MICHAEL D. ANDERSON

THE SEMICONDUCTOR TOOLKIT FOR JMP

Contents

Introduction 9

Annotate 11

Mapping 13

Analysis 19

Utilities 23

Credits and Information 25

List of Figures

1 The Main Interface 9

2 The Annotation Tool 11

3 The Mapping Interface 13
4 The Patterned Map Platform 14
5 Example of the output for The Patterned Wafer Map Tool. 14
6 The Bare Map Platform 15
7 Example of the output for The Bare Wafer Map Tool. 15
8 The Shape File Using Die Indices Platform 16
9 The Shape File Using Die Geometry Platform 17
10 The Shape File Using A Stepper Map Platform 18

11 The Analysis Interface 19
12 The Cluster Spatial Data Tool 20
13 The Explore Patterned Data Tool 20
14 An example of the summary report from the Explore Patterned Data Tool 20
15 An example of the wafer details report from the Explore Patterned Data Tool 21
16 An example of the die details report from the Explore Patterned Data Tool 21
17 The Compare Wafer Maps Tool 21
18 The output of the Compare Wafer Maps Tool 21

19 The Utilities Interface 23

List of Tables

1 Symmetry transforms available in the Bare Wafer Map Tool. 16

Introduction

THE SEMICONDUCTOR TOOLKIT is an attempt to answer the need from the semiconductor industry for specialized visualizations and reframing of existing JMP capabilities. On its initial release, the toolkit contained tools for generating patterned and unpatterned wafer maps, annotating existing graphics with wafer geometry, and a semiconductor specific frontend to the Hierarchical Clustering with spatial measures option. It has now been expanded to include analytical methods for exploring die defect data, making comparisons between wafers, and a collection of tools and utilities contributed by the user community. The toolkit is intended to be a collaborative and living effort by interested parties. Constructive criticism, bug reports, and capability suggestions are welcome and encouraged. Please contribute questions and feedback to Add-in page on the JMP Community (`www.community.jmp.com`).

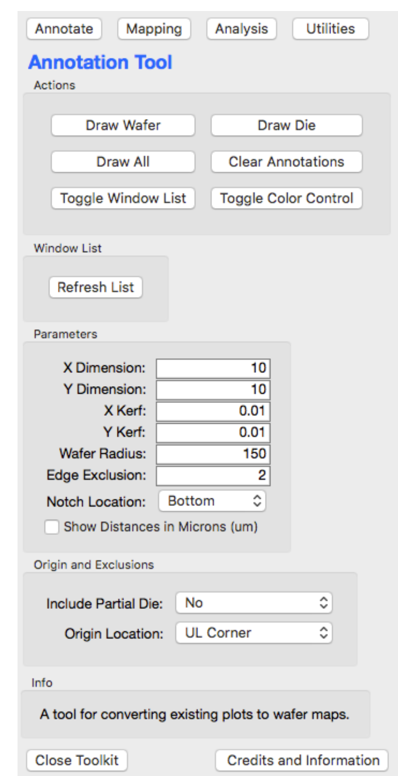

Figure 1: The Main Interface

The Main Interface

The Semiconductor Toolkit has three main parts: the Tool Boxes across the top of the interface, the tool area below the tool box buttons and the buttons for closing the Add-in and getting more information. By default the Annotate Tool Box is active when the Add-in starts. To select a new tool box, click the desired button. This document will go through each tool in each tool box in the order that it appears in the interface.

The Annotation Menu

The Annotation Tool draws different elements of the wafer geometry over an existing graph or series of graphs in the same report. The tool is divided into four sections: *Actions*, *Window List*, *Parameters* and *Origin and Exclusions*. To annotate an existing graph select it from the window list. If the graph is not in the list click "Refresh List." Then click the button for the desired annotation.

