FabTime Cycle Time Management Newsletter

Volume 20, No. 2 **April 2019**

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 development right now include Green-to-Green charts, charts showing the percentage of WIP matching certain criteria, and user control of the number of points on stacked pareto charts.

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Keywords: Metrics and Goals; Fab Management; Tool Availability

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Welcome

Welcome to Volume 20, Number 2 of the FabTime Cycle Time Management Newsletter. In this issue we have a call for papers for an upcoming conference. Our software tip of the month is about using our new interface for renaming, copying, and linking to home page tabs. We also have an extensive subscriber submission about capacity planning, on-time delivery, and dispatching from Thomas Quarg at AMTC.

In our main article, we discuss the metric Green-to-Green (G2G) time, which we are in the process of implementing in our software. This metric captures each instance of downtime, scheduled and unscheduled, from when a tool first goes down until it comes back up, even if there are multiple switches between downtime sub-states in between. We believe that this metric will be helpful to fabs in understanding and reducing downtime-related variability. As always, we welcome your feedback.

Thanks for reading – Jennifer

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Community News/Announcements

Call for Papers: e-Manufacturing & Design Collaboration Symposium 2019 & ISSM 2019

Conference Date: September 6, 2019

Paper Submission Due Date: June 1, 2019

Joint Symposium Website: http://www.tsia.org.tw/seminar/eManufacturing2019/

The Symposium attends to recent technological advancements to align the needs of designers, manufacturers, equipment suppliers, software vendors, solution providers and researchers. It offers a public arena for the exchange of up-to-date experiences among manufacturers for adoption of technological developments. With green notions of supply/engineering/value chains, coverage of the joint symposium includes, but is not limited to, the following topics of interests (subset selected by FabTime):

- Benefits and Justification (ROI, CoO, OEE ...)
- Big Data / Analytics / Machine Learning / AI
- Data Collection/ Quality/Storage/Management
- Fab Management/ Scheduling/Dispatching
- Factory Integration/Physics/ Operations/Queueing
- Final/Lean/Green/Smart/Intelligent Manufacturing
- Manufacturing Control and Execution Systems
- Manufacturing Strategy and Operation Management

FabTime welcomes the opportunity to publish community announcements, including conference notices and calls for papers. Send them to newsletter@FabTime.com.

FabTime User Tip of the Month

Copy, Rename, and Link Home Page Tabs

FabTime has a new interface for copying, renaming, and linking to home page tabs. From the home page, you can now copy all of the charts on any home page tab (your own or a shared tab that you are viewing) by clicking the "Copy Tab" button. FabTime will copy all of the charts on that home page tab to a new tab named "OriginalName Copy01". For example, if you copy your Default tab, you will get a new tab with the same charts, named "Default Copy01". If you copy it again, your new tab will be named "Default Copy02" (etc.).

You can then switch to the tab (switching to your own account first if copying a

shared tab) and use the new "Rename" function to rename the tab to something more useful to you. Once you copy a tab, FabTime maintains no links to the tab you are copying from. You can reorder or delete charts, edit charts, apply different filters, etc. This copy functionality could be helpful to new users, for example, by letting them start with someone else's shared tab, but then customize it to their own needs. Or, you might want to copy your own tab to begin the process of creating a new area- or lot-specific tab.

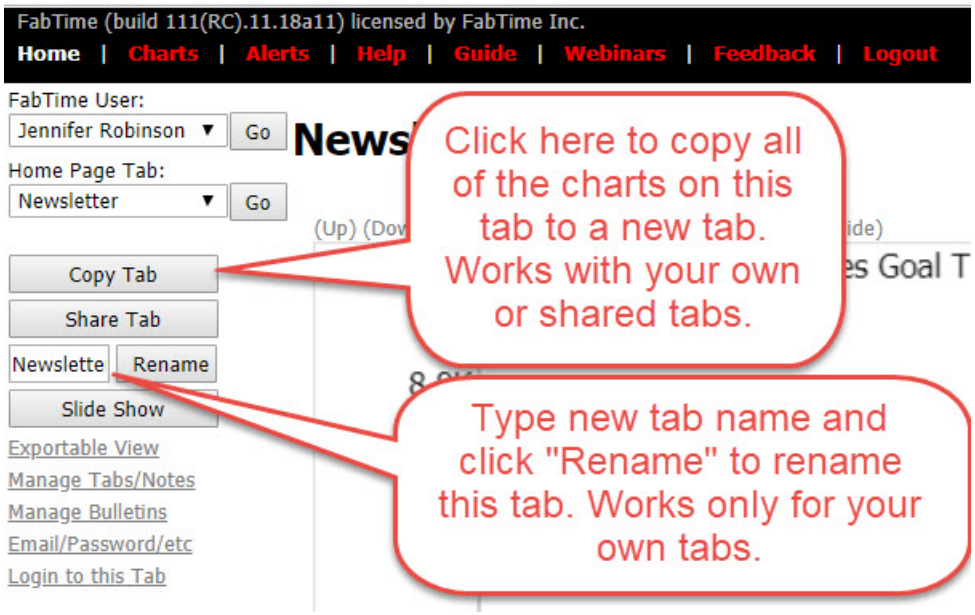
An example of the copy and rename functions from the user's own tab is shown below.

