Excerpts From SuperSMITH™ Weibull And SuperSMITH Visual Instruction Manual and Guide

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SuperSMITH Weibull and SuperSMITH Visual Software Instruction Manual and Guide,

Fourth Edition

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Preface

This manual is intended as a home study guide or a 1 to 2-day training class in how to use SuperSMITH Weibull and SuperSMITH Visual software for those who want more details about the common features of the software. This manual does not include the more elaborated subjects and details offered in PlayTIME for SuperSMITH.

SuperSMITH Weibull (SSW) is a stand-alone menu-driven probability plotting/analysis software program. The program provides for best-practice Weibull analysis including many techniques not available elsewhere. SuperSMITH Weibull software is the defacto standard for life data analysis, prediction, and for evaluating variability and uncertainty in practically all industries. Capabilities of SuperSMITH Weibull include Weibull, normal, lognormal, and Gumbel (lower and upper) distributions, and variations of these, as well as likelihood plotting, confidence plotting, design comparison, probabilistic analysis, outlier detection, optimum replacement, failure forecasting, test substantiation planning, accelerated testing, and mixture analysis.

SuperSMITH Visual (SSV) is a general plotting/analysis program with complimentary capability to WinSMITH Weibull. Capabilities of SuperSMITH Visual include general function plotting, transforms, curve fitting, aggregate cumulative hazard (ACH) plotting, and Crow-AMSAA/Duane reliability growth plotting.

SuperSMITH Weibull and Visual software offer more useful options and capabilities than any other current life data analysis program, although it is extremely compact in size. This wide ranging usefulness is due to the many applications in industries including automotive, components, aerospace, medical, electronic, electric power, petrochemical, nuclear, rail transport, dental, materials analysis and others. The compact program size allows easy transfer/use over networks. This training manual is intended to illustrate most of the frequently used capability and many of the applications. Hopefully, it is helpful for both novice and expert.

The reference book for all the material herein is The New Weibull Handbook, authored and published by Dr. Robert B. Abernethy. SuperSMITH Weibull and SuperSMITH Visual software are written by Wes Fulton.

You can obtain the latest version of DEMO software for no-charge downloads from Wes Fulton's website (http://www.weibullnews.com) or from Paul Barringer's website (http://www.barringer1.com).

See Barringer's website for general introduction to reliability in practice, the latest Problems at http://www.barringer1.com/problem.htm, and details from Dr. Abernethy's library posted as no-charge downloadable files concerning Weibull Analysis.

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SSW-SSV Get Software Ready

Software Setup Details-
SuperSMITH Weibull and Visual are two different programs supplied on the same CD and provided as the SuperSMITH software.

Assume the installation CD is placed in the D: drive. Assume the program will be setup into the C:\SMITHW directory (the setup program will make this directory—or you can specify the location of the directory in a dialog box). The programs are 32-bit Windows programs. These 32-bit programs will Windows systems from Windows 95 through Windows VISTA on workstations or servers. RAM requirements are modest and space required on the hard drive is also modest.

Note to LAN managers: perform the entire setup on the machine you intend to use (do not set it up on one machine and copy the files to another server). Install these five OCX files on the client machines: **COMDLG32.OCX, MSFLXGRD.OCX, PICCLP32.OCX, SPIN32.OCX, and THREED32.OCX.**

For each program, run its SETUP.EXE file on the CD provided. From Windows, select START, select RUN and enter D:\SETUP.EXE after the path locating SETUP.EXE. Or you can use BROWSE to locate SETUP.EXE on the CD, and then run the SETUP.EXE program. Follow the on-screen instructions given during SETUP.

Starting Instructions: Start the software from the main Windows screen by first selecting START and then PROGRAMS. Then select and run the appropriate SuperSMITH software program as listed either above the PROGRAMS selection or by first selecting PROGRAMS. You should initially see the opening screen with one button displaying "<Y> Yes I Agree To The Above" and another button displaying "<X> Exit". Choose "<Y> Yes I Agree To The Above" to accept the usage disclaimers shown and continue to the main screen. The main screen displays all of the options available in the software with icons and menu items for each choice plus a data spreadsheet and a results window.

Usage Instructions / On-line User Manual: The use of the software is described in detail in the on-line HELP file user manual that comes with the software. To access the electronic user manual, choose the HELP option from the main screen. **The New Weibull Handbook**© (ISBN 0-9653062-3-2) by Dr. Robert B. Abernethy is the reference manual for the methodology in our Weibull-related software. This handbook is the standard reference used to describe Weibull technology and is available separately.

Server/LAN Operation: Server/LAN use is completely acceptable given that ***the purchaser's network administration must limit access to one simultaneous user per purchased copy***. The software reads information from the command line (can be different for each user) to assist LAN operation. Add " –cXXX" to the comand line to store user-specific configuration files into path XXX. Add " –tYYY" for temporary file storage location as path YYY. Include a space between entries. Please see the HELP file in the software for more command line examples. See section 35 for an example.

Getting Started After Software Is Loaded-

Here are a couple of tips about the appearance of the software differences. For SuperSMITH Weibull (*the probability plotting and analysis software*) refer to Figure 1:

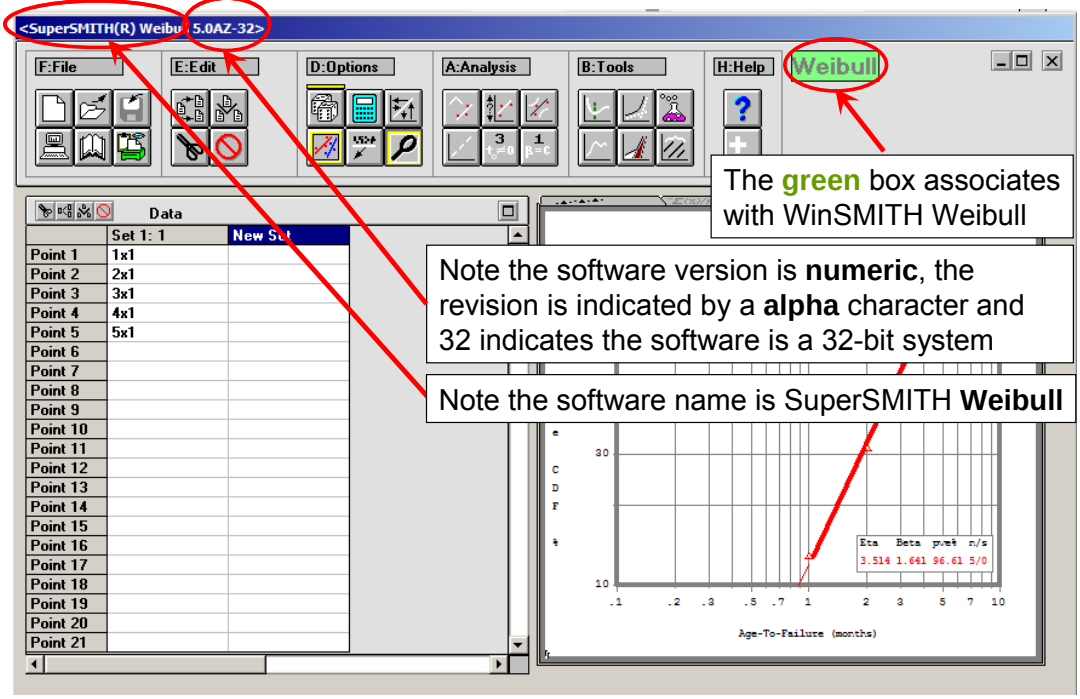


Figure 1: SuperSMITH Weibull

Figure 2 shows the icons for SuperSMITH Weibull.

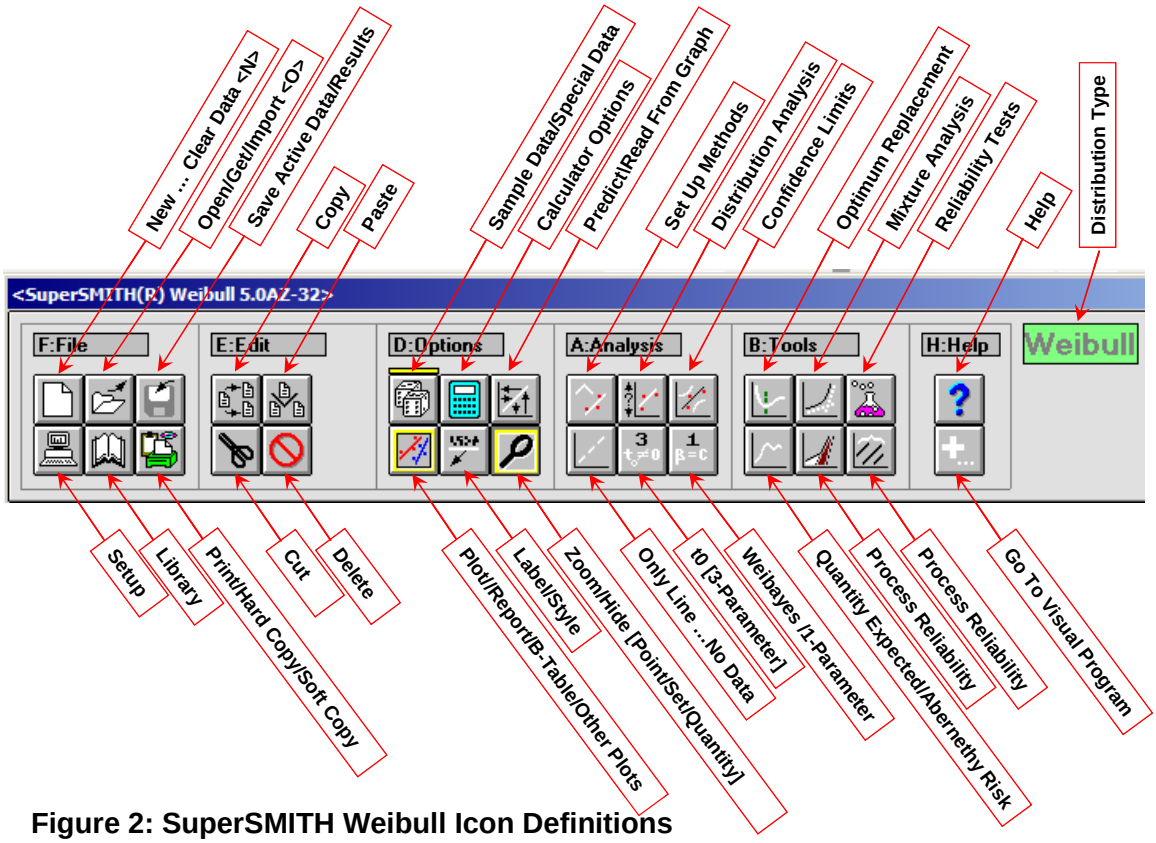


Figure 2: SuperSMITH Weibull Icon Definitions

Look at the differences for SuperSMITH Visual (*the general scientific graphing and Crow-AMSAA plotting software*), in Figure 3. Notice the name Visual in the red box and fewer icons than for SuperSMITH Weibull.

