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reliability designed, reliability delivered

Reliability Communication:

MTBF. Is There a Better Way?

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DfR Solutions Webinar Series (5/22/2014)

[originally presented to the Avionics Maintenance Conference]

Who is DfR Solutions?

Best Design Verification Tool
- Printed Circuit Design

The Industry Leader in Quality-Reliability-Durability of Electronics

50 Fastest Growing Companies in the Electronics Industry
- Inc Magazine

2012 Global Technology Award Winner

Key Facts

- Founded in 2005
- 30+ Employees, Multiple worldwide locations
- Software, Consulting, Research, Lab Services

Over 600 Customers

Most Major Avionic OEMs and Suppliers

What is MTBF?

- $$MTBF = \frac{Hours\ of\ Operation \times Samples}{Number\ of\ Failures}$$

- $$MTBF = \frac{1}{\sum Failure\ Rate\ (\lambda)}$$

- $$MTBF = MTTF + Mean\ Time\ to\ Repair\ (MTTR)$$

Why MTBF?

A well-manufactured and screened product ('box') will have no defects

AND

A well-designed product will not experience wearout during its operational lifetime

Why MTBF? (cont.)

BIG numbers are easier to remember
than small numbers

153,000 hours vs. 0.00065%/hour?

(of course, why not 5.7%/year?)

Why MTBF? (cont.)

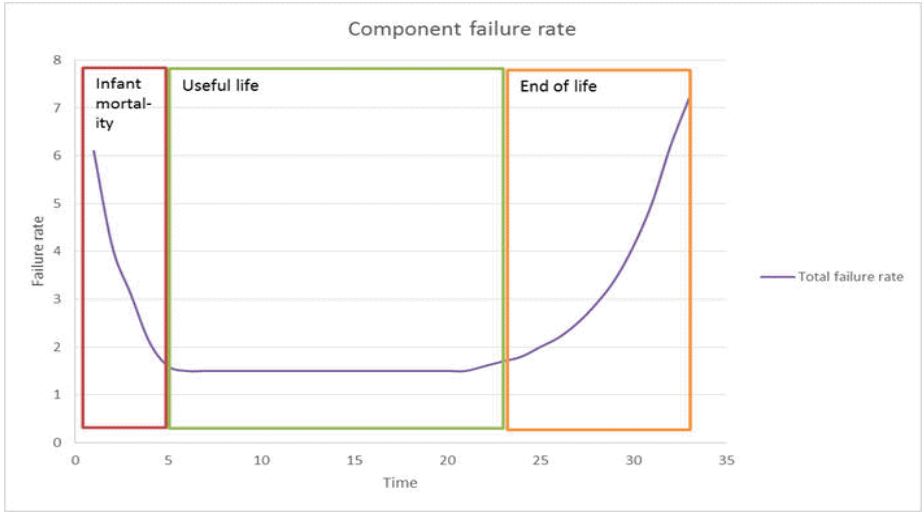
Only One Number

Why MTBF? (cont.)

- Airworthiness Requirements are Business Critical
- Safety Assessments demonstrate compliance with Airworthiness Requirements
- Reliability Prediction 'feeds' Safety Assessments
- FAA encourages MTBF for Reliability Prediction

Why NOT MTBF?

- Misunderstandings are common among non-reliability experts
- Must assume a constant failure rate
- Assumes failure must occur



- Encourages use of empirical handbooks

Key Reminder

- MTBF can be used for predicting reliability at the design/concept stage

- MTBF can also be used for extrapolating reliability from existing events

What Are the Alternatives?

- Failure Rate
- Reliability with a Confidence Interval / B10
- Failure Free Operating Period (FFOP) / Maintenance Free Operating Period (MFOP)
- Mean Cumulative Function (MCF)
- Rate of Occurrence of Failure (ROCOF)

Failure Rate

- Simply invert MTBF

- Advantages -
  - More intuitive
  - No assumptions regarding constant failure rate

- Disadvantages -
  - More challenging to incorporate time to repair
  - Can just invert MTBF (has anything really changed?)

