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FabTime® Newsletter

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Information

Publisher: Acquired by INFICON in 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 Factory Operations (IFO) group.

Editor: Jennifer Robinson, Cycle Time Evangelist for INFICON

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Welcome

Welcome to Vol. 27, No. 4 of the FabTime Cycle Time Newsletter. For our main topic, we discuss operational improvement for semiconductor back-end factories. We have announcements recapping SEMICON West (including links to new whitepapers on Behnke's Rule of n and back-end scheduling) and introducing the newest AskJen capability. We have subscriber discussion about setup time and tool qualification and generating lists of lots approaching a queue time limit.

Happy Holidays! – Jennifer

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Community News/Announcements

In this month's announcements, we share a wonderful new ability in our AskJen chat engine and a recap of SEMICON West.

AskJen now analyzes your data and makes recommendations

The AskJen chat engine in FabTime can now answer questions using your fab data. When your site enables AskJen data usage, you can ask: "What are my biggest bottlenecks?" and "Why am I constantly missing my moves goals?" and limitless other questions. AskJen generates FabTime charts, reads the numbers, makes calculations as needed, and explains what it found, sharing a link to each chart behind every finding.

You can also AskJen to explain a chart and highlight "what's most important and actionable," as shown below. The result will be a report with sections like The Bottom Line, Findings (most important first), What To Do, and Caveats, plus a full home tab with supporting charts and findings.



AskJen works by logging in as you, so it sees only what you can see in FabTime. It can save its analysis as a home page tab with notes and live charts for you to share and revisit. Data usage is disabled by default: your FabTime administrator enables it with one system setting. While it is off, no fab data is sent to the AI service. For users who prefer AI command-line tools such as Claude Code, Codex CLI or Gemini CLI, FabTime also offers downloadable skills that connect to FabTime with a personal access token. See the "AI Skills" help article in FabTime for details.

This is the next generation of fab reporting. Key users like production supervisors can ask practical questions and get quick yet detailed recommendations for action, as well as supplemental charts and reports to share with other stakeholders. Interested? Current customers should contact their FabTime support engineer. Prospective customers can Reach Out to Jennifer.

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INFICON at SEMICON West



INFICON had a booth and extensive representation at SEMICON West in October. A few of our team members are shown above. Highlights of the show for us included:

- Packed attendance at the Smart Manufacturing Pavilion, including for presentations by **John Behnke** on *"Behnke's Rule of n"* and **Igor Kuvychko** and **Holland Smith** on *Scaling Factory Scheduling for Modern Back-End Semiconductor Manufacturing*. Whitepapers about Behnke's Rule of n and Factory Scheduling for Back-End Semiconductor Manufacturing are now available on the INFICON website.
- 250 attendees at the first-ever **Women's Lunch**, co-sponsored by the Women of the FOA. Shown left to right: discussion panel moderator **Michelle Williams** (SEMI) with panelists **Megan Dube** (Energetiq Technology), **Jennifer Robinson**, and **Melinda Gomez** (SEMI).
- The Q4 Fab Owners Alliance meeting, where **Mario Faria** and **Jennifer Robinson** represented INFICON.



INFICON will be at SEMICON West in Phoenix in March. We will see you there!

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Interesting Reads

Semiconductor Insights and Productivity Tips

Recent articles shared on Jennifer's LinkedIn include:

- An article by **John Behnke** about the relationship between factory size, quantified by the average number of like tools, and performance. While I have written frequently about this behavior at the tool group level, John discusses the impact of "**Behnke's Rule of n**" on the bigger picture.
- A WSJ article about ASM's strong earnings, shared as a representative indicator of how AI is driving profits across the semiconductor industry. In similar news, ST expects revenue to grow 23% this year on strong AI-related sales. Intel, on the other hand, had disappointing third quarter results thanks to a decline in personal computer sales. This was despite a 58% increase in foundry revenue (one bright spot for the company).
- INFICON has a new whitepaper about the **future of semiconductor manufacturing** and AI-driven smart factories. It looks at where competitive pressure is coming from, how digital twins and process-aware sensors help fabs catch problems before they become scrap, and what early adopters are already seeing in yield and cycle time. It ends with a practical roadmap for fabs and equipment suppliers.

For more industry news, connect with Jennifer on LinkedIn.

Subscriber Discussion Forum

We have subscriber discussion in response to the prior issue's main topic about setup time tradeoffs as well as FabTime software tips about generating lists of lots approaching a queue time limit and lists of operations with WIP and few qualified tools. If there is a topic you have been wondering about, please reach out to Jennifer on LinkedIn.

