UDR-TR-2015-153

UNIVERSITY of DAYTON RESEARCH INSTITUTE

Report

Probability Of Detection (POD) v4.0 – User's Manual

July 2015

Francis R. Smith

Thomas R. Boehnlein

Peter W. Hovey, Ph.D.

NOTICE

Approved for public release

Probability Of Detection (POD) v4.0
User's Manual

July 2015

USAF Contract Number FA8650-09-D-5224-0009

Prepared by:

Francis R. Smith
Thomas R. Boehnlein
Peter W. Hovey, Ph.D.

UNIVERSITY OF DAYTON RESEARCH INSTITUTE
STRUCTURAL INTEGRITY DIVISION
300 College Park
Dayton, OH 45469-0120

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

FOREWORD

The work described in this report was performed for the Material State Awareness and Sustainability Branch in the Structural Materials Division of the Materials & Manufacturing Directorate, Air Force Research Laboratory (AFRL/RXCA) under Contract FA8650-09-D-5224, 0009, "Probability of Detection (POD) Software Development with Validation/Verification." Dr. Jeremy Knopp of AFRL was the Program Manager. The Structural Integrity Division, University of Dayton Research Institute (UDRI), Dayton, Ohio conducted the program with Mr. Thomas Boehnlein and Mr. Frank Smith acting as the principal investigator and program manager, respectively.

1.0 INTRODUCTION

A prime objective of this program was to update the POD v3 computer program to take advantage of current computer capabilities. The analysis codes were rewritten in IronPython, statistical tests of the â versus a assumptions were made an integral part of the analysis, and selected plots were added as standard options. This appendix describes the user interface, and the standard outputs along with a detailed use of the program. Since a primary goal of the software was to provide dynamic documentation to the user as needed, this manual is terse compared to a more traditional user manual. The bulk of that information is included as part of the software itself. The primarily focus of this manual is on using the software and critical high level aspects of the software such as data importing and analysis exporting. Information such as that helps the user understand how best to integrate the software into their current workflow.

The new POD software is a marriage of the existing POD v3 algorithms with a new intuitive user interface that leads the user through the process of developing a POD analysis. The goal is to enable the new/occasional user to develop a quality POD analysis with a minimum of effort. The previous programs had a fairly steep learning curve which could be intimidating to new users.

From the user's perspective, the software is essentially a new program since the user interface is completely new. It can also be looked at as an update since UDRI utilized the same algorithms from POD v3 for the analysis calculations. The only change made to the backend algorithms was to port them to IronPython.

This user's manual assumes familiarity with the objectives and analysis methods for fitting the cumulative lognormal and log odds models to â versus a and hit/miss (find/no find) forms of NDE reliability data. See References 1, 2, 5, and 6 for details of such analyses. Reference 2 contains a discussion of the specific analyses performed by POD v3.

Section 2 presents a description of the use of the program and the worksheets of a POD workbook for both the â versus a and hit/miss (find/no find) analyses. The descriptions emphasize the required input for a POD(a) analysis and the explanation of the output tables and graphs. The output sheets are standard worksheets of an Excel workbook. Knowledge of Excel is assumed. Section 3 presents the details of implementing the commands of the POD window. The list of references are in Section 4.

2.0 DESCRIPTION OF POD V4

The POD analysis process is broken down into a series of steps that leads the user through the development process. These steps include: project setup, data sources, and analysis. The user is lead through these input steps which will generate a preliminary POD analysis.

The POD program display consists of a step window in the center and a number of reconfigurable child windows on the sides. These windows include the Project Manager, 1823A, Quick Help and Project Setup Progress windows. All windows are resizable and can be displayed, hidden or docked on either side of the step window. This allows the user to maximize screen space regardless of size and screen resolution of their monitor. These windows bring up relevant information for each step and are updated when the user changes steps.

A typical project setup step window will consist of a project manager window, the MIL-HDBK 1823A and the quick help windows, project properties, notes and a project overview of any completed analysis. The 1823A help window displays relevant sections from MIL-HDBK 1823A while the quick help window displays step specific information. Finally, the bottom right of each step window contains a series of buttons that allows the user to navigate through the step. This is an important aspect of the software because it doesn't require the user to know what they should do next when performing a POD analysis. They can simply select the Next button and the software will take them to the next relevant step. This makes the software less intimidating to new users who wouldn't necessarily know what they need to do next. However, to minimize the amount of required clicks to get through a series of steps, power users can quickly jump between multiple steps by selecting from the list of steps in the Progress Manager or from the available context menu. The left side of the bottom bar contains relevant actions that relate to that specific step. This allows the user to consistently find what they can do at a particular step without the need to search for additional functionality. In addition it minimizes the chances that the user will forget that such functionality is available.

2.1 Opening Window

When users start POD v4 they will be presented with a welcome window (Figure 1) that will allow them to either start a new project or quick analysis or open an existing project. These choices are shown on the upper left hand side of the window. Beneath these are a list of the most recently used project files. When the user places their mouse over one of the file names, its information is displayed in the Overview window to the right. This allows the user to know what analyses is in the file without having to open it. POD v4 allows the user to choose a help layout that works for them and provides 3 layouts that can be changed at any time

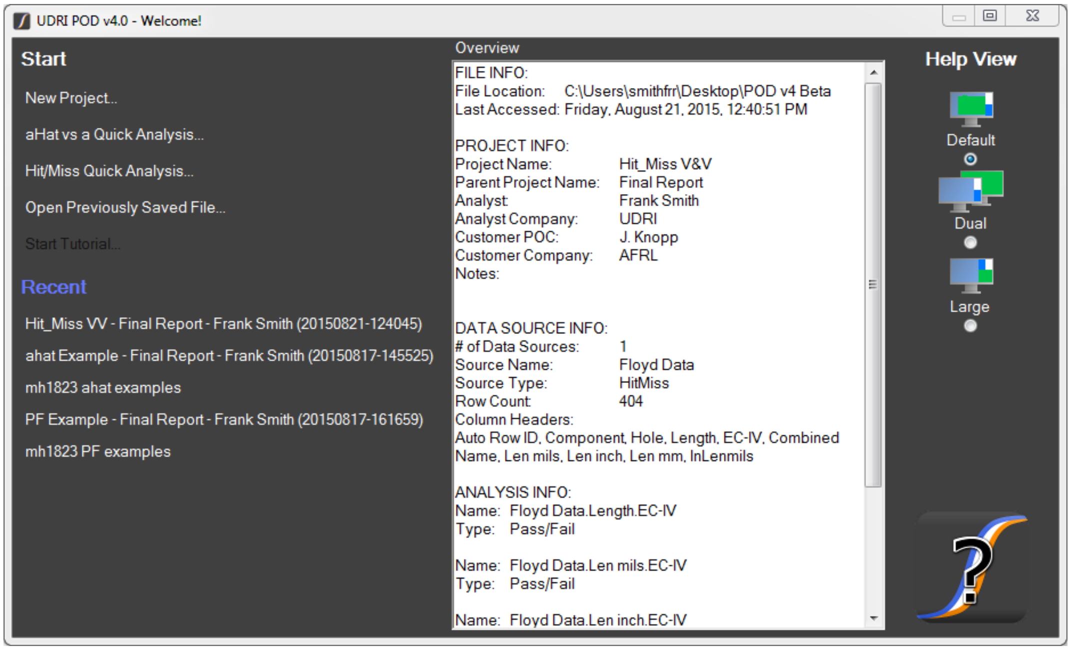


Figure 1. POD v4 Opening Window

2.2 Project Setup Window

The project setup window, shown in Figure 2, is probably best thought of as a project documentation window. At the top of the window are areas for entering the name of the analyst and their company/ organization, the project name and parent project. And customer POC and company/ organization. The majority of the step window is space for any notes that you want archived with this analysis. If the user opens an existing project, the window also includes project overviews of any completed analysis. Double clicking on theses will open the specific analysis.

Once you have finished setting up your project you would move on to the import data window by either selecting the next navigation button at the bottom right or selecting the data sources from the project manager window on the left.

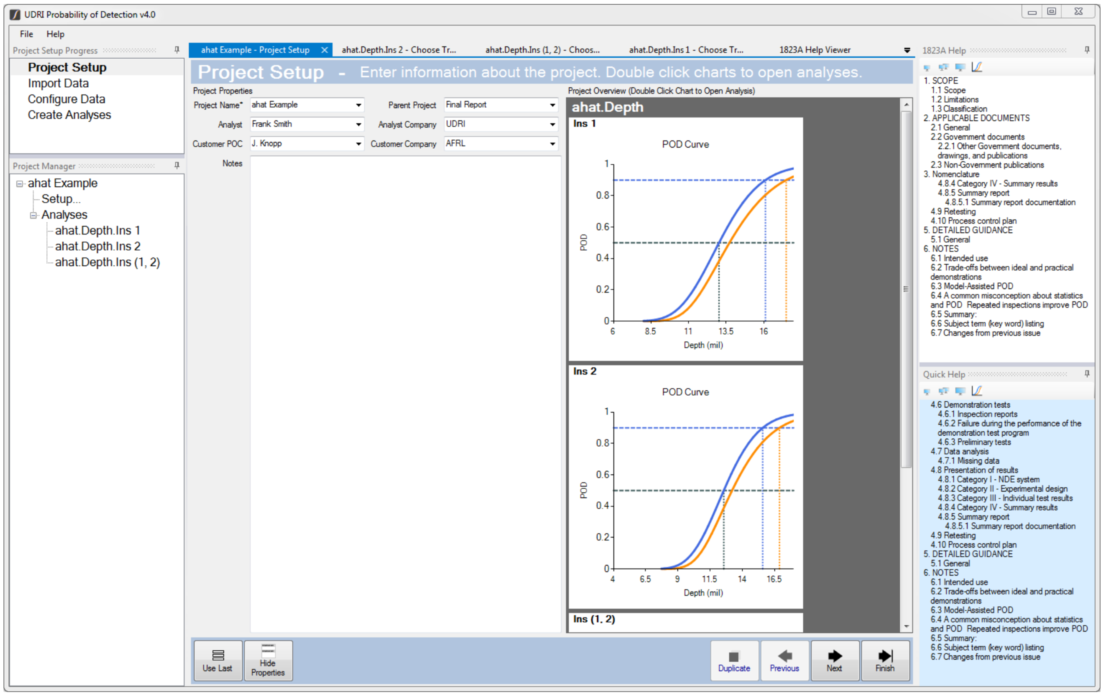


Figure 2: Project Setup window

2.3 Import Data Window

Initially, the Import Data window is empty and the user will need to paste data into it. This can be done by copying and pasting from either an Excel spreadsheet or from a comma separated value text file. The current software has been written to allow maximum flexibility when entering data. All data files created for POD v3 will work with the current software.

Once the data has been imported, the user will next need to define the columns by color coding them. The top of the step window contains the required color coding: ID Columns – Light Blue, Metadata Columns – Violet, Flaw Columns – Dark Green, and Response Columns – Light Green. Columns can be colored by selecting the color button and then clicking on the column. A shortcut method is to click on the column you want to color. If it is not the correct color than repeat until the correct color is displayed. Just make sure that you have selected on of the definitions from the top of the window. Figure 3 shows a data sources window with defined (color coded) data ready for analysis.

Once the data has been imported and defined, the user is ready to proceed to the Configure Data window by selecting Next from the navigation buttons at the bottom of the page.

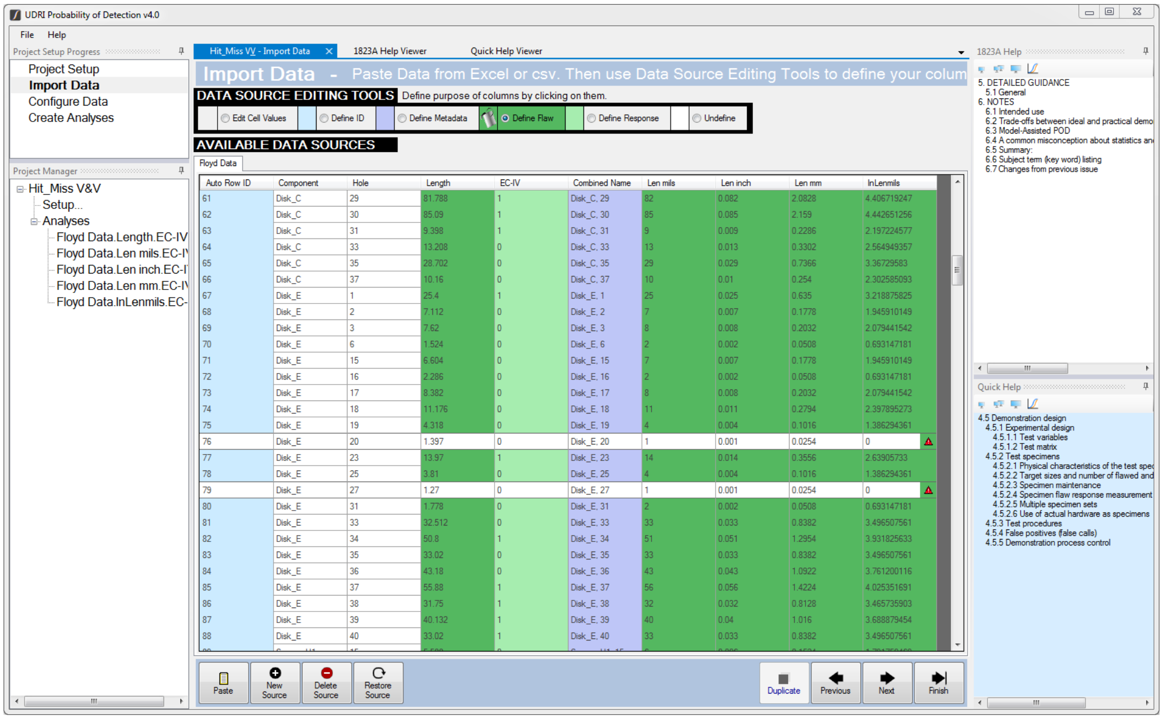


Figure 3: Import Data Window

2.4 Configure Data Window

The Configure Data window is used to setup the names, units and default values for the new data. These data are entered into the dialogues on the left side of the window. In order to minimize the repetitive nature of entering data properties into POD v4, checkboxes are available to let the user apply the entered values to all of the columns at once. By default, the boxes are checked for the most common scenario. The interface was also designed such that it automatically cycles through columns as each is column is renamed. This saves the user considerable time and effort and eliminates the need to return to the column list after renaming each column. The window also includes plots for each set of data with a table of values (Figure 4). The window displays individual plots for each column of data identified as a response column from the import data step. There is also a button on the bottom left of the window that allows the user to toggle between individual plots and group by flaws (shown).

The displayed table of values is for the selected plot. Selecting a different plot will cause the table to be updated with the current data. If a user clicks on a point in a plot, it will be highlighted in the table. This allows the user to ascertain the crack number, size and response.

Once a user is satisfied with their data they can navigate to the Create Analysis window by selecting Next from the navigation buttons at the bottom of the window.

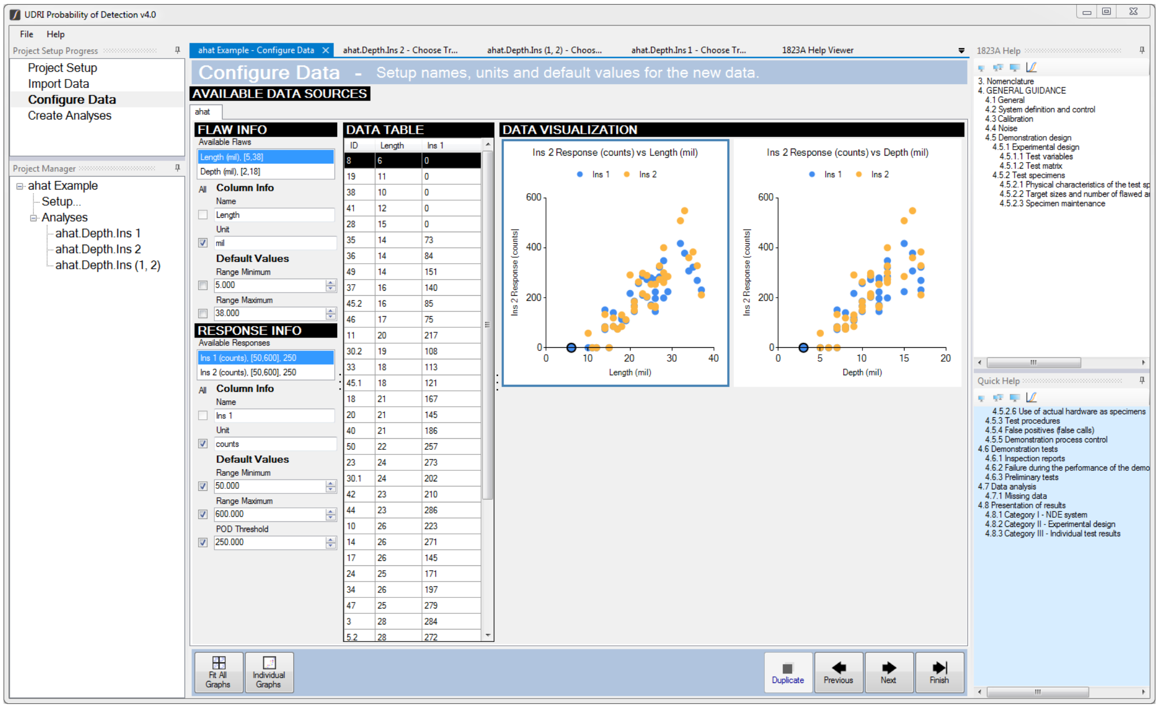


Figure 4: Configure Data Window

2.5 Create Analysis Window

The Create Analysis step window shown in Figure 5, allows users to select individual or multiple flaw and response data sets. The data can be selected individually or in a group and multiple analyses can be created from the same pool of data. The window has two panes, the left pane (Available Data) is used for selecting the data to include in an analysis while the right pane (Analyses Created) displays the created analyses.