Common among part manufacturers

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Reliability with a Confidence Interval

- 99% Reliability with 95% Confidence

- Advantages -
  - More intuitive
  - No assumptions regarding constant failure rate
  - Forces a discussion on confidence levels (moves away from empirical handbooks)

- Disadvantages -
  - More challenging to incorporate time to repair

Common among industrial controls, auto manufacturers

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B10

- Time to 10% probability of failure
- Often thought of the beginning of wearout
- A variance of reliability with confidence level

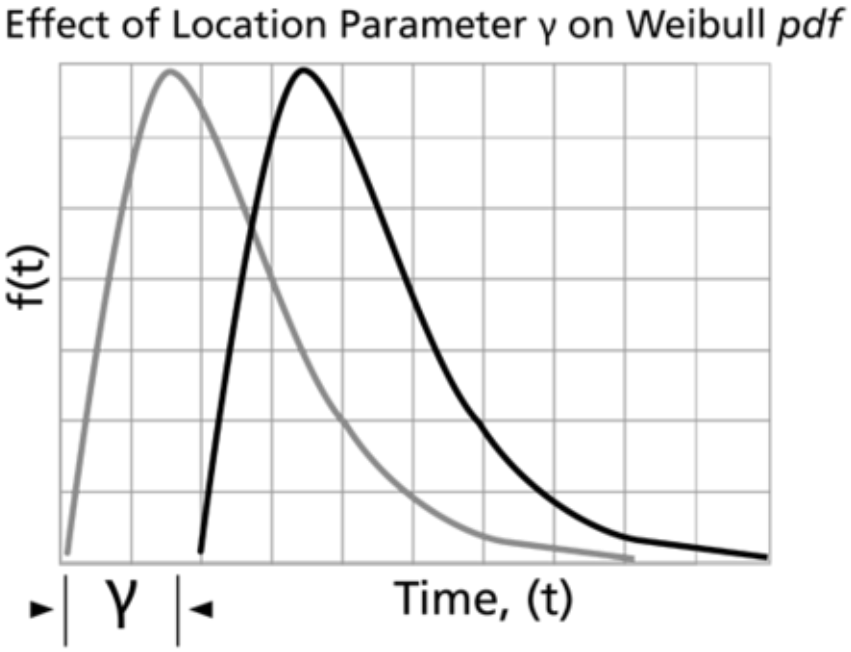
Common among moving parts that wearout (fans, motors, etc.)

Failure Free Operating Period (FFOP)

- Initially proposed in the early 1980's
  - Incorporated into MIL-STD-781D (failure-free period life tests)
- Concept was to extrapolate concepts from mechanical parts and apply them to electronic boxes
- Two approaches
  - Constant failure rate is low enough that the probability of failure is highly unlikely (below a certain value) over a given period of time (possibly brings us right back to MTBF)
  - Replacement of exponential distributions with three-parameter Weibull

Three Parameter Weibull

- Potentially valid concept for some mechanisms



- Major challenge is under-standing gamma (γ)
  - Requires large number of samples
  - Need to characterize change as a function of stress

- Major benefit is changing the default conversation from 'will fail' to 'will not fail'

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Maintenance Free Operating Period (MFOP)

- Proposed by the UK Ministry of Defense in mid 90's
  - Defined as period of time, typically starting from initial use, where the equipment is to perform its function without any maintenance (unscheduled)
- Concept is driven by the manufacturer taking some responsibility for maintenance (similar to performance-based logistics)
- Calculating MFOP requires an estimate of survivability of the system during the maintenance-free period (MFOPS)

MFOP (cont.)

- Different organizations have taken different approaches to MFOP
  - Some have applied FFOP to MFOP
  - Others have overlaid MFOP over MTBF metrics (MFOPS)
  - Many have used it to justify greater fault detection and fault tolerance (beyond safety)

