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Removing Ambiguity from Surface Analysis: QSA Lessons Learned and Future Directions

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Challenges Discussed

- Ambiguous inspection scenarios
- Variations in authentic electronic component packages
- Identification of ‘peppered’ heterogeneous lots
- Traceability of parts

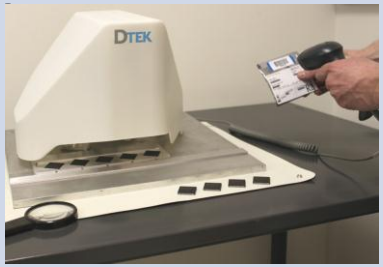
Agenda

- Information content of electronic component packaging
- Lessons learned from production deployment of DTEK™ QSA
- ASTM E826 framework for homogeneity testing
- Low-cost visual traceability of electronic components

Background

- Covisus is a subsidiary of ChromoLogic LLC dedicated to commercial deployment of pattern analysis technology
- ChromoLogic is a diversified research & development firm
  - Capabilities in optics, information processing, diagnostic tools, and spectroscopy
- Research Attribution: Supply security technology funded by the US Army Research Office and US Missile Defense Agency

DTEK Product Progression

Version TRL Level Date	Version 0.2 TRL 6 Dec 2010	DTEK 1.1 TRL 7 July 2011	DTEK 2.0 TRL 7 Dec. 2011	DTEK 2.1 TRL 7/8 May 2012
Hardware				
Data Entry Time (min per lot)	6 minutes	5 minute	15 seconds with barcode integration	15 seconds with barcode or instant (0 sec) with ERP integration
Scan & Analysis Time (min per component)	4 minutes	1 minute	Per component: 30 seconds full batch time, < 1s scan time	Per component: 20 seconds full batch time, < 1s scan time
Key Features	Field validation on “blacktopped” counterfeits	Enhanced precision, drastically enhanced scan speed.	Custom glancing angle illumination, barcode integration, five component tray, ESD safety.	Modular design, ESD enhancements, increased precision.

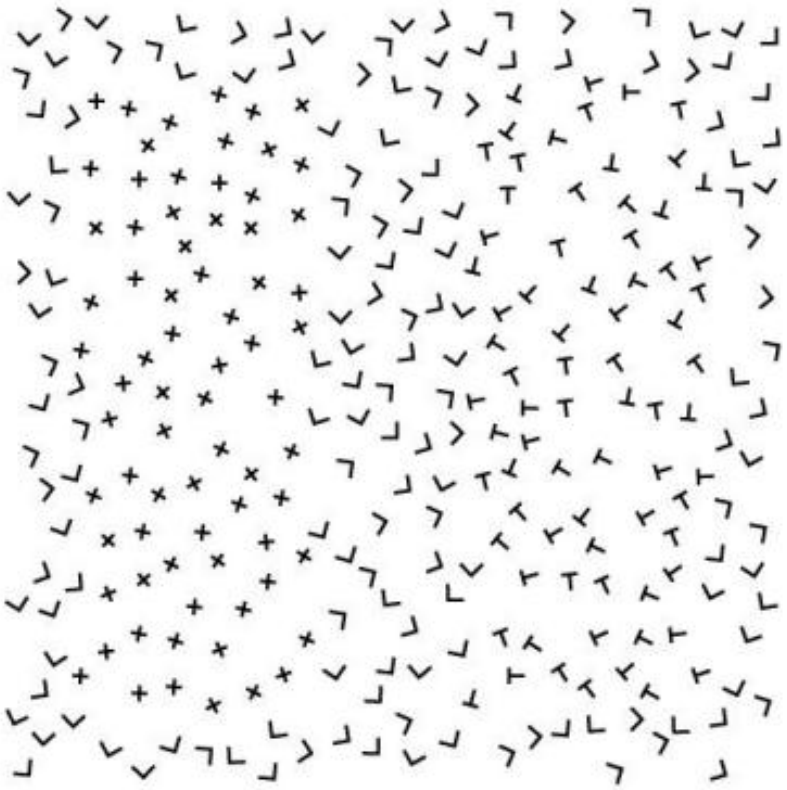
QSA

- From AS6081:

"Quantitative Surface Analysis is the use of unambiguous, quantitative information about component packaging through comparative surface feature analysis. Changes to the external packaging of electronic components due to resurfacing techniques (i.e., altering the original surface by sanding, lapping, micro-blasting and/or recoating and remarking) produce subtle changes to surface patterns on the sub-millimeter scale.

These patterns may be measured quantitatively with nondestructive optical and/or spectroscopic techniques with resolution and sampling rates sufficient to identify resurfaced components with a high degree of statistical confidence. QSA techniques and systems provide evidence of resurfacing through comparative analysis in homogeneous lots and can identify heterogeneity within a sample as a test for "peppering" of counterfeit parts within authentic components. Evidence of resurfacing obtained through QSA is considered a failure."