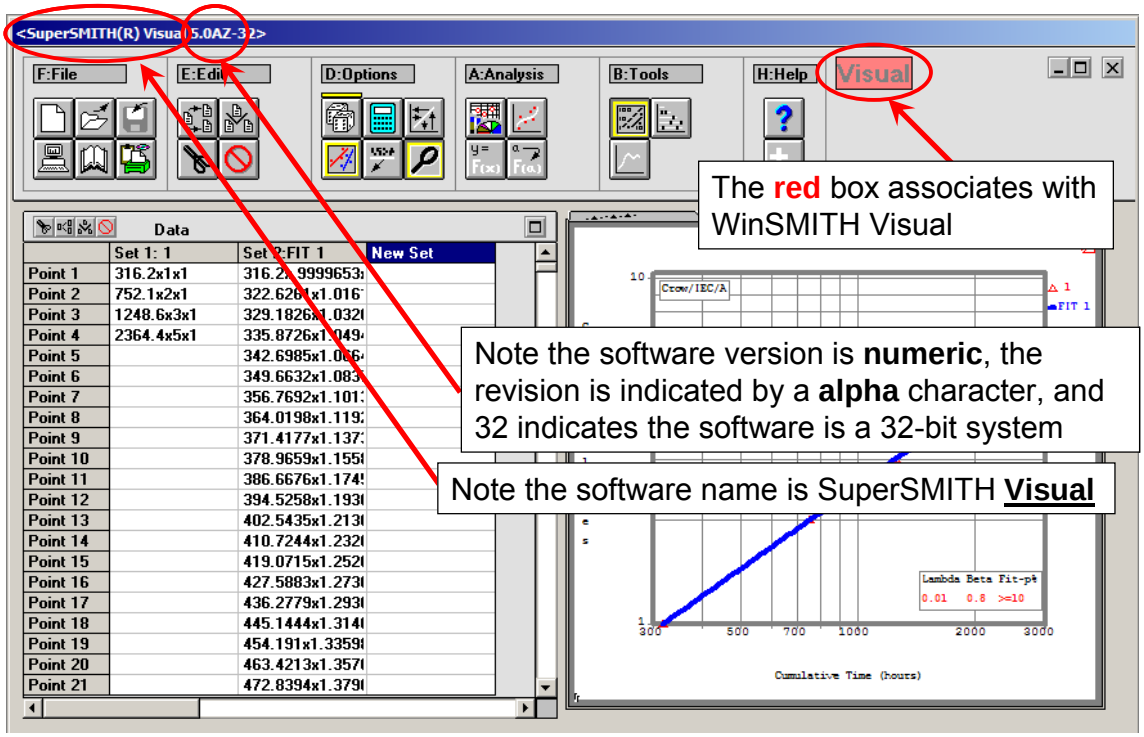


Figure 3: WinSMITH Visual

Figure 4 shows the icons for WinSMITH Visual.

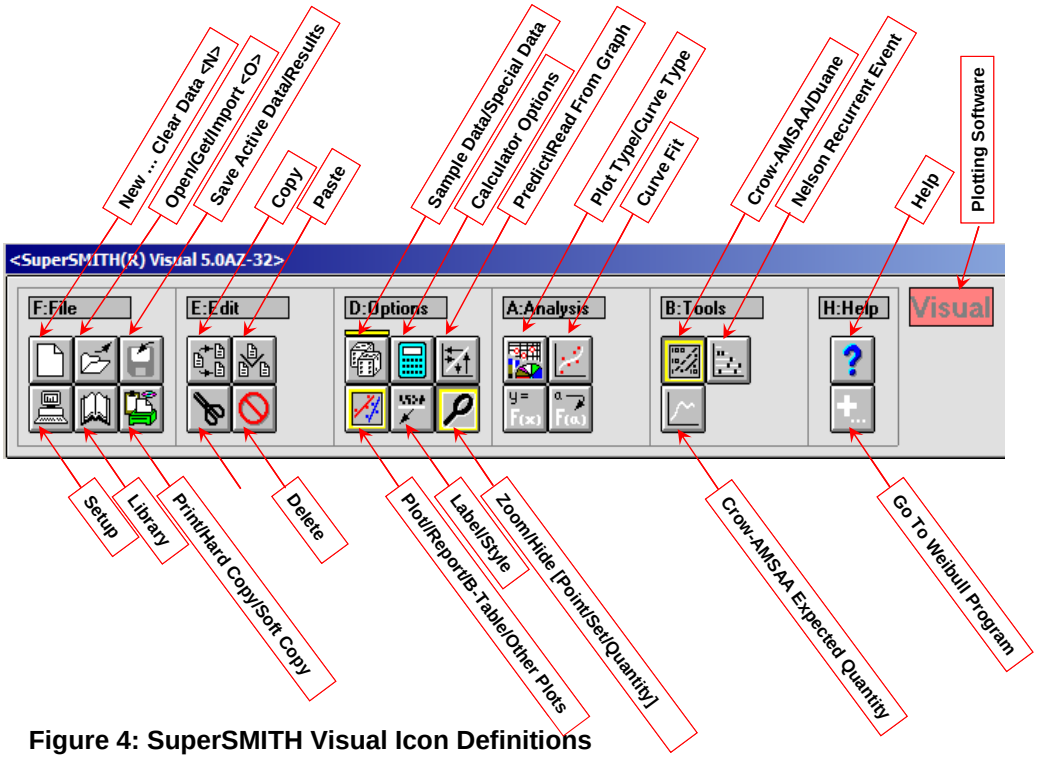


Figure 4: SuperSMITH Visual Icon Definitions

Notice each software has a spreadsheet for data entry, a thumb size graph, and special icons for peforming the calculation or routine chores. Traditional pull-down menus are available.

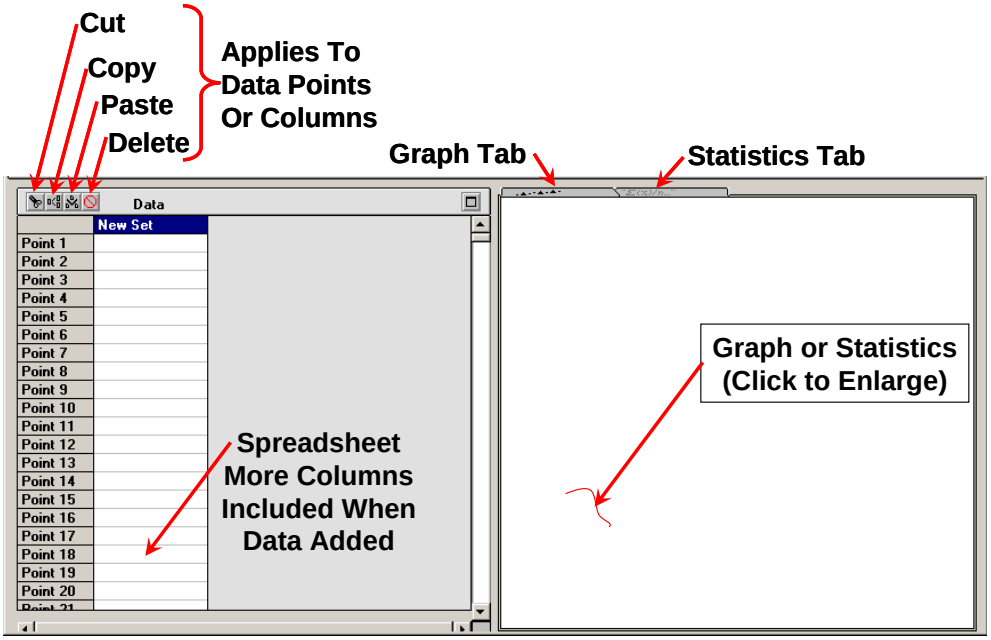


Figure 5: SuperSMITH Weibull And Visual Spreadsheet With Thumbnail Graph

Both SSW and SSV have on-board help files which address specific issues. Access the search issues by clicking on the **?-mark** icon or clicking on the pull down help menu as shown in Figure 6. SSW's help file is more extensive than WSV.

