FabTime Newsletter

Volume 22, No. 5 **December 2021**

Information

Publisher: FabTime Inc. FabTime sells cycle time management software for wafer fab managers. FabTime's mission is to help the people who run fabs improve performance by 1) helping them to understand the factors that drive fab performance and giving them the data to identify current improvement opportunities; 2) letting them control that data by setting parameters for their own charts, so they don't have to go back to IT every time they want a different piece of information; and 3) including them in a community of people around the world who are all working to drive better fab operations.

Editor: Jennifer Robinson

Contributors: Dave Kayton (onsemi)

Date: Tuesday, December 14, 2021 – Vol. 22, No. 5

Keywords: Operators; Operator Productivity; Fab Management; Dispatching

Table of Contents

Welcome

Welcome to Volume 22, Number 5 of the FabTime Cycle Time Management Newsletter. We hope this issue finds you all well. In our community news section, we share links to several articles about the current chip shortage and resulting capacity expansion plans. In our subscriber discussion forum, we share some additional resources related to a topic raised in the previous issue: critical ratio values by zone.

In our software tip and our main article this month we address the topic of managing operators during a staffing shortage. We chose this topic after hearing from various fabs that the current economic environment has led to difficulties in finding sufficient operators. In the main article, we identify four fab management issues that may be exacerbated by a lack of operators and discuss ways to mitigate the impact of operator unavailability on cycle time.

Here at FabTime we are keeping busy with:

- Rolling out our new user interface to existing customers,
- Installing the software for a new customer (Site 53!), and
- Delivering sessions of our remote cycle time management course to a variety of company sites around the world. Contact Jennifer for details.

Wishing you a joyful holiday season and an ever more normal 2022! – Jennifer, Frank, Lara, and the FabTime Team

Community News/Announcements

A Few Highlights from Jennifer's LinkedIn

Jennifer continues to share articles about business management, the semiconductor industry, and productivity improvement on her LinkedIn feed. Recent links have included:

- A Wall Street Journal piece about how the race to expand fab capacity continues as Micron Technology "plans to boost investment to more than $150 billion over the coming decade to cater to booming demand and is urging Congress to pass legislation that would aid domestic plant expansion. Micron Chief Executive Officer Sanjay Mehrotra said some of the planned spending would go toward expansion of existing chip-production facilities and potential construction of new ones." Also reported: Samsung is building a $17 billion fab in Taylor, Texas and Texas Instruments is planning a new 300mm fab in Sherman, Texas, and Ford Motor Company and General Motors are getting more directly involved in the semiconductor industry to better protect their access to capacity.
- An in-depth article from The Wall Street Journal about how although there has been much capital spending announced in the #semiconductor industry, "less than $1 of every $6 is earmarked for the so-called legacy chips facing the longest backlogs right now." This reflects in part the lower cost to make those chips, but also the economic risks of expanding capacity at the older technology nodes. This means that supply problems will continue, as "the restrained bets on the hardest-hit types of semiconductors mean that the world's legacy-chip supply won't catch up with projected demand through 2024… Some legacy-chip makers are boosting investments to levels they say reflect a prudent response to demand. United Microelectronics Corporation (UMC) has pulled the trigger on a $2.3 billion expansion this year—but only after securing advance bookings from customers and locking in pricing." There's a robust discussion in the comments on the LinkedIn post.
- The above article followed an earlier piece about the chip shortage as it applies to older manufacturing technologies, and the difficulty that fabs are having in procuring used equipment to expand capacity. "A longer-term trend, of expanding and insatiable demand for microchips in every electronic device you can name, has for years been taking slack out of the supply chains for the equipment at the heart of the supply chain for microchips." That piece had quotes from several companies represented on this newsletter's subscriber list.
- Meanwhile, a NY Times piece carried in the San Jose Mercury News talked about how (and why) independent chip manufacturers like Microchip Technology Inc., Infineon Technologies and onsemi are getting new attention as "power players" in the semiconductor industry in light of the chip shortage.

