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FabTime® Newsletter

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Information

Publisher: Acquired by INFICON in early 2024, FabTime has been helping fabs with cycle time and performance improvement since 1999. FabTime's flexible reporting software, cycle time management course, and this newsletter are now part of the INFICON Intelligent Manufacturing Systems (IMS) group.

Editor: Jennifer Robinson, Cycle Time Evangelist for INFICON

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Keywords: Equipment Downtime; Metrics and Goals; Factory Behavior; AI/ML; Reporting

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Welcome

Welcome to Volume 25, Number 6 of the FabTime Cycle Time Management Newsletter. In this issue we have an exciting announcement about AskJen™, a new AI-powered expert chat feature for the FabTime software that is based on the content from this newsletter. Thank you to everyone who has been reading this newsletter over the years, asking questions, and incentivizing us to keep providing content. We are excited that the INFICON Data Science team has found a way to make this archive of content useful going forward.

We also have announcements about a repeat session of our webinar on equipment downtime and plans for the newsletter distribution going forward. Our software tip is about decluttering home page tabs. We also respond to a subscriber question about quantifying the benefits of cycle time reduction.

In our main article, we introduce The Waddington Effect, a condition in which doing scheduled maintenance can sometimes cause a short-term increase in unscheduled downtime. We discuss whether the Waddington Effect contradicts our advice to separate maintenance events rather than grouping them, as well as how to generate and use Waddington Effect Plots. We hope you find this effect as fascinating as we do and welcome your feedback.

Wishing you all a wonderful holiday season and a productive 2025! – Jennifer

Community News/Announcements

INFICON Introduces AskJen™ – A Cutting-Edge AI-Powered Expert Chat Feature for FabTime

Syracuse NY – December 3, 2024 – INFICON's FabTime, the leading provider of flexible reporting software for the semiconductor industry, is proud to unveil **AskJen**, an innovative AI-powered expert chat feature designed to provide 24/7 access to advanced insights into semiconductor operations.

AskJen harnesses cutting-edge Large Language Model (LLM) technology combined with over 25 years of expertise in cycle time management to empower semiconductor professionals with instant answers to operational questions.

This groundbreaking feature is built on the extensive knowledge base of FabTime co-founder **Dr. Jennifer Robinson**, whose globally recognized newsletter has provided practical insights into wafer fab productivity for over two decades. With more than 180 editions blending academic rigor with real-world feedback from semiconductor fabs worldwide, Dr. Robinson's expertise is now available at users' fingertips.

Powered by Retrieval-Augmented Generation (RAG) technology, AskJen provides specific, accurate, and actionable answers, complete with citations for further exploration. Users can consult AskJen just as they would an expert advisor, gaining valuable insights to improve operational efficiency and profitability.

"AskJen is a great way to leverage the unique value of the FabTime newsletter archive, and it represents just the beginning of our integration of AI technologies," said **Dr. Holland Smith**, Director of Data Science at INFICON. "We see strong opportunities to enhance usability and deliver insight across our product portfolio by harnessing the benefits of LLMs."

With AskJen, semiconductor fabs can now unlock unprecedented operational insights, transforming how they manage cycle time and achieve productivity goals.

Availability: An initial trial version of AskJen will be introduced as a feature in FabTime **2411.0.0**, set to launch **this month**.

Current FabTime software customers who are interested in testing this feature using our FabTime Demo development server, please reach out to jennifer.robinson@inficon.com.

Prepare for changes to the distribution of the newsletter and to the legacy FabTime website

Starting with the next issue, we will be sending newsletter mailings via HubSpot. You will receive a formatted e-mail with overview blurbs for each section of the newsletter and will have the opportunity to click through to read more. We appreciate your support of the newsletter during

this time of change and welcome any feedback. **Some subscribers will need to re-subscribe to meet legal privacy requirements**. If you fall into that category, we will notify you before the next issue. If you would like to be proactive, please fill out the newsletter subscription form on the INFICON website. Thank you!