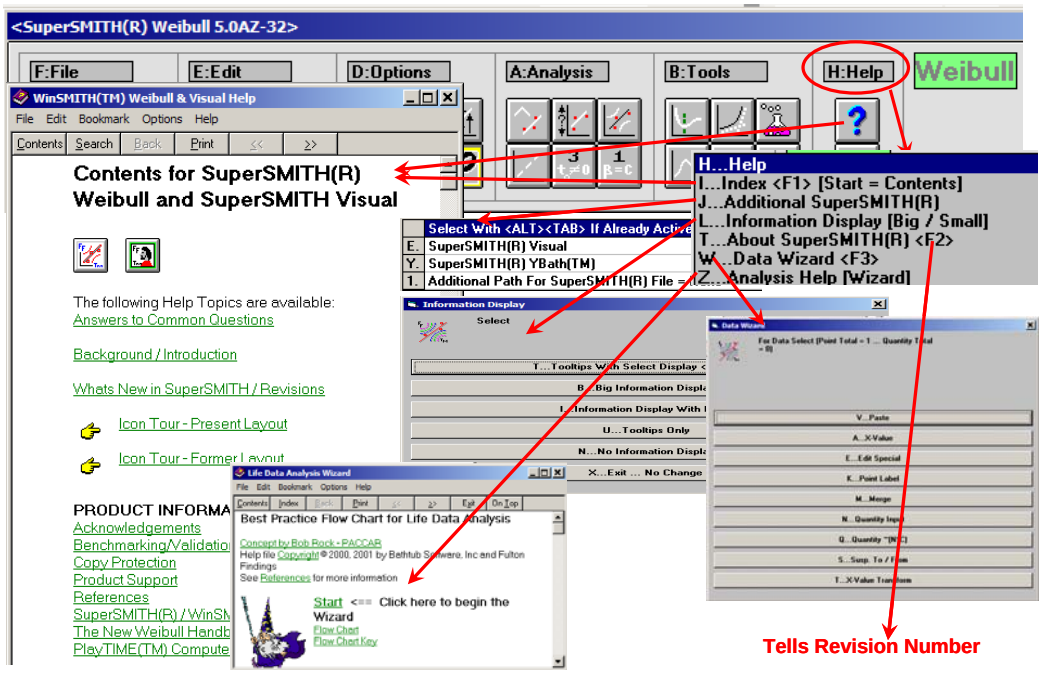


Figure 6: SuperSMITH Help Files—Weibull Is Shown

The yellow finger pointing to the Icon Tour in Figure 6 provides hyperlinks to the active help icons from the front page for accessing detailed help files.

SuperSMITH Weibull Software For Probability Plots-Excerpts

1. Manual Data Input-

The spreadsheet becomes active when you click in the sheet (just like occurs with Excel™) and it changes appearance to give you clues the sheet is active, see Figure W1.

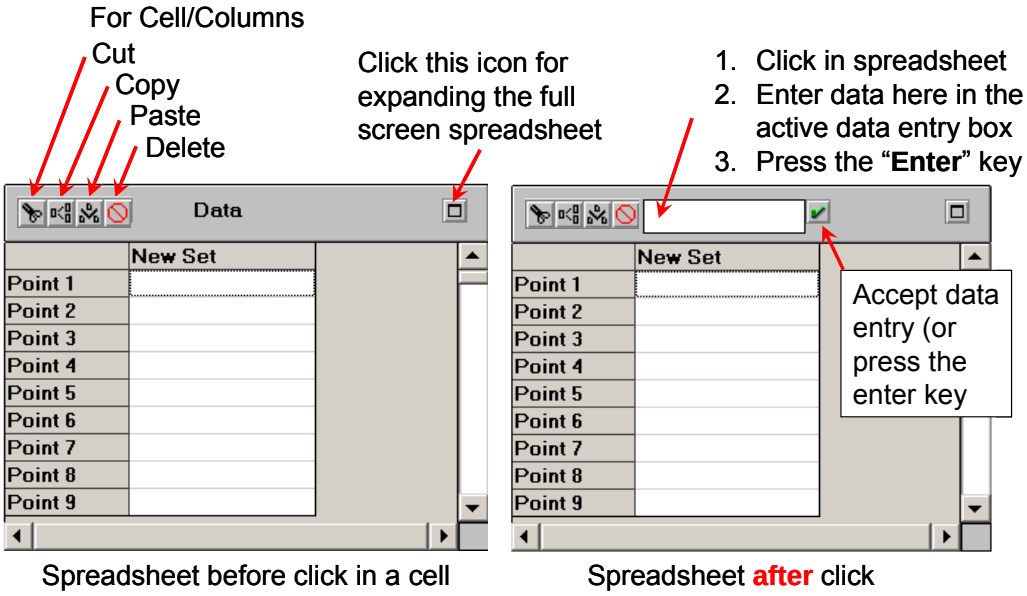


Figure W1: SuperSMITH Weibull Spreadsheet

Use the active data entry box to enter data (8, 14, 17, 21, 33—you do not need to order the data) by use of the edit box such as 8, **Enter**, 14, **Enter**,…33, **Enter**. Check for data input errors by viewing the data ***BEFORE*** you move the mouse over the thumbnail graph or return to the main screen. When the mouse is moved over the graph, the data are automatically ordered and you loose the input arrangement. If the data entry is a suspension, enter a "—" (minus) sign before the number. See Figure W2 for data appearance before and after entry.

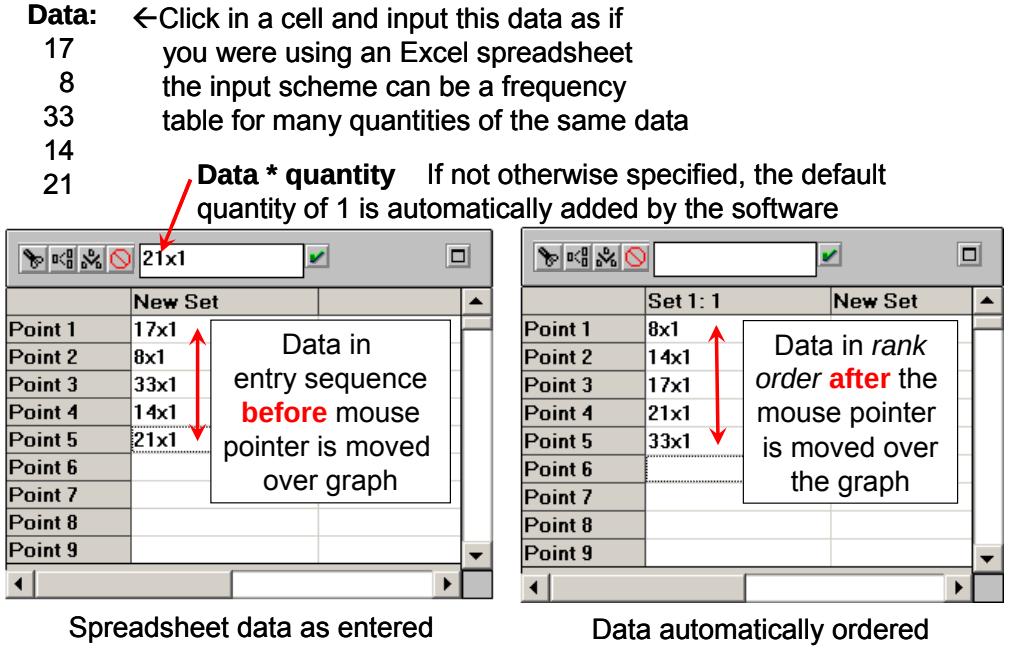


Figure W2: SuperSMITH Weibull Spreadsheet During And After Data Entry

2. Make A Probability Plot-

Using the spreadsheet data in Figure W2, move the mouse pointer to the small size plot. The thumbnail plot appears as shown in Figure W3.

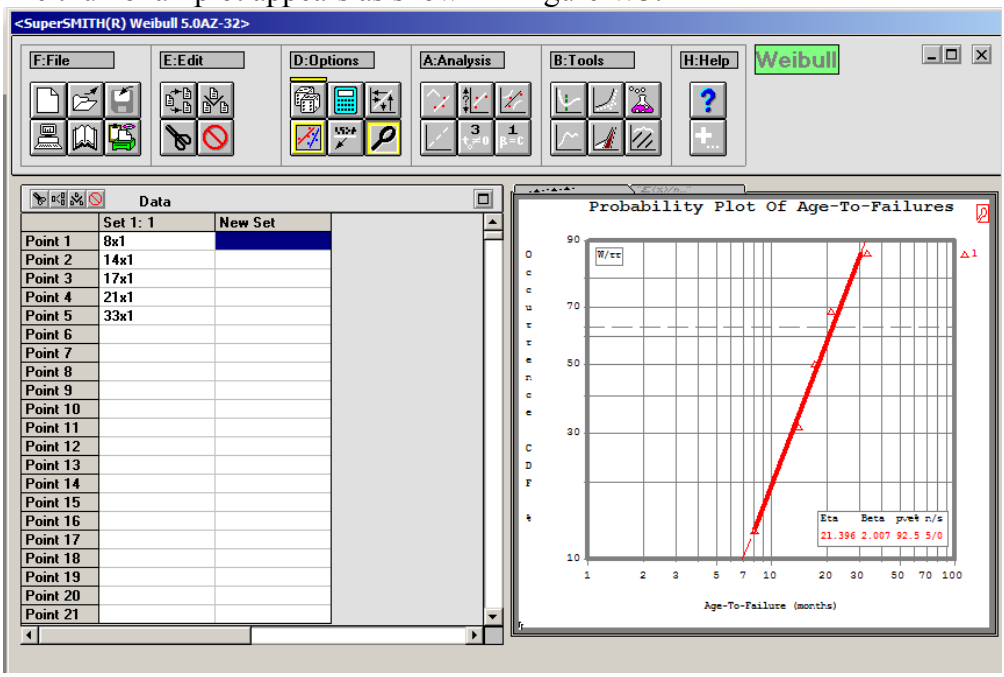


Figure W3: SuperSMITH Weibull Probability Plot

Enlarge the thumbnail plot, by mouse click. It will go to full screen as in Figure W4.

