Lean Six Sigma Master Black Belt Project Report (SSGI)

Project: Probe Card Repair Process Transformation

Author: Colin Henry
Organization: Honeywell SPS – Richardson, TX
Email: colinhenryjr@gmail.com
Submission Date: February 07, 2026

Executive Business Case

At the Honeywell Richardson facility, specialized testing tools known as Probe Cards are required to verify the functionality of environmental sensor chips, including pressure, humidity, and infrared sensors, before they can be shipped to customers. These high-value assets are the final checkpoint in the manufacturing process; if a probe card is unavailable, finished product cannot be tested and shipments are delayed.

When probe cards required repair, they entered a disorganized process tracked only by manual paper logs. There was no visibility into where assets were, what stage of repair they were in, or when they would be returned. Repairs depended on the informal expertise of individual technicians rather than a documented, repeatable process. As a result, probe card availability consistently fell below 50%, effectively halving the factory's testing capacity and forcing the business to rely on slow and expensive external vendors to maintain production schedules.

The primary goal of this project was to transform this unpredictable bottleneck into a reliable, high-speed internal capability by replacing manual tracking with a digital asset governance system and enforcing standardized, repeatable repair processes. This transformation successfully restored tool availability to over 97%, reduced average repair time to approximately 16 hours, and eliminated the need for outside vendors, delivering $1.06 million in financial impact.

Table of Contents

1. DEFINE PHASE

1.1 Problem Statement and Business Context

Probe card availability at the Honeywell Richardson Sensor Fab was a chronic operational constraint directly impacting on-time delivery and capital utilization. Probe cards are critical test assets required at the final stage of wafer fabrication, where the majority of product value has already been realized. When unavailable, test operations stalled, shipments were missed, and the business was exposed to revenue risk.

Historical performance indicated availability consistently below 50%. Repairs combined undocumented internal activities with external vendor cycles of two to four weeks. Asset location and status were tracked using manual paper logs, resulting in lost visibility, unplanned holds, and extreme variability. These conditions created a hidden factory of waiting and rework that required daily management firefighting. This project was initiated to address the systemic causes of unavailability rather than isolated repair events.

1.2 Voice of the Customer (VOC) and Cost of Poor Quality (COPQ)

The internal customer, Test Operations, required probe cards returned from repair within 48 hours to maintain production flow and meet shipment commitments. Production supervisors and planning consistently identified probe card unavailability as the single largest constraint to on-time delivery.

The Cost of Poor Quality included external vendor repair costs, expediting charges, lost throughput from idle test equipment, and daily management overhead for firefighting. These costs represented approximately $1.06 million annually in avoidable spend.

1.3 Project Objectives

The primary objective was to transform probe card repair from an unpredictable liability into a stable, high-velocity internal capability using the DMAIC methodology. Specific objectives included increasing probe card availability to greater than 97%, reducing internal repair cycle time by 50%, eliminating reliance on external vendors, establishing real-time asset visibility, and creating a standardized process independent of individual technicians.

1.4 Critical-to-Quality (CTQ) Definitions

CTQ-1: End-to-End Probe Card Turnaround Time, defined as elapsed time from repair request initiation to asset release back to production. This reflects customer-perceived availability risk and directly impacts on-time-to-promise performance.

CTQ-2: Core Repair Cycle Time, defined as time required to execute repair and verification steps once the asset is actively being worked. This isolates repair execution performance from tracking-related special causes.

1.5 Project Scope

In Scope	Out of Scope
Probe card repair value stream from request initiation through release	Probe card design changes
Internal repair execution, verification, and documentation	Wafer test program modifications
Asset tracking and visibility mechanisms	External supplier quality beyond repair interfaces
Repair workstation layout and standard work	
Management operating system integration	

1.6 SIPOC Summary

A SIPOC analysis clarified system boundaries, information flow, and customer expectations across the repair value stream. This reinforced that probe card availability was a system-level issue involving asset governance, information flow, and repair execution rather than a purely technical problem.

Suppliers	Inputs	Process	Outputs	Customers
Test Operations	Failed probe card	1. Repair request initiated	Repaired probe card	Test Operations
Engineering	Repair specifications	2. Asset logged into PACMAN	Updated asset status	Production Planning
Stockroom	Spare parts, consumables	3. Diagnose failure mode	Verified functionality	Manufacturing
SME Technician	Repair expertise	4. Perform repair & rework	Repair history & data	Quality

Table 1. SIPOC analysis of the probe card repair value stream. The SIPOC clarifies system boundaries, supplier inputs, and customer expectations related to the 48-hour repair turnaround requirement.