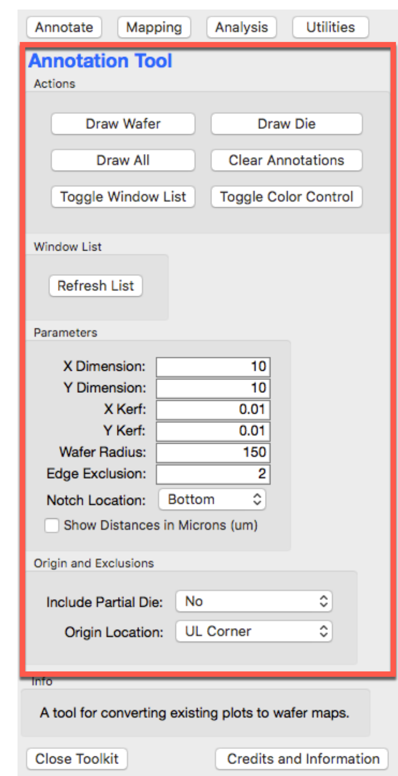

Figure 2: The Annotation Tool

Actions contains the options for what to draw on the report. *Draw Wafer* draws the wafer edge, exclusion edge, and notch location. *Draw Die* draws only the die. *Draw All* draws both the wafer geometry and die geometry. In all cases when an action button is pressed the previous annotations will be removed. *Toggle Window List* hides the window list if it is too long or if additional screen space is needed. *Toggle Color Control* shows a set of controls for choosing a different color for the geometry lines.

The Window List contains a list of available reports. Each report will have a radio button next to it. Use this radio button to indicate which report to draw on.

Parameters contains the wafer geometry information. All units are assumed to be millimeters, but can be changed to micrometers using the check box at the bottom of the parameters list. The dimension parameters are for the active area of a die. The kerf parameters are the width of the scribe lines between die. Wafer Radius and Edge Exclusion define the active area of the wafer. Notch location will change where the notch is drawn. The default is "Bottom."

Origin and Exclusions contain the parameters for where the die origin is located including an option to define an arbitrary origin. The default is "UL Corner" (*i.e.*, Upper Left Corner). The partial die can be included using the Include Partial Die option.

The Mapping Menu

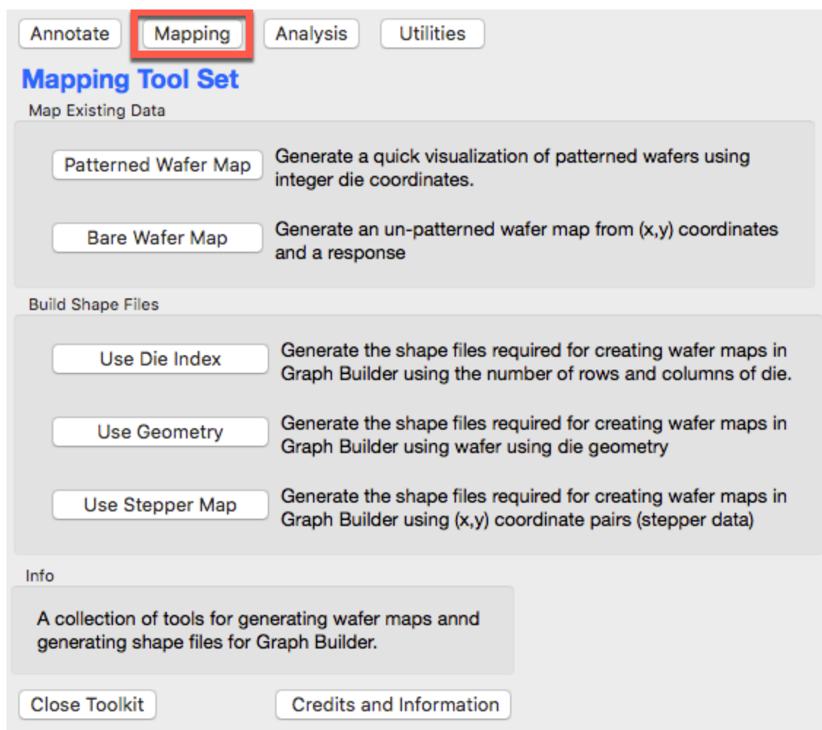

Figure 3: The Mapping Interface

The Mapping Tool Box contains tools for generating wafer maps for patterned and un-patterned (*i.e.*, bare) wafers. While there is some element of modeling in building a wafer map[1], the main reason for generating them is visual inspection of complex data. Because of this, these tools are mainly focused on creating visual representations of spatial data. The tools are divided into two subsets: *Map Existing Data* and *Build Shape Files*. The tools in *Map Existing Data* provide some summary and analytical capability for creating maps from existing data set. The *Build Shape Files* tools are for creating the support files required for building patterned wafer maps in Graph Builder.