To create an analysis, select the data from the Available Data pane and use the Add button to create the analysis. The selected data will be displayed in the Analyses pane and will be automatically named by the program. Automatic naming was developed to eliminate the considerable mental effort that can go into naming analyses. Users also have a tendency to give less than ideal names when forced to create a large set of them due to the tedious nature of the task. Automatic naming is optimized to create the shortest name possible by taking advantage of commonality between column names. However, the user can still rename the analysis if the automatic naming algorithm does not meet their needs. To further save the user time, any of the analyses created can be set to automatically open after the user has finished this step by checking the box next to each analysis. Once the user has finished creating all their analyses, the next step is the Choose Transform step. To bring up the Choose Transform window, select the analysis, click on either the Open on Finish or Open All on Finish buttons and then select the Finish button at the bottom left of the step window.

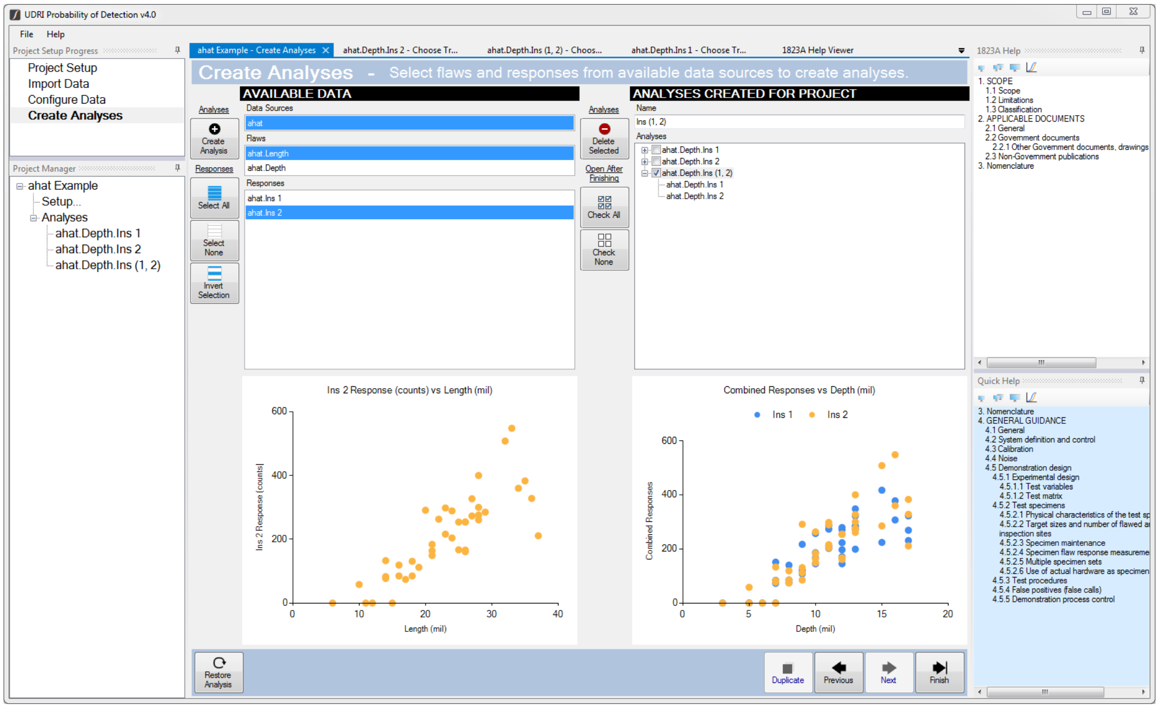


Figure 5: Create Analysis Window

2.6 Choose Transform Step

The Choose Transform window is used to evaluate the results for each possible transform combination. Figure 6 shows the Choose Transform window for an $\hat{a}$ versus a analysis. . By default, only the four most common transforms are shown, linear-linear, linear-log, log-linear and log-log. The flaw transforms are displayed in rows while the response transforms are displayed in columns. All available transform combinations can be shown by selecting them from the available transforms lists on the right of the main window. To select the transform, click on the plot. The plot will be displayed with a red box around it. In addition to choosing the transforms to display, the user can change the flaw range and response range minimums and maximums.

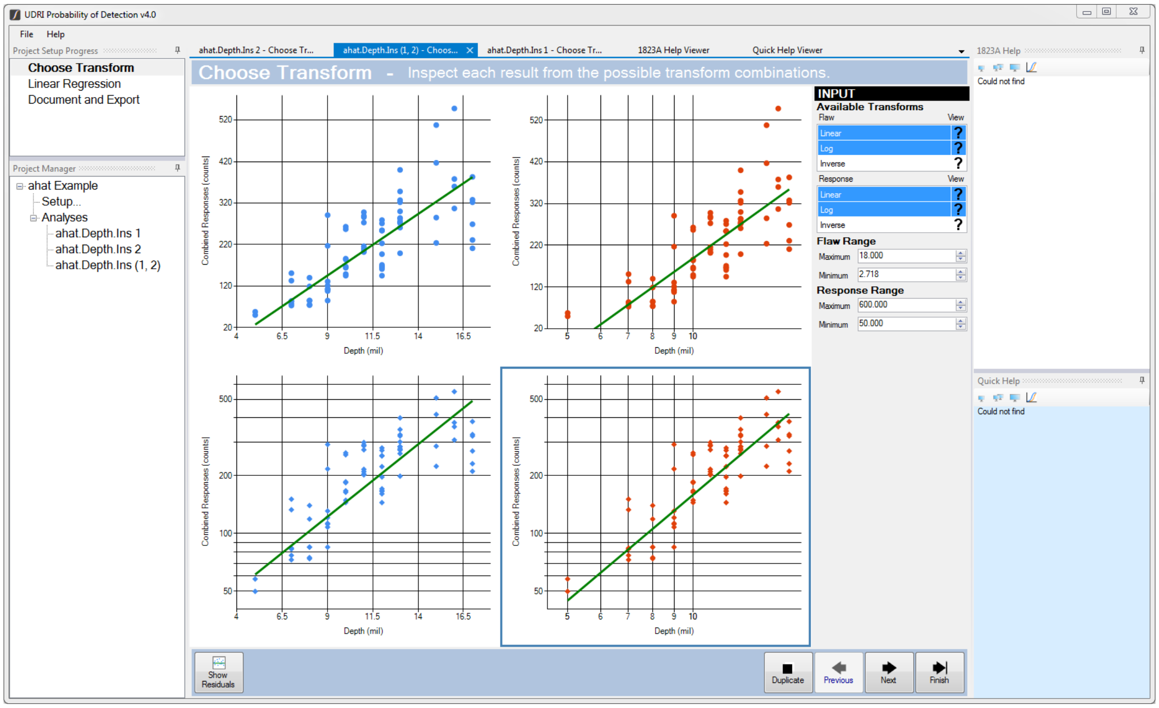


Figure 6. Choose Transform Window

The user can also view the residuals for each fit by selecting the Show Residuals button from the bottom left of the window or selecting it via the context menu. The residual plots are shown in Figure 7.

The Choose Transform window for the hit/miss analysis is similar to the *â* analysis window and is shown in Figure 8. By default, only the linear and log flaw transforms are shown along the normal and log-odds models. The flaw transforms are displayed in rows while the models are displayed in columns. All available transform combinations can be shown by selecting them from the available transforms lists on the right of the main window. To select the best fit, click on the plot. I will be displayed with a red box around it. In addition to choosing the transforms to display, the user can change the flaw range.

The user can also view the both the normal and log-odds models on the same plot by selecting the Overlay Models button at the bottom of the window or via the context menu. This allows the user to clearly see the differences between the models for the data. The overlaid model is shown as a light green line on the plot.

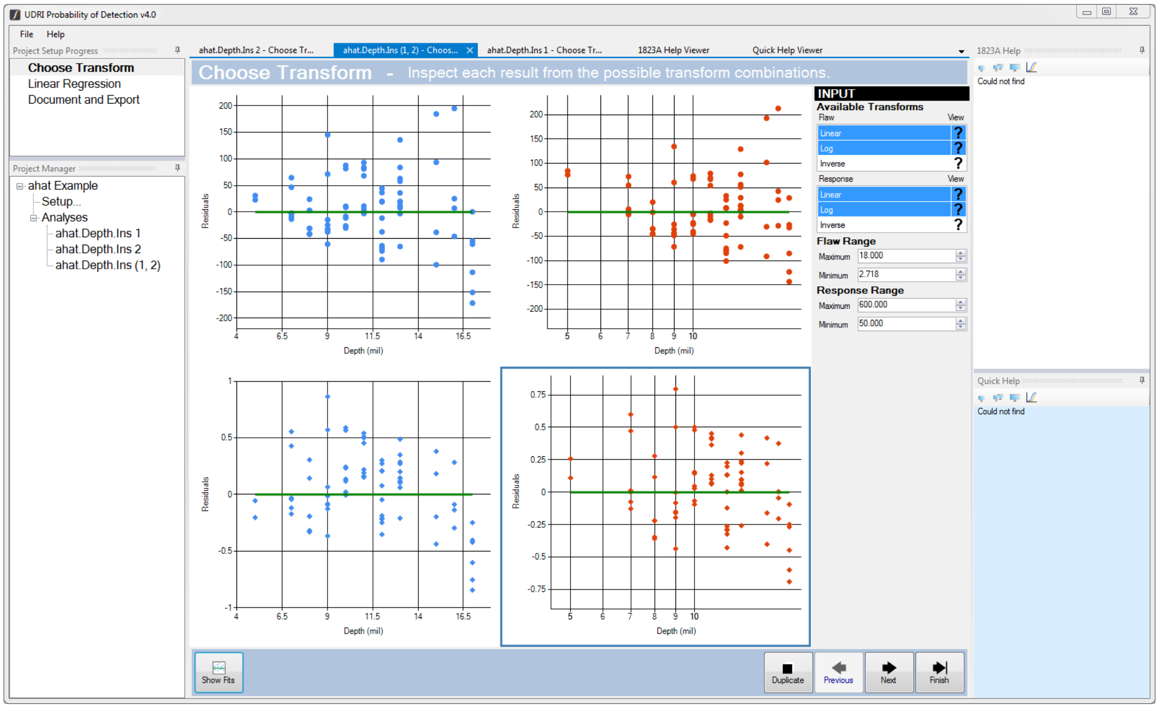


Figure 7. Choose Transform residuals window for $\hat{a}$ analysis.

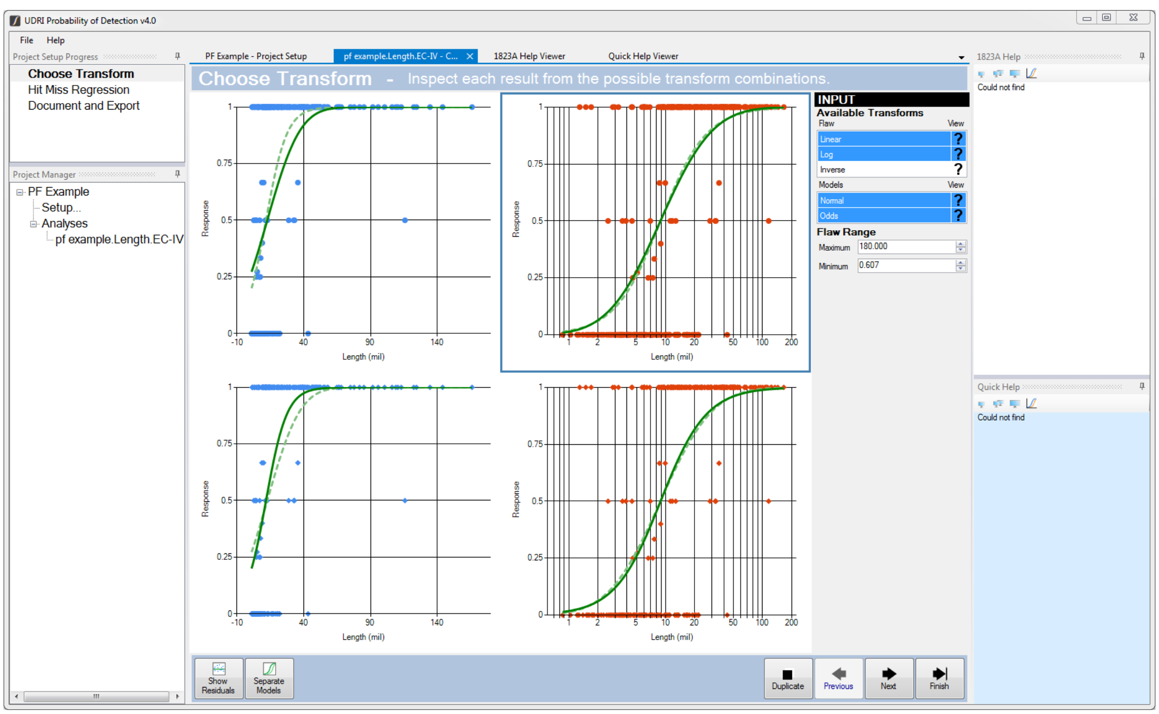


Figure 8. Choose Transform Window for Hit/miss Analysis

Once the user has decided on appropriate transformations, the next step is the Regression step. To bring up the Regression window click on either the Next button at the bottom right of the step window or right clicking and selecting it from the context menu.

2.7 Regression Window

Up to this point the user interface for both the $\hat{a}$ versus a and the hit/miss analyses are nearly identical. This is not true for the Regression step, which is unique to the analysis being performed. The following sections describe the regression steps for the $\hat{a}$ versus a analysis and the hit/miss analysis.

2.7.1 $\hat{a}$ versus a Regression Window

The Linear Regression step window is shown in Figure 9 and has three sections. The section on the left contains real time plots of the data resulting from the current linear regression fit while the right section contains a list of the current inputs and outputs for the regression fit. The center section contains the fit plot for the current linear regression fit.

In the fit plot, the solid green line is mean fit line while the symbols are the inspection responses. Each inspection is displayed using a different color symbol. For this example there were inspections made by two different inspectors.

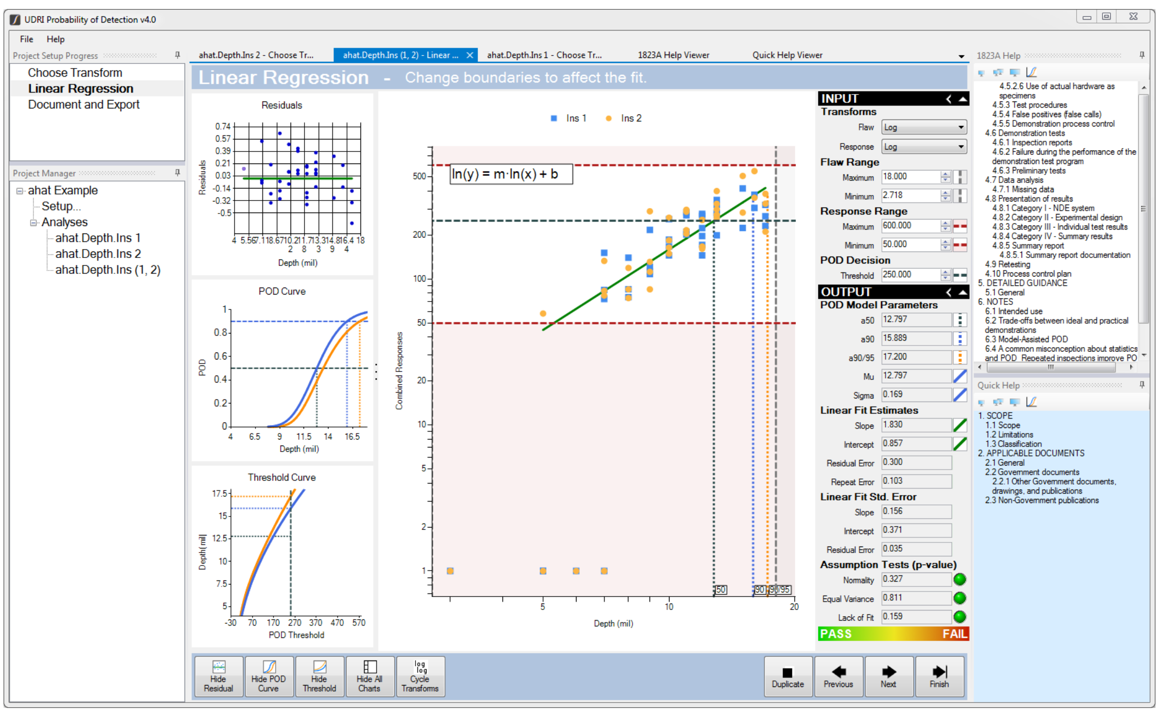


Figure 9: $\hat{a}$ versus a Linear Regression Window

The chart shows the a_{50}, a_{90} and $a_{90/95}$ values that are computed as part of the analysis. These values are represented by the dotted lines and change in response to changes in the regression fit. There are also a series of dashed lines that represent various user inputs that can be changed as part of the analysis. These lines can be dragged by the user using the mouse. In order to increase discoverability of this feature, the lines increase in thickness and the cursor changes when the mouse is over them prompting the user of the available interaction. The pair of black vertical dashed lines control the minimum and maximum crack sizes. Dragging the left vertical line to the right increases the minimum crack size, while dragging the right line to the left decreases the maximum crack size. The red horizontal lines control the censoring of the data. Dragging the bottom line up increases the minimum response (left censor), while dragging the top line down decreases the maximum response (right censor). The final line is the black horizontal line between the censor lines is the decision threshold line. Dragging it up increases the decision threshold value while dragging it down decreases the decision threshold. In addition to dragging, the user can left click anywhere on the chart and select one of the lines to be positioned at that point. Finally, all of these values can be directly changed via the Input menu on the right side of the window.

