Fault Detection by Upgrading Control Charts with Change Point Detection Function

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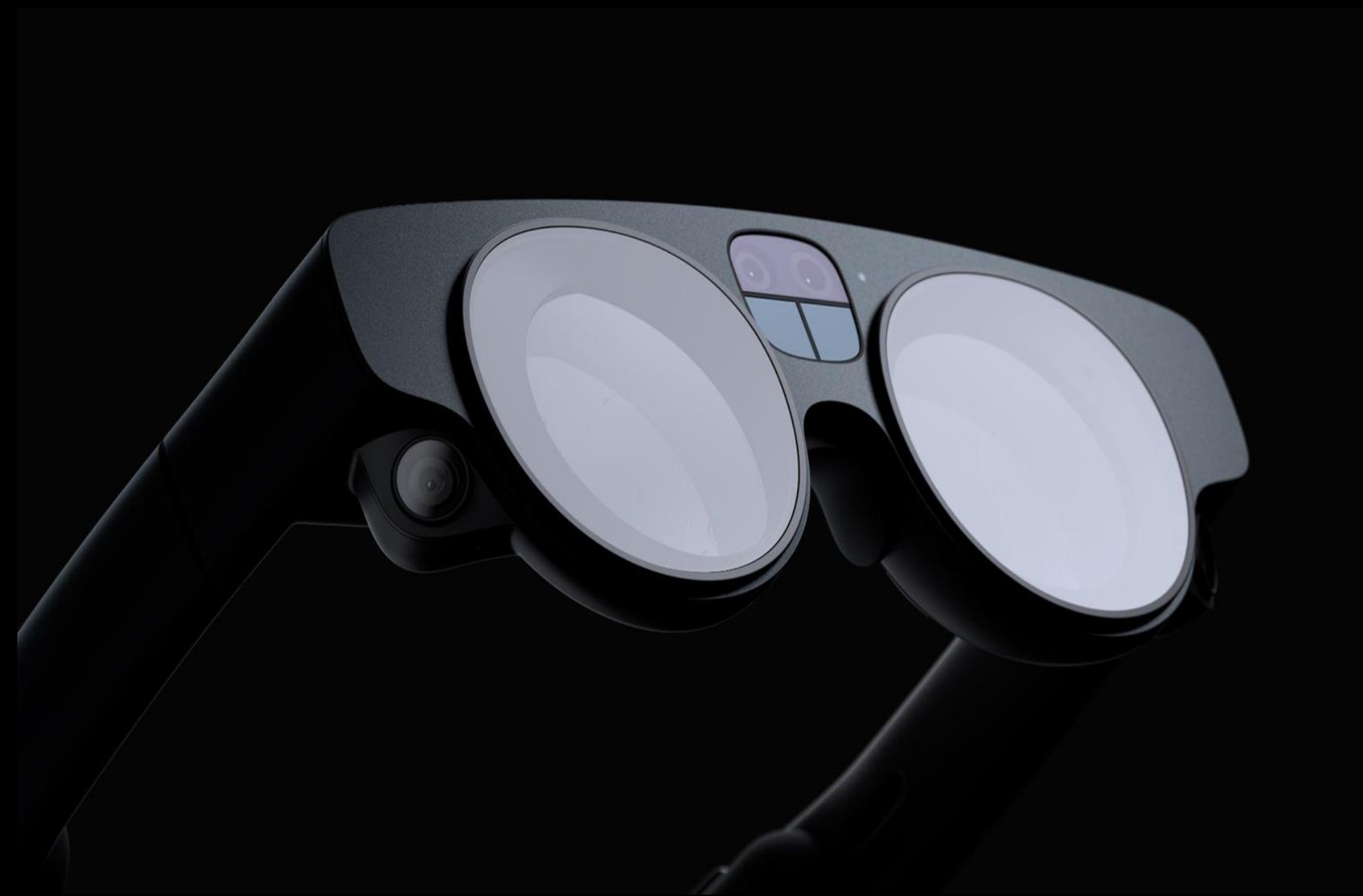
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MagicLeap

Agenda

1. Magic Leap & Optics Manufacturing
2. DMAIC problem solving with JMP tools
3. Our Challenges in Control Phase
4. Upgrading Control Charts with change point
5. Detecting and Diagnosing Faults
6. Case Studies & JMP Demo
7. Takeaways

A world where the physical and digital are one
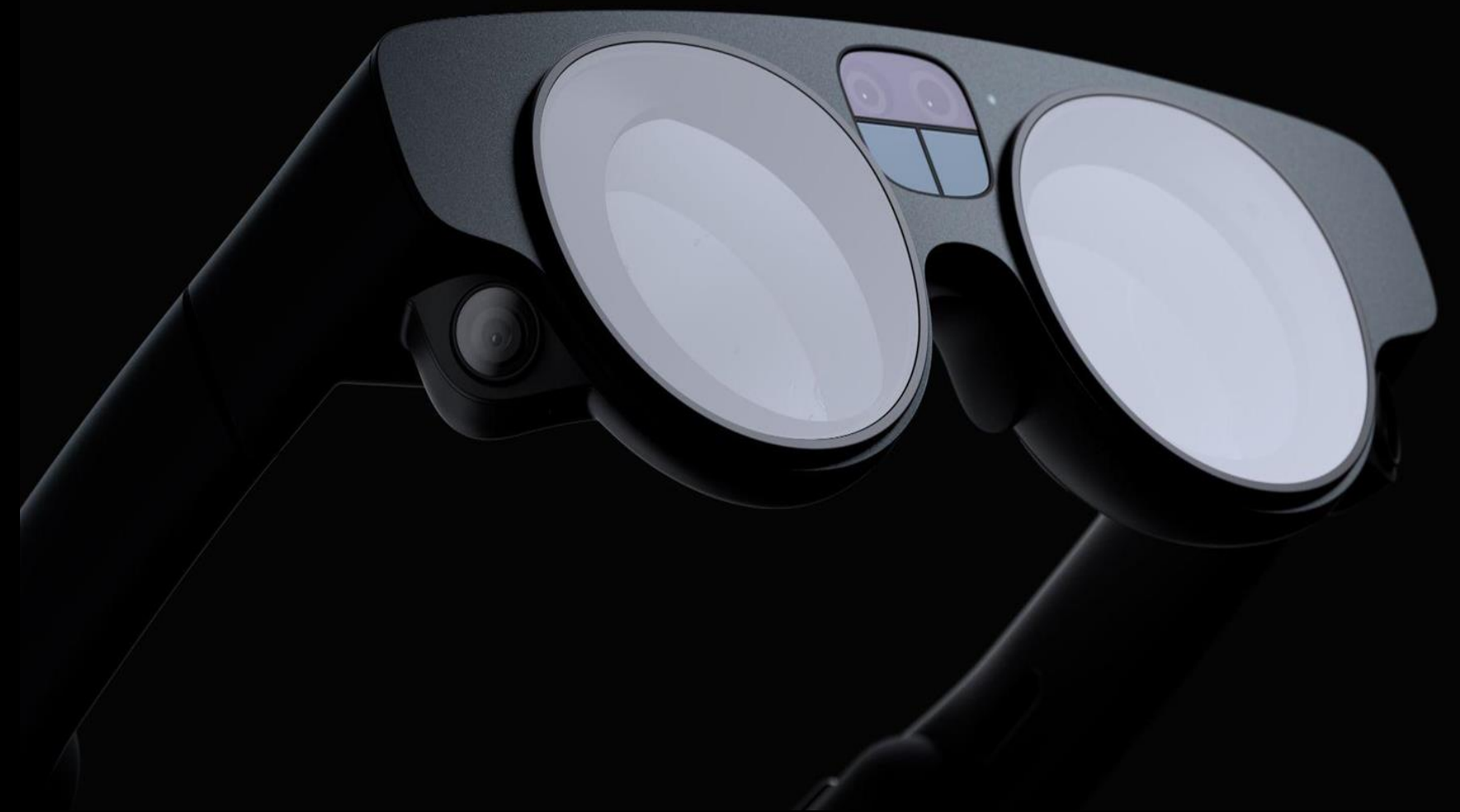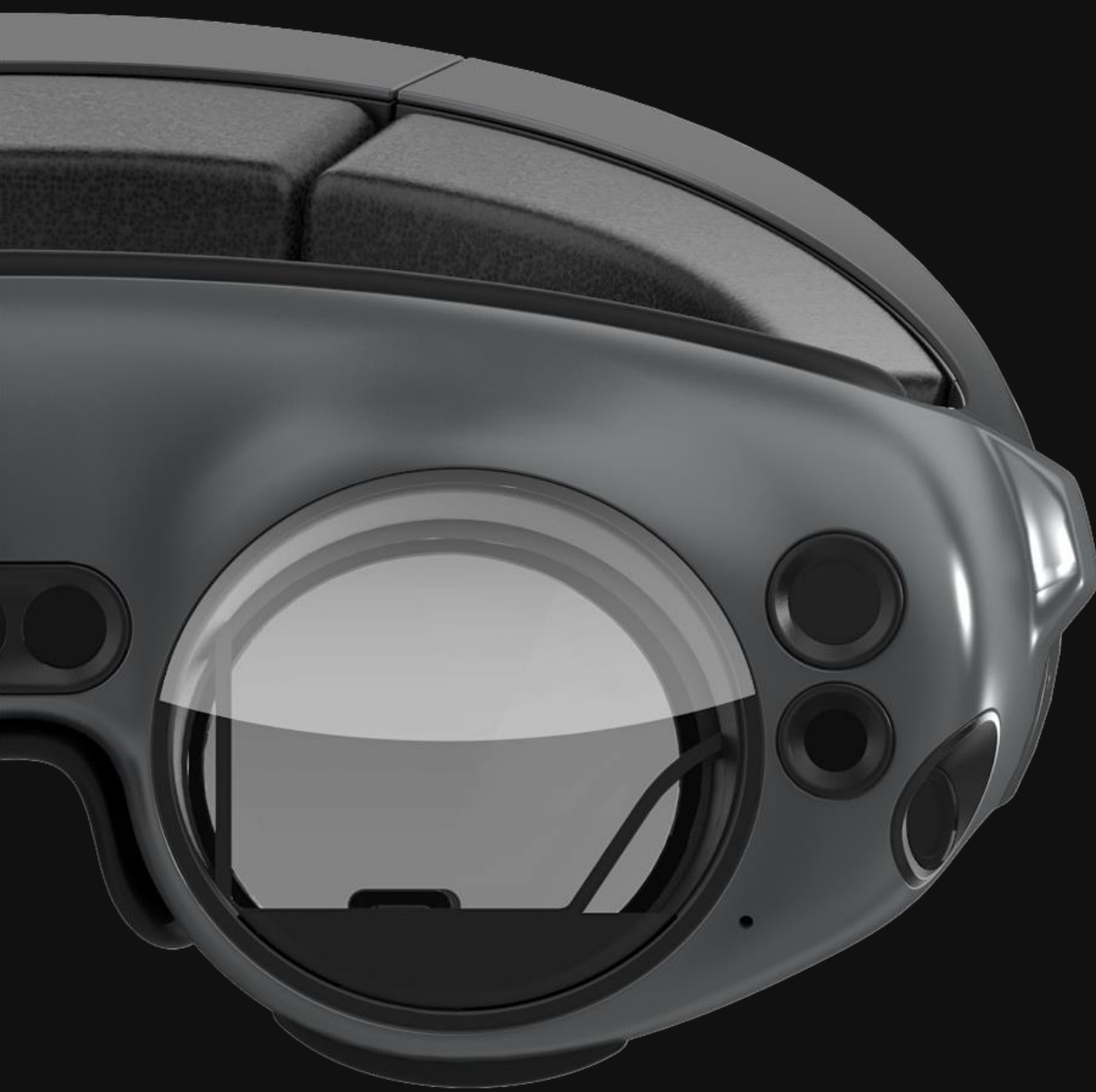
Collaboration & co-presence