[1] *All Wafer Maps Are Wrong, JMP Discovery Summit 2016, M. Anderson*

Patterned Wafer Map

Select Coordinates
7 Columns
Sampling Pattern
Wafer ID
x
y
Response
Gaussian Process Formula
Gaussian Process Variance
Cast Selected Columns into Roles
Y, Response — required
Y, Label — optional character ordinal
X, Die — required numeric ordinal, required numeric ordinal
Wafer ID — required
By — optional
Summary Statistic: Count
Color Theme: Blue to Gray to Red
Die Style: Outlined
Generate Table of Maps
Actions
OK
Cancel
Reset
Remove
Recall
Help

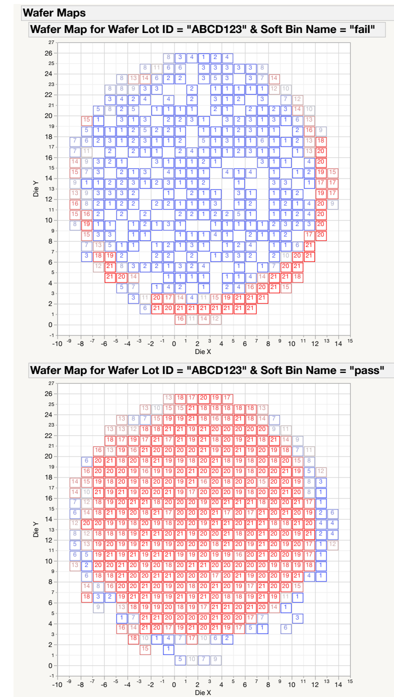

Figure 5: Example of the output for The Patterned Wafer Map Tool.

Mapping > Patterned Wafer Map uses die indices and a response variable to generate a patterned wafer map. The platform also provides summary statistic capabilities for the wafer map. To generate a wafer map put the response into y, response. Next put the X and Y die index columns into x, die. The Wafer ID goes in wafer id and is required. If the response is Nominal or Ordinal, then the optional y, label field will become active. Use this field to label the categories in the response column, *i.e.*, Pass/Fail, Failure Type, *etc.*. A range of summary statistics can be selected from the summary statistics drop down menu. Color and Die Style can be controlled using the second and third drop down menus. The generate table of maps check box will take the maps from the report and create a JMP data table with the map in an expression column.

