FabTime Cycle Time Management Newsletter

Volume 7, No. 3 March/April 2006

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 this version (7.5) include a qualified tools factor for dispatching, making it possible to favor lots that are qualified on one or a few tools ahead of lots that are qualified on many tools.

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Welcome

Welcome to Volume 7, Number 3 of the FabTime Cycle Time Management Newsletter! This was a banner month for FabTime. The newsletter received its two thousandth subscriber, and on the same day, Frank Chance, FabTime's President, welcomed his first child into the world. Although those two milestones are hard to top, we also have an announcement regarding future newsletter topics. Our FabTime user tip of the month describes the use of the new "stripe" control to apply a target band across a chart. We also have subscriber discussion regarding the continuing topic of M-Ratio (maintenance ratio), by James Ignizio, and about a cross-fab metric called Process Cycle Efficiency.

In our main article this month, we summarize our current recommended set of metrics for managing and improving cycle time in a wafer fab. Metrics are an indication of management priorities. Fabs that are cycle time focused need metrics that drive cycle time improvement. Such metrics should highlight current opportunities for improvement, and, if followed, should lead to improvements in shipped lot cycle time. In this article, we discuss several metrics that we believe are helpful for cycle time improvement. We have categorized these metrics as open lot, closed lot, shift-level, and tool-level, and have briefly defined each one. We welcome your feedback.

Thanks for reading!—Jennifer

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Community News/Announcements

Newest FabTime Stakeholder

Frank and Beth Chance are pleased to announce the birth of their first child, Benjamin Haines Chance, born on March 8th, in San Luis Obispo, CA. All members of the Chance family are doing well, and FabTime welcomes its newest stakeholder. Congratulations may be emailed to the Chances at Frank.Chance@FabTime.com.

FabTime Cycle Time Management Newsletter Reaches 2000 Semiconductor Industry Subscribers

San Jose, CA. March 8th, 2006 - FabTime Inc. today announced that its cycle time management newsletter had received its two thousandth subscriber. The newsletter is a monthly email forum for introducing and discussing best practices in wafer fab cycle time management. It contains articles about how various factors (product mix, hot lots, setups) affect fab cycle time, as well as the introduction of cycle time-related metrics. Each issue also includes a subscriber discussion forum, in which readers raise and address topics related to fab cycle time and performance improvement. Recent subscriber discussion topics have included the relationship between staffing levels and utilization, M-Ratio (a metric for tracking the ratio of scheduled to unscheduled maintenance), and the causes of declining moves in a wafer fab.

Recent newsletter topics have included:

- Operator Variability and Cycle Time
- Running Development Lots in a Production Fab
- Operational Recommendations for Wafer Fab Cycle Time Improvement
- Setup Avoidance and Dispatching
- Cycle Time and Holds

The newsletter is now in its seventh year of publication. More than 400 companies and universities are represented in the newsletter subscriber list. The companies with the most subscribers are Intel (NASDAQ: INTC), Analog Devices (NYSE:ADI), Infineon Technologies (NYSE: IFX), Freescale Semiconductor (NYSE: FSL), Atmel (NASDAQ: ATML), Micron Technology (NYSE: MU), STMicroelectronics (NYSE: STM), Texas Instruments (NYSE: TXN), Philips (NYSE: PHG), and TECH Semiconductor.

A newsletter subscription form is available at FabTime's website, www.FabTime.com/newsletter.htm. There is no charge to subscribe for the current issue of the newsletter each month. Past issues are currently only available to customers of FabTime's web-based digital dashboard software or our cycle time management course.

Future Newsletter Topics

This is the newsletter's sixty-second issue. As you might imagine, we sometimes have trouble thinking of topics month after month. Therefore, we would like to ask you for suggestions of topics that you would like to see addressed in future newsletter issues. We can't promise to write about everything suggested (we have to consider relevance to the larger newsletter community), but we will do our best. Send your suggestions to newsletter@FabTime.com. Thanks!

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

FabTime User Tip of the Month

Use the New Stripe Control to Add a Target Region to Charts

For many metrics, the behavior that we want relative to a single goal is one-directional. For moves charts, we would like to see the actual moves remain above the goal. For cycle time charts, we would like to see the actual cycle time values remain below the goal. Some goals, however, have both upper and lower bounds. For example, when we look at WIP by area, we might want the WIP to remain in a particular target range, neither above nor below that range. FabTime's new Stripe control is designed to let you quickly set up these types of target ranges on individual charts, without having to formally maintain goals. The Stripe control allows you to draw a horizontal or vertical stripe across any chart, at whatever axis values you choose.

