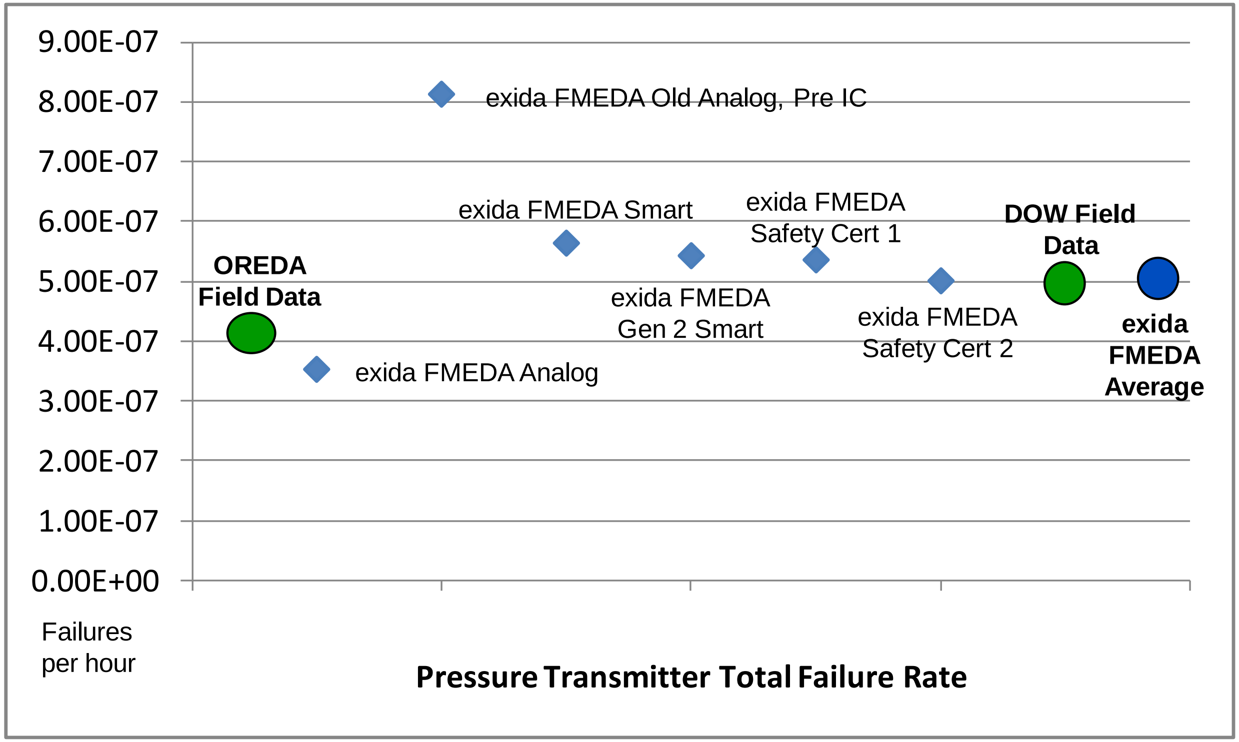
FMEDA Considers

- Component Failure Rates are a function of operating environment
- Study Design Strength
  - Application
  - Operating Conditions
- Predict Useful Life
- Predict test coverage
  - Automatic Diagnostic
  - Proof Test

