FabTime Cycle Time Management Newsletter

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 software this month include an administrator option to limit users to viewing only specific sub-sets of data, and a new high-level line summary chart.

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Contributors: Daren Dance (WWK); Chan CM (Chartered Semiconductor Manufacturing)

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Welcome

Welcome to Volume 7, Number 10 of the FabTime Cycle Time Management Newsletter! In this issue, we have a FabTime software tip of the month concerning use of a new priority-based alert. We also have two subscriber discussion questions – one about integrated metrology, and one about staffing models. We're pleased to introduce both topics, because subscriber discussion has been rather sparse lately, and we hope that some of you will choose to contribute. We also have a response to last month's article about "7 Things You Should Know about Wafer Fab Cycle Time."

In our main article this month, we have a special year-end write-up of industry resources on cycle time management for wafer fabs. We were inspired to put this together by various inquiries from subscribers about where to get started in learning about fab cycle time, and what to do to start a cycle time improvement project. People asked us about papers, conferences, software products, links, tutorials, and the like. Naturally, many of the resources that we have to suggest come from FabTime's own website, since we have been working in this area for seven years. But, in our travels, we've also come across other useful industry references, books, conferences, and sources for papers, and we wanted to share some of those with you. We hope that you find this article useful. We welcome your feedback and additional suggestions.

Frank and I wish you all a happy holiday season, and a productive 2007! — Jennifer

FabTime

Community News/Announcements

FabTime welcomes the opportunity to publish community announcements. Send them to Jennifer.Robinson- @FabTime.com. We have no community announcements in the current issue.

FabTime User Tip of the Month

Receive Alert Messages for Lots of a Priority Class

In a recent enhancement to FabTime, we have added a new type of alert: an alert based on priority class. This alert lets you generate a list of all of the lots of a particular priority class that have been in queue for more than a specified period of time. To set up an alert for a priority class, follow these steps:

1. Find the "New Priority Class Alert" row at the bottom of the table on the Alerts page.

2. Select the priority class of interest to you from the drop down list in the second column ("Alert Object").

3. Currently the only variable available by priority class is time in queue at the current operation, so leave "Variable" set to "Opn Queue (hours)".

4. If applicable, enter text in the "Owner" field (e.g. enter "Mfg" to have the alert apply only to manufacturing lots).

5. Leave the "Comparison" section set to ">=".

6. Enter the cutoff that you would like to use for queue time for lots of this priority class, in hours, in the "Alert Value" column (e.g. enter "4" to learn about lots that have been in queue for more than four hours).

7. Enter a "Sleep After" value to tell FabTime how frequently to notify you if the same lots of this priority class remain in queue (e.g. enter "1" to be alerted again every hour).

8. Select the shift for which you would like the alert to apply.

9. If applicable, enter alternate email addresses to which you would like this alert sent in the "Additional Email" field. For example, you might set up an alert for high-priority lots, and copy people from the hot lot team. Any alerts that you set up will always be sent to you, also.

10. Press "Save" in the lower right-hand corner of the page. This will create a row for your new Alert up above all of the "New" rows, and give you another "New Priority Class Alert" row.

After following these steps, you should have an alert that lets you know which lots of this priority class, owned by whatever owner filter you have specified, have been in queue for more than your specified cut-off time. This alert is most useful for detailed monitoring of hand-carry lots.

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

Metrology Systems and Cycle Time

Daren Dance (WWK) suggested a discussion topic for newsletter members: "Are fabs with in-situ or integrated metrology systems seeing cycle time improvements?" If you have thoughts on this topic, please send them to newsletter@FabTime.com.