The legacy FabTime website will be redirected to inficon.com soon. Key content from the FabTime website now available on the INFICON website includes:

- Past issues of the FabTime Newsletter in PDF format. You can download individual issues or a full archive. There is also a PDF file containing the abstracts from all newsletter issues to date.
- The FabTime Operating Curve Spreadsheet, a useful Excel-based tool for exploring tradeoffs related to variability, utilization, and number of qualified tools.
- Information about the FabTime Cycle Time Management Course.
- A PDF file containing book reviews written back in the earlier days of FabTime by **Dr. Frank Chance** and **Dr. Jennifer Robinson**.
- A PDF file containing a tutorial on wafer fab cycle time as well as various queueing formulas, created back in the early days of FabTime.
- A video of Jennifer's FOA Fab Star Webinar on the fundamental drivers of fab cycle time. Follow this link and scroll to the bottom of the page.

We are also building up a set of key main articles from the FabTime newsletter, available as news articles at inficon.com. Just type "FabTime" in the search box and select "Pages." See, for example, the main article from the September issue: A New Metric for the Functional Utilization that Drives Cycle Time.

See highlights from Jennifer's LinkedIn

Jennifer continues to share articles about business management, the semiconductor industry, and productivity improvement on her LinkedIn feed. Recent posts (in addition to the announcement of AskJen) have included:

- A team photo from a FabTime Integration Workshop held last week in San Jose. Shown left to right: **Frank Chance, Mike Neel, Dave Wizelman, Erica Flint, Lara Nichols-Brown, Steve Lakeman, Jennifer Taylor and Jennifer Robinson**.
- A WSJ report that Qualcomm has approached Intel with a takeover offer. That would be big news if it happened. See also this follow-up about how Intel "Fell from Global Chip Champion to Takeover Target."

- A more recent WSJ article about Intel receiving a $7.9B Chips Act award.
- A report that the UK government is purchasing the Coherent fab in Newton Aycliffe to preserve domestic access to chips for the military. The fab is a Gallium Arsenide site employing about 100 people and will be renamed Octric Semiconductors UK.
- A report by the Center for Strategic and International Studies (CSIS) that says that America cannot afford to lose Intel Corporation as a US-based manufacturer of advanced semiconductors.
- An encouraging update from SEMI that "The global semiconductor manufacturing industry in the third quarter of 2024 showed strong momentum with all key industry indicators performing positive quarter-on-quarter (QoQ) increases for the first time in two years."
- A summary of the recent Women of the FOA event at the Fab Owners Alliance meeting in South Portland, Maine. Jennifer notes: "Last week's FOA meeting included an excellent day of discussion and team bonding with the Women of the FOA. I've always enjoyed the FOA meetings, but the new focus on bringing more women into the organization has made the events significantly more meaningful. It's also been nice, after years of generally representing FabTime on my own, to attend with my INFICON colleagues. Thanks to the team at Texas Instruments for hosting, and to the SEMI team for organizing. The October weather in Maine was also absolutely perfect, which helped, too."

For more industry news, connect with Jennifer on LinkedIn.

Attend another session of our webinar on equipment downtime metrics

We had some technical issues with last month's webinar: **FabTime®: Improve Fab Cycle Time by Tracking the Right Equipment Reliability Metrics**, causing us to get a late start and necessitating an abridged Q&A session. Therefore, we've decided to schedule another live session of the same webinar on Wednesday, Dec 11, 2024 from 11:00 AM - 12:00 PM EST. Register here for the new session.

If you did register for the prior session, but found yourself stuck in the waiting room, **please accept our apologies**. You should have received an e-mail with the slides and a link to the video of that session. If you did not, please reach out to Jennifer. We are working to ensure that the next webinar runs smoothly.