1.7 Stakeholders and Team Structure

This project required a high-performance cross-functional team spanning manufacturing, engineering, quality, IT, and operations leadership. A weekly cadence was established to drive Rolling Action Item List (RAIL) completions, and working sessions were used to clear obstacles, address challenges, and coach team members through the change process.

2. MEASURE PHASE

2.1 Objective

The Measure phase established a data-driven baseline of probe card repair performance while evaluating the integrity and stability of the measurement system. Early investigation revealed that traditional averages were masking significant variability and special-cause behavior, so this phase emphasized process stability assessment before any performance comparison.

2.2 Data Sources and Measurement Integrity

Historical repair data was extracted from internal records covering calendar year 2017. Each record included repair request date, resolution date, repair classification, probe card identification, and calculated cycle time in hours. Cycle time was selected as the primary metric due to its direct relationship to asset availability and delivery risk. The measurement method was reviewed to confirm consistency in time-stamping and event definitions. While recorded dates were accurate, the process generating the data was not controlled with respect to asset tracking and status updates, a limitation considered in subsequent analysis.

2.3 Current State Process Map and Waste Identification

The team developed a process map to illustrate the current repair workflow and identify sources of waste. Analysis revealed the process was dominated by three of the Seven Wastes: waiting (assets sitting untracked between steps), transportation (unnecessary movement between locations), and defects (rework due to inconsistent repair execution).

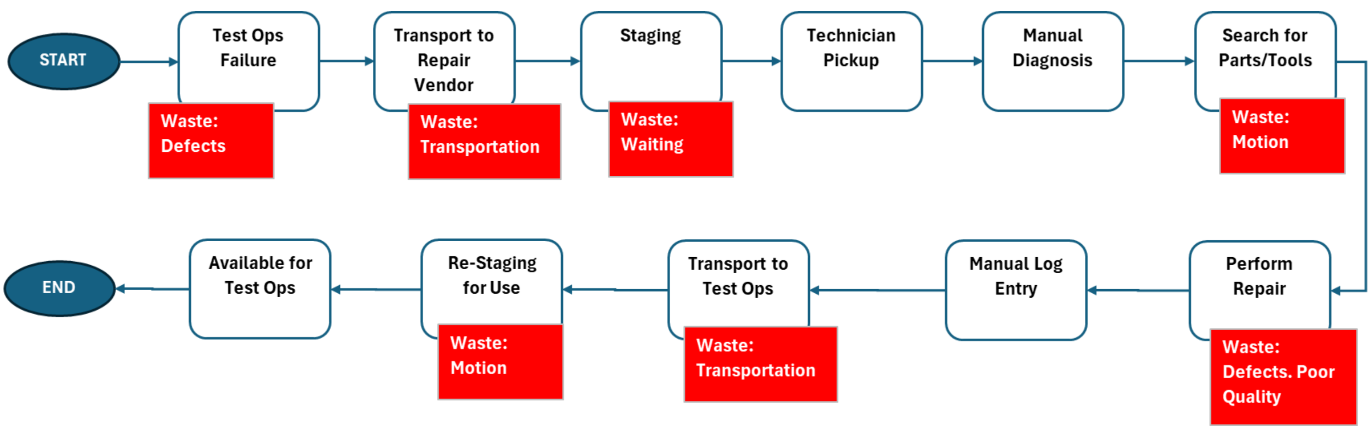


Exhibit 1: Process Map Current State illustrating major process steps and waste categories observed.

2.4 Pareto Analysis of Repair Drivers

To understand the dominant reasons triggering repairs, a Pareto analysis was performed. Following the 80/20 principle, approximately 80% of repair volume was attributed to Probe Contact, Edge Sensor, Planarization, and

Maintenance categories. This analysis informed both resource prioritization and the Voice of the Customer by identifying what failures most frequently disrupted production.