For more industry news, connect with Jennifer on LinkedIn:
http://www.linkedin.com/in/jenniferrobinsonfabtime

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

FabTime® User Tip of the Month

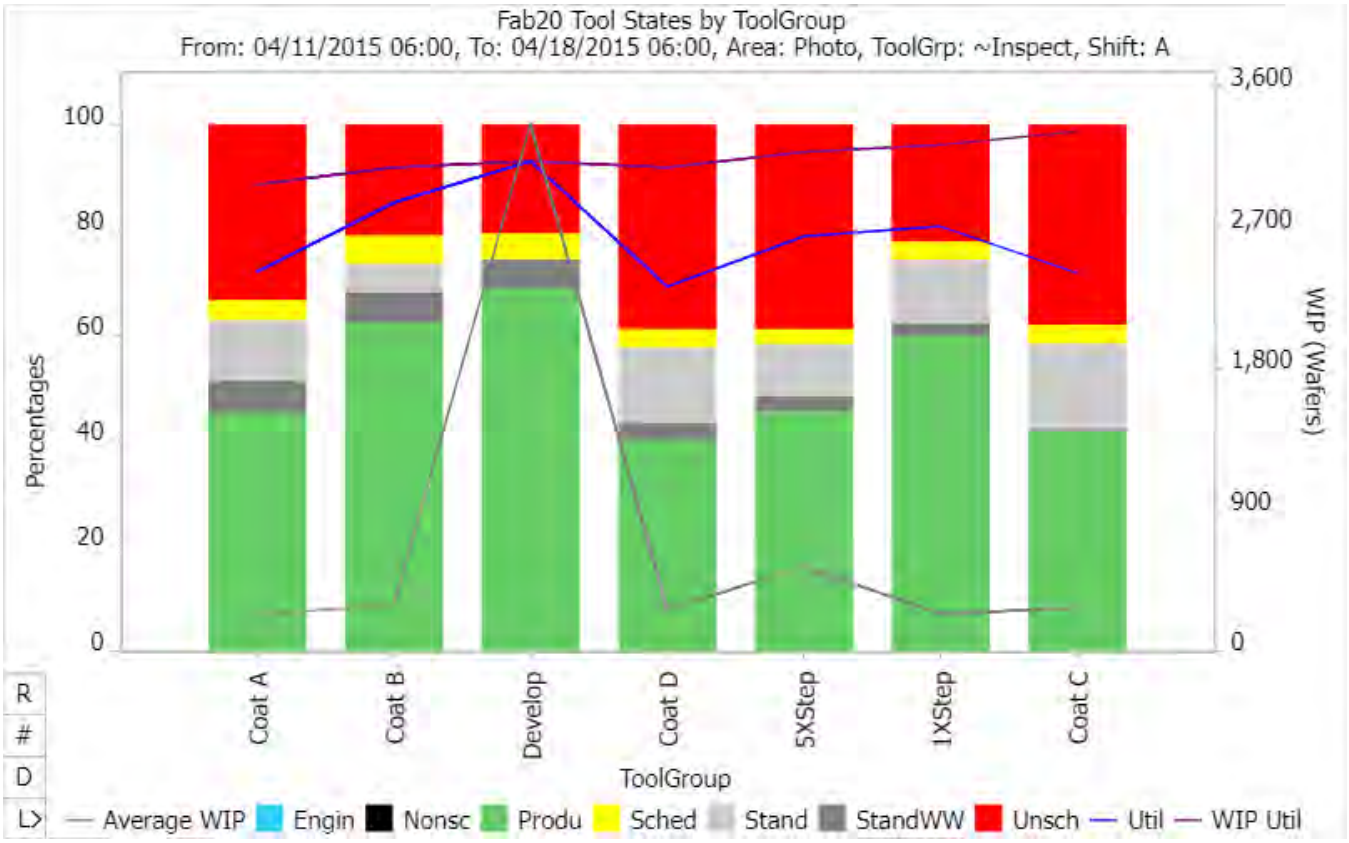
Use Standby WIP Waiting Time to Identify Operator Delays

As discussed in the main article below, many fabs are finding it difficult to hire enough operators these days. When a fab is running with fewer operators than needed, it is useful to have an indicator of where lack of operators is leading to forced idle time on tools. One useful metric for this is the Standby WIP Waiting field on the Tool State charts in FabTime.

Standby WIP waiting is time that the tool is available, and has qualified WIP waiting, but is not being run. For more detail, see Tip #117: Understand How FabTime Calculates Standby-WIP-Waiting Time. Often, though not always, standby WIP waiting time is an indicator that there is no operator available to load the tool.