If you are looking at someone else's shared tab, you will not see a "Rename" option. What you will see is a "Link Tab" option. What clicking this this does is list that shared tab within your Home Page Tab list. Linked tabs will appear at the bottom of your Home Page Tab list, prefaced by the name of the person who created the tab. For example, if I am looking at Frank Chance's shared Default tab, and I click "Link Tab", when I return to my own account and view my Home Page Tab drop-down, I will see the item "[Frank Chance]-Default". This is a shortcut that was suggested by members of our User Group. Instead of having to select the person's name from the FabTime User dropdown every time you wish to see a shared tab, you can use the link option to list and quickly switch to shared tabs of interest to you.

Viewing a linked tab is just like viewing a shared tab. You can resize the charts, apply tab filters, or drill down to the charts. However, you cannot change what charts are displayed on the tab or reorder them. If the person who created the tab makes changes (adding new charts, etc.), you will see those changes the next time to you refresh the page. You can, as always, drill down and add any chart to one of your own tabs. From there you can edit and save at will.

We hope that you find this tip useful. If you do not see the options described in this tip, please contact your internal FabTime administrator. Your site may need a patch upgrade. We would like to express our thanks to our User Group for the suggestions and guidance that led to this usability enhancement.

If you have questions about this item, or any other FabTime software questions, just use the Feedback form inside FabTime's software. Subscribe to the separate Tip of the Month email list (with additional discussion for customers only). Thanks!



Subscriber Discussion Forum

Response to Issue 20.01: Thoughts on Capacity Planning, Production Planning, and Dispatching

Thomas Quarg (Advanced Mask Technology Center) sent some extended comments in response to the last issue:

"I´ve been following your Newsletter for years and I like it. I think I can provide some ideas for the audience to think about and decide if it would make sense to go deeper into them. These are my personal views based on my experiences. Some of them may be a little controversial.

Capacity Planning:

Cycle time and capacity are described in Little´s Law but what is "your" Fab capacity? I think that is the most important question to answer before we can get into the dispatching problem. Capacity modeling including smart simulation is essential for "On Time Delivery" and dispatching.

We all know, capacity calculation starts with the common approach of using throughput and availability, loading by product and exact process flow parameters, along with the number of tools. A second level would be the power of the lot distribution system (manual or automatic).

Assuming that we have no bottlenecks in the distribution system and are feeding the tools in time (this should not be underestimated as a risk and can be tracked using the standby states "no Operator" or "no AMHS available"), the following questions come up:

- How to calculate capacity by recipe?
- How to group recipes into "Operations"?
- How to aggregate/consolidate different transistor nodes into technologies for capacity corridors?

Second level details are:

- How is the tool interacting inside (robot vs. chamber sequence, priority chamber)?
- Cascading assumptions
- Batch processing assumptions
- First Wafer effects
- Do we have a load port limitation in the case of fast recipes?
- What is our CET (Carrier exchange time) that is required to provide continuous loading and cascading?
- Are sufficient "Tool Models" available?

A third level could be:

- Are enough recipes qualified on multiple tools within a tool family? (And are they getting re-qualified when it is required?)

After analyzing all our E10 states and different mixes, hopefully we have an understanding of the capacity of our FAB with all the different products and technologies.

Production Planning:

Going into the production planning part now.

How much can we start (based on our capacity) and how should we do it?

At first: Define what you would like to achieve. What is your main target?

- Most output?
- Deliver on time?
- Feed your Back End continuously?
- Or a mix of those things

Requirements: We have our theoretical cycle time and our queue time with a "flow factor" for all different nodes. (By the way, time is the only constant.)

