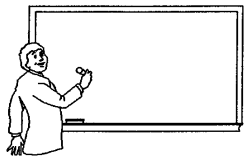


WeibullNEWS

Sixth Edition | From:Dr. Bob Abernethy & Wes Fulton | Summer 1992

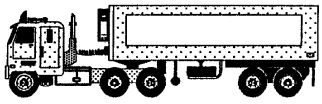
Dr. Bob Learns from New Software: Playing with MonteCarloSMITH™ software has actually changed my mind on some things: WeiBayes is much more accurate for small samples than I ever dreamed. The t_0 correction needs larger sample sizes than I thought, 15-20 minimum. t_0 cannot be accurately determined from small samples. Beta is log normally distributed. Wes has taken 18 months to develop this amazing software. He has also achieved a major upgrade of WeibullSMITH™. There is a companion program, Visual*SMITH, to tell you about. There is much to say so we have expanded this edition of the WeibullNEWS.

WeiBayes for Improved Accuracy: Prior knowledge of the slope, beta, can significantly improve the accuracy of small sample Weibulls. WeiBayes is a one-parameter (η) Weibull. WeiBayes will have smaller uncertainties than the two parameter Weibull. Similarly, the two parameter (η & β) Weibull has smaller uncertainties than the three parameter (η, β, & t_0) Weibull. WeiBayes uncertainties are reduced by the prior knowledge of the slope, beta. A Weibull library or databank to provide Weibull slope histories is strongly recommended to get the WeiBayes advantage.

For example, let's compare 90% confidence bounds for B1 life. For N=4, beta=3, and eta=100, MonteCarloSMITH ™ was used to generate 1000 trials, ranking B1. The SUMMARY report option produced the following 5 and 95% bounds with t_0 on, t_0 off, & WeiBayes on:

	Weibull t_0	Weibull	WeiBayes
B1 90% Bounds	1078-0.	64.3-3.5	26.8-15.1
Range	1078	60.8	11.7

WeiBayes is about 100 times more accurate than the three parameter Weibull and about six times more accurate than the two parameter Weibull. This benefit is available **if** beta is known. The conclusion is that WeiBayes should be considered for all small sample Weibulls as well as Sudden Death Testing, **if** beta is known. Figures 1-3 show typical MonteCarloSMITH™ Summary output for a case discussed later.



Prediction of Future Failures-Weibull Risk: Even a few failures of heart pacemakers, heavy truck steering links, aircraft engines, or aircraft fuselages is enough to cause great apprehension. Responsible management immediately wants to know how many failures will occur in the next few months or year. Weibull risk analysis can provide accurate forecasts of future failures. In the past spreadsheet calculations were necessary but this capability is now provided in WeibullSMITH™. For example, Figure 4 shows a Weibull plot for 10 steering failures of wheel heavy trucks in a fleet of 14510 trucks. If the milage is known or can be approximated, how many failures may be expected in the next years? (Figure 4A was made with Visual*SMITH directly from a WeibullSMITH™ saved file.) The technique is also used to predict the effect of corrective action, safety hazards, spare parts requirements, maintenance labor, warranty and support costs.

Cost Effective Calibration Intervals: In the past calibrations were done at fixed intervals, perhaps monthly or quarterly. Some instrumentation is much more stable than others. Some instrumentation need recalibration daily, and other types, yearly or longer. If instrumentation that is out-of-calibration is identified when returned to the laboratory, a Weibull plot is ideal for determining optimal calibration intervals. We define failure as out-of-calibration and suspensions as in-calibration. For critical instrumentation, the B1 life is used as the calibration interval. (See Figure 5) This interval, about 21 months, would provide that 99% of the instrumentation in service is in-calibration. For other instrumentation, B5 (33 months) or even B10 (40 months) may be used.

Calibration Intervals Continued... All the usual Weibull slope interpretations apply. Shallow slopes show infant mortality, perhaps calibration or installation problems. Random events, $\beta = 1$, may relate to abusive practices such as overpressure, over voltage, handling accidents, contamination, etc. Slopes greater than one show wearout modes. Instrumentation returned for recalibration at fixed intervals should use the WeibullSMITH™ inspection options.

One of the newest calibration interval Weibull methods is based on monitoring the differences between redundant instruments. The first few differences after the pair of instruments is recalibrated are used to plot the Weibull. (Figure 6). The B95 difference is recommended as a signal to recalibrate again. This procedure is easily computerized as part of the data reduction to automatically flag out-of-calibration signals. Mr. Paul Barringer, Director of Product Engineering, Hydril Corporation, contributed this new application. He is writing papers for ASQC on both calibration techniques. We will advise when they are published.