Inspection responses can be removed using a couple of methods. The most common way is to remove points by changing either the minimum or maximum crack sizes or changing the left and right sensors. These actions have the effect of removing all points up to a certain value. If the user wishes to remove an individual point this can be done by clicking on the point and choosing Toggle Response On/Off. If the point is removed its symbol will change to black. It is also possible to remove all flaws of a certain size. The user will select a flaw of the size of interest and select Toggle All Responses at this Flaw Size On/Off. As before, all removed point's symbols change to black.

The right section contains a list of inputs and outputs for the current linear regression which are shown in Figure 10. This includes the available transforms for both flaw and response data which is Linear (y=x), Log (y=ln(x)) and Inverse (y=1/x). The outputs contains entries for the a_{50}, a_{90} and $a_{90/95}$ values along with the fit slope (B1) and slope standard error, the fit intercept (B0) and standard error. The standard errors are the standard deviations of the estimates of the parameters and indicate the degree of precision of the estimates. The Fit Residual Error is the standard deviation of the differences between the average $\hat{a}$ values and the linear fit. The Repeatability Error is the pooled standard deviation of the repeated $\hat{a}$ values for each crack. The final three entries are the p values of the hypothesis tests for model fit and are presented in terms of a red-yellow-green format with green indicating that the data are compatible with the assumptions.

The final section of the Linear Regression window is on the left and contains a series of plots that are shown in Figure 11. These plots are generated in real time from the ongoing analysis and are intended to provide the user with immediate feedback on what effect changes made as part of the regression fitting has on things like linearity, POD and the decision threshold. These plots can be hidden or resized through either keyboard shortcuts or mouse interactions. This allows the user to have more control over how the available screen space is used. This can be critical in situations where space is limited such as notebooks. The side plots are optimized to highlight changes in the results as the user manipulates input values. This is done by keeping the axis ranges constant whenever possible. Maximizing the display size of the curves on the plots, while making it easier to see the output, is disorienting to users looking for relative change as they have to look at axis labels to see how the curve shifted. Similar axis ranges are also used throughout all of the plots so it is easier to make direct comparisons between them.

The residuals plot presents the difference between the average and predicted $\hat{a}$ for each crack versus the crack size. The POD plot presents the POD(a) function and its confidence bound along with estimates for a_{50}, a_{90} and $a_{90/95}$. The threshold plot presents the estimates for a_{90} and $a_{90/95}$ as functions of the decision threshold. Once the user is satisfied with the analysis it can be exported to Excel for further analysis on the Document and Export step.

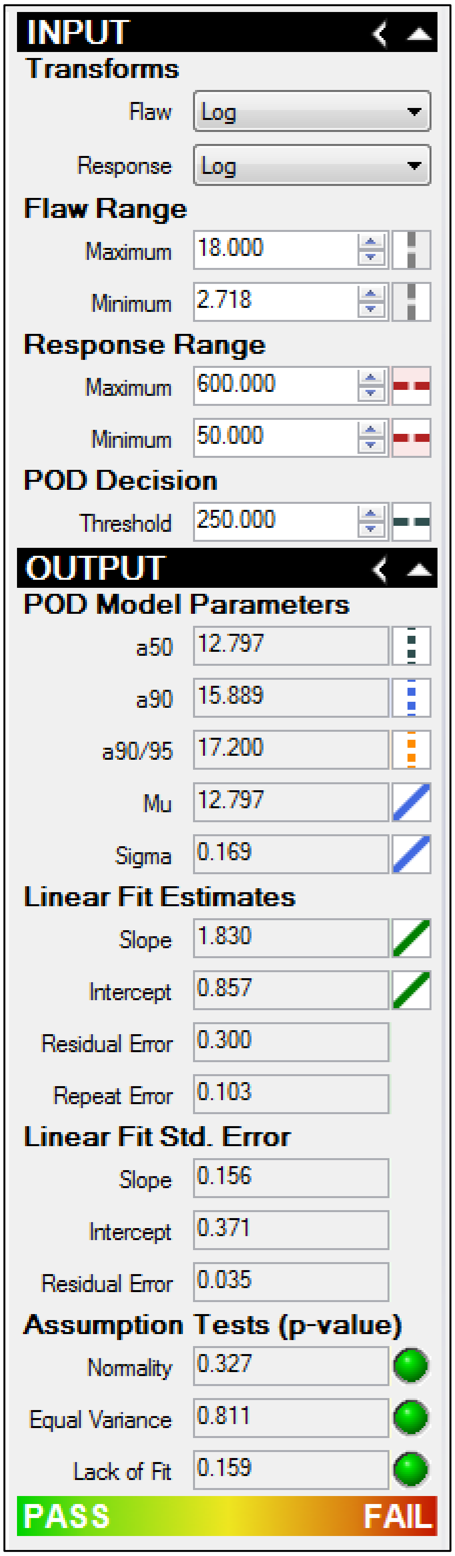


Figure 10: $\hat{a}$ Analysis Input and Output Parameters

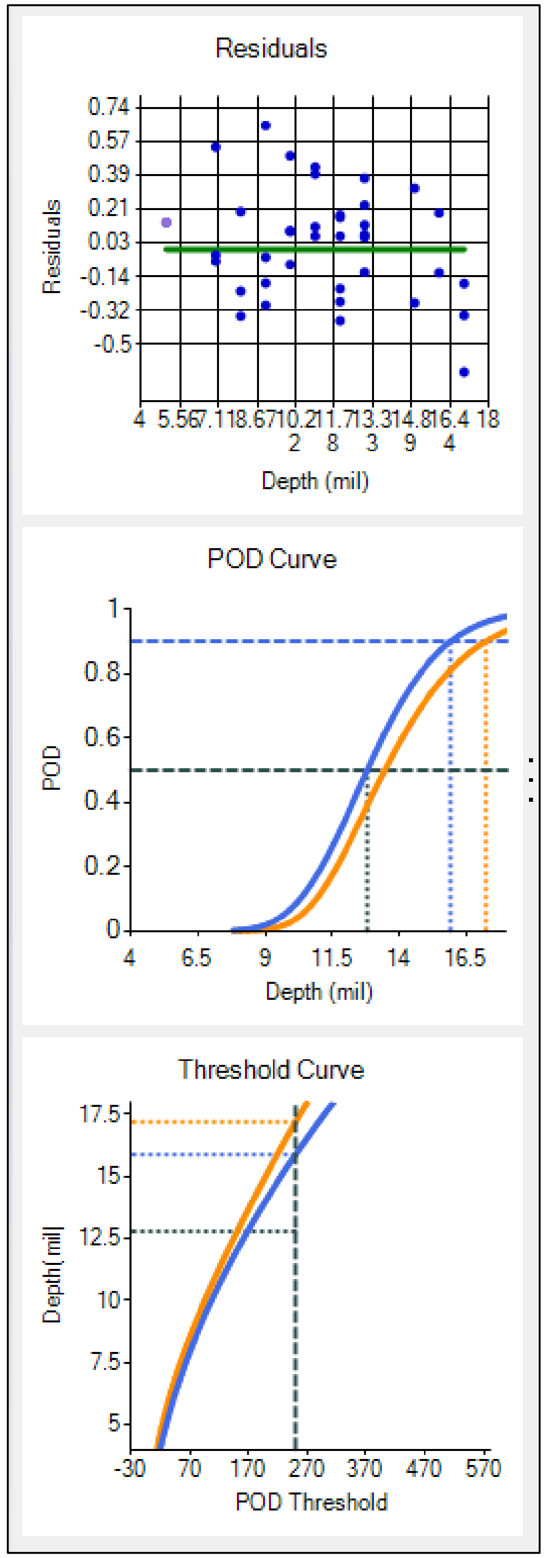


Figure 11: $\hat{a}$ Analysis Informational plots

2.7.2 Hit/miss Regression Widow

The Hit/miss Regression window in Figure 12has three sections. The section on the left contains real time plots of the data resulting from the current linear regression fit and the right section contains a list of the current inputs and outputs for the current hit/miss regression fit.

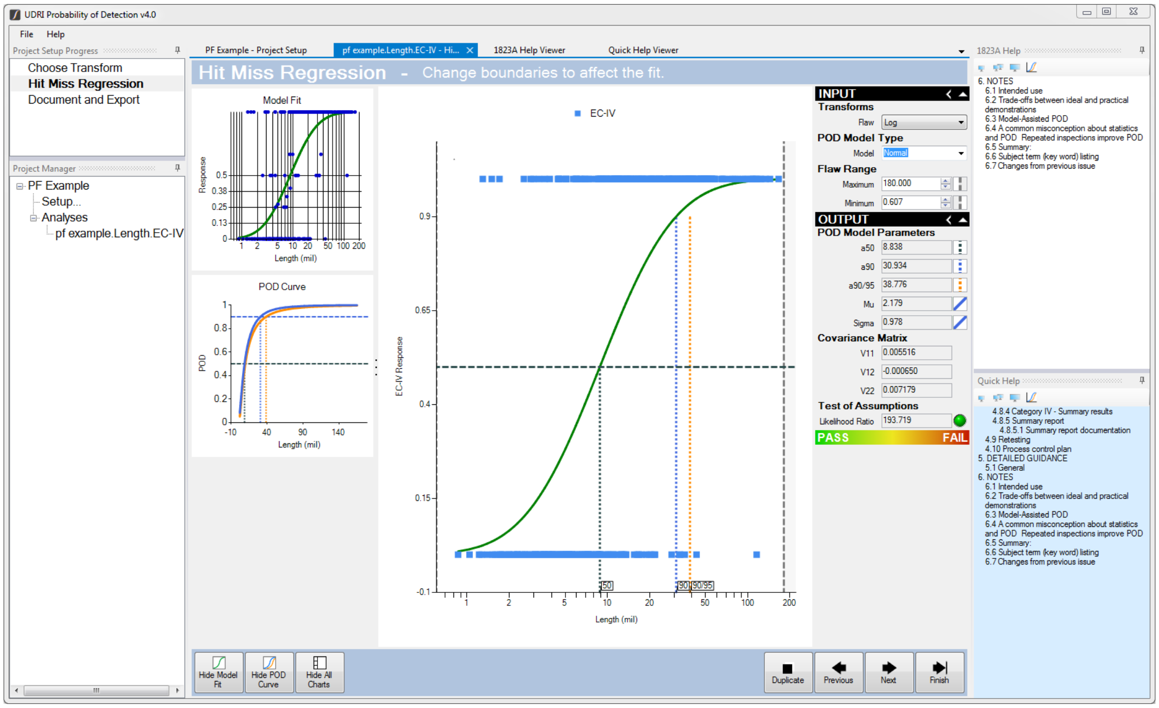


Figure 12: Hit/miss Regression Window

The center section contains the current hit/miss regression fit. The mean fit line is shown as a solid green line and inspection responses are shown as points. Each inspection is displayed using a different symbol.

The chart shows the a_{50}, a_{90} and $a_{90/95}$ values that are computed as part of the analysis. These values are represented by the dotted lines and change in response to changes in the regression fit. There are also a series of dashed lines that represent various user inputs that can be changed as part of the analysis. The pair of black vertical dashed lines control the minimum and maximum crack sizes. Dragging the left vertical line to the right increases the minimum crack size, while dragging the right line to the left decreases the maximum crack size. These values can also be directly changed via the Input menu on the right side of the window or changed using the left click menu.

Inspection responses can be removed using a couple of methods. The most common way is to remove points by changing either the minimum or maximum crack sizes. These actions have the effect of removing all points up to a certain value. If the user wishes to remove an individual point this can be done by clicking on the point and choosing Toggle Response On/Off. If the point is removed its symbol will change to black. It is also possible to remove all flaws of a certain size. The user will select a flaw of the size of interest and select Toggle All Responses at this Flaw Size On/Off. As before, all removed point's symbols change to black.

The right section contains a list of inputs and outputs for the current hit/miss regression which are shown in Figure 13. This includes the available transforms for flaw data which is Linear ($y=x$), Log ($y=\ln(x)$) and Inverse ($y=1/x$). The POD can be modeled either using a cumulative lognormal equation (Normal) or the log odds model (Odds). The outputs contains entries for the a_{50}, a_{90} and $a_{90/95}$ values along with the POD parameters Sigma and Mu The final three entries are the values for the variance-covariance matrix for sigma and mu.

The final section of the Hit/miss Regression window is on the left and contains a series of plots that are shown in Figure 14. These plots are generated in from the ongoing analysis and are intended to provide the user with feedback as quickly as possible on what effect changes made as part of the regression fitting has on things such as fit, and POD. The fit plot shows the POD(a) fit on the observed detection probabilities and can be used to make a subjective judgement of goodness of fit. The POD plot presents the POD(a) function and its confidence bound along with estimates for a_{50}, a_{90} and $a_{90/95}$. Once the user is satisfied with the analysis it can be exported to Excel for further analysis on the Document and Export step..

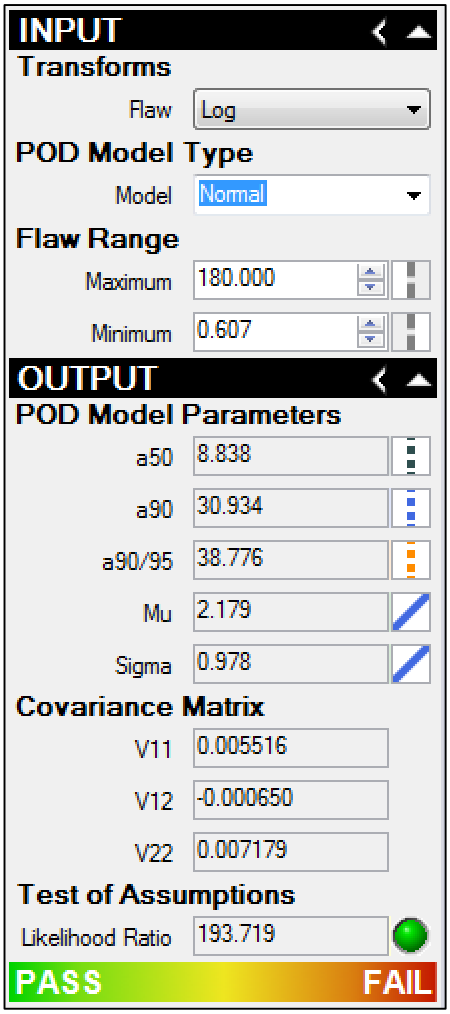


Figure 13: Inputs and outputs for hit/miss analysis

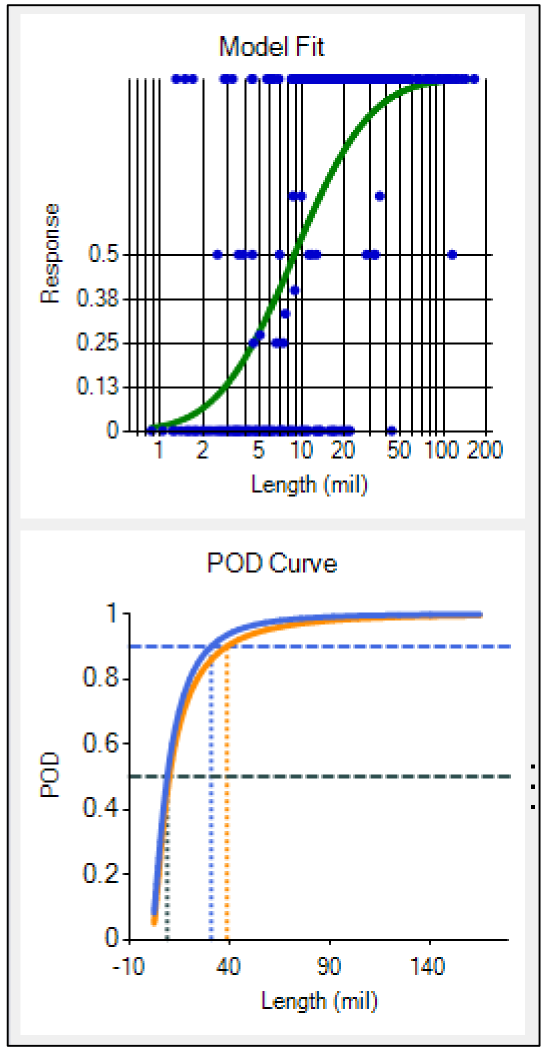


Figure 14: Informational plots for hit/miss analysis

2.8 Document and Export

The document and export step window is shown in Figure 15. The window has two main panels. The left panel contains a list of points that were removed from the analysis and their reason for removal. The right panel contains a dialogue box to enter the reason for removal and a list of templates covering previous reasons that the analyst thought would be used again. The user is required to provide a reason for every point that was removed from the analysis. Because documenting removed points is critical to the POD analysis process, the step's UI design ensures that the user can perform this step as quickly and efficiently as possible. Many keyboard and mouse interaction shortcuts were added to aid the user. An analyst with a good collection of previously used comments can finish their point documentation in a small number of mouse clicks and keyboard presses.