Now: our first exercise is to define our start rate. The first mistake would be to start equal numbers every day and thinking you are getting equal numbers out. Agreed? Because of your product mix and different flow length (different cycle times for different products) you have to consider these differences in your start profile based on your capacity.

Dispatching:

My best experience is to manage the line by due date. Due dates are the key – the definition of the due date provides the priorities. I think that all the classes of HOT LOT, SUPER Hot, high etc. become mostly obsolete if you manage your line by due date. (Except "hand carry" lots. Those lots are getting into the line with the target to minimize waiting times in the way that tools are idling before the lot is arriving.)

Why are priorities obsolete? Compare with the traffic on German highways. In Germany you have to drive on the right side and passing is allowed on the left side only. A lot of drivers like to go fast. Therefore, they are driving in the left lane. But if everybody is driving in the fast lane, nobody will be fast, right(?). The same is true with priority lots. If your flow factor for too many lots is too aggressive then your capacity will go down and your cycle time will increase. Your average flow factor should not exceed your maintainable flow factor. With priorities, you are managing the position in the queue only, but not the time. (Agree?)

Conclusion:

You can drive your lots and balance your line via management by due date much better than with priorities.

You know the average flow factor based on your capacity. You can plan now how many lots you will allow with more aggressive due dates (and related to that, aggressive flow factors). You should only plan for what the line will be able to handle. (Theoretical cycle time is constant. Queue time is flexible.)

Managing by due date also provides the chance for "Exchanging Due Dates". In the case of higher, constant volume of similar products you may be able to use the due date exchange solution. This means that if you have a lot with a certain progress compared with its position in the line and due date and you also have a lot that is behind its target, you can easily exchange their due dates. (If the lots are the same product.)

Example: One lot was running for measurement and the other one bypassed the measurement. The lot that was measured is now behind schedule, the lot that bypassed is ahead of schedule. If you change the due dates then the world is fine.

There are many more ways to manage production lines. What you do in your fab depends on individual targets and philosophy. Unfortunately, often the fab dispatching and planning department gets overruled by management, because they are forced to start more than the fab is able to absorb.

I hope that this provided some views from a different perspective.

FabTime Response: We are grateful to Thomas for taking the time to share these thoughts from his long-time experience working with wafer fabs. Some of his remarks are more controversial than others (e.g. "You can drive your lots and balance your line via management by due date much better than with priorities"), and we would love to see this contribution spark further discussion among newsletter community members.

FabTime welcomes the opportunity to publish subscriber discussion questions and responses. Simply send your contributions to Jennifer.Robinson@FabTime.com.

A Metric for Green-to-Green (G2G) Analysis

Introduction

At the suggestion of one of our long-time software customers, **Hani Ofeck** from TowerJazz Semiconductor, FabTime's technical team has been working on a new chart to display Green-to-Green (G2G) time. G2G time is the elapsed time from when a tool goes down (to unavailable status for scheduled or unscheduled maintenance) to when it comes back up again (available status). It's called "Green-to-Green" time because it measures the elapsed time between two good states (with green color indicating as good).

As with many metrics, while this definition is simple enough in concept, there are a number of decisions that arise upon implementation. We are writing this article to document the assumptions that we have made in our implementation process, in the hope of driving consistent usage of this metric across the industry.

Why is Green-to-Green Time Important?

The main concept of new G2G metric is to be able to see (visually) the elapsed time between two available slots and know by the G2G types what happened and whether the unavailable time involved scheduled or unscheduled maintenance work.

G2G can be used as an advanced Reliability Availability Maintainability (RAM) Key Performance Indicator (KPI), and in the future to help set goals for PM standards.

G2G time is also important because we can use it to identify improvement opportunities. As one example, suppose that two similar tools have dramatically different G2G times for a monthly preventive maintenance (PM) event.

- Tool A has a monthly PM with G2G times that are consistently 2-3 hours.
- Tool B has the same monthly PM but its G2G times are all over the map – sometimes 2 hours, sometimes 13 hours.

What is different between the tools? We know that shorter, more consistent downtimes introduce less variability into the fab, and we always want to drive performance in that direction. In this case, we should focus on Tool B to bring its monthly PM under control. To do this, we can start by looking at whether only PM states were recorded during the G2G instance, or whether there was also some repair time logged.

As another example, suppose that a few tools are responsible for the majority of exceptionally long G2G times in the fab. Can we focus on these tools and shorten the tail of this distribution? That will lead to more consistent uptimes and lower variability across the fab.