exida PROFILE	1	2	3	4	5	6
Description (Electrical)	Cabinet mounted/ Climate Controlled	Low Power Field Mounted no self-heating	General Field Mounted self-heating	Subsea	Offshore	N/A
Description (Mechanical) (Applies to industrial locations with a specified electromagnetic environment, otherwise must include 2 kV with Performance Criteria FS)	Cabinet mounted/ Climate Controlled	General Field Mounted	General Field Mounted	Subsea	Offshore	Process Wetted
IEC 60654-1 Profile	B2	C3 also for D1	C3 also for D1	N/A	C3 also for D1	N/A
Average Ambient Temperature	30 C	25 C	25 C	5 C	25 C	25 C
Average Internal Temperature	60 C	30 C	45 C	5 C	45 C	Process Fluid Temp.
Daily Temperature Excursion (pk-pk)	5 C	25 C	25 C	0 C	25 C	N/A
Seasonal Temperature Excursion (winter average vs. summer average)	5 C	40 C	40 C	2 C	40 C	N/A
Exposed to Elements / Weather Conditions	No	Yes	Yes	Yes	Yes	Yes
Humidity[1]	0-95% Non-Condensing	0-100% Condensing	0-100% Condensing	0-100% Condensing	0-100% Condensing	N/A
Shock[2]	10 g	15 g	15 g	15 g	15 g	N/A
Vibration[3]	2 g	3 g	3 g	3 g	3 g	N/A
Chemical Corrosion[4]	G2	G3	G3	G3	G3	Compatible Material
Surge[5]						
Line-Line[6]	0.5 kV	0.5 kV	0.5 kV	0.5 kV	0.5 kV	N/A
Line-Ground[7]	1 kV	1 kV	1 kV	1 kV	1 kV	
EMI Susceptibility[8]						
80 MHz to 1.4 GHz[9]	10 V/m	10 V/m	10 V/m	10 V/m	10 V/m	N/A
1.4 GHz to 2.0 GHz	3 V/m	3 V/m	3 V/m	3 V/m	3 V/m	
2.0 GHz to 2.7 GHz	1 V/m	1 V/m	1 V/m	1 V/m	1 V/m	
ESD (Air)[10]	8 kV	8 kV	8 kV	8 kV	8 kV	N/A
Altitude	5,000 ft	5,000 ft	5,000 ft	0 ft	500 ft	N/A

