# Weibull Analysis and Advantages
## Carl Tarum, Director of Software Research, Fulton Findings
### www.WeibullNews.com

**What is Weibull Analysis?**

When you test parts to failure, this is called Life Data. There will be variation. For example, if you test a drone while flying in a hover mode, the flight time will vary.

In the 1950's Dr. Weibull proposed the Weibull equation that is a useful tool for estimating life data behavior.

$F(t) = 1 - exp[-(t/\eta)^\beta]$, where

| | |
|---|---|
| $F(t)$ | cumulative distribution function |
| $exp$ | exponential function |
| $t$ | time to failure |
| $\eta$ | "Eta", Characteristic life |
| $\beta$ | "Beta", Weibull Slope |

**Sample Tests**

Suppose you test a drone with fresh batteries, and get times of 375, 381, and 400 seconds. Then test 6 flights that have been 3 weeks from charging. Times are 262, 280, 304, 308, 321, and 356 seconds. Next you test with extra weight, and get times of 246, 255, 287, and 290. (These are actual test data from this author's testing.)

You expect that time after charge and extra weight will affect flight time. These data can answer the following questions:

- Is flight time affected by time since charge?
- How does weight impact flight time?
- Are there enough data?
- Is Weibull a good fit for the data?

SuperSMITH® software provides a Weibull plot of the data (Figure 1) Reading from the chart, 10% of flights with fresh batteries would only last 363 seconds, and 90% will end before 402 seconds.
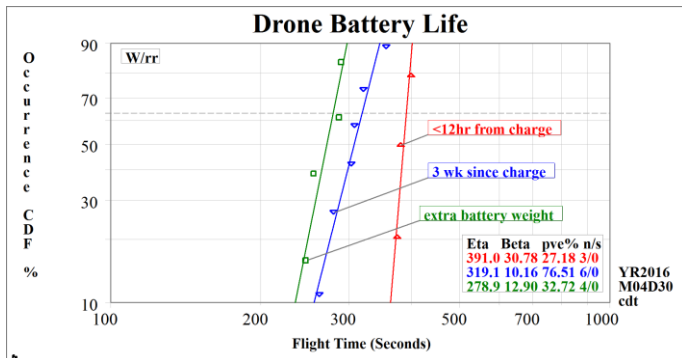


*Figure 1 Drone Battery Life*

**Analysis**

**Flight Time affected:** From Figure 1, the average flight time for freshly charged batteries is 386 seconds, while flights 3 weeks since charge have 308 seconds. Extra weight reduces time to 271 seconds.

> Further data can produce a model for change in flight duration with respect to time since charge, and extra weight.

**Data Sufficiency:** A likelihood ratio test and contour plot (Figure 3) show that tests with extra weight or time since charge are significantly different from the tests with freshly charged batteries.

**Fit Estimation:** The p-value estimate (pve%) comes from Monte Carlo studies where millions of sample data were fit with a Weibull distribution. When this value gets below 10% it is an indication that the fit may not be a Weibull. When it is 5%, it indicates that 95% of the time a random sample would give a better $r^2$ and you should consider other distributions. The Figure 1 fits are good.

**Solution Methods**

There are two common ways to solve a Weibull. The first is least squares rank regression, as shown in Figure 1. Maximum likelihood Estimation (MLE) is the second. MLE tries different models for the data until maximum likelihood is obtained.
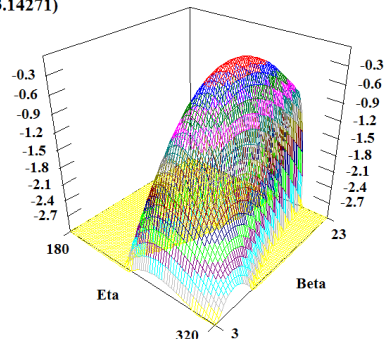