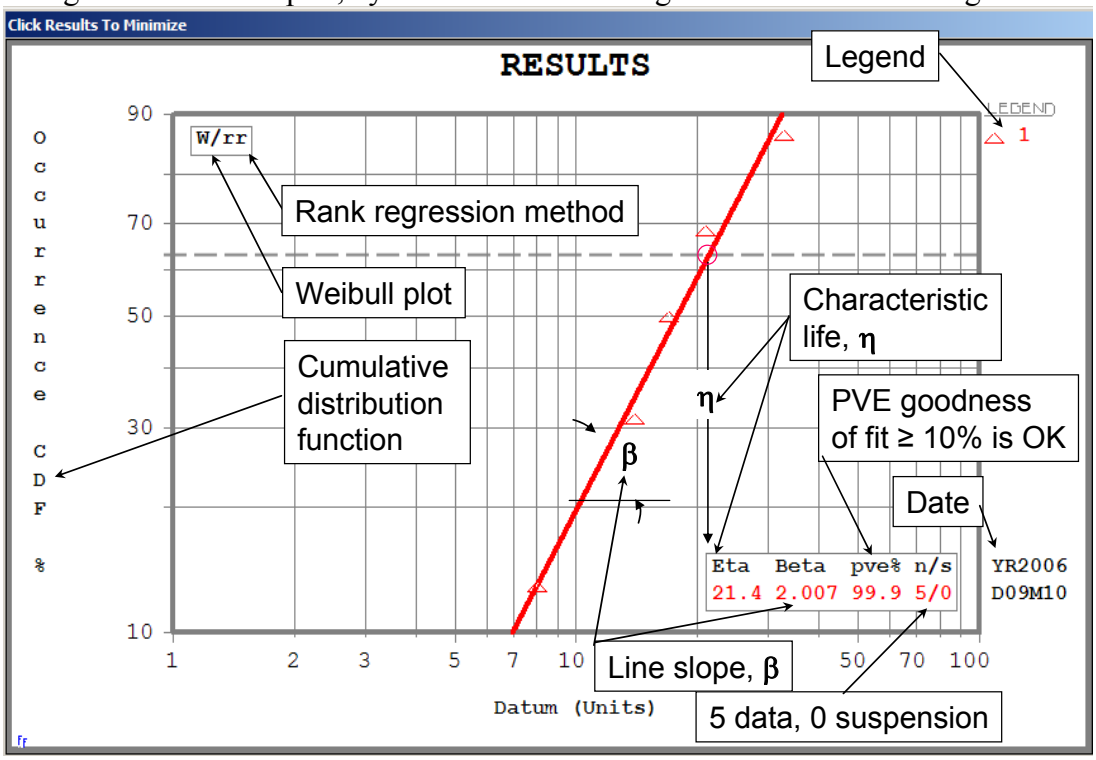


Figure W4: WinSMITH Weibull Full Scale Plot

Remove the full screen plot, by touching the ESCAPE key or left click with the mouse.

3. How To Interpret The Weibull Probability Plot-

In Figure W4, notice:

- It is a **Weibull** probability plot. It uses **rank regression** calculations methods [W/RR]
- **Shape factor β** (line slope **β is 2.007** --it is literally the rise over run calculation for 1:1 graph paper which is obtained under the Zoom icon using Option O) suggests a component wear out failure mode. Shape factor β is dimensionless.
- **Location factor η** (characteristic life **η is 21.4** using raw data units [hours, years, months, cycles, etc.]) occurs where the trend line crosses the 63.2% double line for the cumulative distribution function (CDF).
- The plot contains **5 pieces of data = n** and **0 suspensions = s.**
- **Pve%** ≥ 10% show a good fit of trend line to data. The **coefficient of determination, r^2 = 0.981**, (see tab behind graph) is also a measure of goodness of fit and it suggests the straight line explains 98.1% of scatter in the data.
- The graph was made on the **date** of October 9 , 2006 → **D**09**M**10**YR**2006
- The **small "1"** in the upper right hand corner by the triangle symbol is **the legend** for the graph. DSW graphs can contain up to 12 trend line data sets.

Ten percent (B_{10} or L_{10}) of the population is expected to fail in 7 units of time or less—this means 90% of the population will exceed 7 units of time. Ninety percent of the population will fail in 32.4 units of time or less. Thus 90% - 10% = 80% of the population is expected to fail in the range of 7 units of time to 32.4 units of time.

4. How To Import One Column Of Data From Excel To WSW-

A single column of Excel data can be imported into SuperSMITH Weibull in two steps as shown in Figure W5:

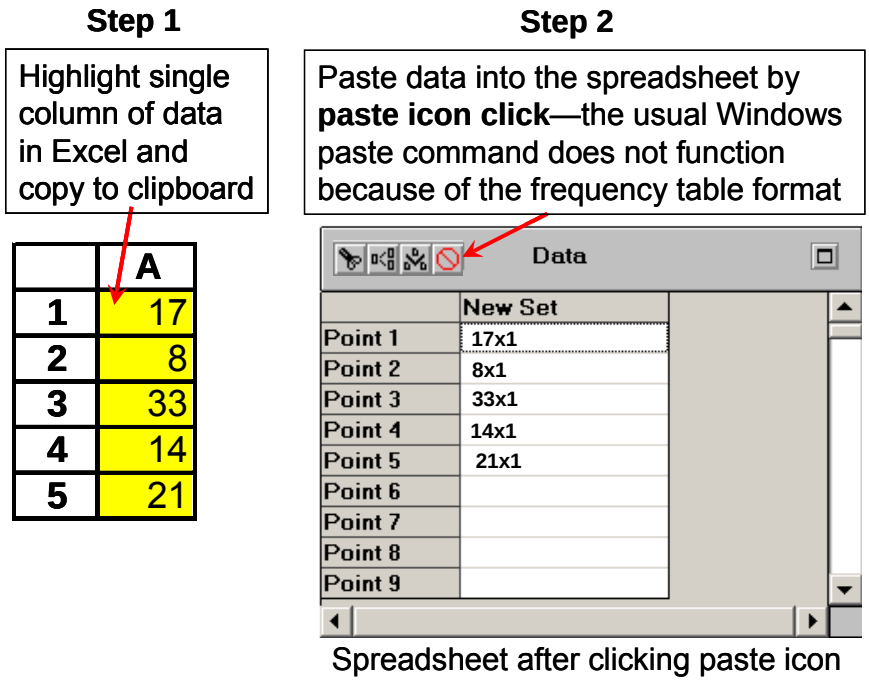


Figure W5: SuperSMITH Weibull Data Import From Excel

The pasted results will look like the data shown in the right hand side of Figure W5.

5. How To Import Two Column Data From Excel With Suspensions-
In Excel, make sure the **left hand column contains age-to-failure** and the **right hand column contains the quantity** (number of occurrences) of data. Copy the data from Excel and paste into WinSMITH Weibull **using the paste icon**—then the WinSMITH Weibull software will recognize the data requires some decisions and select the option that the two column data has "quantities" in the right hand using **Option B** to get the data shown in Figure W6:

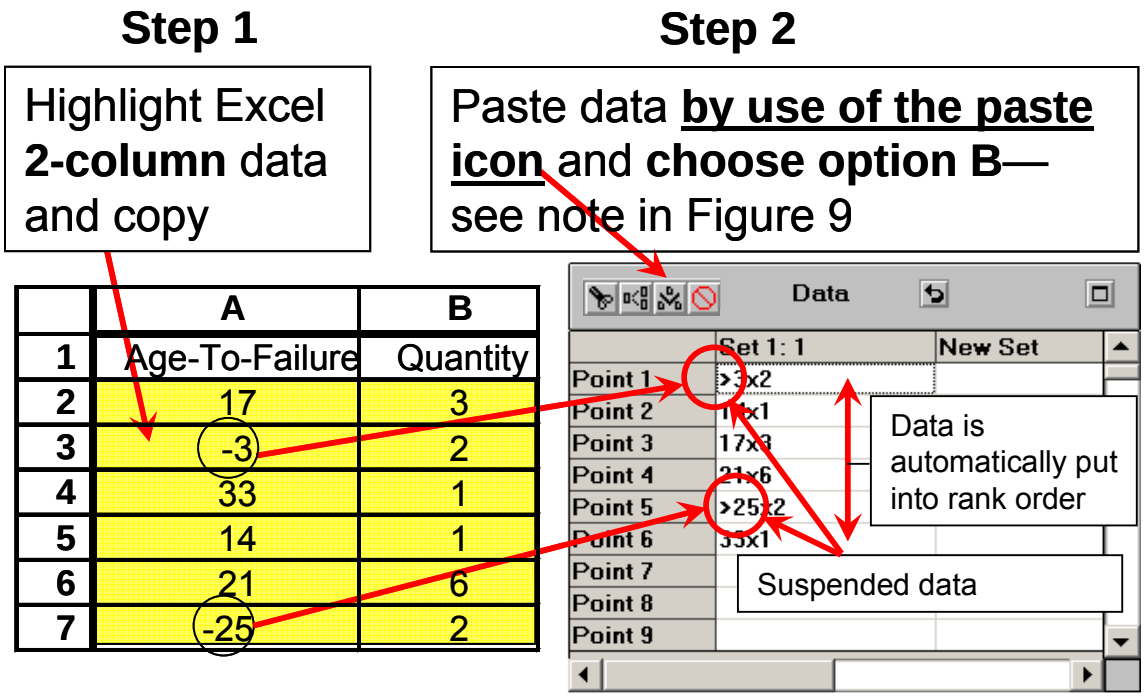


Figure W6: SSW Data 2-Column Import From Excel

Figure W6 has suspended or censored data as evidenced by the "—" (minus) sign in Excel which translates to the ">" sign (which means the item will fail beyond the time) as shown in Figure W6. Thus WinSMITH Weibull handles the conversions automatically.

