



# 412<sup>th</sup> Test Wing



*War-Winning Capabilities ... On Time, On Cost*



**U.S. AIR FORCE**

## Adventures in Reliability: Heavily Censored Data

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**Approved for public release; distribution is unlimited.**

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*Integrity - Service - Excellence*



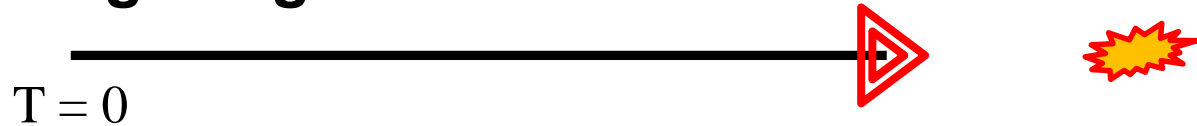
# Flight Test Failure Data



- **Best case is to observe right, left or interval censored data**

- Fails during a flight...that's all we know.

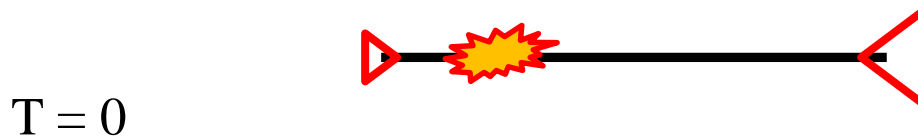
- **Right:**



- **Left:**



- **Interval:**



- Interval data happens when multiple flights occur before a failure is observed.

- **We will ignore intervals this time...maybe next time.**



# Rehash of Rocket Motor Data



## Catastrophic Missile Failures During Launch

- **20,000 missiles in inventory.**
- **1,940 field firings of the missile.**
- **From June 1997 to March 1998 there were 3 catastrophic failures of the motor.**
- ***Estimated service life = 20 years.***
- ***Saw catastrophic failures at:***
  - ***T = 8.5, 14.2, and 16.5 years.***

Olwell, D., Sorell, A. (2001), Annual Reliability and Maintainability Symposium.

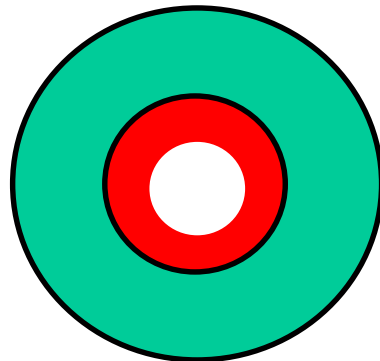


# Possible Failure Causes

## How do we analyze this?... →



- **Believed Failure Mechanism (acc. to NSWC-IH):**
  - **Thermal cycling—caused propellant-to-case bondline AND/OR propellant-to-propellant bondline to fail.**
  - **Causes the surface area to increase and explosive ignition of propellant.**



