FabTime Cycle Time Management Newsletter

Volume 5, No. 4 April 2004

Information

Mission: To discuss issues relating to proactive wafer fab cycle time management

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. New features in the current version (6.0) include support for fractional hour periods on all trend charts. This allows for more detailed analysis, such as examining minute-by-minute changes in WIP levels and tool status.

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Contributors: Dan Siems

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Welcome

Welcome to Volume 5, Number 4 of the FabTime Cycle Time Management Newsletter! This issue is a bit later than usual, because Frank and I have both been traveling. We just returned from doing a series of cycle time management courses for both the fab and probe manufacturing areas at Analog Devices in Limerick, Ireland. Analog Devices has now climbed to the top of our list of number of subscribers by company. We also have quite a few new companies and universities joining the subscriber list this month – clearly cycle time is becoming more of an issue as the industry continues to rebound. We welcome you all!

We have no new subscriber contributed discussion topics this month. However, we have included a sample of responses to our newsletter sign-up question: "What is the biggest cycle time problem in your fab?" and we have posed a topic ourselves for future discussion. We also have a job change announcement from Dan Siems.

In our main article this month, we discuss ideas for presenting fab performance data. These ideas are based in part on concepts proposed by Edward Tufte, author of "The Visual Display of Quantitative Information". Tufte's suggestions include using quantitative metrics for data graphics and integrating text with graphical data in charts. We have included a detailed FabTime-generated example of improving an Excel-generated chart, and summarized a few recommendations from both FabTime and Edward Tufte. We hope that you find it interesting.

Thanks for reading!—Jennifer

FabTime

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Community News/Announcements

Job Change Announcement – Dan Siems

Dan Siems (formerly World Wide Wafer Fab Cycle Time Manager for Philips Semiconductor) wrote: "My days with Philips are drawing to a close 31-Mar-2004. I am going to a small R&D fab in Sunnyvale, CA as General Manager, making MEMS (micro electrical-mechanical systems). The company name is ENDEVCO (www.endevco.com). ENDEVCO's specialty is high-end sensors for aerospace, military, auto safety, medical and ultra-custom applications. ENDEVCO has been in business since 1947, is headquartered in San Juan Capistrano, CA (southern California), and is a subsidiary of U.K.-based Meggitt PLC. Plans are in place to grow the company significantly, and this is a very exciting opportunity for me! Thank you for your help and the resource your newsletter has provided my managers while I've been at Philips."

FabTime welcomes the opportunity to publish community announcements. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

Generate a List of Inactive Lots

Many fabs flag lots as "inactive" or "static" if they wait in queue for more than some amount of time. A commonly used threshold for this is 12 hours. You can use FabTime to generate lists of inactive lots for the entire fab, or for a particular area, toolgroup, or operation. To do this, generate the "WIP Lot List" chart from the FabTime Chart List (under the "WIP Charts" heading). Use the filters to the left-hand side of the screen to restrict the lot list to a particular area, toolgroup, or operation, if applicable. Use the "Age >=" filter to set the threshold for labeling lots as inactive (e.g. enter 12 for a 12-hour cut-off). Make sure that the "Age" drop-down control is set to "Current Opn", and that the "U/M" control is set to units consistent with your threshold value (usually hours). Use the "Queue" drop-down control at the very bottom of the list to select only lots "In Queue". You may also wish to use the "Hold" drop-down control to include only lots that are not on hold. Press "Go" and FabTime will show you a list of all the lots that have been in queue for more than your threshold value. If you add this chart to your home page, it will automatically update to show the latest available data whenever your home page is refreshed. Note that the data table for the lot list will give you current information about the lot (lot size, operation, etc.), and allow you to drill down to the lot history chart for more detail.

If you have any questions about this feature (or any other software-related issues), just use the Feedback form in the software.

