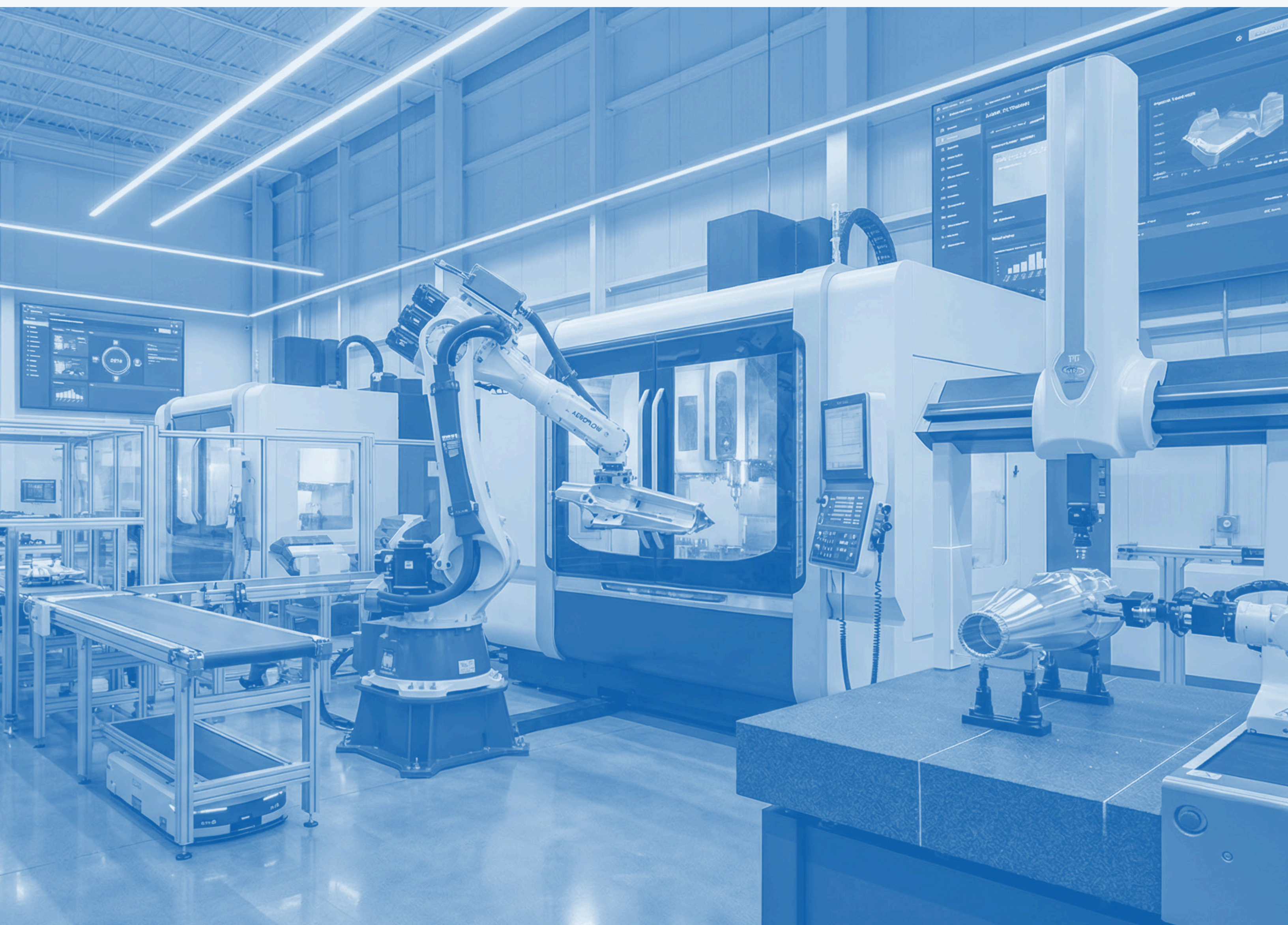
Enabling Automation Through Zero-Defect Machining