MonteCarloSMITH™...for the Weibull Gurus: This new software provides **unique** capabilities. Confidence intervals, median estimates and distributional analysis are obtained for β, η, B lives, reliability, r, r^2, t_0, and the Weibull line. Median rank regression and maximum likelihood estimates may be simulated with or without, suspensions. The Weibull, Normal, and Log Normal distributions may be sampled and probability plotting for all three is simulated. t_0 and WeiBayes are options. Many of these capabilities are not available with any other approach. A computer tutorial is included in the software. WeibullSMITH™ will accept the output of MonteCarloSMITH™ for Weibull line bounds and distributional analysis. Typical problems include:

(1) confidence bounds for all parameters of important data sets with or without suspensions,
(2) comparisons of two data sets to determine if they are significantly different,
(3) distribution analysis for all Weibull, Normal, & Log Normal parameters,
(4) calculation of uncertainties and efficiencies of zero-failure and Sudden Weibull tests.

For example, how about confidence bounds for t_0? MonteCarloSMITH™ 95% estimates are shown on Figures 1-3. For a true value of $t_0 = 100$ and sample size of seven, t_0 bounds extend from -12,279 to +895!!! Note the large bounds for all parameters with the third parameter compared to without t_0 & also, the increase in the correlation coefficient with t_0.

WeibullSMITH™ a Major Upgrade: Normal distribution analysis as well as Weibull and Log Normal is now available. The new Fisher Incomplete Matrix bounds are more efficient, and instantaneous and are extrapolated to the margins. For MLE, the new Likelihood Ratio bounds are more precise but calculation intensive. You may plot the Likelihood Function Contours using Visual*SMITH ™. (Figure 7)The likelihood function is reported to be the most important single statistic, in the latest Royal Statistical News and Notes. Visual*SMITH ™ will also plot risk forecasts (Figure 4A), & the Cumulative and Probability Density Functions for all WeibullSMITH™ data sets, (Figure 8), in case you want to know the "shape of things". The MLE routines are reprogrammed for greater accuracy. Instead of Parameters on the plot, B Lives may be selected, or for management presentations, it may be left blank. There is a new Report Option that writes a Summary of your analysis including reading the confidence bounds for B Lives. Output to color plotters is now included. Perhaps the most important new option is Weibull Risk Failure Forecasting. "Reliability Assurance" covered in the last edition, is also included.

The New Weibull Handbook: The research projects have slowed progress on the Handbook. We thank those that have contributed case studies and will soon be contacting you to review our editing. There is room for more case studies if you have something interesting. I plan to include an order form in the next WeibullNEWS in early 1993.

Weibull Presentations & Workshops: Dr. Bob will speak at the electric utilities Inter-Ram Conference, August 28. Wes and Bob will give a paper at the ASME Winter Annual Meeting in Anaheim the evening of November 11. We will return to the Detroit Chapter of the Society of Reliability Engineers the first week in March. My last public workshop in 1992 will be for SAE in Detroit, four days, September 28-October 1, 1993. WeibullSMITH™ software is provided. Call Ruth Walker at 412 776 7148. In 1993 two day Advanced Weibull Workshops for experienced Weibull analysts (like you) will complement three Basic Weibull workshops for SAE, ASME and University of Tennessee. Software will be included. Wes Fulton will join me for some seminars.

Please...Return the Postcard Included... or if you can't find it, send your address to Wes to continue your free subscription to the WeibullNEWS. Give us your comments, and requests for improved Weibull analysis.

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Figure 1 MonteCarloSMITH Changes Menu

```
A...add/edit B-values = 1% + 5%
B...bring data from disk
C...censored (random suspensions) = NONE
H...histogram of suspensions = OFF
M...method = rr
O...order output parameters = beta; eta ; r; r^2; B1; B5; t0
P...points in each individual trial (n) = 7
Q...quantity of MC trials (nMC) = 1000
R...report = SUMMARY/2.5,97.5%
S...sample (Monte Carlo)
T...t0 = best fit with sample t0 of 100
V...view output
W...WeiBayes = OFF
X...exit
```

Figure 2 Simulation Summary for 95% Bounds with t_0

MonteCarloSMITH Summary

rank%	beta	eta	r	r^2	B1	B5	t0
2.5	0.588	176.688	0.933	0.871	0.085	1.316	%-12279.
97.5	65.512	13382.923	1.000	1.000	12200.006	12604.257	894.64

NOTES: rr

Figure 3 Simulation Summary for 95% Bounds without t_0

MonteCarloSMITH Summary

rank%	beta	eta	r	r^2	B1	B5
2.5	2.015	779.348	0.870	0.757	96.437	217.578
97.5	9.289	1185.481	0.993	0.986	625.470	761.999