Texture Challenge: Human Perceptual Ability



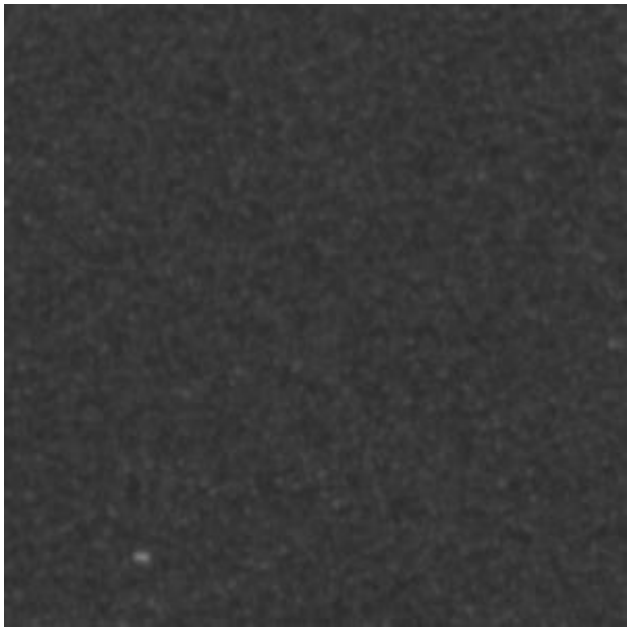
Compounding the problem, human beings have a perception bias that precludes us from recognizing complex textural patterns.[1]

1. *Characterizing the Limits of Human Visual Awareness. Huang, L. Science. Vol. 317 no. 5839 (2007)*

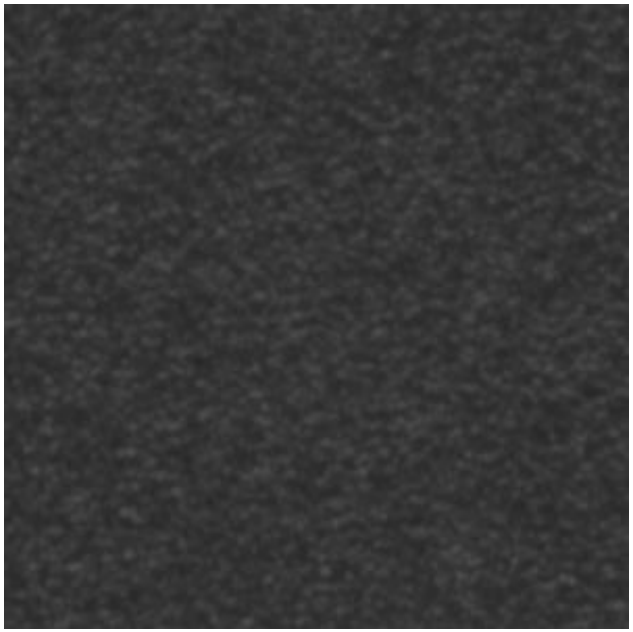
Pattern Analysis: Counterfeit Surfaces

- Human inspectors are not able to perceive, recall, and describe complex patterns exhibited on electronic component surfaces
- Pattern analysis enables each surface to be described with one simple number.

Authentic



Counterfeit

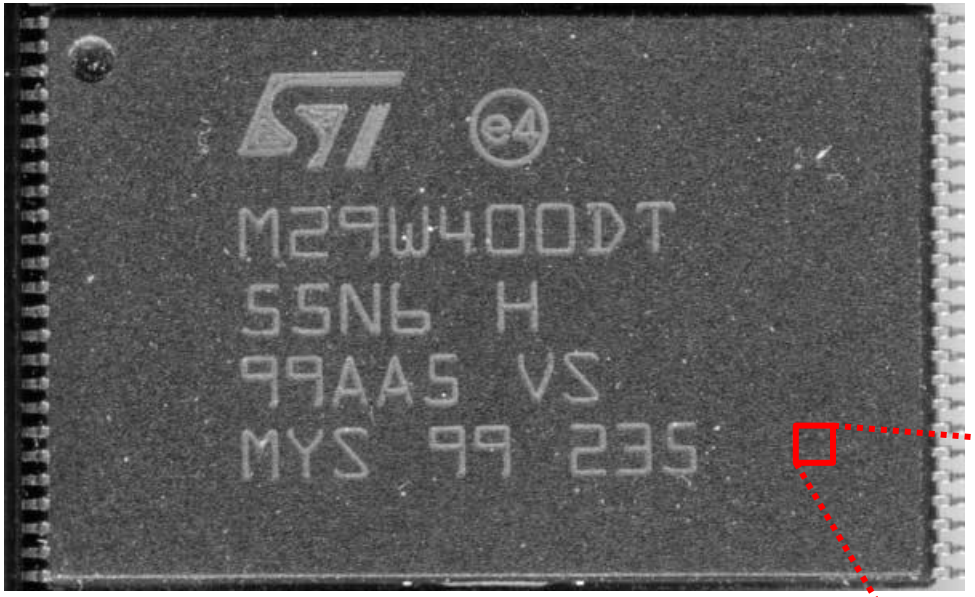


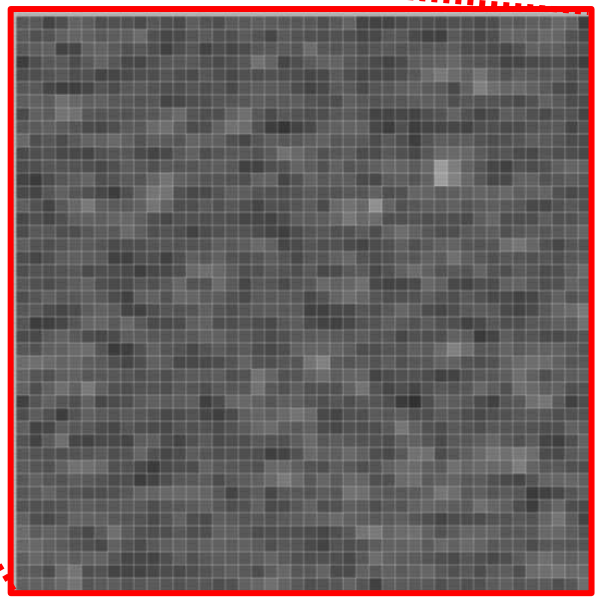
Covisus software quantitatively identifies the component on the right as non-conforming

Surface Information Content

- Noisy Channel Coding Theory
- Maximum information content for binary (2-bit) encoding provides one value per square (0 or 1)