Staffing Models

An anonymous subscriber wrote: "I am curious if you have written or reviewed any articles on staffing/resource models? I am trying to understand what types of systems are used by other companies within the industry and thought I would see if you had some ideas. I specifically would like to know more on the entire factory level and not limit it to just operators and tech/engineering on the production floor. Another question would be: how do people scale the model, i.e. wafer outs, total tools, etc.?"
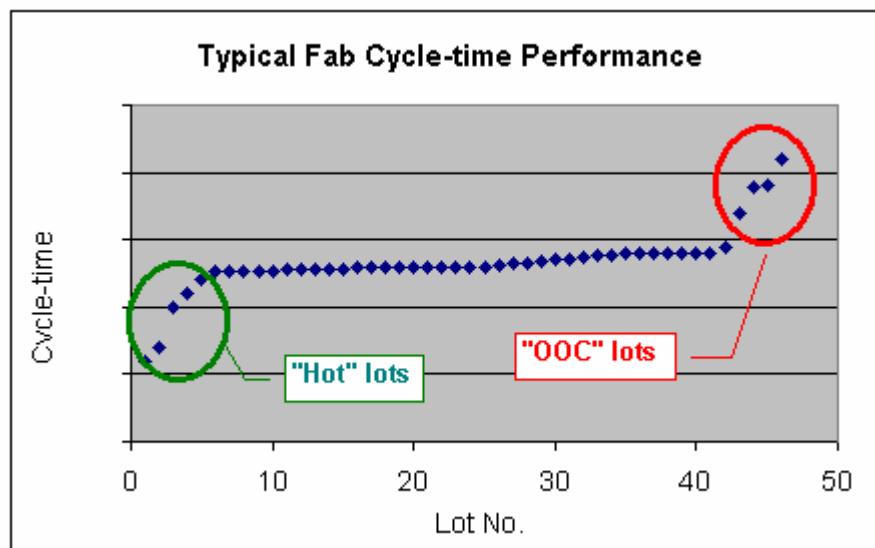
FabTime Response: We did have a bit of discussion about this in the newsletter three or four years ago (Issues 3.09 and 4.06). However, we don't have much current data on what kinds of systems people are using for staffing models. In our software we report moves, scrap and other metrics by employee, so that our customers can monitor historical performance. We also report on the percentage of time that each tool spends in a state that we call "standby-WIP waiting". This means that the tool is available, and has WIP in front of it, but isn't being run. Significant amounts of this time, especially on bottleneck tools, are an indication that a shortage of operators may be causing cycle time problems. However, we don't have any tools for planning the number of operators. We are happy to include this as a subscriber discussion topic, to see if any other readers have any thoughts to contribute. Any thoughts, subscribers?

Issue 7.09 - 7 Things You Should Know About Wafer Fab Cycle Time

Chan CM of Chartered Semiconductor Manufacturing submitted detailed comments in response to last month's main article, writing:

"The article "7 Things You Should Know about Wafer Fab Cycle Time" addressed some very key points in cycle time management of a wafer fab. I would like to add one item to the list, which is held lot management. Lots go on hold through the line due to several reasons: special processing requirement; measurement OOC; or pending some checks or decisions. While the occurrence may not be substantial, such holds can push the

"Typical Fab Cycle-time Performance" — chart showing Cycle-time vs. Lot No., with "Hot" lots circled in green at lower left and "OOC" lots circled in red at upper right.

cycle time of some lots into the wild, thus affecting the 95th percentile of the cycle time performance. Above is a typical cycle-time performance chart over a specific period of time.

In the above chart, there are always a few lots that fall out of the normal cycle-time performance range. One of the most common causes is excessive "held time" incurred on these lots. Hence, by effectively reducing the held time of all lots in the line, it will help to reduce such "OOC" lots. This will eventually help a fab to improve its cycle time spread.

Some common methods for managing held lots include: providing real-time, easily accessible reports on held lots. A high level of visibility enables each responsible person to take quicker actions in disposing of held lots. Automated alert systems like auto-paging, auto-SMS, etc. can also help to shorten the response time from when lots go on hold until notification.