Framing the tradeoff re: setup time and tool qualification

A new subscriber asked a question in response to Issue 27.02: Setup Time, Tool Qualification and Cycle Time. He said: "Your point about redundancy adding setup burden gave me something to think about in PCB manufacturing. When assessing a second qualified tool, do you usually start with bottleneck utilization or the extra setup load? How do you frame that trade-off?"

Response from Jennifer: That's an interesting question. Just to clarify, I think it's that cross-qualification can add a setup burden compared to full dedication. If you have two dedicated tools, each running one recipe, you have no setup time. But if you cross-qualify both tools and need setups when you switch between the two recipes, then you will have some setup time incurred. The utilization of the tools will be higher, but the cycle time per visit will likely be lower (unless the additional setup time takes the tools into an unhealthy utilization range). You can still minimize the setup time by having a setup avoidance policy. (e.g., If there's a lot with a matching setup ID, pick that first. Only do the setup if there are no matching lots.) Where setups are exceptionally long, you probably want to go a step further and only do the setup if lots have been waiting for some longer time. Bottom line: this gets complicated quickly.

As to how to frame the trade-off, I would start with the current utilization of both tools. It is unlikely in practice that the recipes in question are equal volume. This means that if you cross-

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qualify and run both recipes on both tools, your pre-setup utilization will be the average of the utilization of the individual tools. You can then make some conservative estimate for how much setup time will be added and add that to the expected loading on the tools to get a revised utilization estimate. Another way to think about this would be to consider how much setup time the tools could absorb before pushing the utilization unacceptably high.

In summary, you frame the trade-off by considering the current utilization of both tools and the future utilization of the shared set of tools. Of course, the tricky part is estimating how much setup time you will need. Historical data for other similar tools might be informative here, but this is a highly complex question in practice.

INFICON also has a product that can help with tool qualification decisions. Our **Tool Qualification Optimizer (TQO)** product determines the optimal number of tools to be qualified in a forward-looking time frame, typically two to seven days. This helps to balance UPH and demand per tool automatically. Reach Out to Jennifer for more information.

FabTime Tip: Using AskJen to identify where the effective number of qualified tools (n) is less than planned

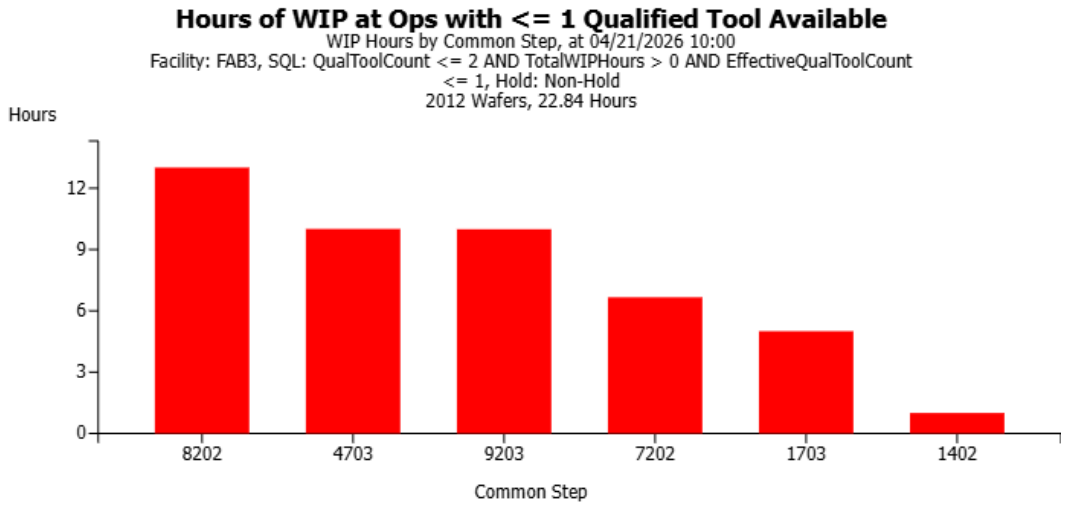
Reading the Behnke's Rule of n paper described above inspired us to think about how to view and respond to the "effective n" in a fab. We've talked in the past about how to use the Tool Qualification WIP Detail chart in FabTime to generate a list of tool qualification-related bottlenecks, defined as operations that have WIP waiting that have a low number of qualified tools. (See software tip #118.) However, this chart only shows which tools are qualified, not which of the qualified tools are currently available to manufacturing. The new AskJen data analysis capability (described in this month's Community Announcements) makes it easy to extend this analysis to also consider the number of available tools. Here is an example:

First, we asked, using our FabTime demo server:

> For facility fab3 only, please generate a list of operations with WIP in queue that have two or fewer qualified tools. Then for those operations, check how many of the qualified tools are available and give me a list of operations with WIP that have 1 or fewer available qualified tools. Recommend next steps.