Subscriber Discussion Forum

We have no subscriber discussion contributions this month. In place of subscriber discussion entries we are including a sampling of recent responses to the question on our newsletter sign-up form: "What is the biggest cycle time problem in your fab?", as well as a new topic introduced by FabTime.

A Sample of Recently Reported Fab Cycle Time Problems

- Hold disposition.
- Out-and-return time for outsourced operations.
- Variations caused by product mix and single source equipment.
- Lead time for spares.
- Implantation bottleneck, with high downtime and high capacity for short time running steps.

Standby No Operator Time

We would like to pose a new discussion topic ourselves this month. One of the SEMI E-10 tool states is "standby time". This is time when the tool is available to manufacturing, but is not processing WIP. The question is: do you break this standby time into more detailed categories? In practice, some of this standby time occurs because there is no WIP available. However, sometimes the tool is in a standby state even when there is WIP available that could be processed. This often occurs because no operator is available, though there can be other causes related to lack of reticles or problems in updating tool qualification matrices. We think that it is worth measuring this time separately, because true "standby no operator" time is a capacity loss, and can significantly drive up cycle time on a tool. The problem, of course, is that this time is not normally logged into the manufacturing execution system (WorkStream, Promis, etc.), because there is no operator there to log it. We would be interested to know whether or not you break out this time in your tool status reports, and if so, how accurate you have found it to be. We will include any responses (with or without your name, as you prefer) in the next issue.

We welcome your responses to this topic, as well as other questions or comments for future issues.

Presenting Fab Performance Data

Introduction

As a company that sells digital dashboard software containing charts, FabTime has always had an interest in displaying quantitative data in a clear and meaningful manner. We read the book "The Non-Designer's Design Book" by Robin Williams several years ago, and have taken its principles to heart in designing presentations and marketing materials. More recently, FabTime's President, Frank Chance, participated in a one-day course on "Presenting Data and Information" led by Edward Tufte. Tufte is the author of several books, including the well-known "The Visual Display of Quantitative Information." Frank was impressed by several points from the course, and wanted to share these ideas with FabTime's subscribers. The points discussed below include quantitative metrics for data graphics and integration of text and graphical data. These points are illustrated via an example that Frank constructed. Additional recommendations based on our own experience are also included.

Quantitative Metrics for Data Graphics

We have all seen good charts and bad charts. The good charts are visually pleasing, present the data in a coherent fashion, and enable straightforward analysis without a lot of effort on our part. The bad charts take up space without transferring any information. Does it require a degree in art or graphics design to create good charts? As engineers, we hope not. Rather, we would like to see metrics that we can use to evaluate our charts and guide our improvement efforts.

The first step is to measure the quantity of data that we are presenting. Quantity of data is a simple metric. However, there is a large variance in the amount of actual data presented within graphics. In the article "The Cognitive Style of PowerPoint," Tufte lists the median number of data entries included in statistical graphics for various publications, based on at least 20 samples:

">1000	Science
> 700	Nature
120	New York Times
112	Wall Street Journal
53	New England Journal of Medicine
12	Sample of textbooks on PowerPoint presentations
5	Pravda (1982)"

The implication here is that publications that want to inform and show comparisons or causality generally present more data in each graphic. In order to do this and keep the charts legible, they naturally have to streamline the charts. The question is how to do this with the fab performance charts that we display every day, to make them more meaningful. Semiconductor manufacturing is a complex, data-driven industry. Analysis of our data will likely require complex, multivariate graphics.

The first step is to check our charts for data content. If a presentation contains slide after slide of Excel charts with one or two dozen points each, we know that there is probably a better way to present the data.