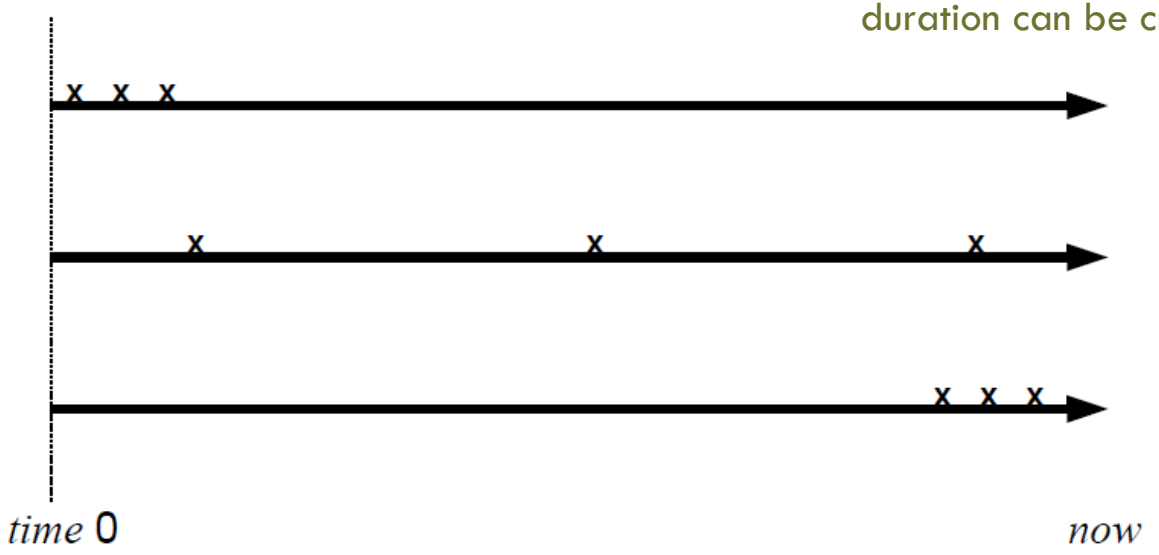
- Benefits
  - Changes the conversation, does not assume constant failure rate, better for repairable systems, provides stronger financial motivation behind any reliability prediction

Mean Cumulative Function

- Designed to replace the use of MTBF/MTBUR in extrapolating field events

What MTBF ignores:

- MTBF assumes independent and identically distributed lifetimes (iid)
- Recurrence data vs. life data (repairable systems are typically not iid). The order and duration can be critical



Heavlin, 2005

is the reliability the same for these three systems?

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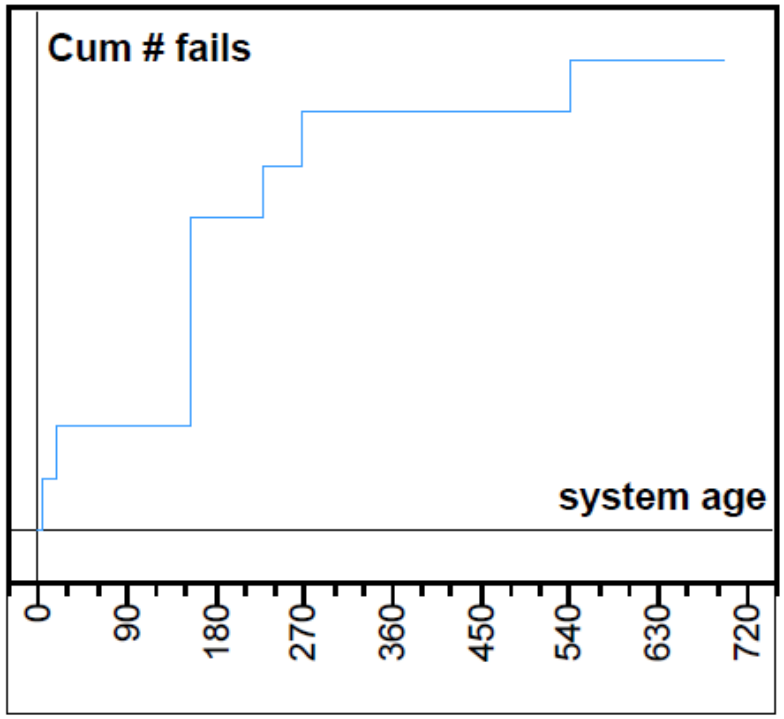
MCF (cont.)