Motor  
Crosssection



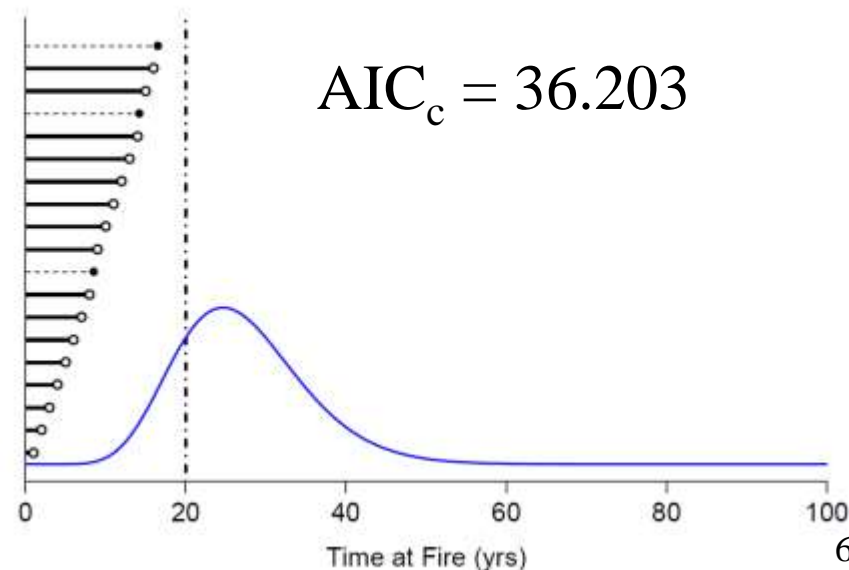
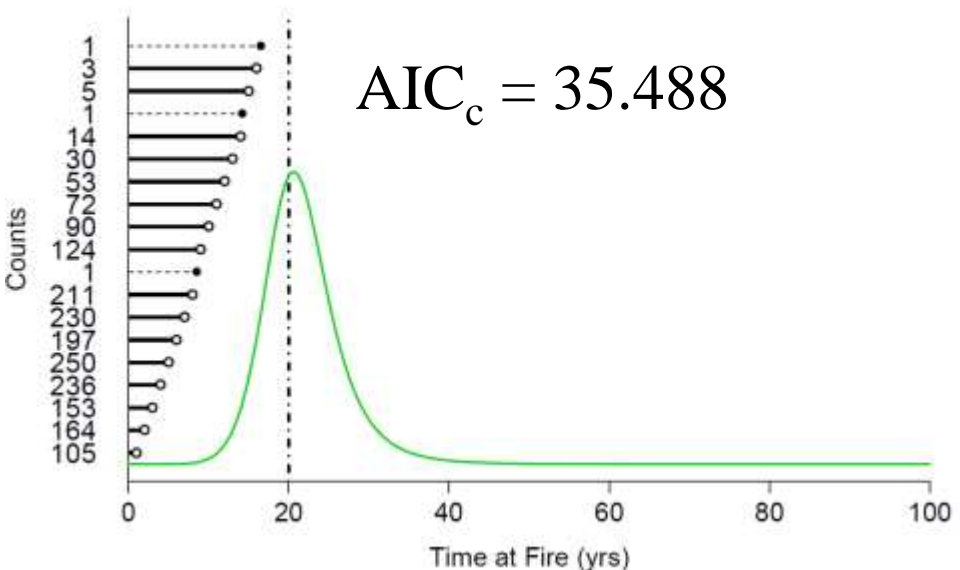
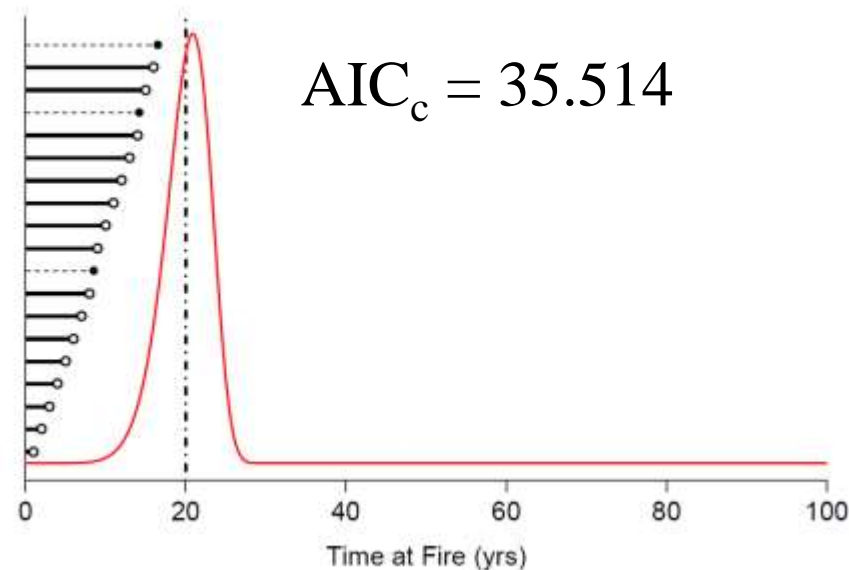
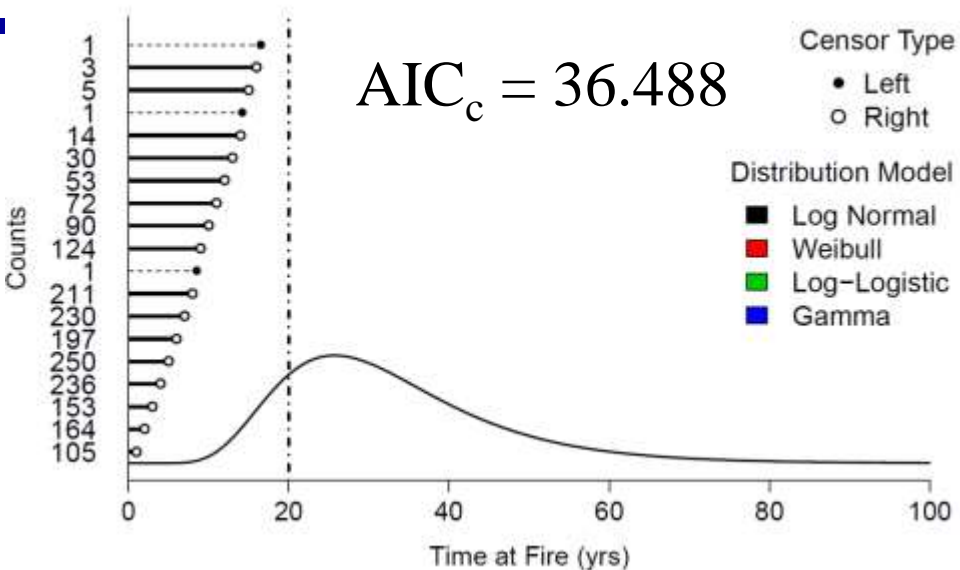
# → ...With one of many models. Choose your Adventure