A practical framework to prevent escapement, reduce cost of quality, and scale automation with confidence



Developed in real production environments to deliver sustained zero-escapement performance across hundreds of precision part numbers

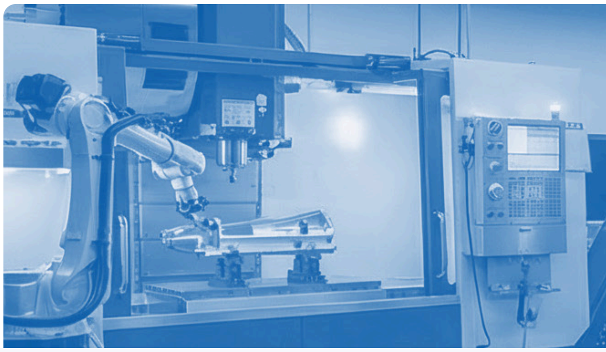
Introduction

Amid persistent workforce challenges, automation is increasingly viewed as a necessary path forward. Investment is accelerating. Timelines are compressing. The pressure to automate is real.

But automation applied to unstable or poorly controlled processes does not solve quality problems. It amplifies them. Defects are produced faster and in higher volume. When failures surface, automation often takes the blame, even though the deciding factor is process control. Without process control, organizations are set up to scale scrap, rework, and escapement instead of throughput.

Automation doesn't fix unstable processes — it scales them.

> This white paper shows why automation magnifies "acceptable" escapement when process control is weak. It defines zero-defects as a controlled process state and introduces six steps to closed-loop quality process control, from early drift detection through verified corrective action effectiveness. Then, provides guidance on ZDMS fit and the capabilities required to sustain process control that enables successful automation.



PART 01

The Hidden Cost of "Acceptable" Escapement

In precision manufacturing, a 1% escapement rate is often treated as a fact of life. Most quality systems are designed around this assumption, building in Material Review Boards, concession processes, and rework protocols as standard practice.

"As the complexity of your operations increases, it becomes much more difficult to effectively track what's going on within your business. Hidden costs develop and they are very difficult to unearth with a traditional approach to quality."

— Mike Dunlop, Founder of Net-Inspect

But acceptable to whom? And at what cost?

The true expense of defect escapement extends beyond visible line items. When a nonconforming part reaches a customer, or even when it's caught internally after leaving the machine, it triggers costs that most manufacturers never fully quantify:

1. **Concessions and MRB burden:** Every nonconformance that reaches MRB consumes engineering time, management attention, and customer goodwill.
2. **Schedule disruption:** When defects are detected late, recovery costs from overtime labor and expedited freight rarely appear in quality metrics.
3. **Customer trust erosion:** Each escapement erodes relationship capital built over years. When audit scrutiny increases, administrative burden compounds.
4. **Cold investigations:** By the time a defect is discovered downstream, conditions at the machine have changed. Evidence disappears. The same failure mode recurs.

Research from the American Society for Quality indicates that cost of poor quality typically represents 15-20% of sales revenue in manufacturing organizations. The **1-10-100 rule** captures the economic reality: $1 to prevent a defect at the design stage, $10 to catch it during production, $100 to address it after customer delivery.

The disconnect isn't effort or intention. Most manufacturers invest heavily in quality programs, trained inspectors, and measurement equipment. The problem is structural: static sampling plans don't reflect actual process health. They sample the past while the process drifts toward the next defect.

What if escapement wasn't inevitable?

PART 02

Zero Defects Is a Controlled Process State

The phrase "zero-defects" triggers skepticism among experienced manufacturing professionals. It sounds like a slogan, disconnected from the realities of material variation, machine wear, and human factors.

But the conversation is shifting. Organizations facing labor shortages are accelerating automation investments, and many are discovering a hard truth: automation does not inherently improve quality. It enforces whatever process already exists. Without effective process control, automation scales defects as efficiently as it scales output. The manufacturers who succeed with automation are those who first establish the process stability that makes unattended operation possible. That's why zero-defect methodology matters now. The goal is not just to reduce the cost of poor quality, but to enable the automation that workforce realities increasingly demand.