FabTime® Software Tip of the Month

Declutter Your Home Page Tabs

If you are anything like me (Jennifer), and you are a regular FabTime user, chances are that your FabTime home page has become a bit cluttered over time. Perhaps you've created special home page tabs for various purposes that you no longer use. Maybe your "Default" home page tab is slower to load than you would like, because you have 153 charts saved there. Or is it that you have trouble remembering whether that super-useful chart that you configured is on your "Morning Meeting" tab or your "Analysis" tab? If any of these situations feel familiar to you, perhaps it's time to do some FabTime home page decluttering. When you have a few spare minutes:

1. Click on your "Home Page Tab" drop-down and scan for tabs that you never visit, or don't even remember why you created them.
2. For any tab that you aren't sure about:
    a. Switch to the tab by selecting it from the drop-down menu.
    b. Take a quick scan to make sure you don't need this tab. (If the tab is shared, consider whether other people are likely to be using it.)
    c. If you are sure you don't need to keep it:
        i. Click the "Delete Tab" button in the left-hand menu.
        ii. Enter the tab name when prompted and click the "Delete" button.
    d. If you do need the tab, but find the tab's purpose unclear from the tab name:
        i. Select the tab name in the left-hand pane and type a new, more descriptive name.
        ii. Press the "Rename Tab" button.
    e. Repeat this process for all the tabs on your account.
3. If you find a tab that loads slowly:
    a. Review the charts on the tab. Delete any that you don't need, or move some of the charts to a different tab.
        i. To move one chart to another tab, just click on the chart to drill down and then add that chart to a different tab. Use your back button to return to the original tab and delete the chart using the small trash can icon above the chart.
        ii. To move a larger number of charts to a different tab, use the "Copy Tab" function to make a copy of the tab, and then delete charts as needed from each of the copies.
    b. If you have many charts that are similar to one another but differ by just a couple of filters (e.g. your tab shows a moves trend for photo, a moves trend for etch, etc., and also a WIP lot list for each of those areas), consider exploring tab filters. Tab filters let you create a single tab where you can modify one or more filter settings on the fly. This lets you create, say, a Module Performance tab where you can vary the setting of the "Area" filter to cycle between modules.

We hope you find this tip useful! Please send your software questions or suggestions for software tips to Elaine Jacobson, the Program Manager of Customer Success for FabTime. Thanks!

Subscriber Discussion Forum

Quantifying the Cost of Cycle Time

A recent attendee in one of our cycle time classes recently wrote: "One thing I have questions about is quantifying cycle time and the cost of not being able to run wafers. I know that there are many more factors than just the average cost of a wafer and the average moves per time frame. If this has been discussed in a previous newsletter, would you mind re-sharing that one?"

Response from Jennifer: Our best summary on that topic is in issue 7.07: Financial Justification for Cycle Time Improvement Effort (available for download from the FabTime Newsletter Archive). This article covers six paths that can be used to quantify the benefits of cycle time improvement. The tricky part is usually getting agreement on the inputs. This is especially true when thinking of things like time to market.

Down at the detailed level, questions like "how much did this particular downtime cost us?" are also tricky (and are not quite what's covered in Issue 7.07). If a downtime event reduces throughput, we can quantify that. But if it holds up something like 20 lots for an average of one day each, that's a harder question. Would those lots have spent some of that time waiting at other tools anyway? Is that full day added to the cycle time of those lots? If so, is there a financial penalty for the lots shipping a day later? It's hard to say. But then we can get back to Issue 7.07, which looks at what one day of cycle time improvement might be worth.

Question for Subscribers: What topics related to wafer fab operational performance would you like to see addressed in future newsletter issues?

You can see a list of the past newsletter issues, with keywords, in our newsletter archive, but you of course can't see what isn't there. If there is a topic that you've been wondering about, please let us know. We of course also welcome the opportunity to publish subscriber discussion questions and responses. Send your responses to Jennifer.Robinson@inficon.com.