In my opinion, the "7 things" mentioned in your article and the above are all very critical in wafer fab cycle time management. However, the most important of all is that our mindsets must be tuned towards cycle time. When cycle time becomes a way of life at work (just like quality), improvement will be prominent!"

FabTime response: We agree!

In-Depth Guide to CT Management Resources

Introduction

We have had several general inquiries recently about industry resources related to cycle-time management and manufacturing performance improvement for fabs. People are looking for where to start to better understand and improve fab cycle times, using conferences, papers, software products, links, and tutorials. FabTime provides resources in many of these areas, and we have also come across a number of other resources from outside of FabTime. We have compiled a guide to these resources as a special year-end issue of FabTime. We hope that you find it useful.

Industry Resources

Links

International Sematech Manufacturing Initiative (ISMI) (ismi.sematech.org). The ISMI provides various industry resources such as economic and simulation models, standards, industry discussion platforms, and the Engineering Statistics Internet Handbook, developed jointly with NIST (ismi.sematech.org/stats/handbook.htm). Several Sematech and ISMI papers are available for PDF download, including a variety of Manufacturing Methods papers (ismi.sematech.org/docubase/wrappers/19.htm). There is also a dictionary of terms

used in the industry (www.sematech.org/-publications/dictionary/index.htm). While most of these resources are not cycle time-specific, this is an excellent place to start looking at general information.

The International Technology Roadmap for Semiconductors (ITRS) (www.itrs.net/). The ITRS is the fifteen-year assessment of the semiconductor industry's future technology requirements. The 2000 through 2005 editions are available for download on the ITRS website. We recommend that you start with the executive summary for 2005. Cycle time targets for the industry, as well as difficult challenges that the industry faces in staying on Moore's Law, are addressed, among many other manufacturing and process issues.

SEMI (www.semi.org) has conference proceedings and other papers available on their website, as well as SEMI Standards that you can purchase online. Standards that we have found particularly useful are:

■ **SEMI E10-0304E**: Specification for Definition and Measurement of Equipment Reliability, Availability, and Maintainability (RAM).

■ **SEMI E35-0305:** Guide to Calculate Cost of Ownership (COO) Metrics for Semiconductor Manufacturing Equipment.

■ **SEMI E79-1106:** Specification for Definition and Measurement of Equipment Productivity (OEE).

Technical Papers

There are many industry papers on topics related to cycle time improvement and performance evaluation. For a short list, see the references listed at www.fabtime.com/CTBiblio.shtml. We are not able to distribute these papers because of copyright restrictions. However, the bibliography is a good starting point for you to track down papers of interest. Any papers that you see listed that are from the Winter Simulation Conference (since 1997) can be downloaded from

www.wintersim.org (follow the link to "Past Conference Programs and Full Papers"). There is also a service called Infotrieve (www.infotrieve.com) from which you can search for and buy electronic copies of papers.

For additional references to papers, Jennifer maintains a categorized bibliography of more than 1100 papers on her personal website at www.jkrconsult.com/capbib.htm. There are sections on capacity planning, queueing models, and lead times. You'll find many cycle time-related papers in the Performance Evaluation section. Again, the papers themselves are not available from FabTime, but there are many references for you to use as a starting point for further investigation. The bibliography was last updated in late 2005.

Another excellent source of industry papers is maintained by IEEE at ieeexplore.ieee.org/Xplore. IEEE Xplore contains full text documents from IEEE journals, transactions, magazines, letters, conference proceedings, standards, and IEE (Institution of Electrical Engineers) publications. Much of the functionality is restricted to IEEE members, but guests can search and browse abstracts, and purchase individual articles in PDF format.

Semiconductor FabTech (www.fabtech.org) and *Future Fab International* (www.future-fab.com) also both provide technical papers in the manufacturing productivity area.

Finally, you can find reports available for purchase from the Berkeley Competitive Semiconductor Manufacturing homepage (esrc.berkeley.edu/csm/). The CSM was a program by which Professor Robert Leachman and students from UC Berkeley made comparative studies of various wafer fabs from around the world. The most recently published report is from 2002.