To identify the tools with the most standby WIP waiting time in FabTime:

1. Generate a Tool State Pareto chart and slice it by Tool or ToolGroup. Add tool-specific filters to narrow the set of tools displayed to your area of interest (e.g. the Photo area).
2. Scroll down to the Sort Chart section of the filters to the left-hand side of the chart and select StandbyWIPWaitingPct. Check the box to sort in descending order and press "Go". FabTime will sort the chart by the tools (or tool groups) that spent the most time in a standby WIP waiting state over the time period specified on the chart.
3. To better understand trends in this behavior, change the date range to look over a week and add a "Shift" filter. The chart will then show you the tools that spent the most time during that shift in standby WIP waiting for the current week. An example is shown below.



In this example, Coat A and Coat B have the most standby WIP waiting time (dark gray bars). However, a tool to be concerned about is Develop, which has a similar quantity of standby WIP waiting time and no true idle time when no WIP is waiting. We can expect a high cycle time through the Develop tool group under current utilization and staffing conditions.

We hope you find this tip useful.

Subscribe to the separate Tip of the Month email list (with additional discussion for customers only) here: http://www.fabtime.com/tip-of-the-month.php. Thanks!

Subscriber Discussion Forum

Critical Ratio Values by Zone (Linear Stage of the Flow) in the Fab

Following up on a topic introduced in the previous issue, Dave Kayton from onsemi shared links to some work he did that included calculating critical ratio by layer. The references and abstracts are shown below. We find the detrimental effects on performance of downtime at non-bottleneck tools especially interesting, given the emphasis that we place on the importance of variability in this newsletter.

- D. Kayton, T. Teyner, C. Schwartz and R. Uzsoy, "Effects of dispatching and down time on the performance of wafer fabs operating under theory of constraints," *Nineteenth IEEE/CPMT International Electronics Manufacturing Technology Symposium*, 1996, pp. 49-56, doi: 10.1109/IEMT.1996.559681. https://ieeexplore.ieee.org/abstract/document/559681

  Abstract: A number of companies have reported significant improvements in manufacturing performance through implementing the concepts of the Theory of Constraints suggested by Goldratt (1986). However, the implementation of these concepts in wafer fabs is not straightforward due to the presence of reentrant product flows. In this paper we examine the effects of downtime at non-bottleneck machines and different dispatching rules on the performance of a wafer fab operating under the Drum-Buffer-Rope release policy (Goldratt and Fox 1986). Our results show that downtime at non-bottleneck machines has significant detrimental effects on fab performance, and that the Critical Ratio dispatching rule performs well in terms of the tradeoff between cycle time and throughput.

Here is a later paper that cites the first one and is related:

- D. Kayton, "Using the theory of constraints' production application in a semiconductor fab with a reentrant bottleneck," *Twenty Third IEEE/CPMT International Electronics Manufacturing Technology Symposium (Cat. No.98CH36205)*, 1998, pp. 352-357, doi: 10.1109/IEMT.1998.731093. https://ieeexplore.ieee.org/document/731093

  Abstract: In early 1995, Harris Semiconductor's Findlay plant embarked on the process of developing the theory of constraints (TOC) drum-buffer-rope (DBR) production application in our wafer fabs, using a reentrant bottleneck, in which the product passes through the bottleneck multiple times. We formed a lead team to customize the generic production application to our unique situation and learned much about how to apply each of the components of DBR to a reentrant bottleneck situation. For example, to determine how many wafers to start each week, we determine the total bottleneck moves for the previous week, divide by the average number of bottleneck repetitions per wafer, and adjust for yield.

  For the past three years, the plant has been using this system, and it has evolved greatly. During that time, the bottleneck has changed several times, though we chose to maintain the formal bottleneck throughout this time. In addition, we have gone through several periods where the constraint shifted to the market, in which capacity outstripped demand. Using five focusing steps, we doubled bottleneck capacity in the focus fab over this time. Activities around the improvement included decoupling the bottleneck operation from a nonbottleneck operation, modifying operator shifts and work rules, improving capability at the bottleneck through various improvement projects, and using critical ratio to schedule all nonbottleneck operations.

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

Managing Operators During a Staffing Shortage

Introduction

Back in 2002 and 2003 we had extensive discussions in this newsletter about operators: how to model them, how to figure out how many were needed, and what their impact was on cycle time. Since then, we've talked about the impact of operators on cycle time in our course and provided certain employee-specific reporting in our software. However, we haven't focused much on operators in the newsletter.

