INSTRUMENTAL | Build Better

Manufacturing Optimization Blueprint

How to accelerate product development and drive engineering efficiency.

Executive summary

Ask yourself: How many of your programs have suffered delays because it took too long to find and fix an issue propagating through your line?

It's a common problem in electronics manufacturing. Though the challenges facing any individual build are unique, the central problem facing product design engineering teams is how to *quickly* and *repeatably* find and fix issues to keep builds on schedule.

And it's leading to billions of dollars in waste. But why is the problem getting worse, and not better? Why haven't we optimized the process around issue discovery and solution validation across the supply chain? Because manufacturing continues to be stubbornly analog and engineers prefer to be heroes on the factory floor.

Prior to the global pandemic, electronics manufacturers could get away with relying on traveling engineers conducting complex forensics on the line. Only a decade ago, the schedules were longer, the teams were smaller, and the products were simpler. It was far easier to solve different problems at the unit-level to hit a ship date and ignore population-level optimization exercises. Now, the schedules are more aggressive, the products are more complex, the teams are larger, and travel to factories is harder. Solving problems only a few units at a time on the factory floor isn't going to cut it anymore.

In order to recover the billions of dollars in waste, electronics manufacturers will have to think bigger than solving problems one unit at a time in mass production. This means they'll need to reimagine what forensics and optimization truly means—and when it happens. Modern manufacturing optimization is about scale and speed—and that takes new tools and technology. We're here to show you what that means.

If 53% of programs were either delayed or cancelled in 2020, **what were the 47% doing right?***

* "2020 Trends in Electronics Sourcing," *Dimensional Research*, 2020

Contents

The history of manufacturing optimization

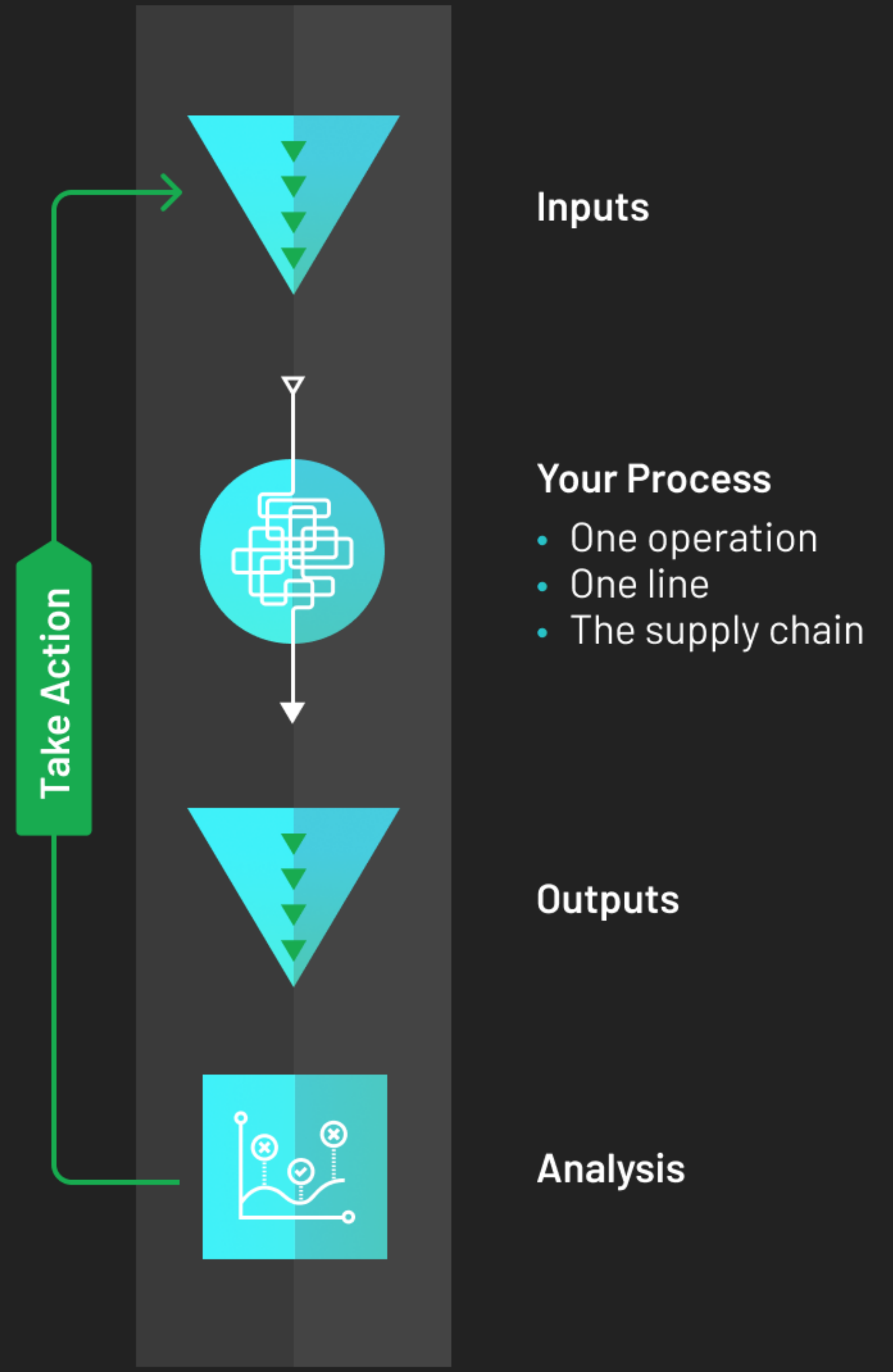
Manufacturing optimization is not a new practice. It has long been the textbook gold standard for streamlining operations and reducing costs, leveraged by manufacturers who plan to run a particular product on the line for years.

Traditional manufacturing optimization meant that an operations lead or expensive consultant would look at the inputs and the outputs of a particular mass production process and use statistics over a large dataset to determine where a potential optimization could be introduced. From there, they would work with their suppliers to adjust the right inputs to get the outputs the brand expected, often with limited success. It was difficult and tedious work but for mass production runs which lasted for many years, these incremental changes added up to big savings.

As a result, many of the tools and methodologies for manufacturing optimization were developed with large companies and long life cycles in mind. Large automotive and industrial brands took the reins for the entire industry, while smaller electronics brands were left to adapt these unwieldy tools to fit their more nimble process or create something new altogether.

For the electronics industry, this resulted in an ad-hoc system which forced leaders to leave optimization to their production counterparts and focus their efforts on hitting schedules at a prescribed yield. As products grew more complex and product lifecycles shortened, individual engineers had to step up and find and fix issues in person, often by chance. That is the opposite of agility, and introduces massive risk that leaders need to target and eliminate.

To compete in today's market, optimization cannot wait until for production. It must begin in development where small changes can have exponential impacts downstream.



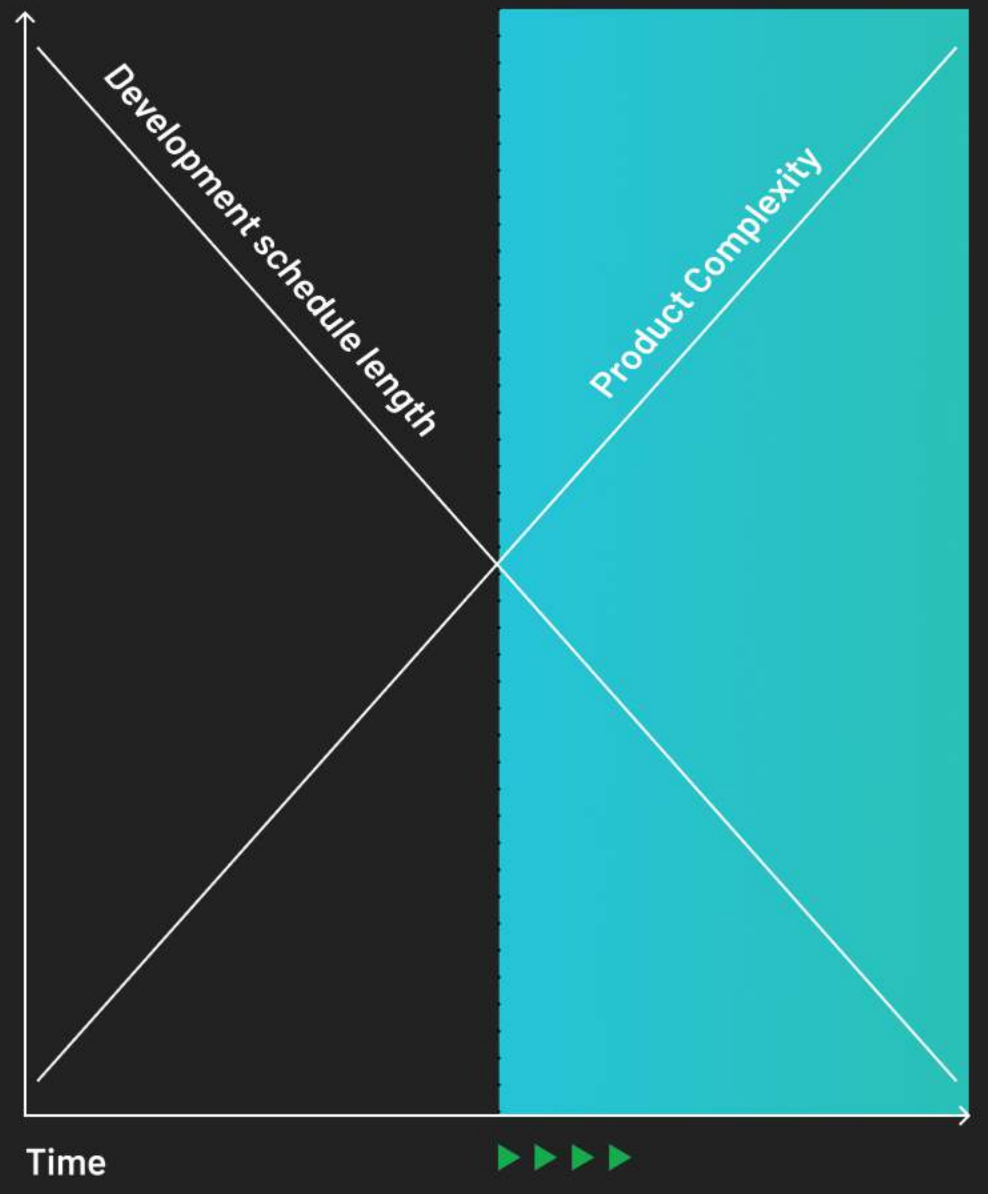
Products are more complex, but NPIs are shorter

In modern times, production often doesn't last long enough to implement any significant optimizations in the traditional manner. What's more, the ever-present pressure to lower cost, increase quality, and reduce time to market still exists.

Where yesterday's manufacturing optimization processes focused on production, featuring long production cycles and large datasets to work with, today's electronics optimizations must happen during product development. Reframing optimization as a development process means that almost every company can get high ROI from even adopting simple optimization tactics.

Here are four reasons why optimization can now occur in early NPI:

- Technology has become affordable and fast enough to be embedded into almost every test station and important location on the factory floor. This unlocks reams of previously unavailable data.
- Artificial intelligence tools like machine learning and computer vision can quickly and accurately synthesize all of this data, identify patterns or anomalies, and present them in actionable ways.
- Connectivity throughout the factory means this new data can also be transmitted instantaneously, giving development teams a chance to make critical decisions in real time.
- Those decisions effectively close loops in the manufacturing process saving time and making development smoother and faster.



Products become too complex to trouble shoot on necessary schedule

What is manufacturing optimization today?

Prior to 2020, fewer than one in four electronics programs performed significant or consistent manufacturing optimization exercises. Though manufacturing optimization should be part of every program, large optimization exercises are time consuming, and so typically teams rely on bit-by-bit continuous improvement techniques, which take a long time to accumulate a large impact. In the world of programs that only last a few years, this is impractical.

Manufacturing optimization today is the iterative set of actions taken throughout a product's lifecycle, starting in early development to identify issues and solve them - leading to improved quality, reduced costs, and increased efficiency. The results of these iterations are then carried across product lines and product generations.

Doing this well ultimately enables companies to execute on more ambitious designs faster than their competitors. To most electronics manufacturers, this is obvious. Every brand already does some basic form of optimization in order to ship quality products - especially in industries where products were designed and built over many years. But manufacturers who do **optimize are focused on optimizing the wrong things at the wrong time** - and are often stifled by limited tools, and team or organizational incentives that don't culturally encourage holistic optimization.

Optimizing mass production offers the most obvious impact to yield, but it is also the most expensive time to do it. We optimize during MP because that's where the most complete data is contained. Until recently, the traditional methods of optimization weren't well-suited for fast-paced electronics products or rapidly iterating development programs. With new technology, however, it's now possible to accelerate and automate much of the process in development, before mass production. This can enable hundreds of optimizations per program - where before there were none.

Why is now the time to implement manufacturing optimization?

Issues are becoming more complex at an exponential rate as components get smaller and designs get more ambitious. New technologies enable us to bring optimization early into the development process where we can affect the most change at a lower cost for short-cycle product development.

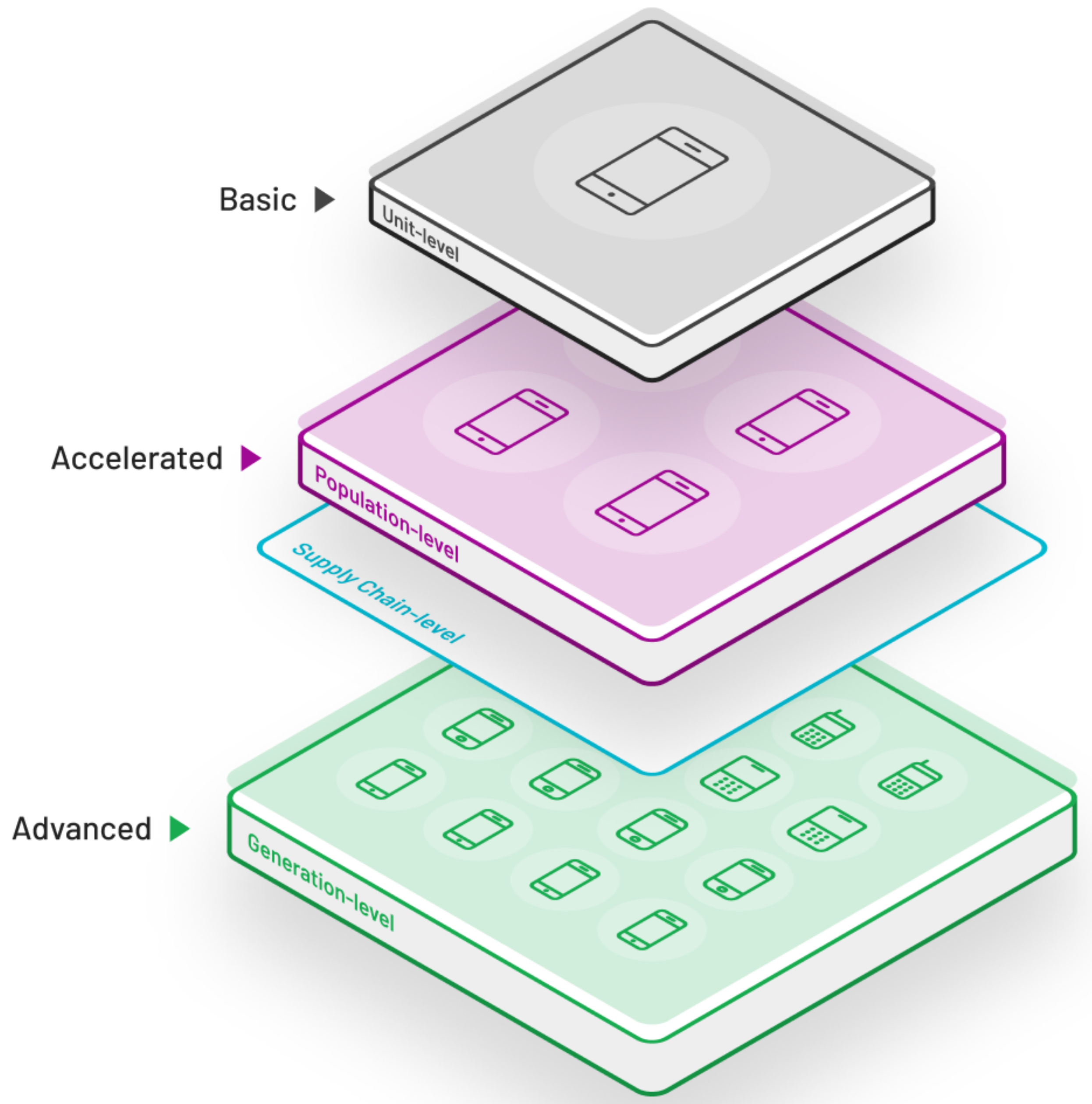
Breaking down manufacturing optimization

Fundamental manufacturing optimization: Unit-level
Putting the structure in place to be able to successfully conduct failure analysis on an individual unit with a problem, determine the root cause, introduce a solution and monitor for the issue on additional units within the population.

Accelerated manufacturing optimization: Population-level
Aggregating relevant datasets linked by serial number and using technology to identify correlations across multiple units to solve defective inputs before they propagate into mass production

Advanced manufacturing optimization: Generation-level
Combining population-level optimizations from across multiple programs and aligning partners across the supply chain in order to reduce costs and accelerate timelines and tackle harder problems across generations of products.

Bonus: Supply chain-level optimization requires (contractual) alignment across suppliers, CMs, and brands which weights structural, institutional optimizations over cost-cutting shortcuts for particular programs.



What is your optimization maturity?

Fundamentals	Acceleration	Advanced
Build Better Units	**Build Better Products**	**Build Better Supply Chains**
Almost all companies do some form of basic optimization when building products. As you solve problems and finalize your designs, you are finding ways to improve efficiency, move faster, and save money at the unit-level. This section will break down the fundamentals of optimization to give you the language needed to describe common practices to facilitate unit-level optimizations.	As you look for optimizations for multiple-units or at the population-level, you'll need to go beyond the fundamentals. Now you need to learn how to accelerate product development by introducing optimizations for multiple-units or at the population-level. This section can help your team level up by incorporating more structured processes and advanced tooling for multi-unit optimizations.	Use the adoption of technology as a catalyst to create a new culture of optimization. Align your teams and manufacturing partners on goals that prioritize speed, quality, and transparency. Leverage these changes to unlock the opportunities your company wants to pursue that will help you make better products for your customers.
This section is perfect for engineers who want to create common ground and common language for their teams.	**For team leads that want to uplevel their optimization strategies, this section is for you.**	**Discover new ways that executives can drive cultural change to optimize products, process, and people operations here.**

Fundamentals

Build Better Units

Excel at the fundamentals to quickly solve problems on a unit level.