Books

The book that we most frequently

recommend for understanding the dynamics of fab behavior and cycle time is *Factory Physics*, by Wallace Hopp and Mark Spearman. You can find a review, and link to purchase, at www.fabtime.com-/physics.shtml. In our review we said that: "Factory Physics is the kind of textbook that people actually refer to while doing jobs out in the real world. It places a mathematical framework around the behavior of factories, describing the underlying relationships with clear, easy-to-read examples and summing them up into straightforward Factory Physics Laws."

Another classic book to help you understand factory behavior is *The Goal*, by Eli Goldratt and Jeff Cox. You can find our review at www.fabtime.com-/goal.shtml. We said "This book has been widely read by semiconductor manufacturing personnel since it was first published in 1984. It accurately describes the behavior of manufacturing facilities, including such fundamental concepts as bottlenecks, constraints, and the impact of variability. One reason why it has been so broadly read is that it frames these concepts in the guise of a novel. This makes the ideas easy to read and digest."

Conferences

There are a variety of semiconductor industry conferences. The ones that we have found most relevant to people working on manufacturing productivity and cycle time improvement for wafer fabs include:

Advanced Semiconductor Manufacturing Conference (ASMC). ASMC 2007 will be held on 11-12 June in Stresa, Italy. "Featuring presentations and participants from leading device manufacturers, their suppliers, and academia, ASMC provides practical manufacturing solutions direct from the fab. ASMC 2007 is being co-chaired by Thomas Beeg of Qimonda and Dave Gross of Advanced Micro Devices." For more information, see www.semi.org/asmc.

International Symposium on Semiconductor Manufacturing (ISSM). "ISSM is the industry's largest forum of semiconductor manufacturing professionals dedicated to sharing technical solutions and opinions on the advancement of manufacturing science. This symposium has been held in Japan and in the U.S. on alternate years since 1992. ISSM aims to establish new concepts for semiconductor manufacturing technologies and to promote them as systemized and universalized technologies." See www.issm.com for more information. The next conference will be held next fall, in the US.

ISMI Manufacturing Effectiveness Symposium. This annual conference is held in Austin, TX in October, organized by the International Sematech Manufacturing Initiative. "The conference focuses on information and methodologies for reducing manufacturing expenses in both existing and next-generation fabs through advances in equipment, process, resources, fab design, and manufacturing methods." It is usually a relatively small (~300 people) conference, and is excellent for catching up with industry trends, and meeting people. You can find more information at ismi.sematech.org/ismisymposium/.

Winter Simulation Conference (WSC). The Winter Simulation Conference (WSC) is "the premier international forum for disseminating recent advances in the field of system simulation. In addition to a technical program of unsurpassed scope and quality, WSC provides the central meeting place for simulation practitioners, researchers, and vendors working in all disciplines and in the industrial, governmental, military, and academic sectors." WSC 2006 was just held in Monterey, CA. WSC has for several years been featuring a semiconductor manufacturing track, with a variety of industry-focused papers about performance improvement.

FabTime Resources

FabTime Papers

We have several papers that we've written about cycle time and performance improvement, many from our days prior to starting FabTime. These are available for download from our website at www.FabTime.com/bibliogr.shtml. All of them are in PDF format.

Queueing Models: FabTime Characteristic Curve Generator spreadsheet

You can download a small spreadsheet tool from our website (www.fabtime.com/-charcurve.shtml) that lets you change variables, and look at their impact on the cycle time operating curve for a tool. A more advanced version of this tool, one that includes toolgroups with multiple tools, and various other factors, is used as a teaching tool for our cycle time management course. The spreadsheet uses queueing formulas to estimate cycle time based on utilization and variability. We also have some queueing formulas available on our website, at www.fabtime.com-/formula.shtml.