Once all the points have been documented, the user is able to export either the entire project or specific analysis to Excel using the Export Analysis and Export Project buttons at the bottom of the window.

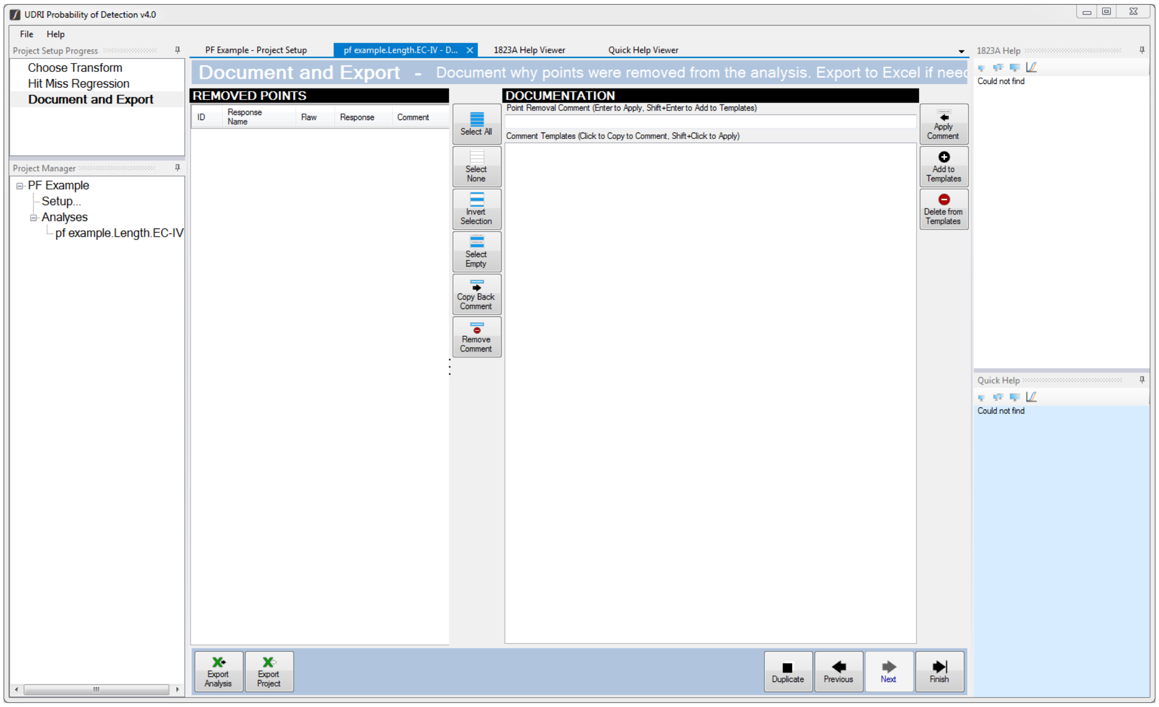


Figure 15. Document and Export Window

2.9 Quick Analysis

The last element to the user interface is the quick analysis mode. This mode is meant to be used for reference while a user is generating data. As such, the input and output capabilities are limited. This capability is not to be used in place of the full analysis described previously.

The assumption behind the quick analysis is that an inspector is in the process of collecting data and would like to see what an analysis would look like based on the current (limited) set of data. This information could then be used to guide them through the rest of their data collection.

To generate a new quick analysis the user can either select it from the open dialogue box when opening POD v4 or on the File menu. Select New and then either aHat vs a Quick Analysis or Hit Miss Quick Analysis. This opens up the window shown in Figure 16 where the user setups up the flaw and response ranges along with entering information on the operator, specimen set and instrument used. The purpose of this window is to ensure that the quick analysis starts with the proper plot ranges and that the input data will be well defined if it is later exported by the user. To minimize the burden on the user of entering all of this information, previous values entered into this window are remembered. In addition, the last data range used with a given specimen set or instrument are also remembered. This allows the user to fill out the information very quickly in any subsequent cases in which they are working with the same data.

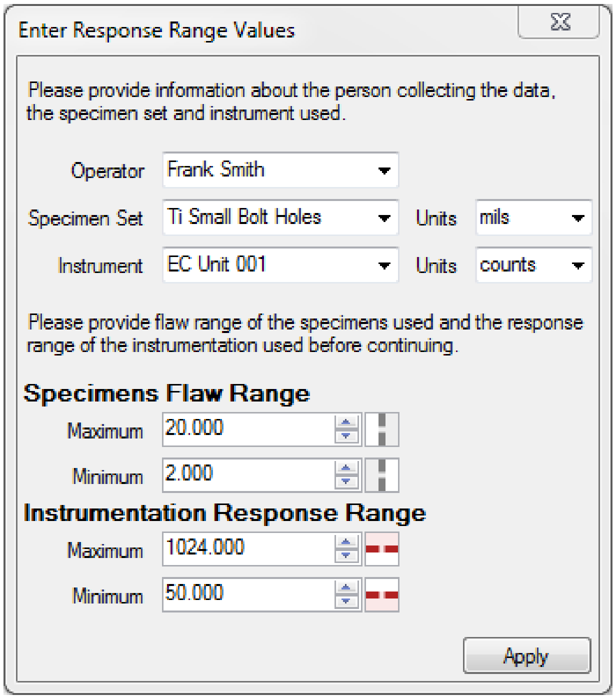


Figure 16. Quick Analysis Parameter Input Window

After entering the requested information, the quick analysis main window is displayed (Figure 17). This window is similar to the regression windows for the full analysis except that it contains a data input table. The data table is limited to columns for an ID, flaw size and response. If the user does not have unique ID numbers, the program will generate an auto ID number for them. Data points can be pasted in from Excel or CSV files or typed into the table by hand. The user can tab through columns as they enter data. The user must input a minimum of 8 points in order to generate an analysis.

The rest of the analysis works the same as the full analysis except that it cannot be exported. Since this is not considered a complete analysis there is no capability for outputting the analysis. The data points can be exported to Excel via the Export of Excel button at the bottom of the window.

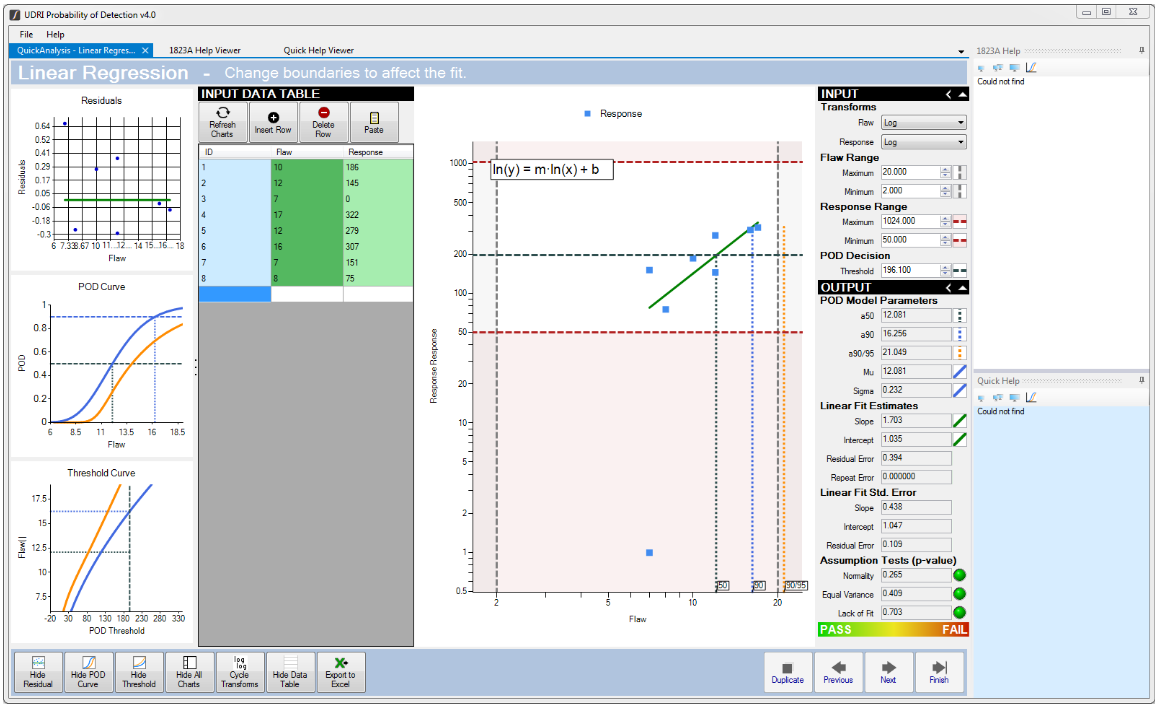


Figure 17. Quick Analysis Main Window

2.10 Output

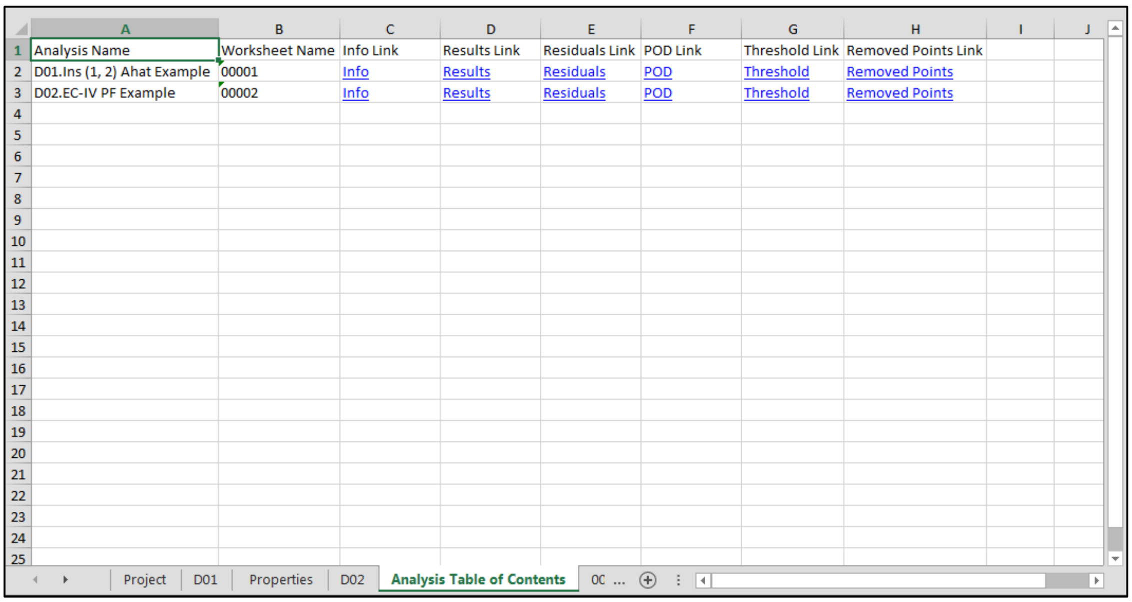
The POD program allows a user to export their results to Microsoft Excel using the .xlsx format to allow for further analysis and archiving. The exported workbook is made up of a series of worksheets that as much as possible, replicate the worksheets found in the POD v3 software. When an entire project is exported, the workbook contains a Project sheet which includes all of the information that was entered during the initial Project Setup step. This is the first sheet the user see when opening a workbook created by POD v4.This section describes the Excel output files for both the *â* versus *a* analysis and the hit/miss analysis.

2.10.1 *â* versus *a* Analysis

Since each output file could contain multiple analyses and each analysis has multiple output sheets, a method was needed to provide users with an efficient way to navigate through their data. This functionality is provided through the Analysis Table of Contents (TOC) worksheet shown in Figure 18.

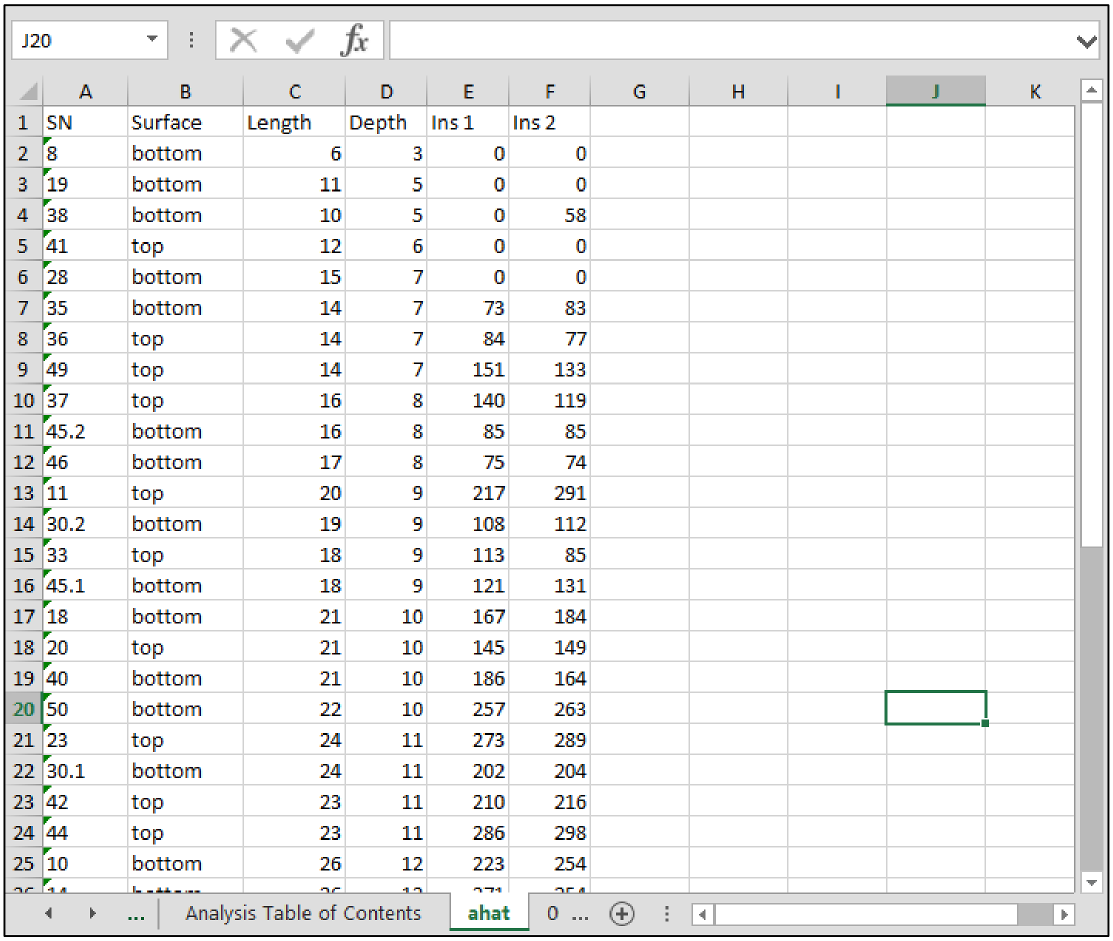
From the Analysis Table of Contents (TOC) worksheet, we see that each analysis is listed separately and has its own series of hyperlinks to other worksheets that make up the analysis. For the *â* versus *a* analysis, there are six worksheets: Info, Results, Residuals, POD, Threshold and Removed Points. In addition to these sheets, each analysis has a sheet containing the input crack data used to generate the analysis. Figure 19 shows an example of an inspection data input sheet for an $\hat{a}$ analysis.