Component Surface Information Content





After discarding information content for error correction, total possible combinations are:

$64^{5,000,000}$

Background: Testing Process (4 Tests)

Test Name	Description of Comparative Test
DELTA **'Golden' Sample Comparison**	Compares the test sample surfaces against a user-supplied reference sample of known quality
TANGO **Top vs. Bottom Comparison**	Compares the top and bottom characteristics of the test sample components
ECHO **Top Surface Homogeneity**	Examines variations within the top surface characteristics of the test sample in order to identify lot mixing or "peppering"
KILO **Bottom Surface Homogeneity**	Examines variations within the bottom surface characteristics of the test sample in order to identify lot mixing or "peppering"

Production Deployment

COVISUS

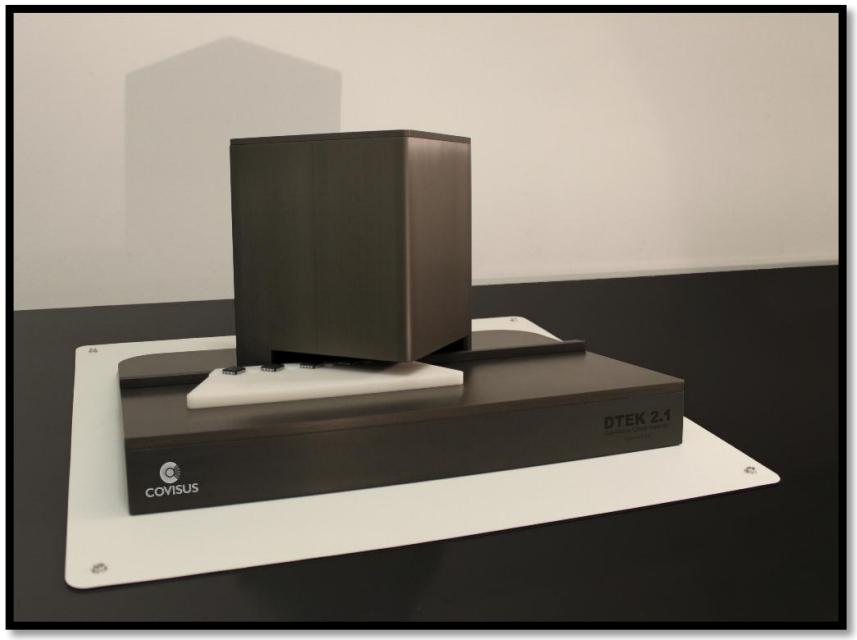
- Government labs
  - High parts mix
  - Many parts are non-production
  - Production parts are scrutinized heavily
- Prime Contractors
  - Throughput is key
  - Desire rapid, PASS/FAIL results
- Government Agencies (Enforcement)
  - PASS/FAIL results
  - No external sharing
- Distributors (Open Market)
  - Highly skilled inspectors
  - Seeking additional quantitative and qualitative information for tough disposition cases

Lessons Learned

- Confounders
  - Intensity (color)
  - “Outliers”
- Myth: The surfaces of counterfeit parts are more inconsistent than authentic parts
- Myth: parts from different date codes / countries of origin are completely different
- Qualitative vs. Quantitative Mix
  - Establishing firm thresholds creates clarity
  - Pass/fail information should be augmented with additional qualitative inspection information

DTEK Testing Process

- Nondestructive
- Less than 10 minute cycle time
  - Scan time less than 1 second per part
- Non-expert operation and interpretation
- Stores previous scans for comparative purposes



Statistical Background and Terms

- Good reference document: ISO 35:2006
- Measurement mean (μ)
- Standard deviation (σ)