Bare Wafer Map

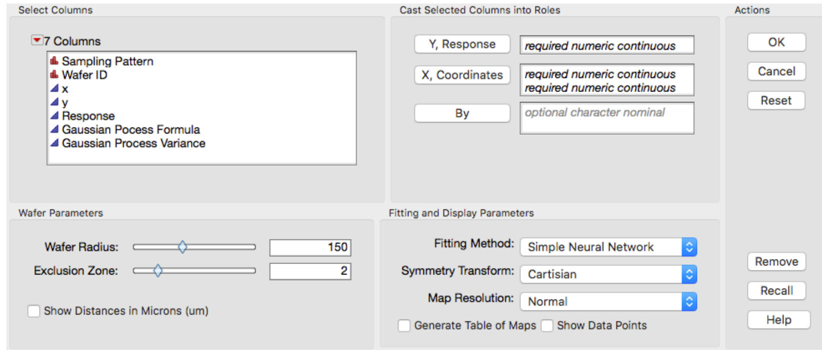

Figure 6: The Bare Map Platform

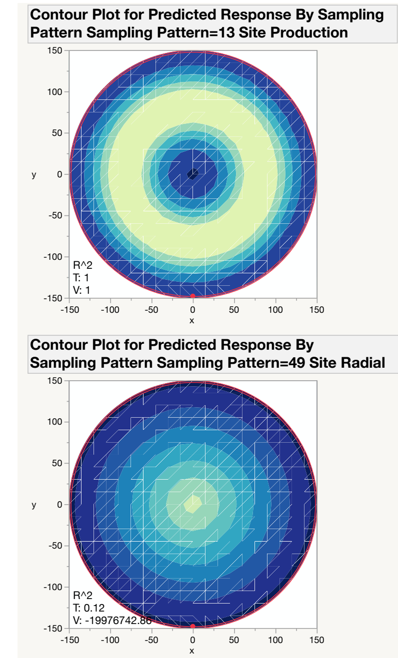

Figure 7: Example of the output for The Bare Wafer Map Tool.

MAPPING > BARE WAFER MAP uses coordinate information and a response variable to create a bare wafer map. The tool provides information about the quality of the fit for the smoothing algorithm used. The tool currently supports Neural Network models - one type in JMP and two types in JMP Pro and Gaussian Process Models. To generate a wafer map put the response into Y, RESPONSE. Next put the X and Y coordinate columns into X, COORDINATES. The wafer size and exclusion edge are controlled using the sliders in the WAFER PARAMETERS area. All units are assumed to be millimeters, but can be changed to micrometers using the check box below the sliders. The fitting method can be selected using the drop down menu. By default either Neural Network or Pro Neural Network are selected, depending on the version of JMP being used. The SYMMETRY TRANSFORMS drop down applys a transform to the (x, y) coordinates. See below for more details. The map resolution increases the quality of the final map by increasing the step size of the grid used in the Contour Plot. The GENERATE TABLE OF MAPS check box will take the maps from the report and create a JMP data table with the map in an expression column. SHOW DATA POINTS will mark the final maps to show where actual data was collected.

Symmetry Transforms

The following symmetry transforms are provided:

Table 1: Symmetry transforms available in the Bare Wafer Map Tool.

Menu Item	Description	Usage Example	Operation
Cartesian	Use (x, y) as provided in the data table.	Processes with no discernible symmetry.	(x, y)
Radial	Use the radius between (x, y) and the wafer center.	Processes with radial or "bullseye" patterns.	$\sqrt{x^2 + y^2}$
Y-mirror Plane	Treat data on the left and right side of the wafer as if they are on the same side.	Process appears to have a mirror plane running through the center of the wafer from top to bottom.	$(\|x\|, y)$
X-mirror Plane	Treat data on the top and bottom of the wafer as if they are on the same side.	Process appears to have a mirror plane running through the center of the wafer from left to right.	$(x, \|y\|)$

Shape File Tools

The Shape File Tools generate a pair of tables that Graph Builder can use to generate wafer maps directly. These tools were developed so that once a layout is determined for a particular product the shape files for that product could be generated and distributed within a company. This would standardize the visual representation of the data across the JMP users in that company. Due to the differences in IT policy, the files are generated on the user's Desktop and it is left to the user to move these files to the correct location in the file system. These locations can be found on page 308 in the JMP 13 book "Essential Graphing." This book is included in the JMP install and can be found under Help > Books > Essential Graphing in JMP.