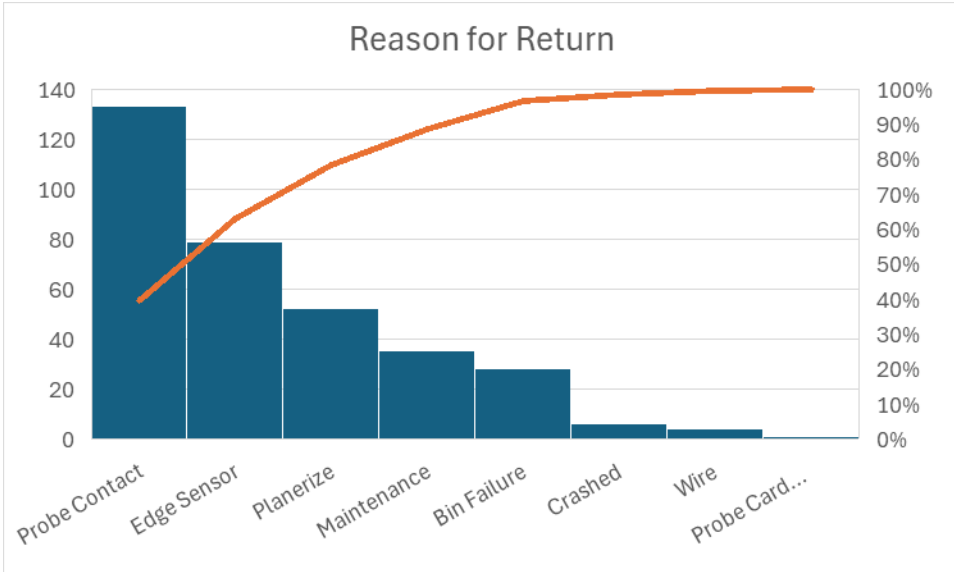


Exhibit 2: Pareto chart illustrating the reasons for return which triggered the Probe Card Repair process.

2.5 Baseline Process Stability

Individuals and Moving Range (I-MR) control charts were constructed for end-to-end cycle time prior to improvement. The I-Chart demonstrated a process dominated by special causes with no meaningful state of statistical control. Under these conditions, average cycle time was not a reliable indicator of performance and any comparison based solely on mean values would be misleading.

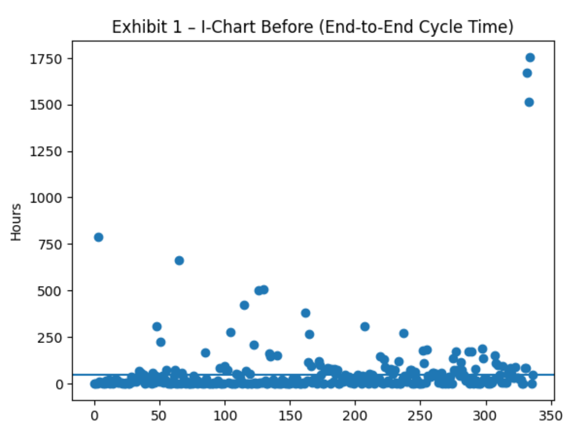


Exhibit 3: I-Chart Before State (End-to-End Cycle Time) showing process instability and special-cause dominance.

The team concluded that meaningful improvement required first addressing the structural causes of variation, specifically the absence of controlled asset tracking, which introduced excessive noise and obscured true repair.

2.6 Measure Phase Outcome

The Measure phase established that the baseline process was statistically unstable and unsuitable for traditional performance comparison. By validating data integrity, mapping current-state waste, identifying dominant repair drivers through Pareto analysis, and confirming process instability through control charts, the team created a reliable foundation for the Analyze phase.

Following implementation of digital asset tracking, end-to-end cycle time was re-evaluated:

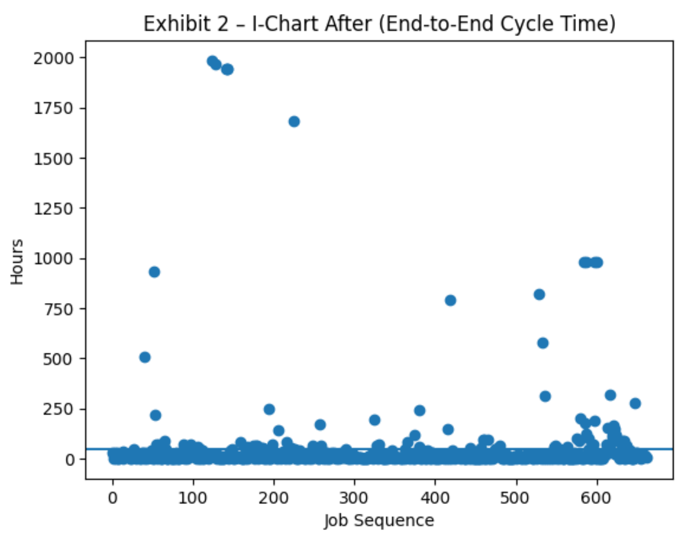


Exhibit 2: I-Chart – After State (End-to-End Cycle Time) significant outliers remain.

While special causes remained (e.g., engineering holds), the frequency and magnitude of extreme cycle times were materially reduced. Importantly, these remaining outliers were now visible and classifiable, enabling structured management response.

3. ANALYZE PHASE

3.1 Analyze Phase Objective

The Analyze phase determined whether observed changes in repair performance represented true process improvement or random variation, and identified the dominant factors limiting capability and sustainability. The analysis emphasized statistical proof and variation understanding rather than reliance on averages.