FMEDA PREDICTION VS OREDA ESTIMATION

Pressure Transmitter Failure Rate Comparison

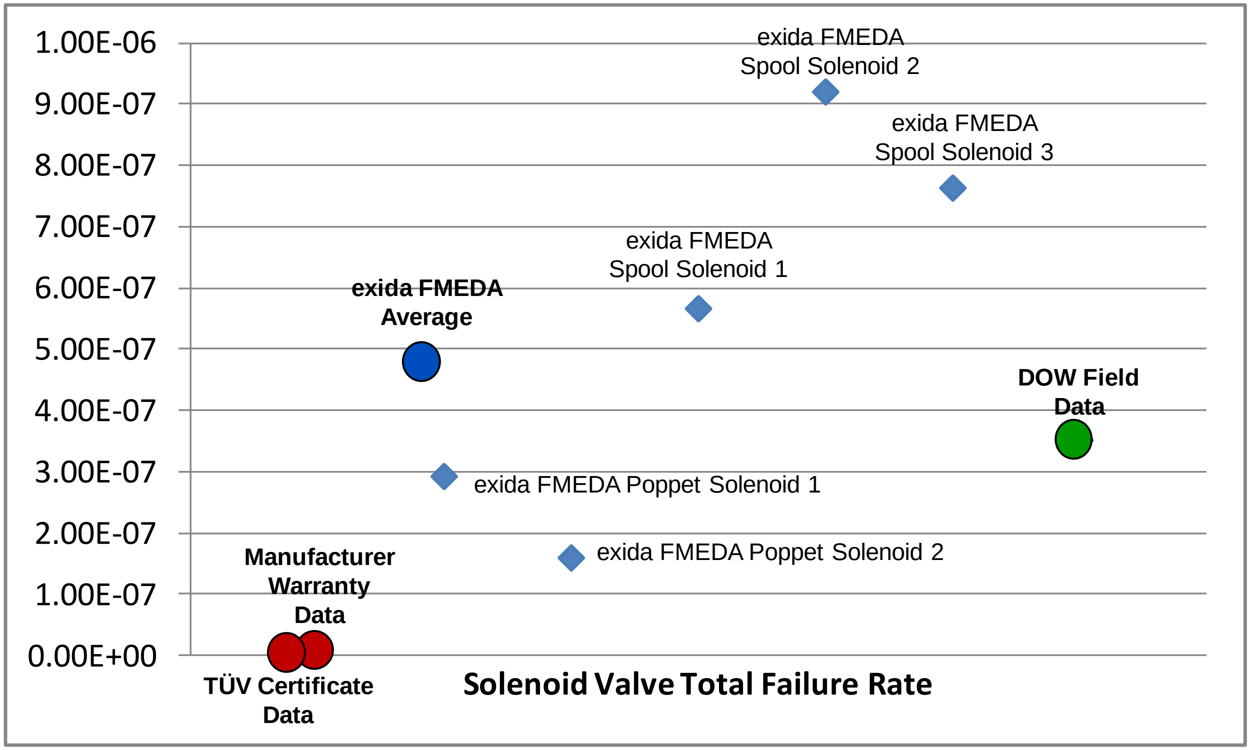


OREDA: 5th edition, Volume 1 – Topside Equipment, 2009

DOW: paper, 63rd Annual Instrument Symposium for the Process Industries, 2008, Texas A&M

OREDA:	4.20E-07 failures/hour
DOW:	4.96E-07 failures/hour
FMEDA average:	5.02E-07 failures/hour

Solenoid Valve Failure Rate Comparison

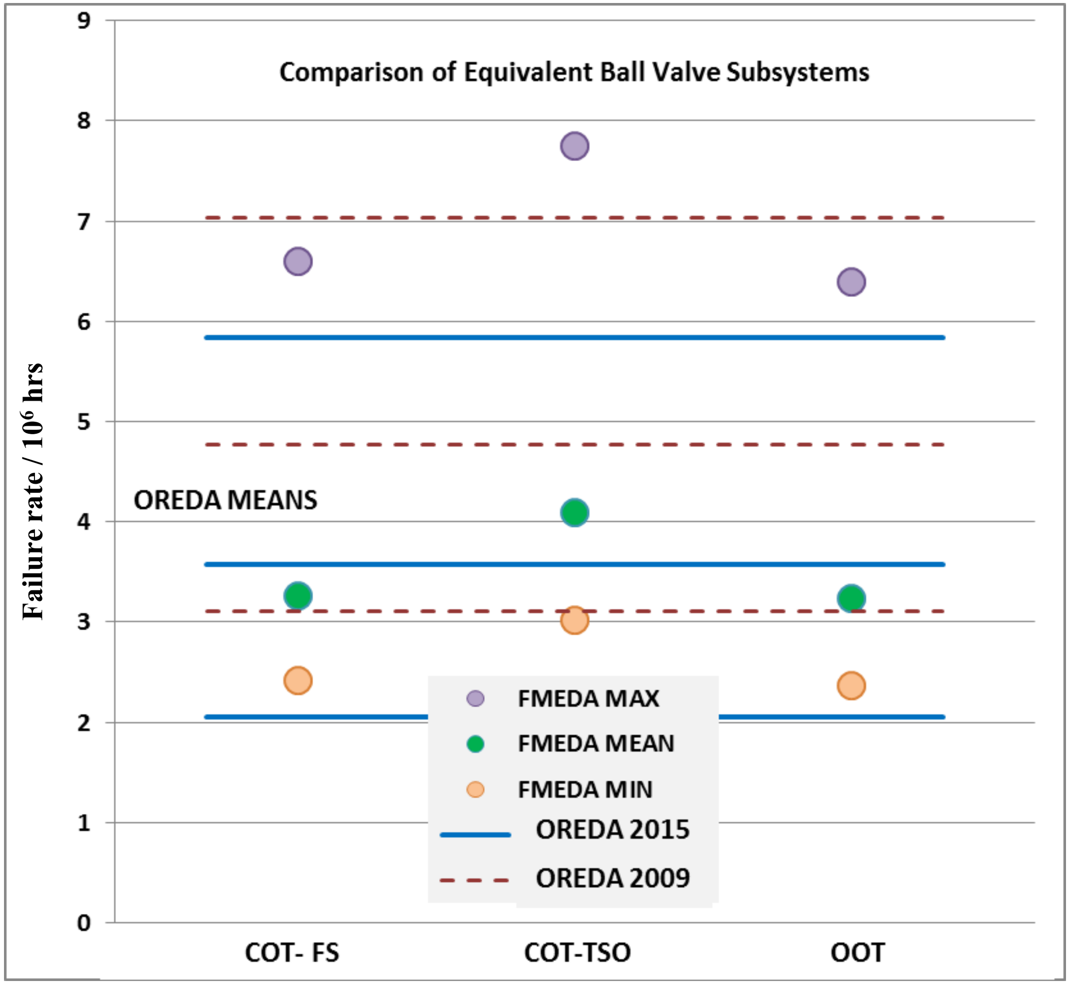


OREDA only has complete final element assembly data

DOW: paper, 63rd Annual Instrument Symposium for the Process Industries, 2008, Texas A&M
Combines Poppet and Spool solenoids

When comparing failure rate data, it is essential to understand the assumptions made used to derive the each data set.