Complicated spreadsheets may have age and quantity in widely separate columns. Consolidate multiple columns into one column for insertion into WSW using Excel's CONCATENATE* function.

Data in column AA in the Excel spreadsheet is Age*Quantity for import as a single column of data for pasting directly into WSW.

An equivalent consolidation function involves use of the **&**-operator for concatenation. For example **=concatenate(c1,"*",q1)** in Figure W7 is equivalent to **=(c1&"*"&q1)** where the parentheses are optional with the **&**-operator but are shown here for clarity just as might occur for clarity in an Excel spreadsheet.

The concatenation function works well when many columns of data must be imported into WSW as columns of frequency data (Datum x Quantity) by copy and paste. See Figure W7.

Special note: Depending upon the Excel language selected, the concatenate function has different spelling (for example in the German version **concatenate = VERKETTEN**) and may cause Excel to behave differently for this task! The equivalent operator **&** seems to overcome most of these compatibility problems. Sometimes you may also need to use **"x"** rather than the asterisk **"*"**.

Use the Excel consolidation function "concatenate" to produce a **1-column** of data in Excel. Highlight the Excel data and copy to the clipboard. Insert the consolidated data into WinSMITH Weibull via the paste icon.

	C	Q	AA
1	17	3	17*3
2	-3	2	-3*2
3	33	1	33*1
4	14	1	14*1
5	21	6	21*6
6	-25	2	-25*2

The Excel consolidation function in column AA is
= concatenate(c1, "*",q1)
(the "*" text function tells Excel the information is not a math function but rather a text symbol)

Special note about the concatenate function: Depending upon the Excel language selected, the concatenate function has different spelling and may cause Excel to behave differently for this task! The equivalent operator, **&,** seems to overcome most of these compatibility problems. Sometimes you may also need to use **"x"** rather than the asterisk **"*"**.

Figure W7: SuperSMITH Weibull Data Imported From Excel

6. Data Entry Reminder-

When the mouse pointer is on the spreadsheet, a dialog box appears as a reminder concerning data format. The dialog tells you the data should be in the format of Data x Quantity [-Datum = Suspension]. The reminder dialog box is shown in Figure W8.

Mouse pointer and **tooltip reminder box** about data format. The memory jogger says the data must be in **Datum = age x Quantity = number of observations.** If the age is a suspension, it must be preceded by a **minus sign** to signify a suspension or censored data. The "_" allows labels on data points.

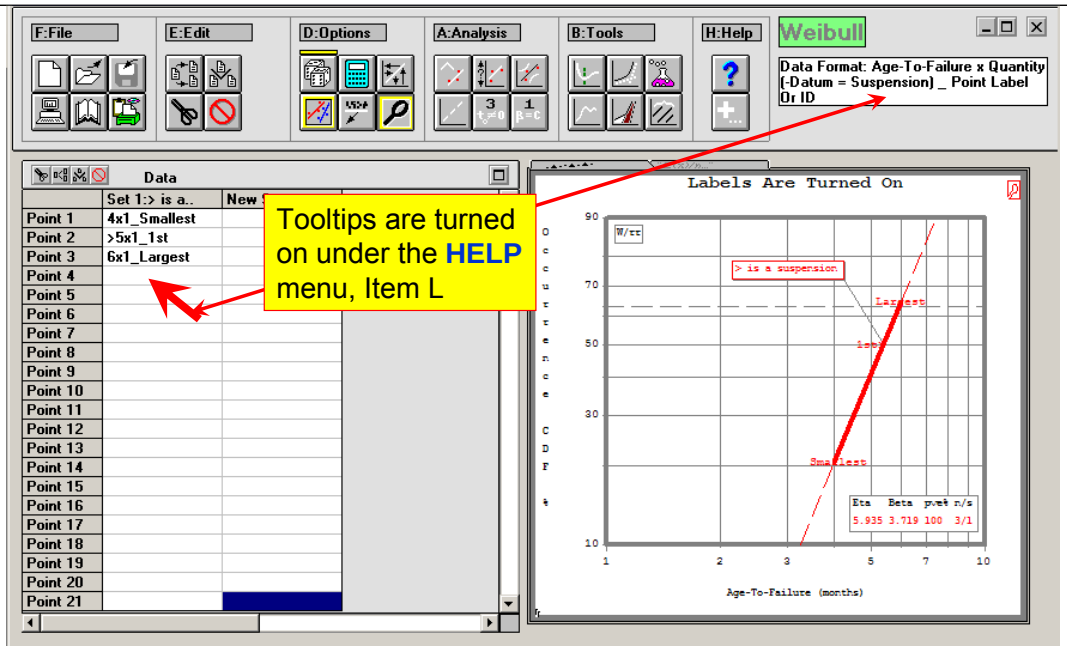


Figure W8: SuperSMITH Weibull Tooltip Reminder Box

Notice Figure W8 contains labels in the data sheet by inputting data as age-to-failure then use of the underscore symbol "_" for the label. Also note the censored or suspended data is shown on the graph as ">". These visual clues require use of the magnifying glass icon setting as shown in Figure W9.

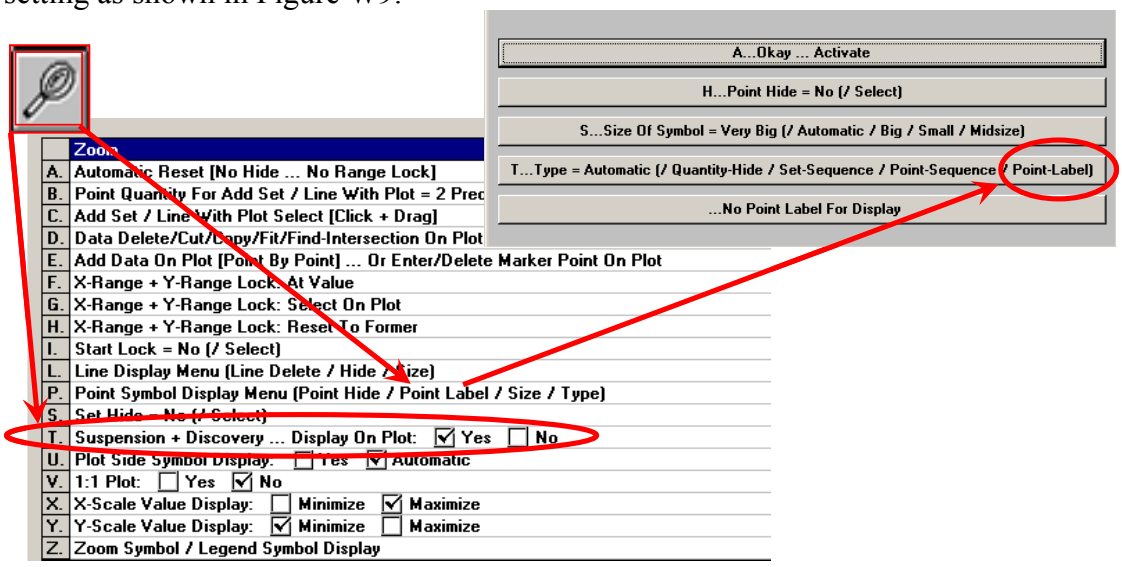


Figure W9: SuperSMITH Display Point Labels And Suspensions

SuperSMITH Visual Software Excerpts-

1. Manual Data Input-

The spreadsheet becomes active when you click in the sheet (just like occurs with Excel) and it changes appearance to give you clues the sheet the sheet is active as shown in Figure V1.

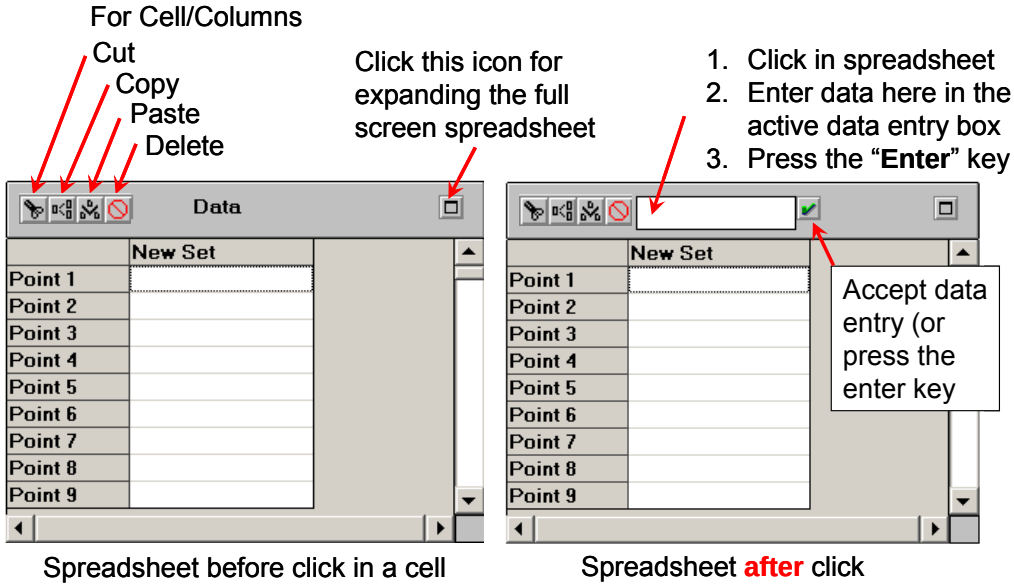


Figure V1: SuperSMITH Visual Spreadsheet

Data is enter into the plotting software in the format **X-scale * Y-scale * Quantity** (the quantity feature is also used for a Z-scale 3-dimensional plot and unless specified is by default = 1)—when the quantity is not specified, then the default value of "1" is supplied by the software. Unlike the probability plotting software, the data does not change after entry. If data is input in the wrong format (e.g., Y-scale*X-scale a data transform icon is discussed below to unscramble the error without data re-entry.