3.2 Core Process Segmentation

As established in the Measure phase, end-to-end cycle time was dominated by special causes related to asset tracking failures. To enable valid analysis of repair execution, records exceeding 120 hours were classified as special-cause events driven by visibility or hold conditions rather than repair work. This segmentation allowed independent analysis of CTQ-2 (Core Repair Cycle Time) while preserving CTQ-1 (End-to-End Turnaround Time) for enterprise risk assessment.

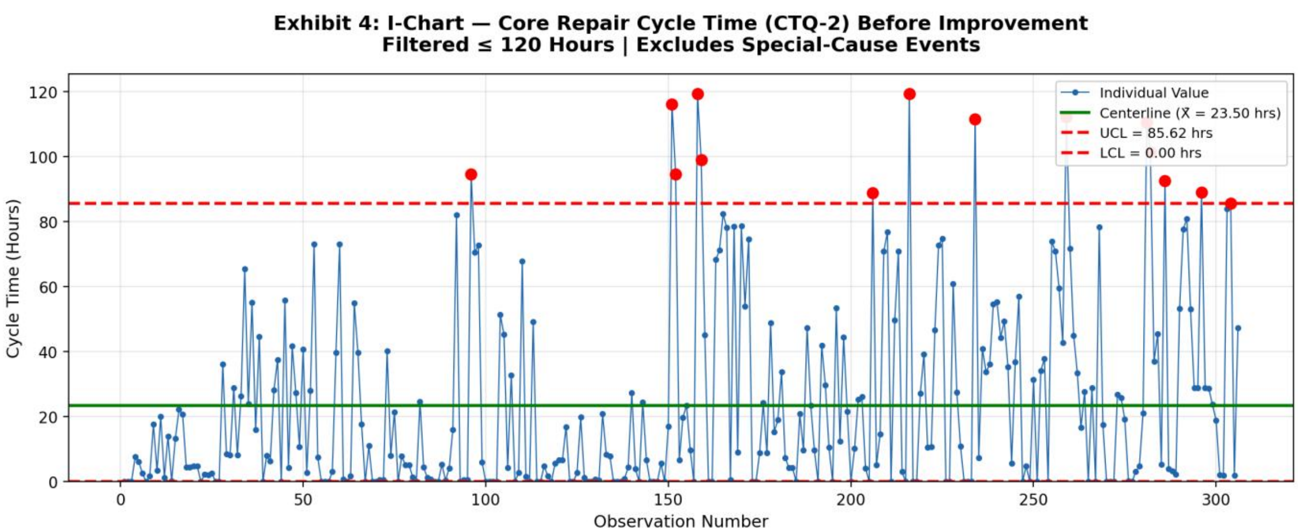


Exhibit 4: I-Chart Core Repair Cycle Time (CTQ-2) Before Improvement, filtered to exclude special-cause events exceeding 120 hours.

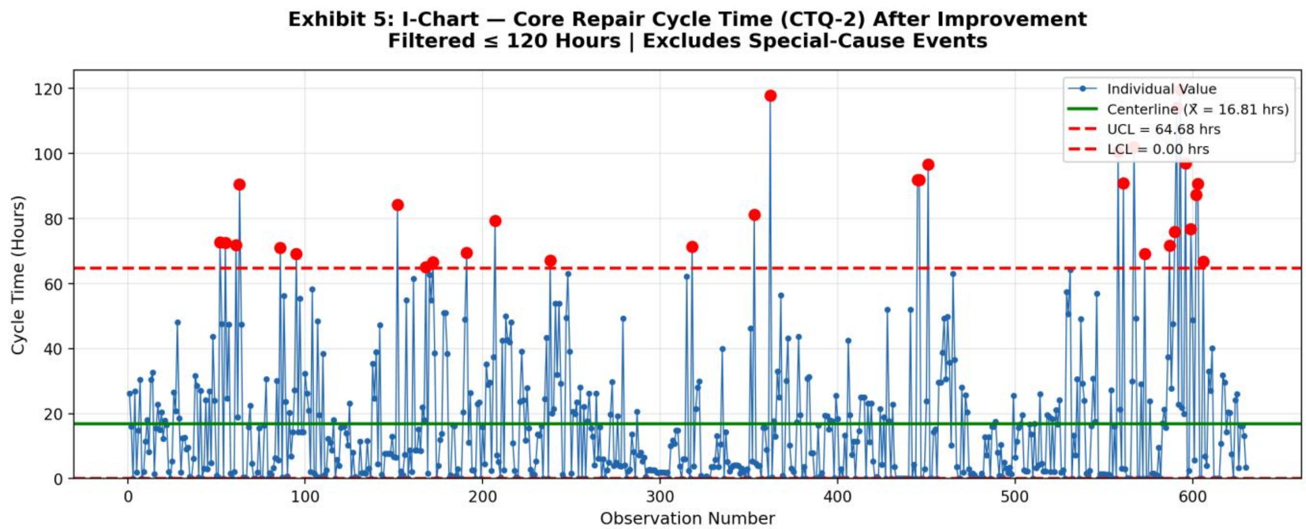
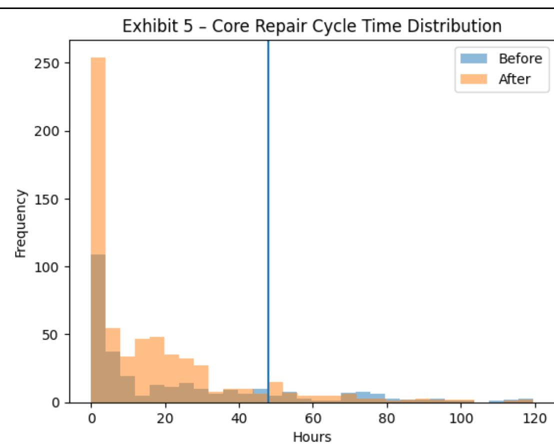