How teams are building good units today

Manufacturing can often feel like a series of firefights on the road to launch, so it's understandable that many teams want to cut corners to focus on the biggest challenges. But if you spend the time to establish the fundamentals of building good units, you will make fewer mistakes, achieving more on-time builds and higher yields.

More importantly, you'll be able to devote more engineering resources to innovation instead of firefighting and set your team up to take advantage of true manufacturing optimization.

Things to consider as you read ahead:

- What is your framework for problem solving?
- Are you able to find issues as quickly as possible?
- Do you have all the data you need to solve problems quickly?
- Why do problems come back once they've been solved?

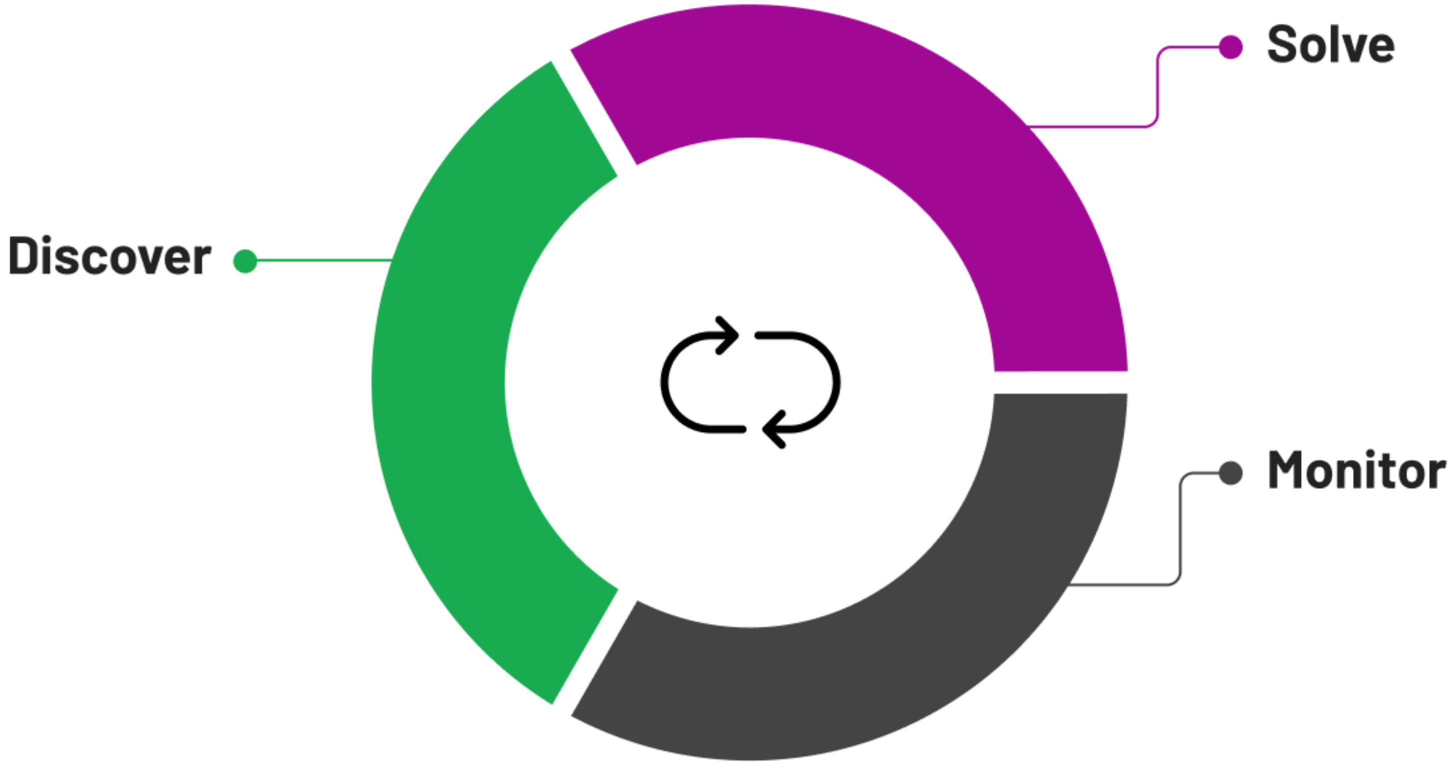
We'll begin our optimization journey with a fundamental principle: The Core Loop.

Defining The Core Loop

Engineers solve problems, and in electronics manufacturing, they do this with a simple framework called the Core Loop. The loop consists of three steps: **Discover** > **Solve** > **Monitor**

- **Discover:** Identify issues with your designs and processes.
- **Solve:** Find root cause and fix problems through design or process changes.
- **Monitor:** Validate that the issue was resolved and make sure it doesn't come back.

The Core Loop is where engineers provide the most value. A lot of time and effort is spent finding and resolving issues to make products better throughout the development process. Let's explore each of the main components in the following section and identify the best practices to make this framework work for you.



Discover

Find issues in your process

Ask yourself these questions:

- Are you discovering defects or issues before they propagate through your validation stages?
- Are the methods you are using to collect data antiquated or innovative?
- When in your EVT/DVT/PVT build stage do you expect to have resolved specific types of issues? How does this impact what data you gather?

The challenges of issue discovery

The first component of the Core Loop is **Discover**. Issue discovery sounds simple, but it is incredibly challenging to conduct during an accelerated development cycle. Until recently, this has been a somewhat blind and mostly reactive process. Traditional methods rely on people and functional tests which can often miss important issues. Creating systems and leveraging technology to ensure issues are discovered quickly is incredibly important to any build aiming to hit their ship date.

A good discovery process will:

- Identify critical junctions in your process where issues might be detectable via testing, inspection, or another method.
- Determine what information is necessary to gather and the best way to record the data.
- Surface anomalies in processes and data before they propagate through your line.

In spite of what engineers might prefer to think, issue discovery is never complete. Even in production, perturbations in even a well-honed process can create issues. This is why it's important to have a robust system for discovery. Banking on being in the right place at the right time is not a strategy, it's a risk.

Preventing issues earlier in your cycle

One of the best times to discover problems is before they happen in the first place. While not everything can be resolved this way, easy wins can be had by thinking ahead and following some simple processes. Here are a few ways traditional product teams are being proactive about issue discovery.

- Predict where failures occur by running a Failure Mode Effects and Analysis (FMEA) study early in the program. Use the results to identify and prioritize issues to work on before tool release and other major expenditures.
- Prepare tests and countermeasures to deal with expected problems that were identified.
- Follow Build Entrance and Exit criteria. Before committing time and resources to a build, make sure everything is ready and signed off by key stakeholders. This includes everything from tools and parts, test stations and assembly processes, to device firmware and software.

Finding issues before a build is inconvenient and requires additional time be spent resolving issues that are found through an FMEA or Build Readiness Review. But it’s not as big a bummer as finding issues at the build, where stopping the line wastes time and money. Worse, if issues aren’t found and instead escape, another build may be needed to set things right. Spend the time getting the design and process ready by writing documentation and planning the build before traveling. Not only will a good number of issues be prevented, but by being more organized, you will be more prepared to handle issues when they occur.

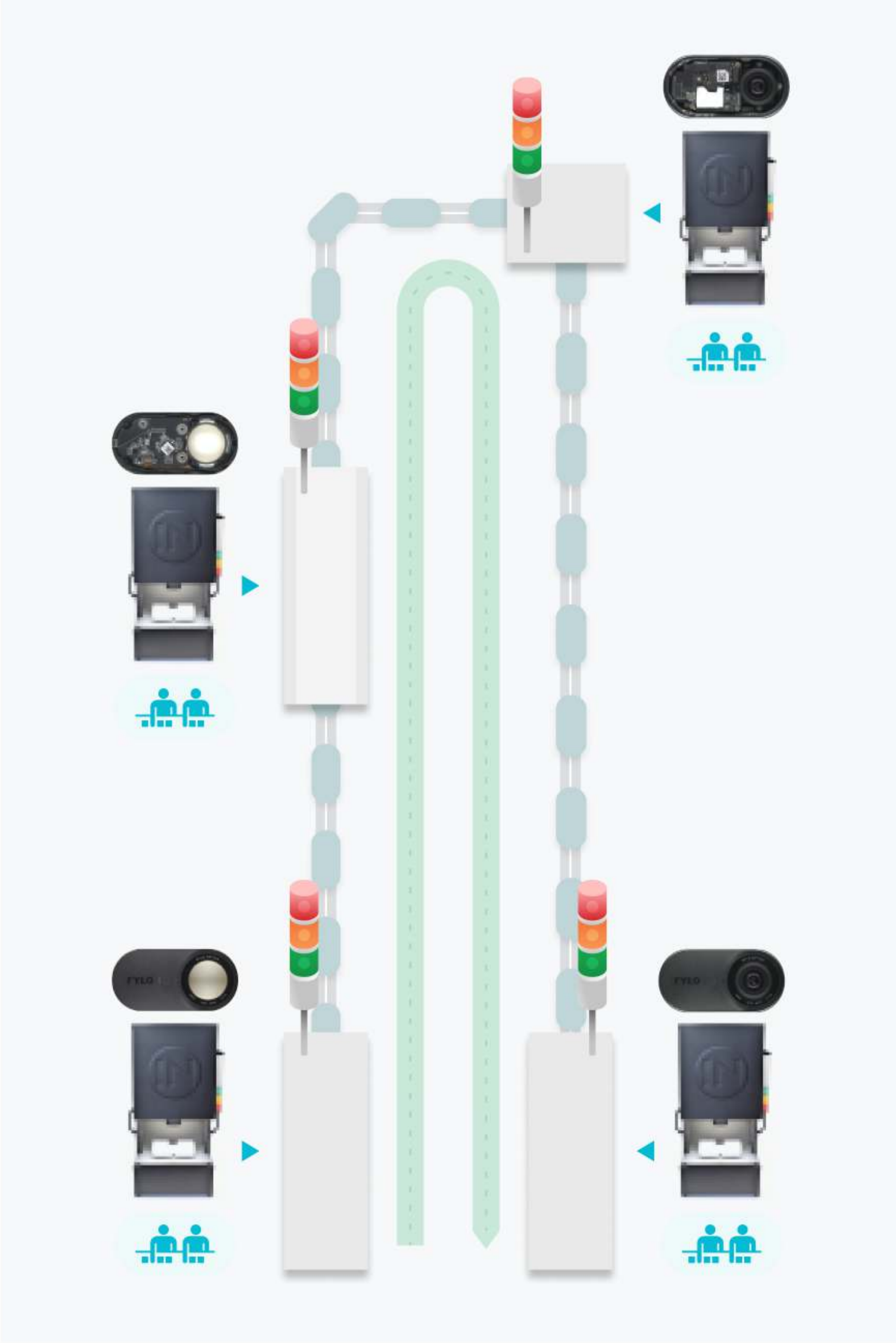
Identifying critical transforms in your build

Not all issues can be prevented, but determining where they are likely to occur will help the team prepare to deal with them. Implement inspection steps and tests at critical transforms (or junctions) in the product development. Critical transforms are any step in the process where an action is performed that significantly changes a product's form or function. Examples include assembly steps where major components come together, integrating electromechanical components, and testing for functionality. Another common place to find issues are through rigorous reliability tests that subject a device to extreme conditions.

Key takeaways for data collection:

- Identify which process steps and functional tests could cause or reveal a failure.
- Determine what data could be collected at those process steps that could separate good and bad units.
- Prioritize the riskiest steps in terms of assembly complexity, potential component damage, or scrap cost.
- Plan to implement tests or inspections to check the form and function of the product before and after each of these critical steps (manually or through a system like Instrumental).

Be prepared to deal with both the expected and unexpected during the build. Often, issues crop up that were not identified earlier. Make sure to track and record as much data as possible about a given issue. The faster the team reacts, the better the data will be.



Treating test stations with respect

Test stations aren't just passive pass and fail vehicles, but are heroic front-line workers in the issue discovery process. They can collect detailed information about each and every device. While the main purpose of the test stations is to check a subsystem's functionality, you can also capture quantitative data of the test and useful metadata like timestamps, serial numbers and configurations that create a fuller history of each device.

- A functional test station should evaluate the performance of a device for a given subsystem and return quantitative data such as audio waveforms, display brightness or antenna response times. Determine the pass and fail limits based on theoretical performance and acceptable variation due to component and assembly tolerances.
- Qualify your test stations through gage repeatability and reproducibility tests prior to each build. This will expose the statistical variation between operators and test equipment and ensure the test station has the capability to capture what you are trying to measure.
- Use visual inspection checkpoints to catch bumps, scrapes and scratches as devices progress through the line. Prior to blind or expensive assembly steps, use visual inspection to make sure parts are where they are supposed to be and cosmetically clean.

Insist that your manufacturers and suppliers link the test stations and their results into your manufacturing platform in real-time to enjoy up to the minute access to this invaluable data source. For qualitative data from visual inspections, digitize or automate the results as much as possible just in case you need it.

Digging deep for underlying reliability issues

While functional tests and visual inspection can surface inconsistent process or unanticipated functional failures, reliability tests often identify underlying issues. Putting the product through challenging mechanical and environmental loads catch poor quality parts or highlight issues with the product's architecture. Choose which tests to include in your waterfall based on customer use cases and set your pass/fail criteria based on anticipated product life with a margin of safety. Reliability tests should push your product to the limit so you can find out what needs to be fixed before it's too late to make meaningful changes.

- Environmental testing validates a product's resistance to common thermal, moisture, and chemical situations that may occur during its life.
- Mechanical testing validates a product's resistance to impacts, pressure, torsion and other sources of mechanical fatigue.
- Controlled and Randomized testing: For the most part, consistent controlled testing is useful to identify failure modes in a product. However, randomized or uncontrolled tests better simulate real life. For example, in a charging cable insertion test, a mechanical tester will consistently push the plug in and pull it out perfectly each time while a human doing so will impart additional loads which would be hard to simulate.
- Waterfall testing should be used to maximize the number of tests performed with the given allocation of units and to precondition units prior to destructive mechanical testing.

One of the downsides of thorough reliability testing is the sheer amount of time it takes to run enough devices through the waterfall. On the other hand, spending too little time, or running too few units may let critical failures propagate to subsequent builds. Communication of the results in a timely fashion is critical so engineers can begin the process of searching for root cause, which is what we'll get to in the next chapter.

Environmental tests:

- High Heat/High Humidity
- Temperature Cycling -20 to +60deg C
- Waterproof Dunk Testing
- Chemical Resistance Testing
- ESD testing

Mechanical Tests:

- Controlled Drop Test
- Random Drop Test
- Ball Drop
- Torsion
- Connector Cycling
- Connector Side Loading

Visit instrumental.com/resources for our reliability test kit.

Solve

Fix problems and validate solutions.

Ask yourself these questions:

- How do you programmatically validate solutions?
- How long does it take from designing a solution to implementing it on your line?
- How often do old issues pop up again in later builds?

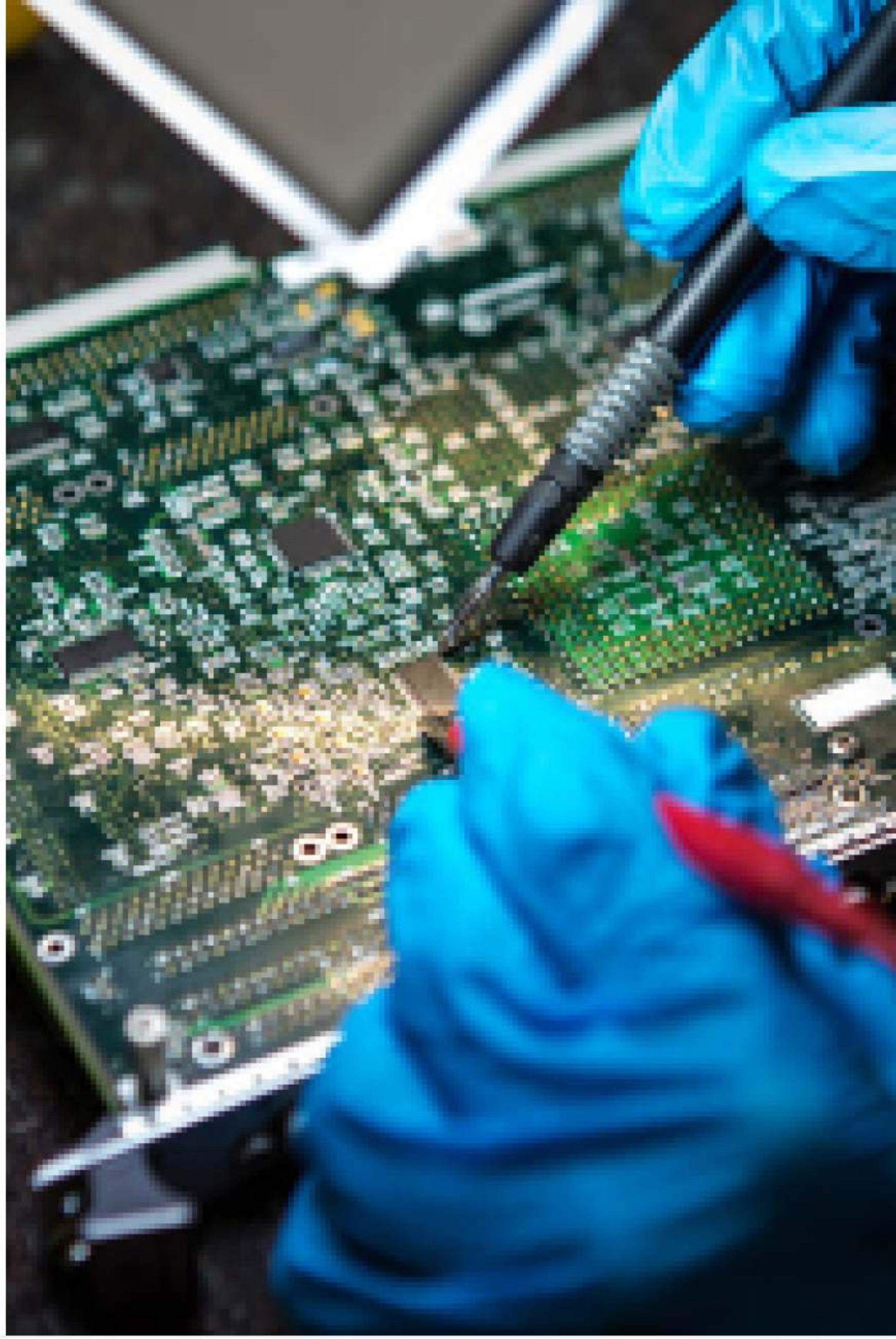
The challenges of finding and fixing issues

The second component of the Core Loop is **Solve** - the part of the job the engineers love most. Solving problems is itself an iterative process that requires understanding the problem, using data to determine a root cause, and testing out theories to implement a corrective action. In addition, you have to fit this process into the project constraints like budget, timelines, and stakeholder requirements.