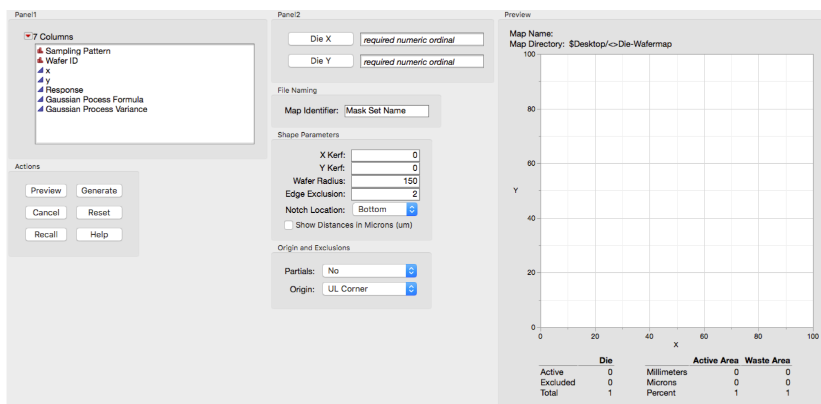

Figure 8: The Shape File Using Die Indices Platform

Mapping > Use Die Index uses a table of die indices to generating approximate wafer map shape files. The tool attempts to determine the aspect ratio of the die based on the number of unique die in the x and y directions. This will generally give a result that closely approximates the actual die layout, but incomplete data sets may impact the accuracy. To generate shape files provide the X and Y index columns to the die x and die y fields. The map identifier may be used to give the shape files a unique name. If the scribe line widths are know they can be entered in the x/y kerf fields. As with the Annotation Tool, adjustments can be made to the die origin, notch location, etc. using the menu items. See the section on that Annotation Tool for each of the options. A preview can be generated before committing to generating a shape file by clicking preview. This will update the graphic and statistics in the Preview Area to show where the origin die, *i.e.*, die-$(0,0)$, is located and the statistics for number of die and wafer utilization. The origin die can be moved by clicking the correct origin die in the preview window. The die indices will then be adjusted in the preview. Once the map looks correct in the preview pressing the generate button will create a folder on the desktop with the shape files and a test file to test the map behavior in Graph Builder.

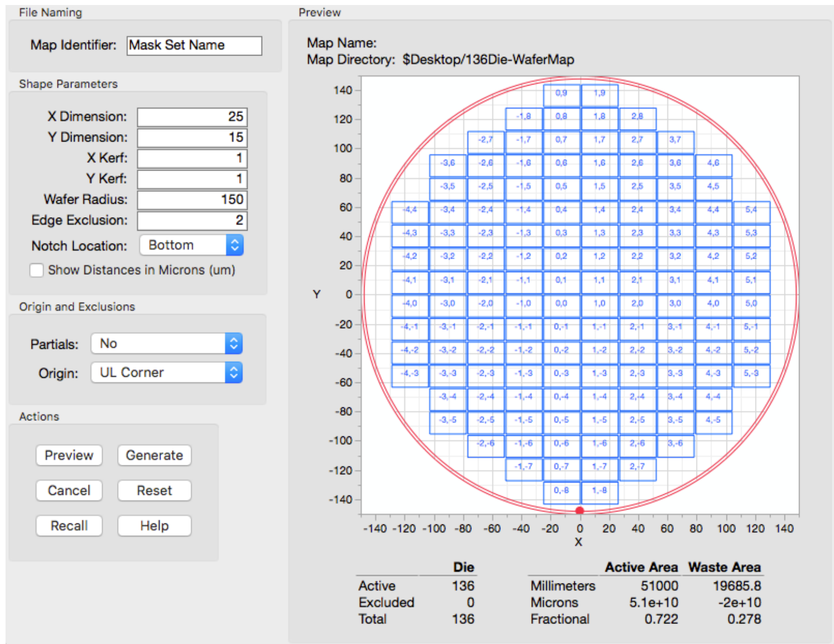

Figure 9: The Shape File Using Die Geometry Platform

Mapping > Use Geometry is the most general form of the shape file generation tools. To generate shape files provide a name for the map in the map identifier field. All units are assumed to be millimeters, but can be changed to micrometers using the check box at the bottom of the parameters list. The dimension parameters are for the active area of a die. The kerf parameters are the width of the scribe lines between die. Wafer Radius and Edge Exclusion define the active area of the wafer. Notch location will change where the notch is drawn. The default is "Bottom." Where the die origin is located may be changed using the origin option. The default is "UL Corner" (*i.e.*, Upper Left Corner) but there are options for "Body Centered" as well an option to define an arbitrary origin. The partial die can be included using the Include Partial Die option. A preview can be generated before committing to generating a shape file by clicking preview. This will update the graphic and statistics in the Preview Area to show where the origin die, *i.e.*, die-$(0,0)$, is located and the statistics for number of die and wafer utilization. The origin die can be moved by clicking the correct origin die in the preview window. The die indices will then be adjusted in the preview. Once the map looks correct in the preview pressing the generate button will create a folder on the desktop with the shape files and a test file to test the map behavior in Graph Builder.