For example, to apply a target region to a WIP Trend chart, drill down to the chart (the detailed chart page, not the home page), and make sure that the filters are set to your preferred values, and then do the following:

1. Scroll down the left-hand pane until you find the controls labeled "Stripe:" (just below the "Sort" controls and above the "Format:" controls).

2. Enter the minimum and maximum values that you would like to have for your target region (in the same units that apply to the chart) in the "from" and "to" boxes.

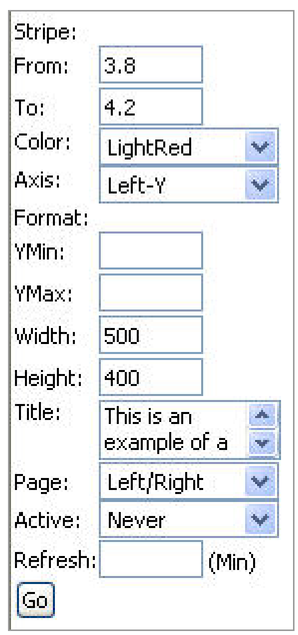
3. Select a color for your stripe from the "Color" drop-down.

4. Indicate which axis you are referring to with the minimum and maximum values that you have selected (this defaults to the left-hand y-axis).

5. Press the "Go" button below the "Format" controls.

You will likely want to experiment with stripe widths and colors. The stripe appears behind the columns on your chart, so that it does not interfere with your viewing of any data. The appropriate values to enter will depend on which axis you have selected. Once you have your stripe looking the way that you want it, you can add the chart to your home page. The stripe is merely a cosmetic formatting item for the chart, and does not in any way affect the data included in the chart.

Note that if you select the x-axis (to create a vertical stripe on a chart), the values that you enter should be integers, reflecting the column numbers to which the stripe should apply. For example, if you have a trend chart showing seven days of data, and you want a vertical stripe to appear between the columns for the second and third days, you should type "2" and "3" in the "from" and "to" boxes. You do not enter the actual dates displayed in the x-axis, just the integer column number. This is also true for Pareto charts – you enter the column numbers, not the object names, in the "from/to" boxes. Note that re-sorting the chart columns will NOT move the stripe.



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

Subscriber Discussion Forum

More on M-Ratio

James Ignizio responded to last month's continuing subscriber discussion about M-Ratio: He said "Ulrich Dierks of AMD brought up an interesting point in your previous newsletter; i.e., that an M-Ratio of 9 might be too high a goal to set for semiconductor fabs. Based, however, on the recent ISMI PM efficiency survey of 200mm and 300mm fabs, I do see that a number of 200mm tool sets have best-in-class M-Ratios of 4, 4.5, 5.5, 6.8, and even 8. Given those results, I'm not convinced that an M-Ratio of 9 is all that high.

My major concern, however, is with regard Ulrich's recommendation to focus primarily on Availability – and, by means of raising Availability achieve a subsequent increase in Capacity and a reduction of Wafer Cost.

The problems with a focus mainly on Availability, Capacity, and Wafer Cost may be demonstrated via a simple example. Consider a tool set with the following performance measures:

- Availability = 60%
- Coefficient of Variability of Arrivals = 2
- Coefficient of Variability of Effective
- Process Time = 1
- Utilization = 90%
- Process Time = 1 hour

Assuming, for sake of discussion, that the tool set has no reentrancy (the argument that follows is just as valid for more complex situations), its Cycle Time may be computed. Using the formulas found in most any book on queuing theory, the cycle time for this tool set is 39.2 hours.

If the Availability of the tool set is increased by 50% (i.e., from 60 to 90%), the new Cycle Time is 26.1 hours. However, if we reduce the variability of arrivals by 50%, the Cycle Time would be reduced, from the baseline of 39.2 hours, to just 16.7 hours. (And it should be noted that, generally speaking, it is easier to reduce variability than to increase Availability.)