Here are a few guidelines to remember:

- Review data to understand the conditions that led to the failure.
- Group failures by functional area.
- Run Failure Analysis to determine the root cause.
- Test hypotheses through experiments and simulations.
- Create corrective actions by changing designs or processes.

Once a solution has been found, engineers still need to make sure it is viable for their program. Not only do they need to communicate the changes to partners and stakeholders, but they will need to validate the solution at subsequent builds and ensure it does not inadvertently cause new issues or crop up again in mass production. Upon reviewing the list of issues discovered during the build process, prioritize them based on how they impact the critical performance metrics to meet the project's goals and customer experience.



Finding a root cause early

Once a particular problem has been identified, dig through all of the collected data to look for possible sources of error that could have caused the issue. Use a systematic approach to prioritize the investigation.

- Create a prioritized list of possible reasons for the failure. Consider factors like different part suppliers or configurations in addition to design or assembly issues.
- Correlate any test results with physical measurement data to look for possible areas to investigate.
- Develop hypotheses to explain how a problem was created and propagated through the design until it was caught.
- Run experiments to isolate each possible reason and determine which input has the biggest impact on your outputs.

Sometimes multiple problems stem from the same root cause and clustering can occur. This is where issues may appear smaller because there are multiple symptoms and the root cause is not prioritized first. Other times, there might be multiple causes for a single symptom. So before you tackle the biggest issues, look for patterns when starting your failure analysis process.

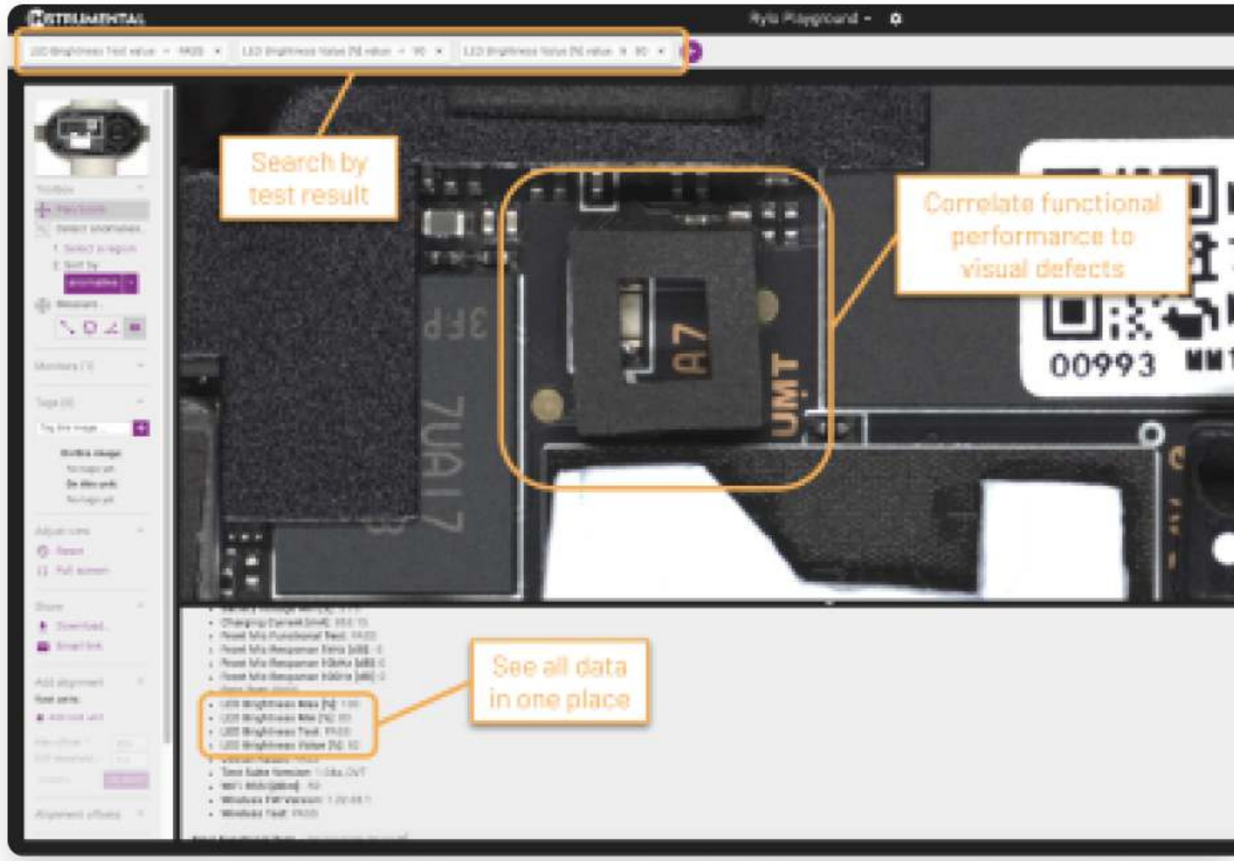


Image of correlating test results with visual defects using Instrumental.

Making corrective actions

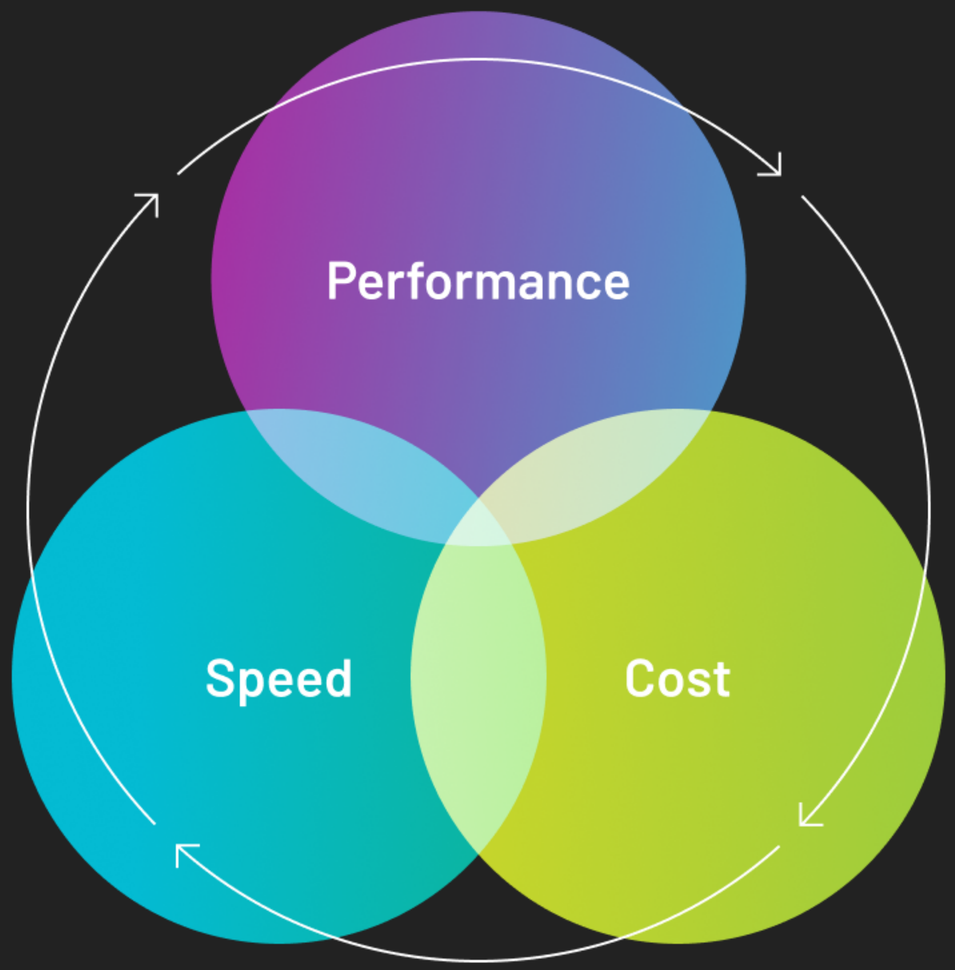
Once you have determined the root cause of a failure, the next step is to implement a solution. The changes to parts and processes to fix the failure are known as corrective actions and the goal of a corrective action is to eliminate or address the source of the failure. Changes come in different forms.

Some changes are obvious refinements to the process that will mitigate failures in operation or assembly. Make sure that updates are added to the documentation and instructions are added about how to train new operators on what to look for. Other fixes require tool changes which means you will have to update your tolerance analyses and documentation. You also will need to wait until the next build to validate the solution and truly close the loop.

Next, you'll need to communicate the proposed changes to the broader team before releasing them in case other functional teams are impacted by the change. For example, adding material to stiffen a part might detune nearby antennas or interfere with component placement on a circuit board. Remember that other teams will also be making changes at the same time so you want to understand how their changes affect your functional area before finalizing your own. For example, after a prototype build, electrical teams often request more grounding of the PCB and antennas.

Making the right corrective actions means considering what the impact of the change is on the whole product and striking the right balance between cost, performance, and speed.

Finding the right balance



The butterfly effect of corrective actions

Team	Step 1	Step 2	Step 3	Step 4
Mechanical Team	**Failure mode:** Display cracked in drop test	**Root Cause:** Housing structure is not stiff enough	**Corrective Action:** Add material to stiffen housing	**Risks:** Changes don't solve the problem or cause a new problem to occur
Electrical Team		**Impact:** Board no longer fits into housing	**Changes:** PCB needs new layout and tighter component envelopes	**Risks:** New layout causes more failures
RF Team		**Impact:** Antenna detuned by new housing	**Root Cause:** Antenna needs to be redesigned and to work with new mechanical design	**Risks:** Poorer antenna performance and delay in certification
Factory		**Impact:** Fixtures and jigs no longer work with the main housing	**Changes:** Modify assembly fixtures, update incoming quality inspection, and update the SOP	**Risks:** Missed changes could delay the build
Supply Chain		**Impact:** All parts are changing meaning new tools and jigs are required for every team	**Changes:** Costs of each component will change and existing tools will need to be modified or scrapped	**Risks:** Kicking off mass production tools is either delayed or at risk due

Team	Step 1	Step 2	Step 3	Step 4
Electrical Team	**Failure mode:** Noise during antenna transmit	**Root Cause:** Not enough grounding	**Corrective Action:** Add conductive points to board	**Risks:** New ground points require new layout and routing to meet grounding location requirements

CA for **Materials and Parts**

If the corrective action is a material or part change, make sure to properly evaluate the change and communicate it to other stakeholders. If a critical active component like the display or antennas are affected, make sure to give enough time to evaluate the update. Depending on the scope of the change, the part manufacturer may also require DFM and in the worst case to cut new steel.

- Run simulations on the proposed changes to validate they will fix the problem.
- Once you have decided on the changes, update the tolerance analyses and documentation. This will ensure the new design still meets the requirements. You can also incorporate process capabilities from your vendor to refine the tolerances as you go.
- Keep your vendor up to date on the proposed design changes in case new steel needs to be cut. If the proposed changes are not tool safe, you can ask them to prepare some of the raw materials to save time in the schedule.
- Make sure any fixtures are updated to accommodate the design changes.

Once a solution has been found, engineers still need to make sure it is viable for their program. Not only do they need to communicate the changes to partners and stakeholders, but they will need to validate the solution at subsequent builds and ensure it does not inadvertently cause new issues or crop up again in mass production. Upon reviewing the list of issues discovered during the build process, prioritize them based on how they impact the critical performance metrics to meet the project's goals and customer experience.

CA for Processes

If the corrective action is a process change, it will require a cross-functional solution. Here are a few things to keep in mind as you introduce a corrective action to a process:

- Do a sanity check on the process change itself and make sure that the problem doesn't just get moved further down the line.
- Communicate the changes to the team responsible for updating the SOP and make sure they understand what happened and why the change is required.
- If possible, validate the changes to the SOP through physical prototypes or small experiments. An example of a process change that could have a big impact on reliability performance is the pressure and time duration applied to a pressure sensitive adhesive.

Some changes are obvious refinements to the process that will mitigate failures in operation or assembly. Make sure that updates are added to the documentation and instructions are added about how to train new operators on what to look for.

Monitor

Close the Loop

Ask yourself these questions:

- Do my suppliers and manufacturers know what's changed?
- How can I be sure I am building with the latest designs?
- Do issues ever come back after they have been "solved"?

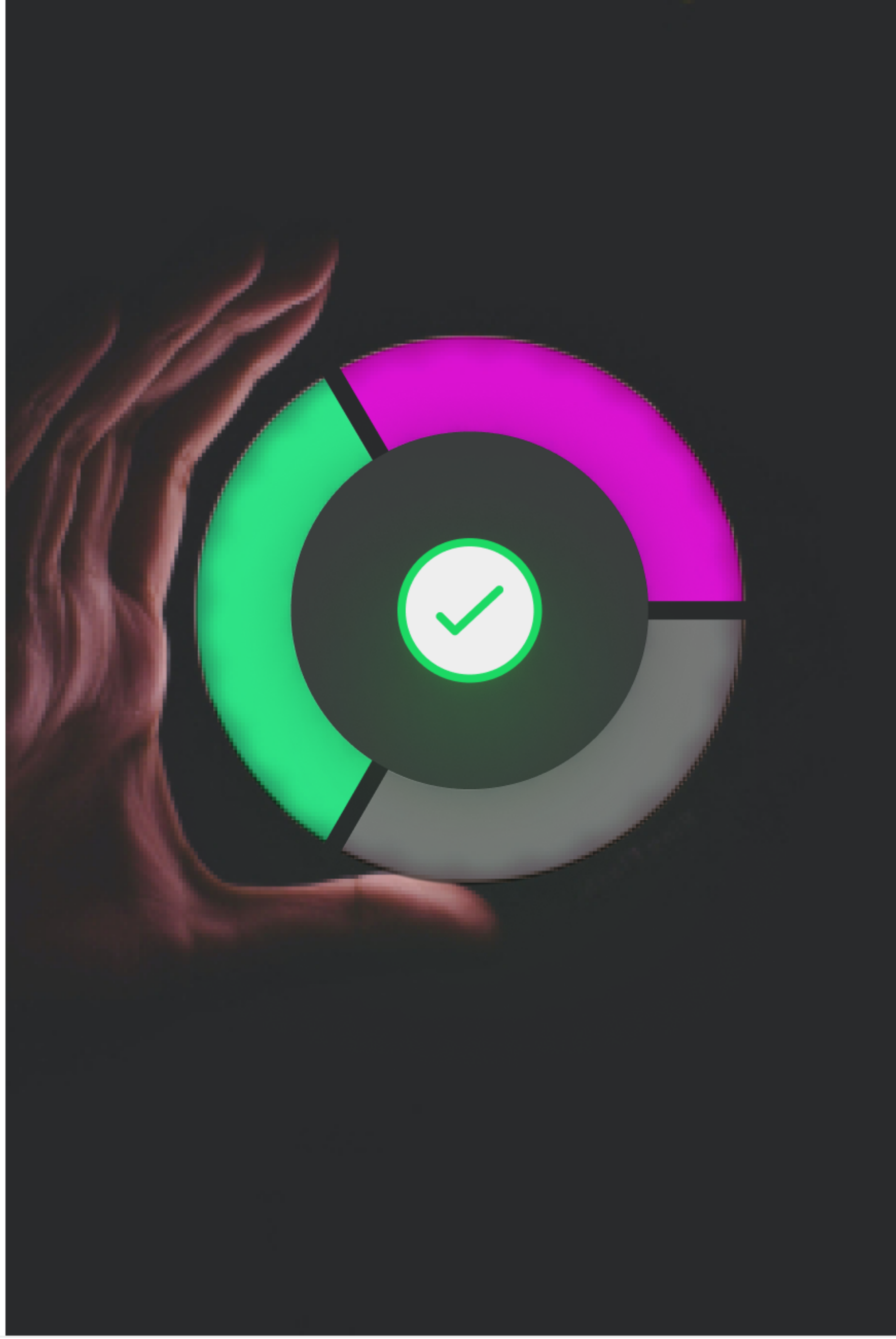
Monitor to close the loop

The final component of the Core Loop is **Monitor**. While monitoring is the last step in the Core Loop, this framework is really a cycle. New monitoring processes become the criteria for the next discovery. Ideally, a solved issue stays solved, but problems can crop up throughout the supply chain so it is important to stay vigilant and continue to check parts and devices at critical junctions in the process.

Monitoring involves:

- Making sure vendors implement changes, collect new data based on updated documentation, and isolate out-of-date parts.
- Updating assembly instructions, processes, and fixtures to make sure operators can reduce or eliminate known problems.
- Implementing continuous testing for all known issues, regardless of frequency, to validate the solution and prevent recurrence.

While it is tempting to phase out monitoring processes in production to save costs, defects can crop up even in production. And during times when travel is restricted, the ability to monitor remotely becomes even more important.



Monitor upstream suppliers after part changes

When making changes to parts, the easiest step is creating the new CAD model. The hard work lies in the effort to update the design intent, communicate the changes, and make sure all the new parts meet expectations. Upstream suppliers who make the parts are going to be the first place where problems might occur. Keep on top of them as you validate the new designs.

- Do tolerance analysis for critical stacks in the assembly to set the individual part tolerances in the design and drawings. Keep these analyses up to date as changes are made.
- Make sure the supplier updates their measurement process to include new dimensions from the latest drawings.
- Make sure part revisions are reflected in the serial number on the part and isolate previous revision parts so that they can't get mixed in with the new parts. Requalify parts using FAI and Cpk reports before approving the tools for the line. Modified tools may behave differently from new tools.
- At mass production, pay attention to the differences in copy tools especially near areas that were modified in the first tool.

Drawings and other specifications will not only be used to qualify the parts for the assembly and evaluate the manufacturer's processes, but they are the first step in gathering data. If an issue arises on a critical component, the documentation is the first place to refer back to. Drawings and specifications also serve as the foundation for the standard operating procedure (SOP) helping guide the step by step assembly process and test fixture design.

What is Design Intent?

It is the information that the designer needs to convey to partners about why a part or product is designed a certain way.