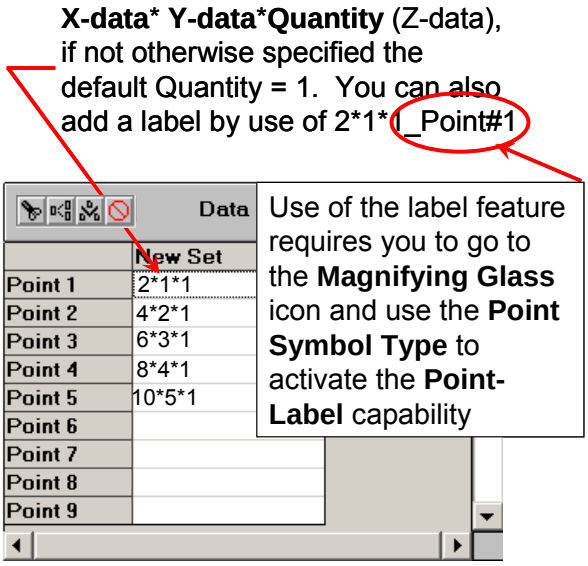


Figure V2: SuperSMITH Visual Spreadsheet Data Entry Format

Use the active box on the spreadsheet to enter data (2x1, 4x2, 6x3, 8x4, 10x5—the data must be in the sequence your want it to appear on the plot following the format X-data * Y-data * Quantity(Z-data)). For data entry, you can use the asterisk or the "**x**" or "*****" key to separate the data for use by the software. Input the data as 2*4, **Enter**, 4*2, **Enter**…10*5, **Enter**. The data will appear as shown in Figure V2.

2. How to make a plot-

When you have finished data entry, move the mouse over the thumbnail blank screen and the plot will appear in Figure V3. as data points and without trend lines. You can connect the dots by use of the Plot Type icon (bottom row, left icon) and choose curve type as point + line, line only, or point only. If you prefer, you can fit the data to a variety of different math models found under the Curve Fit icon on the bottom row, third from the left. Interpretation of the plot requires no comment.

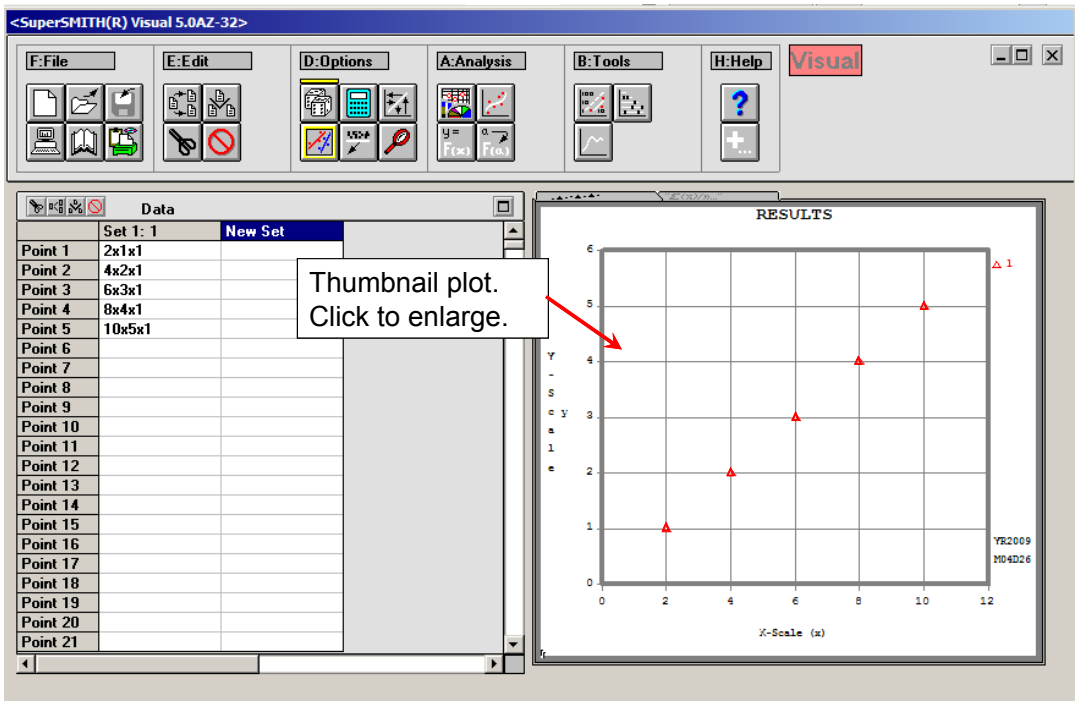


Figure V3: SuperSMITH Visual Spreadsheet Thumbnail Plot

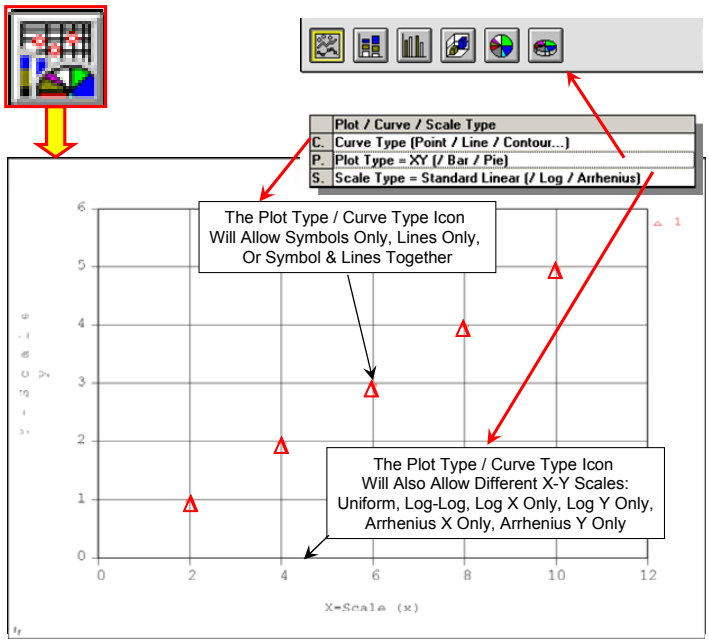


Figure V4: SuperSMITH Visual Spreadsheet Full Scale Plot

Enlarge the thumbnail plot in Figure V3, by mouse click and it will go full screen as shown in Figure V4.

You have options under the Curve Type in Figure 4 of connecting the dot, or you can have lines, only, etc.

Under the options of Scale Type in Figure 4 you can configure each axis for a different type of transform as required for the specific data.

3. How to Import X-Y data from Excel-

Make sure the data columns in Excel are **X-data** in the **left column** and **Y-Data** in the **right column,** the highlight the cells and copy. To paste the two data columns into WinSMITH Visual, click on the paste pot icon (DO NOT do a typical Windows paste into WSV because it won't work!!) and select option B from the paste into the spreadsheet dialog box which tells the software how to handle the data. The four steps are shown in Figure 5.

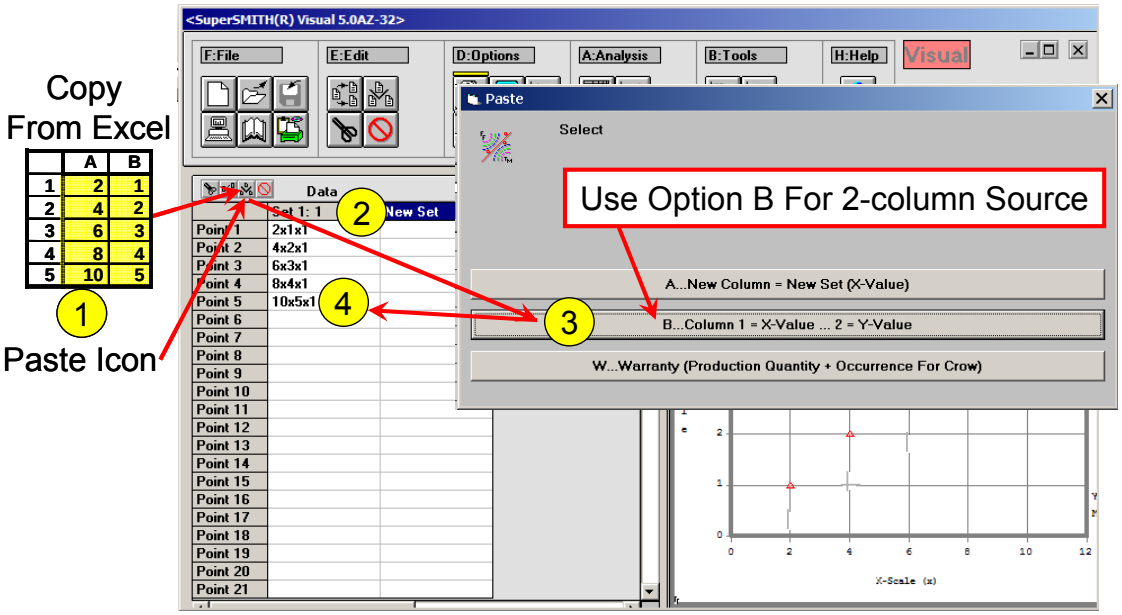


Figure V5: WinSMITH Visual Copy/Paste From Spreadsheet

You can also use the Excel concatenate function to take multiple columns of data and prepare a single column import using option A in Figure 5 during import—the concatenate function is explained in the SuperSMITH Weibull section of this manual.