We also recommend the Queueing ToolPak 4.0, available for download from The University of Alberta School of Business. We use it to help with some queueing analyses via Excel spreadsheets. The QTP website says: "The Queueing ToolPak (QTP) is a Microsoft Excel add-in consisting of a library of functions that perform basic calculations for waiting line analysis. Once the Queueing ToolPak is installed on your computer you can use the functions as you would any other Excel function. The functions allow integration of queueing performance measures into spreadsheet models without the limitations imposed by templates with fixed input and output areas that are commonly used for analysis of waiting lines." You can find the Queueing ToolPak at www.bus.ualberta.ca-/aingolfsson/qtp/.

Cycle Time Management Software

FabTime's cycle time management software is a web-based digital dashboard for managing current fab performance, and identifying improvement opportunities. FabTime extracts lot move and equipment state transaction data from the fab manufacturing execution system (MES) in near-real time (every one to five minutes), and processes this data into a database. Users then access the data via a web browser from anywhere within the corporate Intranet. The software is very flexible in its applicability to related types of manufacturing (solar cells, masks, etc.), but does require the customer to have some sort of MES in which lot moves are tracked. We have interfaced with most of the standard MES systems used in the industry, and with custom systems. We currently have 11 customer sites using the software.

The FabTime software consists of a series of pre-optimized charts demonstrating critical fab performance measures such as cycle time, work-in-process, moves, turns, scrap, utilization, and OEE. Users can filter data by lot owner, shift, production area, route, and other variables, and can drill-down for more detailed information. FabTime also includes a user-defined alert capability by which users can be notified by email or pager when a condition of interest is met (such as a critical tool being down for more than one hour).

The software is designed to help your company to manage and reduce variability, and hence to improve cycle times. It is a real-time tool for measuring and reporting day-to-day performance, but the historical data in the software is also a key analysis tool for cycle time improvement. Optional production planning, lot dispatching, and capacity planning modules extend these capabilities, with the dispatch module being especially helpful in driving down cycle time.

A Note about Simulation Software

What FabTime's software is not a simulation or scenario planning tool. FabTime includes some look-ahead and what-if capabilities for individual lots. However, if you want to build detailed models of your fab, and understand the impact that specific changes will have on your overall cycle time, then you may need to build a full fab simulation model. The product that we recommend is one called Factory Explorer (www.wwk.com), which FabTime's Frank Chance originally developed, before selling it to Wright Williams & Kelly. Factory Explorer (FX) includes queueing models for capacity analysis, as well as full simulation and cost analysis capabilities. There are several other simulation products available in the industry, but we are less familiar with them, and cannot comment on their specifics.

FabTime Course

FabTime offers a one-to-two day course on cycle time management for wafer fabs. Designed for fab production personnel, the course covers basic cycle time relationships, metrics and goals, cycle time intuition, and the impact that specific operating practices have on cycle time. Designed to be highly interactive, the course includes spreadsheet-based exercises and quizzes. The course is held at client sites, for a fixed price for up to 15 people. This format allows for open discussion about site-specific issues. We have held the course at more than a dozen fabs over the past four years. Participation in the course entitles your site to a complete set of past FabTime newsletter issues, as well as to our enhanced operating curve spreadsheet and other Excel-based tools.

One Hour Talk on Fundamentals of Wafer Fab Cycle Time

For a preview of FabTime's cycle time management course, you can request our one-hour talk on fundamentals of wafer fab cycle time. FabTime is currently offering to have Jennifer Robinson visit your site to give a one-hour talk on the factors that influence cycle time in wafer fabs, and the best metrics for cycle time improvement. This talk is a sub-set of our one-to-two day cycle time management course, and is being offered at no charge to fabs in the United States. The talk will be paired with a one-hour demonstration of FabTime's web-based digital dashboard software, with emphasis on ways that the software supports cycle time improvement efforts. If you are interested in scheduling a visit, please contact Jennifer.Robinson-@FabTime.com. We are currently scheduling visits for mid-January and later. This talk is an excellent way to get a preview of FabTime's cycle time management course.