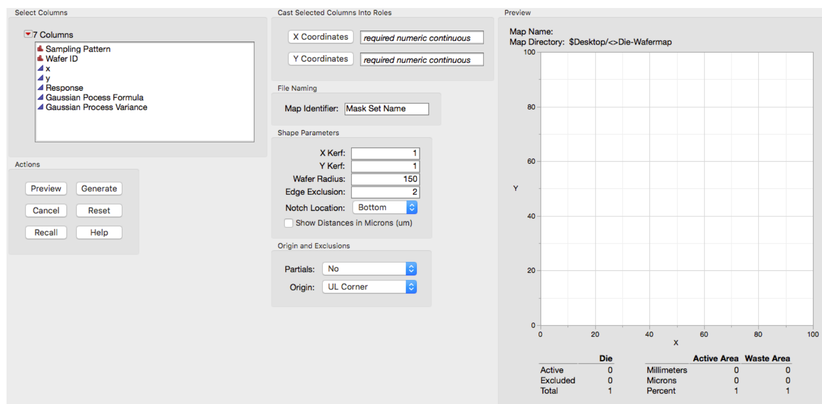

Figure 10: The Shape File Using A Stepper Map Platform

Mapping > Use Stepper Map uses a table of Lithography Stepper coordinates, some times called a "shot map," to create a shape file of the lithographic exposure fields. Where there is one die per field this will be equivalent to a die map, however in production settings it is common to have multiple die per exposure (field). So this may differ in those cases. The settings are otherwise identical to the Die Index tool.

The Analysis Menu

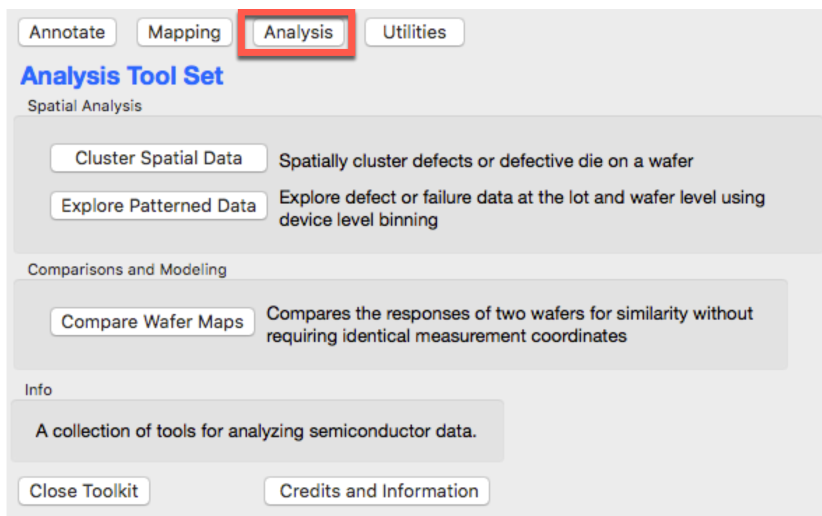

Figure 11: The Analysis Interface

The Analysis Tool Box contains a collection of tools for doing various analytical processes that are common in the semiconductor industry. The goals of the tools here are to move away from visual inspection to towards conclusions and statistical analysis. The tools are divided into two groups: *Spatial Analysis* and *Comparisons and Modeling*. The spatial analysis tools focus on examining patterned wafers, while the other group will focus on statistical comparisons, root cause analysis and predictive modeling.