In other words, a reduction in the variability of arrivals provides greater leverage over Cycle Time than an increase in Availability. One particularly effective way to reduce the variability of arrivals at a tool set is to increase the M-Ratio of the feeder tool set (or sets).

In short, an increase in the M-Ratio of a feeder tool set reduces the arrival rate variability of the subsequent tool set – and reduces its Cycle Time. Given the fact there is a definite and substantial value to Cycle Time reduction, there is a definite and substantial value to increasing the M-Ratio.

Finally, I would be reluctant to lower expectations as to the achievement of a substantial increase in the M-Ratio. Pharmaceutical and petrochemical firms have been able to significantly increase their M-Ratios primarily by means of Predictive Maintenance, a concept only recently receiving consideration in semiconductor fabs. Further, the ISMI survey indicates that best-in-class M-Ratios of from 4 to 8 have already been achieved. Given the influence on Cycle Time by means of an increase in the M-Ratio, I must continue to recommend that it remain a primary metric in any and all factory performance improvement efforts."

Process Cycle Efficiency

An anonymous subscriber wrote in with the following question. I'm currently working to develop a process for the measurement and improvement of process cycle efficiency (PCE) in our wafer and final assembly factories. Our goal is simply to benchmark our internal operations to drive improvements in cycle time by comparing PCE (defined below).

Process Cycle Efficiency (PCE) is a measure of the relative efficiency of the process calculated by dividing the value added (VA) time by the total process lead time (PLT); or PCE = (VA time) / (PLT). The VA time is only that time in which value is being added to the product. This would be work that the customer would be willing to pay for. Examples of this in a semiconductor environment would be diffusion, metal deposition, implant, etch, diebond, wirebond, mold, final test, etc. Non-value added (NVA) activities are things that do not add value; things the customer is not willing to pay for. Examples include waiting, loading, transportation, rework, inspections, etc. Of course, PLT is simply the actual cycle time of the process. There are generally accepted ranges of performance that are considered poor, typical and world-class so this can be a good metric with which to assess and compare factories.

The VA time is largely a function of the process recipe time so the opportunity for improvement rests in reducing the NVA time. One generally determines VA time from process recipe durations and then measures actual process cycle time (PLT) to perform this calculation. As you certainly know, the factory loading will affect the process cycle time (reference your discussion on the cycle time X-factor) and will therefore strongly affect the PCE measurement. We are considering techniques to normalize the PCE to enable comparison of different factories (each loaded to a different level of their full capacity) on an equal basis. Do you have any ideas on how to do this? Can you seek opinions from other fabs on this matter?

FabTime Response: To summarize this question a bit, the issue concerns how to justly compare fabs on the basis of their cycle time when the cycle time is driven in large part by fab utilization. It's relatively easy for a fab with low utilization to obtain good cycle times. It's much harder for a fab running with high equipment utilization to do the same. Normalization is difficult, because the operating curve of cycle time vs. utilization is highly non-linear. We would like to know how other subscribers, particularly those from companies that have many fabs, handle this issue in benchmarking performance.

Cycle Time Metrics Baseline

Over the past seven years, we have talked about a number of metrics in this newsletter. In this article, we summarize FabTime's current recommended set of metrics for driving cycle time improvement. We have three guiding principles in thinking about metrics, though not all three will apply to all metrics.

1. We want metrics that drive improvements in shipped-lot cycle time.

2. We want metrics that highlight current opportunities for cycle time improvement.

3. Where practical, we want metrics that can be applied to multiple areas of responsibility (e.g. fab-wide and also to specific area or products)

We have categorized our recommended metrics into four categories: closed lot metrics, open lot metrics, shift-level metrics, and tool-level metrics. Each is further discussed below.

Closed Lot Metrics

Closed lot metrics are metrics that are calculated on the basis of shipped lot cycle time. It is a self-fulfilling prophecy, then, that improving closed lot metrics will improve shipped lot cycle times. Closed lot metrics are not, however, helpful for highlighting current opportunities for cycle time improvement. By the time a lot ships, that lot's cycle time has been completely determined by past performance. The cycle time does not tell us very much about what to do make improvements for the future. What closed lot cycle time metrics are more used for is benchmarking a fab's overall performance, either compared to itself, or to other fabs. The two most common closed lot cycle time metrics are defined below, although FabTime more strongly recommends the second of the two.