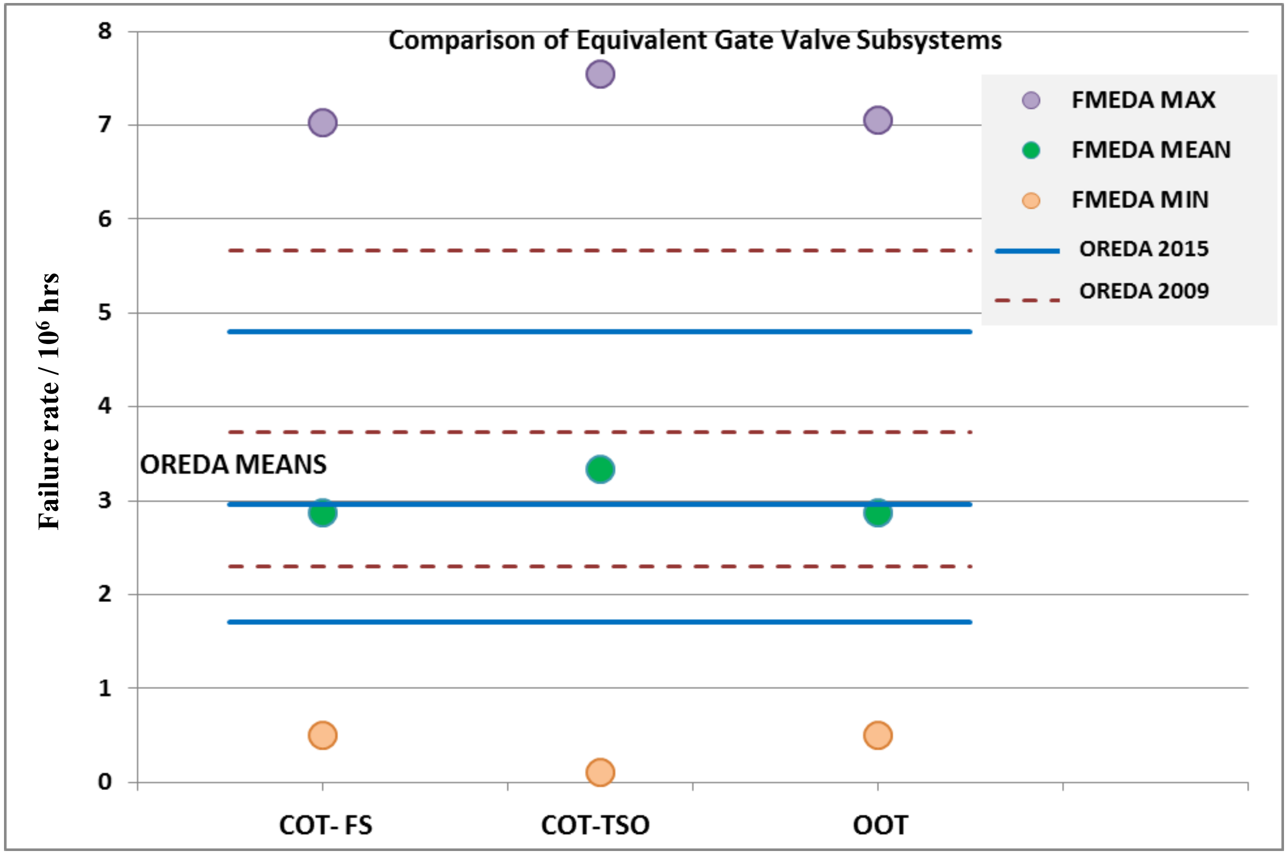
Ball Valve Subsystem Failure Rate Comparison