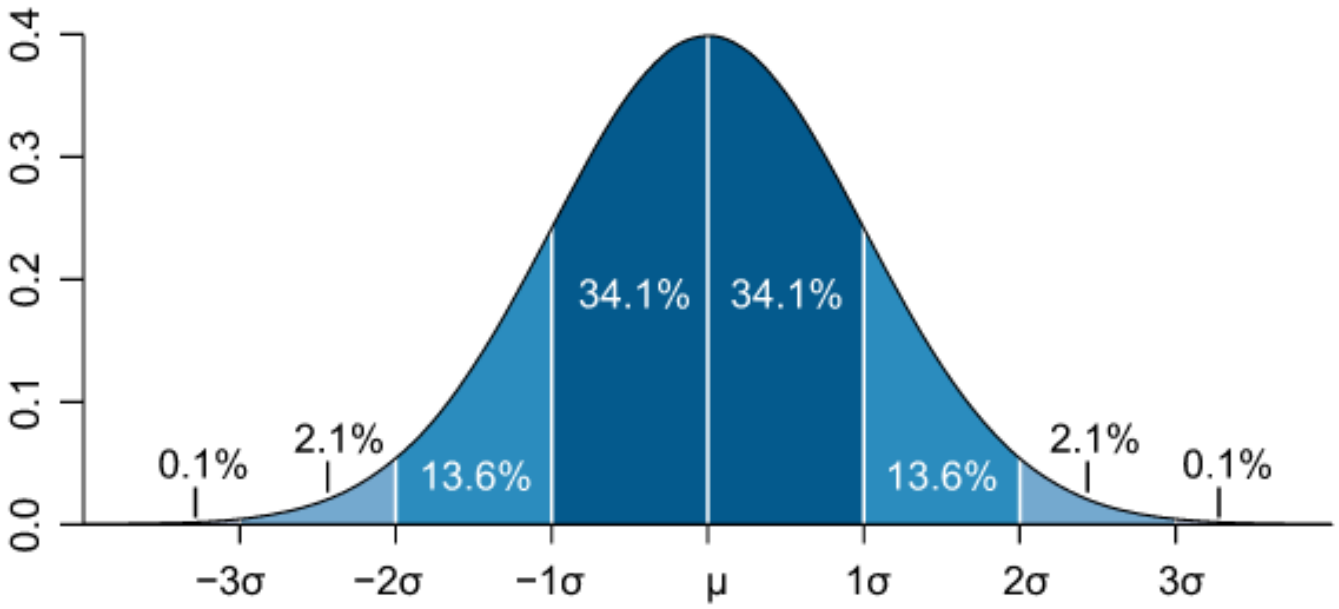


Image attribution: Jeremy Kemp.
W. Commons, 2005

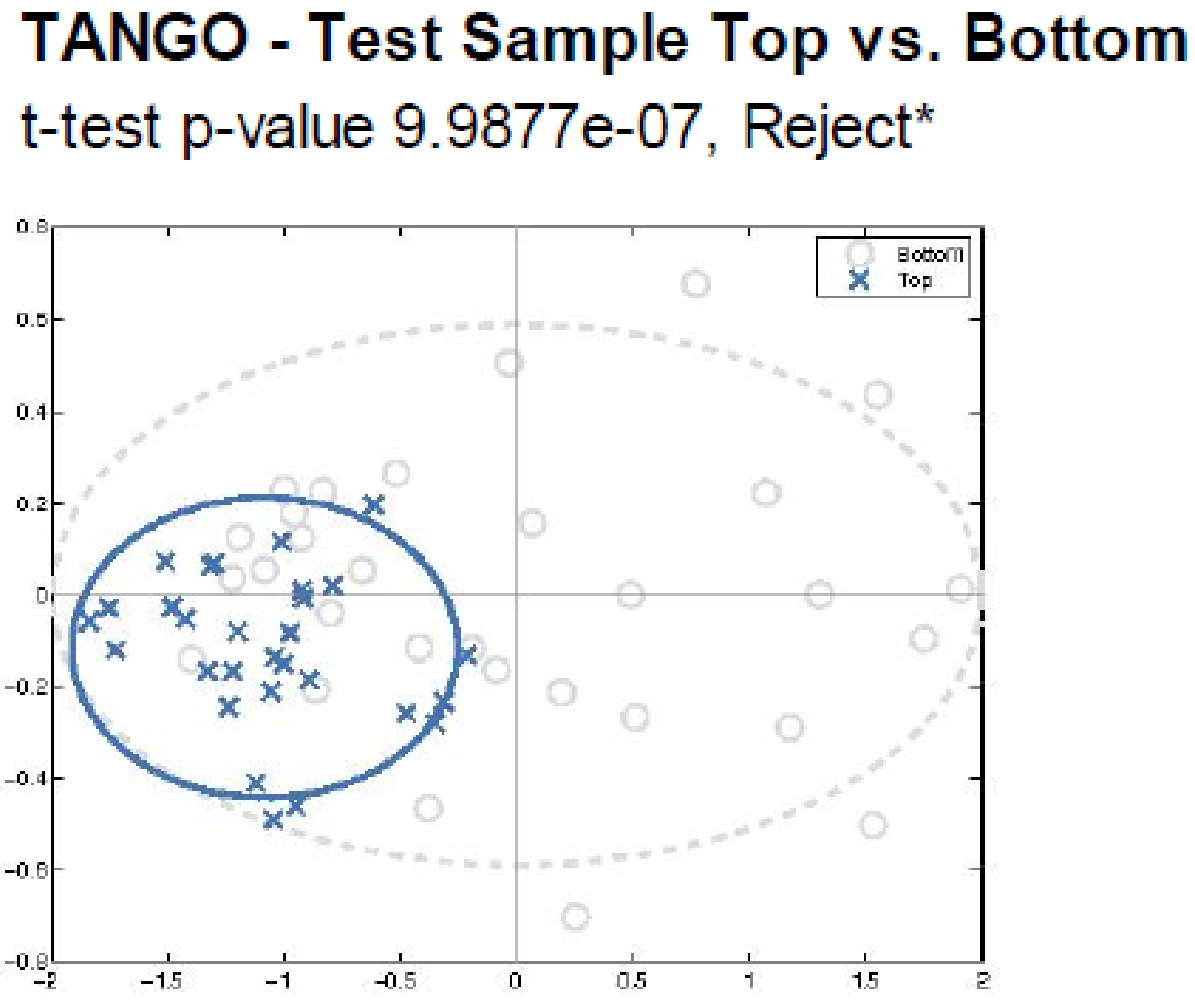
Interpretation of Results: Hypothesis Testing

The “null hypothesis” is that the mean surfaces textures are the same, and any difference between the surfaces being compared is due to normal, random variation in surface texture.

The hypothesis test conducted by DTEK either ACCEPTS or REJECTS the null hypothesis that the mean textures are the same.

The user sets the degree of statistical confidence (default is 99% confidence)

Example DELTA Test



*Rejection of null hypothesis at the 99% level of statistical confidence

Outlier Detection

"As counterfeiters improve, we are often looking for the one component where they made a mistake"

