

TECHNICAL DATA CHALLENGES IN THE SEMICONDUCTOR INDUSTRY

Yield analysts in the semiconductor industry face several challenges. Billions of dollars are invested in equipment for wafer fabrication and a rapid return on investment is critical to a semiconductor manufacturer. Rapid yield learning and yield enhancement is an important competitive advantage during the ramp-up stage of semiconductor production. To maintain productivity levels, the amount of time spent finding and correcting manufacturing problems must remain at least constant. Small improvements in yield, of tenths of a percent, can save the industry hundreds of millions of dollars annually.

Semiconductor yield analysis makes use of multiple sources of data collected from every stage of the manufacturing process. As the fabrication processes increase in complexity, the amount of data collected has increased dramatically. Increased wafer dimensions and decreasing line width are creating huge quantities of data from the fab environment.

The nature and quantity of data available to the analyst is dependent on the stage in the yield learning cycle. At the earliest stages, relatively small quantities of data are obtained due to the low volumes of manufacturing required to support feasibility studies and experiments. As the process matures from the experimental stage to the early production stage, automated data collection and test functions are designed to maximize yield learning while increasing wafer production. The number of device measurements may reach several thousand per chip.

Flexible yield analysis software is a critical component in a proactive integrated yield management system. Yield analysis facilitates the understanding of the manufacturing process through modeling and prediction of yield.

The data collection and analysis requirements usually make it difficult or impossible to use single-purpose off-the-shelf applications to meet the yield analysis goals of a semiconductor manufacturer.

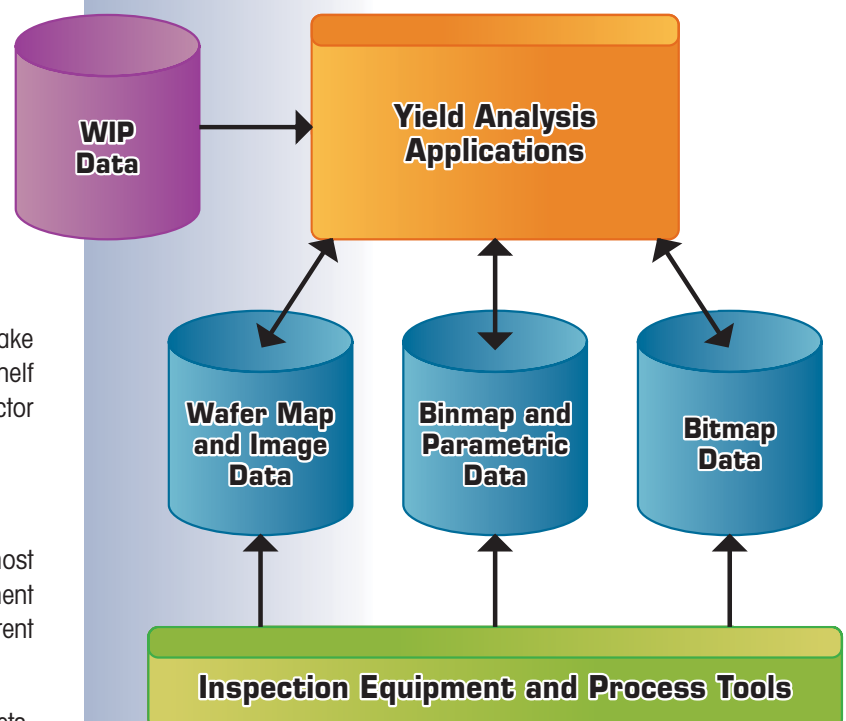
Some of these specific requirements include:

- The ability to read data from a wide variety of sources. The most effective yield programs will include design data, equipment data and failure data. Often the data is stored in different locations and may not be easily queried from a data base.
- The ability to read, manipulate and chart very large datasets. Production yield data can range into gigabytes of data.

- Negative binomial and Seed's functions for building clustering yield models useful for early stage yield learning.
- Poisson and binomial functions for the simpler yield models used in mature manufacturing processes.
- Image processing and frequency distribution functions for automated defect classification.
- Linear and logistic regression analysis and CUMSUM charts for spatial signature analysis.
- The need to rapidly develop custom solutions that can be quickly adapted to new yield analysis techniques and manufacturing parameters.