3D visualization

Augmented workforce

Up to 70° FOV

Best image quality

Color uniformity

Dynamic dimming

High yield (RTY) and process capability using JMP statistical tools

The optical lens is a critical component of Magic Leap 2, enabling best-in-class image performance

- The optical lens goes through 25+ complex processes and metrology stations during the manufacturing process
- It is tested over 100+ critical-to-quality (CTQ) parameters
- Each individual process needs to reach high 99% yield targets to attain 90% Rolled Throughput Yield (RTY) targets
- The process requires extremely precise fault detection, which JMP tools have helped us monitor and analyze

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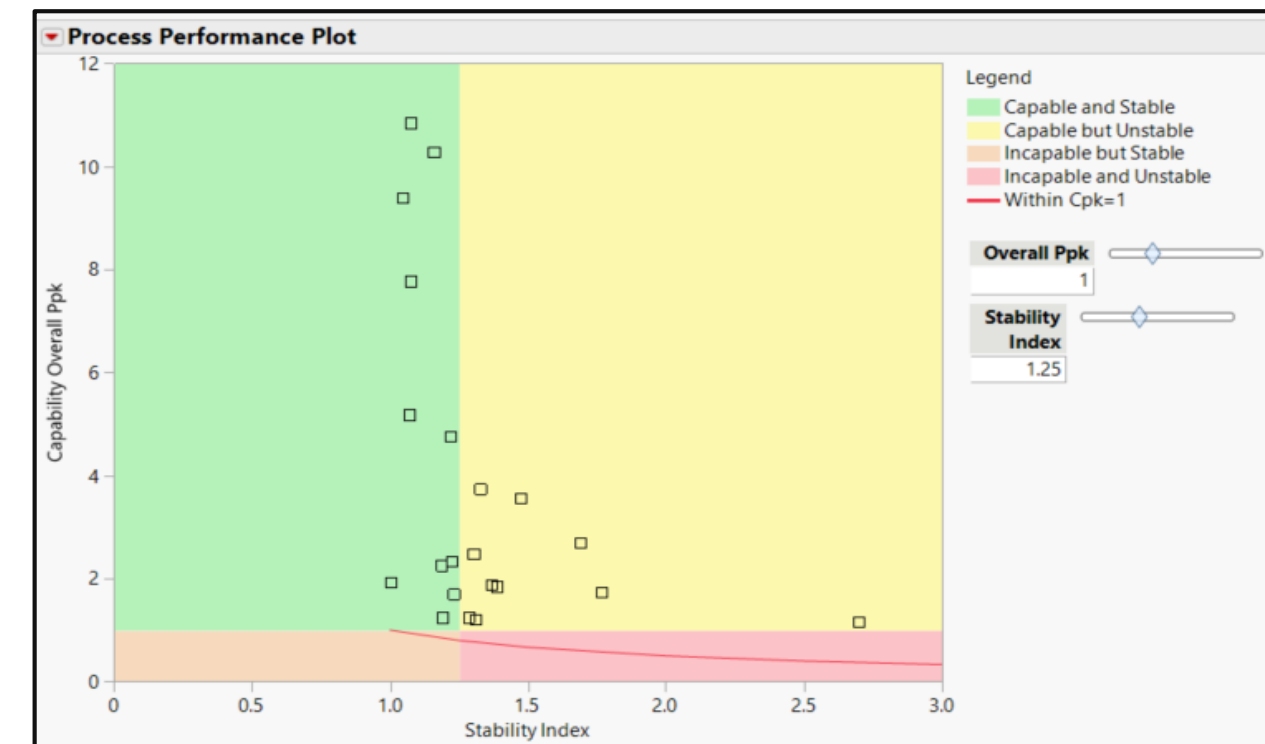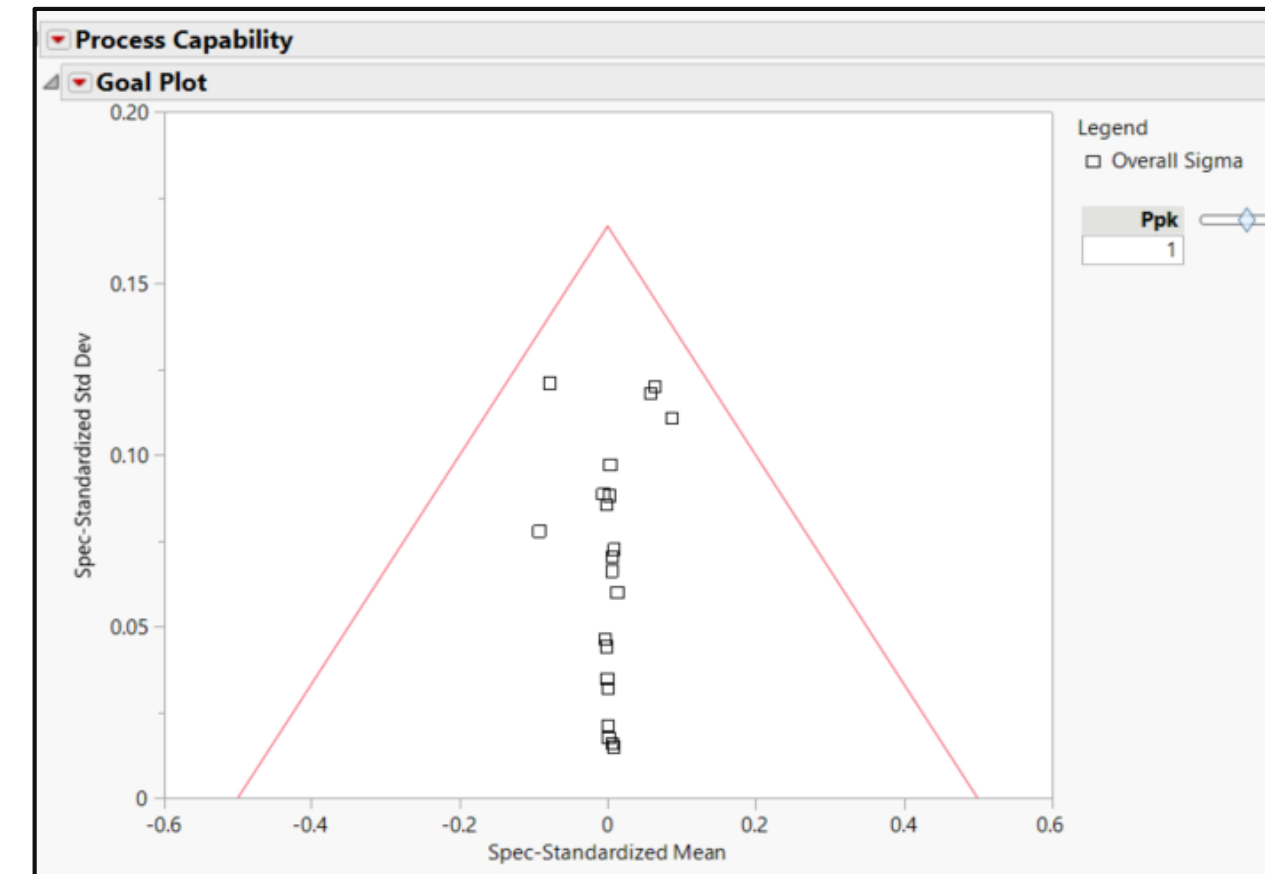
Precise placement and alignment