- Scott McKey, 4STAR Electronics

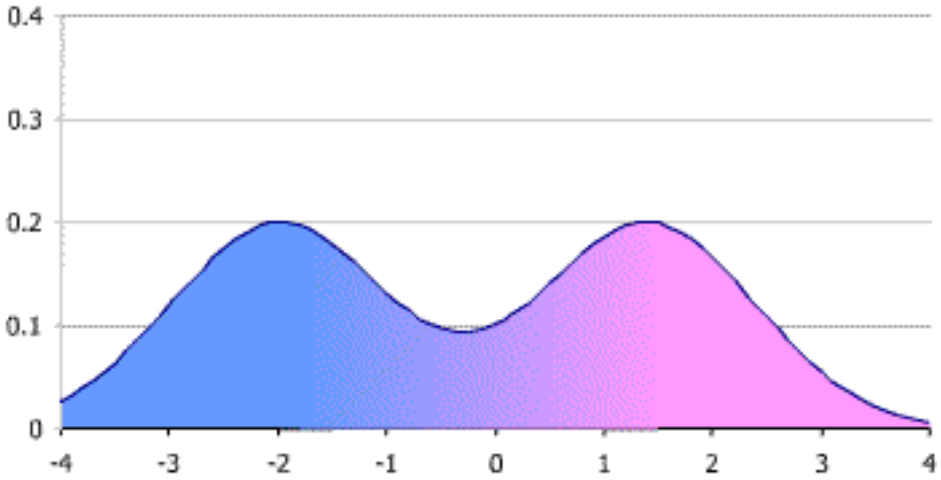
- **The goal:** Detecting outliers (extreme deviations from the statistical mean) could be a useful method to catch "bad" counterfeits in a test sample, and help identify peppering.
- **The challenge:** Outliers are part of every normal population (including authentic parts)

Outliers and Heterogeneity

- ASTM E176: Flag parts that exceed a threshold of X standard deviations from from the mean
- Most statistical outlier detection methods make the assumption of a normally distributed, *homogeneous* sample.

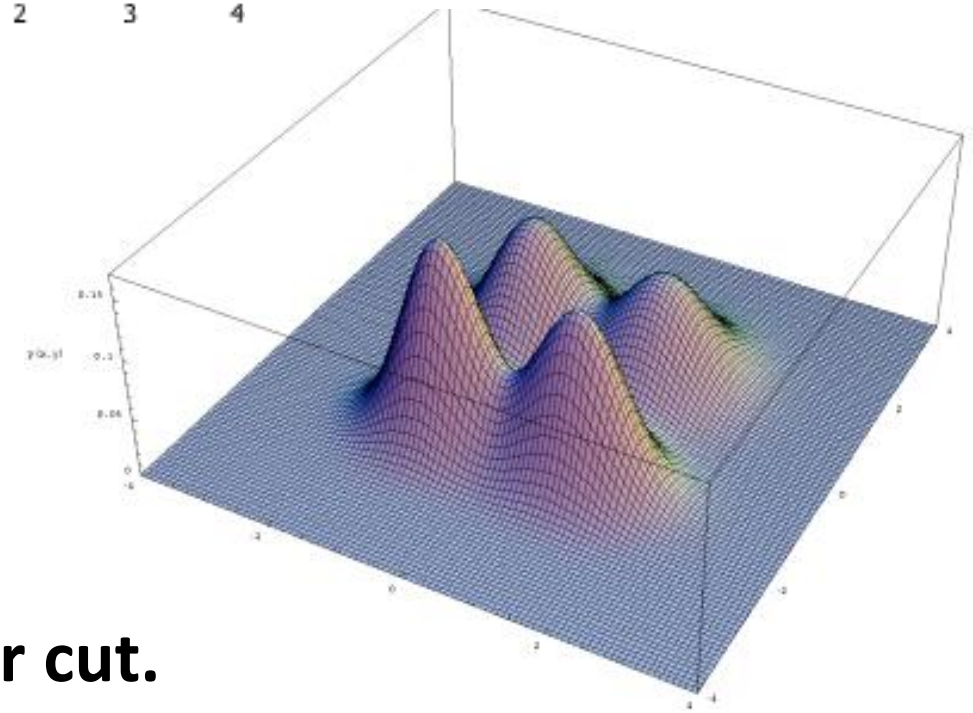
Bottom Line: Homogeneity is an invalid assumption for open market parts

Heterogeneous Sample Distributions



Simple Bimodal Distribution

Bivariate, Multi-Modal Distribution



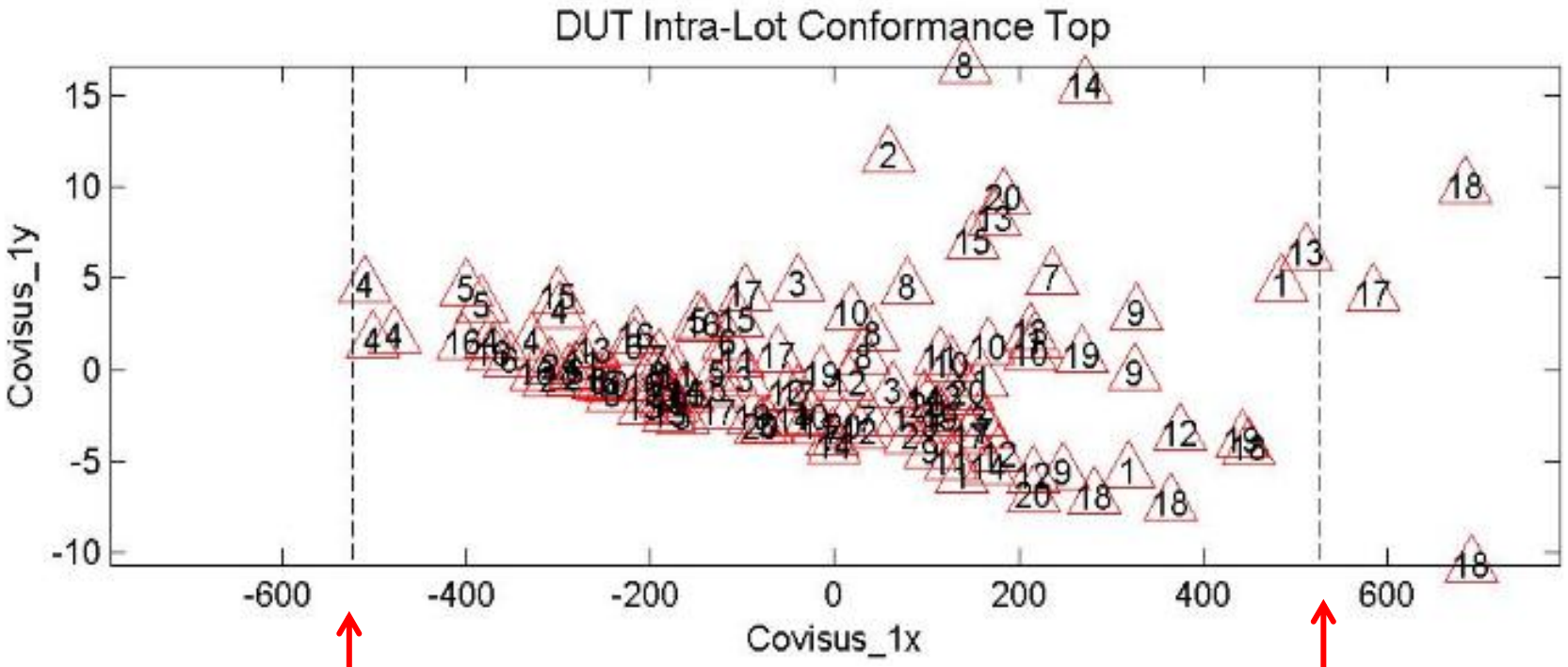
Real data is rarely this clear cut.