- Plot of cumulative failures vs system age (analogous to cumulative hazard functions for non-repairable systems)



Age (days)	0	8	22	159	233	272	302	320	545	550	619
System A Fails @ Age	0	1	1	4	0	1	0	0	1	0	0
(cum) Fails by Age	0	1	2	6	6	7	7	8	9	9	9
System B Fails @ Age	0	0	0	0	3	0	0	1	0	0 (censored)	
(cum) Fails by Age	0	0	0	0	3	3	3	4	4	4	
System C Fails @ Age	0	0	0	0	0	0	0 (censored)				
(cum) Fails by Age	0	0	0	0	0	0	0				
MCF Fails @ Age	0	1	1	4	3	1	0	1	1	0	0
# @ Risk	3	3	3	3	3	3	3	2	2	2	1
Increment	0	1/3	1/3	4/3	3/3	1/3	0	1/2	1/2	0	0
MCF by Age	0	1/3	2/3	6/3	9/3	10/3	10/3	23/6	26/6	26/6	26/6
	0.00	0.33	0.67	2.00	3.00	3.33	3.33	3.83	4.33	4.33	4.33

Heavlin, 2005

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MCF (cont.)

- Once MCF is calculated and plotted, a number of statistical techniques are available

- Cochran-Mantel-Haenszel (CMH) to identify outliers
- Archetypal analysis to separate out groups of systems, detect trends, identify outliers
- Rate of Occurrence of Failure (ROCOF)
  - Derivative of MCF

Rate of Occurrence of Failure (ROCOF)

- Why ROCOF? Operating hours / total failures equals MTBF only works if the failure rate is constant (exponential distribution)

- MCF is the expected value of the number of failures over some time interval
- ROCOF is the instantaneous rate of change in the expected number of failures
  - Designed to measure the in-service performance of repairable units