The sheet naming convention used is to preface the link names with the worksheet name. For each analysis, this generates a series of named worksheets with the format "Worksheet_Name Link_Name." Each of these worksheets contains a link in the upper right hand corner to quickly return back to the TOC worksheet. This approach of using circular links with a TOC is more efficient and user friendly than using the traditional approach of relying on worksheet tabs to navigate the workbook as the entire contents of even a significantly large project can be seen all at once and more informative naming schemes can be used. The individual worksheets are summarized in the following sections.



Analysis Name	Worksheet Name	Info Link	Results Link	Residuals Link	POD Link	Threshold Link	Removed Points Link
D01.Ins (1, 2) Ahat Example	00001	Info	Results	Residuals	POD	Threshold	Removed Points
D02.EC-IV PF Example	00002	Info	Results	Residuals	POD	Threshold	Removed Points

Figure 18:   Analysis Table of Contents Worksheet



SN	Surface	Length	Depth	Ins 1	Ins 2
8	bottom	6	3	0	0
19	bottom	11	5	0	0
38	bottom	10	5	0	58
41	top	12	6	0	0
28	bottom	15	7	0	0
35	bottom	14	7	73	83
36	top	14	7	84	77
49	top	14	7	151	133
37	top	16	8	140	119
45.2	bottom	16	8	85	85
46	bottom	17	8	75	74
11	top	20	9	217	291
30.2	bottom	19	9	108	112
33	top	18	9	113	85
45.1	bottom	18	9	121	131
18	bottom	21	10	167	184
20	top	21	10	145	149
40	bottom	21	10	186	164
50	bottom	22	10	257	263
23	top	24	11	273	289
30.1	bottom	24	11	202	204
42	top	23	11	210	216
44	top	23	11	286	298
10	bottom	26	12	223	254

Figure 19: Example Input Data Sheet for $\hat{a}$ analysis

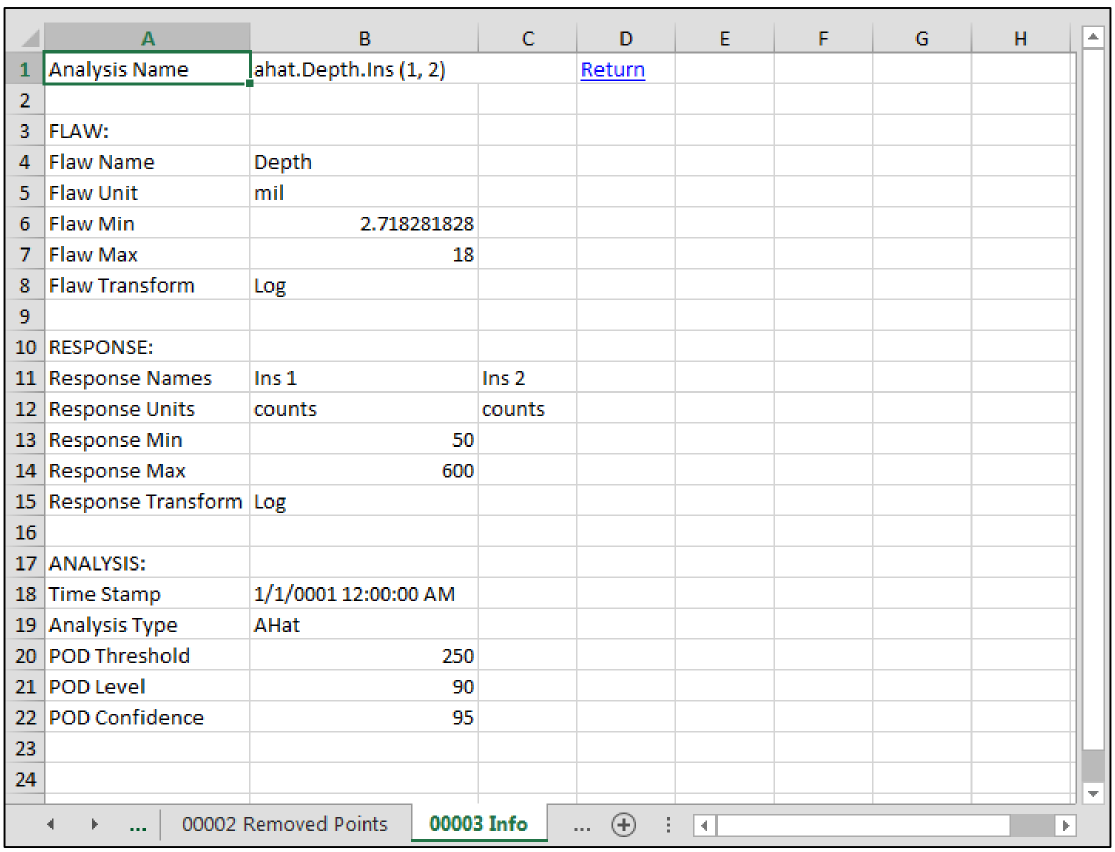
2.10.1.1 Info Sheet

The Info sheet of a POD workbook contains information that the program used to generate the output tables and graphs. An example Info Sheet is shown in Figure 20. The information is grouped in 3 categories for ease of interpretation. Entries in column A define the type of information in the row.

Column B of the Info sheet contains the following information for the POD pertinent rows:

- Analysis Name – Identification entry that will appear on the all output sheet and all graphs.
- Flaw Name – Depth or Length
- Flaw Units – Flaw size units.
- Flaw Min – minimum flaw size
- Flaw Max – maximum flaw size
- Flaw Transform – Definition of flaw size transformation used in the analysis. The default transformation for flaw size is the linear. Different transformations can be used and are entered via the Linear Regression step window.

- Response Name – Response name entered by user
- Response Units – Response size units (counts)
- Response Min – Minimum â value that can be registered by the NDE system.
- Response Max – Maximum â value that can be registered by the NDE system
- Response Transform – Definition of response transformation to be used in the analysis.
- Time Stamp – Data analysis was created
- Analysis Type –AHat
- POD Threshold – *â* decision threshold for a plot of the POD(a) function with confidence bound.
- POD Level – POD percent value for which confidence bound will be calculated. Default value is 90 percent.
- POD Confidence – Percent confidence bound for POD value.

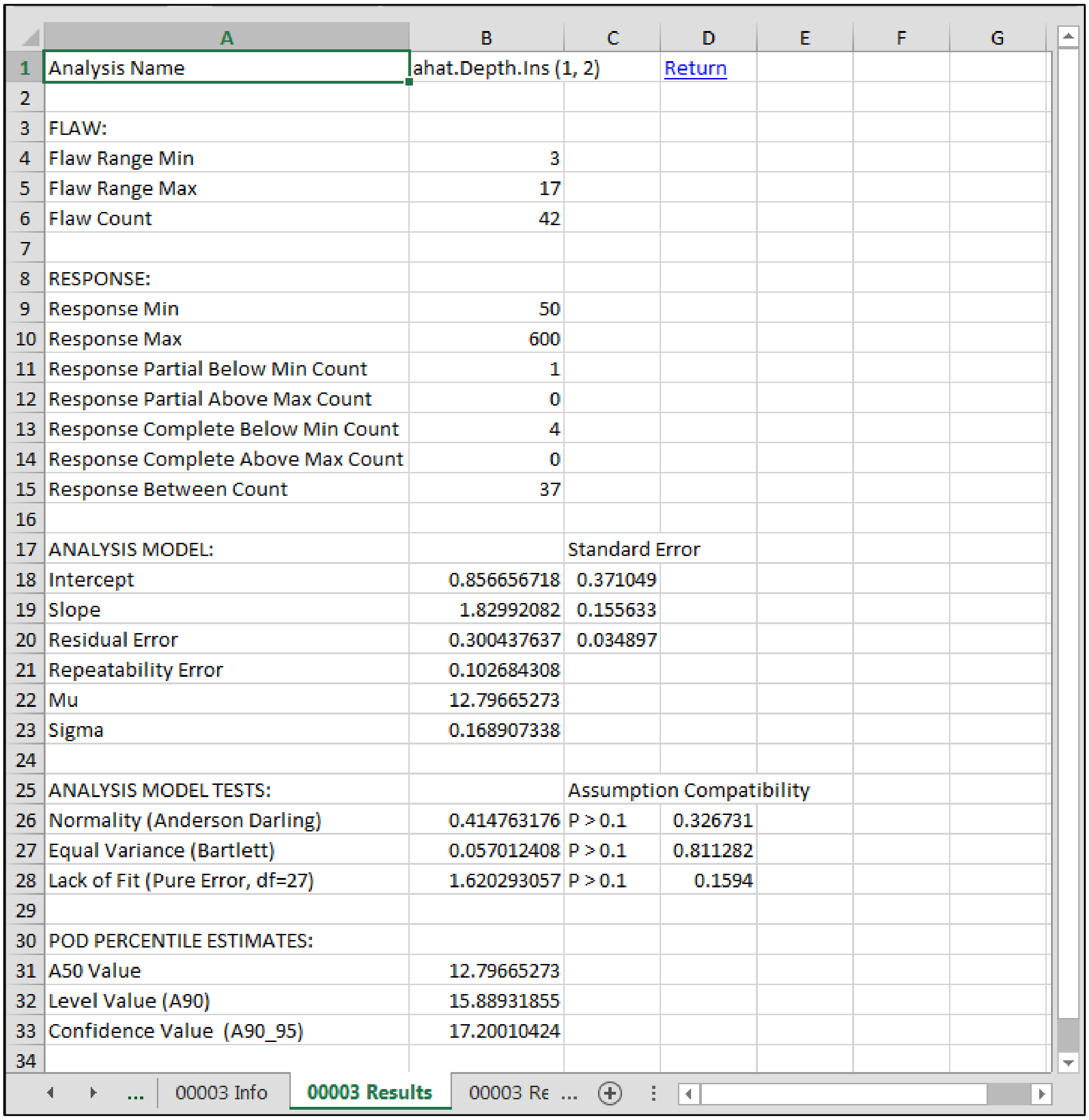


	A	B	C	D	E	F	G	H
1	Analysis Name	ahat.Depth.Ins (1, 2)		Return				
2								
3	FLAW:							
4	Flaw Name	Depth						
5	Flaw Unit	mil						
6	Flaw Min	2.718281828						
7	Flaw Max	18						
8	Flaw Transform	Log						
9								
10	RESPONSE:							
11	Response Names	Ins 1	Ins 2					
12	Response Units	counts	counts					
13	Response Min	50						
14	Response Max	600						
15	Response Transform	Log						
16								
17	ANALYSIS:							
18	Time Stamp	1/1/0001 12:00:00 AM						
19	Analysis Type	AHat						
20	POD Threshold	250						
21	POD Level	90						
22	POD Confidence	95						
23								
24								

Figure 20: Example Info Sheet for an *â* Analysis

2.10.1.2 Results Sheet

The Results sheet contains a summary of the *â* versus *a* analysis and an example is shown in Figure 21. The top line is again the Analysis Name. The identification lines are followed by the range of crack sizes, the number of cracks, and the number of censored recordings. Four of the cracks had both responses less than the minimum (signal threshold), and one crack had one response above and one below the minimum. None of the cracks had â values above the maximum (saturation).



	A	B	C	D
1	Analysis Name	ahat.Depth.Ins (1, 2)		Return
2				
3	FLAW:			
4	Flaw Range Min	3		
5	Flaw Range Max	17		
6	Flaw Count	42		
7				
8	RESPONSE:			
9	Response Min	50		
10	Response Max	600		
11	Response Partial Below Min Count	1		
12	Response Partial Above Max Count	0		
13	Response Complete Below Min Count	4		
14	Response Complete Above Max Count	0		
15	Response Between Count	37		
16				
17	ANALYSIS MODEL:		Standard Error	
18	Intercept	0.856656718	0.371049	
19	Slope	1.82992082	0.155633	
20	Residual Error	0.300437637	0.034897	
21	Repeatability Error	0.102684308		
22	Mu	12.79665273		
23	Sigma	0.168907338		
24				
25	ANALYSIS MODEL TESTS:		Assumption Compatibility	
26	Normality (Anderson Darling)	0.414763176	P > 0.1	0.326731
27	Equal Variance (Bartlett)	0.057012408	P > 0.1	0.811282
28	Lack of Fit (Pure Error, df=27)	1.620293057	P > 0.1	0.1594
29				
30	POD PERCENTILE ESTIMATES:			
31	A50 Value	12.79665273		
32	Level Value (A90)	15.88931855		
33	Confidence Value (A90_95)	17.20010424		
34				

00003 Info | 00003 Results | 00003 Re ...

Figure 21: Example Results Sheet for $\hat{a}$ Analysis

The analysis model lists the parameter estimates and errors associated with the â versus a fit parameters. The Residual Error is the standard deviation of the differences between the average $\hat{a}$ values and the linear fit. The Repeatability Error is the pooled standard deviation of the repeated â values for each crack. The results of the hypothesis tests for model fit are presented in terms of the calculated test statistic and the significance level of the test. High values of P indicate that the data are compatible with the assumption.

The POD parameters are summarized in terms of sigma, mu, a_{50}, a_{90}, and $a_{90/95}$ values for the POD Threshold listed on the Info sheet. The parameter μ depends on the decision threshold, $\mu = \ln(a_{50})$. The variance-covariance matrix for the estimates of μ and σ are contained in a different worksheet.

2.10.1.3 Residuals Sheet

Figure 22 presents a portion of the Residuals sheet of the $\hat{a}$ example. The Residuals sheet for an $\hat{a}$ versus a analysis comprises two tables that are used to generate the $\hat{a}$ versus. a, Fit Plot, and Residuals Plot graphs. The residual table lists only the cracks used in the analysis and includes the crack sizes, the average $\hat{a}$ for each crack, the log of crack size, log of average $\hat{a}$, and the differences (residuals) between the average and predicted log $\hat{a}$ values.

	A	B	C	D	E	F	G	H
43	UNCENSORED RESIDUAL DATA:							
44	a	ahat	ln(a)	ln(ahat)	fit	diff		
45	5	51.52262234	1.609437912	3.94202098	3.801800662	0.140220318		
46	7	77.83957862	1.945910149	4.354650024	4.417518213	-0.062868188		
47	7	80.42387705	1.945910149	4.38731111	4.417518213	-0.030207102		
48	7	141.7145017	1.945910149	4.953814483	4.417518213	0.53629627		
49	8	74.49832213	2.079441542	4.310776603	4.661870088	-0.351093485		
50	8	85	2.079441542	4.442651256	4.661870088	-0.219218832		
51	8	129.0736224	2.079441542	4.860382958	4.661870088	0.19851287		
52	9	98.00510191	2.197224577	4.585019538	4.877403717	-0.29238418		
53	9	109.9818167	2.197224577	4.700315049	4.877403717	-0.177088668		
54	9	125.9007546	2.197224577	4.835493934	4.877403717	-0.041909783		
55	9	251.2906684	2.197224577	5.52661031	4.877403717	0.649206593		
56	10	146.9863939	2.302585093	4.990340024	5.070205118	-0.079865094		
57	10	174.6539436	2.302585093	5.162806551	5.070205118	0.092601432		
58	10	175.2940387	2.302585093	5.166464785	5.070205118	0.096259667		
59	10	259.9826917	2.302585093	5.560615059	5.070205118	0.49040994		
60	11	202.9975369	2.397895273	5.313193846	5.244615201	0.068578645		
61	11	212.9788722	2.397895273	5.361192969	5.244615201	0.116577768		
62	11	280.8860979	2.397895273	5.637949242	5.244615201	0.393334041		
63	11	291.9383497	2.397895273	5.676542649	5.244615201	0.431927448		
64	12	152.7907065	2.48490665	5.029069054	5.403839131	-0.374770077		
65	12	168.9881653	2.48490665	5.129828684	5.403839131	-0.274010447		
66	12	180.8369431	2.48490665	5.197595759	5.403839131	-0.206243373		
67	12	237.9957983	2.48490665	5.472253019	5.403839131	0.068413888		
68	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		

... 00003 Results | 00003 Residuals | 00C ...

Figure 22: Example Residuals Sheet from $\hat{a}$ Analysis

The Residuals Plot presents the difference between average and predicted log $\hat{a}$ as a function of the size of the crack. An example Residuals Plot is shown in Figure 23 and aids in identifying crack size regions for which the fit may not be linear or for which the scatter in residuals is changing. The Residuals Plot is also useful in identifying the outlying data points that may be affecting the tests of hypotheses.