Fast forward to 2021. As the impact of the Covid-19 pandemic lingers, companies around the world are facing staffing shortages. We all see this when we go to restaurants and experience delays in service. We read about workforce participation rates and the shortage of truck drivers in the newspapers. Every time FabTime does a cycle time class with a fab, lack of operators is mentioned as a contributor to cycle time. Sometimes operators are named first, ahead of tool utilization, downtime, or product mix (perennial favorites). Staffing challenges, particularly as applied to operators, have also been a topic at Fab Owners Alliance meetings this year. Thus, it seems an appropriate time to revisit operators and cycle time in the newsletter.

Here are a few cycle time challenges that may be exacerbated by not having sufficient operators:

- Forced idle time due to operator unavailability. This lost capacity increases tool utilization. The forced idle time also increases variability in both process times and times between arrivals. Utilization and variability increases, of course, increase cycle time. This may be especially pronounced during shift change.
- Operator preferences / soft dedication. When operators feel overloaded, it seems likely that they would focus on tools in the closest proximity, and on the most efficient tools. While these are rational choices, they may increase soft dedication, leading to higher utilization on the chosen tools.
- Lot transport delays. For fabs that have manual lot transfer, having fewer operators means that lots will wait longer before being moved downstream to the next step. Where there are carts in use, they are likely to sit longer until they're full, so that operators can reduce trips. This also increases variability.
- Insufficient operator cross-training. During a staffing shortage there is probably more turnover among operators. This makes it harder for fabs to keep up with cross-training, resulting in more tools assigned to a single operator (and increasing forced idle time further).

These challenges are each discussed below, followed by FabTime's recommendations.

Identifying Tools with Forced Idle Time Due to Operator Unavailability

The core issue with having insufficient operators is that situations will arise in which there is no operator available to either: 1) load an idle tool that has WIP waiting; or 2) unload a lot that has finished processing.

In both cases, we have a lot that is ready to do the next useful thing, and we're stopped, temporarily, by the absence of an operator. We also have a tool that's ready to do the next useful thing and is similarly stopped. At the lot level, both delays are at least potentially a direct addition to overall lot cycle time. How direct depends on whether the lot would be processed right away at the next step or would end up at the back of another queue.

At the tool level, both delays increase the effective utilization of the tool via what is in effect a hidden capacity loss: forced idle time. They also increase the process time variability for arrivals to the tool, and hence the arrival variability for downstream tools. As was discussed in the previous issue, these increases in utilization and variability lead to increased cycle time through the tool (for all lots).

Here are two metrics that can be used to identify the places in the fab where forced idle time due to operator unavailability is most pronounced.

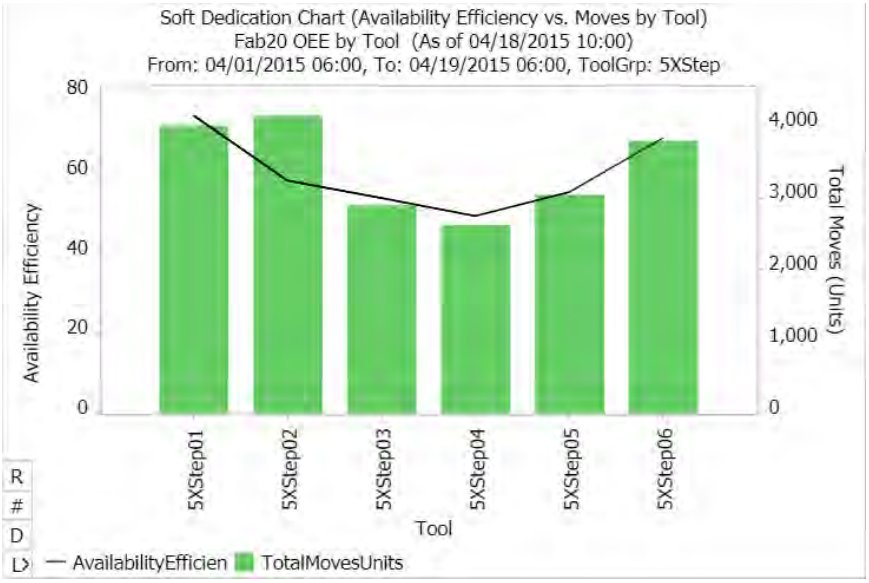
- **Standby WIP Waiting** is time that a tool is available to manufacturing, has qualified WIP in queue, and is not being run. Standby WIP waiting time is reported in our software on the E10 Tool State charts. We break standby time up according to whether WIP is waiting, typically treating lots that have moved out of the prior operation as being in queue for the current operation. Standby WIP waiting time is usually, though not always, an indicator that there was no operator there to load the tool. [Sometimes it indicates that WIP is being held at a step such as a clean operation to avoid moving it downstream too early.] The important thing in measuring standby WIP waiting time is that the system determines it automatically (from move and tool state transactions), rather than relying on an operator to log the tool into a standby WIP waiting state.
- **Post-Process Time** is time between when a lot has finished processing and when it is moved out of a tool. This measurement is typically only available if your tools automatically send an End Run transaction that is separate from the Move Out transaction logged by the operator. In FabTime, for customers whose MES logs this level of detail, you can slice the Operation Cycle Time Details Pareto by tool or tool group. Sorting in descending order by ActualAvgPostProcessTime will then bring the tools with the largest quantity of post-process time to the top of the list.