Make process changes stick

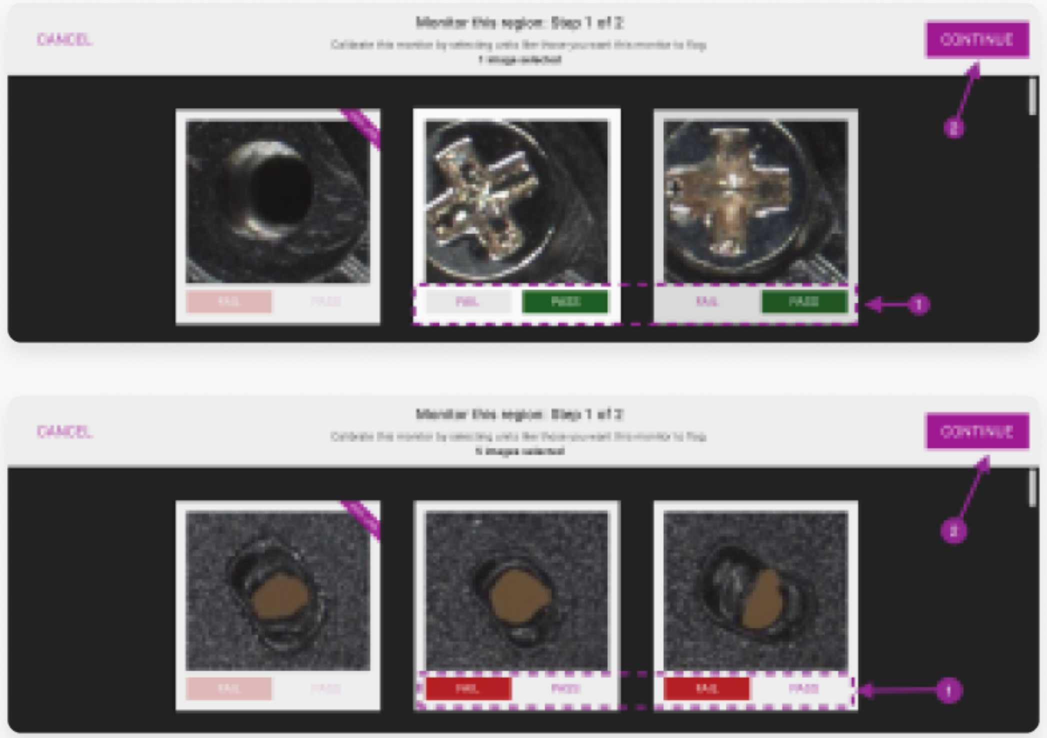
Assembly line changes require special attention because they can easily get lost in the chaos of builds and flurry of updates. Line leads and operators may also change between builds so process documentation needs to be the source of truth.

- Update instructions in the SOP and include more detail about each step. If there is any change of ambiguity, highlight things like the order of operations or position of a resulting cable to ensure that it is called out.
- Include photos of the desired final state of the process step and highlight common no good (NG) parts for comparison.
- Operators and line leads should be trained ahead of subsequent builds.
- Change assembly jigs and test fixtures to make it more difficult to cause failures. For example, if operators were accidentally damaging the PCB or cosmetics when screwing parts together, add covers with holes where the relevant screw bosses are.

Continue to monitor at each build and into production

Engineers often make the mistake of assuming an issue has been closed once a solution has been designed and released. But to successfully monitor an issue, processes need to be put in place so it's not just the DRI engineer who remembers to check on the issue, but rather everyone who comes into contact with the process can quickly determine whether things are on track.

- At each build, review critical failures and validate that the parts and SOP reflect all the changes (including changes from previous builds or tests).
- Pay attention to performance on the line and through reliability testing. Human processes can tend to vary based on factors like time of day, so be sure that you have good monitoring in place that gives your team oversight across the day, across shifts, oversight across different shifts.
- Track the frequency and severity of issues on the line to make sure old issues don't crop up and that the fix didn't cause new issues. This requires some process for discovering whether new (unintended) issues have started to appear. Using a flexible inspection system is critical at this stage to ensure it isn't prohibitively difficult to get the coverage you need.



With Instrumental, you can monitor for issues and setup live pass/fail tests to ensure process changes are measured.

Existing best practices for building good units

Failure Type	When in the Process	Detection	Mitigation
Design & Architecture	In early prototype design and each time changes are made to parts.	CAD Interference Checks Simple Physical Prototypes	Design Reviews, Cross Functional reviews, DFM reviews, DFA Reviews
Component and Supplier	Pre-Prototype Build, more often at Proto and EVT	Fit checks with Jigs or other parts, First article Inspections, Critical Dimension Cpk Reports	Dimensioned Drawings, Tool and process reviews, Recurring progress meetings
FATP Process	During prototype Builds, usually at Proto and EVT but can happen at DVT and Ramp	Go/No Go gauges, Test results vs test limits, Visual Inspection	Validate all test stations prior to FATP, Gauge R&R testing, Review SOP and disposition potential failures, Observe operators and where they struggle, Empower Operators and line leads to identify issues, Stop the line
Reliability and Lab Failures	After each prototype build. Most failures will be found at Proto and EVT builds	Reliability Waterfall, Visual inspection Before and After Photos, Cross-Sectioning Functional Testing	Test to Failure, Design Changes, Test Changes, Simulations
Unknown Failures	Can happen throughout the process	Bug Tracker, Reliability test failures, Anecdotal feedback, Dogfood testing	Major Issues List, Pareto Sorting, Use Failure Analysis tools, Pre-emptive Data collection

Manufacturing optimization platforms like Instrumental can unify all of these data points easily so you can close more loops earlier in your build.

Why best practices are not enough

While managers and executives like to think that whole programs are a single Core Loop, that is an oversimplification of all the blood sweat and tears that goes into making hardware. In reality, engineers might work through the loop hundreds of times. The best teams today run through a lot of loops per build, with the assistance of some of the tools and processes described earlier.

But have you noticed that even if your team executes all the Core Loops, and does all the little things right, every program still feels like a struggle? We have been doing things the same way for many years and yet launches are still delayed, problems are missed or crop up again, and we rely more than ever on hero engineers to spend half their time at the factory to save the day.

Something is still holding us back from achieving the holy grail of programs: good, fast, and cheap. In the next section, we will show you that beyond the industry best practices, there are new ways to more effectively complete those Core Loops.

The answer is **Manufacturing Optimization**.

Acceleration

Build Better Products

Use optimization to raise the quality of your products and do it quickly.

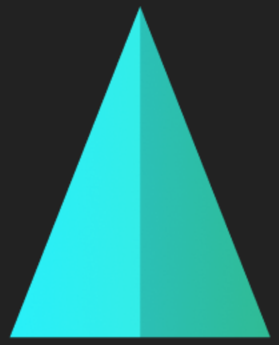
Better optimization is key to improving the most critical business outcomes

If you've ever looked at a competitor's product and wondered how they were able to deliver so much more quickly, the answer is likely that they have put significant internal focus on optimizing their manufacturing execution - tightening feedback loops between discovery, information gathering, collaboration, and implementing design or process changes.

Their outcomes typically speak for themselves:

- **On-time build and program delivery.** Optimized teams are characterized by high predictability in delivering production-ready lines to their ramp teams on time and exceeding yield minimums.
- **High engineering retention & satisfaction.** By reducing the amount of fire-fighting and forensics, engineers tend to be more satisfied and spend more time on innovation.
- **Ability to deliver more ambitious product designs.** Complete data coverage and tight issue resolution workflows allow teams to push the edge of buildable industrial designs.
- **Rare field escapes or dark yield issues.** Optimization-focused teams are able to avoid field failures because they are able to better monitor every potential issue that they learned about in development, and align their CMs and suppliers toward continuously improving quality.

Leaders with vision over-perform KPIs:



- ↗ **Yield**
- ↗ **Product Margins**
- ↗ **Throughput**
- ↗ **On-Time Delivery**
- ↗ **Customer Satisfaction**

"Because we don't change technology [between prototyping and production], we don't throw anything away. We don't waste time. And it's led to one of the healthiest relationships between an engineering and manufacturing group I've ever seen in my life. They're all working off the same databases. They're all working on the same processes. They're all working in a very disciplined process environment, to where, when any processes are changed, they all get together and review the proposals, and all buy into it."

Steve Jobs

Start with changing your mindset

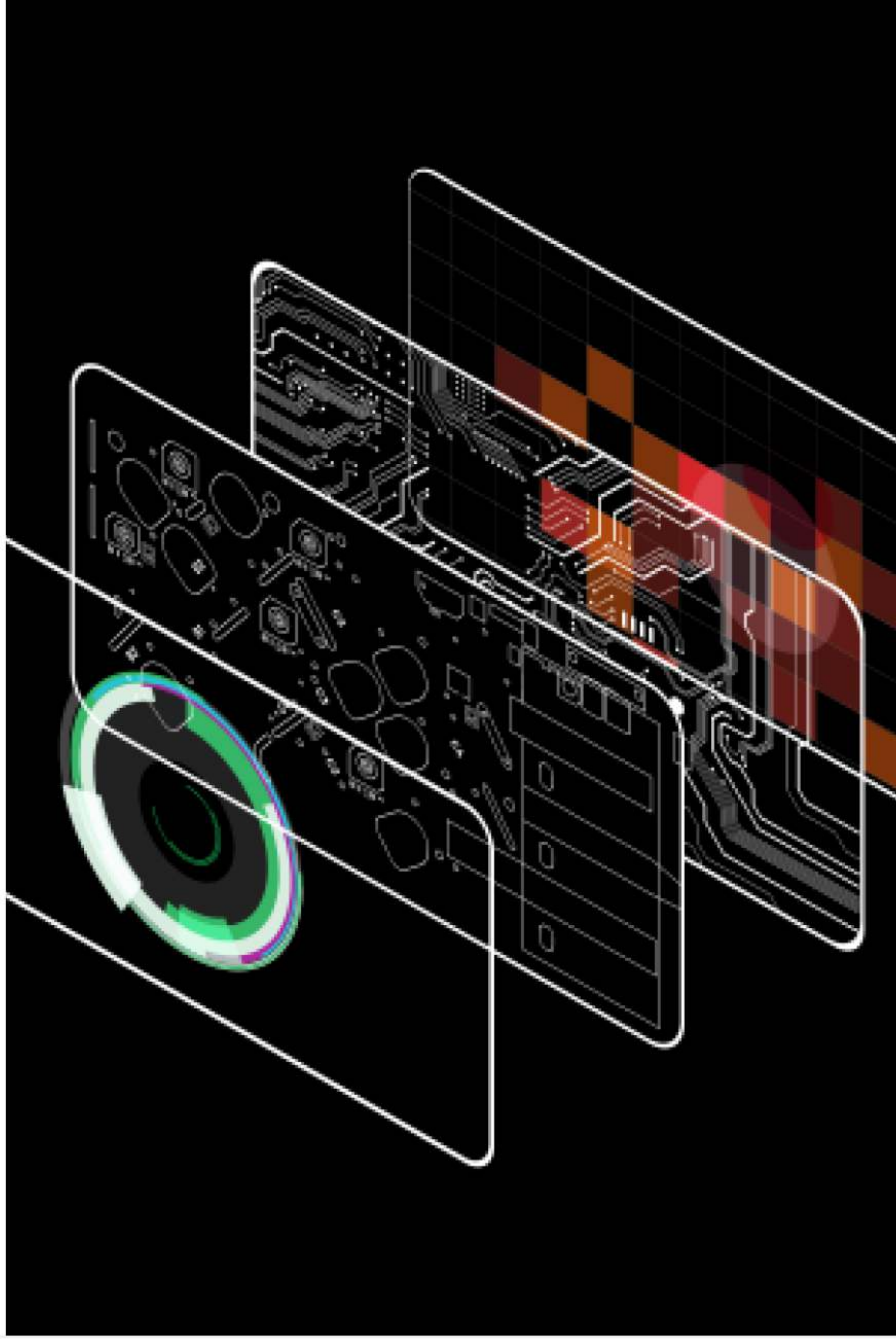
Engineers and managers frequently make the mistake of thinking optimization is something that can be left to the end of development or even into production. This is fundamentally wrong because optimizations are both easier and more cost-effective when they happen earlier in the process, starting in early EVT. Optimization should be a continuous, proactive practice performed throughout development and into mass production.

True optimization means:

- **Data democratization.** When everyone is looking at the same dataset, the problems become clearer. Less time is spent exchanging hearsay and more time can be used to study and act on what you find.
- **Closing more loops, earlier.** Reducing the gap in time between identifying an issue and solving it makes it easier and cheaper to solve.
- **Adding efficiency.** Closing loops faster also means you can perform more loops in the same amount of time with the same resources.

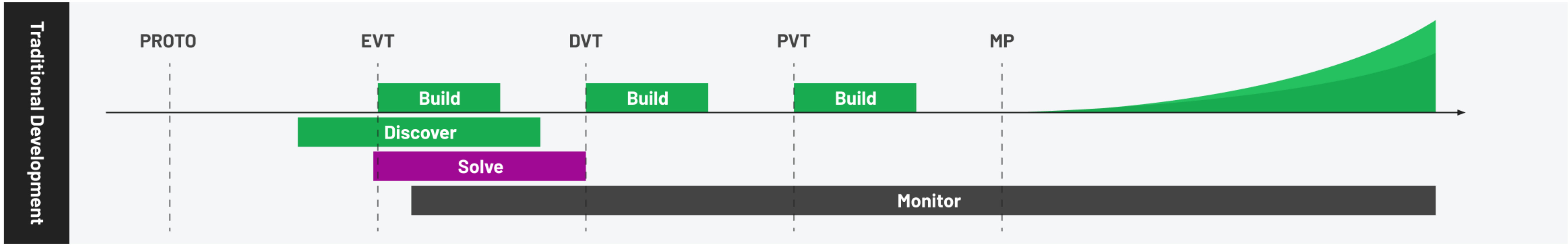
So why is it so hard to get proactive about optimization? Because the way we approach development at the fundamental workflow level has stagnated, even though product complexity increases and build schedules shorten. Today, there is a generation of engineers who think constant fire-fighting has always been a normal part of product development. Many teams think they're treading water when, in reality, they are quickly falling behind.

Once you realize this, you're ready to effect change in your organization.

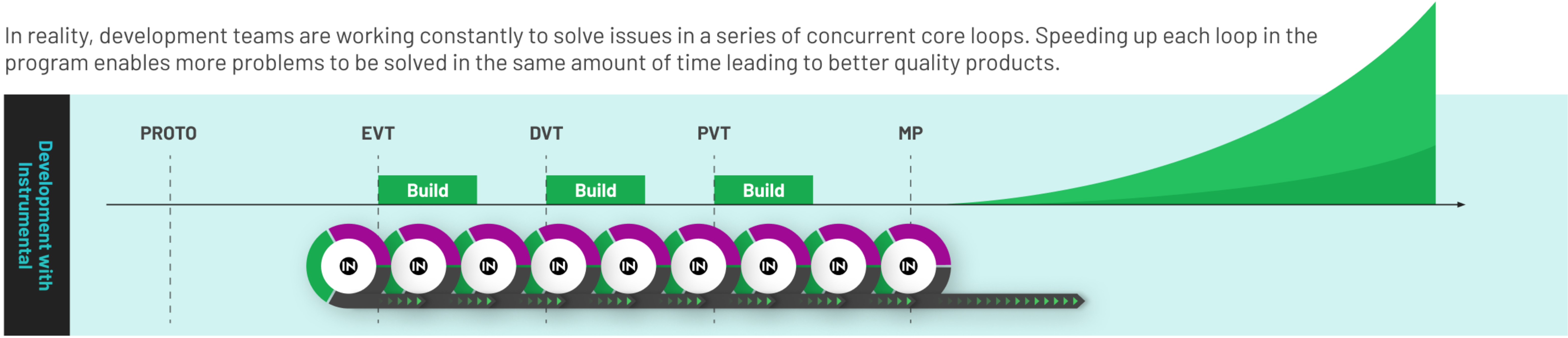


Visualizing traditional versus optimized development

We like to think of development programs in linear terms with a few minor issues discovered and solved before DVT.



In reality, development teams are working constantly to solve issues in a series of concurrent core loops. Speeding up each loop in the program enables more problems to be solved in the same amount of time leading to better quality products.



Build better products by clamping down on friction

Mastering unit-level optimization is the starting line for delivering products today, and it's where many programs or companies still stall. But to compete in the current rapid-innovation electronics environment, competitive companies must focus on true product-level and inter-generational optimization by focusing more engineering time on innovation instead of firefighting.

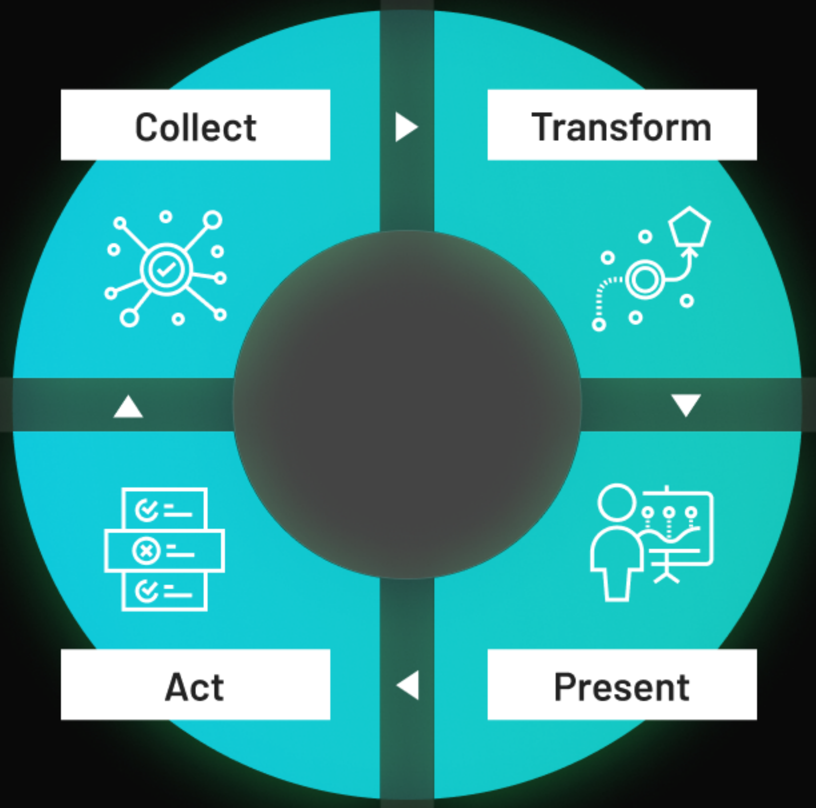
That is to say: they must seek out and eliminate friction in their engineering processes, tools, organizations, and supply chains. Friction against optimization can come from many sources. Here are a few of the most common:

- **A flawed optimization mindset.** Many PDE teams think of the Core Loop as their JDM or CM's problem. Not so! Taking ownership of optimization as the brand is the necessary first step, because ultimately only the brand can drive supply-chain wide change.
- **Reactive issue discovery.** Discovering issues too late and too slowly, that is - reactively - leads to slow failure analysis and missed opportunities to optimize within builds. Instead of waiting for problems to come to you, ask what are you doing to proactively find and solve issues?
- **Not enough data.** Turn good data into great data by collecting more product data, adopting traceability to organize that data, and integrating everything into a single system to make it easier to see the big picture.
- **Delays from poor communication.** Eliminate fruitless back and forth by taking control of your supply chain. Democratize data so all teams in the supply chain can be on the same page. Find out where issues are and how to fix them without the drama.
- **Reporting overhead.** Every minute spent reporting and updating others is time lost on engineering.