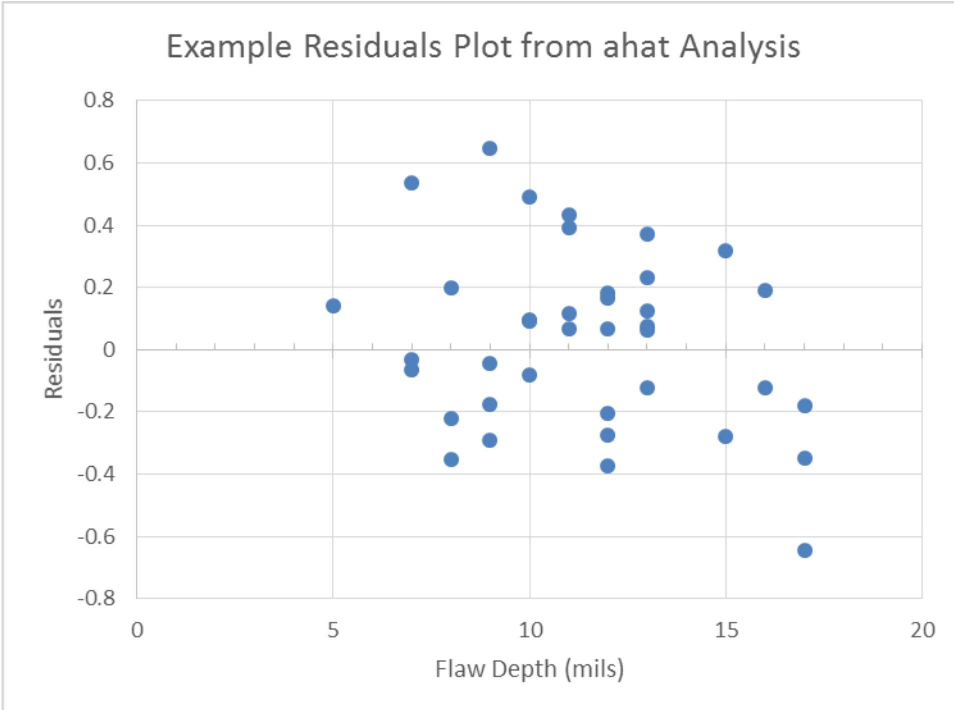


Figure 23: Example Residuals Plot from $\hat{a}$ Analysis

The Fit Plot data table lists all of the cracks from the Data sheet and contains the crack sizes, the individual $\hat{a}$ values from all inspections, and the predicted $\hat{a}$ for the crack size. Figure 24 shows an example fit plot data table.

The Fit Plot sheet for an $\hat{a}$ versus a analysis contains a plot of the average $\hat{a}$ for each crack versus the crack size with a superimposed straight line fit obtained from the analysis. Figure 25 presents an example fit plot for the data of Figure 24. The Fit plot provides for easy visual inspection of the goodness of fit and can be used to choose crack size regions for which the relation might be more linear.

	A	B	C	D	E	F	G	H
1	Analysis Name	ahat.Depth.Ins (1, 2)		Return				
2	FIT PLOT DATA:							
3	a	fit	Ins 1	Ins 2				
4	5	44.78174872	0	58				
5	7	82.89031375	73	83				
6	7	82.89031375	84	77				
7	7	82.89031375	151	133				
8	8	105.8338158	140	119				
9	8	105.8338158	85	85				
10	8	105.8338158	75	74				
11	9	131.2893567	217	291				
12	9	131.2893567	108	112				
13	9	131.2893567	113	85				
14	9	131.2893567	121	131				
15	10	159.2069803	167	184				
16	10	159.2069803	145	149				
17	10	159.2069803	186	164				
18	10	159.2069803	257	263				
19	11	189.5428653	273	289				
20	11	189.5428653	202	204				
21	11	189.5428653	210	216				

... 00003 Results | 00003 Residuals | 00C ...

Figure 24: Example Fit Plot Data Table in Residuals Sheet from $\hat{a}$ Analysis

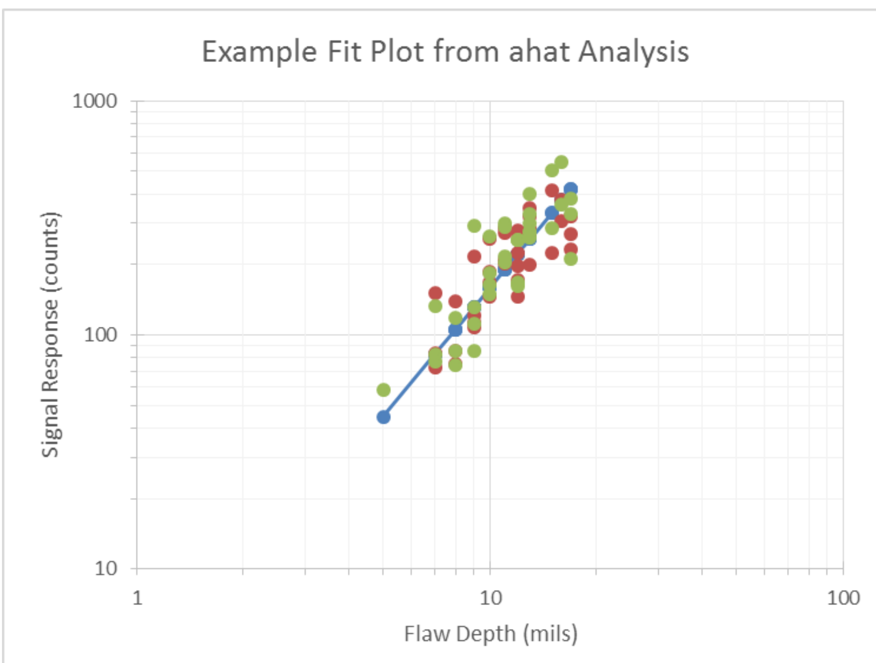


Figure 25: Example Fit Plot from $\hat{a}$ Analysis

2.10.1.4 POD Sheet

The POD Data sheet comprises three columns that contain the array of crack sizes, the estimated POD(a) function, and the confidence bound for POD(a). Figure 26 presents a small portion of the POD Data Sheet for the example $\hat{a}$ versus a analysis.

Figure 27 presents the plot of the POD sheet for the example $\hat{a}$ versus a analysis. In an $\hat{a}$ versus a data analysis, the decision threshold of the POD(a) function is that identified as the POD Threshold on the Info sheet. In Figure 27, the POD(a) function and the confidence bound stop at the maximum crack size (a = 17 mil) in the data of the analysis.

	A	B	C	D	E	F	G	H
1	Analysis Name	ahat.Depth.lns (1, 2)		Return				
2	POD DATA:							
3	a	POD(a)	95 confidence bound					
4	7.803882901	0.001705701	0.000109389					
5	8.070332673	0.003174009	0.000283697					
6	8.335392975	0.005575706	0.000669958					
7	8.599334163	0.009302442	0.001454709					
8	8.862450579	0.014817974	0.002929037					
9	9.125069552	0.022640577	0.005509681					
10	9.387561893	0.033317347	0.009746104					
11	9.650353959	0.047393079	0.016306607					
12	9.913940973	0.065377108	0.025940066					
13	10.17890064	0.087711443	0.039415016					
14	10.44590485	0.114742573	0.057443094					
15	10.71572559	0.146697726	0.080597843					
16	10.98922885	0.183664306	0.109241422					
17	11.26734886	0.225569616	0.143470618					
18	11.55103566	0.272157757	0.183090102					
19	11.84117516	0.322963438	0.227616105					
20	12.13849254	0.377288707	0.276308803					
21	12.44346339	0.434195989	0.328227658					

... 00003 Residuals | 00003 POD | 00003 ...

Figure 26: Example POD Sheet from $\hat{a}$ Analysis

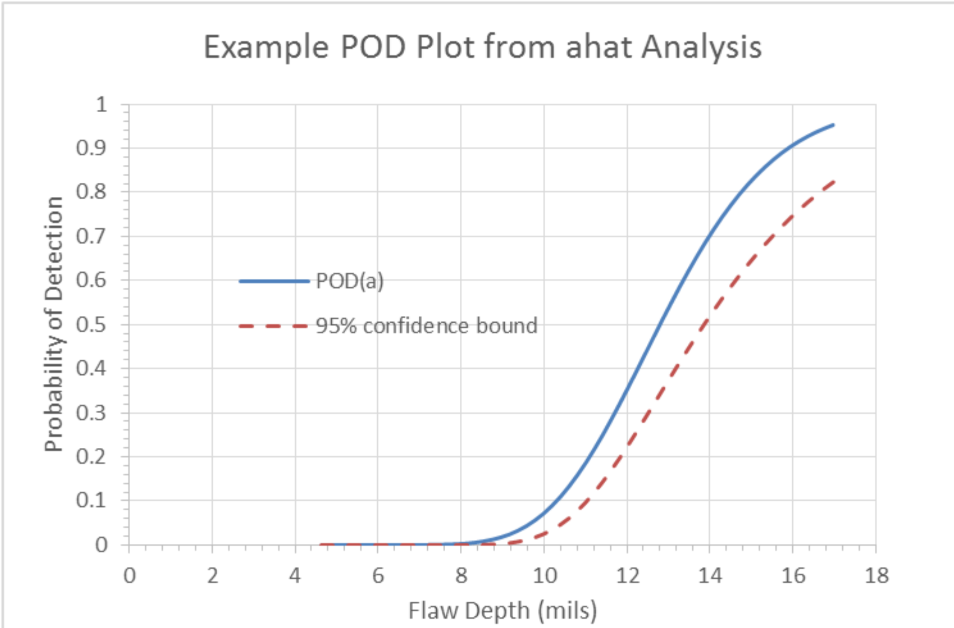


Figure 27: Example POD Plot from *â* Analysis

2.10.1.5 Threshold Sheet

The Threshold Data sheet is a table that contains a_{50}, a_{90}, $a_{90/95}$, V_{11}, V_{12}, and V_{22} for ranges of thresholds that are specified for the analysis on the Info page. Figure 28 presents a portion of the Threshold Data sheet.

The Threshold Plot presents the estimates of a_{90} and $a_{90/95}$ as functions of the decision threshold. An example Threshold Plot is presented in Figure 29. This plot has become the most useful characterization of NDE capability for â versus a data because a single demonstration of capability is often used for different target a_{90} values. Further, thresholds in automated systems often need to be adjusted, and the threshold plots readily yield the a_{90} values that would result for different choices.

	A	B	C	D	E	F	G
1	Analysis Name	ahat.Depth.Ins (1, 2)		Return			
2	POD THRESHOLD DATA:						
3	Threshold	a90	a90_95	a50	V11	V12	V22
4	2.718281828	1.34285308	1.809870638	1.081482788	0.038479669	-0.00249331	0.000508459
5	6.573936797	2.175791986	2.745734089	1.752300098	0.024202797	-0.001962968	0.000508459
6	10.42959177	2.79996848	3.415522116	2.254988102	0.018081947	-0.0016858	0.000508459
7	14.28524673	3.325158479	3.964640587	2.677956149	0.014437386	-0.001496883	0.000508459
8	18.1409017	3.788962742	4.441070638	3.05148646	0.011954825	-0.001353389	0.000508459
9	21.99655667	4.209763914	4.867742064	3.390383716	0.010132228	-0.001237656	0.000508459
10	25.85221164	4.598211128	5.257723209	3.703224325	0.008728346	-0.001140663	0.000508459
11	29.70786661	4.961139772	5.619299698	3.995513249	0.007610234	-0.001057179	0.000508459
12	33.56352157	5.303252552	5.958118827	4.271037868	0.006697566	-0.000983897	0.000508459
13	37.41917654	5.627951789	6.278237774	4.532538282	0.005938462	-0.000918592	0.000508459
14	41.27483151	5.937794886	6.582690948	4.782074126	0.00529768	-0.000859698	0.000508459
15	45.13048648	6.234762818	6.873821135	5.021240802	0.004750311	-0.000806067	0.000508459
16	48.98614145	6.520427772	7.15348435	5.251304489	0.004278175	-0.000756835	0.000508459
17	52.84179642	6.796062762	7.423182539	5.473290425	0.003867644	-0.000711335	0.000508459
18	56.69745138	7.06271604	7.684152813	5.688042831	0.003508279	-0.000669041	0.000508459
19	60.55310635	7.321263236	7.937429304	5.896266908	0.003191925	-0.000629531	0.000508459
20	64.40876132	7.572444875	8.18388715	6.098559045	0.00291211	-0.000592461	0.000508459
21	68.26441629	7.816893993	8.424274447	6.295429065	0.002663621	-0.000557546	0.000508459

... 00003 POD | 00003 Threshold | 00003 Remo ...

Figure 28: Example Threshold Sheet from $\hat{a}$ Analysis

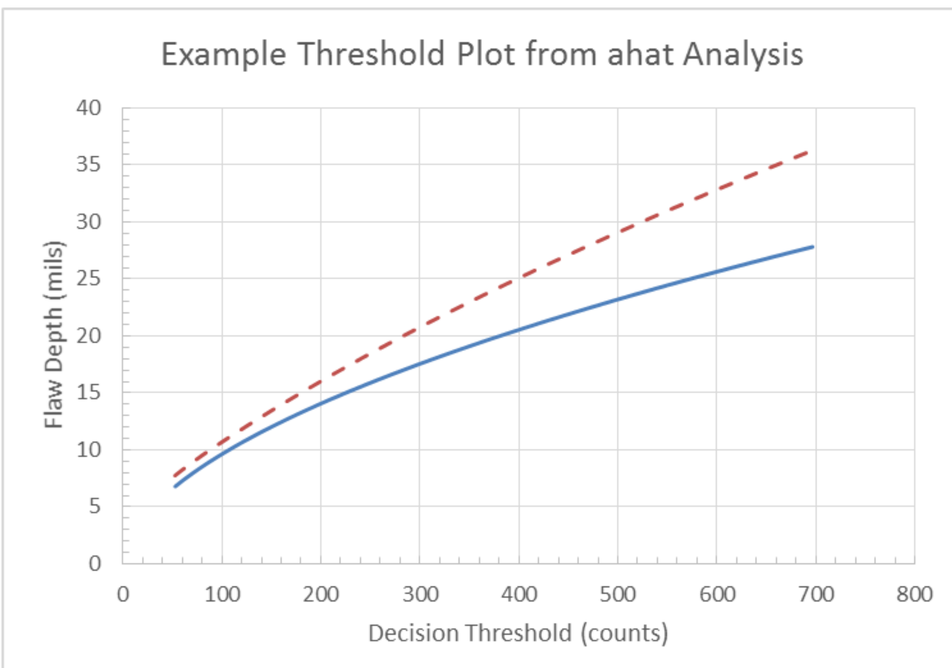
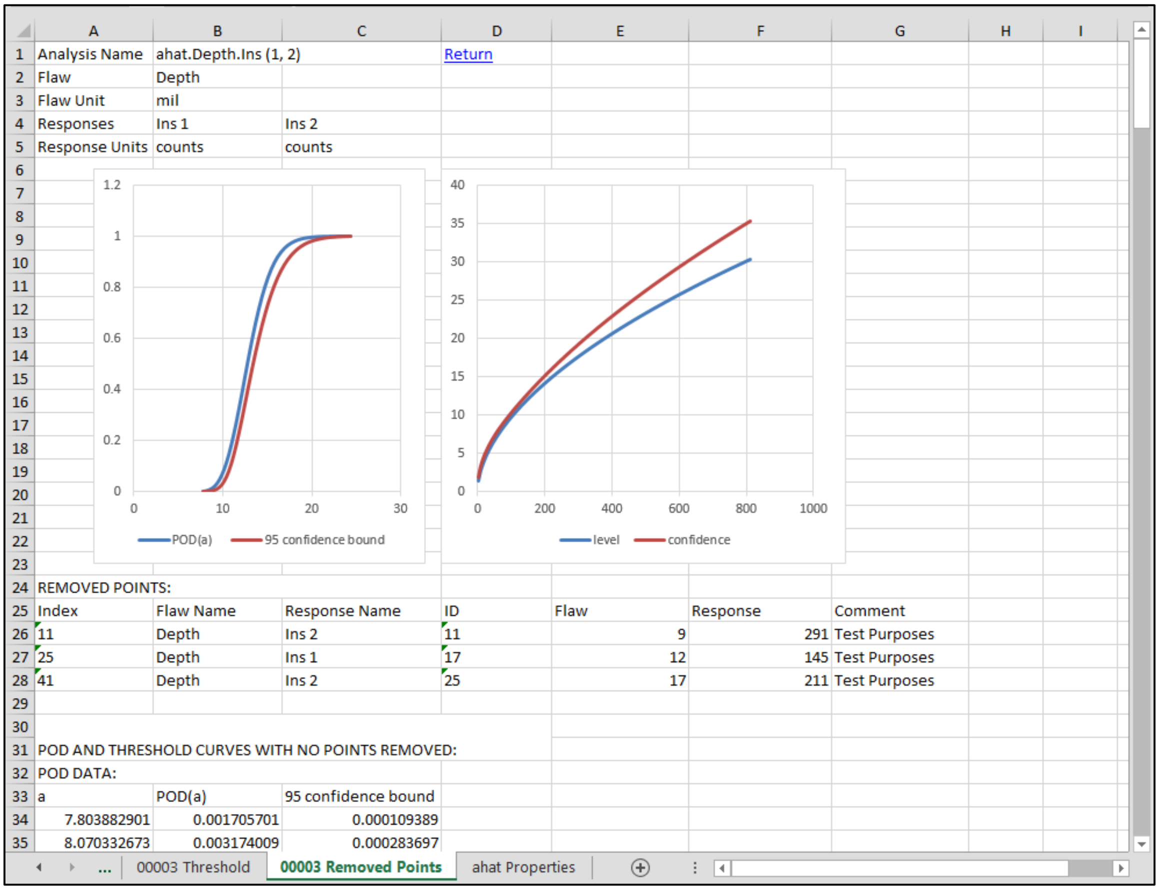


Figure 29: Example Threshold Plot from $\hat{a}$ Analysis

2.10.1.6 Removed Points Sheet

The Removed Points sheet contains a list of points not included in the analysis including the point identification number, the flaw size, the signal response and reason for removal. Figure 30 presents a portion of the Removed Points Sheet. If points are removed from the analysis, this sheet includes both the POD and POD Threshold plot of the analysis as if no points were removed. This allow someone who is looking at the data to not only know why points were removed but also the effect of removing those points.