- High–yield process that achieves 99%+ RTY on 22 CTQs or KPIs
- The Lithography patterning operates between tight control limits
  - Less than 20 nanometer film thickness
  - Less than 1 arcmin rotational alignment
  - Less than 100 micrometer drop placement
  - Less than 500 micrometer template alignment
- The tolerances are extremely small (for reference Human hair is 20 to 100 um)

Imprint Lithography requires precision placement and alignment that are indistinguishable to the human eye

Step 1: Orient template and substrate — Transparent template (mold), Planarization layer, Substrate

Step 2: Dispense drops of liquid imprint resist — Resist dispenser, Imprint resist

Step 3: Lower template and fill pattern — Imprint fluid fills template pattern

Step 4: Polymerize imprint fluid with UV exposure — UV blanket exposure

Step 5: Separate template from substrate — Exact replica of template pattern

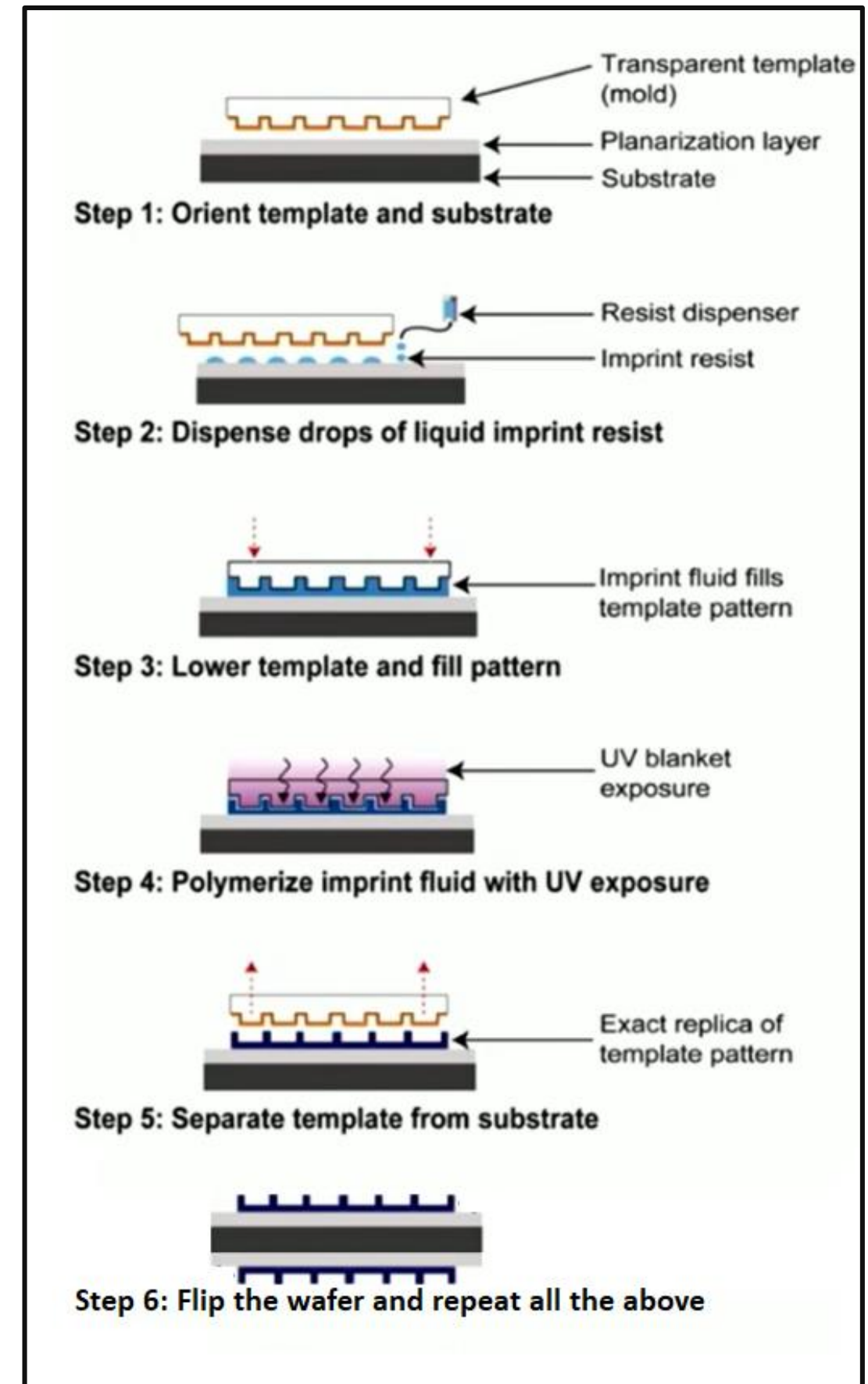Step 6: Flip the wafer and repeat all the above

Figure: A unique Imprint Lithography process that involves precise wafer placement, resist drop placement, and alignment

Change point dashboard optimizes problem-solving process

D	M	A	I	C

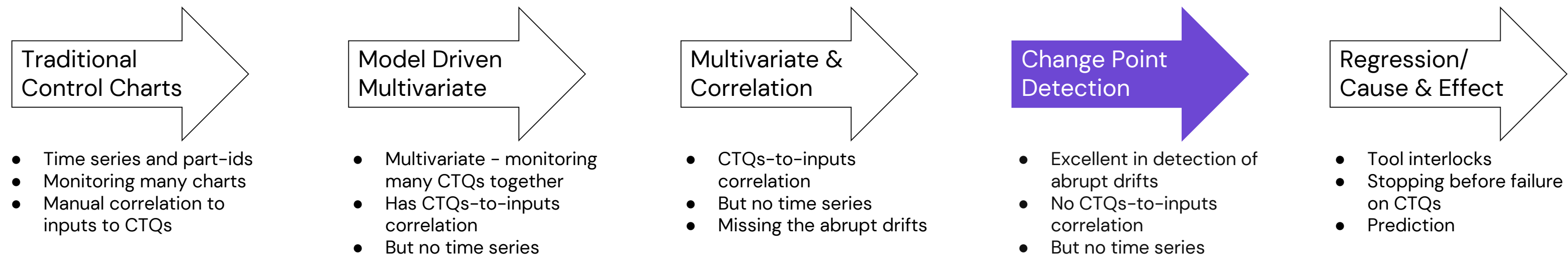| Define	Measure	Analyze	Improve	Control
• 8D problem statement • Project Charters • Goal plots	• Goal plots • Process capability • Process stability • Summary tables	• Fish–Bone diagram • Pareto plot • Multivariate methods • Correlation Matrix	• DOE and Prediction profiler • Response screening • Process capability	• Control charts • Time series diagnostics • Change point detection

Change point Dashboard makes our control phase efficient

Escalation before Change point control chart dashboard	Escalation after Change point control chart dashboard
1. Operator monitors yield dashboard and identifies the yield loss 2. Operator reports to technician to looks into faults 3. If Tech unable to resolve, escalates to Engineer 4. Engineer analyzes control charts data using control charts alarms and trends. Manually joining the outputs and inputs correlation 5. Engineer diagnoses the fault 6. Engineer implements corrective actions	1. Operator and Technician monitor change point dashboard on shop floor 2. If changes found, they look into correlation of inputs with before and after change and diagnose the issue 3. Implement corrective actions Easy transition to our TPM model where operators, technicians, and engineers are all coming together to minimize faults