Zero-defects isn't a goal to chase. It's a standard to achieve. A controlled process state reached through systematic methodology, not heroic effort.

The evidence comes from production floors:

> Same methodology. Different facilities. Different part families. Repeatable results.

QPM Aerospace, a precision machining facility in the Pacific Northwest, implemented a closed-loop process control methodology and achieved sustained zero-escapement performance across more than 420 part numbers. The company grew from $300,000 to $30,000,000 in annual sales while virtually eliminating internal scrap and MRB backlogs.

Autonomous Machining, a separate facility in Kirkland, Washington, independently implemented the same methodology and validated these results. Process capability indices (Cpk) consistently exceeded 1.67, the industry threshold for lights-out manufacturing.

The methodology that produced these outcomes treats process control as the primary quality mechanism, not inspection. Inspection verifies. Process control prevents.

> "At QPM Aerospace, we relied fully on the real-time statistics generated by Net-Inspect. The system instantly highlighted all deviations in our manufacturing processes, which then allowed us to implement effective and permanent corrective action. **By rapidly eliminating variation in our processes, we were able to implement full automation and lights-out operations."** *— Mike Dunlop*

The insight: zero-defects isn't about perfection. It's about visibility. When every measurement feeds back into the process in real time, when every deviation triggers immediate investigation, defects become the exception that proves the system works.

PART 03

Six Steps to Closed-Loop Quality Control

The Zero-Defect Machining System (ZDMS) translates quality philosophy into operational practice through six interconnected steps. Each step builds on the previous. Together, they create the closed-loop architecture that makes sustained zero-escapement achievable and automation successful.

STEP 1

Capture Timely, Accurate Measurement Data at the Source

Quality control begins with data integrity. Measurements must be captured in real time, directly from calibrated instruments, at the point of manufacture. Data that is delayed, manually transcribed, or stripped of context loses diagnostic value and delays response.

This principle extends beyond speed. Effective quality data must meet five criteria, what we call the TAPAS standard:

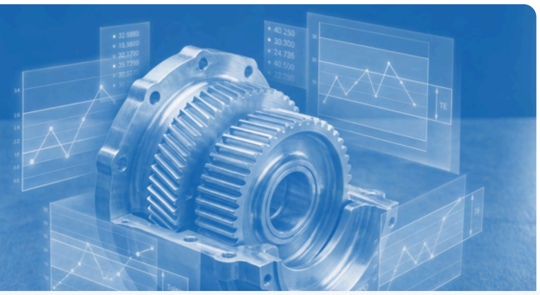
The TAPAS Standard

Quality data must be...

Timely — Recent data, not yesterday's news
Accurate — Reliable data from calibrated instruments
Personalized — Show me only the data I need, not data I have to find
Actionable — Drives immediate response, not just information
Secure — Authorized data access, maintaining data integrity and compliance

When measurement data fails any of these criteria, downstream analysis suffers. Delayed data means investigations happen after conditions have changed. Inaccurate data creates false signals. Data that is not personalized or is too difficult to access is often ignored. Non-actionable information gets treated as noise. And data that isn't secure creates compliance risk, erodes customer trust, and can compromise sensitive technical information.

ZDMS treats data capture as foundation, not afterthought. Everything that follows depends on getting this right.



Six Steps to Closed-Loop Quality Control

STEP 2

Create an accurate root cause for every unexpected increase in variation

Measurement variation without a proper root cause does not improve quality. For every major variation in the process , whether out-of-tolerance or out-of-control, root cause information must be captured while the knowledge of why it happened is still available. Often if it's discovered in a traditional quality department days later the reason for the variance is rarely remembered accurately.

Why the urgency? Root cause accuracy and information decays rapidly with time. When a defect is discovered hours or days after machining, the setup has changed, the tooling has rotated, the operator has moved to other work. Evidence disappears. Investigation becomes guesswork.