Cluster Spatial Data

Analysis > Cluster Defects is a front end for the Hierarchical Clustering Platform with the spatial measures option used. This front end recasts the general terms used in the Hierarchical Clustering Platform into terms that are more familiar to the semiconductor

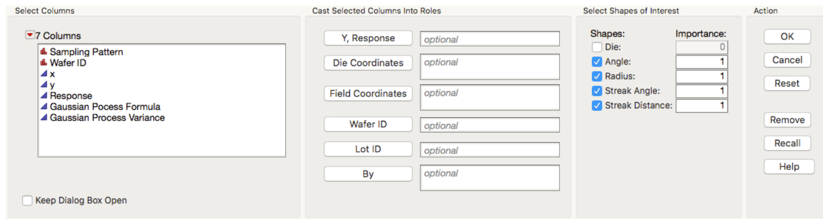

Figure 12: The Cluster Spatial Data Tool

industry. To run a clustering analysis place the columns in the appropriate fields and click OK. Not all columns are required, but all combinations of columns must be represented for each row in the data set.

The *Shapes of Interest* area contains options for refining what the clustering algorithm looks for and how important each feature type is for the analysis. In general, leaving DIE: off will speed up the analysis and is recommended.

Explore Patterned Data

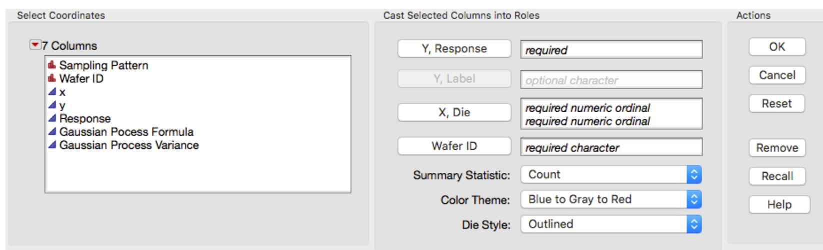

Figure 13: The Explore Patterned Data Tool

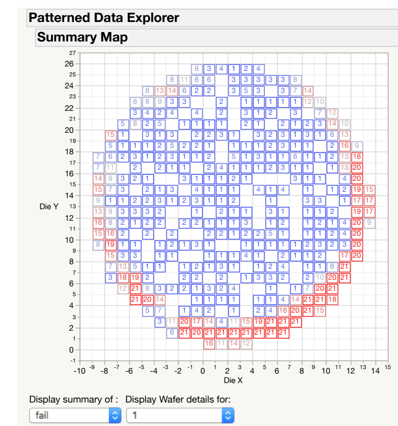

Figure 14: An example of the summary report from the Explore Patterned Data Tool

ANALYSIS > EXPLORE PATTERNED DATA generates a report that supports exploration of binning and test data. It provides the same summary statistics as the Patterned Wafer Map tool with additional drill-down capabilities. To run the analysis provide the response into Y, RESPONSE. Next put the X and Y die index columns into X, DIE. The Wafer ID goes in WAFER ID and is required. If the response is Nominal or Ordinal, then the optional Y, LABEL field will become active. Use this field to label the categories in the response column, *i. e.*, Pass/Fail, Failure Type, *etc.*. A range of summary statistics can be selected from the SUMMARY STATISTICS drop down menu. Color and Die Style can be controlled using the second and third drop down menus.

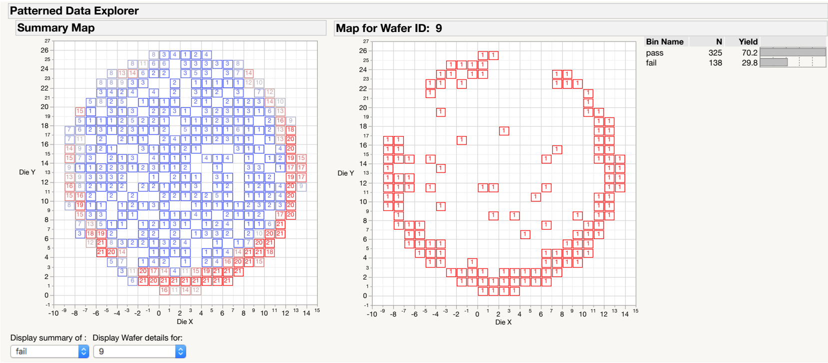

Figure 15: An example of the wafer details report from the Explore Patterned Data Tool

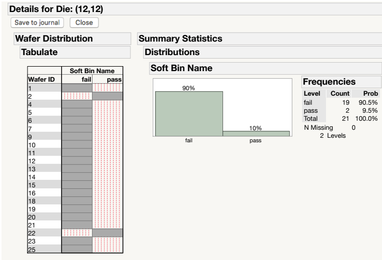

Figure 16: An example of the die details report from the Explore Patterned Data Tool

Clicking OK will generate a report with a summary wafer map and two drop down menus. The first drop down is a list of responses or response labels in the data set. The second pull down is for the wafers in the data set. Selecting a wafer will open a view of the selected wafer. Clicking on a die in the summary map will produce a summary report for that die across all wafers.