Exhibit 5: I-Chart Core Repair Cycle Time (CTQ-2) After Improvement, with UCL, LCL, and centerline identified.

3.3 Hypothesis Testing

To test whether core repair performance improved following implementation of digital tracking and standardized work, a Welch two-sample t-test was conducted comparing pre- and post-implementation cycle times. Welch's test was selected due to unequal sample sizes and non-identical variances.

- **Null Hypothesis (H_0):** No difference in mean core repair cycle time between states
- **Alternative Hypothesis (H_1):** Mean core repair cycle time decreased following implementation.



Metric	Before	After
Sample Size (n)	306	630
Mean Cycle Time (hrs)	23.5	16.8
Mean Improvement		6.7 hrs (28%)
Statistical Test	Welch 2-Sample t-test	

p-value	0.00038	

Exhibit 6. Statistical comparison of core repair cycle time before and after improvement.

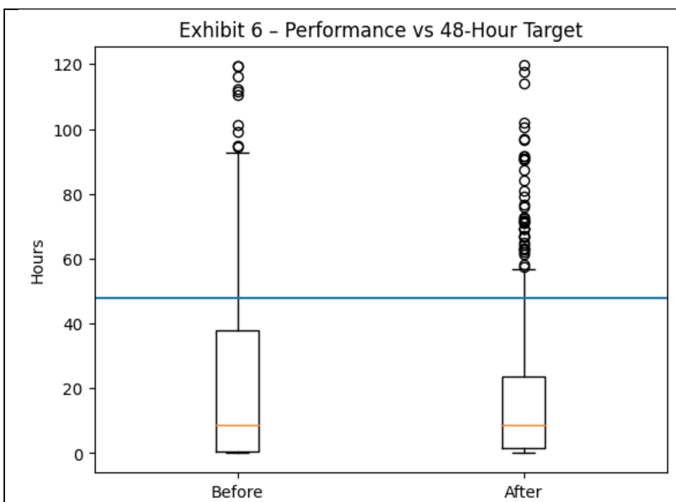
The p-value fell well below α = 0.05, rejecting the null hypothesis. The reduction in repair cycle time was statistically significant and not attributable to random variation.

3.4 Control Chart Interpretation

Exhibits 4 and 5 demonstrated a downward shift in centerline, reduction in moving range, and fewer high-end excursions post-implementation. Improvement was not limited to speed alone; process consistency improved, indicating partial reduction in common-cause variation. However, variation remained significant relative to the 48-hour customer requirement, reinforcing the need for continued improvement.

3.5 Process Capability Assessment

Process capability was evaluated against the 48-hour service requirement. Capability indices improved post-implementation but remained below acceptable thresholds (Ppk < 1.0).



Metric	Before	After
Sample Size (n)	306	630
Mean Cycle Time (hrs)	23.50	16.81
Median Cycle Time (hrs)	8.84	8.63
Standard Deviation (hrs)	29.05	21.50
Ppk	~0.28	~0.48
% of Repairs ≤ 48 hrs	81.4%	89.8%

Exhibit 7. Process capability of core repair cycle time relative to 48-hour requirement, showing 8.4% improvement in meeting the target, cycle time standard deviation reduced by 8 hours, and mean reduced by 6.69 hours. This confirmed the need for a Phase-2 roadmap to further address remaining sources of variation.

3.6 Failure Pattern Analysis

A Weibull analysis was performed on repair outcomes. The resulting shape parameter ($\beta < 1$) indicated an infant mortality failure pattern, meaning a subset of repairs failed shortly after completion. This was consistent with inconsistent repair execution, operator processing error, lack of standardized verification, and reliance on undocumented expertise. These findings directed the Improve phase toward standard work codification, training certification, and embedded verification steps.