ZDMS requires immediate root cause documentation at the moment of detection. This applies not only to out-of-tolerance measurements (parts that fail specification) but also to out-of-control conditions (measurements that exceed statistical control limits while still meeting specification). An out-of-control signal is a defect in formation. The process has shifted. Whether this particular measurement happens to fall within tolerance is chance, not control.

No orphan defects. Every abnormal event traces to a documented cause and corrective action.

STEP 3

Prioritize Root Cause Elimination by Business Impact

Not all causes matter equally. A shop floor generates many signals: minor variations, tooling wear patterns, environmental fluctuations, operator differences. Treating every signal with equal urgency dilutes improvement effort and exhausts teams.

ZDMS ranks root causes by cost to the business: scrap value, rework labor, schedule disruption, customer exposure, and downstream risk. Improvement cycles focus on fully eliminating the highest impact causes first, then move to the next tier.

This Pareto-driven approach concentrates resources where they generate the greatest return. A single high-impact root cause, fully eliminated, often delivers more value than partial progress on a dozen minor issues.

The key word is **elimination**, not reduction. ZDMS targets permanent corrective action that removes the cause from the system, not temporary containment that manages symptoms.

PART 03

Six Steps to Closed-Loop Quality Control

STEP 4

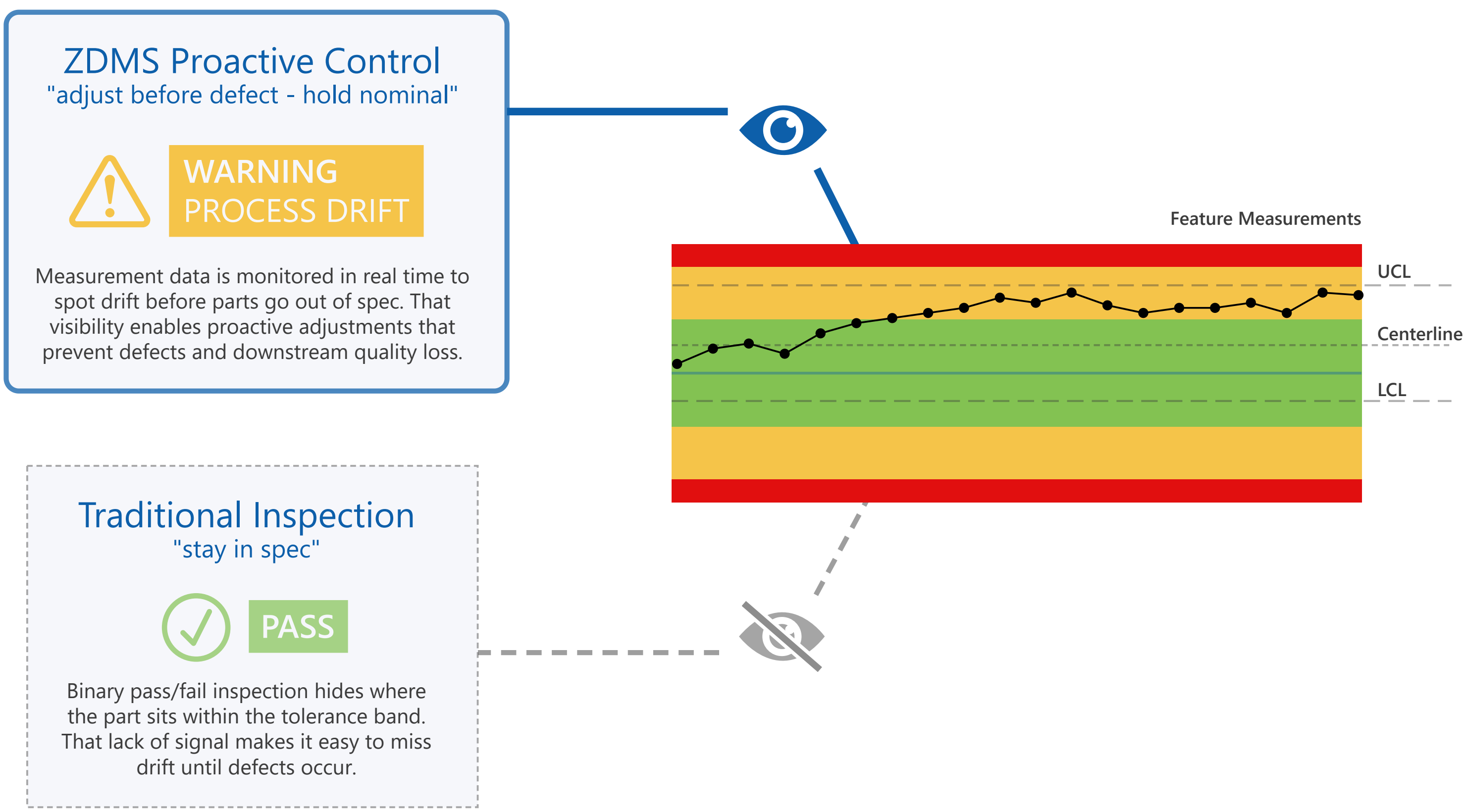
Drive the Process to Target, Not Just Within Tolerance