Plotting MCF

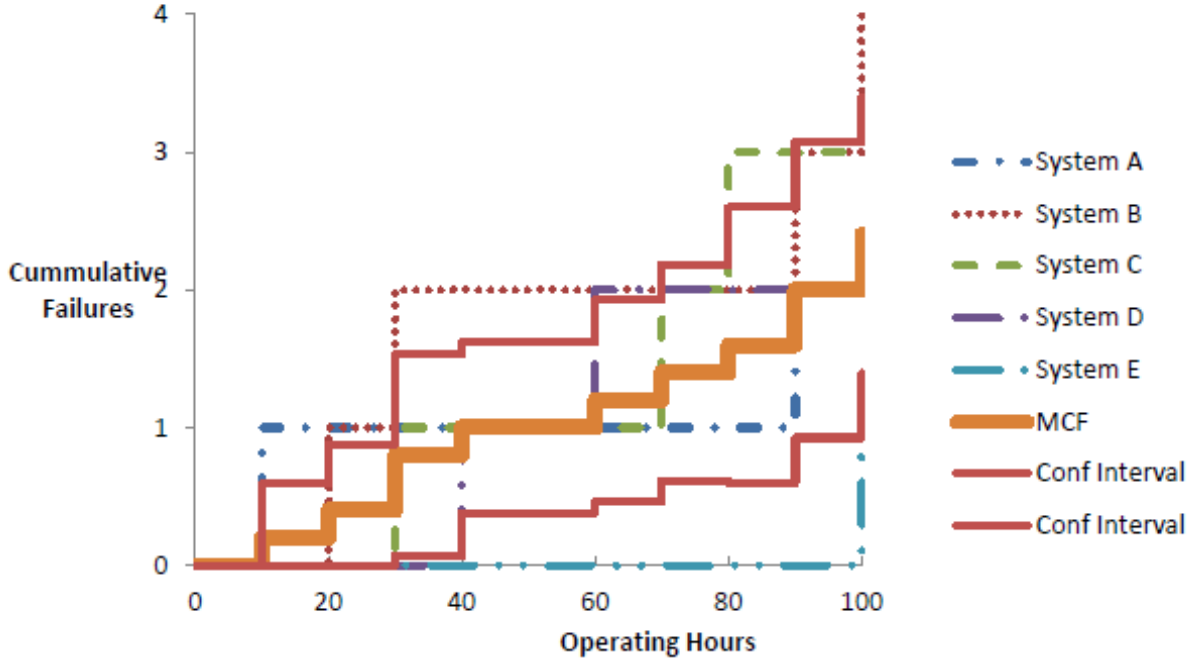

Figure 5 Plot of the MCF for Five Similar Systems with 95% Confidence Interval

Hogge, 2012

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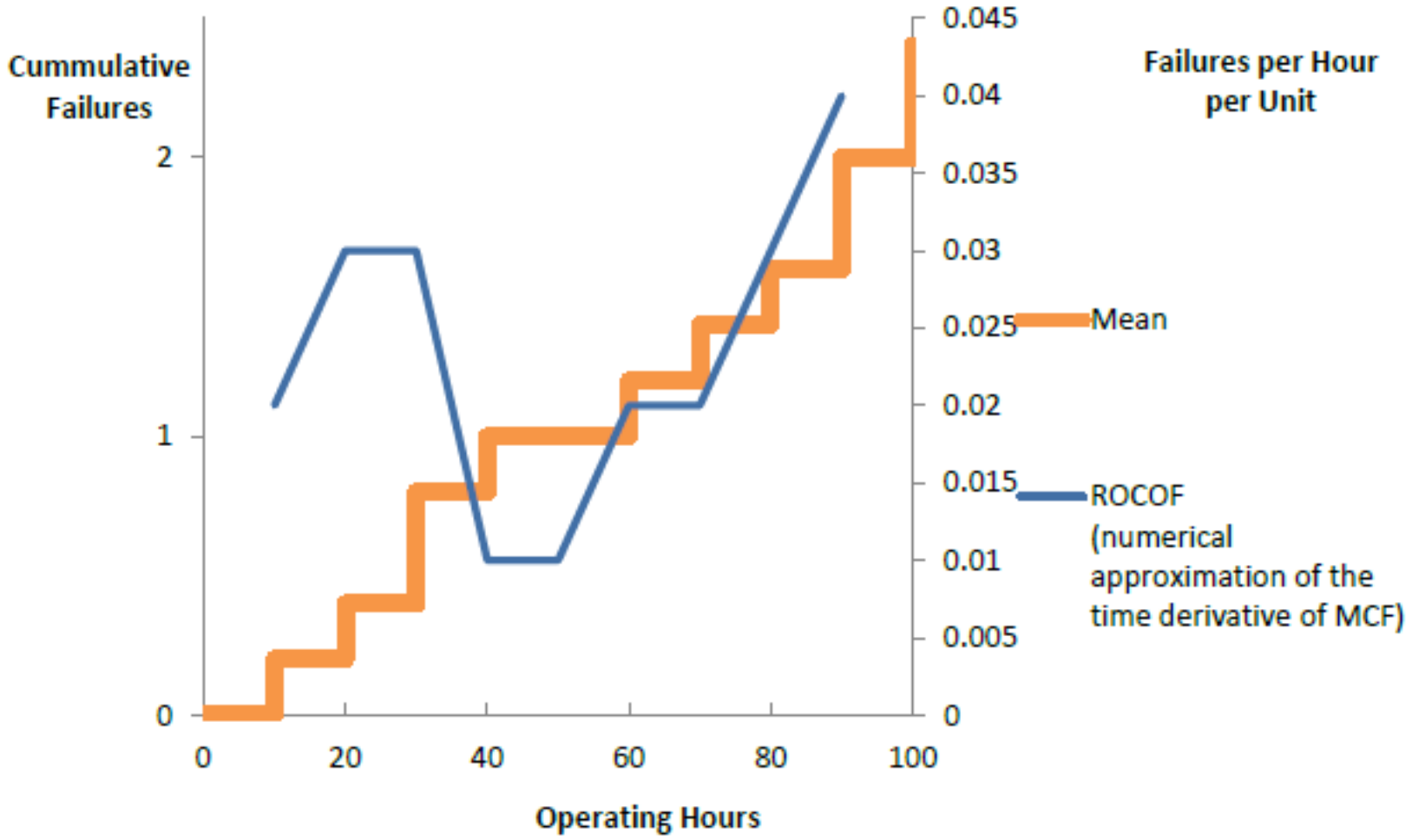
Plotting ROCOF