Using the Tool Qualification WIP Detail chart, as well as the WIP Hours chart and the Tool WIP and State List chart, AskJen generated a chart showing hours of WIP waiting at operations with less than or equal to one qualified tool available, as shown below. A chart showing the tool state of the relevant tools was also generated but is not shown here.

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AskJen also presented key findings and recommended next steps:

Findings, ranked

1. **3-5XStep01 is down and holds up 3 operations: 29.7 WIP hours.** Its two partner tools are running, but each now carries the whole load for its operations. 3-5XStep02 has 13.0 hours for 8202. 3-5XStep06 has 16.7 hours for 9203 and 7202. Both are above an 8-hour shift. In FabTime's guidance, WIP hours per tool beyond one shift deserve attention (H195).
2. **The 3-Nitride Deh ASIC3 pair is effectively at zero.** #2 has been down unscheduled for 32 hours. FabTime counts #1 as available, but it is in Engineering, so neither tool is processing the 15.0 hours waiting at 4703 and 1703. This is the highest risk on the list.
3. **3-Wet Etch ASIC2#2 is in a quarterly PM (1.1 h).** Only 1.0 WIP hour is waiting at 1402 and #1 is running. Low risk.

What to do

- **Nitride Deh ASIC3:** release #1 from Engineering, or delay the engineering work, until #2 is back. Escalate the RC05 repair on #2, which has been down 32 hours.
- **3-5XStep01:** escalate the RC05 repair (14 hours down). Until it is back, run 8202 on 3-5XStep02 and 9203/7202 on 3-5XStep06. Keep other work off those two tools where you can.
- **Avoid making it worse:** don't schedule PMs or engineering time on 3-5XStep02, 3-5XStep06, Nitride Deh ASIC3#1 or Wet Etch ASIC2#1 while their partner tool is down.
- **Structural:** each of these operations has only two qualified tools, so one failure leaves it with one tool or none. Look at qualifying a third tool for the operations that keep showing up here. Before deciding, check how often the pairs lose availability with ToolAvailTrend.

FabTime Tip: Generating Queue Limit charts, excluding and including held lots

A **new customer** asked us recently about generating charts that show lots approaching a queue time limit, both excluding and including lots on hold. Seeing lots that have a queue time limit approaching is, of course, important for reducing the probability of missing the queue time limit and requiring reprocessing. In FabTime, there are two ways to do this.

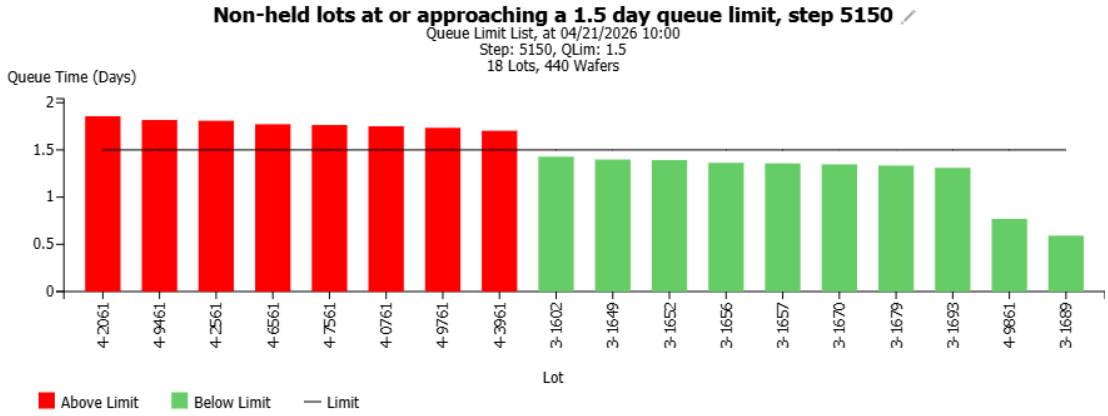
Method A: Use the Queue Limit Lot List chart to see a list that excludes lots on hold

The Queue Limit Lot List chart is a standard chart in FabTime. This chart displays a list of **non-held queued lots**, color coded based on a user-specified queue time limit. To use it:

1. Enter “Queue” in the FabTime search box and select “Queue Limit Lot List” from the Charts section of the results.
2. Expand the “Lots” section of the filters on the left side of the screen and enter your preferred value in the “QLim:” filter. You can set this value to be a few hours less than the time that triggers reprocessing, to flag the at-risk lots earlier.
3. Ensure that your entered value is consistent with the units in the “Time” drop-down in the “Age/Cycle Time” section of the filters (minutes, hours, days, or weeks).
4. Filter for your operation or tool group of interest.