An optimization mindset will also open the door to creating more complex products by saving time and building the confidence to unlock potential functionality that your product teams might otherwise have been too nervous to tackle.

Optimizing with the CTPA Framework

Tackling this cross-functional challenge doesn't have to be daunting. The CTPA Framework is a simple way for you to evaluate how well your manufacturing technology stack and processes support efficient, continuous optimization and enable engineers to quickly close loops.



How do you get the data that matters most from wherever it is, into one place where your team as well as other collaborators can access it?

- Are you collecting data wholly (every data point of every unit), or just a sample?
- Is it accessible in real time?
- Is it accessible remotely and securely?
- Which data sources are you integrating? Visuals? Functional tests?

What tools and techniques are you using to make this data useful and automate forensics?

- Are you using active algorithms to crawl datasets for things like new anomalies or shift?
- How are teams alerted to these discoveries?
- Are you relying on third parties like your CM or JDM to make judgements on what is relevant?

How do you turn insights into action?

- How long does it typically take from issue identification to a solution implemented on the line?
- How do you validate that solutions have successfully eliminated an issue?

How do you communicate insights to each stakeholder with immediacy and relevance?

- Are presentations time-consuming or automatic?
- Are they widely available across teams and people responsible for analysis or inputs?
- How do you document key insights so you don't repeat the same mistakes in future builds or programs?

Why start with CTPA?

When you're in the midst of firefighting last-minute issues on any given program, it can seem impossible to scope out an optimization effort. The prospect of re-aligning team incentives, re-evaluating your tech stack, and experimenting with a more holistic data approach can quickly slide down the priority list.

Approach optimization incrementally, with a focus on data collection.

The CTPA Framework exists to help you and your team quickly evaluate where the biggest gaps are in your optimization practice today. By breaking down your workflows down to the basic components of how you collect data, automate transformation, present it relevantly to stakeholders, and act on it to improve your design, process, or supply chain - you'll find it easy to analyze and improve your workflows incrementally.

Most importantly - great optimization starts with gathering the right data, at the right resolution. You can't improve what you can't measure.

Starting with modern data tools to gather complete data sets, not just samples, are key to success. Over time you'll be able to leverage more of that data - but only if you collect it now. By implementing a modern manufacturing tech stack with an optimization system at its center, you can take the first step toward end-to-end supply chain optimization across programs and generations.

Issue Resolution Tech Stack

Ask yourself these questions:

- When issues arise, do you have the right data to quickly resolve them?
- How does your team complete core workflows like programmatic issue discovery, failure analysis, reporting, and solution documentation?
- How are you benchmarking KPIs like time to issue resolution, yield, and schedule slips across programs?

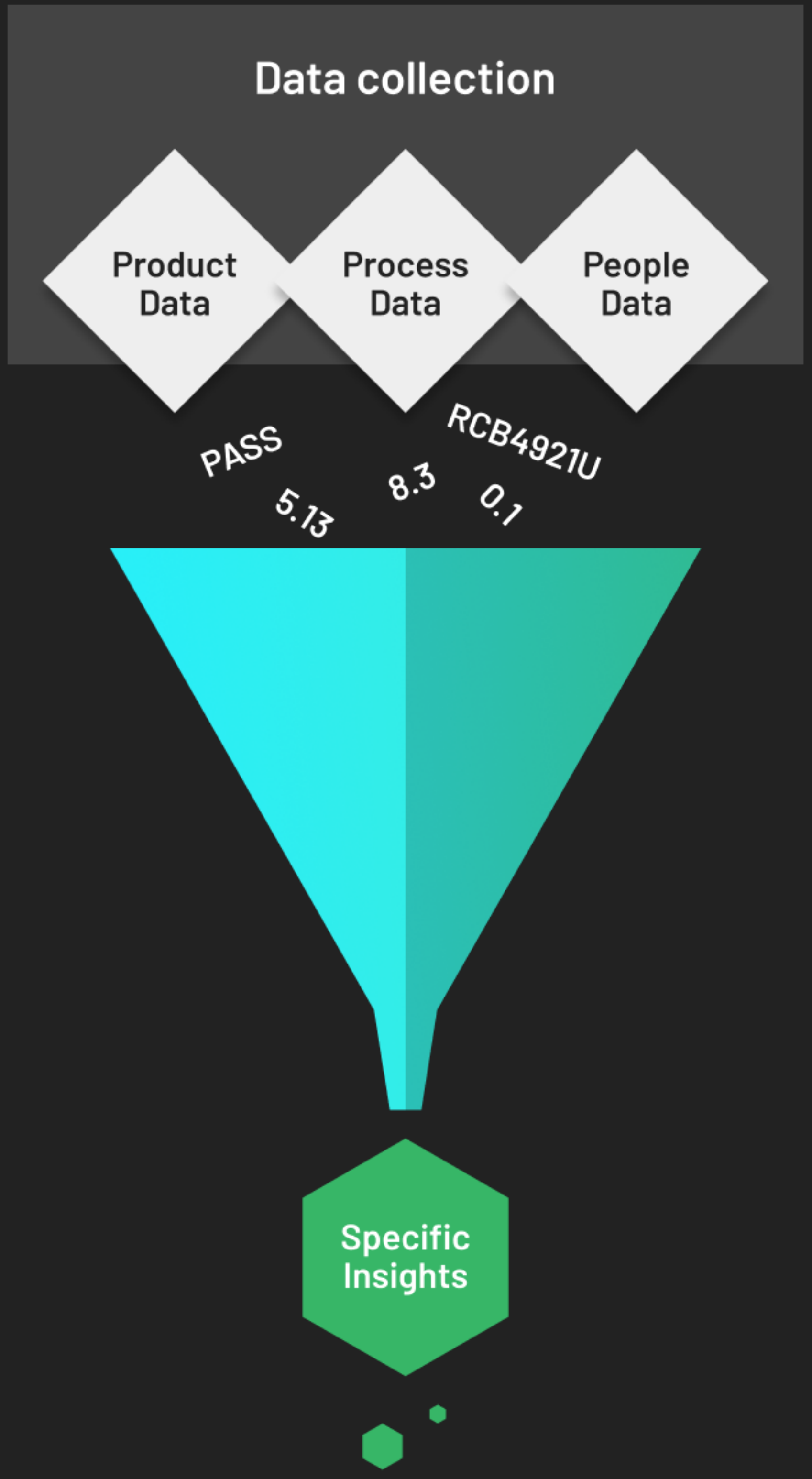
Start with holistic data collection

Much of Smart Manufacturing and Industry 4.0 rhetoric is focused on leveraging machine learning and artificial intelligence to find insights in your data that would otherwise be too time consuming to find.

What this misses is that any ML system is only as good as the data you put into it, and most teams today aren't collecting enough data, or the right data. To start thinking of your data strategy, consider the three primary types of data in discrete manufacturing:

- **Product data** represents data streams that can be tied to an individual unit at the product-level. It may include part data, photos, functional tests, or inspection information. Ideally it will include a data thread that starts with suppliers and extends through to return centers.
- **Process data** is information about the operation of machines on the line that can indicate when maintenance is necessary and prevent line downtime - this is rarely the most relevant data type in modern electronics manufacturing, where manual assembly predominates.
- **People data** is information related to the human activities, typically assembly steps. This may include shift information or live video of the assembly line.

When scoping your data strategy, it's important to consider what data may be relevant to diagnosing issues at a later date, keeping in mind that you probably don't yet know what is likely to go wrong. Err on the side of collecting complete data sets, and leverage algorithmic learning to find the signal in the noise.



What is product data?

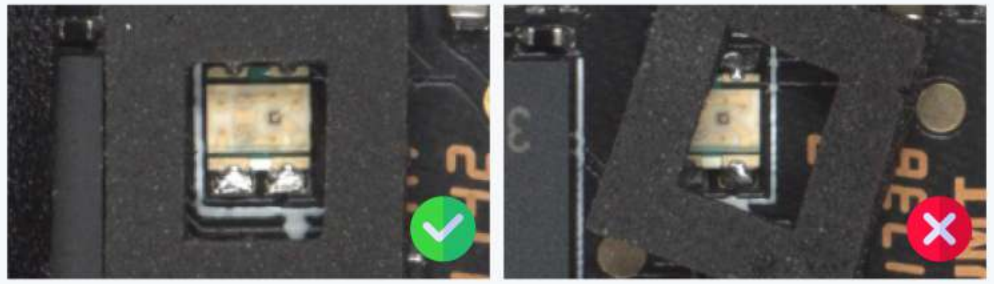
While most data collection technologies for the last two decades have focused on **process data,** this is rarely the most relevant data type in modern electronics manufacturing, where manual assembly predominates. In new product development and optimization, product data tends to be far more valuable.

Product data includes visuals, functional tests, measurements and parametric data captured for each unit. In order to optimize a specific program, we believe the first and most critical piece of the product data puzzle is high resolution images of your devices at critical junctions on the line that can be linked to product tracking systems. This is a new concept in manufacturing enabled by advances in technology, connectivity, and data storage. These photos are useful in many ways that tie into your data analysis toolkit.

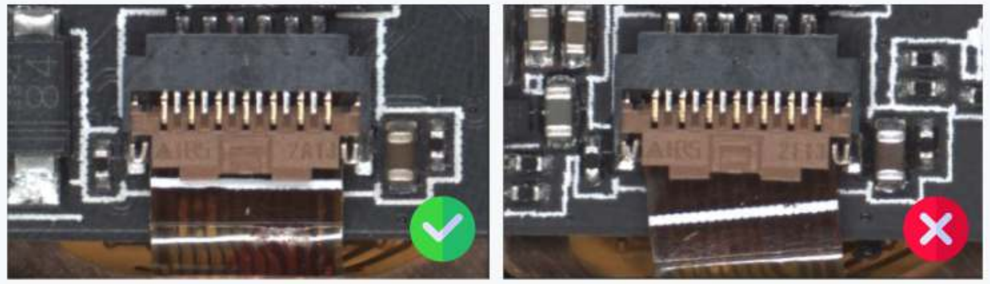
When diagnosing issues in electronics manufacturing, the most relevant data is typically product data - that is, information that is associated with the units themselves. This includes:

- Historical photos of every unit at every key transform
- Functional test results & Metrology
- Custom data sources such as metadata about when the unit was produced
- Return center data (for production programs)

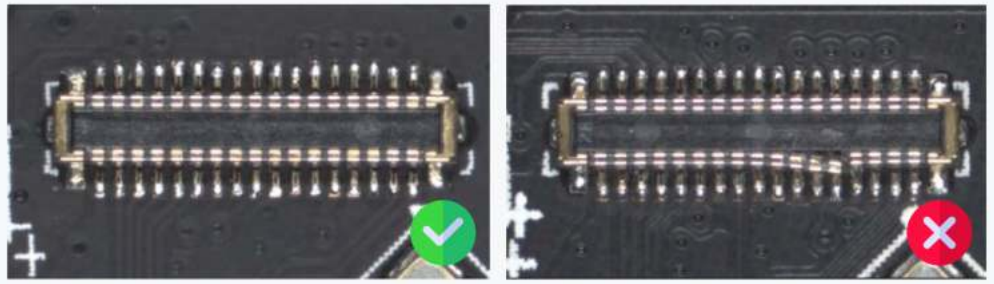
Shifted gasket



Unsecure ZIF connection



Damaged B2B Pins



Examples of *product data.* These are images of specific units and can be tied to other data streams vie a single serial number.

Data access across the supply chain

Paying lip service to optimization is not enough. To truly optimize, you need buy-in from not only your internal team, but also your external partners. Have you ever asked your vendors who is responsible for a problem, only for them to point to another vendor? Instead of a useful discussion, this abdication of responsibility often just delays the work needed to find and solve issues. One of the biggest causes of this is the knowledge gap between teams. How often has information been presented to you that you have been skeptical of? Until you yourself performed the measurements, there is a natural inclination to discount data from untrusted sources. Tools cause issues in two ways:

- **Single Purpose Tools:** Analysis tools like Excel and Minitab are useful for solving problems but terrible for communicating results. Because they are independent documents, each copy of a spreadsheet can be modified or revised without anyone else knowing.
- **Data Silos:** Data at one vendor is not often shared with another vendor and it becomes incumbent on engineers to find and organize the available information. This is a sisyphean task as new data is constantly created and needs to be sorted.

In a classic example of a data mismatch, a supplier might measure their parts at their outgoing quality inspection and send a report with their shipment. A manufacturer may measure samples of the lot at incoming quality on a different machine and in a different way and come up with a different set of values. Who is right? Should the parts be rejected? Who is responsible for resolving the dispute?

Instead, imagine a world where everyone has access to each other's data, use the same tools, and can follow along as the supplier and the vendor measure parts. The finger pointing can fall by the wayside as the teams come together to resolve problems. What's stopping you from achieving this vision?

Aggregate data in a single, accessible system

Good data by itself does not lead to faster outcomes. What you really need is a way to transform that data into timely actionable tasks to prevent or solve issues in real time. You can do this through a manufacturing optimization platform that can aggregate all of your data and serve up useful ways to view this collective information.

- **Invite all stakeholders to the platform.** Giving everyone access to the data means getting their data into the system and the ability to access relevant information from the system.
- **Link data by serial number.** As parts are assembled to a device, link the serial numbers together to the unit to create a log of every operation and configuration used in a particular device.
- **Ensure unfettered access.** The platform should be accessible by domestic teams and those abroad especially in China which limits some traffic to popular sites through the Great Firewall.

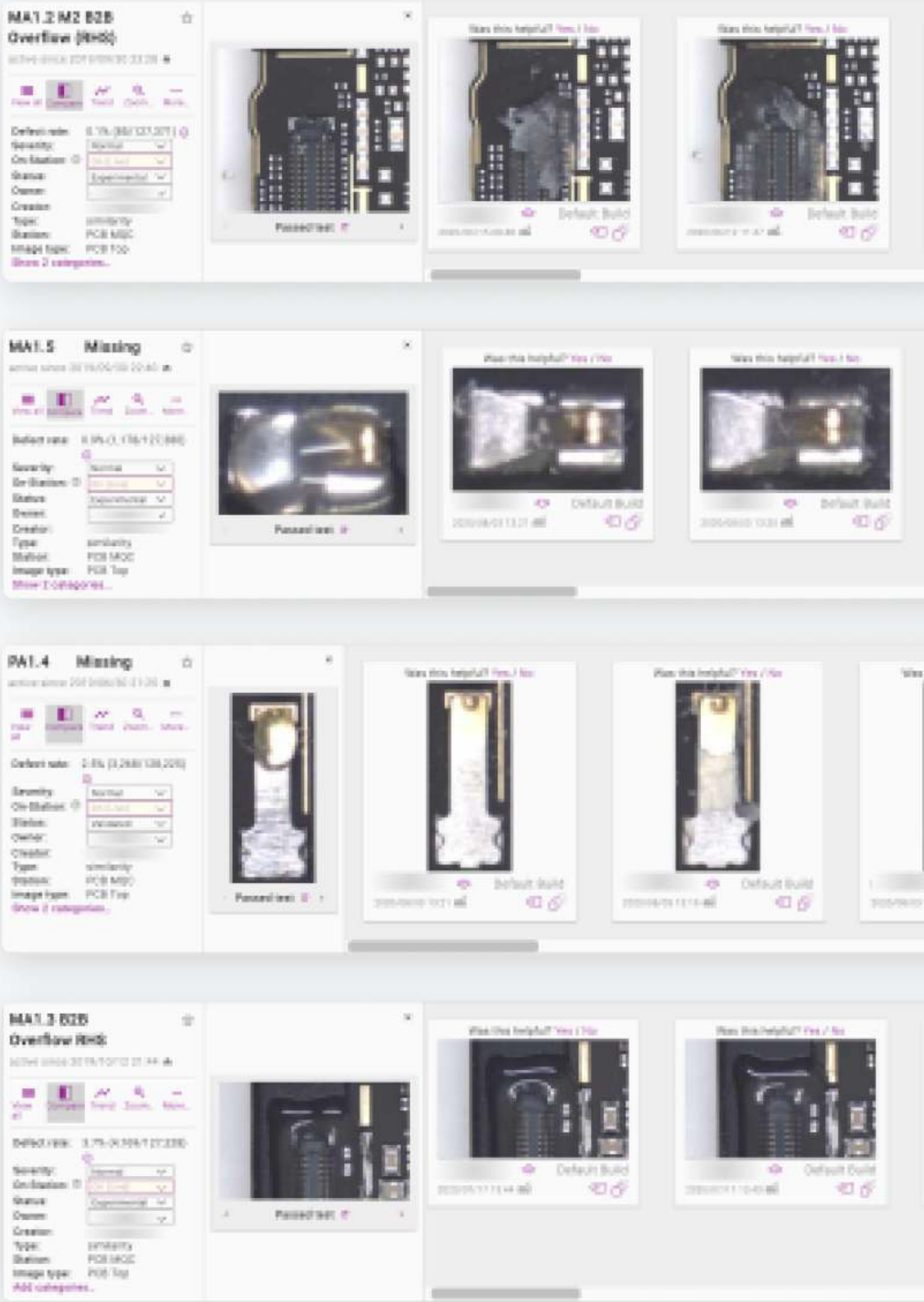
This allows you to regain the time and resources you would have spent chasing down vendors, deciphering between different revisions of a spreadsheet or document, or formatting the data into another tool to run analysis.

The importance of serialization

Serialization and other methods of traceability are critical to speeding up failure analysis and unlocking further manufacturing optimizations. It does this by adding useful metadata about each part and where the part is used in your assembly process.

- **Serialize all critical parts.** Serial numbers encode important information such as the date and time of manufacture, the vendor name, configuration.
- **Record serial numbers at critical junctions.** As parts are assembled into a device, link the serial numbers together to create a log of every operation and configuration used in a particular device.
- **Access the records during failure analysis.** Use the metadata in each device record during failure analysis. Isolate anomalies associated with a specific part and find others from the same lot or that share the same characteristics.

It may seem like an onerous step to track each component, but when problems occur, serial numbers allow you to react quickly. Use them to assist you in making decisions on what to do with products built with parts from the same lot or find out how many devices may have been built in the same configuration.