Once you have a sense of which tools appear to be experiencing forced idle time due to operator unavailability, you can look at where these tools are significantly contributing to cycle time (see Issue 22.01, about finding cycle time bottlenecks). These are the key places to consider changes to staffing policies. In the simplest example, if you find that your bottleneck tool group spent 5% of time in standby WIP waiting over the past week, you should look at mitigation methods. In general, where you have significant standby WIP waiting or post-process time and utilization is high, you should attempt to allocate additional operator resources.

What can help in reducing this type of forced idle time is to minimize the number of distinct tools that each operator monitors at one time, at least for bottleneck tool groups. Staggering shift changes and break schedules can also help. In general, operators should be reassigned, if possible, to reduce the quantity of forced idle time on the tool groups that have the most queue time and/or the highest utilization.

Operator Preferences (Soft Dedication)

As discussed most recently in Issue 22.02, operators sometimes have preferences for which tools they like to use. These can differ from the set of tools identified in the tool qualification matrix. For example, operators may avoid a tool that is technically part of the tool group but is located in another part of the fab. Alternatively, operators might prefer to use the newest tool in the tool group because it is faster, passing over the older tools. It makes sense that display of this soft dedication would increase during staffing shortages.



Operator preferences and/or communication problems regarding qualification can result in fewer tools being used for a particular operation than planned. The resulting utilization on the tools may then be higher than

expected. If you are finding that actual cycle times are much higher than expected for an operation, checking the actual set of qualified tools is a good first step. The figure above shows an example of a method for identifying soft dedication (compare availability efficiency vs. moves by tool in the tool group).

Lot Transport Delays

For fabs that rely on manual transfer of lots, operator shortages may mean that lots wait longer before being moved to the next operation. This is particularly true for fabs that use carts for lot transfer. Operators who are heavily loaded will be more likely to wait until a cart if full before moving it. This has a direct impact on the cycle time of the waiting lots, and increases variability to downstream operations (less frequent, larger batches arrive).

Some fabs use dedicated lot transport operations. There's a tradeoff here. You can better keep the tools running. After moving a lot out, an operator can immediately focus on loading another lot. However, you'll have more delay while lots wait for the presumably limited transport operators. This, again, leads to higher arrival variability downstream. Transport operators also end up walking significant distances, which could increase burnout, potentially exacerbating shortages.

As with most problems, the first step to tackling the issue or transport delays is to collect data to see if and where it has an impact. Fabs that track travel times can have their industrial engineers assess this. For fabs that don't directly track travel times, a proxy is to look at arrival variability to different tool groups. One relatively low-cost recommendation, if you wish to reduce arrival variability due to carts, is to get smaller carts. But this may not be the best strategy during a staffing shortage.

Insufficient Operator Cross Training

During a staffing shortage, turnover among operators may be higher, due to a combination of burnout and competition for resources. This makes it harder for fabs to keep up with training operators. This is a problem because high levels of operator dedication (one operator running some large set of tools) tend to increase the forced idle time described above.

Some fabs try to cross-train operators to perform small maintenance tasks, which eliminates long waits for equipment techs, but increases the load on operators. Other fabs cross-qualify operators as much as possible, so that each operator can be responsible for many tools at one time. Both approaches raise the question "how far can you go?" On the one hand, if all your operators are fully cross-trained, then whenever any tool needs an operator, the likelihood is very high that an appropriate operator will be available. However, this raises logistical issues because the operators need to know which tools to monitor. You can easily simulate having one large pool of operators, but in practice, you need to assign the operators to areas.