But what if we have a graphic with hundreds or thousands of data points? Does Excel produce excellent graphs by default? In most cases the answer is no – we need to manually refine the graph to highlight the data and minimize the non-data clutter. To guide these refinement efforts it would be helpful to know if our changes are making the graph better or worse. In "The Visual Display of Quantitative Information", Tufte outlines a metric that he calls the data-ink ratio:

Data-ink ratio = (data-ink) / (total ink used to print the graphic)

The best-case data-ink ratio is 1.0 – no piece of the graphic could be removed without also removing data. More common, however, are ratios well below 0.5, and even below 0.2. These low ratios mean that the vast majority of the ink is used for non-data items. One problem with default Excel charts is that they include so much extra ink (backgrounds, axis labels, thick lines, etc.) that the essential points of the data are obscured. Thus a first step in our refinement is subtraction of ink that does not present data.

Integration of Explanatory Text and Graphics

Another point that Tufte makes in his books and course is that the most useful graphics integrate explanatory text with graphical/quantitative material. Typically we generate charts in which the numbers are displayed only on the chart axes, as axis labels, and any explanatory text is included in a caption, or chart title. Often when presenting such graphs, or writing about them, we end up pointing out highlights. But how much more useful would the charts be if the highlights were pointed out directly, right next to the data?

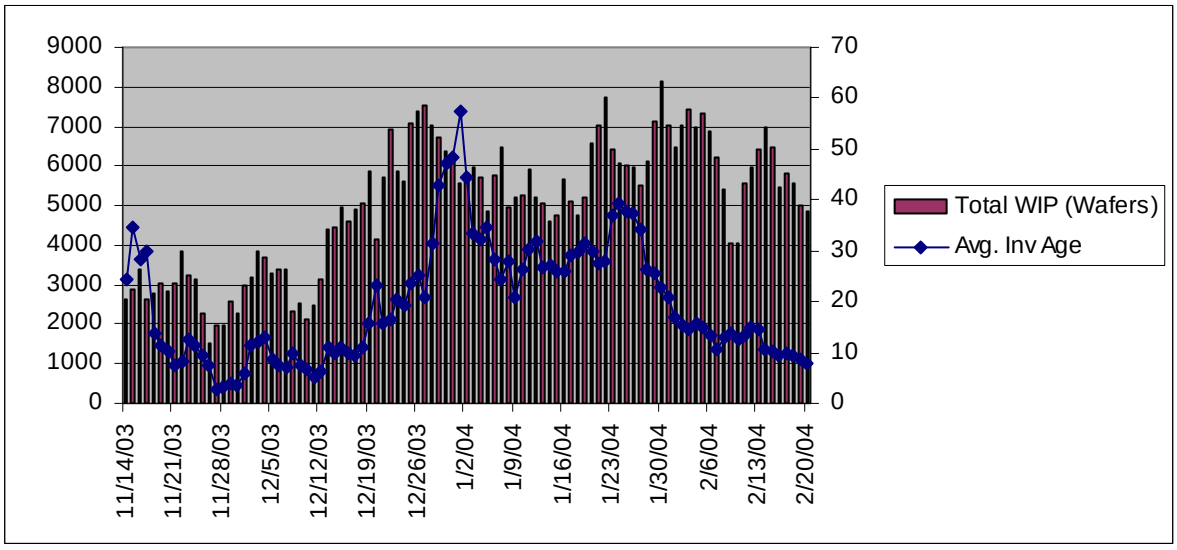
Example: WIP and Inventory Age Data Displayed in Excel