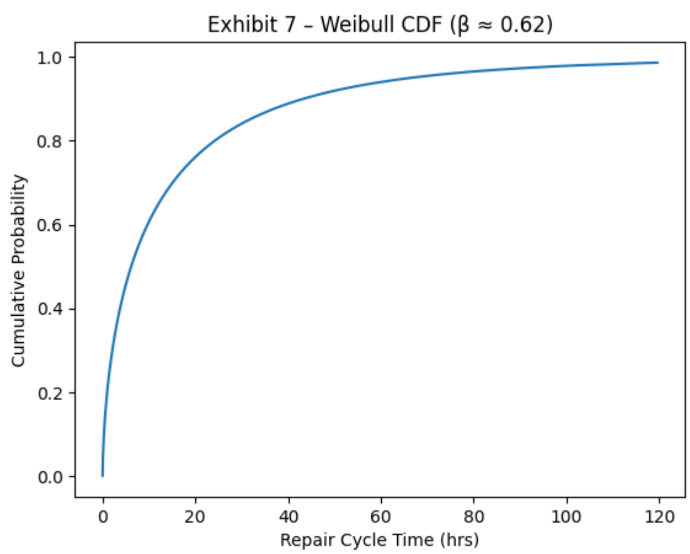


Exhibit 7. Weibull analysis of repair outcomes indicating infant-mortality failure behavior.

3.7 Root Cause Analysis

A Fishbone (Ishikawa) diagram was constructed using the 6M methodology to categorize contributors to poor performance across Manpower, Methods, Machines, Materials, Measurements, and Mother Nature. The analysis highlighted systemic contributors across multiple categories, reinforcing that the root cause was not a single failure point but a system-level deficiency requiring architectural solutions.

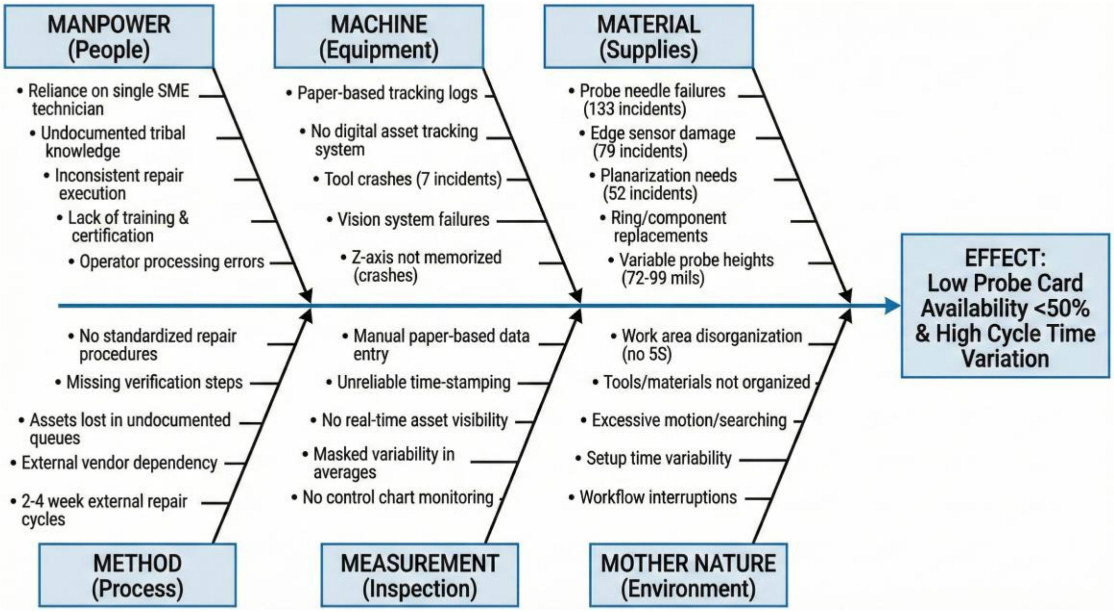


Exhibit 9. Fishbone diagram illustrating contributors to poor performance across 6M categories.

4. IMPROVE PHASE

4.1 Objective

The Improve phase designed and implemented solutions addressing the root causes identified in the Analyze phase: asset visibility failures, excessive variation in repair execution, and reliance on undocumented expertise. The improvement strategy targeted three complementary dimensions: visibility and control of high-value assets, standardization of repair execution, and structural error-proofing to prevent regression.