Days per Mask Layer: Shipped Lot Cycle Time / Number of Layers (averaged across all lots, or across all lots in a product family). This metric is very popular for comparing performance across fabs, and has the advantages of familiarity and ease of calculation. However, it is a trailing metric. It is also not particularly applicable to multiple levels of responsibility, although it can be broken down by product family.

Closed Lot X-Factor: X-Factor = Shipped Lot Cycle Time / Theoretical Cycle Time (averaged across all lots, or across all lots in a product family). Theoretical cycle time is the best case cycle time that can be achieved for a lot, if it never has to wait for a tool for any reason. It is also sometimes called "Raw Process Time". X-Factor is a bit more difficult to monitor than days per mask layer because of the need to know the theoretical cycle time. However, at FabTime we believe that X-Factor is a more useful metric than days per mask layer, because it tells you how you are doing relative to the best that you could be doing. X-Factor can also be broken down and estimated by toolgroup, area, and product, making it more versatile than days per mask layer. For these reasons, we recommend X-Factor over days per mask layer, although both are trailing metrics.

Open Lot Metrics

Open lot metrics are calculated based on short-term, fab-wide performance. They give an immediate indication of how a fab is doing in terms of cycle time, and can often be projected forward, to give an idea of what future cycle times are likely to be. Improvements in an open lot cycle time metric will, if maintained, translate directly into improvements in current and future performance. Three different open lot cycle time metrics are defined below.

Overall WIP Effectiveness: Overall WIP Effectiveness looks at how much value-added time a lot achieves in 24 hours. Using WIP States (in queue, in process, on hold, etc.), we define OWE as (non-rework theoretical process time) / 24 * 100% for a lot. OWE can be aggregated by product or route for some time interval, and trended over time. OWE is similar to Overall Equipment Effectiveness, in that we maximize it by keeping lots moving, with no delays. Driving OWE toward 100% will drive towards improved cycle time, through the reduction of non-value-added time. Understanding the WIP States that lie beneath OWE gives further insight into how to make this improvement.

Dynamic X-Factor: DXF = Total Wafers / Wafers in Process, where Total Wafers includes production and engineering WIP, and Wafers in Process includes wafers being worked on now, but may exclude rework wafers. DXF is equivalent in the long run to standard X-Factor (CT/RPT), but DXF is easier to calculate on an ongoing basis. DXF measures the current speed of the line. If DXF drifts upward, this is an early indicator that CT will drift upward in the future. DXF can also give useful information about short-term, periodic behavior such as shift change effects. DXF can be broken down by product or area.

Summed Operation Cycle Time: This is a forward-estimate predictor of cycle time, based on current performance for the current day or week. For each time period, calculate the average cycle time by operation during the period, and then sum across all of the operations in a process flow. Fill in with planned numbers for operations not performed during the time period. Summed operation cycle time says, for example, if each day was exactly like today, this is what the cycle time would be.

Shift-Level Metrics

All fabs need shift-level metrics to tell them whether current performance at each tool group or area is driving towards cycle time improvement. If tracked on a shift-by-shift basis, improvements in these metrics will translate to improvements in shipped lot cycle time. These metrics are most often measured at the area level, and sometimes at the toolgroup or operation level, in addition to measuring them at the fab level. In this way, they highlight current local opportunities for improvement.

WIP Turns: Most fabs that we talk with have advanced from looking primarily at moves per shift to also looking at metrics that take WIP into account, such as WIP Turns. WIP Turns = Operation Moves / Starting (or Average) WIP. The intuition behind WIP Turns is that Turns reflect how many times per day (or per shift) the fab moves each wafer, on average. Turns also give a forward look at cycle time. If we move each lot four times per day, and the process flow has 400 steps, then the cycle time, based on the current turns rate, will be 100 days. Turns for tools, tool groups, and areas are calculated the same way.

Queue Delay: Average queue per visit can be measured for all operation completions, and rolled up to give average values per tool, tool group, operation, or module. Sorting the data in descending order shows which tools, steps, or modules, are contributing most to cycle time on a current basis. The important thing to remember about cycle time is that it can be improved at any tool, including non-bottlenecks.