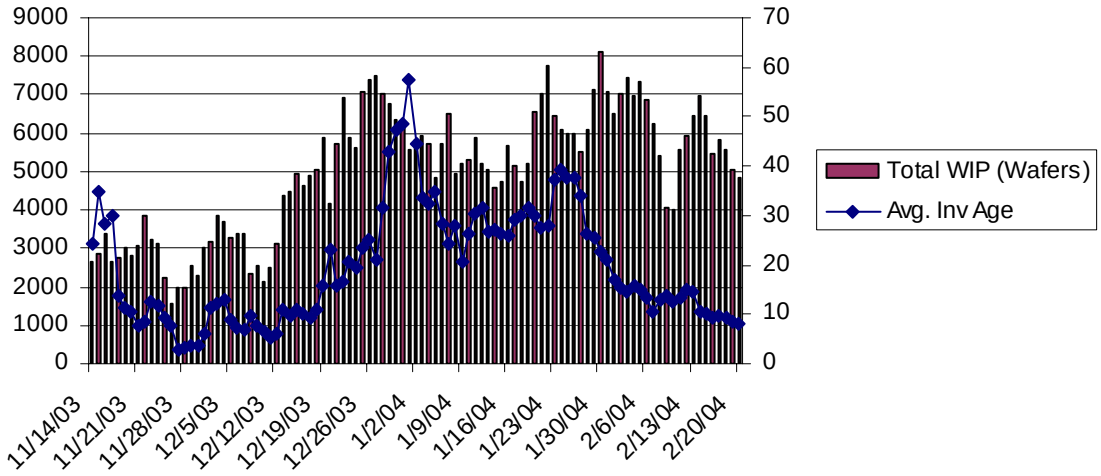
Excel is a commonly used tool in fabs for summarizing and displaying data. However, the default charts produced by Excel tend to have a very low data-ink ratio. They usually include considerable extra ink that isn't necessary to show highlights of the data. Have you ever noticed that the default background of charts produced in Excel is usually gray? Do you find yourself routinely going in whenever you create a chart, to change this background to "none", to make the data stand out more?

Similarly, most charts generated in Excel by default include no integration of text and graphical data. The text is all in the chart axis titles and labels, rather than on the chart. (Pie charts tend to be an exception.) However, Excel is a highly flexible tool, and by doing a bit of extra work, we can increase the data-ink ratio, and also better integrate explanatory text and graphics.

As an example, suppose we want to create a chart that displays three months of WIP and average inventory age data for a fab, based on daily observations. (Inventory age is the time that each lot has been at its current operation. Averaging it across the fab gives an indication of how long lots are spending in queue before being processed.) Based on 90 days of data, with two data points per day (WIP and average inventory age), the chart will have 180 data points.

The default chart produced by Excel for a sample set of data is included below,





followed by successive revisions to the chart in which we increase the data-ink ratio and eliminate the separation between text and graphic. The steps taken in revising the chart are outlined below:

Revision 1 (Shown above):

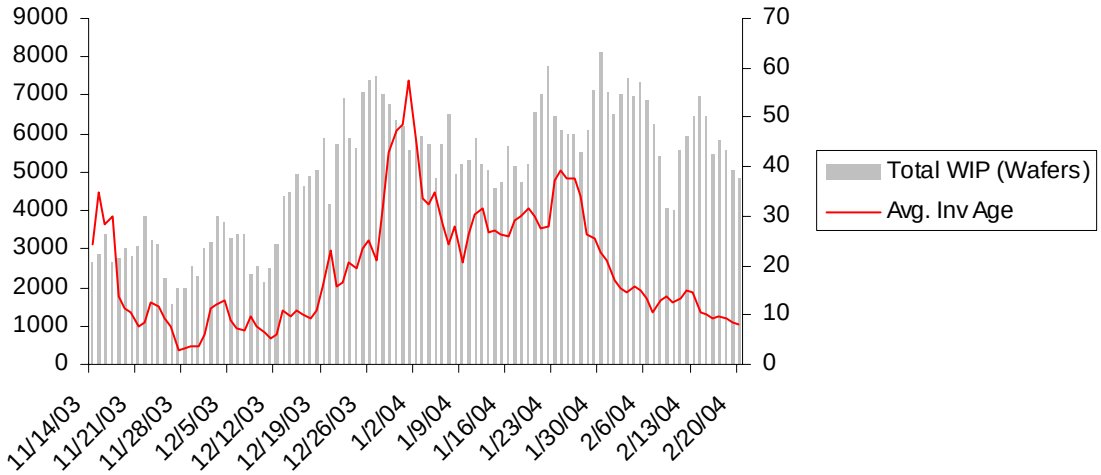
- Remove inner chart area fill, and remove inner chart border.
- Remove outer chart border (for pasting the graphic into other documents).