We believe that the amount of cross-training to use depends on the size of your factory, and on how much slack capacity the operators have. If your operators end up very highly loaded due to additional activities, then you'll end up with more forced idle time, and higher cycle time. During a staffing shortage, when you already have heavily loaded operators, and more new employees, you will probably end up leaning towards less cross-training.

As in the case of tool dedication, however, the situation you want to avoid is where you only have one person trained to do a job. This is the same as having a single path operation (see Issue 20.05), and significantly increases delays in the fab. As with tool dedication, the benefit of going from one person who can do something to having two people who can do something is significant. The marginal benefit, while still present, decreases from there.

A Note on Technicians

Thus far we have talked primarily about operators. Most of the issues identified also apply to technicians and can be even more significant given that technicians typically cover more distinct tools at one time. Here we again recommend:

- Cross-training to ensure that at least two people can handle any issue.
- Collecting data that identifies areas where the delays due to lack of technician are most significant. Most fabs include a "Waiting for Technician" option when logging tools down. Checking where this time is most significant, particularly where cycle times are high, is the first step in making improvements.

Conclusions

Because the tools used in wafer fabs are so expensive, it has traditionally made sense to hire enough operators to minimize capacity losses due to operator unavailability. While the financial argument remains in place, a staffing shortage around the industry has made hiring sufficient operators more challenging in practice. We have spoken with people from many fabs in recent months and heard the same complaints. As companies race to expand capacity in response to the chip shortage, operator shortages will likely continue.

In this article we have explored four fab management issues that are likely to be exacerbated by staffing shortages: forced idle time on tools; soft dedication; insufficient operator cross-training; and lot transport delays. We have recommended metrics for identifying the locations in the fab where staffing shortages are causing the most difficulty, and suggested reallocating operators (and technicians) to these areas. We hope you find this discussion useful, and we welcome your feedback.

Closing Questions for Newsletter Subscribers

Is your fab having trouble hiring enough operators and technicians these days? What adjustments have you made on the manufacturing side to account for this? Do you track forced idle time or other metrics to understand where operator delays are increasing cycle time?

Further Reading

- J. Robinson and F. Chance, "The Impact of Staffing on Cycle Time," FabTime Newsletter, Volume 3, No. 9, 2002 and "In-Depth Guide to Operators and Cycle Time," FabTime Newsletter, Volume 4, No. 6, 2003.
- See also "Finding and Analyzing Cycle Time Bottlenecks (Issue 21.01)" and "10 Recommendations for Fab Cycle Time Improvement (Issue 22.02)". The latter includes a discussion on soft dedication.
- All of the above issues are available for download by subscribers from the FabTime newsletter archive. The current password is "FabTimeCommunity".

Subscriber List

Total number of subscribers: 2875

Top 20 subscribing companies:

- onsemi (200)
- Infineon Technologies (155)
- Analog Devices (includes Maxim) (132)
- Intel Corporation (123)
- Micron Technology, Inc. (123)
- GlobalFoundries (105)
- NXP Semiconductors (82)
- Skyworks Solutions, Inc. (76)
- Microchip Technology (71)
- Carsem M Sdn Bhd (69)
- STMicroelectronics (66)
- Western Digital Corporation Inc. (63)
- Seagate Technology (56)
- Texas Instruments (55)
- X-FAB Inc. (52)
- Wolfspeed, Inc. (42)
- Qualcomm (38)
- Tower Semiconductor (32)
- Hitachi Energy Ltd. (30)
- Honeywell (30)

Top 3 subscribing universities:

- Arizona State University (9)
- Ecole des Mines de Saint-Etienne (EMSE) (8)
- Virginia Tech (7)

New companies and universities this month:

- Cabot Hosiery Mills
- Dupont
- Genpact
- LaRue Tactical
- SimWell
- Sivers Photonics

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 to the newsletter. Past issues of the newsletter are now available in PDF for download by newsletter subscribers from FabTime's website. To request the current password, email your request to Jennifer.Robinson@FabTime.com, or use the Contact form.

To subscribe to the newsletter, send email to newsletter@FabTime.com, or use the form at www.FabTime.com/newsletter-subscribe.php. 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® Software: If you would like more information about our web-based dashboard for improving fab cycle times, please visit our website. A sample home page and a sample page from FabTime's new Charts menu are shown below.