Inventory Age: Lot Inventory Age = Time elapsed since move-out from prior operation = Time at current operation. This can be averaged across all of the lots at a tool, operation, or area, or can be summed across all of the lots. The idea is that high WIP tells you that inventory is piling up. High inventory age tells you part of your inventory is sitting for longer than it should be. Many fabs use inventory age, by individual lot, to set a threshold for identifying lots that are inactive (or have waited for too long at the current operation).

Tool-Specific Metrics

Ultimately, cycle time accrues from lots spending time in front of tools. Fabs have many metrics for tool performance. We discuss four here that we feel particularly influence tool-level cycle times.

Utilization: At the tool level, utilization directly drives cycle time. For time periods when a tool has higher-than-usual utilization, per-visit cycle times are likely to be high also. The easiest way to estimate utilization is to track productive (% busy) and standby time on each tool, and then calculate Utilization = Productive / (Productive + Standby) for the time period of interest. If not tracking these tool states, it may still be possible to estimate utilization from WIP transactions. The problem with utilization, however, is that we have conflicting goals. For throughput, we want to see utilization increased. For cycle time we want to see utilization decreased. For this reason, we have proposed a modified version of utilization, WIP Utilization Percentage.

WIP Utilization Percentage: This metric is a modification of Utilization, designed to reward operators for always processing WIP whenever WIP is available. To estimate WIP Utilization %, break standby time up into Standby WIP Waiting vs. Standby Other. Standby Other means that the tool was up, and WIP was waiting, but nothing was being processed on the tool. WIP Utilization % = Productive Time / (Productive Time + Standby WIP Waiting). As long as the operator always keeps the tool busy whenever WIP is waiting, WIP Utilization = 100%. And keeping the tool running whenever there is WIP waiting to be processed is good for cycle time.

Availability: By increasing equipment availability (productive + standby time), fabs can either increase starts, while maintaining cycle time, or improve cycle time. Cycle time improvement comes when downtime is reduced, and standby time is increased (for the same % busy). Reducing the variability of availability is also helpful for cycle time.

M-Ratio: This metric, Maintenance Ratio = total hours of scheduled downtime / total hours of unscheduled downtime, across all production tools, during a time period. This has been discussed extensively in recent newsletter subscriber discussion forums. The idea is to minimize the amount of unscheduled downtime by performing preventive scheduled maintenance instead. Reducing unscheduled downtime reduces fab variability, and hence improves cycle time. We think that it is a promising companion metric to availability.

Sidebar: Exercise for FabTime Software Users

If you have FabTime's software, you can look at most of the metrics described above directly. If you would like to estimate M-Ratio using FabTime, you will need to export data to Excel, and make some additional calculations. Perform the following steps:

1. Generate the "Downtime Duration CV Trend" chart, and filter to only display the active production tools (perhaps by listing tools or tool groups in the appropriate filters).

2. Change the period length to 168 (to estimate M-Ratio for the current week of data) and press "go". Note that unless you change the "From" date, the chart will only have a single point, and the data table a single row. This is ok.

3. Press the "Excel" button to export the data to Excel.

4. Multiply "Count" by "Avg Duration" for both scheduled and unscheduled downtime events, to get the total hours of scheduled and unscheduled downtime. Divide the total hours of unscheduled downtime by the total hours of scheduled downtime. This is your M-Ratio for the current week.

Contact FabTime if you have questions.

Conclusions

It has long been said that "what gets measured gets done." Metrics are an indication of management priorities. Fabs that are cycle time focused need metrics that drive cycle time improvement. Such metrics should highlight current opportunities for improvement, and, if followed, should lead to improvements in shipped lot cycle time. Ideally, these metrics should also be scalable to different areas of responsibility (fab, area, tool, product, etc.). In this article, we have outlined several metrics that we believe promising for cycle time improvement. We have categorized these metrics as open lot, closed lot, shift-level, and tool-level, and have briefly defined each one. We welcome your feedback.

Closing Questions for FabTime Subscribers

Do you use the metrics described here? Are there other metrics that you use in your fab that you think drive cycle time performance?