4. Data Entry Reminder-

When the mouse pointer is on the SuperSMITH Visual spreadsheet, a dialog box appears as a reminder concerning data format. The dialog tells you the data should be in the format of X-Data x Y-Data x Quantity. The reminder box is shown in Figure V6.

In case your software does not have a tooltip dialog box, it may have been turned off. To restore the tooltip, go to the pull down menu icon. Choose option I to restore the tooltip box.

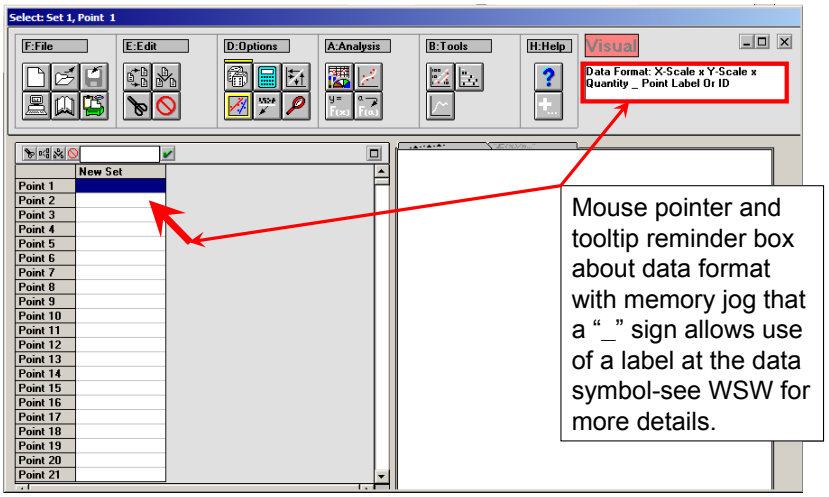
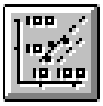


Figure V6: WinSMITH Visual Tooltip Reminder Box

5. Make A Crow/AMSAA Plot-

The Crow-AMSAA plot in log-log format produces a straight line for stable processes as a naturally occurring series of events (the trend line models the process and just not the system). The task of reliability engineering improvements is to put cusps on the trend lines by make improvements so as to reduce safety problems and reduce costs. Thus some judgment is required in selected the trend lines and where line segments start-stop. Also note that MTBF and cumulative failure rate go with repairable systems, and MTTF and instantaneous failure rate go with non-repairable systems.

When line slopes on the C-A plots of cumulative failures vs cumulative time is $\beta \sim 1$ the process is called a homogenous Poisson process. If $\beta \neq 1$ the process is called non-homogenous.



The following explains how to interpret the Crow-AMSAA plots under the C-A icon with options. C-A data *can only have suspensions at the end of the dataset* where the data is entered with suspended time and the same number of failures as last reported (eg, …1000*4, 1050*4). The Crow-AMSAA technique has three widely used methods and two less widely used rates, each with cumulative time on the X-axis and most produce straight lines for stable processes on log-log plots:

1. **Cumulative failure events vs cumulative time**—this is the default method which produces a line slope of β (if $\beta<1$ failures are occurring more slowly, if $\beta \sim 1$ no change in the failure rate, and if $\beta > 1$ then failures are occurring more quickly) and λ which is the Y-axis intercept identifying MTBF or MTTF = $1/\lambda$. This is the WinSMITH Visual **default method** involving a nose count of events and time. It is useful for predicting future failures and identifying cusps where significant events have occurred. [$N(t) = \lambda t^{\beta}$]

2. **Cumulative MTBF or MTTF vs cumulative time** which requires a transform of the Y-axis and thus the actual line slope of the trend line is $1-\beta$. This is **Option T** for WinSMITH Visual. This method requires a transform of the Y-axis (cumulative time)/(cumulative failures). The direction of the curve is a pointer for audiences with attention deficiencies: up for improvements, down for deterioration, and sideways for no change in reliability. [$M(t) = (1/\lambda)t^{1-\beta}$]

3. **Instantaneous failure rate vs cumulative time** which is **Option R + Option I superimposed** for WinSMITH Visual. The line slope is $\beta-1$. This method is often helpful for development activities. [$c(t) = \lambda\beta t^{\beta-1}$]

4. **Instantaneous MTBF or MTTF vs cumulative time**. This is **Option T + Option I superimposed** for WinSMITH Visual. The trend line slope is $1-\beta$. [$m(t) = (1/\lambda\beta)t^{1-\beta}$]

5. **Cumulative failure rate vs cumulative time** which is **Option R** for WinSMITH Visual. The line slope is $\beta-1$. [$C(t) = \lambda t^{\beta-1}$]

Most used features above are 1), 2), and 3). Often you will see the term $\alpha = 1-\beta$ in European literature.

Suppose we have the following data set:

Cumulative time:	**316.2**	**752.1**	**1248.6**	**1788.9**	**2364.4**	**2969.5**	**3600.6**	**4254.6**	**4929.5**	**5623.4**
Cumulative failures:	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

What are β, λ, what do the symbols mean, and when will failure number 11, 12, 15, and 20 occur?

Enter the data, click on the C/A icon, view the plot, interpret the data, and click the 2nd tab for failures. Figure V7 shows the main screen with a Crow-AMSAA plot and the IEC61164 method results.

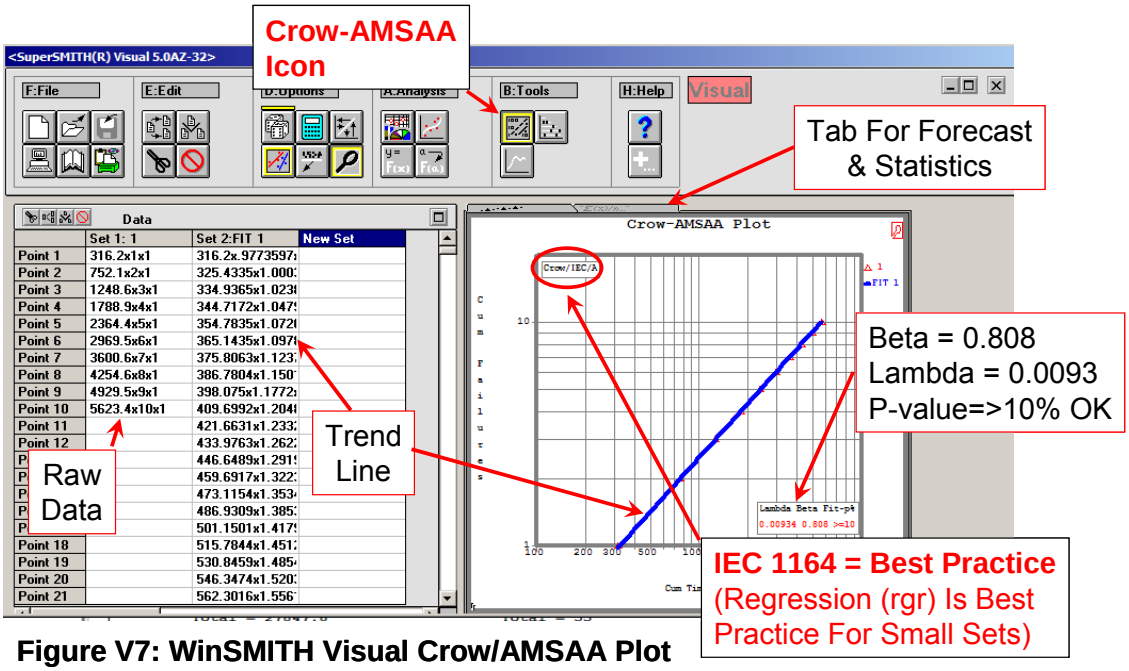


Figure V7: WinSMITH Visual Crow/AMSAA Plot

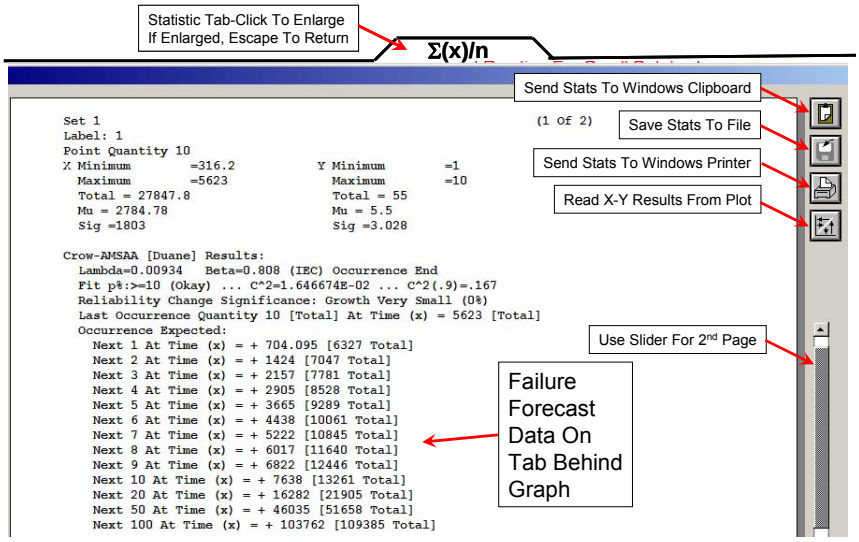


Figure V8: SuperSMITH Visual Crow-AMSAA Failure Forecast

Click on the tab above the graph in Figure V7 to get the statistics and the failure forecast as shown in Figure V8.