- **Probability Models:**
  - Exponential
  - Lognormal
  - Weibull
  - Logistic
  - Log Logistic
  - Rayleigh
  - Frechet
  - Normal
  - SEV
  - LEV
  - ...
- All have descriptions of why they are useful.
- **Censoring ⇒ Model Fitting Difficulty**
  - Use likelihood methods...
- *Which one should we use?*
- *Does it matter?*

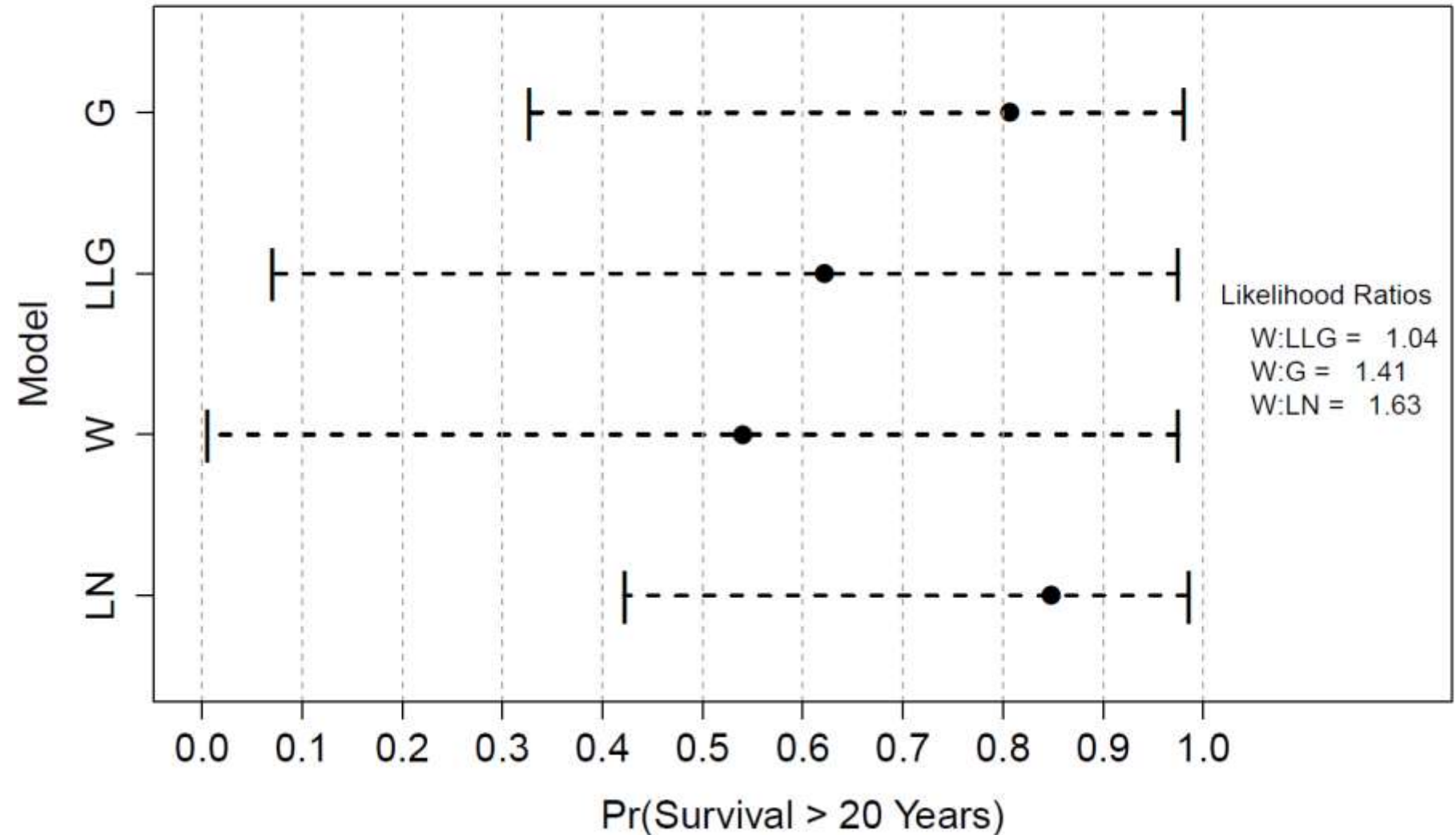


# Fitted Life Models {Best is $MIN(AIC_c)$ }





# Which model would you choose? Based on Reliability Estimation and CI's





# Summary



- **Stake holders on both sides of the fence may choose different models based on interests.**
  - **Uncertainty in decisions, or indecision.**
  - **Implies model selection uncertainty.**
  - **Somebody has to choose...unbiasedly.**
  - **What tool or method will they use?**
- **Who can justify their choice?**
- **MORE QUANTITATIVE RIGOR**
  - **More to come on this in the future...**