Upper Confidence Limits

Lower Confidence Limits

Gate Valve Subsystem Failure Rate Comparison



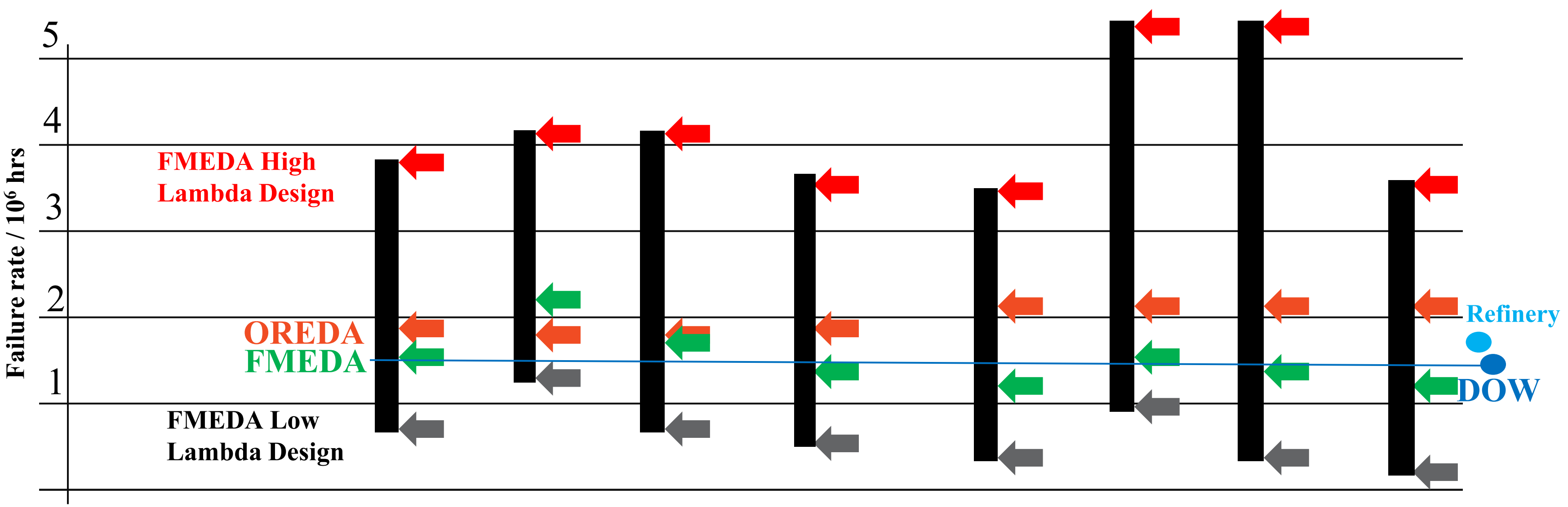
Upper Confidence Limits

Lower Confidence Limits

CONCLUSION

Determine Realistic Failure Rate Ranges

	Failure Rates (per 10^6 hours)							
	ESD Ball Valve Subsystem				ESD Gate Valve Subsystem			
Application	COT	TSO	COT/TSO	OOT	COT	TSO	COT/TSO	OOT
FMEDA $\lambda_{D\ MAX}$	3.95	5.10	5.10	3.63	3.66	5.79	5.79	3.60
2015 edition OREDA λ_D	1.91	1.91	1.91	1.92	2.19	2.19	2.19	2.19
FMEDA $\lambda_{D\ AVG}$	1.45	2.27	1.86	1.29	1.23	1.69	1.46	1.16
FMEDA $\lambda_{D\ MIN}$	0.69	1.25	0.70	0.51	0.46	0.98	0.45	0.42



Need for Failure Rate Prediction

- Application Specific, Product Specific, field failure data is the best source for real life failure rates
- Collecting failure rate data takes time
  - Product may become obsolete
  - Typically not enough data for statistical analysis
- No field data available for new product designs

- FMEDA Failure Rate Prediction
  - Requires clear definition of failure
  - Requires good component data handbook
  - Yields realistic failure data based on design strength analysis and expected operational stress conditions

QUESTIONS?