What Is a Green-to-Green Instance?

A G2G Instance is simply one G2G time for one tool. For example, if we have the following ETCH01 history:

- 08:00: Standby
- 09:00: Scheduled down (PM)
- 12:00: Standby
- 13:00: Unscheduled down (Failure)
- 17:00: Standby

We have two Green-to-Green instances:

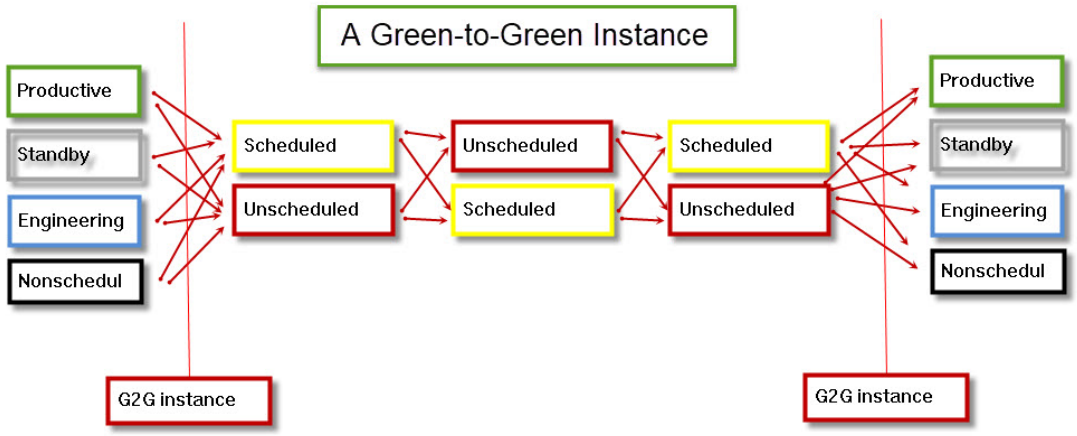
G2G instance #1: 09:00 to 12:00 (3 hours)

G2G instance #2: 13:00 to 17:00 (4 hours)

A schematic of a G2G instance is shown in the image at the top of the next page:

What Is a Green-to-Green Type?

A Green-to-Green Type splits the G2G instances into categories, so that we can focus on particular types of downtime. The two standard types are:



- **PM Standard:** All the downtime in the G2G instance is scheduled downtime.
- **Repair Standard:** All the downtime in the G2G instance is unscheduled downtime.

In addition, there are four mixed types:

- **PM to Repair:** The downtime starts as scheduled downtime but ends with unscheduled downtime. E.g. it starts as a PM but ends as a failure repair.
- **PM with Repair:** The downtime starts and ends as scheduled downtime but includes unscheduled downtime somewhere in the middle.
- **Repair to PM:** The downtime starts as unscheduled downtime but ends with scheduled downtime. E.g. it starts as a failure repair, but along the way a PM was added.
- **Repair with PM:** The downtime starts and ends as unscheduled downtime but includes scheduled downtime somewhere in the middle.

For example, using the same ETCH01 history introduced above:

- 08:00: Standby
- 09:00: Scheduled down (PM)
- 12:00: Standby
- 13:00: Unscheduled down (Failure)
- 17:00: Standby

We can add the G2G types to the two G2G instances:

- G2G instance #1: 09:00 to 12:00 (3 hours). G2GType = "PM Standard"
- G2G instance #2: 13:00 to 17:00 (4 hours). G2GType = "Repair Standard"

Why Is Green-to-Green Type Useful?

We can use G2G type as a filter in our downtime analysis. For example, we could look at:

- Only "PM Standard" G2G instances for ETCH01. Because these instances consist of PM and not repair, we would expect these G2G times to be more consistent than the "Repair Standard" G2G times. If these "PM Standard" instances for the same type of PM do not have consistent length, then we should investigate.
- Only "PM to Repair" G2G instances for ETCH01. Why did we start out with a PM and end up with a failure? Is there any pattern we can address?
- Only "Repair with PM" G2G instances for ETCH01. Why did we transition to a

PM as part of a repair, and then end up with another repair? Is there an opportunity for improvement?

We can also use G2G type in setting goals. For example, we should use only "PM Standard" G2G instances for ETCH01 for setting future PM goals.

What Is a Green-to-Green SubState Count?