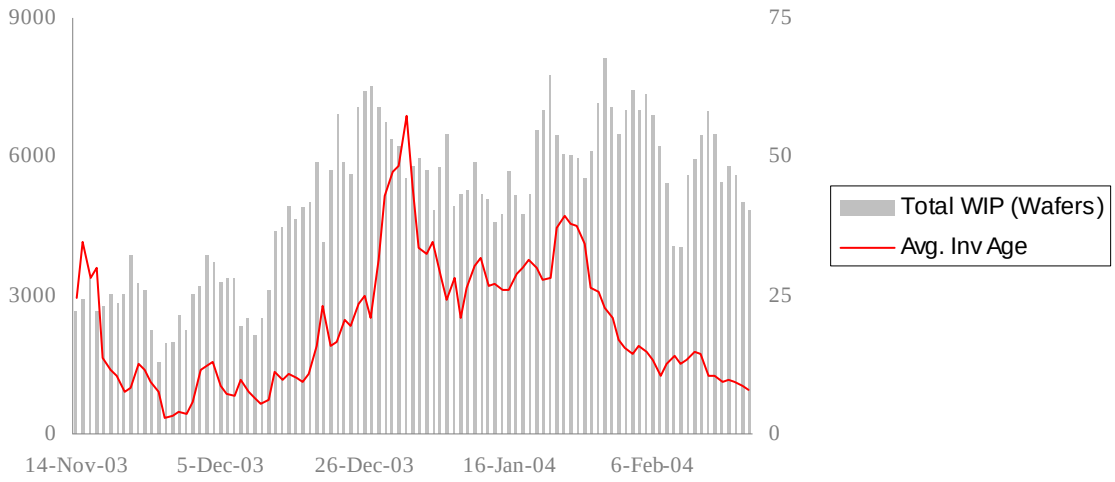
→ These revisions remove ink from the chart without removing any data. If the outer chart border remains when the chart is pasted into PowerPoint, the border becomes a stark separation between the chart and any explanatory text.

Revision 2 (Shown below):

- Remove gridlines.
- Remove the border on the WIP columns, and change the columns to a lighter color.
- Remove the point markers for inventory age, and change the color of the line to red (to stand out more).

→ An alternative is to keep the gridlines but change them to a lighter color so that they do not overwhelm the data points.





Revision 3 (Shown above):

■ Format the x-axis to times roman, smaller font, horizontal instead of vertical text, mixed text and numbers, a lighter color font, and to include fewer labels. This makes it easier to read and interpolate, and makes the whole axis stand out less.

■ Remove tick marks from both axes. The labels and numbers already identify positions, and the tick mark labels are distracting.

■ Format the y-axes (left and right) to times roman, smaller font, fewer labels, etc.

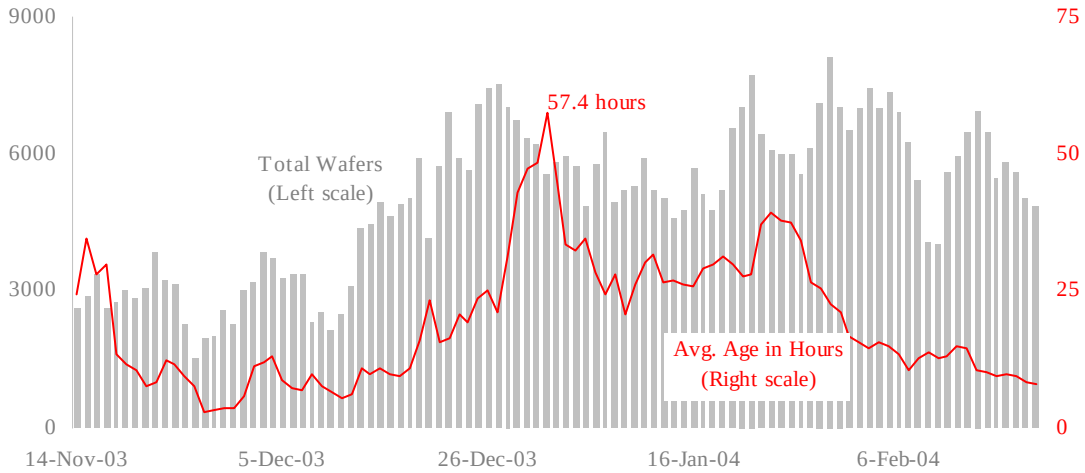
■ Remove the right-hand y-axis line. The axis labels are enough.