Meeting specification limits is insufficient. A part at the edge of tolerance passes inspection but carries higher risk of downstream fit issues, assembly problems, or field failures.

ZDMS applies the Taguchi principle: quality loss increases as a process deviates from its nominal target, even when parts remain within tolerance. Two parts may both be "in spec," but the one produced at nominal with minimal variation is objectively higher quality than one riding the tolerance boundary.

This requires visibility that traditional pass/fail inspection doesn't provide. Operators need to see where each measurement falls within the tolerance band, not just whether it passed. They need trend direction. They need percentage of tolerance consumed.

With this visibility, process adjustments happen before defects exist. The goal shifts from "stay in spec" to "hold nominal."



Six Steps to Closed-Loop Quality Control

STEP 5

Detect and Correct Process Drift Before Defects Occur

Statistical Process Control only works when control limits reflect actual process behavior. Control limits derived from specification limits, a common shortcut, defeat the purpose entirely. They measure conformance, not stability.

ZDMS auto-generates control limits from actual process data. Once a feature accumulates sufficient measurements (typically 20+), the system calculates Upper and Lower Control Limits using standard statistical methodology. These limits represent the "Voice of the Process," the natural variation inherent in your specific equipment, tooling, and methods.

Control limits become early warning systems. When a measurement exceeds control limits but remains within specification, that's not a pass. That's a signal. The process has shifted, and the next part may not be so lucky.

ZDMS treats out-of-control conditions with the same seriousness as out-of-tolerance events: immediate investigation, documented root cause, corrective action. Stability is the prerequisite for capability.

STEP 6

Optimize Inspection Through Capability-Driven Sampling

Fixed sampling plans allocate inspection resources uniformly regardless of demonstrated performance. A feature running at Cpk 2.5 receives the same scrutiny as one struggling at Cpk 1.1. This wastes capacity on stable processes while potentially under-sampling risky ones.

ZDMS adjusts sampling frequency based on demonstrated capability. Features with high process capability (Cpk above 1.67) earn lighter inspection burden. Marginal features (Cpk below 1.33) receive denser sampling automatically. Inspection resources concentrate where risk is highest.

When a control limit is breached, the system escalates immediately to 100% inspection of the affected feature for the current batch. Once statistical control is lost, the batch population can no longer be characterized by the sample. Complete inspection restores certainty.

The system returns to adaptive sampling only after root cause is identified, corrective action is implemented, and subsequent measurements demonstrate the process is back in control. This creates a natural incentive: improve your process, reduce your inspection burden.

PART 04

Is ZDMS Right for Your Operation?

ZDMS delivers measurable results, but it isn't universally applicable. The methodology works best in operations with specific characteristics.