A G2G Substate Count is the total number of distinct substate visits within a G2G instance. For example, adding more detail to our previously introduced ETCH01 history we might have:

- 08:00: Standby
- 09:00: Scheduled down (PM), SubState=Wait-For-Tech
- 09:15: Scheduled down (PM), SubState=Wait-For-Tech (this is not a distinct substate visit, since there's no change in substate).
- 09:30: Scheduled down (PM), SubState=Wait-For-Parts
- 10:00: Scheduled down (PM), SubState=Repair
- 10:30: Scheduled down (PM), SubState=Wait-For-Parts
- 11:00: Scheduled down (PM), SubState=Repair
- 11:30: Scheduled down (PM), SubState=Qual
- 12:00: Standby

This is one G2G instance. Within this instance we have five distinct substate visits: Wait-For-Tech, Wait-For-Parts, Repair, Wait-For-Parts, Repair, and Qual. Therefore the G2G SubState Count for this instance is five.

Why Is Green-to-Green SubState Count Useful?

We use the substate count to highlight G2G instances that are unusual and may present opportunities for improvement.

Suppose we list all the "PM Standard" G2G instances for ETCH01:

- Instance #1: 4 hours, SubState Count=4
- Instance #2: 5 hours, SubState Count=4
- Instance #3: 4 hours, SubState Count=4
- Instance #4: 3.5 hours, SubState Count=4
- Instance #5: 5 hours, SubState Count=12

Why did instance #5 have so many distinct substates? This looks odd and may be an opportunity for improvement.

Other Implementation Details

In this section, we discuss a few other details that require consideration as G2G charts are implemented.

Ongoing Downtime Instances:

If a tool has gone down but isn't back up yet, would we count this downtime as a G2G instance? FabTime's position on this is no, because we don't yet know the following:

- The length of the G2G instance (we don't know the G2G time!)
- The G2G type.
- The G2G substate count.

Short Instances of Uptime During a Downtime Instance:

If a tool is down for 10 hours, is reported up for 30 seconds, and then goes down again for another 8 hours… is this one G2G instance or two instances FabTime's position is that this is one G2G instance, because the uptime in the middle is so small it doesn't count as really being up. We've included a site-specific parameter in our calculations (default=2 minutes), and we ignore elapsed uptimes smaller than this value.

G2G Instances that Cross Chart Boundaries:

If we are looking at G2G instances for workweek 15 (Monday 00:00 to Monday 00:00), do we include G2G instances that started during this workweek but ended in workweek 16? FabTime's position on this is no, we treat G2G instances as similar to shipments – we include the G2G instance in the period when the instance *ends*, not the period when the instance *starts*.

Outstanding Questions

We are still in the process of defining a few other implementation questions:

- How will the calculations work for multiple tools when merged on a trend or pareto chart?
- What would a trend version of this metric look like? Would it be useful?
- What if there are multiple ReasonCodes for a single G2G instance? How would you allow people to filter based on ReasonCode in that case?
- How should G2G goals be incorporated into the charts?

Conclusions

Equipment downtime is a major driver of both capacity loss and cycle time increases in wafer fabs. Both scheduled and unscheduled downtime events are tracked in detail in the fab MES and are used in calculating a variety of metrics (availability, utilization, OEE, etc.). We believe, however, that there is value in reporting the additional downtime metric of Green-to-Green time. G2G instances are time periods from when a tool goes down (scheduled or unscheduled) until it returns to a standby, engineering, nonscheduled, or productive state. That is, they measure instances in which a tool is not available to production because of some combination of scheduled and/or unscheduled downtime.

It is these G2G instances that truly reflect the variability impact of downtime on tools. The longer a tool is unavailable for production, the more chance there is of WIP piling up and cycle time increasing. This data can be captured via the G2G metric in a way that might be missed by purely looking at downtime percentages, or even mean times to repair.

In this article we have outlined the decisions that we made in implementing the G2G metric in FabTime's software. We believe that this metric could be useful to anyone responsible for keeping equipment running smoothly in a fab. We welcome your feedback.

Closing Questions for Newsletter Subscribers

Does your company use something like a Green-to-Green metric? Do you think that G2G would be valuable for you in identifying downtime improvement opportunities? Have we missed any important details in defining the metric? Do you have feedback regarding our outstanding questions list?

Acknowledgements

FabTime would like to thank **Hani Ofeck** from TowerJazz Semiconductor for suggesting this metric, and for her continued insights throughout the process of implementing it and writing this article. We are also grateful to **Elaine Jacobson** from On Semiconductor and **Aubrey Howe** from Skyworks Solutions for their time in reviewing and improving this metric. We also appreciate the other members of the FabTime User Group who have contributed to discussion on this topic.