Further Reading

- **A20/A80 Availability Variability:** J. Robinson and F. Chance, "Quantifying Availability Variability," *FabTime Newsletter*, Volume 4, No. 2, 2003.
- **Dynamic X-Factor:** J. Robinson and F. Chance, "Dynamic X-Factor", *FabTime Newsletter*, Volume 4, Number 8, 2003 and "Dynamic X-Factor Revisited", *FabTime Newsletter*, Volume 5, Number 3, 2004.
- **WIP Utilization:** J. Robinson and F. Chance, "WIP Utilization Percentage", *FabTime Newsletter*, Volume 5, Number 5, 2004.
- **Overall WIP Effectiveness:** J. Robinson and F. Chance, "A WIP-Centered View of the Fab: Part 2: Overall WIP Effectiveness," *FabTime Newsletter*, Volume 6, No. 3, 2005.

Subscriber List

Total number of subscribers: 2058, from 447 companies and universities. 22 consultants.

Top 10 subscribing companies:

- Intel Corporation (117)
- Analog Devices (77)
- Atmel Corporation (67)
- Infineon Technologies (65)
- Freescale Semiconductor (60)
- STMicroelectronics (58)
- Micron Technology (57)
- Texas Instruments (51)
- Philips (49)
- TECH Semiconductor (43)

Top 3 subscribing universities:

- Virginia Tech (11)
- Arizona State University (8)
- Ben-Gurion Univ. of the Negev (7)

New companies and universities this month:

- advanced clean production Information Technology AG
- Alcoa
- Castech S.A. de C.V.
- Draper Laboratory
- Dublin City University
- Enterprise Systems Partners
- National Tsing Hua University
- Superna
- Trinity College Dublin
- Tronic's

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 Software

"Instead of spending time preparing reports, shift facilitators can get the data they need quickly from FabTime, and then spend their time making real improvements."
Mike Hillis
Cycle Time and Line Yield Improvement Manager
AMD Fab 25

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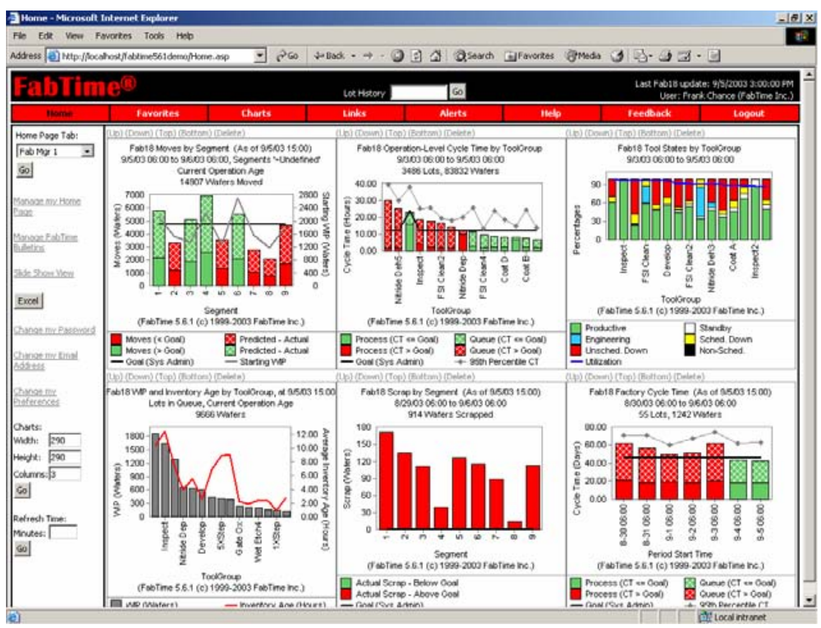
Do you have the best possible information?

- Are your supervisors swamped with daily reports, but lacking real-time information?
- Is it difficult to link equipment performance to cycle time?
- Does each new cycle time analysis require IT resources?

FabTime is a digital dashboard for your fab. In real-time, it provides a comprehensive view of fab performance data – everything you need for proactive management of cycle time. FabTime is designed for hands-on use by managers and supervisors, unlike traditional reporting tools, which were designed for programmers. FabTime also now includes **lot dispatching** (via dispatch rules) and static **capacity planning**.

A Web-Based Digital Dashboard

"I use FabTime every day, and so do the supervisors who report to me. The data that I need is right on my home page where I need it when I come in every morning."
Jim Wright
Production Manager
Headway Technologies



FabTime Benefits

- Cut production cycle times by 10%, hot lot cycle times by 20%.
- Focus improvement efforts on the tools that inflate cycle time.
- Improve supervisor productivity – cut reporting time by 50%.