NOTES: rr

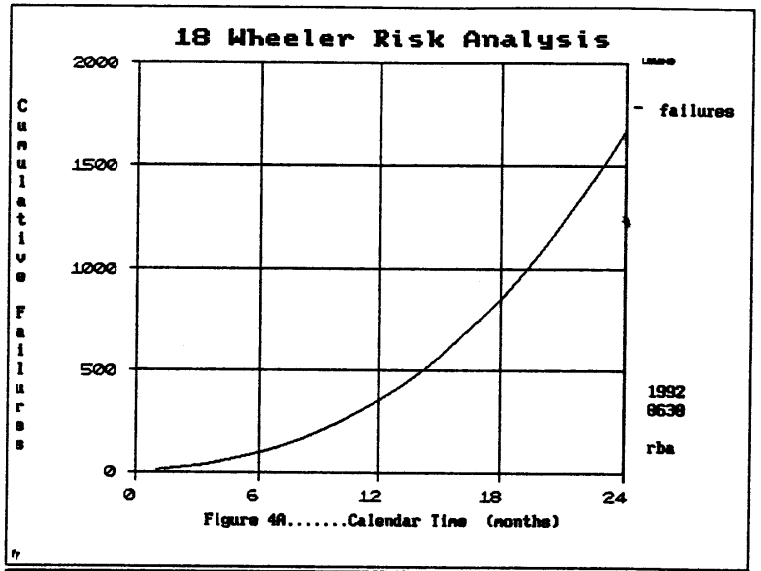

Figure 4A.....Calendar Time (months)

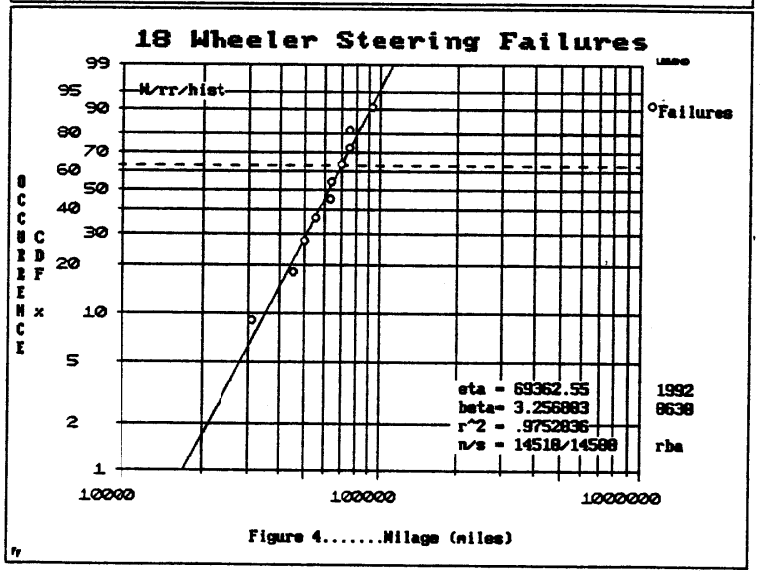

Figure 4.....Milage (miles)

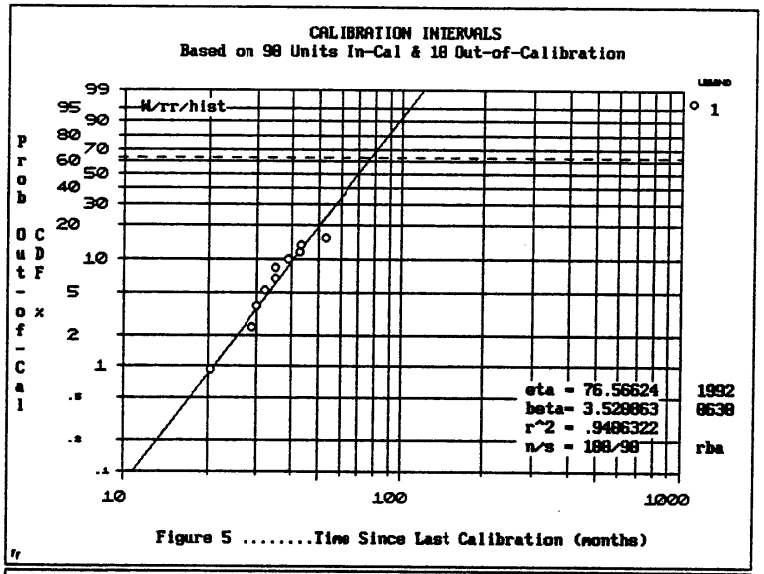

Figure 5 .....Time Since Last Calibration (months)

