

Small Sample Size Datasets: Help or Hindrance

H. Paul Barringer
Barringer & Associates, Inc.
P.O. Box 3985
Humble, TX 77347-3985
Phone: 281-852-6810 Website: www.barringer1.com
FAX: 281-852-3749 E-mail: hpaul@barringer1.com

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Wants vs Needs

- We all **want** large datasets, free from outliers
- We **get** small datasets filled with outliers, different failure modes, and time uncertainty
- We live with a **time crunch** and **budget limitations**--our need is to use the small data we have to help make decisions
- Do we **accept the risk and move forward** or do we **reject the risk and do nothing?**

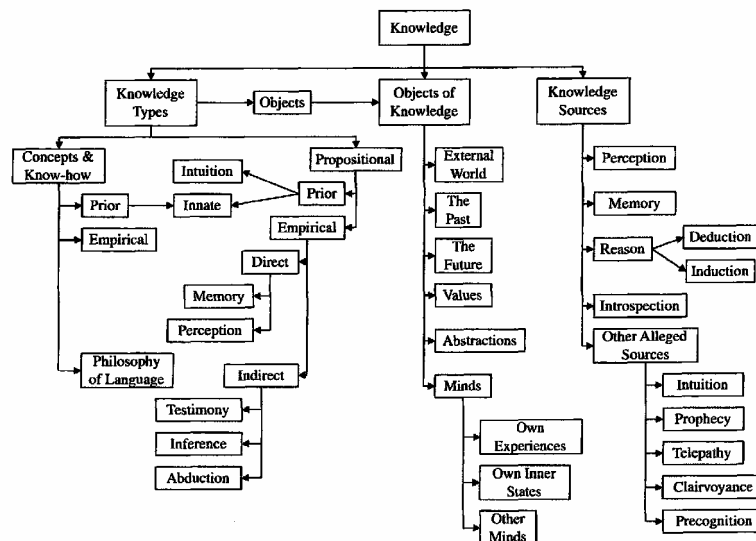
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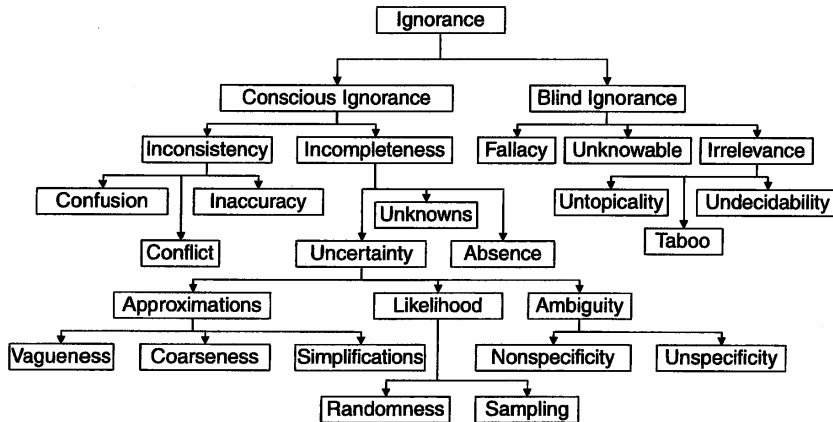
Some Quotes—Set The Stage

- The Scientist studies **what is**, the engineer **creates what has never been.**
Theodore von Kármán
- Shall I **refuse my dinner because I do not fully understand** the process of digestion?
Oliver Heaviside
- You'll never have enough data for a risk free decision.

What Do You Know?



What's Your Level Of Ignorance?



Source: Ayyub, page 31

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Work Out The Puzzle

- Four H-bombs lost off the coast of Spain in 1966 during a B-52 refueling collision. Three found pronto. Fourth one was lost but found just before the Russians snagged it. How?
- Submarine *Scorpion* lost in 1968 at sea with all hands aboard from a hot running torpedo. Found within 220 yards of predicted site.
- How? Bayesian statistics, Los Vegas odds makers, and simulator scenarios. **Where's the data?**

Source: Blind Man's Bluff, pgs 65 & 116

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Heat Exchanger Problem

- Last year we completed a turnaround and discovered (by test) a heat exchanger with three leaking tubes
- Before turnaround, we did not suspect tube leaks as a problem
- Now we're worried--is the heat exchanger at end of life?
- **Should we hold the course or buy a new tube bundle for installation at the next turnaround?**