FabTime Newsletters

Cycle time and wafer fabs are, of course, what we talk about extensively in FabTime's newsletters. Past issues of the newsletter are reserved for customers of FabTime's cycle time management course or software. You can find a complete listing of the past newsletters issues at www.FabTime.com/newsletter.shtml. Clicking on any issue title will take you to an abstract for that issue. The main topics covered so far in the newsletter are also listed below. For those of you who have been subscribers since the first issue (all 33 of you!) you should have quite a collection of cycle time improvement resources.

- The Hawthorne Effect (Issue 1.1)

- The P-K Formula (Issue 1.2)

- Little's Law (Issue 1.3)

- Theory of Constraints (Issue 1.4)

- Theory of Constraints and Just-in-Time Manufacturing (Issue 1.5)

- Performance Measures Typically Used in Wafer Fabs (Issue 1.6)

- Improving Factory Cycle Time through Changes at Non-Bottleneck Tools

Conclusions

Wafer fab cycle time is a complex topic. Cycle time is influenced by capacity (tool utilization), number of tools, and the many sources of variability in wafer fabs (reentrant flow, operators, equipment downtime, product mix, setups, batching, holds, and a host of other factors). For fabs commencing a cycle time improvement effort, it can be difficult to know where to begin. We hope that some of these resources will be useful to you in beginning, or enhancing, your cycle time improvement efforts. Thanks for reading, and Happy Holidays!

Closing Questions for FabTime Subscribers

What topics would you like to see in future issues of the newsletter? What industry resources for understanding and improving cycle time have we missed that you think should be included? We will include a follow-up in next month's subscriber discussion forum.

Subscriber List

Top 20 subscribing companies:
- Intel Corporation (154)
- Analog Devices (75)
- Micron Technology, Inc. (75)
- ATMEL (73)
- Infineon Technologies (63)
- Cypress Semiconductor (59)
- Freescale Semiconductor (59)
- STMicroelectronics (58)
- Texas Instruments (55)
- NXP Semiconductors (51)
- ON Semiconductor (48)
- TECH Semiconductor Singapore (47)
- Chartered Semiconductor Mfg (44)
- IBM (35)
- X-FAB Inc. (35)
- Seagate Technology (33)
- BAE Systems (31)
- Honeywell (29)
- FlipChip International (28)
- Spansion (27)

Top 5 subscribing universities:
- Virginia Tech (11)
- Arizona State University (7)
- Ben Gurion Univ. of the Negev (7)
- Nanyang Technological University (5)
- University of Texas (5)

**New companies and universities this month:**
- CSWC
- Fluidigm

- Hynix-ST
- Intellion
- Micralyne
- Rochester Institute of Technology
- University of Hagen - Germany
- University of Limerick – Ireland
- Zentrum Mikroelektronik Dresden (ZMD) (Pietro Anastasio NICOLAIDI)

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.

There is no charge to subscribe and receive the current issue of the newsletter each month. Past issues of the newsletter are currently only available to customers of FabTime's web-based digital dashboard software or cycle time management course.

To subscribe to the newsletter, send email to newsletter@FabTime.com, or use the form at www.FabTime.com/newsletter. htm. To unsubscribe, send email to newsletter@FabTime.com with "Unsubscribe" in the subject. FabTime will not, under any circumstances, give your email address or other contact information to anyone outside of FabTime without your permission.

FabTime® Dispatching Module
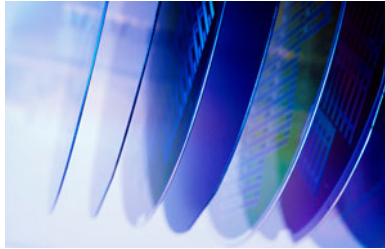
Dispatch Configuration

Configuration projects are quoted on a fixed price basis for each site, and typically include:

- Dispatch rule and factor configuration.
- Training.
- Dispatch list feed to the MES (if applicable).