Normal Variation in Authentic Parts

- Epoxy molded parts – built in an array
- Mold-to-mold variation
- Cooling variation
- Cleaning / wash / bake variation

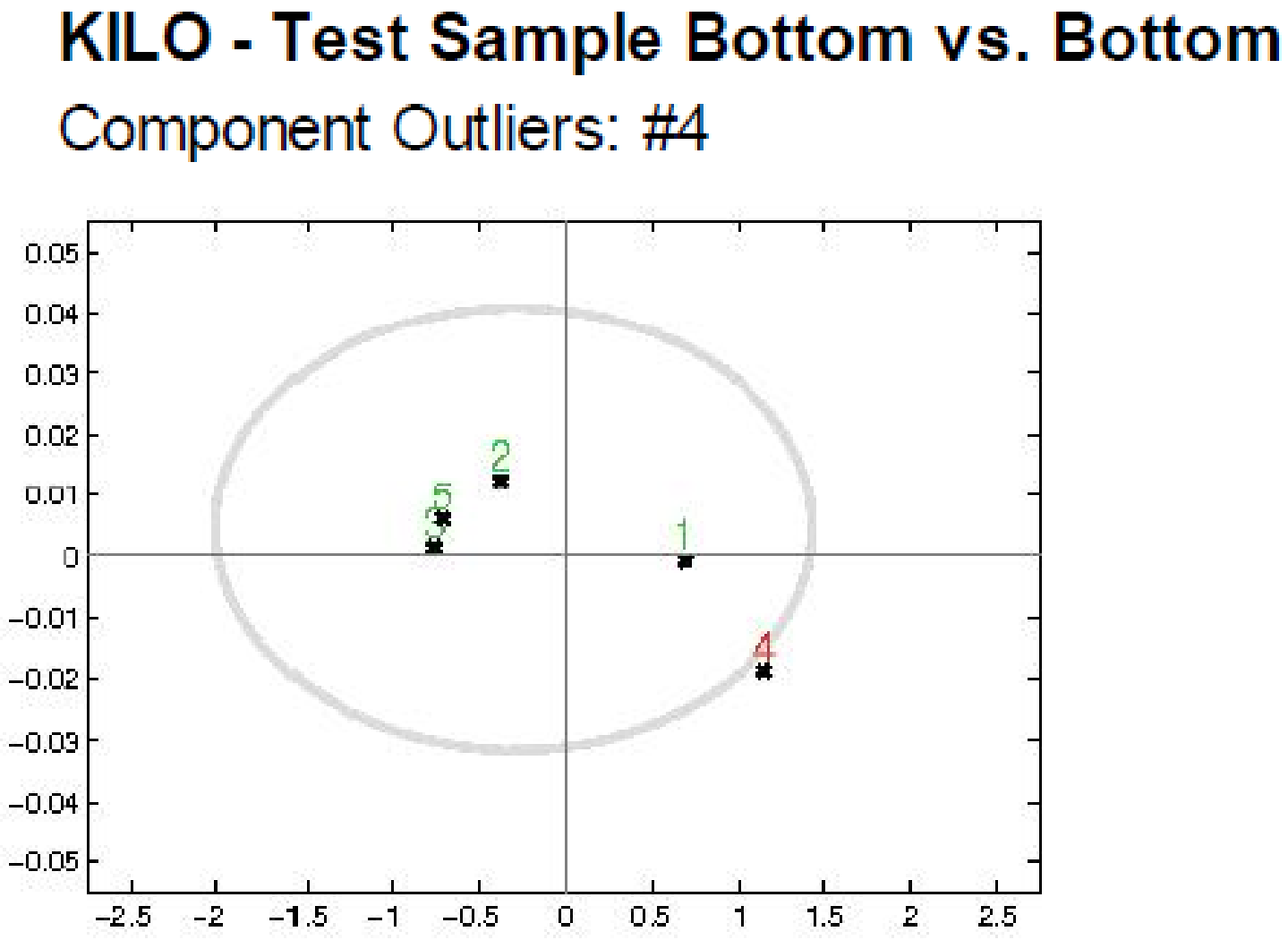
Package fabrication is a parallel process, with significant variation exhibited between different components in the same manufactured lot.