Main Article: The Waddington Effect on Wafer Fabs

By Jennifer Robinson

As we've been recommending metrics for mitigating the impact of downtime on fab cycle time, something we've wondered about is the impact of **The Waddington Effect**. The Waddington Effect, named and promoted by author **James P. Ignizio**, is based on World War II era research into maintenance of the British RAF's B-24 Liberator Bombers. Researcher C. H. Waddington and his team found that scheduled maintenance of these aircraft, if too frequent, could do "positive harm by disturbing a relatively satisfactory state of affairs." Specifically, Waddington found that unscheduled downtime events **increased** after scheduled maintenance, rather than decreasing. (See this Sport Aviation Magazine article by Mike Busch for an overview.)

This result seems potentially in conflict with recommendations in this newsletter (see Issue 22.01, e.g.) and our cycle time course to refrain from grouping maintenance events. We've made that argument based on the observation that longer periods of unavailable time are much worse for cycle time than shorter periods. All else being equal, this is certainly true. However, if more frequent scheduled maintenance events lead to subsequent longer unscheduled downtime events, overall cycle time could end up worse.

In this article, we introduce the Waddington Effect, as well as Waddington Effect Plots. We then propose a resolution to the apparent conflict between our recommendation for more frequent maintenance events and Waddington's implicit recommendation for doing less frequent maintenance. As always, we welcome your feedback.

What is the Waddington Effect?

According to an article by James Ignizio in the September 2010 issues of PHALANX Magazine (the quarterly journal of the Military Operations Research Society), C. H. Waddington was a geneticist who was assigned during World War II to a British military operations research group. The Operational Research Group was asked to increase the effectiveness of the British bomber command by reducing the time aircraft spent on the ground between flights.

Ignizio reports that:

> "[B]efore scurrying about to provide a slick briefing on a scheme that might or might not work, Waddington and his team had the audacity to stop and think. They requested and analyzed the supporting data, talked with maintenance crews, and took time to carefully and personally observe actual maintenance events."

Ignizio termed what they discovered the Waddington Effect. They plotted the number of unscheduled downtime events, along with the time since the most recently scheduled maintenance event. Their graph showed that soon after scheduled maintenance events, the number of repairs needed increased, declining over time until approximately the time that the next maintenance event was scheduled.

Waddington concluded (as quoted by Ignizio) that:

> "[I]nspection tends to increase breakdowns, and this can only be because it is doing positive harm by disturbing a relatively satisfactory state of affairs. Secondly, there is no sign that the rate of breakdown is beginning to increase again after the 40-50 flying hours, when the aircraft is coming due for its next [preventive maintenance event]."

In other words, says Ignizio:

> "[T]he Waddington Effect is defined as a 'spike' in the number and frequency of unscheduled events 'closely' following a scheduled event – followed in turn by a gradual decline in the rate of occurrence of unscheduled events to a 'more normal level,' until a repeat of this same, troublesome effect following the next scheduled maintenance event."

The solution that Waddington's team proposed to this effect was to improve the execution of the maintenance events and their scheduling, including adding much better documentation. The outcome of these improvements was a 60% increase in the effective size of the British Coastal Command air fleet, without adding equipment or personnel. Isn't it amazing what industrial engineering can accomplish?