Journey from traditional control charts to change point detection dashboard

Evolving from "yield is below baseline today" to "no changes(variation) found in the process"

| Traditional Control Charts	Model Driven Multivariate	Multivariate & Correlation	Change Point Detection	Regression/ Cause & Effect
• Time series and part-ids • Monitoring many charts • Manual correlation to inputs to CTQs	• Multivariate – monitoring many CTQs together • Has CTQs-to-inputs correlation • But no time series	• CTQs-to-inputs correlation • But no time series • Missing the abrupt drifts	• Excellent in detection of abrupt drifts • No CTQs-to-inputs correlation • But no time series	• Tool interlocks • Stopping before failure on CTQs • Prediction
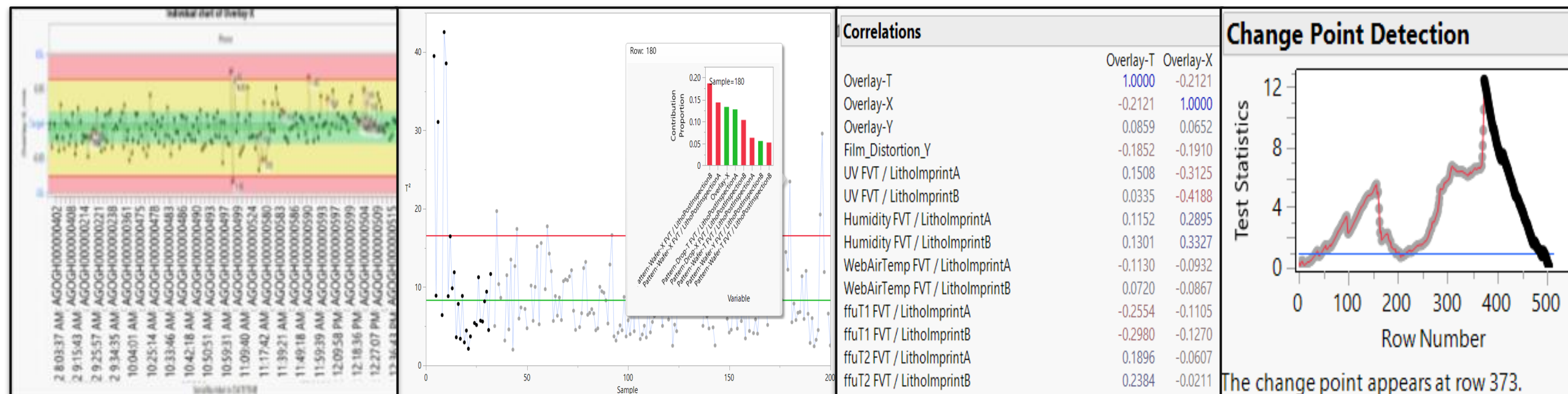
Visualize the exact moment a change occurred