	A	B	C	D	E	F	G
1	Analysis Name	ahat.Depth.Ins (1, 2)		Return			
2	Flaw	Depth					
3	Flaw Unit	mil					
4	Responses	Ins 1	Ins 2				
5	Response Units	counts	counts				
24	REMOVED POINTS:						
25	Index	Flaw Name	Response Name	ID	Flaw	Response	Comment
26	11	Depth	Ins 2	11	9	291	Test Purposes
27	25	Depth	Ins 1	17	12	145	Test Purposes
28	41	Depth	Ins 2	25	17	211	Test Purposes
31	POD AND THRESHOLD CURVES WITH NO POINTS REMOVED:						
32	POD DATA:						
33	a	POD(a)	95 confidence bound				
34	7.803882901	0.001705701	0.000109389				
35	8.070332673	0.003174009	0.000283697				

Figure 30. Example Points Removed Sheet from $\hat{a}$ Analysis

2.10.2 Hit/miss Analysis

The hit/miss output file is structured the same way as the $\hat{a}$ output file. There is an analysis Table of Contents (TOC) worksheet, where each analysis is listed separately and has its own series of hyperlinks to other worksheets that make up the analysis. For the hit/miss analysis, there are also six worksheets: Info, Results, Residuals, POD, Solver and Removed Points. The only new sheet is the Solver sheet that replaced the Threshold sheet from the $\hat{a}$ analysis. In addition to these sheets, each analysis has a sheet containing the crack data used to generate the analysis. Figure 31 shows an example of an inspection data sheet for a hit/miss analysis.

	A	B	C	D
1	Hole	Component	Length	EC-IV
2	5	Disk_A	91.694	1
3	6	Disk_A	10.541	0
4	7	Disk_A	57.658	1
5	8	Disk_A	20.7518	1
6	9	Disk_A	20.5486	0
7	10	Disk_A	95.758	1
8	12	Disk_A	21.59	0
9	13	Disk_A	124.46	1
10	14	Disk_A	113.03	1
11	15	Disk_A	106.172	1
12	16	Disk_A	66.04	1
13	17	Disk_A	115.824	1
14	18	Disk_A	46.99	1
15	19	Disk_A	64.77	1
16	20	Disk_A	100.584	1
17	21	Disk_A	144.018	1
18	22	Disk_A	74.93	1
19	23	Disk_A	58.166	1
20	24	Disk_A	122.428	1
21	25	Disk_A	110.49	1
22	26	Disk_A	166.116	1

... pf example | 00001 Info | 0000 ...

Figure 31: Example Input Data Sheet for hit/miss analysis

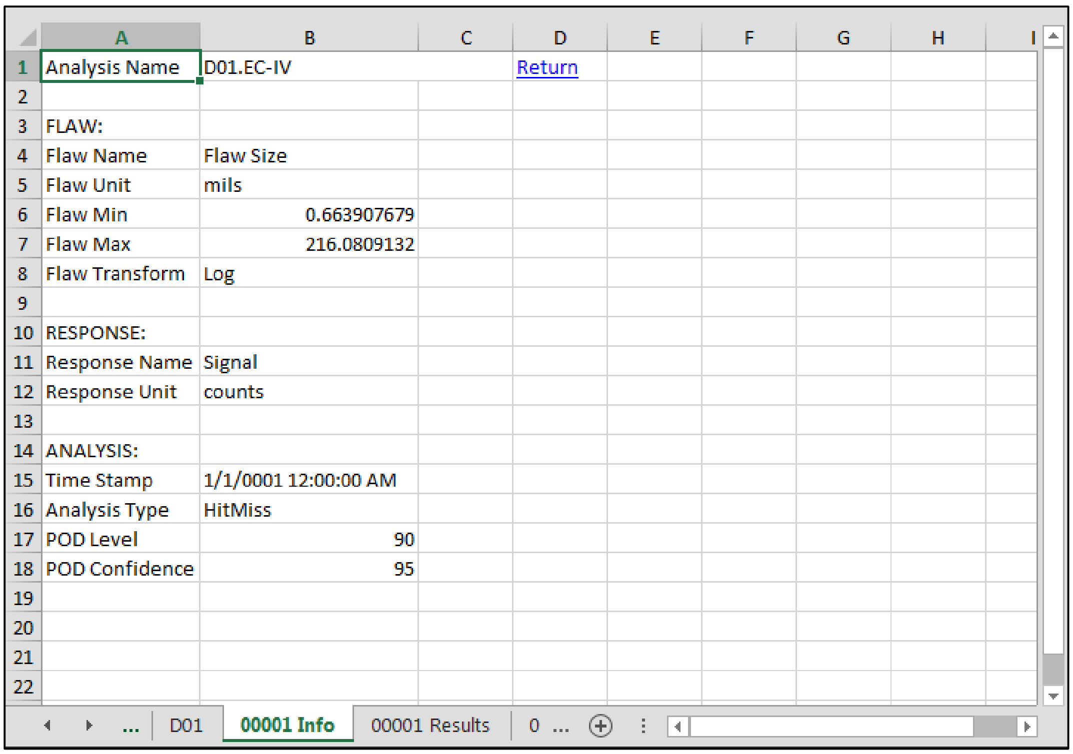
2.10.2.1 Info Sheet

The Info sheet of a POD workbook contains information that the program used to generate the output tables and graphs. An example Info Sheet is shown in Figure 32. The information is grouped in 3 categories for ease of interpretation. Entries in column A define the type of information in the row.

Column B of the Info sheet contains the following information for the POD pertinent rows:

- Analysis Name – Identification entry that will appear on the all output sheet and all graphs.
- Flaw Name – Depth or Length
- Flaw Units – Flaw size units.
- Flaw Min – minimum flaw size

- Flaw Max – maximum flaw size
- Flaw Transform – Definition of flaw size transformation used in the analysis. The default transformation for flaw size is the linear. Different transformations can be used and are entered via the Linear Regression step window.
- Response Name – Signal
- Response Units – Response size units
- Time Stamp – Data analysis was created
- Analysis Type –Hit/miss
- POD Level – POD percent value for which confidence bound will be calculated.
- POD Confidence – Percent confidence bound for POD value.



	A	B	C	D
1	Analysis Name	D01.EC-IV		Return
2				
3	FLAW:			
4	Flaw Name	Flaw Size		
5	Flaw Unit	mils		
6	Flaw Min	0.663907679		
7	Flaw Max	216.0809132		
8	Flaw Transform	Log		
9				
10	RESPONSE:			
11	Response Name	Signal		
12	Response Unit	counts		
13				
14	ANALYSIS:			
15	Time Stamp	1/1/0001 12:00:00 AM		
16	Analysis Type	HitMiss		
17	POD Level	90		
18	POD Confidence	95		

Figure 32: Example Info Sheet for a hit/miss analysis

2.10.2.2 Results Sheet

The Results sheet contains a summary of the hit/miss analysis and an example is shown in Figure 33. The top line is again the Analysis Name. The identification lines are followed by the range of crack sizes, the number of unique cracks. The POD parameter estimates mu and sigma are given and followed by the variance-covariance matrix of the parameter estimates. Finally, estimates of the a50, a90 and a90/95 are listed.

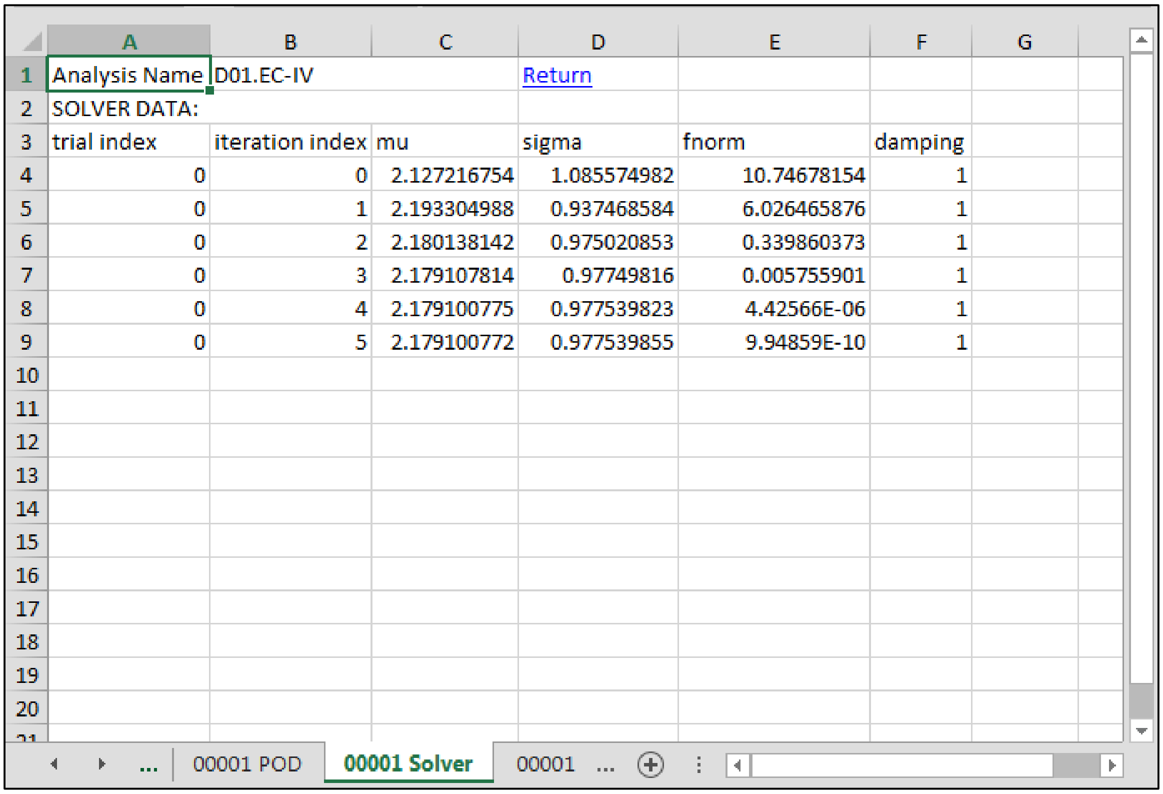
	A	B	C	D	E	F	G
1	Analysis Name	D01.EC-IV		Return			
2							
3	FLAW:						
4	Flaw Range Min	0.8636					
5	Flaw Range Max	166.116					
6	Flaw Count	275					
7							
8	ANALYSIS MODEL:						
9	Mu	2.179100772					
10	Sigma	0.977539855					
11							
12	ESTIMATED COVARIANCE MATRIX:						
13	V11	0.005515691					
14	V12	-0.000649997					
15	V22	0.007178641					
16							
17	POD PERCENTILE ESTIMATES:						
18	A50 Value	8.838354992					
19	Level Value (A90)	30.93438974					
20	Confidence Value (A90_95)	38.77633577					
21							
22							
23							
24							
25							

... D01 | 00001 Info | **00001 Results** | ...

Figure 33: Example Results Sheet for hit/miss analysis

2.10.2.3 Solve Sheet

The hit/miss Solve sheet tracks the iterations of the parameters, usually to convergence for reasonably designed capability demonstrations. If convergence is not reached in 20 iterations, POD changes the initial estimates and tries again. If convergence is not reached at the end of POD's pattern of changes, the program returns a message that convergence could not be reached. The Solve sheet on occasion has indicated the direction of changes that should be made to the initial estimates. Note that convergence to a maximum likelihood solution is not always possible. The Solve sheet for the hit/miss example is shown in Figure 34. Convergence was reached in 6 iterations in this example.



	A	B	C	D	E	F	G
1	Analysis Name	D01.EC-IV		Return			
2	SOLVER DATA:						
3	trial index	iteration index	mu	sigma	fnorm	damping	
4	0	0	2.127216754	1.085574982	10.74678154	1	
5	0	1	2.193304988	0.937468584	6.026465876	1	
6	0	2	2.180138142	0.975020853	0.339860373	1	
7	0	3	2.179107814	0.97749816	0.005755901	1	
8	0	4	2.179100775	0.977539823	4.42566E-06	1	
9	0	5	2.179100772	0.977539855	9.94859E-10	1	

Figure 34: Example Solve sheet from hit/miss analysis

2.10.2.4 Residuals Sheet

The Residuals sheet for a hit/miss analysis comprises the observed proportion of the cracks of each size that were detected, the POD(a) estimate for each crack size, and the difference between the observed and estimated POD. Figure 35 presents the small crack portion of the Residuals sheet for the hit/miss example.

The Fit Plot for a hit/miss analysis is a plot showing the POD(a) fit on the observed detection probabilities. Observed detection probability for a crack size is the proportion of all inspections of cracks of that size that resulted in detections. Figure 36 is the Fit Plot for the example hit/miss analysis. A subjective judgement of goodness of fit can be made from this plot.

2.10.2.5 POD Sheet

The POD Data sheet comprises six columns that contain an array of crack sizes, the estimated POD(a) function, and the confidence bound for POD(a). Figure 37 presents a small portion of the POD Data sheet for the example hit/miss analysis.

The POD sheet contains plots of the POD(a) function and the confidence bound. Figure 38 presents the POD sheet for the example hit/miss analysis.

	A	B	C	D	E	F	G
1	Analysis Name	D01.EC-IV		Return			
2	FIT PLOT DATA:						
3							
4	UNCENSORED RESIDUAL DATA:						
5	a	ln(a)	ahat	ahat	fit		
6	0.8636	-0.14664558	0	0.008675526	-0.008675526		
7	1.0414	0.040565962	0	0.014346817	-0.014346817		
8	1.2192	0.198194906	0	0.021360905	-0.021360905		
9	1.27	0.2390169	0	0.023591177	-0.023591177		
10	1.2954	0.258819528	1	0.024741746	0.975258254		
11	1.397	0.33432708	0	0.029569433	-0.029569433		
12	1.4986	0.404531339	1	0.034735662	0.965264338		
13	1.524	0.421338457	0	0.036076699	-0.036076699		
14	1.5748	0.45412828	0	0.03881502	-0.03881502		
15	1.6256	0.485876978	0	0.04162542	-0.04162542		
16	1.7018	0.531686514	1	0.045968673	0.954031327		
17	1.7272	0.5465016	0	0.047448792	-0.047448792		
18	1.778	0.575489137	0	0.05045514	-0.05045514		
19	1.8288	0.603660014	0	0.053520326	-0.053520326		
20	1.9812	0.683702722	0	0.063038493	-0.063038493		
21	2.032	0.70902053	0	0.066309084	-0.066309084		
22	2.159	0.769645152	0	0.074673822	-0.074673822		
23	2.286	0.826803565	0	0.083276052	-0.083276052		
24	2.4638	0.901704874	0	0.095649564	-0.095649564		
25	2.54	0.932164081	0.5	0.101050855	0.398949145		

... 00001 Results | 00001 Residuals | C ...