First Version ~ Fall 2011

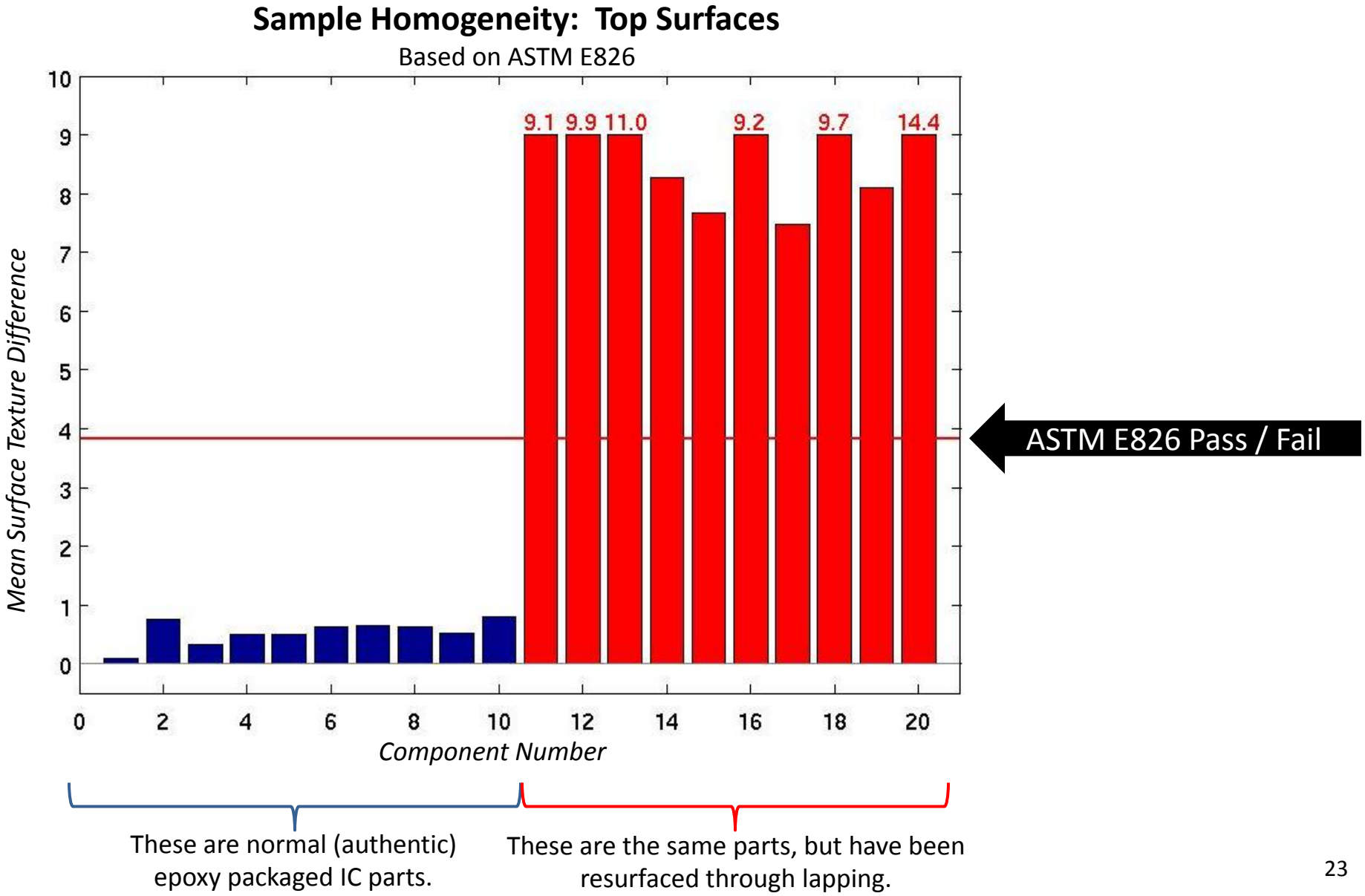


Screening for outliers of more than 2 standard deviations from the mean

2nd Version ~ Summer 2012



3rd Version: May 2013 Release



ASTM E826

- ASTM E826: Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectrometry

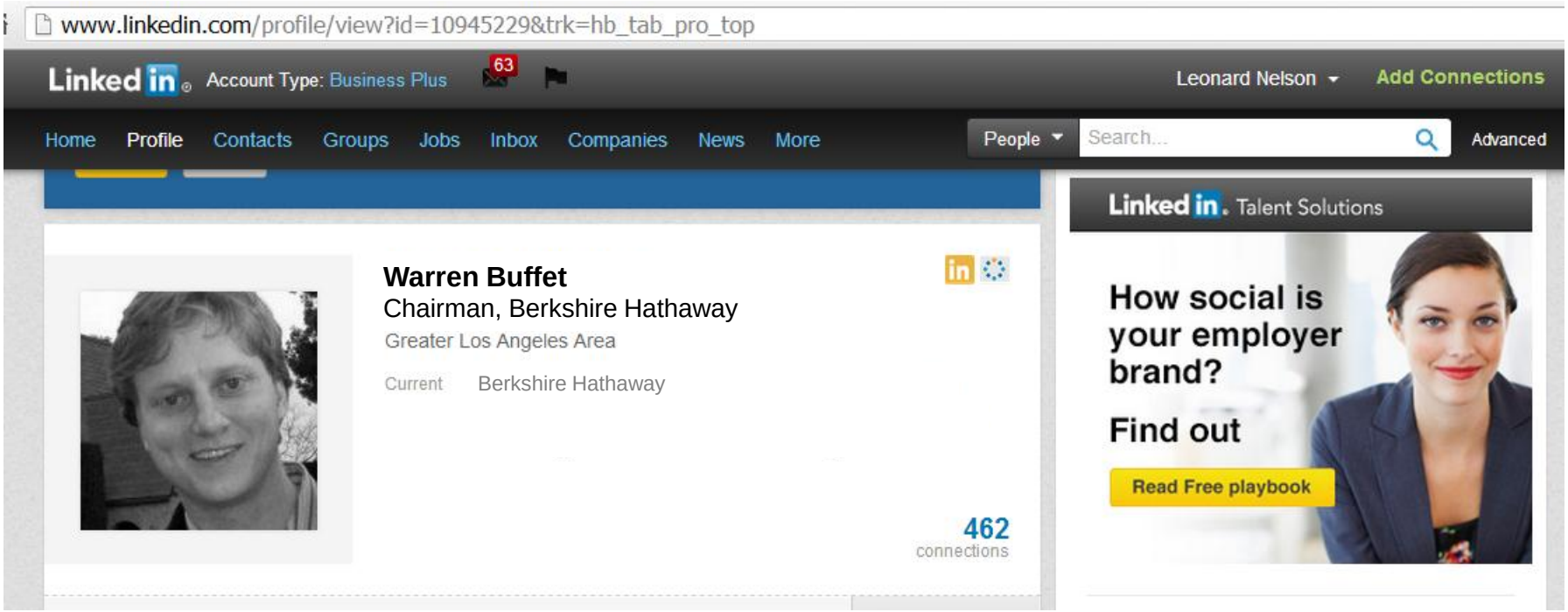
- As noted in the E178 standard: **"This practice is not limited to elemental analysis or techniques. This practice can be applied to any property that can be measured, for example, the property of hardness as measured by the Rockwell technique."**