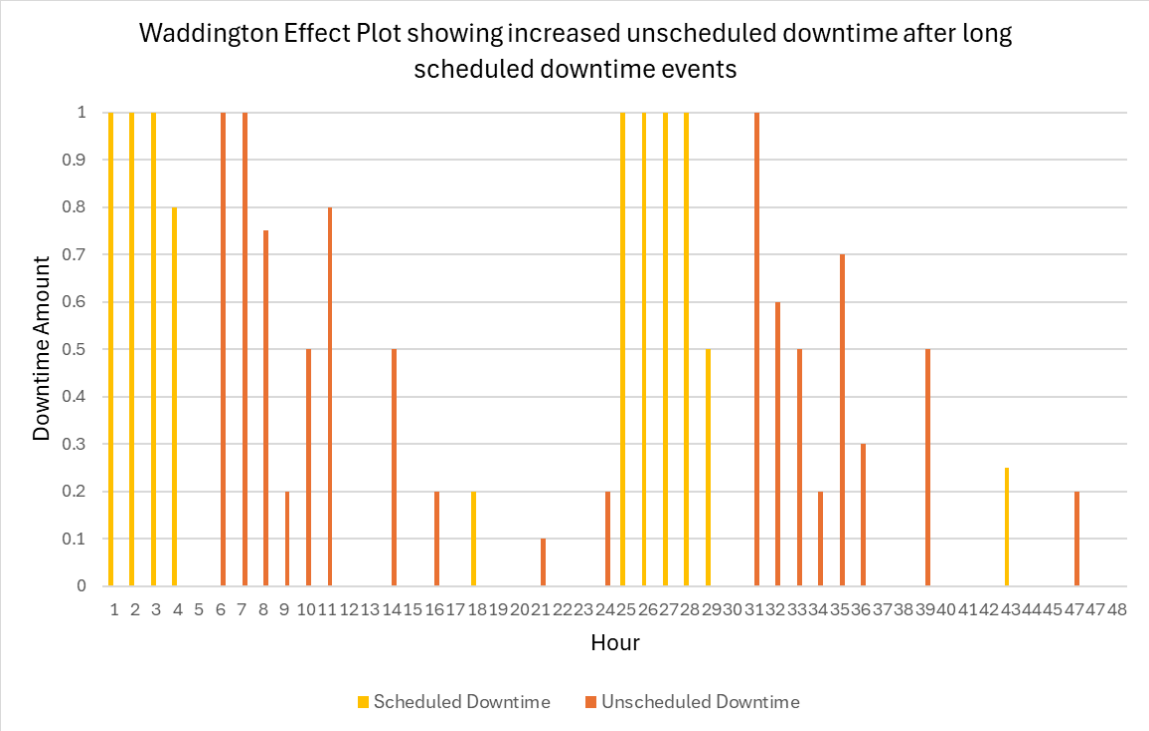
One other note here is that the Waddington Effect may be considered part of the declining failure rate (DFR) portion of a bathtub-shaped failure rate curve that is observed in many mechanical devices. An initial period of declining failure rate due to initial defects is followed by a period with a relatively constant failure rate (CFR). A later period of increasing failure rate (IFR) is then observed as the system ages and starts to wear out. (See Hopp and Spearman's Factory Physics text for details). In wafer fabs, the consequences of the IFR are high, so PMs ideally take place prior to that later period of increasing failure rate.

What are Waddington Effect Plots?

In Ignizio's book, *Optimizing Factory Performance* (McGraw Hill, 2009), he proposes the use of Waddington Effect Plots for analyzing and reducing equipment downtime in factories. Waddington Effect Plots are graphs like the ones that Waddington and his team used, meant to identify situations where an increase in unscheduled downtime *closely* follows a preventive maintenance event (PM).

To create a Waddington Effect Plot for a tool, Ignizio says to create a bar graph with each hour along the x-axis, and the height of the bar indicating the downtime amount during that hour, colored for scheduled or unscheduled. Ignizio shows an example in his book based on actual factory data for a tool that required a five-hour (average) PM every 40 hours. The example shows considerable unscheduled downtime occurring shortly after the PM then tapering off over the next 12 hours.

A similar example created in Excel is shown below. The first long PM (shown in yellow) lasts 3.8 hours and is followed shortly thereafter by a 2.7-hour unscheduled downtime. More downtime follows, then tapers off. The second long PM lasts 4.5 hours and is similarly followed by a period of increased unscheduled downtime that tapers off.