ZDMS works best when you have:

- **Measurable, repeatable dimensional features.** The methodology relies on quantitative data that can be tracked over time and analyzed statistically.
- **Sufficient production volume.** Statistical process control requires data. Features need approximately 20+ measurements to generate meaningful control limits.
- **Commitment to real-time data capture.** Measurement data must flow from the machine to the system without delay. Batch uploads or end-of-shift entry defeat the purpose.
- **Willingness to enforce root cause discipline.** Every out-of-control condition requires investigation. This can't be optional based on workload.

Self-assessment
If your team spends more time managing non-conformances than preventing them, ZDMS is worth exploring.

Honest acknowledgment of challenges:

- **Extreme high-mix/low-volume operations may need modified approaches.** When every job initiated has a risk for variability, traditional statistical methods require adaptation.
- **Cultural shift is required.** Operators become process managers, responsible for understanding and controlling their processes rather than simply running parts.
- **Initial implementation surfaces hidden instabilities.** Expect an adjustment period as underlying process issues become visible for the first time. This is the system working, but it can feel disruptive.

> "**Our employees have really evolved from machine operators to full-fledged advanced process managers.** Their confidence level and insights that they put into our operations have dramatically increased."
> — *Mike Dunlop*

The Platform that Enables ZDMS

ZDMS was born from necessity. When QPM Aerospace sought tools to implement closed-loop process control in the early 2000s, they didn't exist. The methodology required capabilities no commercial software provided: real-time SPC from production data, adaptive sampling based on capability, mandatory root cause capture, and feature-level visibility at the machine.

Net-Inspect was built to solve that problem. The platform didn't emerge from a software company imagining what manufacturers might need. It was developed by manufacturers solving their own production challenges, then refined through years of real-world application.

The Reality Most Manufacturers Face

Most precision manufacturing operations still manage quality data through disconnected systems: Excel spreadsheets, paper travelers, standalone databases that don't communicate with production systems, inspection documentation archived separately from ongoing production data.

These approaches cannot deliver TAPAS-compliant data. They're not timely (hours or days of latency). They're error-prone (manual transcription). They're not personalized (data buried in files). And they're rarely actionable (reports generated, not responses triggered).

How Net-Inspect enables each ZDMS step

STEP 1 **Timely, Accurate Data:** with Bluetooth and keyboard wedge integration capturing data directly from metrology tools, eliminating transcription delay and error

STEP 2 **Immediate Causality:** through the eTag nonconformance system requiring documented root cause for every out-of-tolerance and out-of-control event before proceeding

STEP 3 **Prioritized Elimination:** with dashboards that surface highest-impact issues and track corrective actions to closure

STEP 4 **Target-Centered Control:** through real-time tolerance band visualization showing where measurements fall relative to nominal and spec limits

STEP 5 **Drift Detection:** with auto-generated SPC control limits from process data, providing immediately actionable drift detection

STEP 6 **Optimized Sampling:** through capability-driven sampling configuration that adjusts inspection frequency based on demonstrated Cpk, with automatic escalation when control breaks

Getting Started & Next Steps

Implementing ZDMS isn't a software installation. It's an operational change that requires alignment between technology, process discipline, and organizational commitment. The path forward depends on your current state and objectives.

For manufacturers serious about exploring whether ZDMS fits their operation, the next step is a focused conversation about your specific environment: your part families, production volumes, current quality challenges, and automation objectives.

Our team of quality system experts have implemented this methodology in production environments, from small job shops to global enterprises. They can help assess fit, scope implementation, and support the organizational changes that sustained zero-defect performance requires.

Ready to explore ZDMS in your operation? Let's talk.

Schedule a conversation with an expert

About

Net-Inspect provides cloud-based quality management and supply chain visibility software purpose-built for aerospace, defense, medical device, automotive, and precision manufacturing. The platform originated from the Zero-Defect Machining System methodology developed at QPM Aerospace, where it supported 100x revenue growth while achieving sustained zero-escapement performance.

Today, Net-Inspect serves over 9,000 companies across 59 countries with integrated solutions for First Article Inspection, Quality Management, Supplier Quality, APQP, CAPA/CAR, SPC, and more.

www.net-inspect.com | sales@net-inspect.com

net-inspect