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ROCOF vs. MTBF

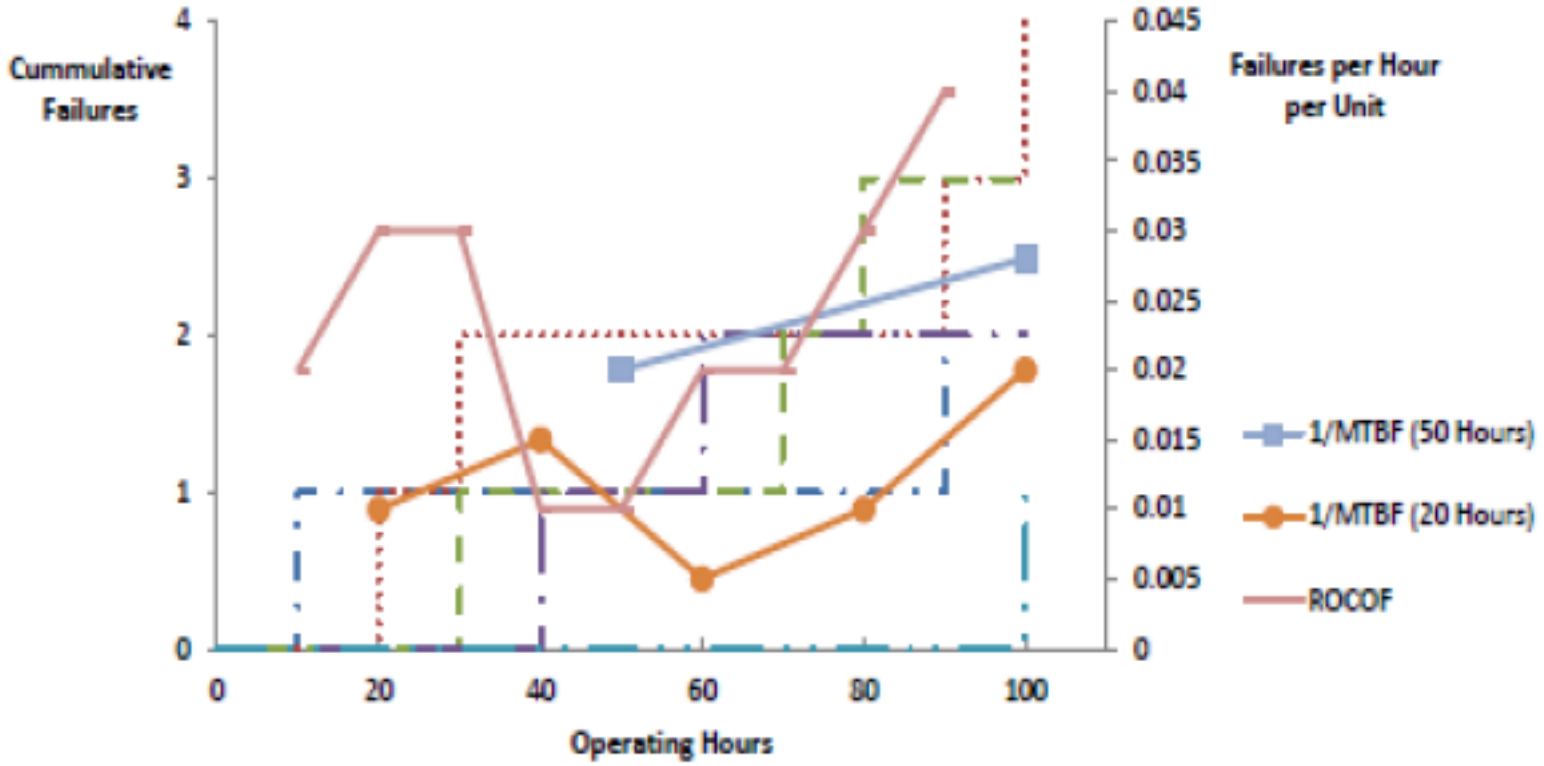

Figure 7. USAF Comparison of MTBF Derived 'Failure Rate' and ROCOF Over Two Different Periods (20 and 50 Hours)