4.2 Digital Asset Tracking (PACMAN)

A web-based digital tracking system, PACMAN (Probe Card Asset Management), was developed to replace manual paper logs. PACMAN required mandatory barcode-based check-in and check-out of probe cards at each process step, providing real-time visibility of asset location and status, automated time-stamping of repair events, repair history traceability at the asset level, and dashboards displaying cycle time and availability metrics. From a Lean Six Sigma perspective, PACMAN served as a poka-yoke mechanism, structurally preventing assets from entering undocumented queues and directly eliminating the dominant special cause identified in Measure and Analyze.

4.3 Standard Work and Knowledge Transfer

Weibull analysis identified an infant mortality failure pattern driven by inconsistent execution and insufficient verification. To address this, undocumented expertise held by a single technician was systematically converted into controlled enterprise assets. This effort produced updated repair and maintenance specifications (237-0095-267), a standardized training and certification checklist (236-0049-001), verification steps for Probe Height measurement embedded into the repair workflow, and support log-sheets for system redundancy (110-1208-001 and 110-00983-001). These documents ensured repair quality was no longer dependent on individual expertise, enabling repeatability and workforce flexibility.

4.4 5S Workplace Organization

The physical repair environment was redesigned using 5S principles. Tools, materials, and fixtures were organized to minimize motion and searching, reduce setup time, and reinforce correct process sequencing. Visual standards were posted at each station to support sustainment.

Exhibit 10. 5S implementation of the Probe Card Repair work area, with visual standards posted for each station to enable sustainment.

4.5 Future State Process Map

Following implementation, the future state process map reflected a simplified workflow with fewer steps, digital tracking integrated throughout, and significantly improved performance exceeding 97% availability. This future state map, compared against the current state map in Exhibit 1, illustrates the elimination of waste categories identified during the Measure phase and embeds the continuous improvement framework by establishing a monitored, measurable process capable of ongoing refinement.

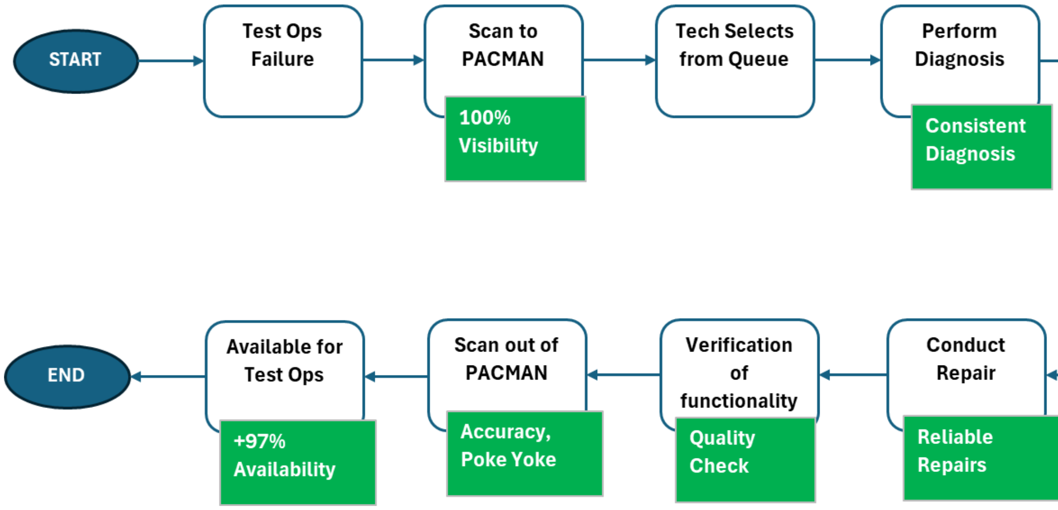


Exhibit 11. Process Map After/Future State illustrates simplified process with fewer steps and significantly better performance over 97% Availability.

4.6 Improve Phase Outcome

The Improve phase transformed probe card repair from an unstable, person-dependent activity into a controlled, visible, and standardized system. By addressing root causes at the system level and embedding error-proofing through poka-yoke, the improvements created sustainable gains in availability and repair velocity while establishing a foundation for continuous improvement.

5. CONTROL PHASE

5.1 Control Phase Objective

The Control phase ensured that improvements were institutionalized and sustained over time. Control is not achieved through documentation alone but through the integration of behavioral, digital, and leadership mechanisms that make regression structurally unlikely.

5.2 Control Plan and Key Metrics

A formal control plan was established to monitor performance linked to the CTQs defined in the Define phase. Primary control metrics included Probe Card Availability (enterprise outcome metric), End-to-End Turnaround Time (CTQ-1, customer risk metric), and Core Repair Cycle Time (CTQ-2, process execution metric). Each metric was assigned a defined owner, review cadence, and escalation threshold. PACMAN provided real-time digital enforcement through mandatory barcode check-in/check-out, automated time-stamping, and a permanent audit trail, ensuring deviations were immediately visible.