Heat Exchanger Data

The Data Set

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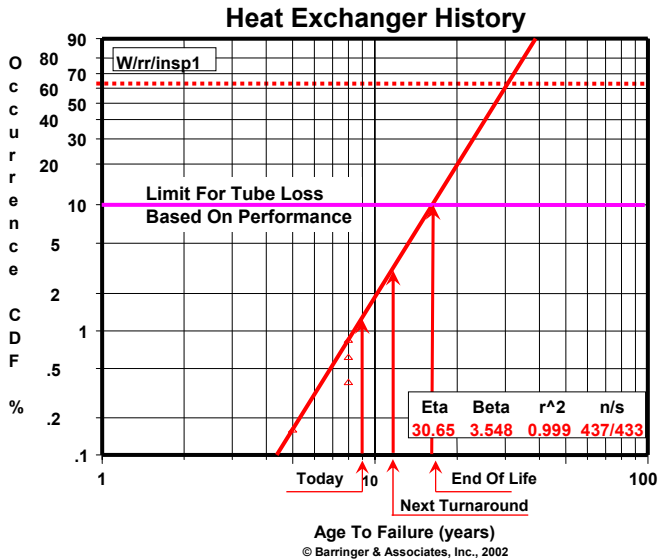
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8*3

-9*432

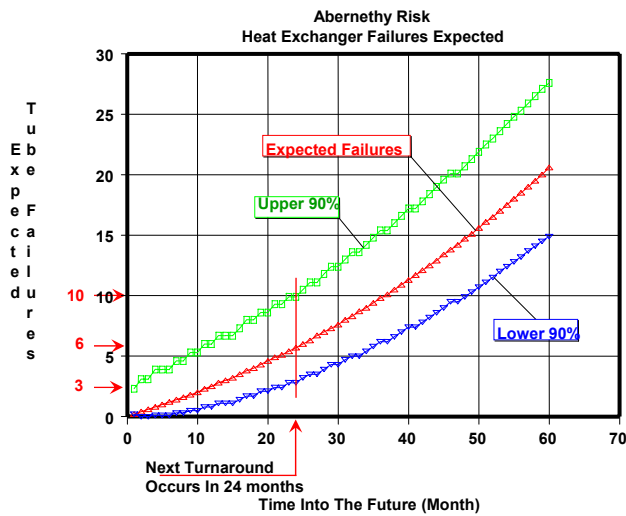
- **Data shows:**
 - 1 tube plugged after 2 years of service—tube plugged because of damage at 2 year turnaround
- 1 tube plugged with demonstrated leak at 5 years during the 3 year turnaround
- 3 tubes plugged at at 8 years with actual leaks discovered during 3 year turnaround
- We're now at year 9 and have 432 tubes still working—**how many more failures for 2 more years** of continuous service until turnaround?
- Continue? Retube with a new \$125,000 bundle? 8

Heat Exchanger Weibull Plot



Use WinSMITH Weibull inspection option to properly handle coarse intervals for inspection which results in "stacks" of data.

Risk Of Future Tube Failures



Failures expected during the next two years operation is about the same level of problems experienced during last period.

Do not retube. Continue with operation as is.

1st idea—don't buy a new bundle

- Expect 6 tube failures during next 24 months
(**If we couldn't see 3 failures— will 6 failures be observable to operations?**)
- 90% confidence intervals say the 6 tube failures may be as low as 3 failures or as high as 10 failures
- During the next 5 years we expect 21 failures with end of heat exchanger life at 18 years of service (for 10% of the bundle to fail)

2nd Idea Maybe $\beta = 3.548$ Is Bad For Heat Exchangers

- Beamer suggest large β 's up to ~ 10
- Barringer finds small β 's down to ~ 0.8 and large β 's up to ~ 11
- Use our data and impose β 's to find what the Abernethy risk would project
- Based on the results, make a decision to accept the risk and run or deny the risk and retube when forecast.

Webayes Estimates

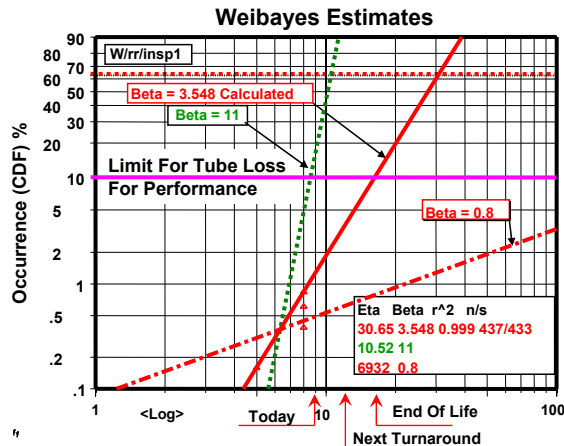


Figure 4: Weibull What If On β Age To Failure (years)

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What Do You Believe Now?

- If $\beta = 11$ expect 16.4% of the tubes to have failed—we do not have performance problems, **reject the hypothesis**.
- If $\beta = 0.8$ expect fewer failures. If we can accept the risk of failures of $\beta = 3.548$ **then continue running**—reevaluate value of $\beta = 0.8$ at the next inspection to accept or reject the hypothesis.

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Summary

- Get your facts lined up
- Do a reasonable analysis by using information from experts
- Use both art and science
- Make a decision and hedge it as best you can
- Always try to get the solution into \$'s and time so every one can understand it.