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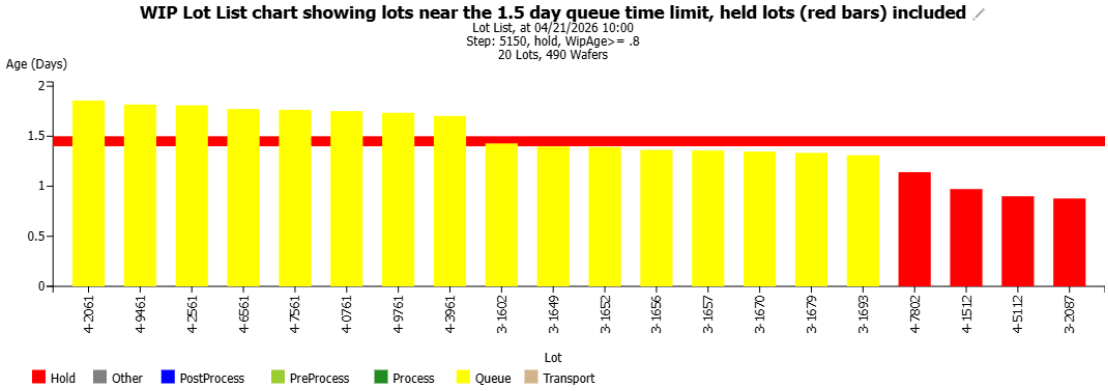
5. Press the green “Apply Filters” box. An example of the resulting chart is shown below.



Method B: Filter the WIP Lot List chart to include lots on hold

The Queue Limit Lot List chart shown above excludes lots on hold. To generate a similar chart that includes held lots, you can use the regular WIP Lot List chart with appropriate filtering. To do this:

1. Use the search box to find the “WIP Lot List” chart.
2. Expand the “Age/Cycle Time” section of the filters and set the “WIP Age >= filter to include lots approaching your desired queue time limit. For example, if the queue time limit is 24 hours, filter to show lots waiting more than 20 hours, so that you’ll see the ones that are approaching the limit. Again, make sure your entered value is consistent with the units selected in the “Time” drop-down.
3. Now click on the “Formatting” tab below the chart and data table. Use the “Stripe” control to create a red horizontal stripe from just below up to your actual queue time limit value. For example, if the queue time limit is 1.5 days, set the “From” to 1.4 and the “To” to 1.5, and set the “Color” to “Red.” An example of the resulting chart, with the held lots included (the red columns) is shown below.



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Main Article: Operational Improvement for Back-End Factories

By Jennifer Robinson

In this article, we turn our long-time focus on factory improvement to the operational challenges of semiconductor assembly and test facilities. Some of these challenges, such as managing variability, are common to all factories. Others, such as long, sequence-dependent setups, are more specific to back-end manufacturing.

In contrast with wafer fab cycle times, assembly and test cycle times are shorter, measured in a few days to a week rather than weeks or months. However, this reduced process complexity usually comes with a dramatic increase in factory scale.

In this article, we will review the assembly and test process flow, discuss back-end-specific operational challenges, and suggest ways to mitigate them.

The post-fab process

There is variation in the post-fab process, particularly between what happens at more manual legacy assembly and test factories and newer, advanced packaging facilities. Here we broadly describe a typical legacy production flow.

Wafer Sort/Probe: This is when each die is electrically tested (probed) to sort good from bad while still part of the wafer. A wafer map indicates the good vs. bad die before the wafer is shipped from the fab to an assembly and test facility.

Die Prep: This stage includes backgrind to make the wafer thinner, putting the wafer on tape, and then saw, laser, or plasma dicing to cut the wafer into die. Each die will be on the tape in its original mapped position and ready for die bond.

Die Attach / Die Bond: At die bond, each good die is picked off and attached to a leadframe, substrate or carrier with epoxy or solder. The frames are grouped temporarily into magazines. Sometimes, with epoxy bonds, there is a bake step to cure the epoxy before wire bond. This cure step takes place in a batch oven.

Wire Bond: At wire bond, each die is electrically connected to the frame via gold, copper, or aluminum wire. A device may require anywhere from one to thousands of wires. Wire bonders can make many bonds per second. A flip-chip process is sometimes used instead of wire bond. The die is flipped over and connected via solder bumps.