Compare Wafer Maps

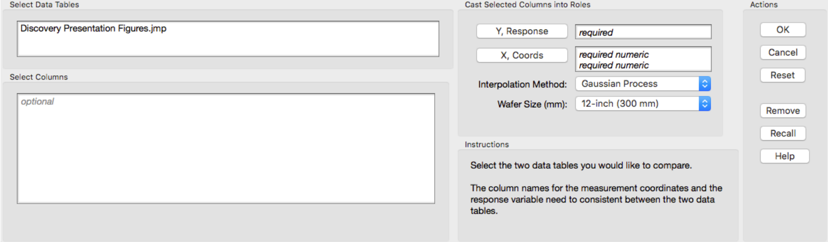

Figure 17: The Compare Wafer Maps Tool

ANALYSIS > COMPARE WAFER MAPS compares two wafer maps with dissimilar sampling patterns, i.e., different products on the same tool or process. The tool requires two data tables with the same column names. To generate a comparison select the two tables from the list of open data tables. Move the response into Y, RESPONSE. Next put the X and Y coordinate columns into X, COORDINATES. Select the modeling method from the first drop down menu (Gaussian Process is the default). Select the wafer size from the second drop down menu. Click OK. The tool generates a Gaussian Process Model for each of the wafers and then creates a contour map of the difference between the two models.

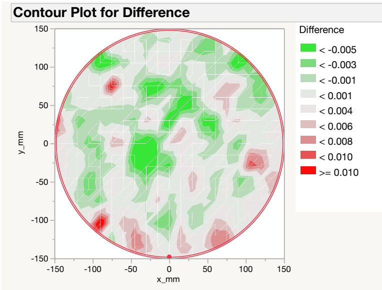

Figure 18: The output of the Compare Wafer Maps Tool

The Utilities Menu

THE UTILITIES TOOL BOX contains tools that help with various data manipulation tasks common to the semiconductor industry.

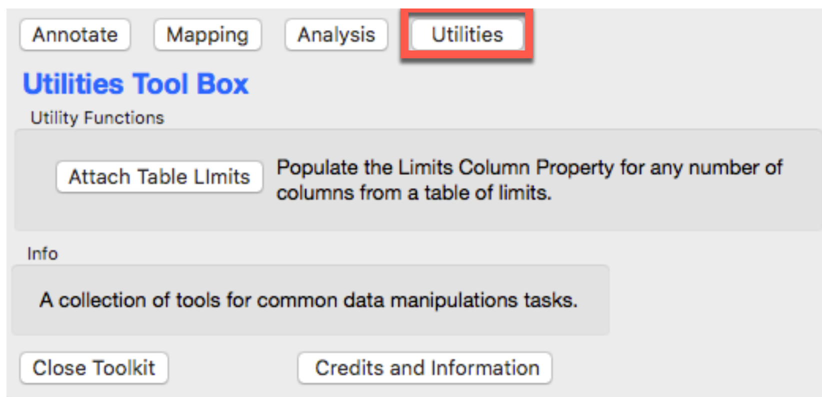

Figure 19: The Utilities Interface

Attach Table Limits

UTILITIES > ATTACH TABLE LIMITS is a port of the tool by @txnelson. Detailed documentation for its use can be found on the community[2].

[2] JMP Community > File Exchange > Add-ins > Write Limits to a Data Table from a Limits Table

The Credits and Information Menu

Look here for information about the contributors and the version history of the Add-in. This is also where you can find the license agreement for the Add-in.