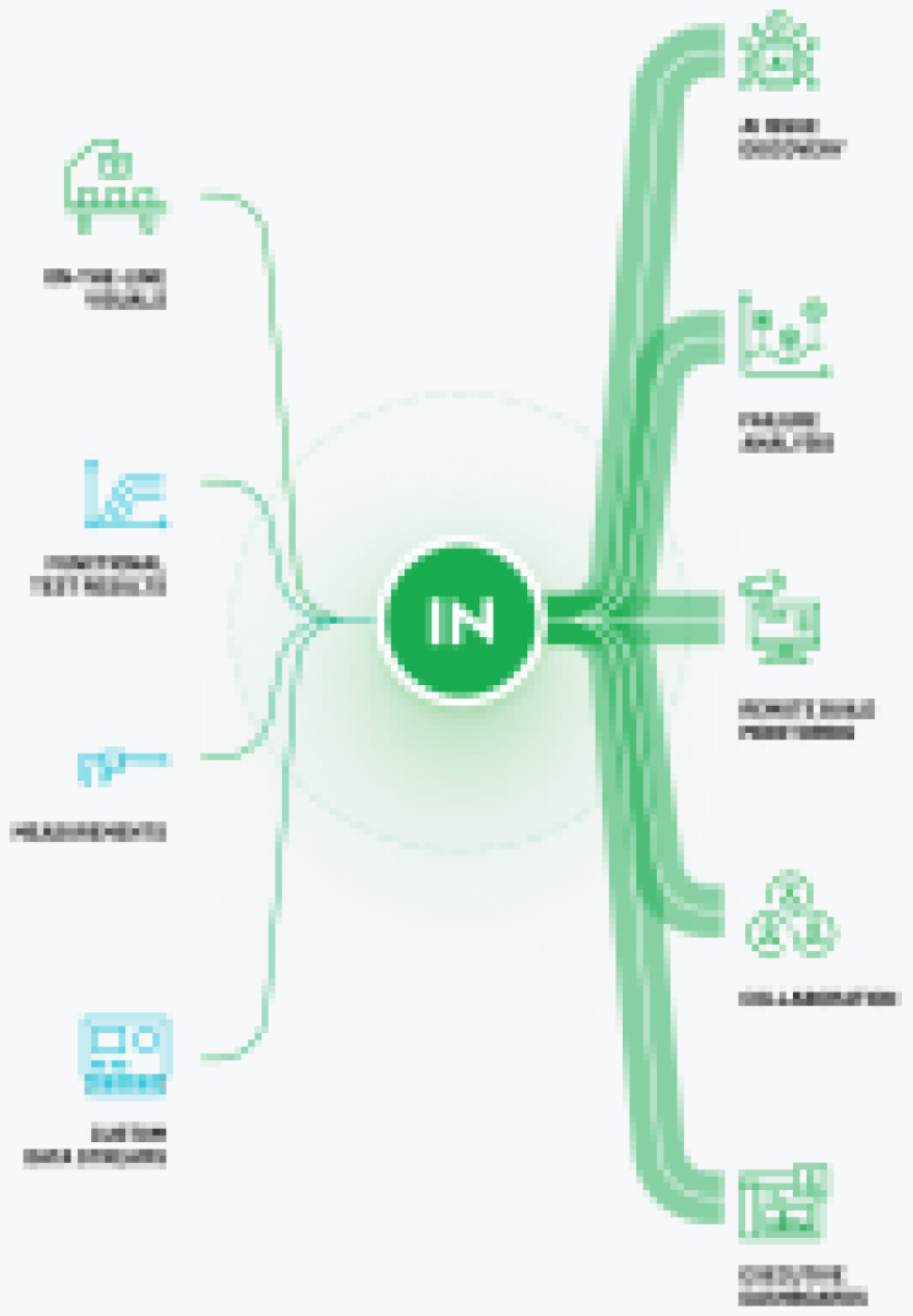


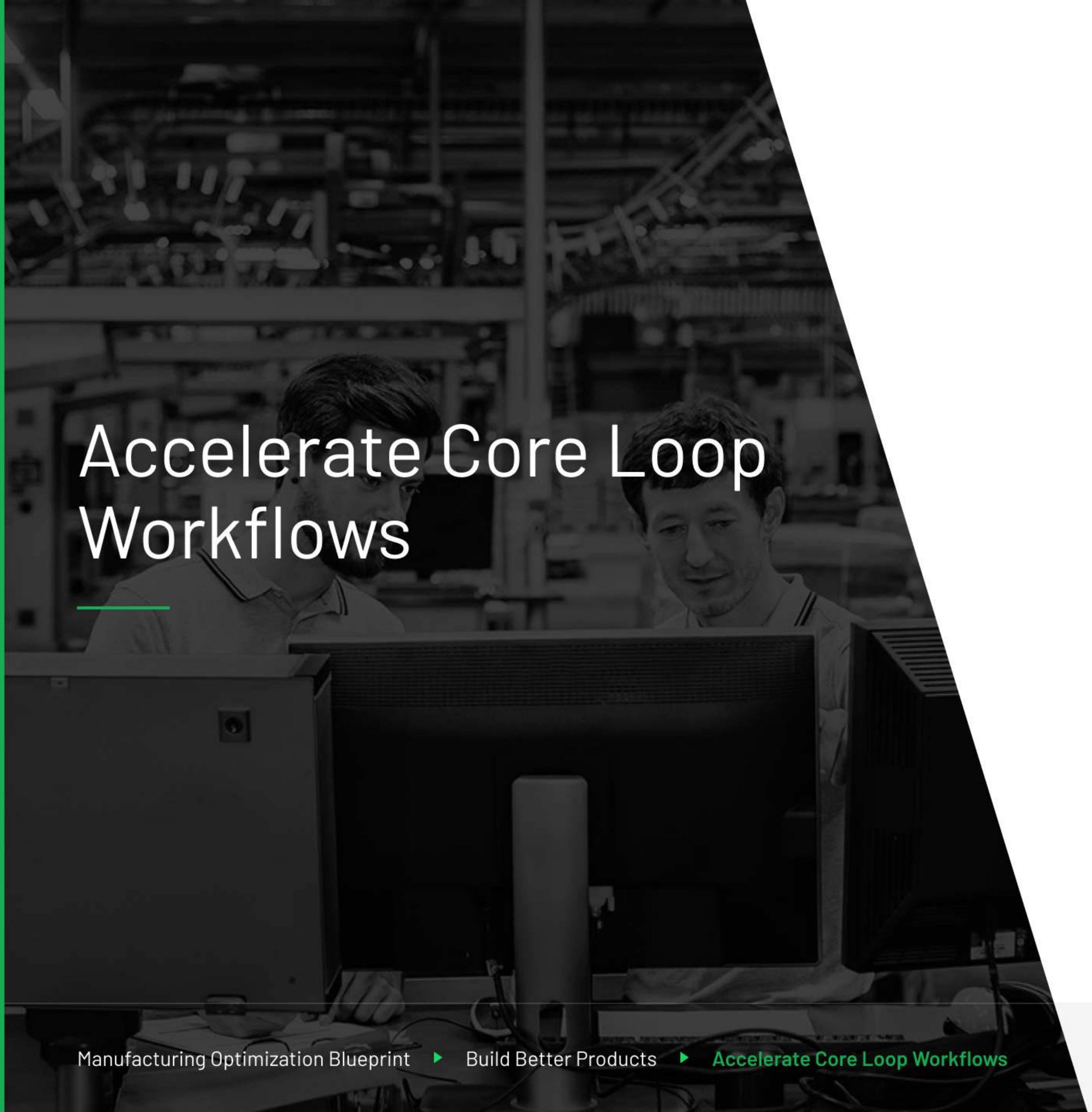
Images Source: Instrumental Manufacturing Optimization Platform

Unlock optimizations with an MOS

A Manufacturing Optimization System (MOS) is a collection of software components that work together to do four things:

1. **Wholly collect** data from key sources in the manufacturing process.
   - "Wholly" means for a given source, 100% of the data is collected without sampling, something that is a required foundation to enable the other steps to work
2. **Intelligently transform** that data using active algorithms.
   - Active algorithms constantly crawl datasets to identify shifts, trends, anomalies and other important data events
3. **Contextually present** this data in ways that are relevant, timely, and actionable.
   - The presentation needs to be widely available and accessible as there are many teams and people responsible for inputting feedback loops
4. **Close loops** in the manufacturing process.
   - An MOS not only pulls data but enables a push of an individual optimization across a singular process or the supply chain — enabling automated continuous improvement





Accelerate Core Loop Workflows

Ask yourself these questions:

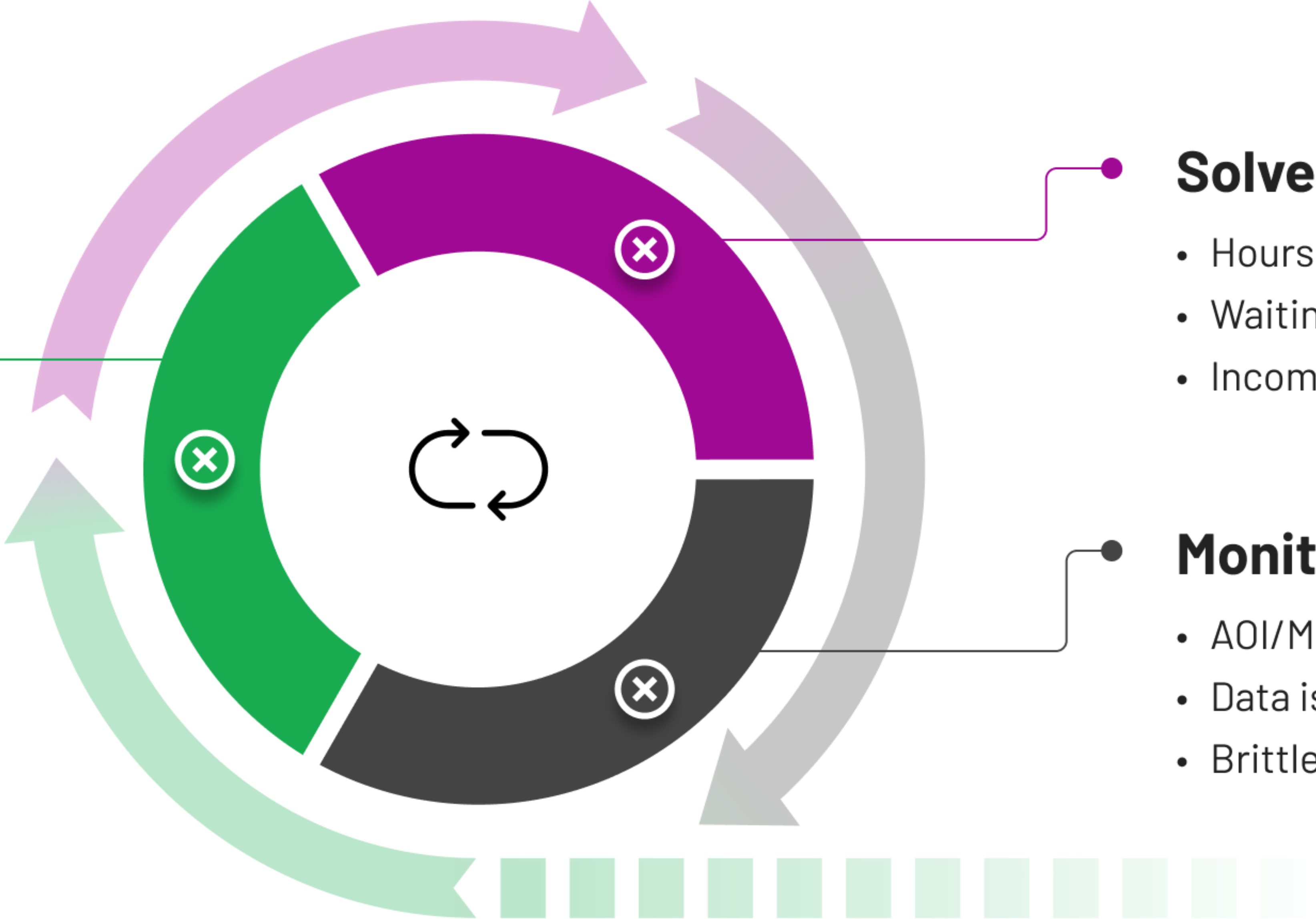
- Am I proactively solving every potential issue before they multiply?
- Am I solving multiple, overlapping issues at the same time?
- How can technology help me?

Market leaders must accelerate the Core Loop

Most programs today are limited by engineering bandwidth - but a manufacturing optimization platform like Instrumental can triple their efficiency without needing to add headcount.

Discover Reactive

- Happens too late
- Depends on people
- Functional tests miss unknowns



Solve Slow

- Hours of phone calls across goes
- Waiting on returned parts
- Incomplete data record

Monitor Static

- AOI/MV only finds known failures
- Data is on-prem only
- Brittle to changes

Every moment spent in development is a loss of market share

Programs rely on engineers to execute their problem solving loops to improve product quality. Aside from actual engineering time, the duration of each loop depends on how quickly issues can be discovered and solved. Traditionally, teams traveled to the factory hoping that they could catch issues by being on site. But even if they are on site, problems still frequently slip through. Instead, focus on how you can get your engineers working at top speed:

- **Automate issue discovery.** Without even knowing what to look for, machine learning algorithms can scan your product data for anomalies and automatically alert your team when an anomaly is discovered.
- **Engage your whole team, not just those on site.** With real-time product data uploads, you can make sure your whole team is aware of problems in the factory, not just those boots on the ground.
- **Eliminate the noise to focus on the real problems.** Instead of wasting valuable engineering time debugging every minor issue, finding issues faster means stopping the little ones before they fester and affect the whole build.
- **Reduce reporting time.** Reporting out to other groups can add up to hours a week of engineering time, and often create other work like decks and follow-ups. The key to speed is developing ways to more automatically keep stakeholders informed and direct suggestions toward the most useful challenges.

Without a relentless focus on optimization, delays are inevitable. Time is wasted when problems aren't discovered early enough to be dealt with before they escape into reliability tests or worse, customers. If in a given program there are more than a hundred core loops to complete, every few hours or even days you can shave from each loop can directly translate to shortened development time. Instead of waiting for reliability test results and performing destructive teardowns to chase down root cause, identify issues on the line before the product is closed up. This lets your engineers look for root cause at the source, winnowing minor problems from your major issues list.

Example of how to speed up a single issue

	Build Without Optimization	Build With Optimization
Issue Discovery	**5-14 Days** A problem at a test station is noted but can't be consistently identified. Reliability testing first identifies the issue 5-14 days after the completion of a build.	**Immediate** A problem at a test station is identified and linked via product data to anomalous photos from one upstream subassembly. A notification is sent to the DRI immediately.
FA & Solution Validation	**Days or Weeks** To find root cause, the device is disassembled and analyzed by engineers. Additional information is found by searching through their email to review dimensional reports and test station data. Ultimately, it's determined that the SOP needs to change.	**Hours** Engineer is alerted to the problem and reviews the image data as well as the test results side by side. An issue with the assembly process is found and the SOP is updated to include a check for the issue. Subsequent devices are monitored for the issue through product images the engineer reviews in real time.
Escapes	**Broad Quarantine & Scrap** All devices built during this build could be susceptible to issues. Team must determine whether units should be discarded if they cannot retroactively diagnose the issue.	**Minimal Quarantine & Scrap** All devices with similar upstream anomalies are quarantined for rework, but the rest of the build was defect free for this issue and could continue.

Automate issue discovery and alerting with tools

Many early Digital Transformation initiatives focused on collecting massive amounts of data from factories. The problem is that no human engineer had time to sift through all of that data, and most of it was siloed and hard to access. The new wave of Artificial intelligence (AI) and machine learning (ML) algorithms can now make real-time use of this data to find problems before you know what to look for.

Machines are the perfect tool for looking through mountains of data to find anomalies. They don't get tired or bored, and can continuously analyze information, updating their algorithms as new data comes in.

- **AI can surface anomalies automatically.** By comparing visual data, computers can be trained to highlight differences between known good units and unknown anomalies. Sample sets as small as 30 units can be used to baseline what a good or bad product is and this technology is getting better every day.
- **Engineers can focus on refinement and insights** to zero in on the most impactful anomalies and spend time on solutions instead of forensics.
- **Connecting multi-stream product data inputs to test outputs** represents the most advanced version of this workflow today.

How Instrumental Helps: Automated issue discovery tools like Instrumental's Discover AI can proactively identify parts or assemblies that are out of the ordinary. Engineers can be notified of issues immediately to evaluate the detected anomalies and make a determination on how to proceed. If they get the alert early enough, they could very well be on their way to solving the issue before too much time and material are wasted in a bad process.

Keep remote teams engaged by design

Most products are built far from their engineering teams, mainly in Asia with increasing geographical distribution. With both engineering headcount and development timelines contracting, it's often impractical to have engineers on site for entire builds. This means at any given point, your entire build schedule relies on just a small portion of your team being in the right place at the right time. With modern product complexity, there are too many places to look, and too little time to watch every device as it progresses through each step on the line. Bridge the gap between your team on the ground and those back home by:

- **Pushing alerts.** When a test fails or an automated system detects an anomaly, alert everyone in real-time. Set up a process or leverage an MOS to do this.
- **Sharing data.** Ensure remote teams have access to the same data as the on-site team so they can help with troubleshooting and failure analysis. This will require an internet connection in your factory, and a cloud data storage system.

If your engineers can't travel, then you could be losing even more precious time. You might rely on partners that don't know the design as well as your engineers to find issues on the line or you might only discover issues after reliability tests. Not to mention the added time as you wait for parts to be shipped back to teardown devices. Who knows whether the issue was from the line, the reliability test, or in transit to you. It's better to review the data in real time so everyone can help ask the right questions to solve the problem.

Retroactive discovery and failure analysis

Sometimes you discover an issue later in your development process and can't be sure if the issue was always there or if something changed in your parts or process. With product data stored on a single platform, you not only get the benefits of real-time data, but you can also look back retroactively. Some issues slip through even the best processes because you didn't know to look for them.

- **Revisit old data and make it work for you.** With product data you can review previous builds and look for an issue that was discovered later. Check if a scratch existed on a device before or after a test station to eliminate it from.
- **Virtual Teardowns.** If a device fails in reliability testing or several months later in beta testing, you can easily do a virtual teardown in seconds. Images of the device can be shown at each critical stage of assembly meaning you can see what the product looked like when it was built and compare it to what it looks like now. You don't need to open the unit or send it for an X-ray or CT scan.

Because this level of detail is recorded in high resolution, your teams don't have to try and piece together the circumstances of the build from their memories, but rather they can start from a direct understanding of what the product looked like.

The path to manufacturing optimization

Status Quo: Reactive	Innovative: Mitigation
Open loops: Things break and no one knows or knows it's fixed.	**Closed loops:** Real-time workflows discover issues earlier before it's more expensive to fix.
Single purpose tools: Multiple tools solve singular issues but do not communicate for a shared purpose.	**Cross-functional platform:** A single platform that enables many teams and solutions to work together.
Data silos: Lack of visibility into specific workflows or processes across the supply chain where data is either collected or could easily be collected.	**Data democratization:** End-to-end product data is available to everyone, which has a resolution higher than sampling for actionable, executive-level decision making.
High waste: Resources - people, time, money, environmental - are wasted resulting in a higher carbon footprint.	**High efficiency:** Design of experiment (DOE) - rework, experimentation, scrap, and manual inspection - costs are down, resulting in a smaller carbon footprint.
Unpredictability: Low resolution forecasting with expected launch delays.	**Transparency:** Predictable assessment or risk due to high data resolution across the product lifecycle.
Organizational misalignment: Poor operational alignment leads to Individual contributor impact over-amplifying failures without a correlative lift to successes.	**Cross-functional alignment:** Visibility and traceability for multinational teams which eliminate friction and conflicting objectives.