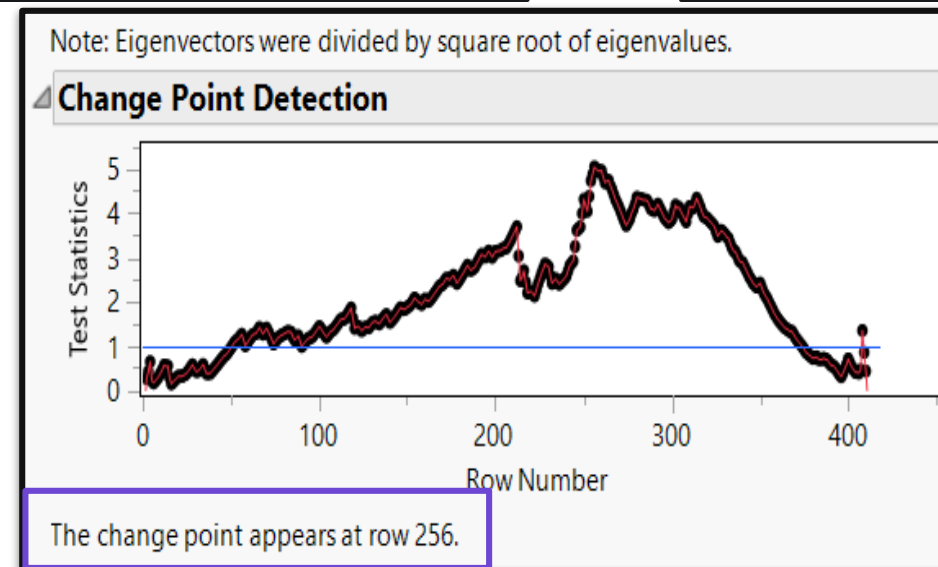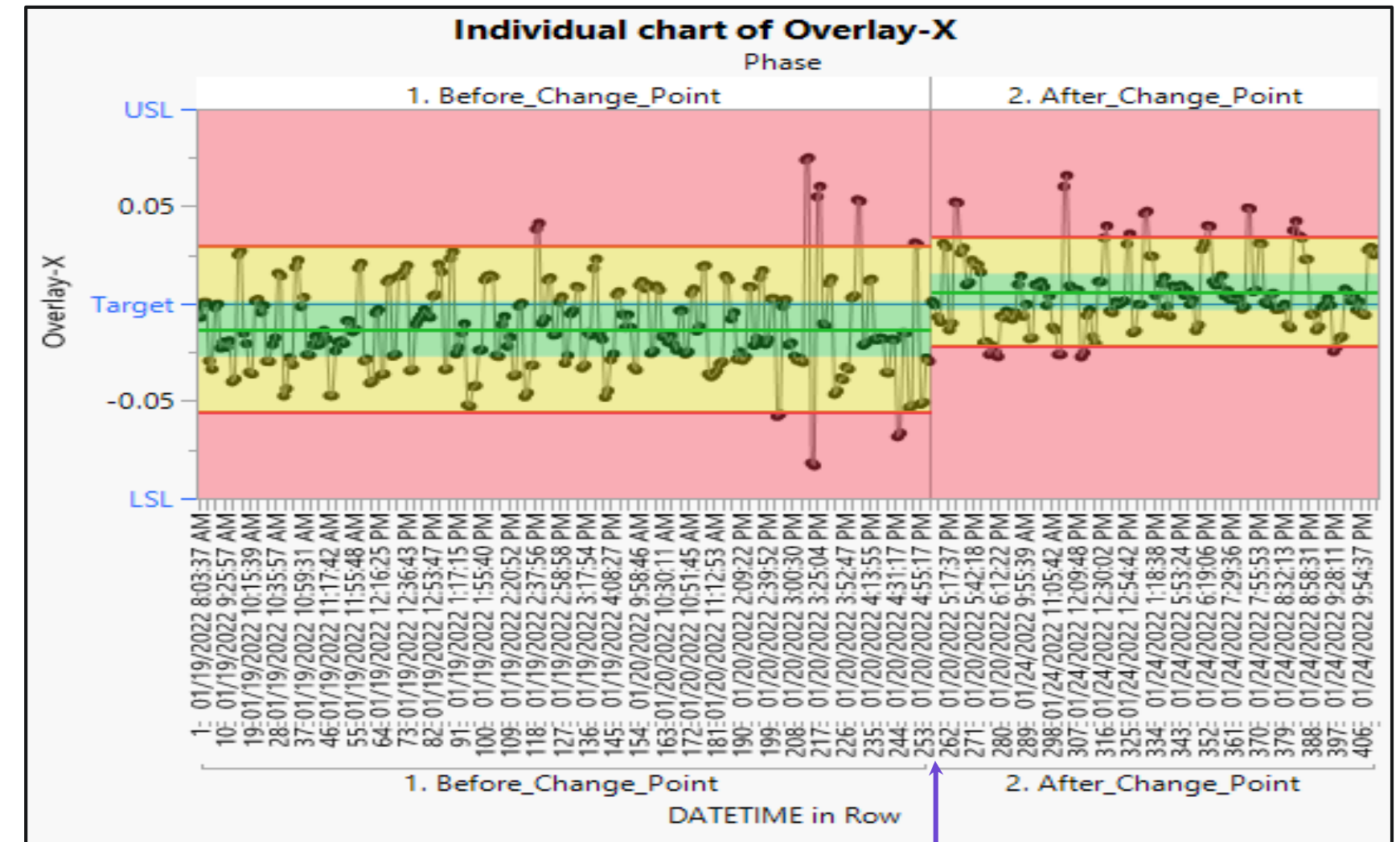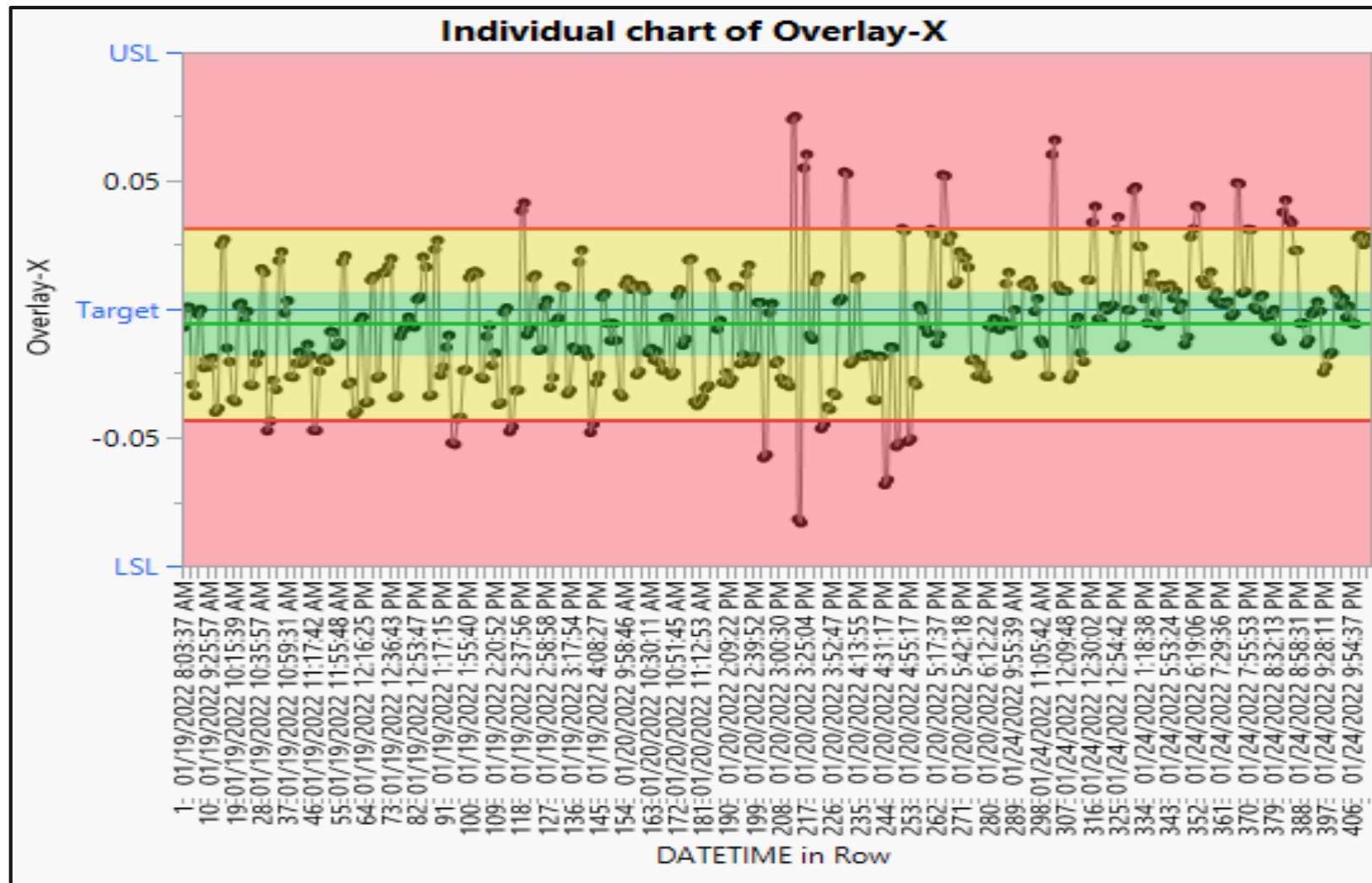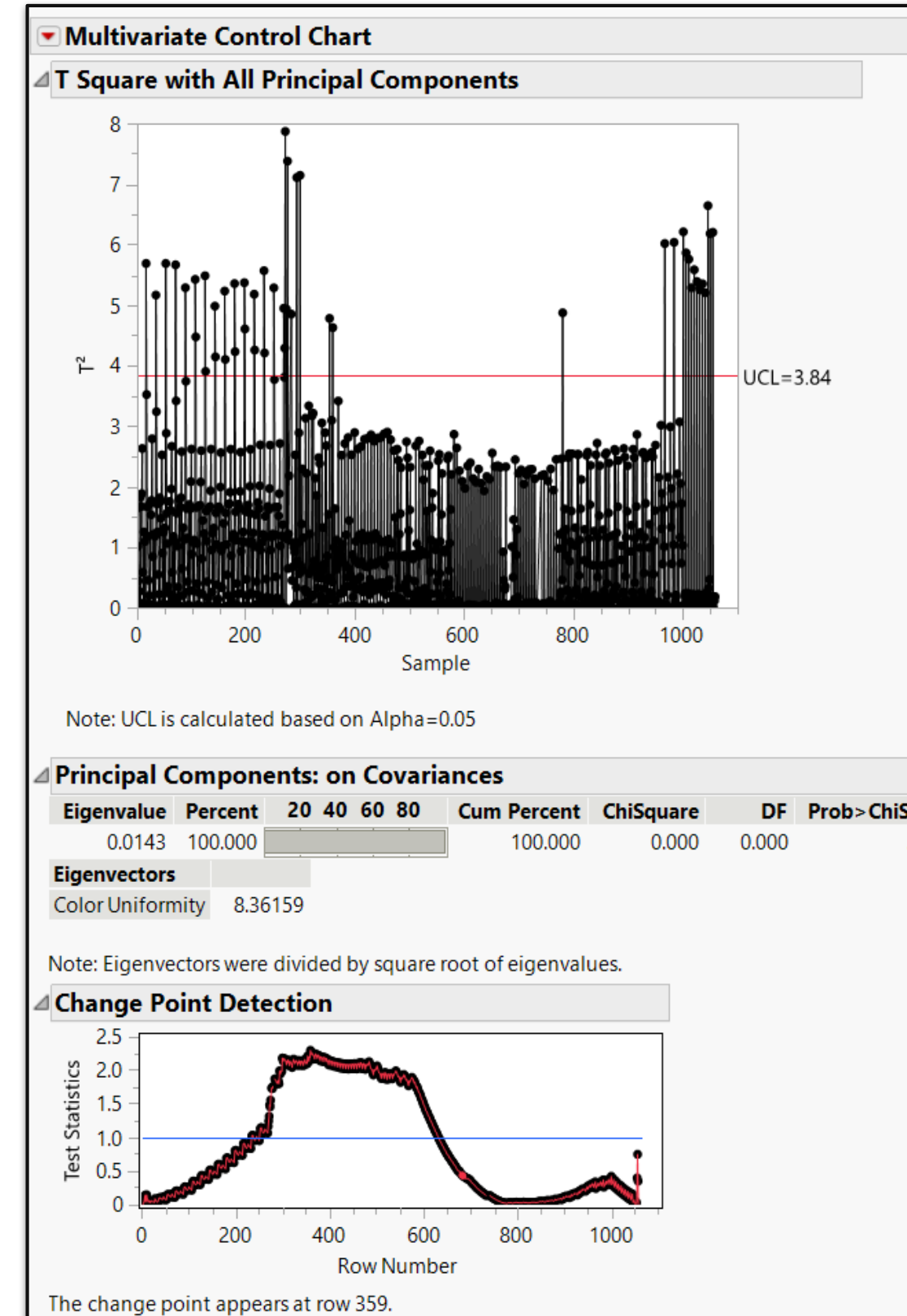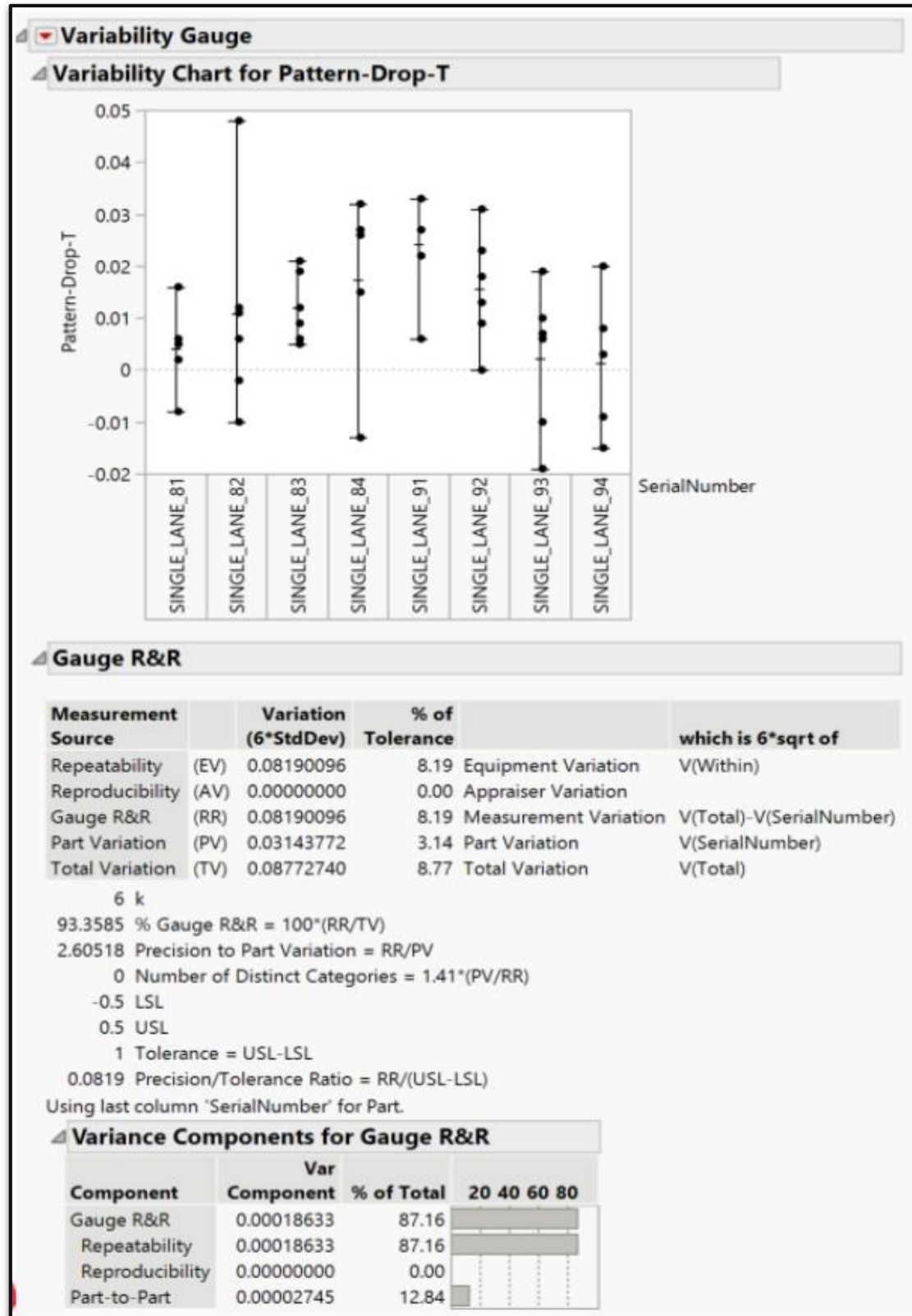
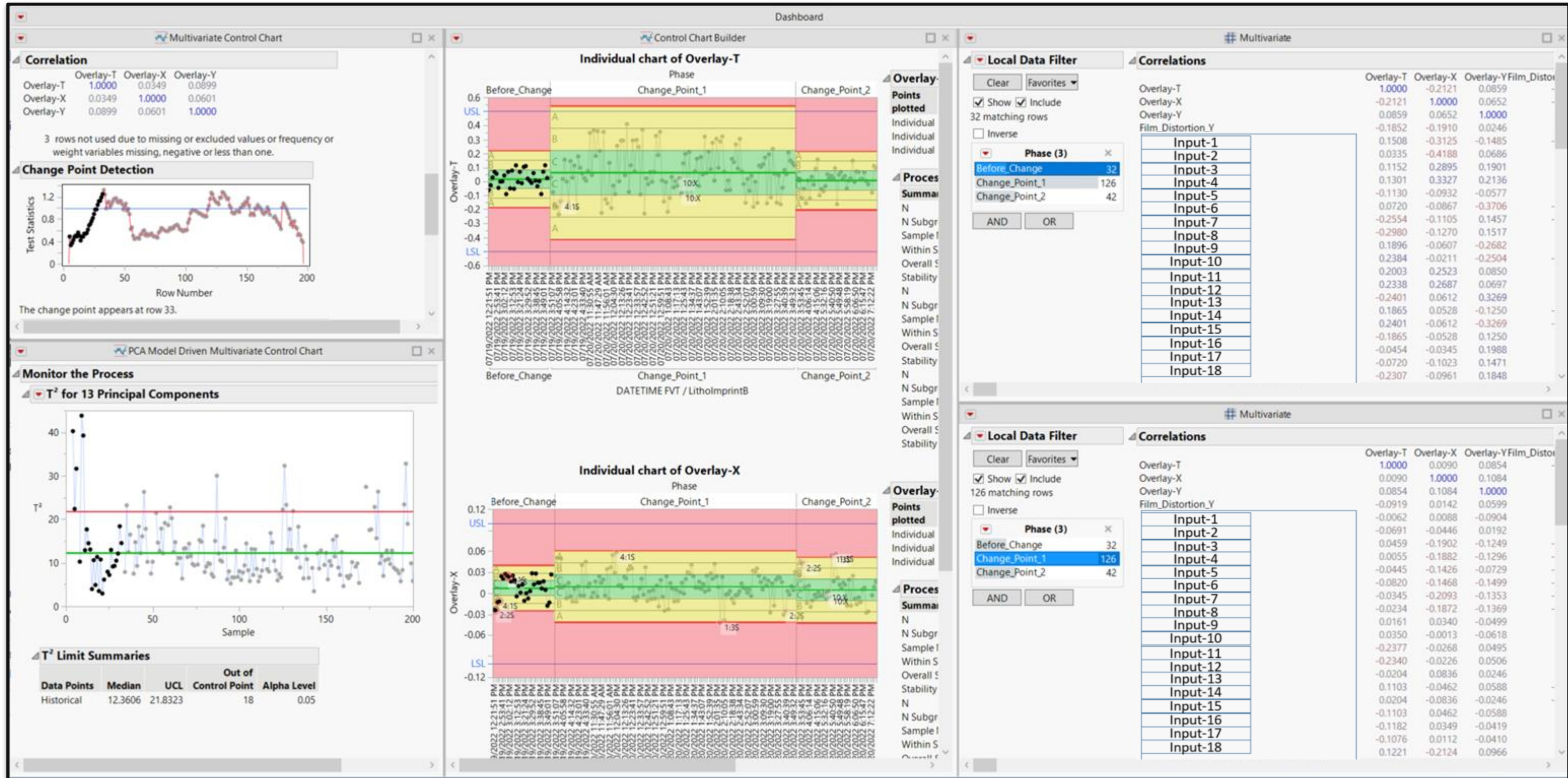# Introduce and validate a known change
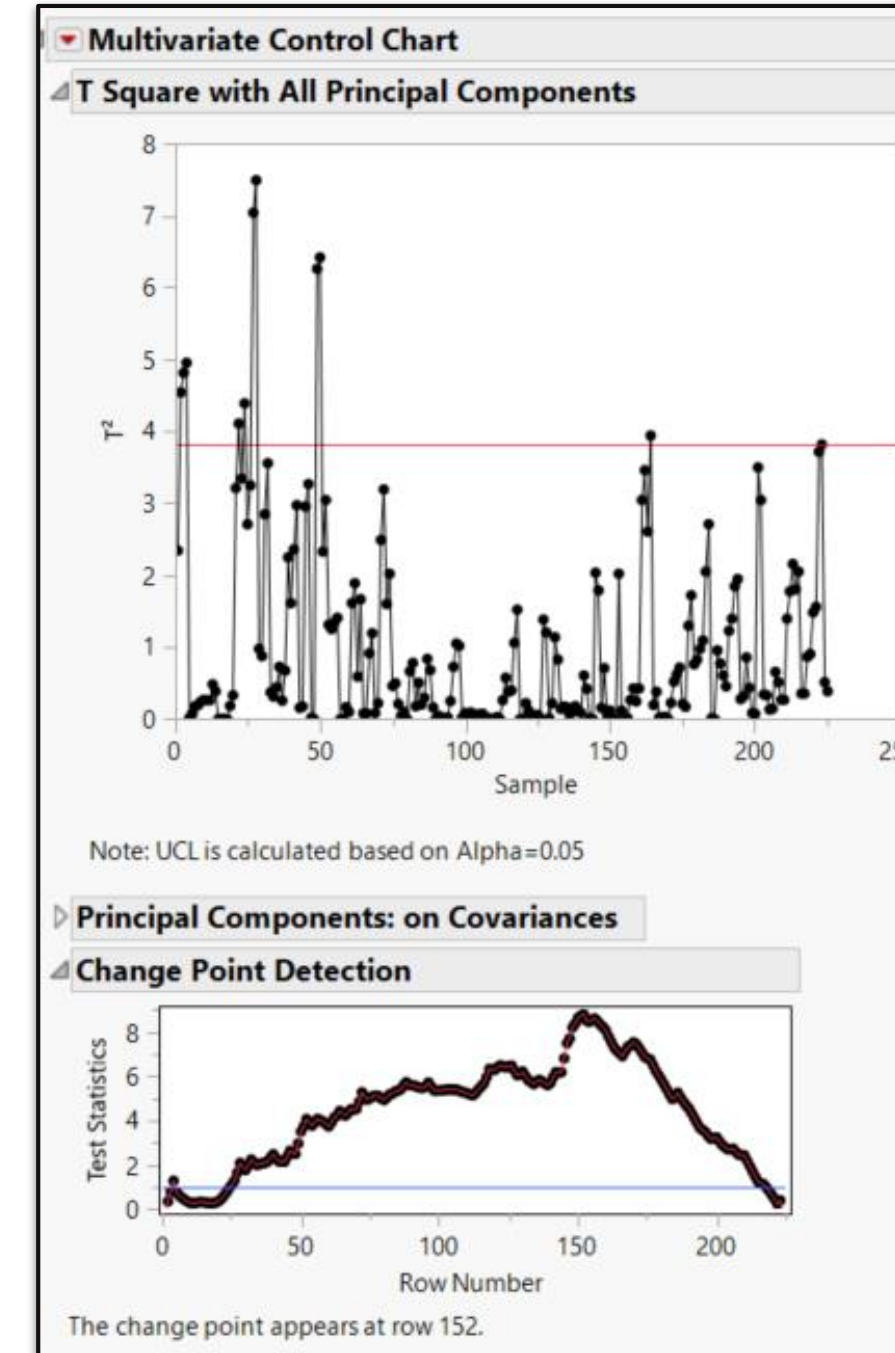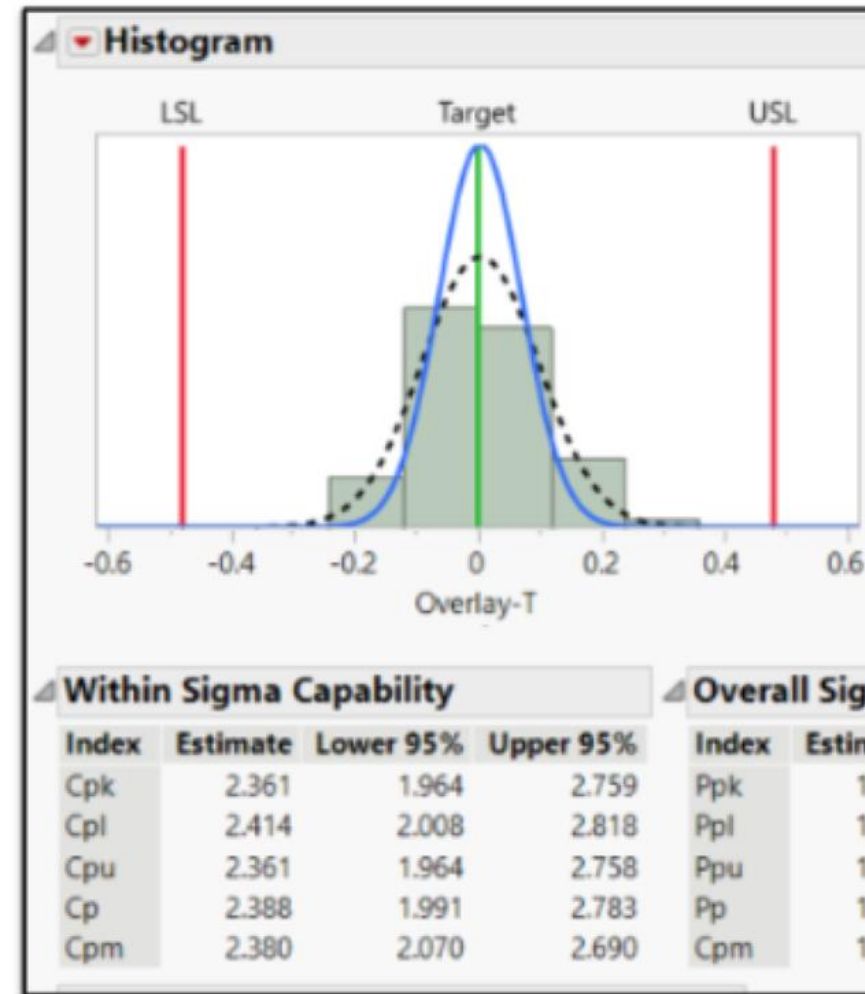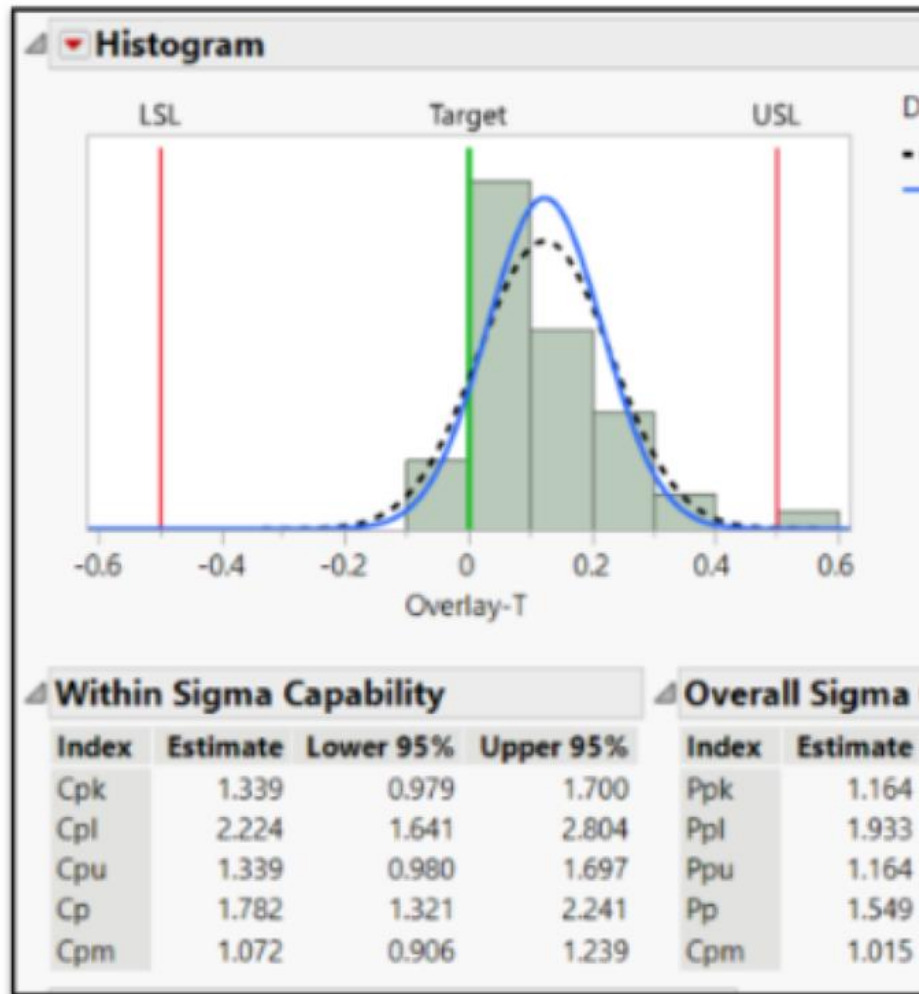
1. Low Cpk
   Mean shift