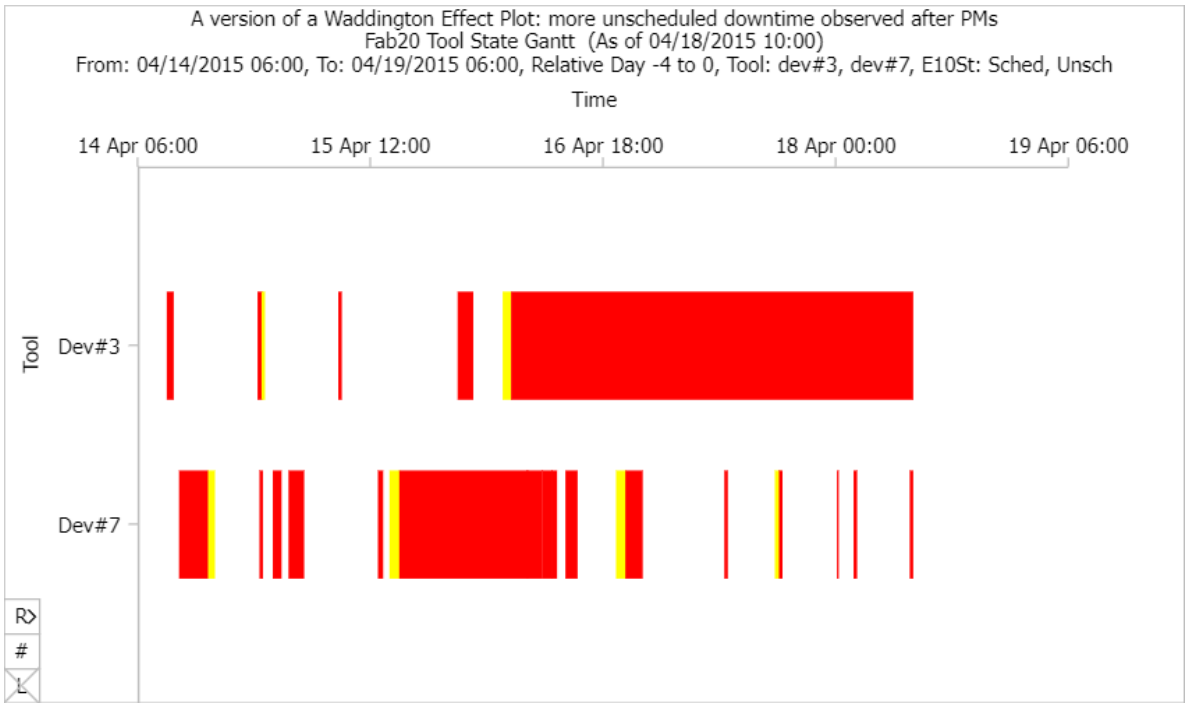


In this contrived example, it is straightforward to infer just from looking at the chart that a Waddington Effect may be occurring. But, of course, if we are to use these plots in practice, we want a) a way to easily generate them on an ongoing basis, b) a way to automatically detect the Waddington Effect from the data, and c) advice on what to do next if we do detect it. Let's look at each of these in turn.

How can we create Waddington Effect Plots Using FabTime?

While we don't directly have Waddington Effect Plots in the FabTime reporting module, we do have Tool State Gantt charts that, if filtered to only include scheduled and unscheduled downtime,

convey similar information. The chart below shows the pattern of scheduled and unscheduled downtime for two tools over a five-day period. This example is from our demo server and does show a large block of unscheduled downtime occurring immediately after scheduled downtime for each tool. We might look at this chart and conclude that the scheduled downtime had influenced the unscheduled downtime (although in practice we would want to see more data, over a longer period).



FabTime software users can easily create a similar view by filtering the Tool State Gantt chart to include the tools of interest (using the "Tool", "ToolGrp", or "Area" filters), selecting the time window of interest, and entering "Sched, Unsch" in the "E10St" filter. They can then save the chart by adding it to a home page tab.

How can we detect the Waddington Effect on an ongoing basis?

Ignizio recommends either using visual inspection or "automated pattern recognition analysis" to identify the existence of the Waddington Effect. A next step in using the Tool State Gantt chart in FabTime to create Waddington Effect Plots would be to in some way automatically detect the Waddington Effect, rather than relying on someone to visually notice it for a given tool.