Further Reading

We did not find any references in the literature to this metric. If you do know of any, we would be happy to hear about them.

Subscriber List

Total number of subscribers: 2724

Top 20 subscribing companies:

- ON Semiconductor (218)
- Infineon Technologies (145)
- Micron Technology, Inc. (126)
- Intel Corporation (111)
- GlobalFoundries (99)
- Maxim Integrated Products, Inc. (96)
- NXP Semiconductors (78)
- Microchip Technology (70)
- Carsem M Sdn Bhd (69)
- Skyworks Solutions, Inc. (64)
- STMicroelectronics (63)
- Western Digital Corporation Inc. (59)
- Texas Instruments (57)
- Seagate Technology (51)
- X-FAB Inc. (48)
- TDK (47)
- Analog Devices (40)
- Zymergen (34)
- Cree, Inc. (32)
- Honeywell (30)

Top 4 subscribing universities:

- Ecole des Mines de Saint-Etienne (EMSE) (14)
- Arizona State University (9)
- Virginia Tech (7)

New companies and universities this month:

- Akoustis

Sampler Set of Other Subscribing Companies and Universities:

- Boise State University (1)
- Centum Rakon India Pvt. Ltd. (1)
- Cimetrix Inc. (1)
- Comlase AB (1)
- Foxconn Hon Hai Logistics Texas LLC (1)
- GAL-EL (1)
- International SEMATECH (7)
- KLA-Tencor (6)
- Linde Group (1)
- MIT (1)
- Polar Semiconductor (21)
- Production Management Institute (Germany) (1)
- PRTM (1)
- Tesla Motors (1)
- Test Advantage (1)
- Uppsala University (1)
- VDL ETG T&D (1)
- Vishay (6)
- Wright Williams & Kelly (3)

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.

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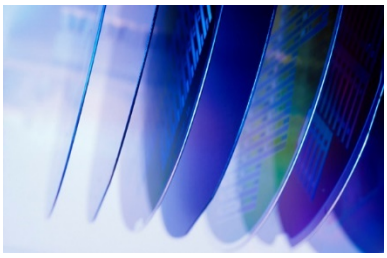
FabTime® Dispatching Module



Dispatch Configuration and Support

We offer our dispatching module for a single, fixed monthly fee (on top of your regular FabTime subscription). This includes:

- Dispatch rule configuration via user-friendly web-based interface for standard factors
- Training.
- Dispatch list feed to the MES (if applicable).
- Support and upgrades.

Custom dispatch rules and consulting from our dispatching expert available for additional fee

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
- WIP level or staging time at downstream tools.

Interested?

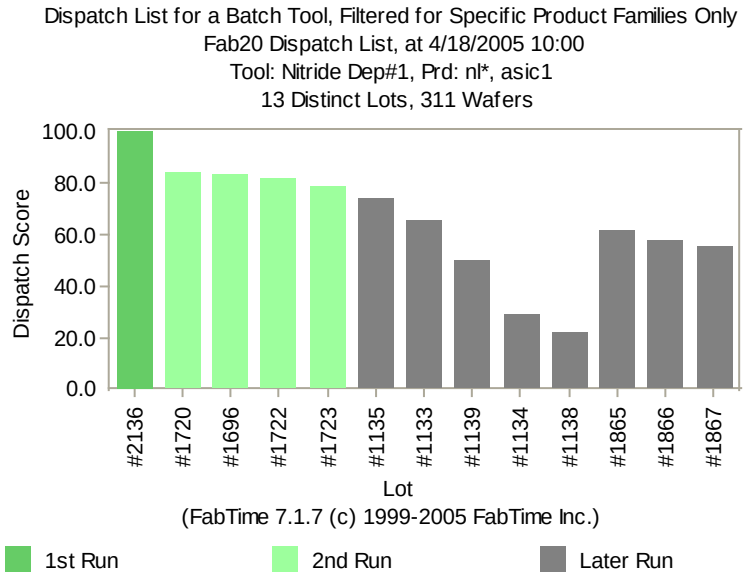
Contact FabTime for details.

FabTime Inc.
Phone: +1 (408) 549-9932
Fax: +1 (408) 549-9941
Email: Sales@FabTime.com
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 dispatch 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. FabTime now (as of 2016) also includes an optional **short-interval scheduler**.



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.