TECHNICAL SOLUTIONS FOR THE SEMICONDUCTOR INDUSTRY

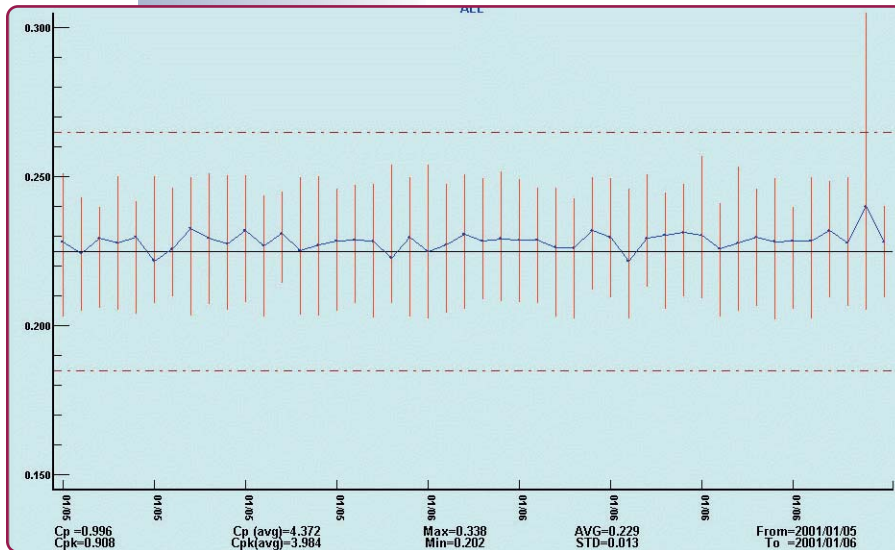
For the analytical and visual components of a custom yield management solution, the PV-WAVE family of products provides the functionality required to meet the challenges. Our team of experienced consultants is available to build your yield analysis applications and integrate the applications into your yield management solution.



THE PV-WAVE FAMILY – AN ALL-IN-ONE SOLUTION

PV-WAVE is the core product in the visualization solutions family. It is the forth-generation language engine that provides the broad functionality and ease of use for many applications. It has functionality for data import/export, data manipulation, basic analysis, and user interface development. **PV-WAVE Advantage** includes the integrated IMSL numeric and statistic libraries which provide a broad base of analysis useful in many applications. **PV-WAVE Extreme Advantage** includes IMSL and also the Image and Signal Processing Toolkits, which offer extensive functionality for state-of-the-art analysis in these areas. **TS-WAVE** is an application built using PV-WAVE for the analysis of time-series data. It provides a powerful point-and-click user interface and is easily extensible using the PV-WAVE language and pluggable modules. **JWAVE** is a web-enabling technology to let you run PV-WAVE applications from remote locations using a web-browser.

Whether you need an interactive desktop solution to explore data and create one-off solutions, a custom application to perform analysis and generate plots, an off-the-shelf solution that is extensible and easily imports complex data, or a web-based solution to share information with people outside of your group, the PV-WAVE Family delivers. It has the functionality you need in a flexible, open systems environment that easily adapts to your data needs.



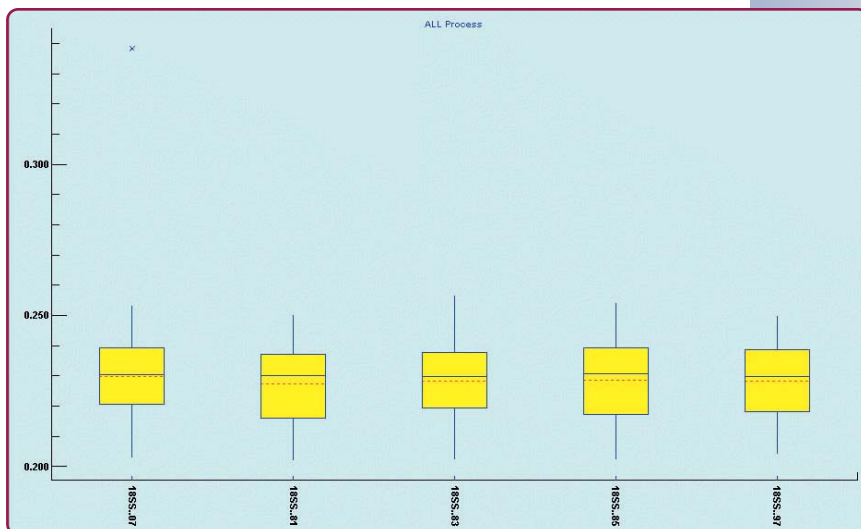
The trend chart gives you a graphical and statistical overview of the selected lot data. The blue line shows the mean values for each lot. Each bar shows the minimum, maximum and range for a single lot. The Upper Specification Limit (USL) and the Lower Specification Limit (LSL) and the target values are shown easily identify out of specification values. The bottom of the chart shows the statistical values: Cp, Cpk, Max, Min, Avg. You can click on a bar to easily drill down and gain more information about the selected lot.