The beta value of 0.8 is less than one. This indicates failures are coming more slowly and reliability is improving. Future failures are predicted in Figure V8 along with their timing.

The lambda value of 0.01 is related to the system failure rate at time = 1. Of course with beta < 1 , the failure rate λ, will be decreasing with time as the reliability improves and in turn the system mean time (1/λ) is growing from 100 at time 1 to 562.3 by the 10th failure. If beta were ~1, then the system would keep it's failure rate and display a constant mean time = ~100. Likewise if the system is deteriorating, then β > 1 and expect increasing failure rates and declining mean times to failure.

Click on Option E (for extrapolate) under the C-A icon will show the failure trends for the graph in Figure V7 into the future which is the basis for a "fearless forecast" about failures which will occur unless action is taken to correct the trend line. The extrapolated line is shown in Figure V9. Remember for Figure V9, the plot will always increase upward with more failures and the best you can hope for is a significant improvement which would incur large intervals between failures which would cause the line to break sideways. If the trend line for Figure V9 moves upward rapidly it signifies bad news with deteriorating reliability and more failure s coming faster which is an unhappy situation.

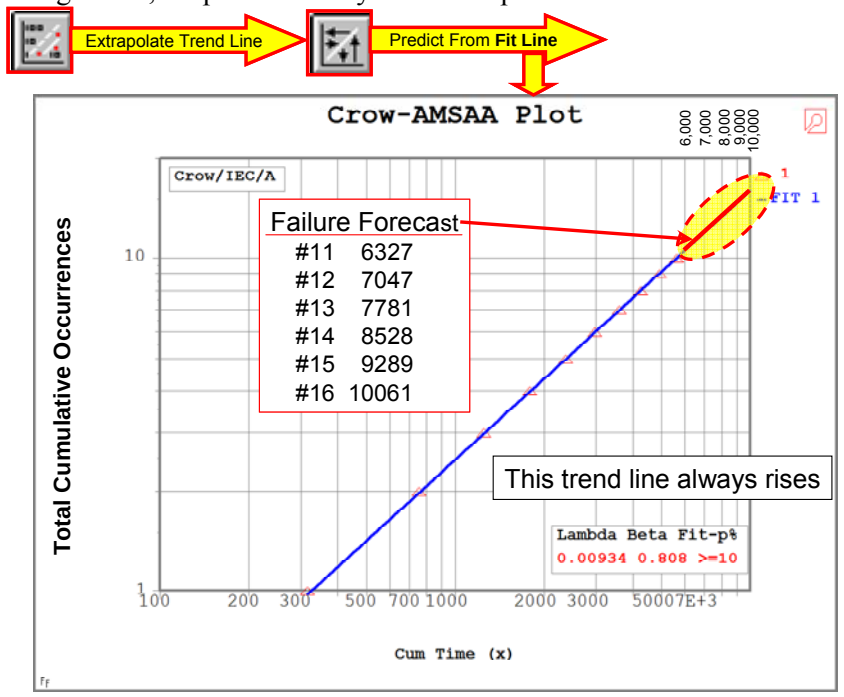


Figure V9: SuperSMITH Visual C-A Cumulative Failure Extrapolation

Clicking on Option T (for transform to MTBF under the C-A icon transforms the Y-axis from cumulative failures to (cum failures)/(cum time). For this case of beta < 1 the trend line will point upward (the desired direction) as shown in Figure V10.

Option T's transform will allow he trend line to point upward or downward as indicated by the happy/sad faces. When no improvements occur, the line will move horizontal.

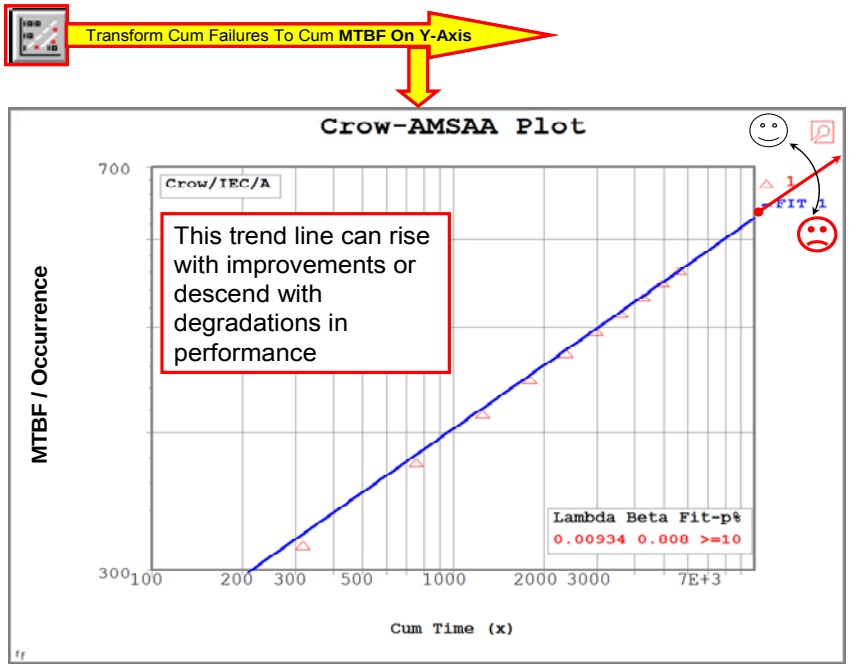


Figure V10: SuperSMITH Visual Crow-AMSAA Cumulative MTBF Plot

The third option frequently used for display of reliability growth involves the instantaneous failure rate which is obtained from Option T along with Option I for the instantaneous trend line. The instantaneous line and the MTBF line will be concurrent if the condition of no-change beta = 1 occurs, however, if beta < 1, the instantaneous line will lie above the MTBF trend line; and likewise if beta > 1, the instantaneous trend line will lie below the MTBF line. The transformed MTBF line and the instantaneous trend line are shown in Figure V11.

In Figure V11, projecting the trend line downward and to the left will show that at time 1 on the log scale the trend line will cross 100 which is equivalent to $\lambda = 0.01$ for the failure rate. Also since the system is improving the instantaneous failure rate is also growing as displayed above the MTBF trend line.

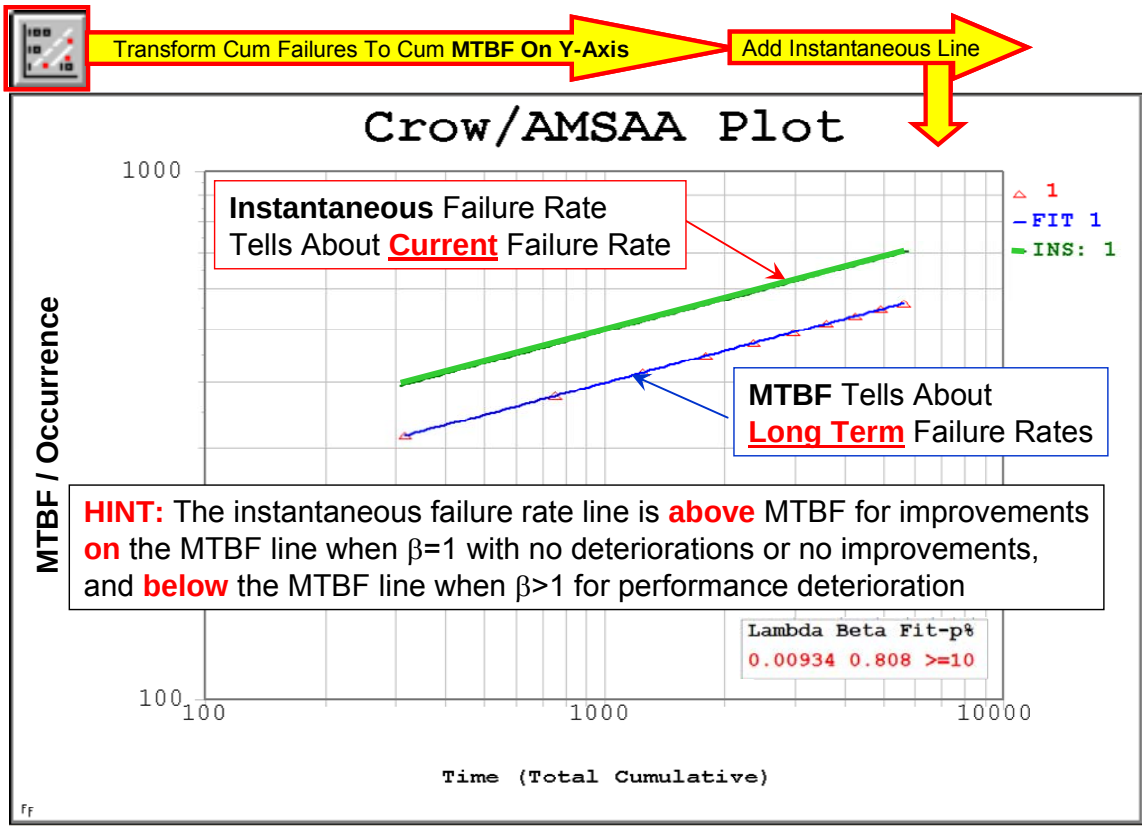


Figure V11: SuperSMITH Visual Crow-AMSAA Cumulative MTBF Plot With Instantaneous Failure Rate

The faster the growth in reliability the greater is the involvement by the development team to introduce improvements and to keep them in place so the instantaneous failure rate plot clearly shows growth opportunities (the gap between the lines) derived from making improvements.

Other options under the C/A icon allow you to have the display to fit your needs such as: the rate of failure occurrences (Option R), the survival transform which is 1- Rate (Option S) which will produce a curved line of both survival and MTBF, and other options to be discussed later.

End of excerpts from the SuperSMITH Weibull and Visual Training Manual