

412TW-PA-15213



Adventures in Reliability: Heavily Censored Data

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**AIR FORCE TEST CENTER
EDWARDS AFB, CA**

May 12-14, 2015

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**AIR FORCE TEST CENTER
EDWARDS AIR FORCE BASE, CALIFORNIA
AIR FORCE MATERIEL COMMAND
UNITED STATES AIR FORCE**



412th Test Wing



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



U.S. AIR FORCE

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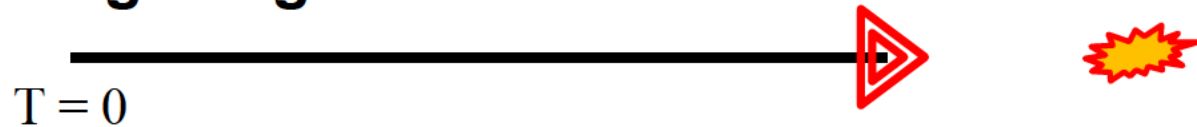
Flight Test Failure Data



- **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.

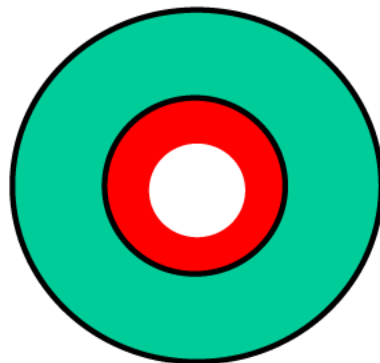


Possible Failure Causes

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



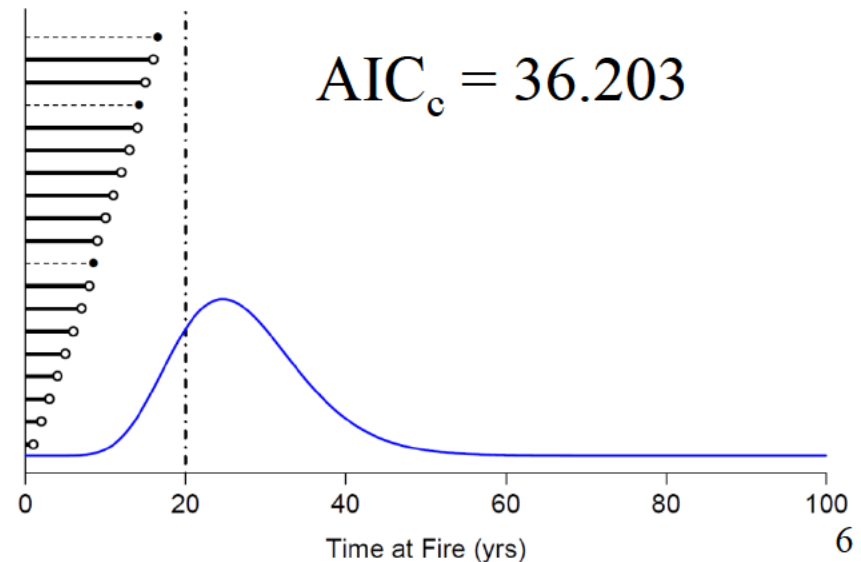
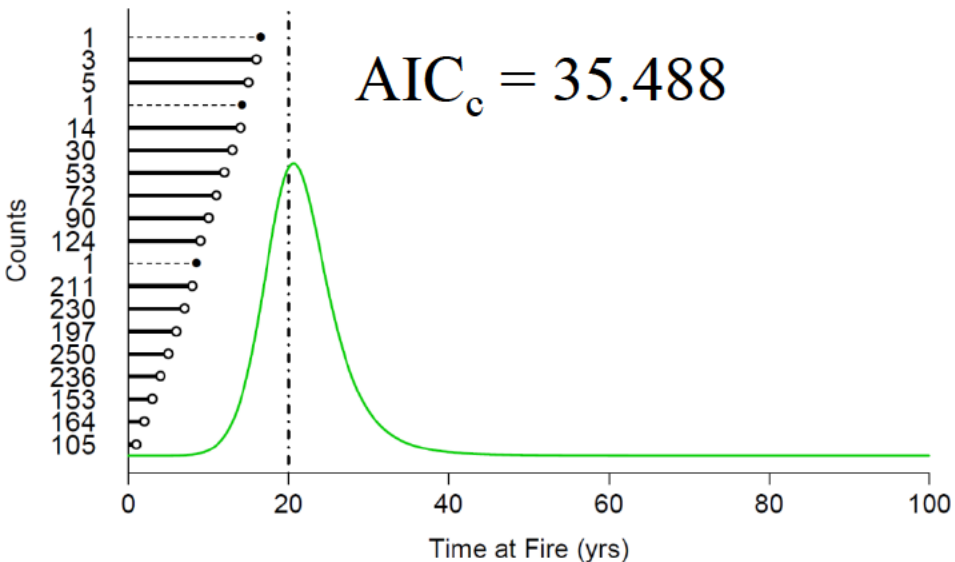
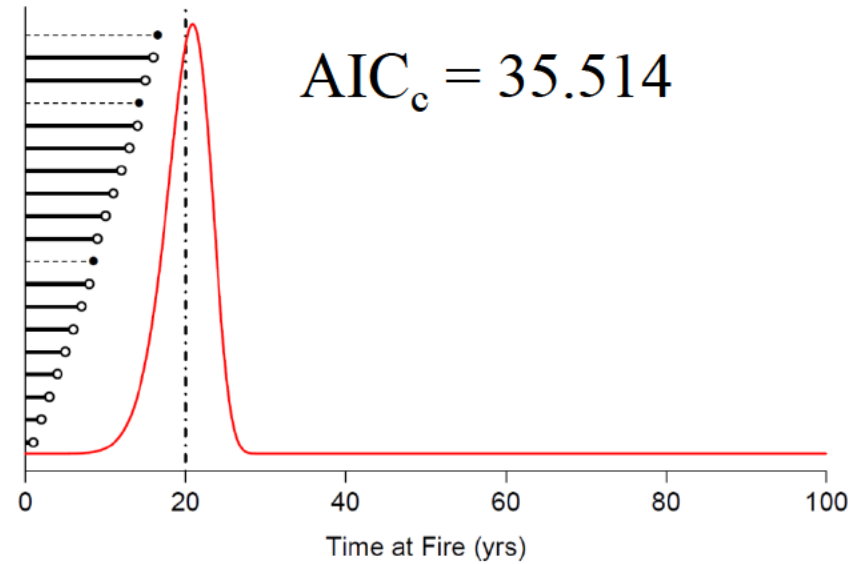
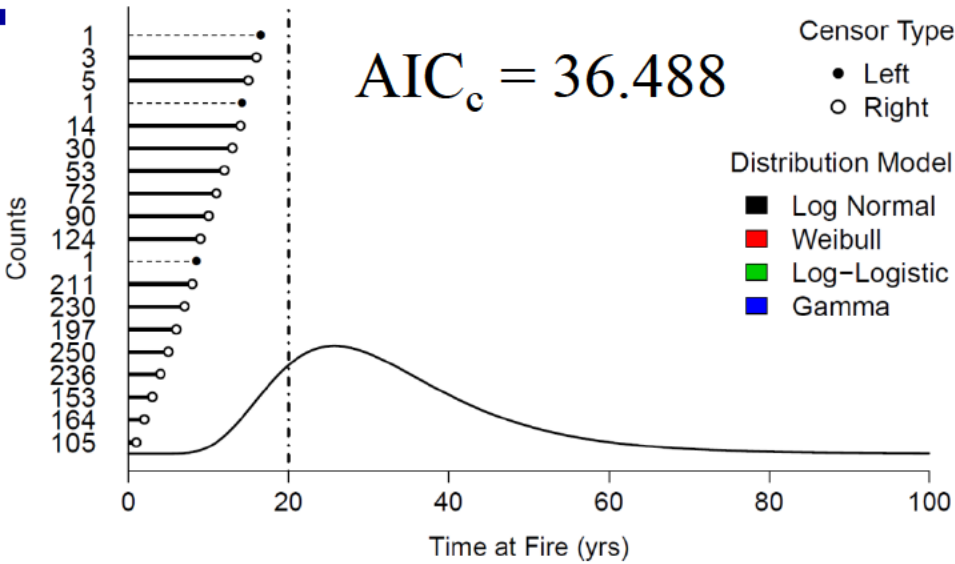
→ ...With one of many models. Choose your Adventure