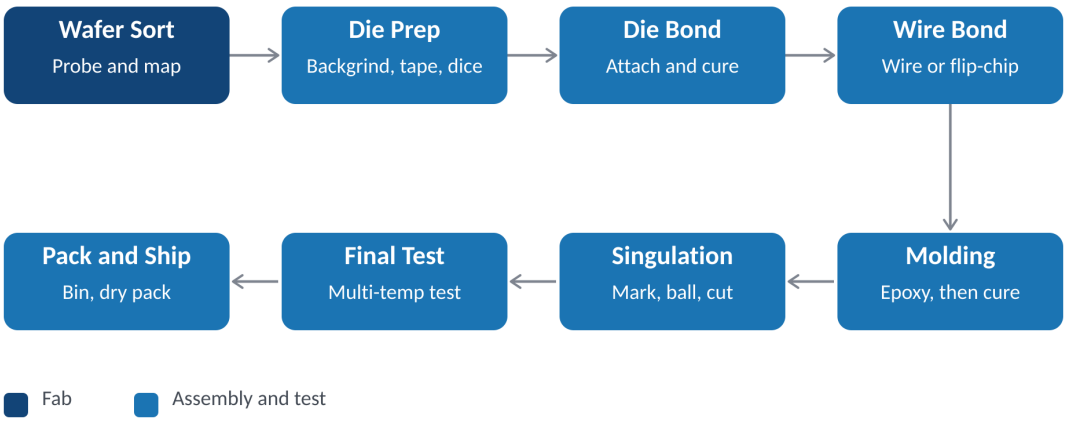
Molding / Encapsulation: To protect the package, the assembly is then encapsulated in epoxy mold. Many packages can be molded together as a strip or matrix array. The mold is cured in an oven afterward.

Marking, Ball Attach and Singulation: Each part is laser-marked with identification. Some packages get solder balls attached. The strip or matrix is separated into individual units.

Final test: The individual units are electrically tested, often at multiple temperatures in a handler that presses them against test sockets. Some devices also go through burn-in, a long high-temperature stress test done in batch ovens.

Pack and ship: Good units are binned by speed or grade, placed into trays or tape-and-reel, moisture-protected (dry pack for moisture-sensitive parts), and shipped.

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Inspection and reliability sampling is done throughout the process and may lead to scrap or rework.

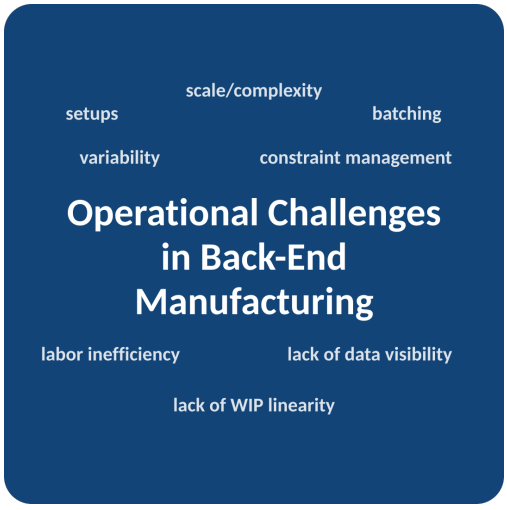
Things about this process that are more straightforward to manage vs. the front-end fab

Three things about the above process are helpful in terms of achieving reasonable cycle times from the back-end.

1. The **linear process flow** does not include any reentrant loops (except for possible rework). This reduces variability and helps reduce scheduling complexity.
2. The relatively short total cycle time (typically not more than a week, and often much shorter) and **small number of steps** also reduce scheduling complexity.
3. There are typically **no single path tools** in assembly and test, which means that a single down tool will not bring the line to a halt.

There are, however, several challenges to manage in assembly and test factories.

Operational challenges in back-end manufacturing



Setups, scale (high WIP levels and many like tools), batching, lack of WIP linearity, manual processing (for legacy assembly and test sites), and other sources of variability all lend complexity to the back-end process.

Setups: One of the biggest operational challenges in back-end manufacturing is tool changeovers. Setups can be many hours to as much as a day long and usually require manual intervention by operators. Longer, more complex setups may require dedicated maintenance technicians. Operations like die bond and wire bond can have ten or more different physical components that need to be swapped in or out by a technician to run a subsequent lot. Changeovers of

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testers often require a set of durables to be available before starting the changeover. The management of these physical items adds to overall complexity. The cost profile and capacity to perform these different types of changeovers can also vary significantly, making the problem of setup optimization a notable contributor to factory profitability. Some facilities are labor constrained in terms of staff who can do setups. High levels of **product mix** and frequent mix changes also compound the setup challenge.

Scale/Complexity: Although assembly and test process flows are not long, the factories can be challenging to manage due to sheer scale. WIP levels may be high, and the number of tools of a given tool type can, in some cases, exceed 1000. While this abundance of like tools is better for cycle time than having a series of one-of-a-kind tools, qualification rules can become quite complex. A single lot might have hundreds of qualified tools at a given step, leading to an enormous number of candidate lot to tool assignments for any decision. **Setup minimization, tool downtimes**, and **varying lot priorities** also need to be considered.