Dispatch Factors

- Batch code at the current tool.
- Lot priority.
- Downstream tool priority.
- Current tool FIFO.
- Current tool idle time.
- Downstream batch efficiency.
- Critical ratio.
- Earliest-due-date.
- Current step processing time.
- Remaining processing time.
- Current step qualified tool count.
- Up to five other site-specific factors.

Interested?

Contact FabTime for technical details.

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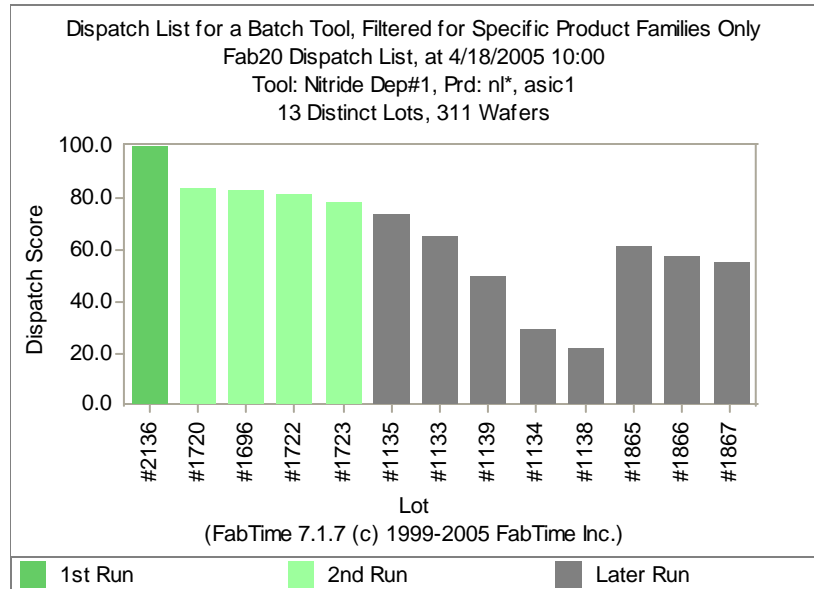Web: www.FabTime.com

Do your operators make the best possible dispatching decisions?

- Do you struggle to balance lot priorities and due dates with tool utilization and moves goals?
- Do your critical bottleneck tools ever starve?
- Do you use standard dispatch rules, but feel that your fab's situation is more complex, requiring custom blended rules?
- Do you know how well your fab executes your dispatching strategy?

FabTime's dispatching module is an add-on to our **web-based digital dashboard software**. At any point, for any tool in your fab, FabTime will show you the list of all lots qualified to run on that tool. This list will be ordered by the dispatching logic that your site has selected for that tool. This logic can use standard dispatch rules such as Priority-FIFO and Critical Ratio. However, you can also create custom dispatching logic using any combination of dispatch factors (shown to the left).

You can display dispatch lists in FabTime, and/or export them back to your MES. FabTime also includes a dispatch reservation system to hold downstream tools when a lot is started on an upstream tool, as well as dispatch performance reporting.

Dispatch List for a Batch Tool, Filtered for Specific Product Families Only
Fab20 Dispatch List, at 4/18/2005 10:00
Tool: Nitride Dep#1, Prd: nl*, asic1
13 Distinct Lots, 311 Wafers

(FabTime 7.1.7 (c) 1999-2005 FabTime Inc.)

1st Run   2nd Run   Later Run

FabTime Dispatching Module Benefits

- Ensure that wafers needed by management are in fact the wafers that are run, while requiring less manual intervention on the part of management.
- Improve delivery to schedule, and the display of performance to schedule.
- Document the dispatching logic used by the best operators and make this available to all shifts.