One idea for doing this would be to record the percentage of unscheduled downtime occurring within a defined time window after a scheduled downtime event and compare that to the overall percentage of unscheduled downtime on the tool. But what time window should we use? Should we do this for every PM, or only for those longer than some amount of time?

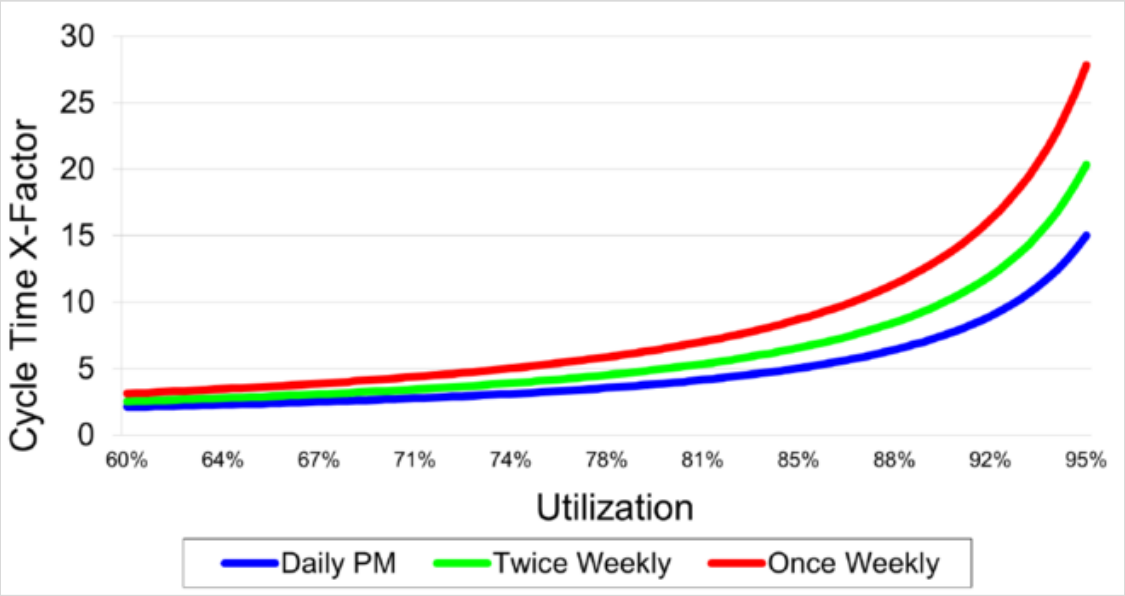
Fortunately, INFICON has a brand-new Data Science team with members who can think carefully about these questions and recommend solutions to implement. If any subscribers have considered and/or implemented Waddington Effect detection and would like to share your thoughts, please send them to Jennifer.Robinson@inficon.com. We will follow up on this topic in a future issue.

So, is the Waddington Effect in conflict with this newsletter's previous cycle time improvement recommendations?

Before we move on to what to do if we detect the Waddington Effect, let's return to the question of whether Waddington's results conflict with this newsletter's recommendation to separate maintenance events.

The Waddington Effect shows that in some cases, if things are running smoothly, doing a PM can disturb the system and cause problems. This effect, where it occurs, could lend support for the idea of grouping PMs. If each PM increases the chance of significant amounts of unscheduled downtime occurring, we might be better off performing fewer PMs.

However, we also know from our work with cycle time operating curves that longer periods of unavailable time are generally much worse for cycle time than shorter ones. For example, the chart below depicts the impact of shorter, more frequent PMs (the blue graph) vs. longer, less frequent PMs (the green and red graphs) for the same total amount of unavailable time. The longer PMs have a much worse impact on cycle time, with the cycle time per visit for the weekly PM being nearly twice as high as the cycle time per visit for the daily (one seventh as long) PM.