→ It's hard to read vertical text on a chart, and in most cases Excel's default behavior is to display far too many axis labels. For example, we can certainly handle the interpolation between November 15th and December 5th without seeing the intervening labels.

Revision 4 (Shown below):

■ Eliminate the legend box, and directly label the data by adding text boxes.

■ Decrease the column gap width (under Format Data Series | Options). This does end up using slightly more ink for this chart, but the data is easier to view.



■ Label the maximum inventory age point (57.4 hours for this example). This shows the units for the second y-axis, and ties to the axis scale.

■ Tie the inventory age line color to the right-scale color (by changing the color of the secondary y-axis labels). This makes it immediately clear which axis belongs to which series.

■ Drop the x-axis line, and change the left-hand y-axis line to be the same color as the WIP bars. This removes distractions.

→ No matter where Excel's default legend box is displayed, it takes up a large portion of the overall chart space, and compresses the data into a smaller portion. Labeling the data directly frees up this space to show the data.

Revision 5 (Shown at bottom of page):

■ Add annotations to highlight interesting data, such as the continued climb of inventory age well after the peak in WIP.

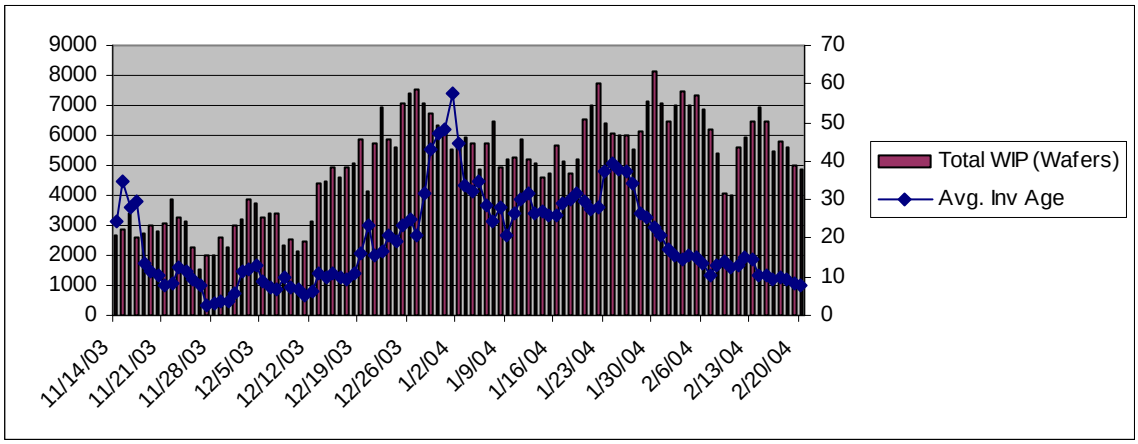
Comparison of Original and Final Versions of the Chart:

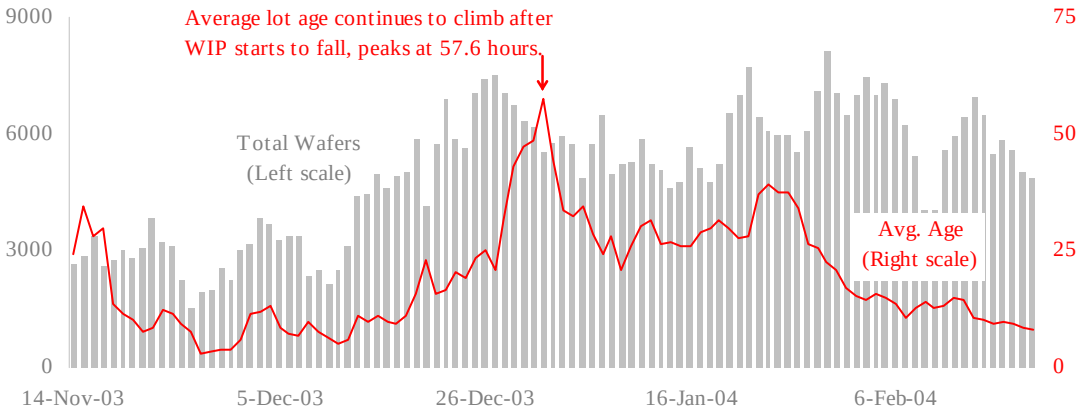
1) It is easier to see the data and read the axes in the final version.

2) There is no need to scan back and forth between the data and the legend in the final version.

3) The final version leaves space for annotations/explanations.

Note that the final chart still has room for improvement. Each WIP point is represented by a solid bar even though it





really just represents a single data point. However, the bottom line here is that it is possible to produce a graphic with a high data-ink ratio in Excel. This process takes several revisions, because the default produced by Excel has a very low data-ink ratio.

Recommendations

A few recommendations, culled from the Tufte material as well as from FabTime's own experience, are listed below.

- Make the most of your charts in terms of number of actual pieces of data. Don't be afraid of multivariate data or using x-y charts to show correlation. If done properly, it is possible to show hundreds or thousands of data points in a graphic and quickly convey your information.

- Use color to highlight good vs. bad performance (though use it sparingly). People are programmed to see green as good, and red as bad, and a chart that includes red and green to indicate relative performance gives a very quick impression. However, if you are showing gradations in a metric you should use gradations of the same color rather than a rainbow of colors.

- If you use Excel-generated charts, at a minimum eliminate the gray background and format the axes to make them legible. See other suggestions for improving Excel-generated charts in the Example outlined above.

- If possible, include axis labels and annotations directly on the chart, instead of requiring people to read secondary captions, legends, etc. This makes the charts easier to read, and also lets you directly include explanations. The explanations are particularly useful if people will be looking at the charts when you are not there in person to explain things.

Conclusions

Wafer fabs are a complex environment, and they generate a considerable amount of performance data every day. In this article, we have presented several ideas for improving the display of this data. These ideas are based in part on concepts proposed by Edward Tufte in his books and one-day course. Tufte's suggestions include using quantitative metrics for data graphics and integrating text with graphical data in charts. We have included a detailed example of improving an Excel-generated chart, and summarized a few recommendations. The ultimate goal is to generate performance charts that are sufficiently clear and detailed to enable informed decisions.

Closing Questions for FabTime Subscribers

Have you spent time thinking about how to best display your fab performance data? Do you have other recommendations that we missed in the discussion above? Do you disagree with any of these recommendations? We value your input.

Further Reading

- The website www.edwardtufte.com/tufte describes Edward Tufte's books, one-day course, and artwork.

- E. Tufte, "The Visual Display of Quantitative Information, 2nd edition," Graphics Press, 2001. Hardcover book available for purchase from www.edwardtufte.com/tufte or from Amazon.com.

- E. Tufte, "The Cognitive Style of PowerPoint," Graphics Press, 2003. Short paperback book/essay available for purchase from www.edwardtufte.com/tufte or Amazon.com.