Batching: There are several steps in the assembly and test process flow in which units are batched together for processing: batch ovens can be found in epoxy cure, encapsulation, and, notably, final test (burn-in). The arrival process downstream of this batching shows elevated levels of variability. This is especially a problem where the arrival variability from epoxy cure leads to starvation of wire bond tools. This batch processing is on top of other **form changes** in assembly and test, as when die are grouped into leadframes and magazines, combined into assemblies and arrays, and later separated into individual units. **Binning** at different stages can also lead to smaller lot sizes. All of this adds variability and complexity to the process.

Not batching exactly, but there are also cases where processing of Material A at a given step is dependent on having Material B available at that step. An example is multichip module die bond, where multiple die bond operations take place on subsequent tools to build a leadframe. Die from Material A are bonded to the leadframe in one tool at the first die bond step, then from Material B in a different tool at the second step. (Sometimes there are additional steps.) This **material dependency** means that to continue processing at the second step, Material B must be available on time. This adds to schedule complexity.

Lack of WIP Linearity: Although process flows in assembly and test are not reentrant, different throughput rates at different production stages, together with grouping and ungrouping of units, result in a non-linear WIP profile. Decisions of how to group material at one stage influence the required setups at the next. When not well managed, this lack of WIP linearity can lead to starved constraint tools. Throughput imbalances between handlers and testers can exacerbate this issue.

This situation is compounded by high product mix and by **non-linear arrivals from wafer fab / sort** into the back-end facility. It can be challenging for assembly and test managers to respond to unpredictable arrival patterns from the fab.

Constraint Management: Because assembly and test process flows are shorter, the focus of back-end KPIs tends to be on utilization of constraint tools, typically **wire bond tools** and **testers**. Die bond can operate several times faster than wire bond, requiring decisions to be made at die bond to avoid starved tools or unnecessary setups at wire bond. Testers can similarly starve due to upstream delays from downtime or setups, leading to capacity loss. Tester downtime, throughput limits, or chamber temperature limitations can also slow product flow.

Manual Processing / Labor Inefficiency for Legacy Factories: Unlike newer advanced packaging facilities, legacy assembly and test factories can be people-constrained, especially in performing setups. **Man-to-machine ratio** is often used by supervisors as a productivity index, with a goal (for

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cost reduction) of having fewer operators per tool. This can run counter to operational improvement, as expensive tools end up with forced idle time while waiting for operators. Productivity losses can also occur during **shift change and breaks**, when all operators leave at the same time. Short processing times make it difficult to keep tools running during the break. Compliance can also be a challenge when implementing modern scheduling solutions in previously operator-managed facilities, especially when a new schedule increases setups.

Back-end tools also have a much higher number of "assist" events than front-end tools. This is especially true in wire bond and die attach. The tools may experience have short pauses requiring operator intervention. While operators can normally resolve these issues quickly:

- Frequent assists can cause actual tool throughput rates to diverge significantly from theoretical throughput rates, leading to missed shipment targets
- These assists can drive down man-to-machine ratio
- Due to assists and other issues, tools often run below their target speeds. Where this speed loss goes unrecognized, overall performance can suffer (e.g. many pattern recognition repeats may be required before success). In general, legacy facilities may operate tools that are not optimally maintained or adjusted

Other Sources of Variability: Of course, other sources of variability compound the back-end manufacturing challenge. These include:

- **Yield losses**: Failures may require rework, scrap, or re-test cycles, which inflate overall cycle time and can complicate scheduling.
- **Test time variability**: Some products take longer to test than planned. Some test times can be unpredictable.
- **Downtime**: With the high number of redundant tools in a back-end factory, a single down tool doesn't take down the entire line. However, equipment downtime still poses a challenge. Downtime is a capacity loss on high-utilization tools and can drive the need for extra setups.
- **Bowl feeders**: Small, non-wafer parts (pins, clips, lids) are sometimes delivered to assembly or test stations via bowl feeders. If the bowl feeder is not working well, it may feed parts more slowly than the capacity of the machine, causing throughput losses. When the bowl feeder is running close to empty, the last parts may require many iterations in the bowl before they finally make it into the machine in the correct orientation. The machine will have forced idle time in the meantime.

Meeting Expected Shipment Dates / OTD: All the variability described above means that assembly and test facilities, like wafer fabs, can experience challenges with meeting expected shipment dates. Although the process flows are shorter than those in the fab, the sheer volume of WIP to be managed at one time can make meeting the due date for a particular unit challenging, particularly in the presence of setups and equipment downtime. Starts planning and setup planning are both critical in meeting shipment dates.