- It is widely applied to other measurement and acceptance techniques for testing lot homogeneity of multiple commodity types

E826 Applied to Electronic Components

Test Intra-Surface Homogeneity → Test Conformance Between Surfaces → Pass / Fail and Identify Homogenous Sub-Samples

Optical Traceability



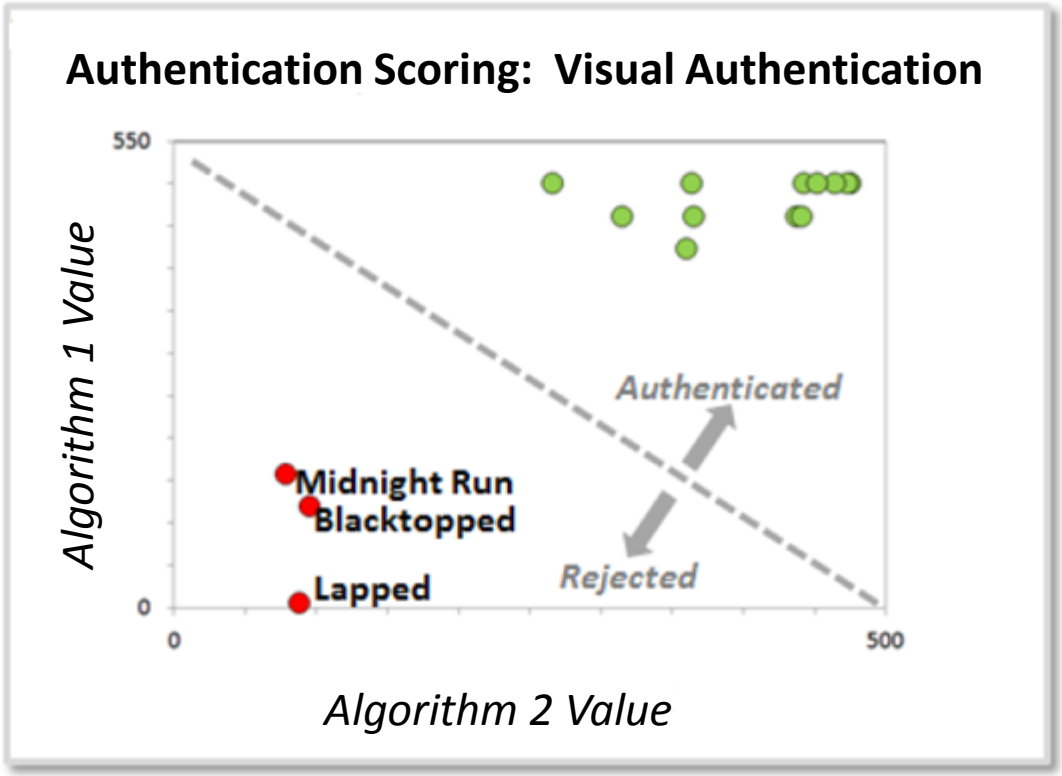
- Simple concept & application: Use computers to “remember” exactly what parts look like.
- Use computers to optically trace parts without adding any labels, markings, or tags.

Goals and Targets

- Low cost
- Non-contact
- Less than 100ms scanning time
- Only internet connection required
- No chemicals, adhesives; ESD safe
- Safe and non-toxic
- Compatible with automation equipment

Pilot Data

- First scan “enrolls” the parts to remember them later
- 2nd scan later in the supply chain matches the parts back to compare against enrolled scans



- **Data storage req: 512 bits/part**
- **17 billion parts can be stored on a 1TB hard disk ($80)**
- **High accuracy rates possible; targeted at parity with ISO/IEC 15426 2D barcodes**

Summary

- Codename: “QuanTEK”
- Large amounts of surface information
- Unlock it!
- Surface texture comparison: hypothesis testing
- Homogeneity testing: ASTM E826 – based testing
- Low-cost, low-hassle traceability: machine recognition without tags, labels, barcodes or additives

Research Attribution: Research conducted by ChromoLogic LLC and funded in part by US Missile Defence Agency

THANK YOU & CONTACT INFORMATION

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