*Figure 2 Likelihood Solution Surface for Extra Weight*

With MLE, one can come down from the "peak" (as shown in Figure 2) and get a contour shape (Figure 3). In Figure 3, the blue oval shows the possible combinations of the true Eta and Beta for the test set that had been 3 weeks since charge. The separation of

the red curve shows that we have 90% confidence that there is a difference between fresh batteries and those that have sat 3 weeks.
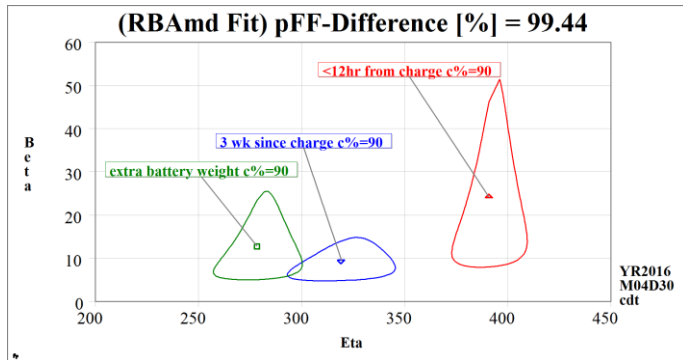


*Figure 3 Likelihood Contour plot 90%*

## Mixture Analysis

Sometimes we get "dirty data," as shown in Figure 4. Perhaps there are multiple failure modes, or different stress levels, but the data are lumped together. SuperSMITH YBath™ will analyze mixture data and can estimate the parameters of the individual failure modes if part failure detail is not available.
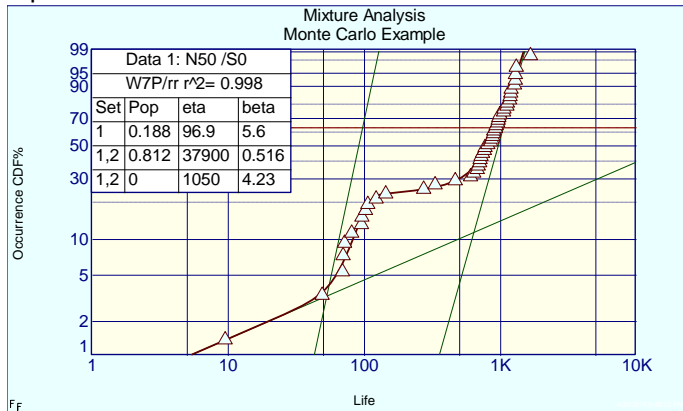


*Figure 4 Mixture Analysis*

## Test Design

Suppose you have a new motor design that should have a longer life. How many motors do you need to test, and for how long, to prove that the new motors are superior? SuperSMITH has a test plan section to determine how many test hours are necessary.

**How can we help you?** (Training/Software/Consulting) Fulton Findings™ provides training in Life Data analysis. We also sell software, books and provide analysis and consulting

**Training:** In addition to the samples shown above, classes cover other models, such as Normal, Gumbel, Lognormal, and Crow-AMSAA. We also cover warranty data and accelerated life testing.

With the 3 day class, students get a copy of *The New Weibull Handbook* by Dr. Robert Abernethy (ISBN: **978-0965306232**), the FULL SuperSMITH Software package, and a tutorial booklet including over 50 examples with step-by-step solutions. Class time includes presentation, hands-on data generation, and two afternoons working through problems on your laptop computers.

Our PUBLIC classes are available through SAE, DSIAC, the University of Tennessee, and other organizations as listed on our web site. We can also come to your site and teach a PRIVATE class to minimize employee travel. We give training worldwide in several languages.

**Software:** SuperSMITH is designed for Windows™ XP or later, and also runs on an Apple with Windows simulator. Disk, memory, and cpu requirements are extremely low. The software runs even on a small Windows tablet. Several languages are available and can be changed in seconds.

**Consulting:** If you have questions about your data or the fit, please contact us. We are happy to offer advice for quick questions on the software or data analysis. For more detailed analysis, our consulting services are available reasonably.

## DEMO Software

A free DEMO version of the software can be downloaded from our web site. This has all of the features. As a DEMO version, it will modify your data before analysis so you can see the performance, but the calculated parameters will not fit your original data.

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Fulton Findings™
SuperSMITH® Software
www.weibullnews.com

Wes Fulton, CEO, (310)548-6358
Wes33@PacBell.Net
PO Box 6517   San Pedro, CA USA 90734

Carl Tarum, Dir Software Research (989)780-5088
ctweb@att.net  (Also contact for technical support)

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