Expert

Build Better Supply Chains

Nailing continuous improvement through culture and technology.

Building good supply chains starts with alignment

Lower margins, late shipments, and mistrust with suppliers: these are the "unoptimized" results of misaligned incentives within a supply chain. Combined - this amounts to billions of dollars lost every year for the electronics manufacturing industry. Organizational leaders need to focus on people improvements alongside product and process improvements in order to recapture this lost capital.

In order to build a truly great organization, relationships between business partners and internal departments need to be optimized which can only be done when you understand where and why the friction manifests. The largest sources of misalignment (and loss of revenue) lie in the following relationships:

- Brand goals and CM goals
- Brand goals and Supplier goals
- Team goals within Electronics Brands

The good news is that this is a challenge that Smart Manufacturing and Industry 4.0 are already mitigating. The bad news is that these are only tools that can collect the data necessary to unblock process change - not drive people change. Aligning incentives is a cultural shift that requires an understanding of goals across business units, leadership, and individual contributors and the relationship between.

Misaligned incentives cost electronics manufacturers **billions annually**, but Industry 4.0 can help.

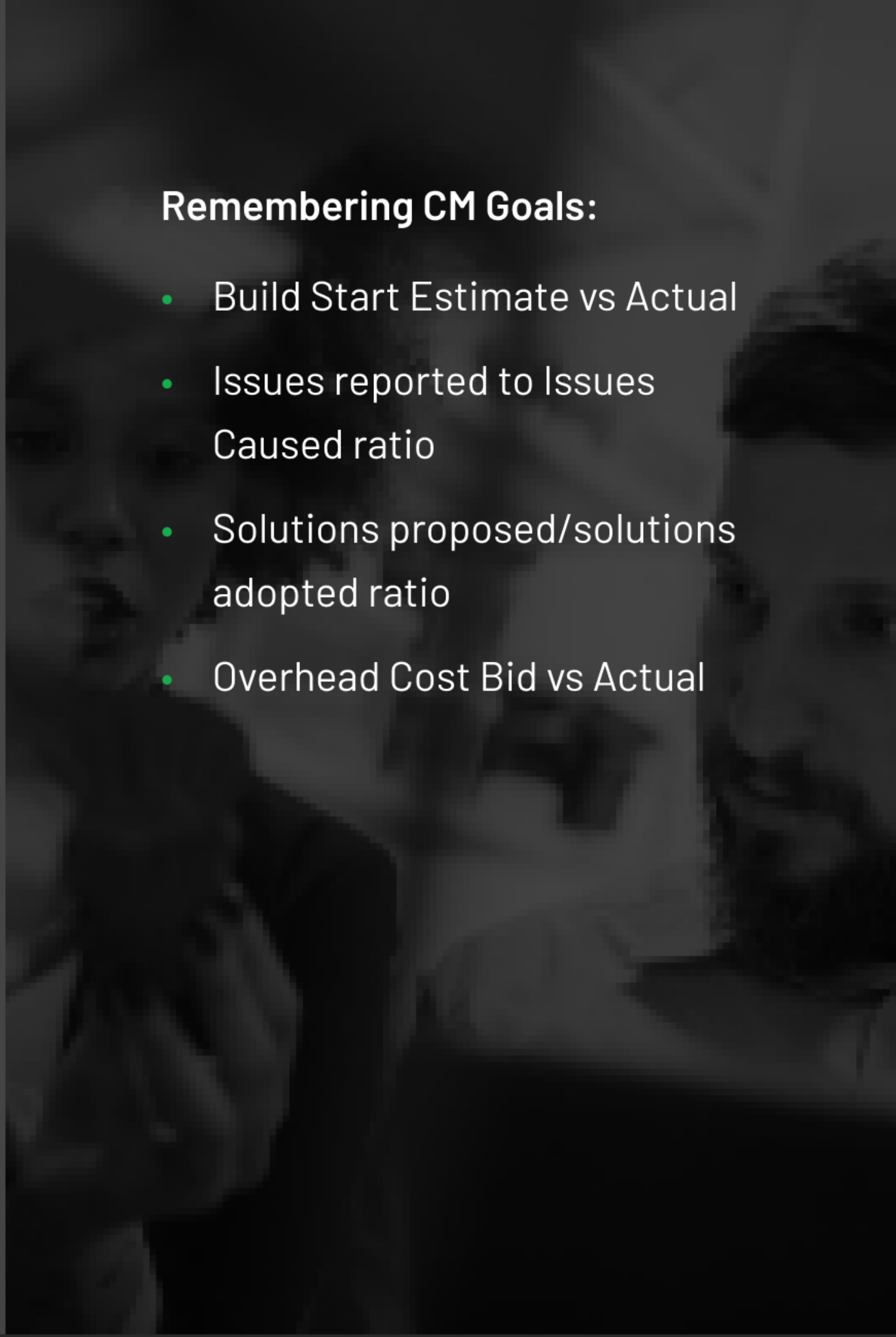
Misalignment between brands and manufacturing partners

The most important relationship in electronics manufacturing is between the Brand and their Contract Manufacturing partner (CM). The misalignment in this critical relationship stems from somewhat different goals: Brands want to ship the best product that will delight their customers; CMs want to transform the product as cheaply as possible without causing returns.

Most misalignments are cemented in the commercial negotiation of the partnership itself. Due to high competition, there's a lot of price pressure and margins are typically between 3-12%. This means that CMs are often underbidding with the primary goal of optimizing the process to make up the margin - but aren't always successful. If CMs bid too low, they could get stuck in an unprofitable arrangement with strong incentives to cut corners and reduce costs.

Many business agreements focus only on the cost of transformation and at what final yield. Manufacturers want protection if the end product ends up being too difficult to manufacture, brands want protections if the yield is too low due to workmanship issues. Who pays for yield fallout (units that don't meet the specifications to be shipped), who pays for rework, who pays for returns, how headcount is charged, who will bear the investment cost of automation, etc.

The lack of ownership is hurting both sides.



Remembering CM Goals:

- Build Start Estimate vs Actual
- Issues reported to Issues Caused ratio
- Solutions proposed/solutions adopted ratio
- Overhead Cost Bid vs Actual

Aligning brands and manufacturing partners

The best manufacturing leaders are seizing the opportunity to rebuild the relationship between the brand and their CM in a new paradigm that is collaborative and win-win. They are drafting commercial agreements that share the gains for improvements, so that both sides are incentivized to ship high quality products.

As you draft your next commercial agreement, consider eliminating rote policies in favor of something new. A common error is to establish the cost of transform as a "price per headcount" on the assembly line — but agreeing to this is a sure-fire way to end up with zero automation and lots of extra inspections or steps you might not need.

Another error is to negotiate rework as a flat fee per unit reworked, instead of the actual cost of the specific rework — or worse, as a flat percentage of all units made (i.e. 10%). This means there's zero (or even negative) motivation to improve the rework rate below 10% because there's no savings to be gained.

What these standard errors fail to consider is how much cost would be avoided altogether if groups were incentivized to share their data freely with the goal of optimizing and without the fear of punitive costs. A cultural shift is required to bring down the data silos and build transparency for both sides.

Transparency won't be accepted if it means lost money for either side.

Misalignment between brands and suppliers

Similar to CMs, suppliers also exist in crowded ecosystems, so in order to beat out competition, they are incentivized to bid low, and then try to make up additional margin with great execution. When pressed with misaligned incentives to cut costs or win business (which may not be awarded until mid-development cycle), they might cherry pick parts in development builds to make their manufacturing process appear more stable than it is.

This process of pre-screening parts is possible when the requirement is for 30 or even 500 pieces – but quickly breaks down as volumes ramp up. If they have been squeezed for low prices, suppliers are incentivized to not throw bad parts out, but instead to “sneak” them into future part shipments later on, where Acceptable Quality Limit (AQL) or First Article Inspection (FAI) processes are unlikely to find them.

This puts the burden of rejection on a downstream supplier or CM, and often creates preventable downstream failures that consume time and energy to analyze.

Remembering Supplier Goals:

Component Vendors

- Estimate vs Actual Part Delivery Schedule
- Measurement data provided on time
- Dimensions out of spec per build
- IQC to OQC Failure ratio

Service Vendors

- Deployment Time Estimate vs Actual
- Uptime
- Service Calls
- Training

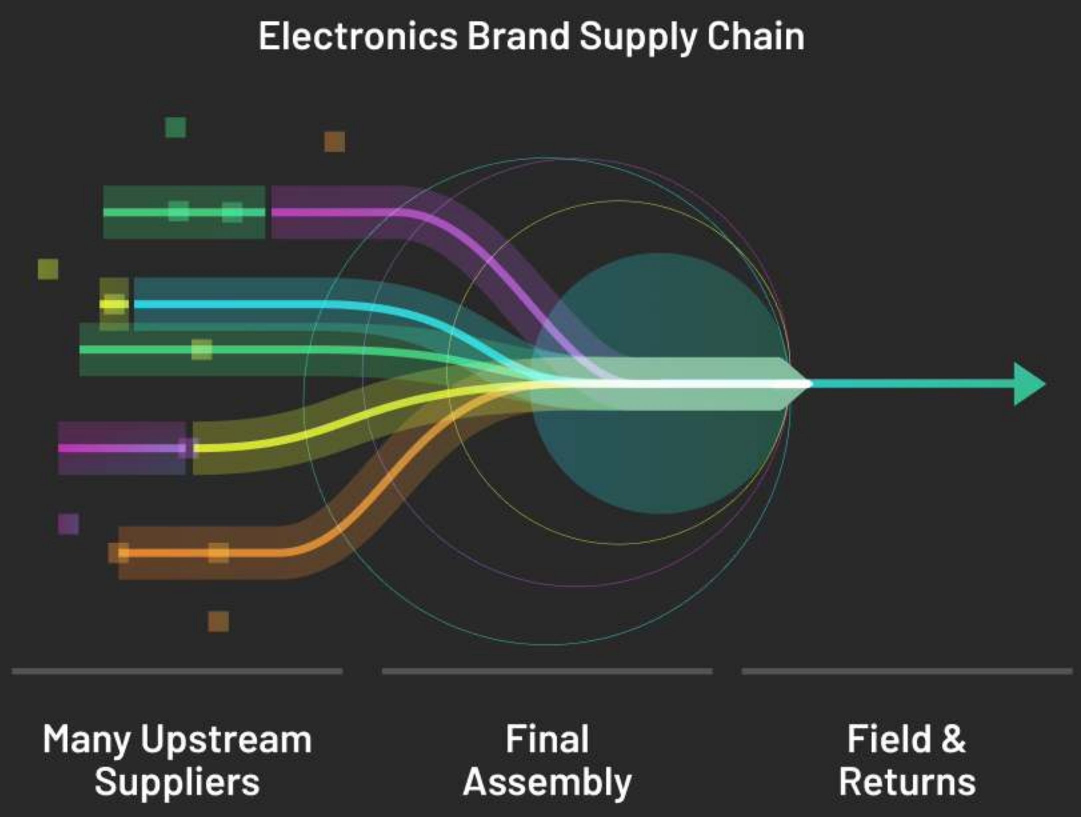
Aligning brands and suppliers

The only way out of this problem is for brands to build a culture of collaboration and transparency by leveraging tools that enable automated aggregation of data across the supply chain. Why the brand? Because their name is on the final product - and they will pay the price for the early failures in the field and poor reviews that will impact sales.

Since brands and suppliers create a one to many relationship, setting up automated tooling must be driven by the brand because they are the owner of each touchpoint. As such, brands should fully expect to set the vision for and to bear the costs associated with leveraging Industry 4.0 data technologies.

While this may seem counterintuitive: most Industry 4.0 technologies are marketed around “productivity gains”, and therefore seem firmly in the purview of the suppliers. The core advantage, however, of many Industry 4.0 technologies is actually in data aggregation — the “digital thread” of data representing a product’s journey through the supply chain — and the corresponding power of collaboration possible when everyone has real-time access to the same, actionable information.

Who helms the supply chain of command?



The **brand** is the common thread among all of the suppliers - and therefore owns the problem.

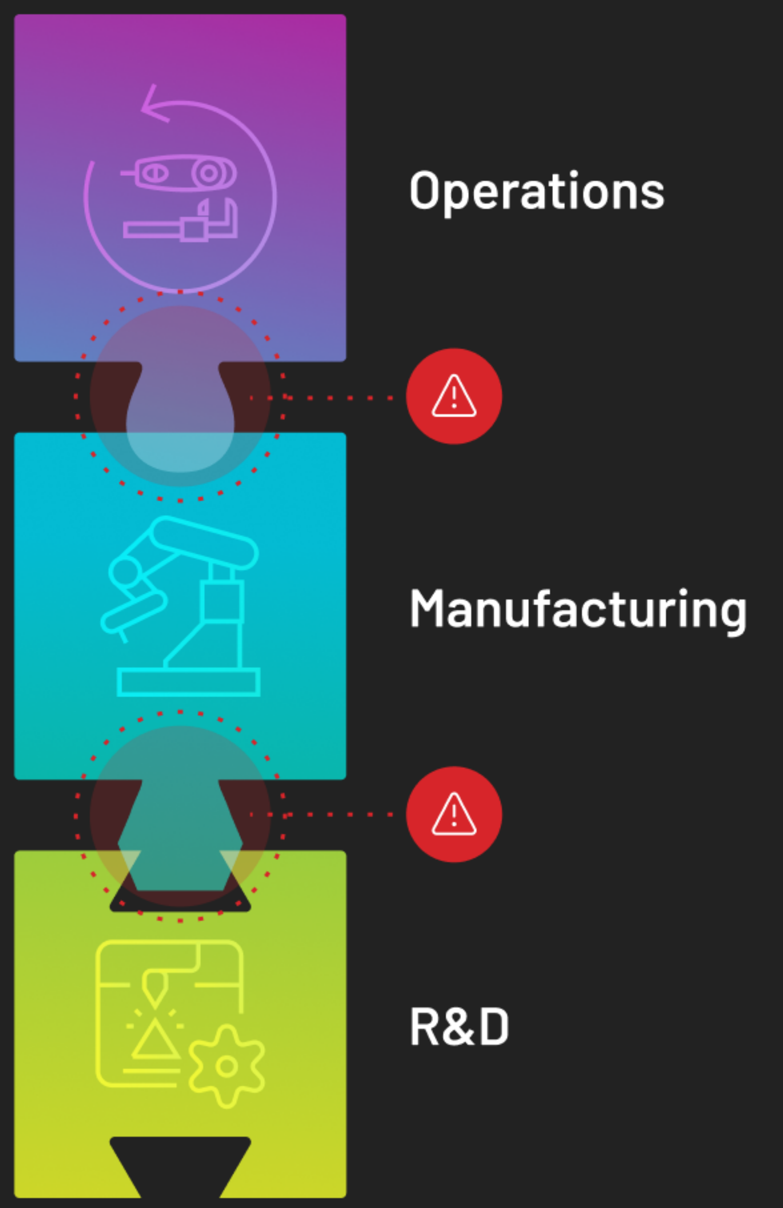
Misalignment within electronics brand teams

Some of the worst misalignments in the industry happen inside the brands themselves even though everyone is wearing the same badge. Even though brands want to deliver high quality products that delight customers, siloed, and competing, teams within brands often do not share data or metrics willingly.

For example, most companies have different reporting chains for R&D and Operations and Manufacturing teams. The R&D team is charged with delivering a product that meets the specifications, and a process that's been proven out on at least one line, by a designated date. Operations and manufacturing teams are often incentivized to improve margins by reducing the cost of transformation. Typical tools in the toolbox include negotiating lower costs from suppliers and removing human headcount from the line, either through combining or eliminating steps or replacing them with automation.

The problem is that both incentives are "open-loop": they influence each other and the business, but since neither side owns a KPI downstream of their part of the process, both can make decisions that result in great team outcomes, but poor business outcomes.

Disconnected teams will never win



Aligning people within electronics brands

There are many misaligned incentives hiding within organizations that only leadership can untangle, but often don't rise to their radars. The core takeaway is that all organizations have misalignments and inefficiencies where manufacturing technologies could have outsized impact – if you don't think yours does, it's probably because you aren't measuring them, not because the problems don't exist.

- This is usually because there is no end-to-end product ownership.
- Most companies have no data to identify the direct relationships between decisions made upstream or early in the process and their true downstream impacts.
- Companies struggle to identify the return on investment for digital transformation technologies because they lack the basic data to even identify the scale and scope of their problems.

In the cultural shift that will happen in parallel to digital transformation, the most visionary leaders are completely rethinking incentive structures within their organizations – tying in downstream KPIs like return rates, customer satisfaction, and Amazon stars with the more traditional KPIs of on-time delivery and improving margins over time.

The most visionary leaders are tying traditional KPIs like on-time delivery and margins to downstream KPIs like return rates and customer satisfaction.

More Ways to Drive Internal Alignment

Ask yourself these questions:

- Do your cross-functional teams share a single set of KPIs?
- Do your teams have conflicting KPIs which are measured in distinct siloes?
- How often are teams communicating their needs, obstacles, goals, and benchmarks with other teams? Is this process automated?

Understanding goals for leaders and individuals

Leadership goals:
Profitability and market share

Individual goals:
Hitting yields on line 1 by target date

Remember to understand each individual teammate's goals. While everyone is driving to the same outcome, their individual goals might not align with your expectations or team goals.