- **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?*

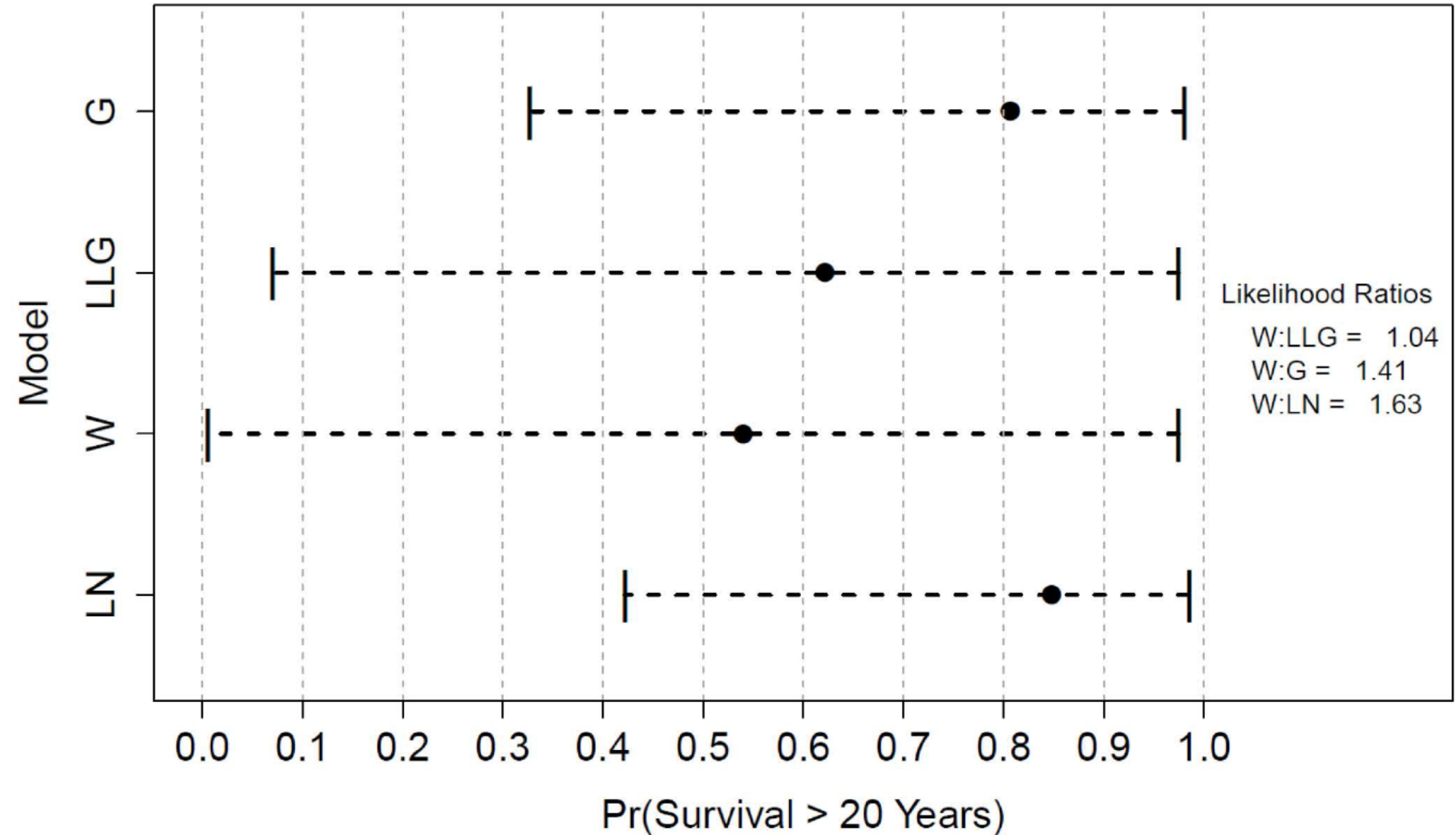


Fitted Life Models {Best is $MIN(AIC)$ }





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...**