5.3 Management Operation System Integration

Key metrics were integrated into the site's tiered management review structure. Tier 2 reviews covered daily and weekly availability and cycle time trends. Tier 3 reviews addressed escalation of chronic issues, resource constraints, or cross-functional barriers. This integration ensured deviations triggered structured problem-solving rather than ad-hoc firefighting.

5.4 Ownership and Reaction Plans

Clear ownership was established for each control metric with defined responsibilities for monitoring, investigation, and corrective action. Reaction plans specified immediate investigation of cycle times exceeding targets, root cause analysis for repeated deviations, and escalation to leadership when systemic issues were identified.

5.5 Leadership and Change Management

Sustaining the improvements required deliberate leadership behavior beyond the technical solution. As the project lead, I had to navigate resistance from technicians who viewed standardization as a threat to their autonomy and value. This required coaching conversations that reframed the change as protecting their expertise by making it permanent and visible to the organization rather than replacing it. Leadership engagement at the Tier 2 and Tier 3 level was essential to signal that the new process was not optional and that accountability would be consistent.

Change management was addressed through structured communication, early involvement of affected stakeholders in solution design, phased implementation to build confidence before full deployment, and integration into existing management routines rather than creating parallel systems. The decision to embed metrics into the existing management operating system rather than creating a standalone review was a deliberate change management strategy, reducing adoption friction by aligning with behaviors leadership already practiced.

5.6 Control Phase Outcome

The Control phase embedded the improved process into the organizational fabric of the site through digital enforcement, leadership accountability, and structured change management. These mechanisms made regression structurally unlikely and established a platform for continued improvement.

6. RESULTS & CONCLUSIONS

6.1 Summary of Results

This project delivered measurable, statistically validated, and sustainable improvements aligned with both operational and financial objectives. By addressing system-level root causes rather than isolated symptoms, the project eliminated a critical constraint to manufacturing throughput and delivery performance.

Key results include:

- Probe Card Availability increased from less than 50% to greater than 97%, removing availability as a bottleneck to final test operations

- Core Repair Cycle Time reduced from 23.5 hours to 16.8 hours, a 28% improvement confirmed as statistically significant ($p = 0.00038$)
- Special-Cause Variation associated with lost assets and undocumented holds was substantially eliminated through digital tracking and governance
- Cost Avoidance of approximately $1.06 million annually through elimination of external vendor reliance
- Capital Utilization improved by returning high-value assets to productive use faster without additional capital expenditure

While capability indices relative to the 48-hour service requirement improved, they remain below optimal thresholds, reinforcing the need for continued variation reduction, first-pass yield improvement, and proper probe card handling by operators in the Test area.

The project successfully transformed probe card repair from an unstable, person-dependent activity into a controlled, transparent, and scalable system. The combination of digital asset tracking, standardized repair execution, and management operating system integration addressed both technical and behavioral root causes. A critical outcome was converting undocumented tribal knowledge into formal enterprise assets, reducing operational risk and enabling sustainment independent of individual contributors. The solution architecture was intentionally designed for horizontal deployment across other asset classes with similar constraints.

7. LESSONS LEARNED

7.1 Stability Must Precede Optimization

Meaningful improvement cannot occur in an unstable system. Initial metrics were dominated by special-cause variation from asset tracking failures. Attempting to optimize repair execution without first stabilizing asset visibility would have produced misleading results and unsustainable gains.

7.2 Averages Obscure Risk in High-Variability Systems

Early reporting relied on average cycle time, which masked extreme outliers and understated delivery risk. Control charts and variation analysis revealed that averages alone were insufficient to characterize performance, reinforcing the importance of understanding distribution shape and failure modes in capital-intensive environments.

7.3 System Architecture Outperforms Procedural Compliance

The most durable improvements came from changes to system architecture rather than additional procedures. Digital tracking, mandatory check-in/check-out, and management operating system integration removed discretion from critical steps. This proved far more effective than relying on training or enforcement alone.

7.4 Knowledge Must Be Institutionalized to Be Scalable

Reliance on undocumented expertise represented significant operational risk. Converting this knowledge into standardized procedures, training requirements, and verification steps was essential to reducing variation and enabling workforce flexibility.

7.5 Leadership Behavior Enables Technical Outcomes

Technical solutions alone were insufficient. Progress depended on deliberate leadership intervention to shift behaviors, encourage collaboration, and create psychological safety for subject matter experts to contribute fully. Coaching leaders to adopt a facilitative role was instrumental in unlocking expertise and enabling standardization. Although significant gains were achieved, capability analysis demonstrated that additional improvement opportunities remain. Recognizing these limitations early and defining a Phase-2 roadmap ensured the project concluded with a forward-looking strategy rather than a false declaration of completion.