Lack of Data Visibility: Legacy assembly and test factories may lack the data visibility needed to identify improvement opportunities. Even where factories implement modern schedulers, good data is necessary to see gaps in compliance. Minimizing future setups may require analyzing historical setup data. Similarly, knowing where forced idle time on bottleneck tools has occurred in the past can help to avoid starvation in the future. All of this requires strong data visibility.

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Recommendations and Solutions

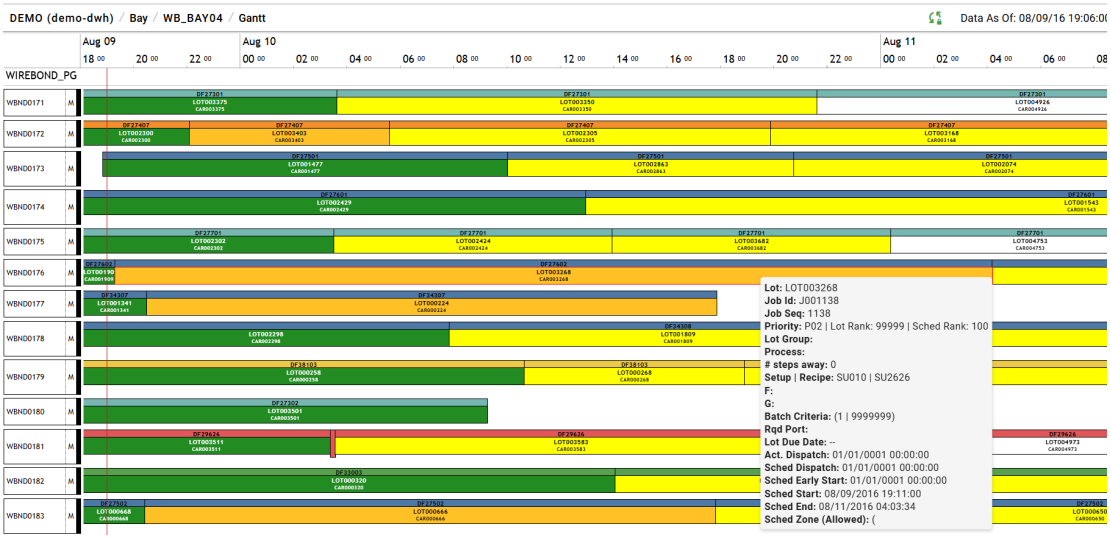
Here, we turn to recommendations for mitigating the operational challenges outlined above. We include brief mentions of where INFICON's solutions can help, though of course other products may be used.

Variability Reduction: Focusing on variability reduction related to equipment downtime, test times, and scrap and rework can drive down cycle times. Lower cycle times track with lower WIP (from Little's Law, see Issue 21.06). Lower WIP helps reduce **the scale challenge** in back-end fabs (fewer lots to manage at the same time).

> **INFICON's contribution:** Our four-hour web-based cycle time management course includes extensive discussion about the impact of variability on cycle time and ways to reduce that impact. Past issues of this newsletter also delve into variability reduction on a regular basis.

Scheduling: The linear flow and small number of steps make it computationally feasible today to compute a schedule for the entire back-end factory. A scheduler can help with **minimizing setups**, keeping **bottleneck tools running**, balancing throughput across the different stages to enable more **linear WIP flow**, and **meeting delivery commitments**.

> **INFICON's contribution:** Our next-generation back-end scheduling engine, Scheduler XTR, is now live at a factory in Asia. XTR combines mathematical programming and optimization with the ability to generate thousands of fast candidate schedules. Together these map out the Pareto-optimal frontier, so planners can see exactly how trade-offs like on-time delivery and throughput play against each other and pick the schedule that best fits the business objectives. A sample Gantt chart for a wire bond area is shown below.



Reporting, Alerting and Simulation: An operations digital twin with a reporting front end can **improve data visibility** to help identify problems. Automatic alerting about actionable situations can also help with improvement. Reporting should also include integration with fab shipment data, to better **optimize starts into the line**. A key benefit of a reporting system with alerting is to **identify tools that are idle with WIP waiting**, as these represent lost capacity.