ROCOF Insight

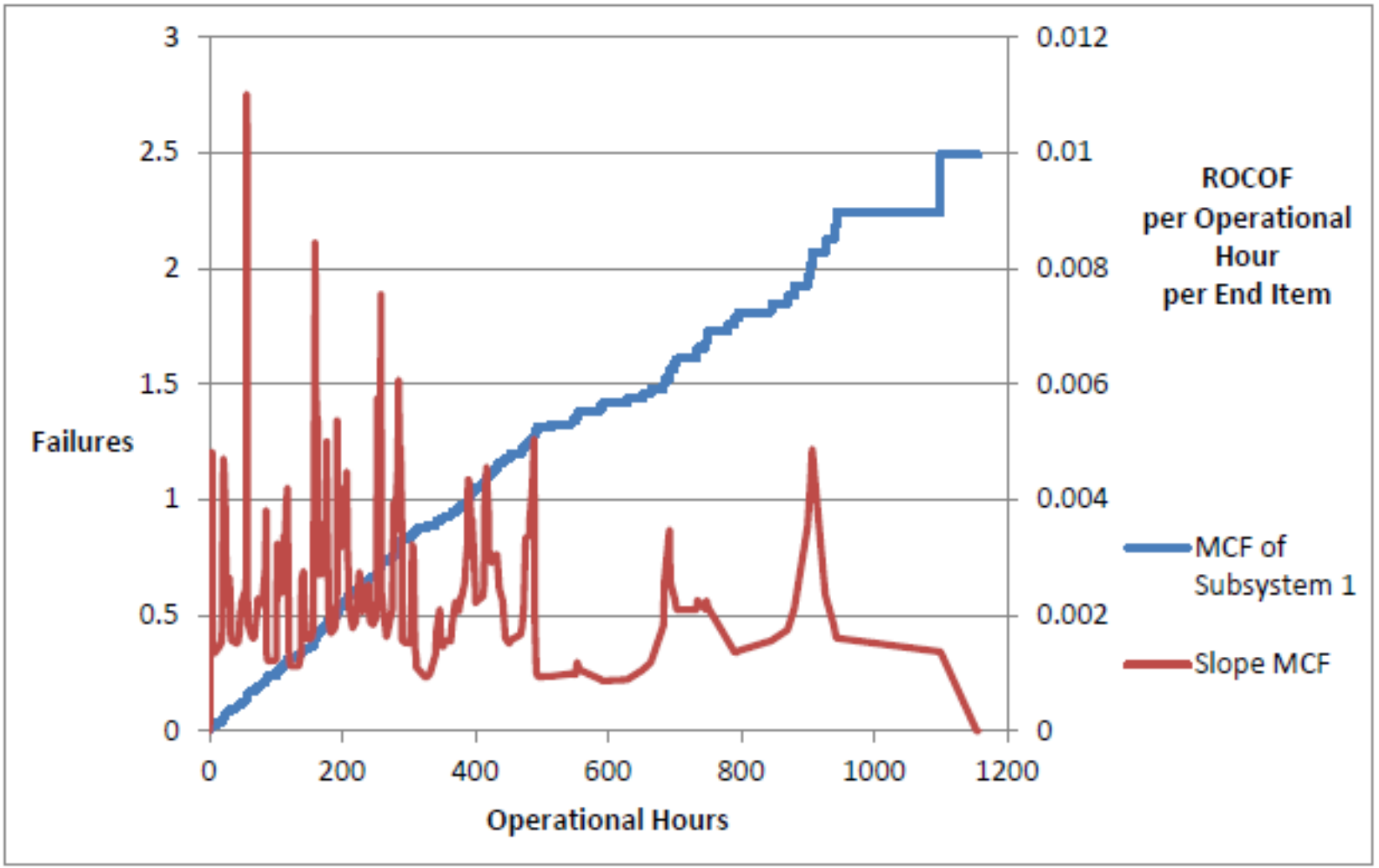

Figure 12 ROCOF Plotted Verses Operational Hours

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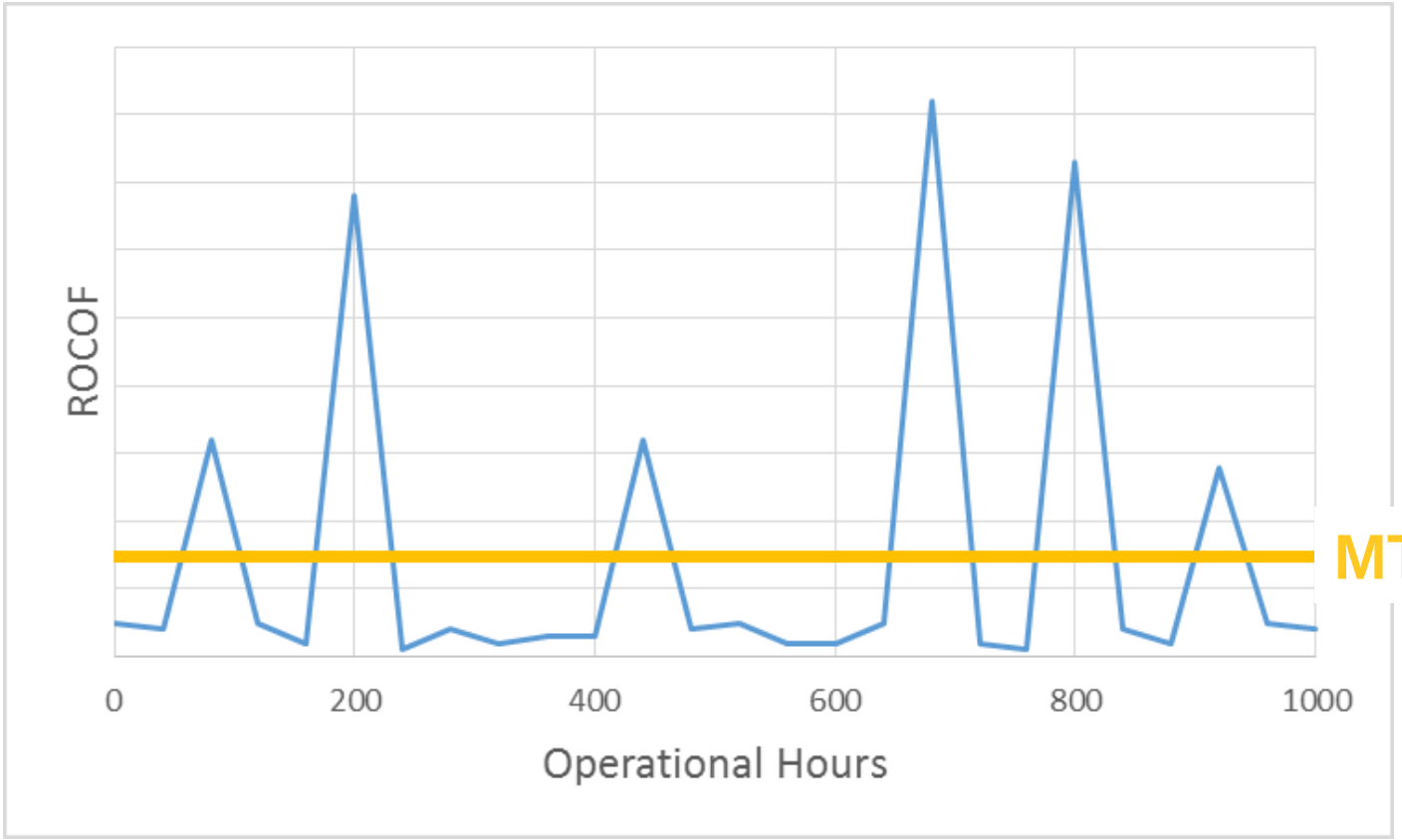
Where Does This Leave Us?

- There needs to be a discussion to determine if average MTBF captures the true pain of failures



Conclusion

- There are a number of advantages in moving away from the use of MTXX to predict and track reliability
- Use of other methodologies will improve maintenance prediction and performance
- However, in a regulated industry, change is difficult without the express backing of the regulator
  - Look at DoD and MIL-HDBK-217!

Questions ?