- R. Williams, "The Non-Designer's Design Book," Peachpit Press, 1994. A review and link to purchase from Amazon is available at http://www.fabtime.com-/designer.shtml.

Subscriber List

Total number of subscribers: 1614, from 390 companies and universities. 26 consultants.

Top 10 subscribing companies:

- Analog Devices (79)
- Intel Corporation (73)
- Motorola Corporation (57)
- Infineon Technologies (48)
- STMicroelectronics (47)
- Philips (45)
- Seagate Technology (41)
- Micron Technology, Inc. (40)
- Texas Instruments (37)
- Advanced Micro Devices (35)

Top 3 subscribing universities:

- Arizona State University (11)
- Virginia Tech (10)
- Technical University of Eindhoven (7)

New companies and universities this month:

- Actel Corporation
- American Technology Research
- ENDEVCO Corporation
- Massachusetts Institute of Technology
- KSTEC
- MEMSCAP, Inc.
- Mykrolis Corporation
- SanDisk Corporation
- Semiconductor Complex Ltd. (SCL)
- SensFab Pte. Ltd.
- Supertex Inc.
- SyChip Inc.

Note: Inclusion in the subscriber profile for this newsletter indicates an interest, on the part of individual subscribers, in cycle time management. It does not imply any endorsement of FabTime or its products by any individual or his or her company.

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FabTime® Cycle Time Management Training

"It was helpful to see best-in-class methods for wafer fab cycle time management. Discussing these matters in-depth with you was quite valuable, as we could ask questions specific to our fab and processes."

Shinya Morishita
Manager, Wafer Engineering
TDK Corporation

Course Code: FT105

This course provides production personnel with the tools needed to manage cycle times. It covers:

- Cycle time relationships
- Metrics and goals
- Cycle time intuition

Price

$4950 plus travel expenses. On-site delivery for up to 15 participants, each additional participant $195. Discounts available for multiple sessions.

Interested?

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Do you make the best possible decisions?

- Do your supervisors possess good cycle time intuition?
- Are you using metrics that identify cycle time problems early?
- Can you make operational changes to improve cycle time?

FabTime's Cycle Time Management Training is a one-day course designed to provide production personnel with an in-depth understanding of the issues that cause cycle time problems in a fab, and to suggest approaches for improving cycle times. A two-day version is also available upon request.

Prerequisites

Basic Excel skills for samples and exercises.

Who Can Benefit

This course is designed for production personnel such as production managers, module managers, shift supervisors, hot lot coordinators, and production control.

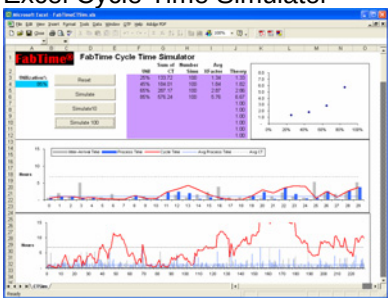
Skills Gained

Upon completion of this course, you will be able to:

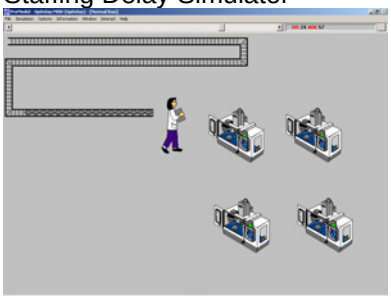
- Identify appropriate cycle time management styles.
- Teach others about utilization and cycle time relationships.
- Define and calculate relevant metrics for cycle time.
- Teach others about Little's law and variability.
- Quantify the impact of single-path tools and hot lots.
- Apply cycle time intuition to operational decisions.

Sample Course Tools

Excel Cycle Time Simulator



Staffing Delay Simulator



Additional Half-Day Modules

- Executive Management Session.
- Site-Specific Metrics Review.
- Capacity Planning Review and Benchmark.