PV-WAVE

provides a broad range of functionality for many different kinds of applications; some of the specific functionality most often used in semiconductor yield analysis applications includes the following:

Data Access – PV-WAVE can easily import data from data bases and legacy file formats. Specific support includes:

- Reading and processing datasets of very large sizes, up to gigabytes, which are common in yield analysis applications. High performance processing of large datasets.
- Accessing data from commercial databases
- Formatted and unformatted read/write of ASCII data using the powerful Data Connect routines which can read an entire file with one command
- Binary data read/write, including platform independent XDR format files
- Image import/export of 8 and 24-bit images in a wide variety of image formats



A box plot provides an excellent visual summary of many important aspects of lot value distribution. From this chart, you can easily see the distribution is similar for all Process IDs (x axis labels). However, an outlier is also shown for the first process ID (as indicated by the arrow in the top left corner). You can easily use the outlier information to delve deeper into the data for the problem process ID.

Data Reduction and Filtering – Use PV-WAVE's powerful array-based language to easily write code to subset, filter, and transform data. Benefits include:

- Loosely-typed and extensible 4GL with an interactive command line interface to an event driven interpreter
- Commands can be interactively interpreted or compiled into programs
- Operators work on both scalars and arrays
- Arrays can be subscripted conventionally or subscripted with other arrays
- Execution of commands contained in strings
- Powerful and convenient array creation/manipulation functions
- SQL-like query functions for tables

Data Analysis – PV-WAVE Advantage delivers powerful data analysis capabilities, which include the industry standard IMSL libraries of over 370 mathematical and statistical routines.

- Interpolation and Approximation: multidimensional gridding, n-linear interpolation, multivariate polynomials, multivariate splines
- Regression: multivariate, linear, polynomial, nonlinear
- Goodness of fit tests: chi-squared, normality, Kolmogorov-Smirnov, Mardia
- Randomness Tests
- Distribution functions: binomial, hypergeometric, Poisson, beta probability, bivariate normal
- Basic Statistics: simple summary statistics, histograms, nonparametric statistics, goodness-of-fit tests, tabulation, sorting, ranking
- Correlation and Covariance
- Analysis of Variance

The initial display shows the defects for all of the selected lots superimposed. At the bottom of the wafer map are the yield percentages. You can subset the data and look at a single lot or a group of wafers. Or, you can subset the data by failure conditions. In this example, we can easily see the DC failure rate is the highest, so that helps us keep focused on analyzing the DC failures.

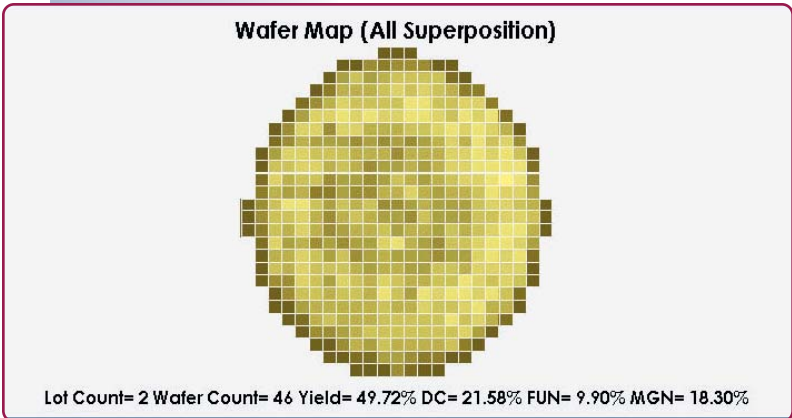
Charting – With PV-WAVE, creating highly customized and interactive charts is easy.

- Plotting 2D and 3D line, scatter, vector, and bar plots
- Plotting meshed and shaded surfaces
- Basic Image Processing functions and display
- Annotation: flexible axis, line and symbol styles; scalable/rotatable software/hardware fonts
- Comprehensive Color table Control
- OpenGL 3D graphics via the Visualization Toolkit (VTK)

Open System Platform – Call your legacy C or FORTRAN code from PV-WAVE, or call PV-WAVE directly from your own C or FORTRAN application. Support for communication between processes using operating system calls, pipes, remote procedure calls (RPCs), and sockets make it easy to develop client/server applications or communicate between PV-WAVE and other in-house or third party applications.