2. Adjust the mean shift by adding an offset

3. Validate the change using change point detection
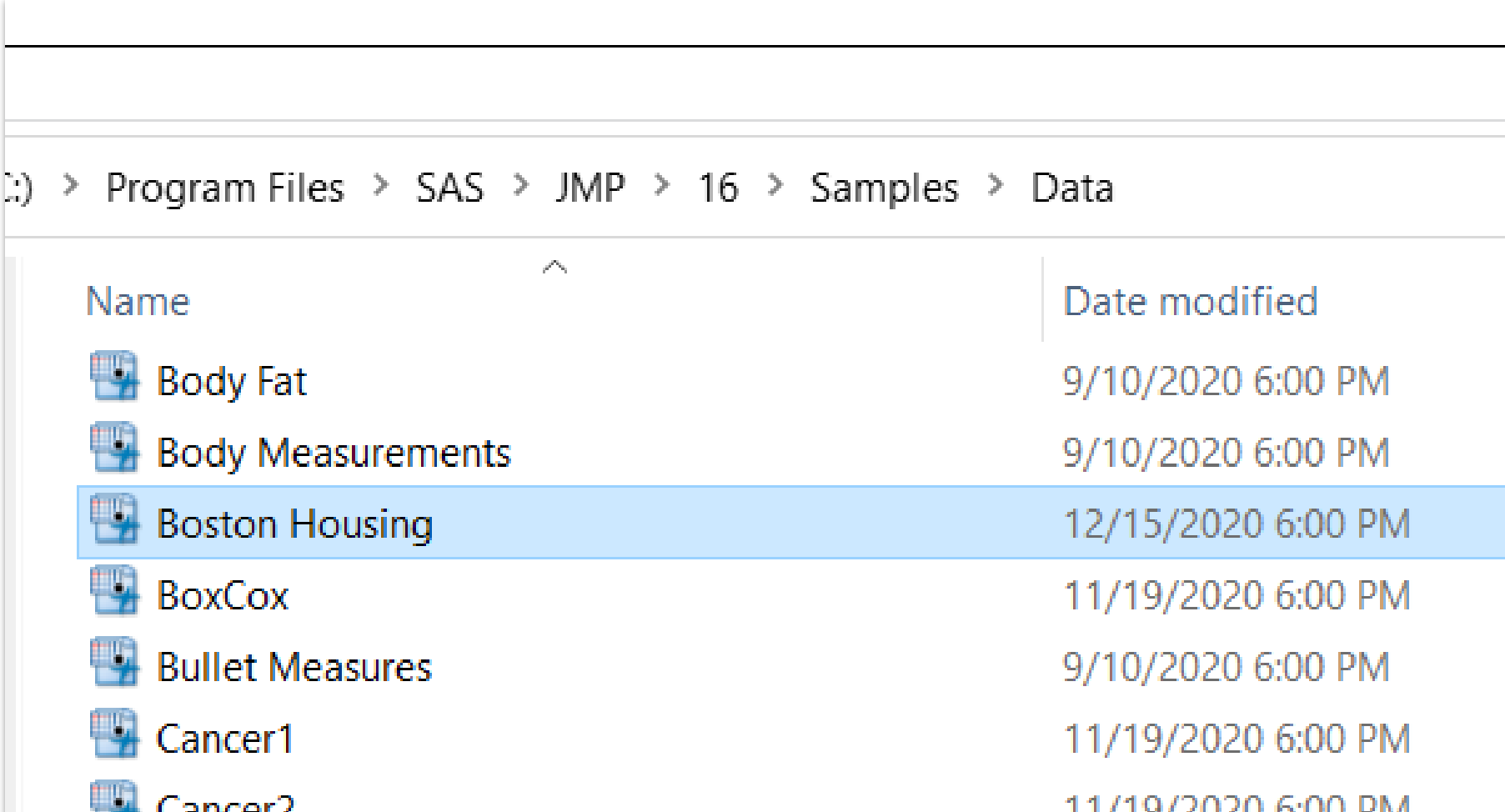
Find abrupt drifts in metrology tools