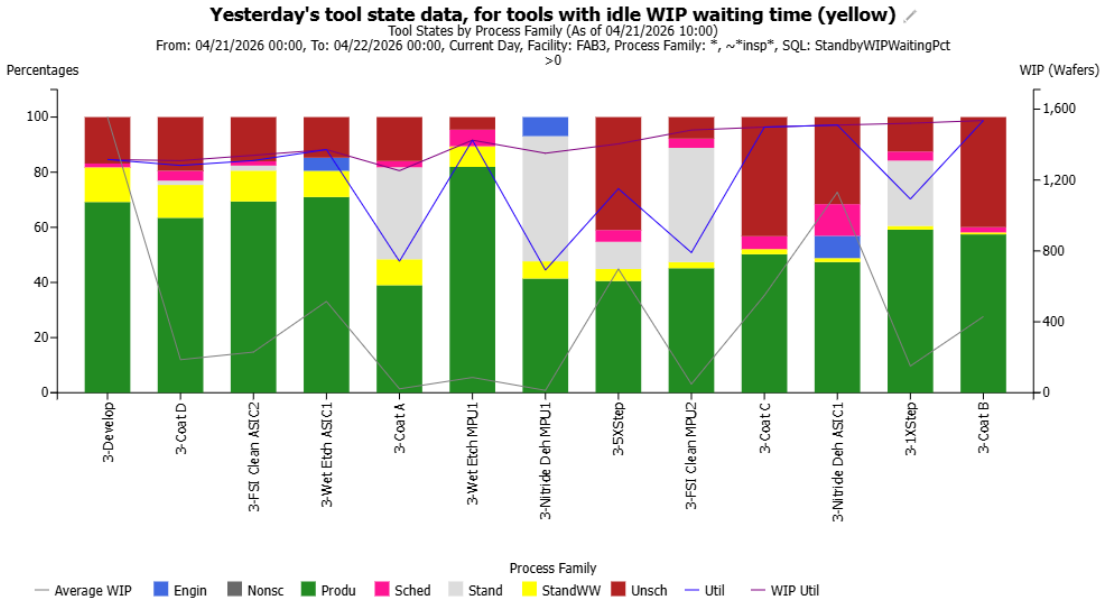
Another key use of reporting is to show the people running the factory what operators accomplished on the floor compared to what they could have accomplished had they followed the plan. This is where **simulation** can be helpful. Planners can show a simulation of what the factory

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could have done (by following a recommended schedule) and compare that with what was achieved, highlighting gaps. Such information about the consequences of behavior is important for manual fabs. For newer, more automated fabs, simulation can help show the impact of the KPI optimization weights that planners selected in comparison to other KPI weights that might have been implemented.

INFICON's contribution: Our FabTime reporting system, which will be integrated into our upcoming FabOptix product, can identify real-time problems, such as tools idle with WIP waiting, as well as longer-term KPIs. In the example shown below, the left four tool groups spent most of their idle time while WIP was waiting, representing significant lost opportunity.

Our back-end scheduler effectively creates a high resolution digital twin-based simulation of the next 3-4 days, allowing customers to see the consequences at a KPI level of business practices. Together with our reporting solution, Scheduler XTR helps companies compare what could have been done with what happened. Seeing this delta is a necessary first step towards improvement.



Conclusions

Although assembly and test factories have relatively short, linear process flows, and few one-of-a-kind tools, they have many complexities that create operational improvement challenges. These include:

- Long, sequence dependent setups that need to be minimized, and for which available operator staffing can be limited
- Batching and unbatching of units at different production steps
- Form-factor changes at various stages of the process flow
- Non-linear arrivals from wafer fab
- Large numbers of tools, making qualification management and dispatching decisions challenging

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- Downtime, test time variation, and other sources of variability
- Lack of data visibility, particularly for operator compliance with schedules
- And lots more…

Solutions to these challenges include variability reduction efforts (including education), advanced scheduling solutions, operations digital twins and reporting dashboards, and simulation tools for scenario assessment. Some of these solutions are available from INFICON, others, like variability reduction, require education and effort by factory management.

We would like this article to be the start of a discussion about how industry experts, industrial engineers, software developers, and factory managers can work together to drive improvements in back-end manufacturing performance.

Closing Questions for Subscribers

What back-end challenges does this article miss? If you work in a back-end factory, what solutions would be most useful for you?

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Further Resources

All past FabTime newsletters are available in PDF format from the FabTime Newsletter Archive. Please look for the link in the most recent email issue of the newsletter or reach out to Jennifer on LinkedIn. You can download individual issues or download a zip file containing all past issues. Some articles have been re-published on the INFICON website. Those are linked above where mentioned. See also:

- From dicing to packing: Examining the packaging process | Semiconductor Digest. This is a good overview but dates to 2001.
- Factory Scheduler for Backend Manufacturing, INFICON white paper, 2026.

For a more in-depth discussion of methods to improve semiconductor factory cycle time and operation performance, consider hosting a session of our four-hour web-based cycle time management course.

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