Executive Leadership:

- YOY Revenue Growth
- Margin
- NPS
- Marketshare
- Daily/Monthly Active Users
- Repeat Customers

Engineering Manager / Team Lead:

- Overall Defect Rates per build
- # of delays per project
- Estimate to Actual Ratios for Tool Release
- Reliability test failures

Mechanical Engineer / Product Designer:

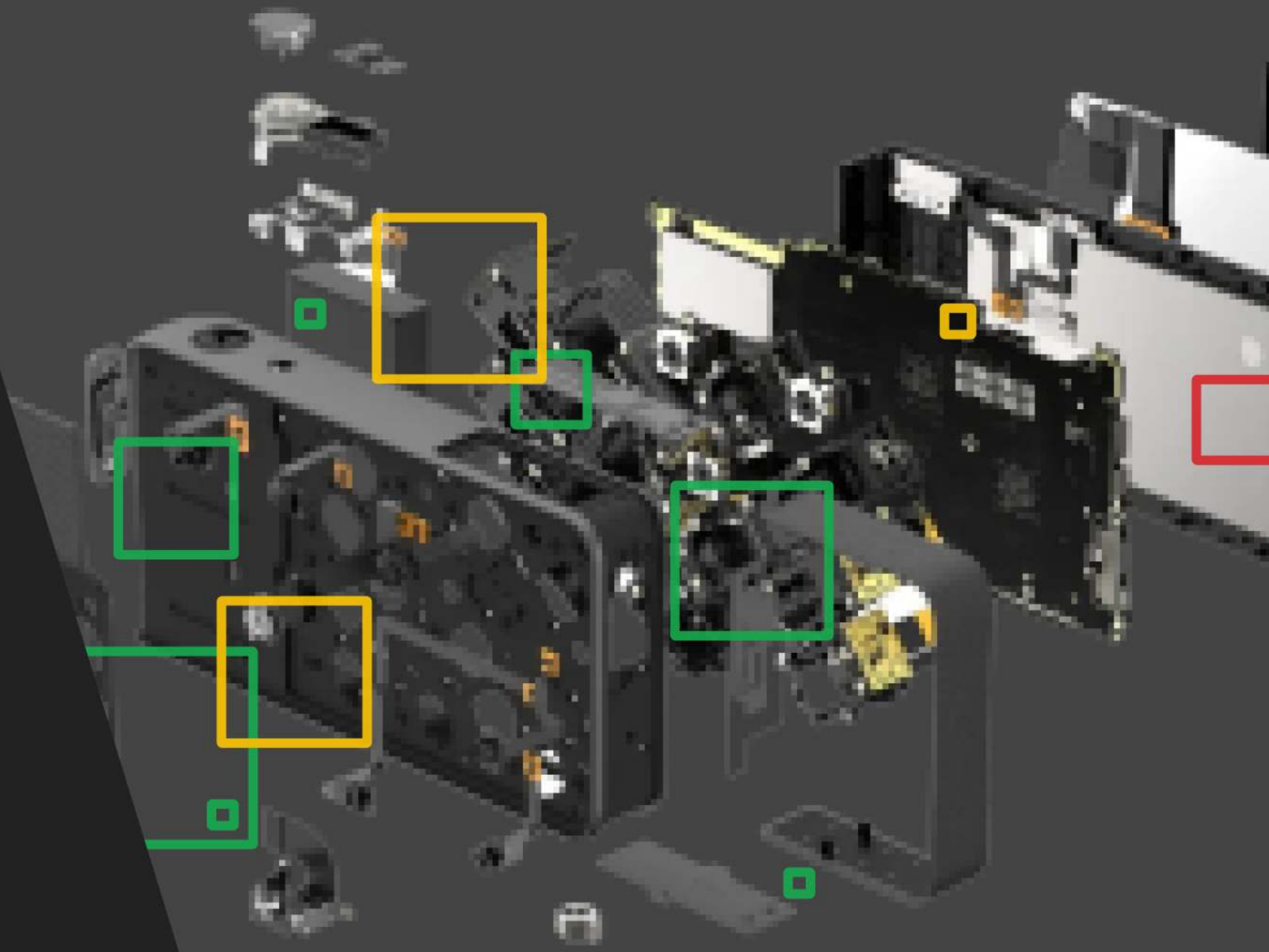
- % of Parts released on time
- Tolerance analyses created
- # Issues solved per build

Operations Lead:

- Development Budget Estimate to Actual Ratio
- Quarterly Cost reductions
- Length of downtime

Real examples of manufacturing optimization today

How Instrumental is helping three top brands get to market faster.

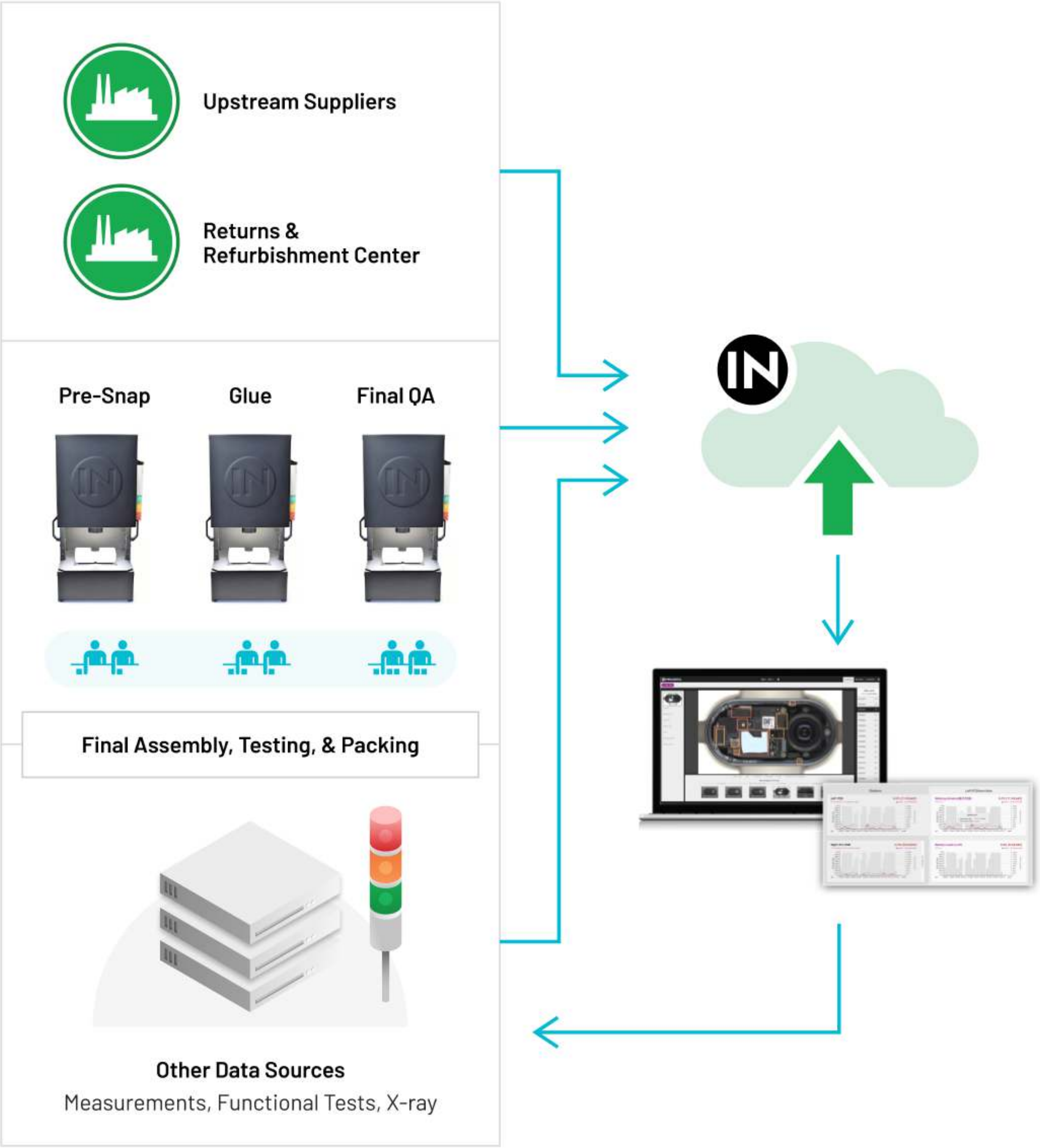


What is Instrumental?

Instrumental is the first **manufacturing optimization platform** to bring all of your product data together in a single, traceable, remote record to accelerate proto-to-production. With Instrumental, you can automate issue discovery with AI, provide a unified platform for fast FA, expedite time to issue resolution, and deliver full build and issue analytics to team leads and leadership. Our AI requires **only 30 golden units** to begin capturing both new and known issues which your team can analyze from anywhere on the globe.

How does it work?

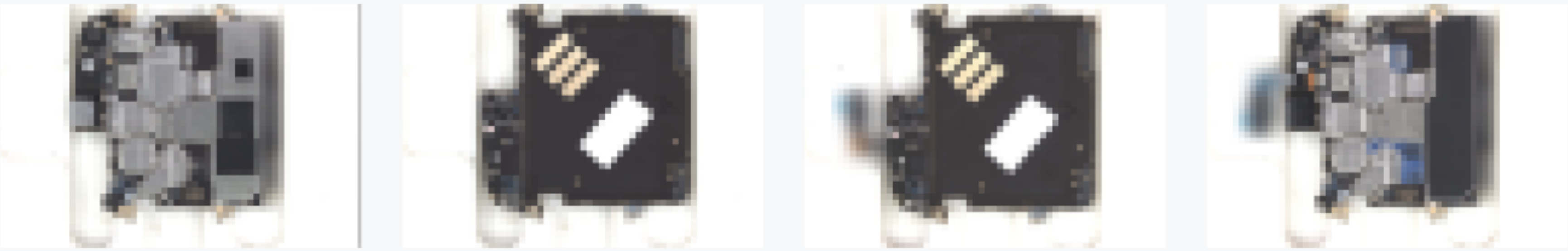
- Deploy collection points and data stream integrations in under 4 weeks.
- Pipe all of your product data into our secure cloud.
- Login to the webapp where our AI automatically surfaces every new anomaly in your builds, every day.
- Use simple views to figure out when and why the issue started.
- Use build and defect monitors to understand progress and report up the chain.
- Manage live pass/fail tests from the same simple interface - as many as you want!



Achieving $1/unit savings with real-time defect detection

The Lenovo team used Instrumental's flexible AI to detect issues with the time-of-flight gasket. This gasket is necessary to allow the device to turn off the touch screen when the user holds the phone up near their ear. Due to the Razr's design constraints, the gasket is difficult to assemble and can sometimes fall off during the assembly process. The Lenovo team used Instrumental's algorithms to intercept shifted and missing gaskets.

Without Instrumental, the Lenovo team would find these gasket defects at a functional test station for the sensor near the end of the line. Given the design of the Razr, the rework required for units that fail at this functional test is particularly challenging and expensive. Finding defects early, when they are very inexpensive to fix, was a major win.



Lenovo used strategically placed stations in production to ensure defects could be detected and intercepted upstream – ultimately reducing rework and scrap costs.

Lenovo™

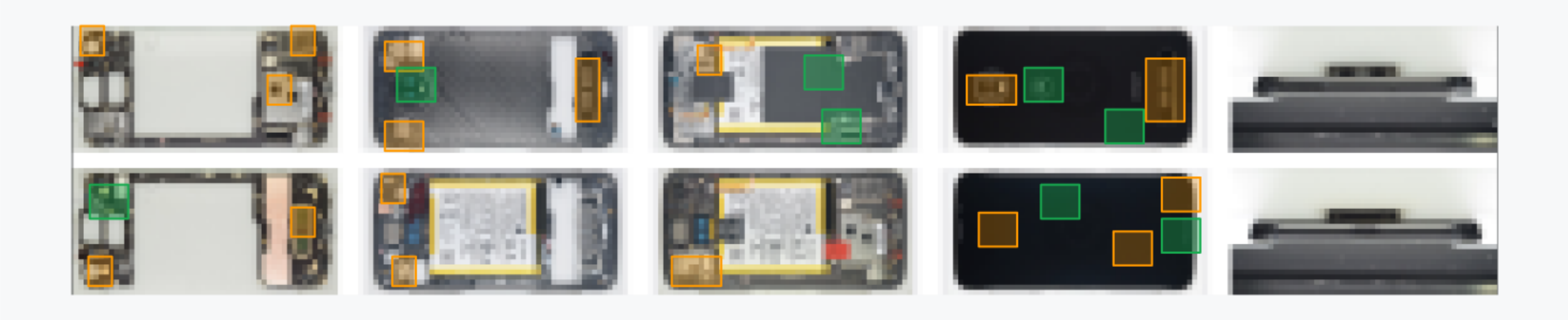
- **~$1/unit Savings** via reduced rework costs
- **Remote line management** With tests & real-time data
- **50% reduced rework** By finding issues earlier on the line

Based on the business case for the Motorola Razr program, Lenovo has continued and expanded its partnership with Instrumental. We look forward to continuing to incorporate smart capabilities into Lenovo's supply chain, enabling their teams to build better products with better processes and improved bottom lines.

Accelerating product maturity by closing more loops, earlier in development

As a leader in the consumer electronics space who set the foundation for today's best practices in NPI, Motorola believed Instrumental technology was an opportunity to eliminate the cost and inefficiency of finding and resolving issues in development, while delivering an even better end product to their customers. With Instrumental, they sought to discover issues faster, strengthen quality control on the line, and streamline their issue response to deliver new products on demanding schedule timelines.

Instrumental has inspected every development and pre-production unit on seven Motorola mobile phone products, with more planned. Instrumental's machine-learning algorithms regularly identify dozens of unique and new issues on each program, and when combined with known issues the Motorola team is tracking, results in tens of live Intercept tests. Since these algorithms are so easy to use and to validate, Motorola usually has its first Intercept test running on a new program within a week of deployment.



Instrumental captures images at key states of assembly as the phone moves down the assembly line.

motorola
A Lenovo Company

Setup Requirements

- Only **30 golden units** needed
- < **30 min installation** - no training required
- **No custom programming** or tuning

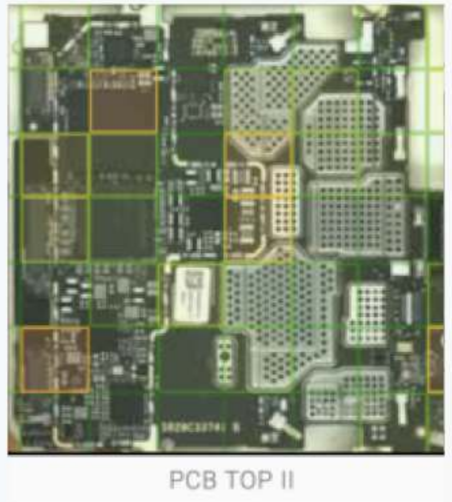
"Programs that used Instrumental during development ramped faster than products that did not use it."

Lyon Wang
Director of Engineering & NPI

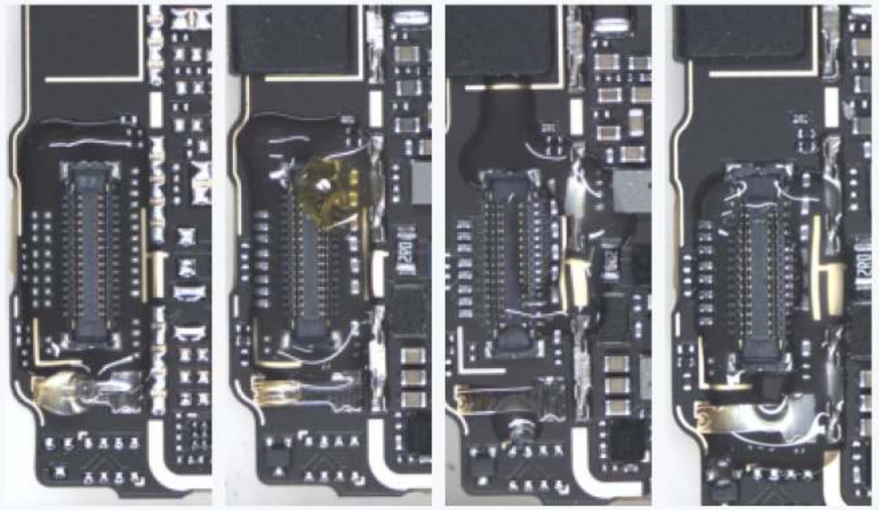
Unlocking product innovation with process innovation

When P2i, a global leader in liquid repellent nano-coatings, discovered that their existing manual quality assurance process was leading to critical escapes downstream in early development, they knew they needed more than manual inspection.

P2i partnered with Instrumental to overhaul their approach to issue discovery and prevention end-to-end. Instrumental technology made it possible for them to discover, characterize, and intercept 78 different issue types during development and production. The technology enabled continuous, remote process improvement through more complete data and the ability to fine-tune quality control tests remotely.



P2i used Instrumental Discover to automatically identify new defect types



P2i used Instrumental to dial in process defects like contamination, handling issues, and registration shift.

PROTECTED BY P2i

Process Results

- **Eliminated** downstream issues
- **50%** reduction in inspection headcount
- **300%** engineering efficiency gain, while remote

100% validation
Instrumental's data helped us to improve our processes, resulting in better parts. They also improved our inspection practices, allowing us to move away from unreliable and expensive operators to trusted, 100% validation."

Neal Harkrider
COO

Conclusion

Conclusion

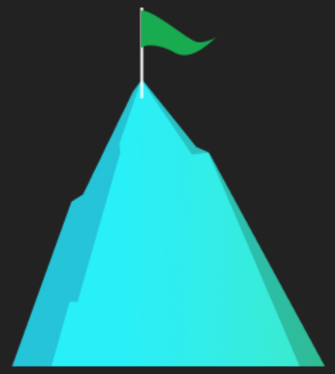
Throughout the 20th and early 21st century, manufacturing evolved as companies sought to reduce waste and increase efficiency on their long-running production lines. New manufacturing practices such as just-in-time delivery and lean manufacturing were big wins to reduce a lot of the overhead and carried costs associated with production.

In recent years, technology has changed so quickly that brands have had to shorten development timelines and release new products more often to keep up with the competition. As a result, traditional production-only optimization is no longer the opportunity it once was - and brands who want to win back their markets will need to reassess their existing processes.

While 53% of 2020 programs were canceled, 100% of Instrumental customers shipped. We attribute this resiliency not to Instrumental, but to a commitment to a culture of continuous optimization across the supply chain.

At Instrumental, we are redefining manufacturing optimization to mean using data and technology to make your product development better, faster. This means getting faster at finding defects, faster at validating solutions, and faster at maturing products so you can get them into customers hands sooner. Oh, and by the way, optimizing early in the process makes overall development costs way cheaper too! If you want to see how we're building better ourselves, connect with Instrumental to get a demo of our newest features.

Traditional Goals:



- **Reduce Production Costs**
- **Increase Yields**
- **Less Overhead and Returns**

Visionary Goals:

- **3X Faster Development Cycles**
- **Sustainable, Ultramodern Processes**
- **Happier Customers and Employees**

Instrumental's vision from CEO and Founder

Anna-Katrina Shedletsky

I spent nearly six years at Apple working in one of the most admired supply chains in the world. I realized that manufacturing is an incredibly inefficient process and that I never had access to the data I needed to discover and solve problems quickly. It's not.

That's why I founded Instrumental. I wanted to build a platform for engineers by engineers to help make their lives and products better. By consolidating AI-powered defect detection, remote failure analysis, and 3rd party data streams into a single hub, Instrumental is helping our customers thrive when all bets are against global manufacturers in a post-COVID world.

Our mission is to eliminate both rework and guesswork from the art of product engineering and inspire better, more sophisticated designs generation after generation.

Accelerate development and continuously improve production from anywhere.

Instrumental's manufacturing platform transforms data captured on assembly lines into insights that increase speed, reduce costs, and improve quality. Instrumental is trusted by Fortune 500s to empower their teams to ship on time and avoid delays.

Email us at sales@instrumental.com to learn more.

Thank You.

INSTRUMENTAL | Build Better

sales@instrumental.com