Use Case 3
Detect and diagnose faults with ease
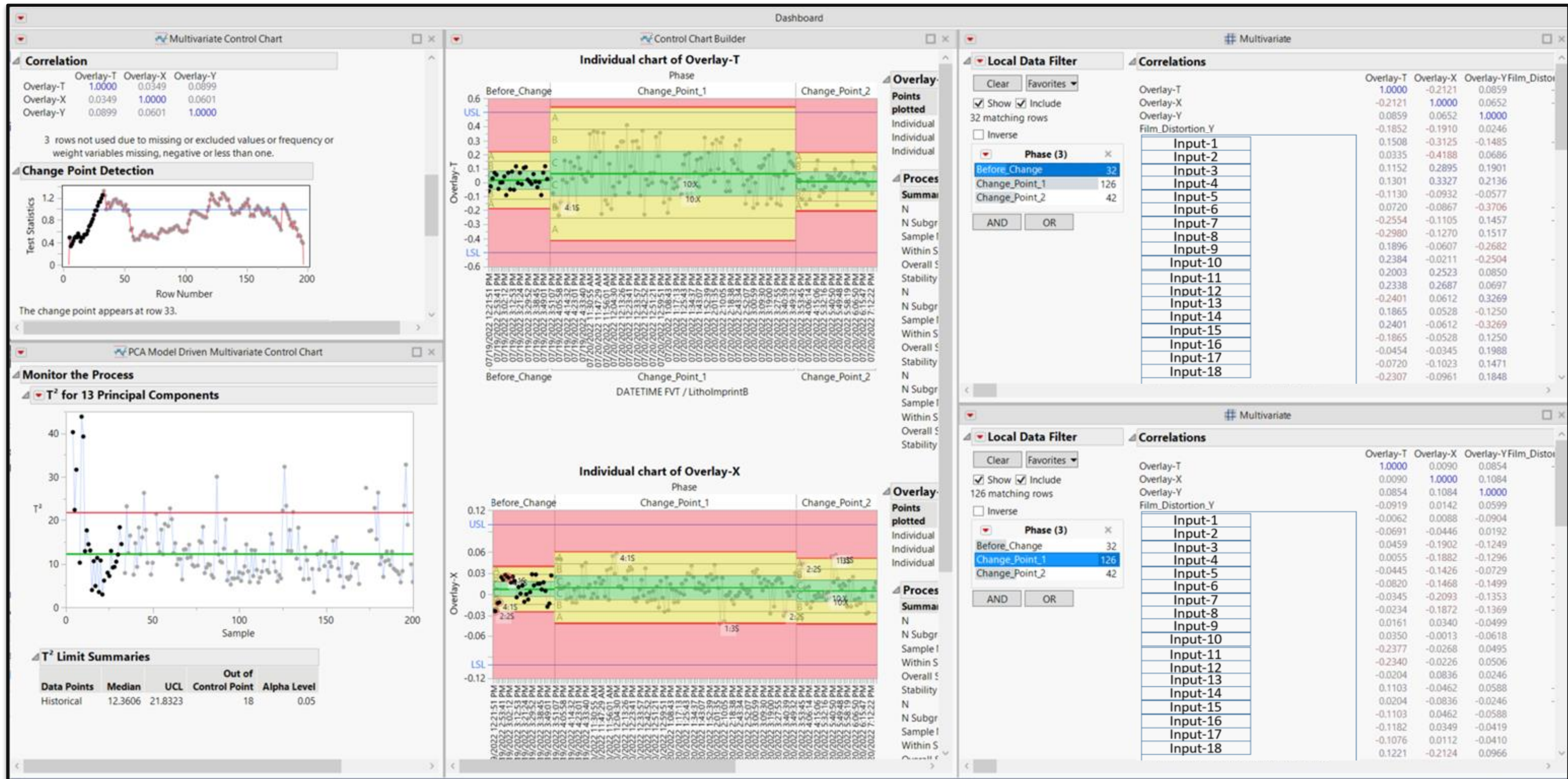
Putting JMP tools in action

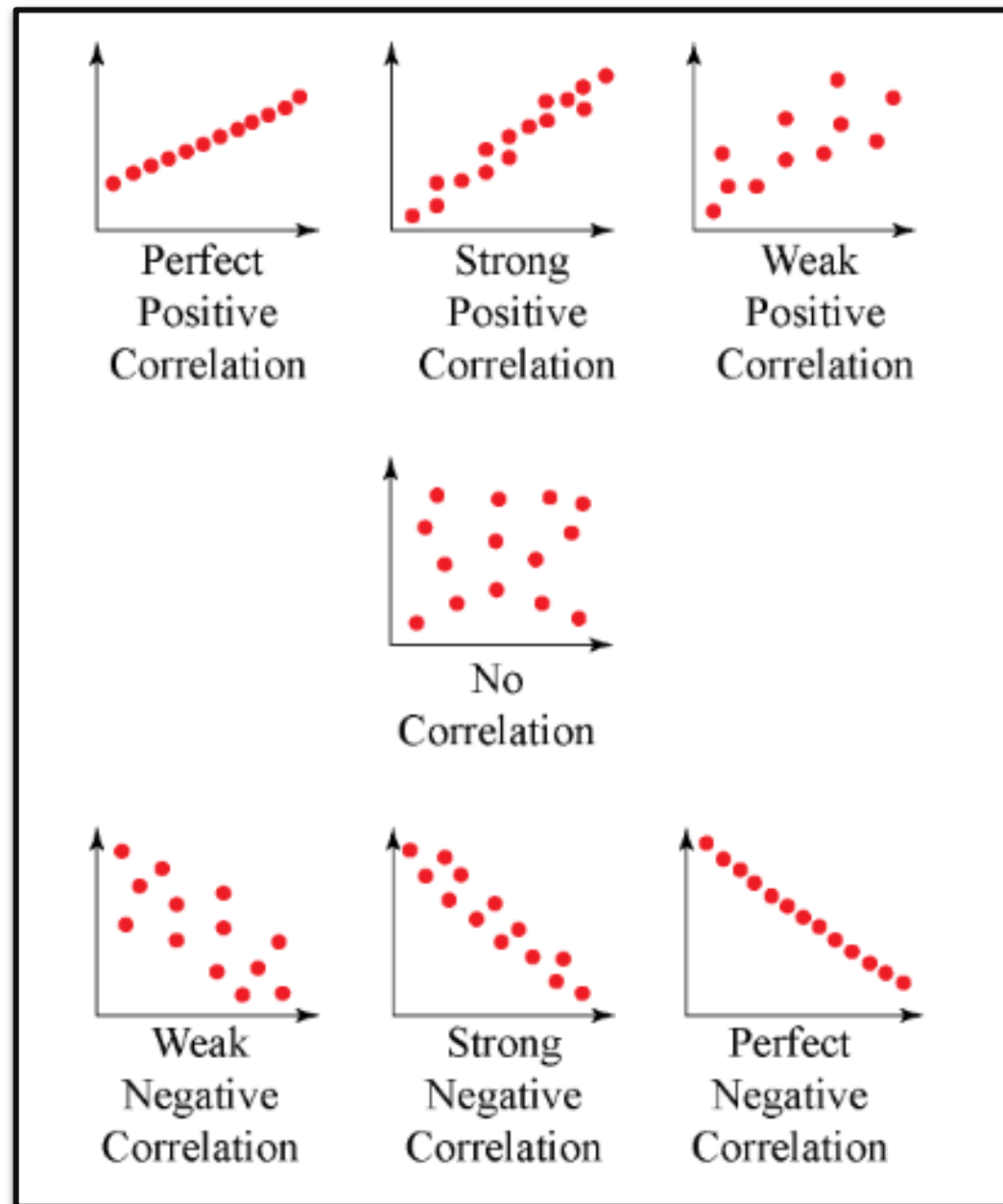Demonstration using Boston housing.jmp,
Sample data set found here:

Detect and diagnose faults with ease

Using Pearson's Correlation Coefficient to understand root causes

Correlations

	mvalue
mvalue	1.0000
crim	-0.4830
zn	0.3243
indus	-0.4882
nox	-0.4852
rooms	0.8055
age	-0.5720
distance	0.3942
radial	-0.2838
tax	-0.4107
pt	-0.1253
b	0.2816
lstat	-0.7501

Phase	Template Change Over	LoadPortId	LoadPortId FVT B	Station FVT / LithoPostInspe...
Change_Point_1	Template_X_MM040	lp3	lp3	A1
Change_Point_2	Template_X_MM039	lp2	lp2	B1
Before_Change		lp1	lp1	
Before_Change	Template_X_MM039	lp2	lp2	A1
Before_Change	Template_X_MM039	lp2	lp2	A1
Before_Change	Template_X_MM039	lp2	lp2	A1
Before_Change	Template_X_MM039	lp2	lp2	B1
Before_Change	Template_X_MM039	lp2	lp2	A1
Before_Change	Template_X_MM039	lp3	lp3	A1
Before_Change	Template_X_MM039	lp2	lp2	A1
Before_Change	Template_X_MM039	lp1	lp1	B1
Before_Change	Template_X_MM039	lp1	lp1	A1
Before_Change	Template_X_MM039	lp1	lp1	A1
Before_Change	Template_X_MM039	lp1	lp1	A1
Before_Change	Template_X_MM039	lp1	lp1	B1
Before_Change	Template_X_MM039	lp1	lp1	A1
Before_Change	Template_X_MM039	lp1	lp1	A1
Before_Change	Template_X_MM039	lp1	lp1	B1

Once we know the exact time of the fault – correlate to non- numerical data sets such change over time, idle time, PM

Detecting and diagnosing faults at same time using change point dashboard

- JMP's change point detection dashboard has been extremely helpful on the MFG shop floor to easily determine abrupt changes (faults)
- Integrating change points into traditional control charts gave us better visual understanding on the shop floor
- The dashboard's ability to demonstrate correlation of inputs and CTQs helps us diagnose issues faster
- We are then able to prevent future faults by understanding the root cause of changes
- Change point detection can be used in ANY time series data analysis through JSL scripting

Change point detection control chart dashboard monitor and diagnose at the faults at the same time

Thank you