User Interface Development – Create simple to complex, platform-independent user interfaces with ease. Comprehensive set of high-level and low-level widgets with resource file support and string services for internationalization.

Advanced Numerics and Graphics – PV-WAVE has a wide breadth of functionality for use in advanced analysis using the IMSL libraries and signal and image processing toolkits, and in advanced visualizations using functionality such as the Visualization Toolkit.



Semiconductor Technical Note

JWAVE

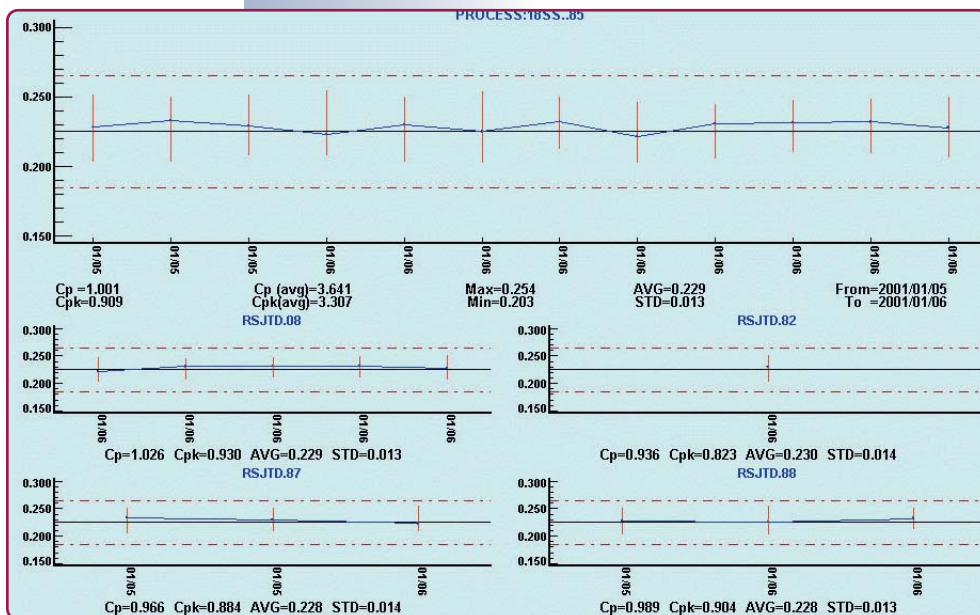
JWAVE allows you to leverage code and application that you have already created using PV-WAVE by web-enabling them for access across enterprise. You can also use JWAVE to create applications from scratch. You can create web-enabled applications just using your PV-WAVE programming skills and simple HTML interfaces (using Java Server Pages), or create powerful Java applets or applications for true web-architected applications.

PV-WAVE – A Valuable Solution for the Semiconductor Industry

The PV-WAVE Family of products – PV-WAVE, TS-WAVE, and JWAVE – delivers yield analysts the tools to efficiently and accurately meet their data challenges, no matter what form or complexity they come in.

PV-WAVE is particularly suited to custom yield analysis solutions for all stages of the yield learning curve. It is able to read, manipulate, filter and display the large, complex datasets often encountered, and provide custom solutions to meet the particular needs of a semiconductor manufacturer.

A more detailed set of trend charts broken down for a particular process.



PV-WAVE Platform and System Requirements

PV-WAVE runs on most platforms, including Windows, Linux, UNIX, and OpenVMS. Code created using PV-WAVE is platform neutral, so it can run on any system.

Platform	Operating System
SPARC	Solaris
Intel x86	Microsoft Windows® 98/NT/2000/XP
Intel x86	Linux Red Hat
HP 9000/s700	HP-UX
IBM RS/6000	AIX
Silicon Graphics	IRIX
HP/Compaq Alpha	Tru64 UNIX
HP/Compaq Alpha	OpenVMS

Visual Numerics®

Visual Numerics Corporate Headquarters
2000 Crow Canyon Place, Suite 270
San Ramon, CA 94583

USA Contact Information

Toll Free: 800.364.8880
Boulder, CO: 303.939.8797
Houston, TX: 713.784.3131
Email: info@vni.com

Visual Numerics has Offices Worldwide
USA • UK • France • Germany • Mexico
Japan • Korea • Taiwan

For contact information, please visit www.vni.com

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