Figure 35: Example Residuals Sheet from hit/miss analysis

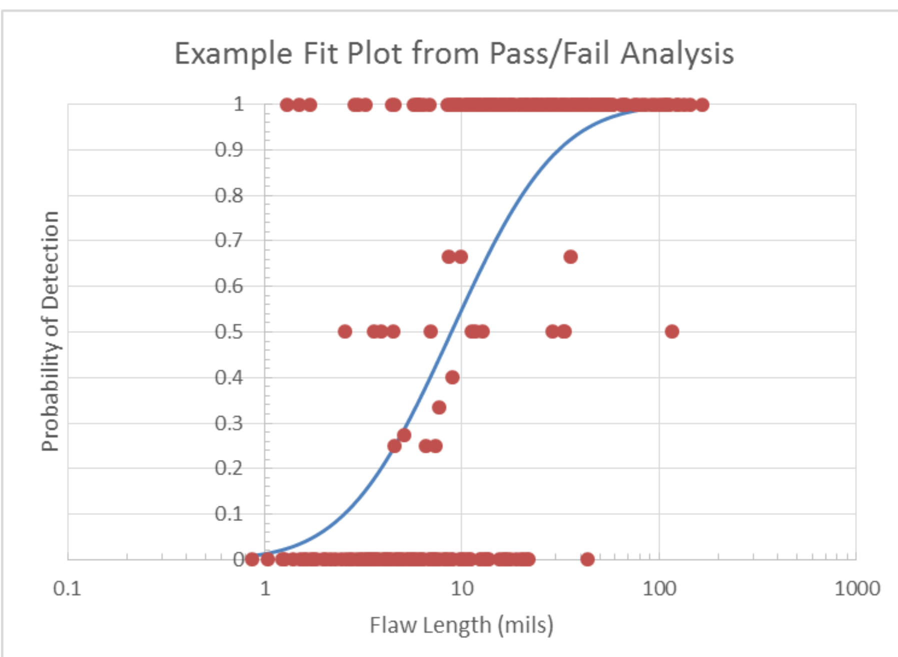
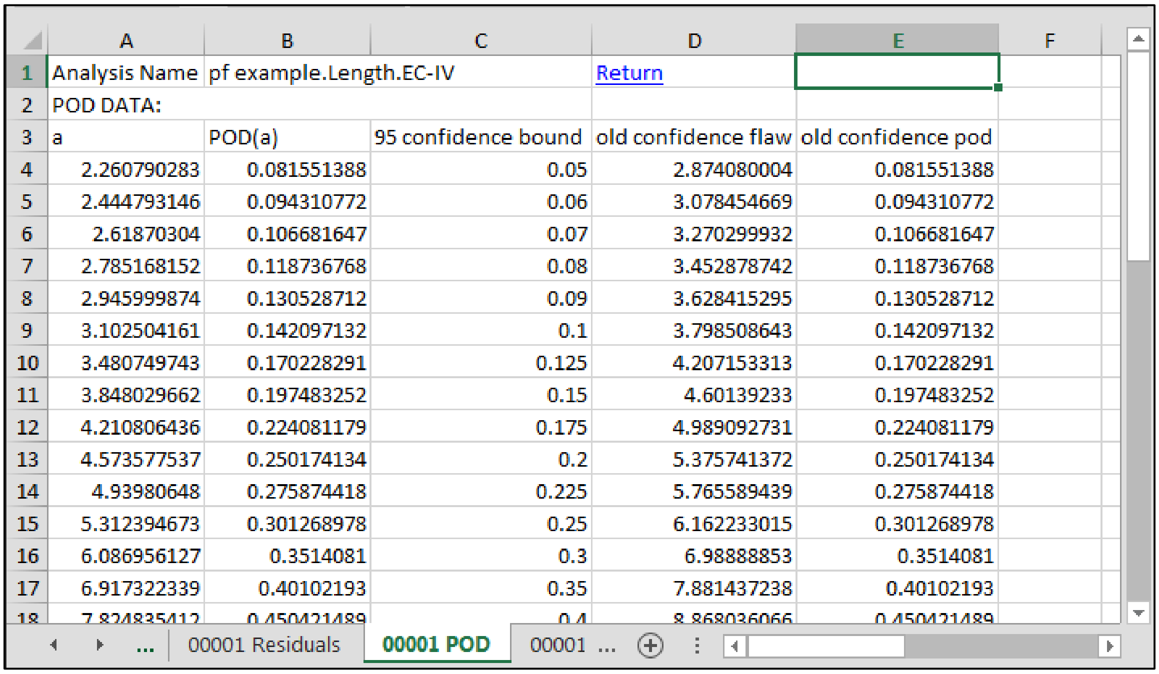


Figure 36: Example Fit Plot from Hit/miss Analysis



	A	B	C	D	E	F
1	Analysis Name	pf example.Length.EC-IV		Return		
2	POD DATA:					
3	a	POD(a)	95 confidence bound	old confidence flaw	old confidence pod	
4	2.260790283	0.081551388	0.05	2.874080004	0.081551388	
5	2.444793146	0.094310772	0.06	3.078454669	0.094310772	
6	2.61870304	0.106681647	0.07	3.270299932	0.106681647	
7	2.785168152	0.118736768	0.08	3.452878742	0.118736768	
8	2.945999874	0.130528712	0.09	3.628415295	0.130528712	
9	3.102504161	0.142097132	0.1	3.798508643	0.142097132	
10	3.480749743	0.170228291	0.125	4.207153313	0.170228291	
11	3.848029662	0.197483252	0.15	4.60139233	0.197483252	
12	4.210806436	0.224081179	0.175	4.989092731	0.224081179	
13	4.573577537	0.250174134	0.2	5.375741372	0.250174134	
14	4.93980648	0.275874418	0.225	5.765589439	0.275874418	
15	5.312394673	0.301268978	0.25	6.162233015	0.301268978	
16	6.086956127	0.3514081	0.3	6.98888853	0.3514081	
17	6.917322339	0.40102193	0.35	7.881437238	0.40102193	
18	7.824835412	0.450421489	0.4	8.868036066	0.450421489	

Figure 37: Example POD Sheet from hit/miss analysis

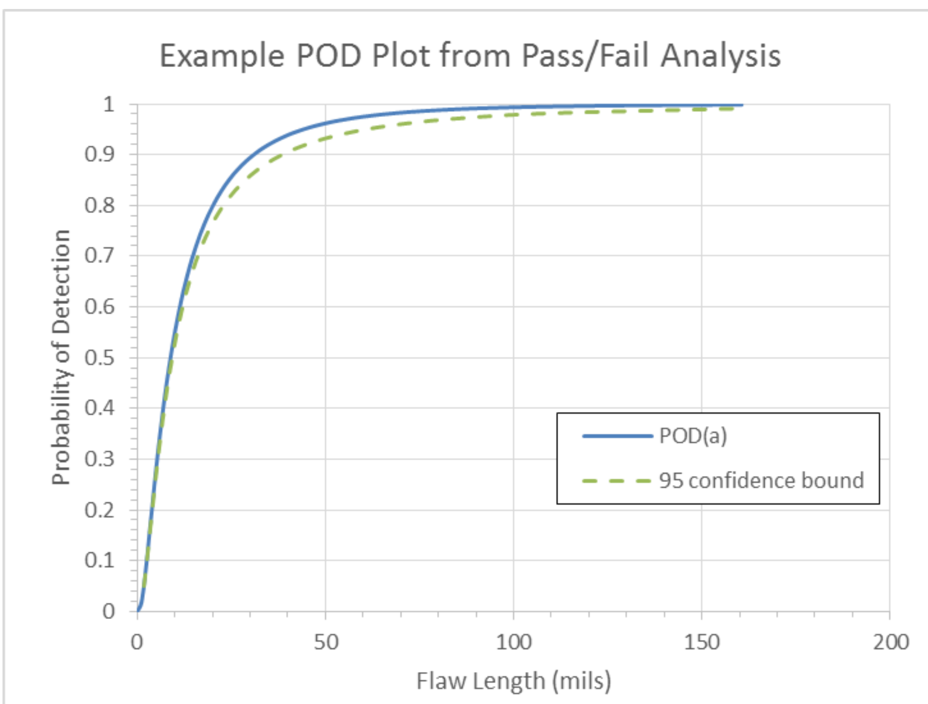


Figure 38: Example POD Plot from hit/miss analysis

2.10.2.6 Removed Points Sheet

The removed data point contains a list of points not included in the analysis including the point identification number, the flaw size and the signal response. Figure 39 shows the Removed Points sheet for a hit/miss analysis.

	A	B	C	D	E	F	G	H	I	J
1	Analysis Name	pf example.Length.EC-IV		Return						
2	Flaw	Length								
3	Flaw Unit	mil								
4	Responses	EC-IV								
5	Response Units									
6	REMOVED POINTS:									
7	Index	Flaw Name	Response Name	ID	Flaw	Response	Comment			
8	177	Length	EC-IV	4	1.2954	1	Demonstration Purposes			
9	150	Length	EC-IV	40	1.4986	1	Demonstration Purposes			
10	319	Length	EC-IV	28	1.7018	1	Demonstration Purposes			
11	83	Length	EC-IV	36	43.18	0	Demonstration Purposes			
12	23	Length	EC-IV	29	115.824	0	Demonstration Purposes			
13										
14										
15										
16										
17										

... 00001 Removed Points | pf example Pr ...

Figure 39. Example Removed Points sheet from hit/miss analysis

3.0 IMPLEMENTATION OF POD V4

This section describes how to use POD v4 to perform POD analyses of $\hat{a}$ versus a and hit/miss data.

3.1 POD v4 Installation

To install, you will need unzip the software into a folder of your choosing. Once the software has been unzipped double click on the POD v4.exe application and follow the prompts. The POD v4 requires Microsoft Windows 7 SP1 (or later), and Excel 2007 (or later) is you with to export your analyses. In addition, the POD program requires Microsoft .NET Framework 4.5, and Open XML SDK 2.5 for Microsoft Office libraries. These can be download from the Microsoft Download Center.

3.2 Starting POD v4

Start POD by double clicking on the POD icon. When POD activates, it opens up the start window shown in Figure 40. The start window allows a user to open up a new project, quick analysis or an existing project from a list of most recently used files.

Figure 40: POD v4 Start up Window

It also allows them to choose how to display their help. The choices are default, large and dual. Dual always keeps the help open in a second monitor, the large displays the files in the help windows on the right side of the step window, while the default view hides the help files until selected by the user. Selecting New Project opens a blank POD Project Setup Window which is shown in Figure 41.

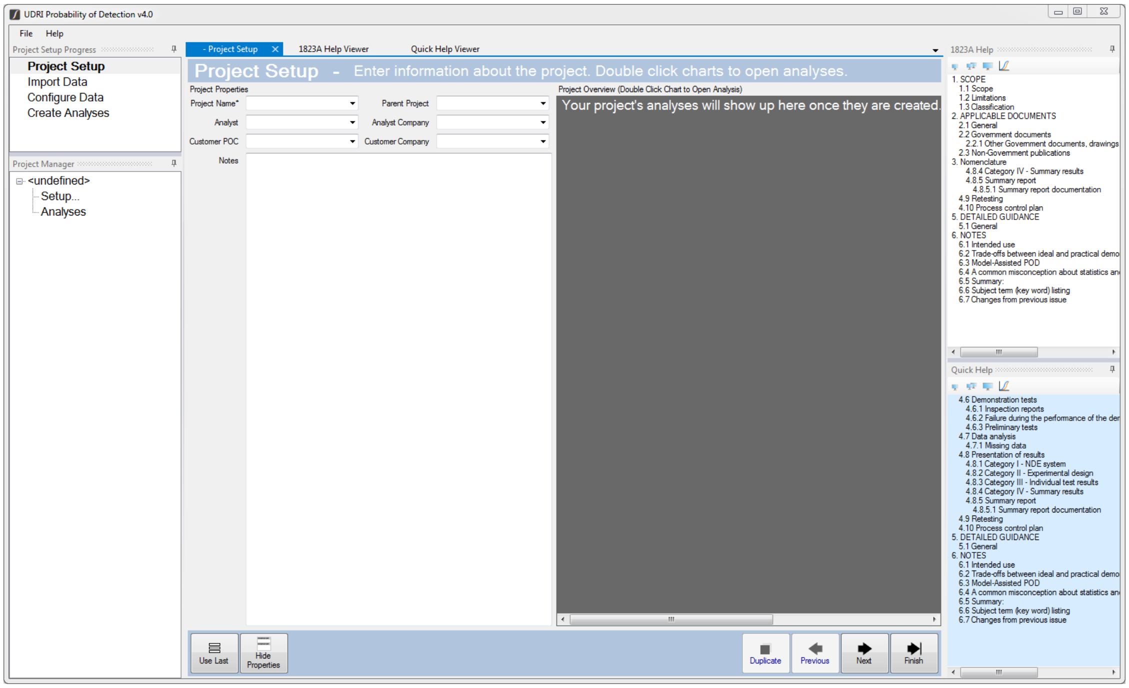


Figure 41: POD v4 Blank Project Setup Window

3.3 File Menu

The File menu in the POD window contains items associated with opening and saving the Excel data and analysis files. It also contains a list of the most recently used files and a menu item for exiting the application. The POD File menu is shown in Figure 42.

Most of the **File** menu items are similar to **File** menu items found on other Microsoft Windows applications.

- **New**– Opens a new POD Project Setup window.
- **Open…**– Brings up a standard Windows open dialogue where the user can select the file they wish to open. The dialogue box will display all files with the .pod extension which is specific to the POD v4 program.
- **Export To Excel…** – Allows users to export their analyses to Microsoft Excel files. Files are saved using the .xlsx format and are compatible with all versions of Microsoft Excel 2007 and newer.

- **Save** – Saves an update of the current saved analysis
- **Save As…** – Saves the current analysis to a file on your computer. This file has the extension .pod. These files can later be opened using the Open menu item.
- **Recent Projects…** – Brings up a list of recently open projects
- **Exit** – Closes the POD v4 program.

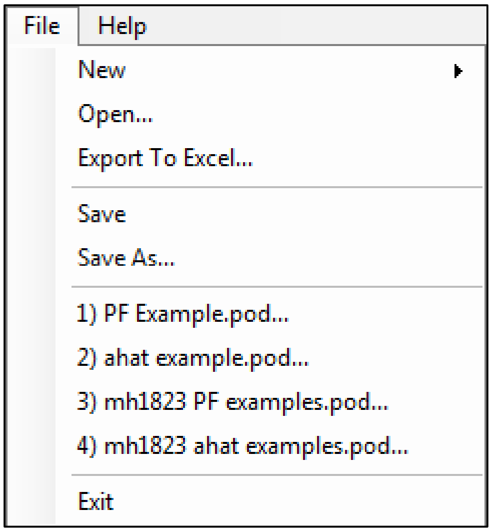


Figure 42: File Menu

3.4 Help Menu

The **Help** menu shown in Figure 43 contains links to: the POD User's Manual, the Nondestructive Evaluation System Reliability Assessment Handbook (MIL-HDBK-1823A) and the About window.

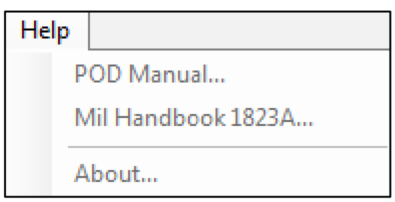


Figure 43: Help Menu

4.0 REFERENCES

1. MIL-HDBK-1823A, "Nondestructive Evaluation System Reliability Assessment," 7 April 2009.

2. Berens, A. P., "Probability of Detection (POD) Analysis for the Advanced Retirement for Cause (RFC)/Engine Structural Integrity Program (ENSIP) Nondestructive Evaluation (NDE) System Development Volume 1 – POD Analysis," AFRL-ML-WP-TR-2001-4010, Air Force Research Laboratory, Wright-Patterson AFB, OH, January 2000.

3. Berens, A. P. and Loomis, J. S., "Probability of Detection (POD) Analysis for the Advanced Retirement for Cause (RFC)/Engine Structural Integrity Program (ENSIP) Nondestructive Evaluation (NDE) System Development Volume 2 – User's Manual," AFRL-ML-WP-TR-2001-4011, Air Force Research Laboratory, Wright-Patterson AFB, OH, January 2000.

4. Berens, A. P., Hoppe, W., Stubbs, D. A., and Scott, O. J., "Probability of Detection (POD) Analysis for the Advanced Retirement for Cause (RFC)/Engine Structural Integrity Program (ENSIP) Nondestructive Evaluation (NDE) System Development Volume 3 – Material Correlation Study," AFRL-ML-WP-TR-2001-4012, Air Force Research Laboratory, Wright-Patterson AFB, OH, January 2000.

5. Berens, Alan P., "NDE Reliability Data Analysis," Metals Handbook, Volume 17, 9th Edition: Nondestructive Evaluation and Quality Control, ASM International, Materials Park, Ohio, 1988, pp. 689-701.

6. Petrin, C., Annis, C., and Vukelich, S.I., "A Recommended Methodology for Quantifying NDE/NDI Based on Aircraft Engine Experience," AGARD-LS-190, Advisory Group for Aerospace Research and Development, NATO, Neuilly-Sur-Seine, France, April 1993.

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

AFRL	Air Force Research Laboratory
ENSIP	Engine Structural Integrity Program
LRB	Likelihood Ratio Bounds
MLE	Maximum Likelihood Estimator
NDE	Nondestructive Evaluation
POD	Probability of Detection
RXCA	Material State Awareness & Supportability Branch
RFC	Retirement For Cause
UDRI	University of Dayton Research Institute
UI	User Interface
USAF	United States Air Force
WPAFB	Wright-Patterson Air Force Base
a	Crack size
$\hat{a}$ or ahat	Response of NDE system to flaw
A*	Anderson - Darling test statistic for normality
a_{90}	"90 percent detectable crack size, POD($a90$) = 0.9"
$a_{90/50}$	Best estimate of 90 percent detectable crack size (about 50 percent confidence)
$a_{90/95}$	Estimate of 90 percent detectable crack size with 95 percent confidence
χ_2	Equal variance test statistic - χ_2 distribution
F	Lack of fit test statistic - F distribution
$\Phi(\ )$	Standard cumulative normal distribution, i.e., zero mean and unit standard deviation
ln	Base e logarithm
μ	Location parameter of POD(a) model, exp(μ) is 50% detectable crack size
$\hat{\mu}$	Maximum likelihood estimate of μ
n	Number of flaws
σ	Steepness parameter of POD(a) model
$\hat{\sigma}$	Maximum likelihood estimate of σ
V_{ii}	Variance of the maximum likelihood estimates of parameter i
V_{ij}	Covariance of the maximum likelihood estimates of parameters i and j