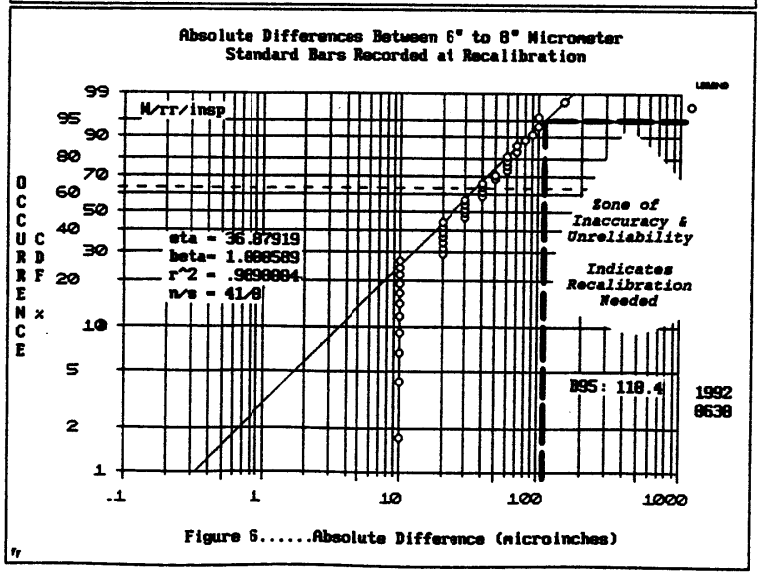

Figure 6.....Absolute Difference (microinches)

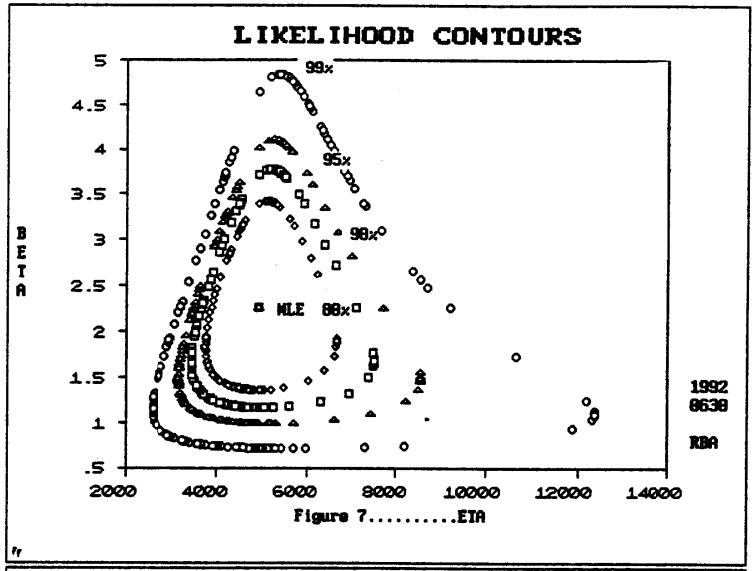

Figure 7.....ETA

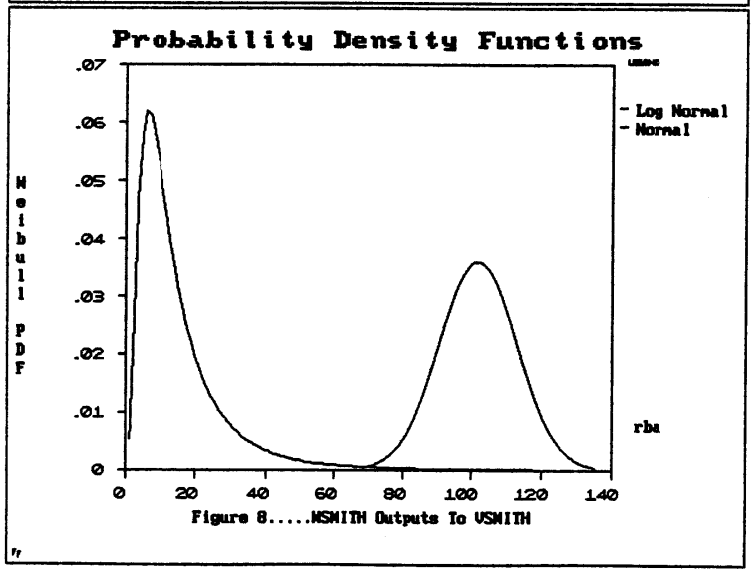

Figure 8.....NSMITH Outputs To VSMITH