So, we repeat a question that we ask during our cycle time course. **For the same amount of scheduled maintenance, should you group your PMs?**

We think that the answer to this question is still generally no. However, we suggest adding a regular check to see whether the Waddington Effect is occurring in your fab. For tool groups where there is no observed Waddington Effect, we can stick with the prior recommendation not to group PMs. (There may be exceptions in special circumstances, as when there's no WIP waiting for the tool, the fab is tightly constrained on engineers, or additional quals are very expensive).

Where you do observe a potential Waddington Effect, the answer shouldn't be to do as few PMs as possible. This is like hearing a clunking noise in your car engine and deciding to turn up the radio so that you don't listen to it. The Waddington Effect means that something is wrong in your maintenance approach. Therefore, the answer should be to figure out what's causing the Waddington Effect for this tool group and eliminate that.

What should we do if we detect the Waddington Effect?

Going back to the PHALANX Magazine article, Ignizio focuses on identifying the causes behind the Waddington Effect and then eliminating or reducing the effect by targeting unnecessary complexity and excess variability. He states that having clear documentation of maintenance specifications is especially important.

Informed by this advice, here are our recommendations for fabs. Where the Waddington Effect is detected, we should:

1. Analyze whatever data is available to identify the underlying causes behind the effect.
2. Eliminate those underlying causes, with particular focus on reducing variability.
3. Learn from this experience and communicate with the team ways to avoid the problem in the future.

As an anecdotal example, we spoke with an engineer who worked at a fab that observed the Waddington Effect after major PMs (40 hours long) for a particular cluster tool. Despite extensive efforts to weed out the root causes of this effect, this fab struggled to eliminate the problem. They eventually dropped that tool from later process flows. In other cases, however, they were able to reduce the chances of the Waddington Effect by focusing on quality and reproducibility.

This fab generally found that shorter PMs had less risk of "going sideways" and that shorter, more frequent PMs were thus less subject to the Waddington Effect than longer ones. This, of course, is consistent with our overall recommendation of seeking shorter periods of unavailable time overall.

It's perhaps worth noting here that Ignizio, who has long promoted the Waddington Effect, also advocates for "declustering" PMs in the factory, to reduce their impact on cycle time.

Conclusions

During World War II, C. H. Waddington and his Operational Research Group worked to improve equipment reliability for British aircraft. The team found that in some cases, when a piece of equipment was performing well, intervening to perform preventive maintenance could increase the possibility of unscheduled downtime occurring soon thereafter. Professor James Ignizio later deemed this behavior the Waddington Effect and proposed the use of Waddington Effect Plots to detect it in modern factories. Ignizio advocated for eliminating the Waddington Effect, where found, through identifying root causes, reducing complexity and variability, and improving documentation.

After reading about the Waddington Effect, we were initially concerned that it might conflict with our repeated recommendation in this newsletter to perform shorter, more frequent maintenance events, rather than grouping them. On further reflection, however, we have concluded that what makes sense is for fabs to guard against the Waddington Effect and eliminate it where it is observed, while continuing to strive for shorter periods of unavailable time.

In this article we have shown how a version of a Waddington Effect Plot can be generated using the FabTime reporting module. We also began discussing ways to automatically identify the Waddington Effect. We also briefly discussed recommendations for mitigating the effect where found. We look forward to sharing further results in the future and welcome your feedback in the meantime.

Acknowledgements and references

The author would like to thank **Frank Chance**, **Igor Kuvychko**, and **Holland Smith** of INFICON for discussions leading to this article, and to thank **Professor James P. Ignizio** for his writings on this fascinating topic. For more information about the Waddington Effect, see:

- Mike Busch, "The Waddington Effect: More maintenance isn't necessarily better," Sport Aviation, March 2011.
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- C. H. Waddington, O.R. in World War 2: Operational Research Against the U-Boat, (Histories of Science Series), Elek Publishing, 1973. Available from Amazon.

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