Counterfeit Mitigation

Center for Advanced Life Cycle Engineering (CALCE)

University of Maryland, College Park, MD, USA

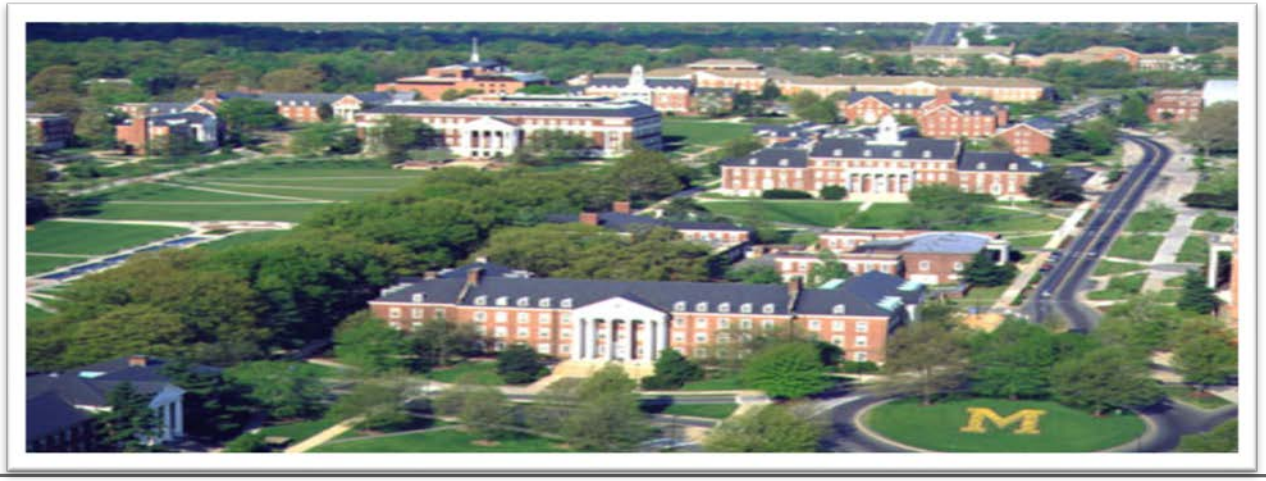
(www.calce.umd.edu)

Parts Standardization & Management Committee (PSMC)

25 - 27 April 2017, LMI – Tysons, VA

CALCE Overview

- The Center for Advanced Life Cycle Engineering (CALCE) at the University of Maryland, College Park formally started as an NSF Center of Excellence in electronics systems reliability (1984).
- One of the world's most advanced and comprehensive testing and failure analysis laboratories.
- Funded by over 150 of the world's leading companies.
- Supported by about 100 faculty, visiting scientists, research assistants and interns.
- Received NSF innovation award in 2009 and IEEE standards education award in 2013.



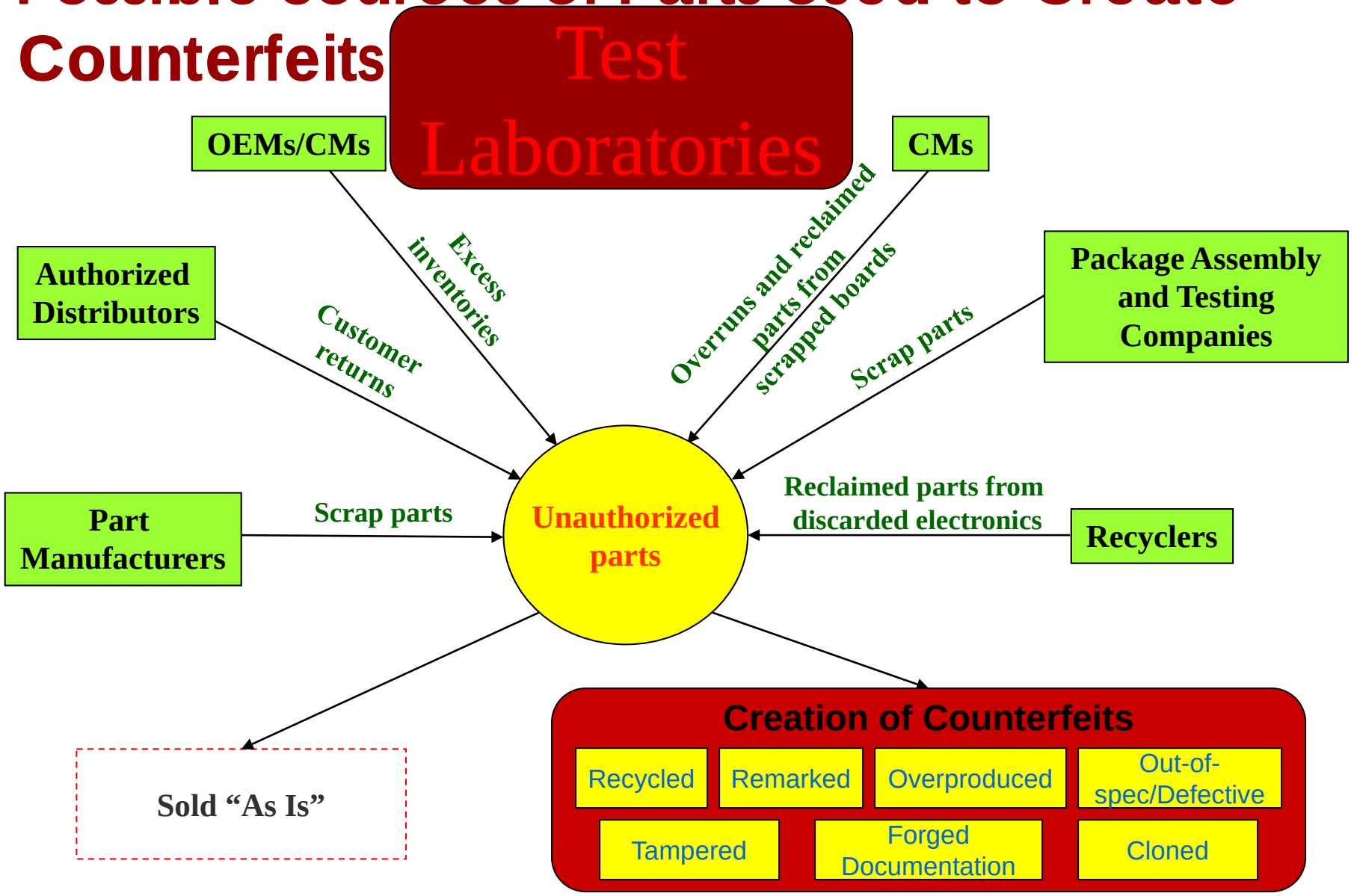
What is a Counterfeit Electronic Part?

- A counterfeit electronic part is one whose identity has been deliberately misrepresented.
- Identity of an electronic part includes:
  - Manufacturer,
  - Part number,
  - Date and lot code,
  - Reliability level,
  - Inspection/Testing,
  - Documentation.

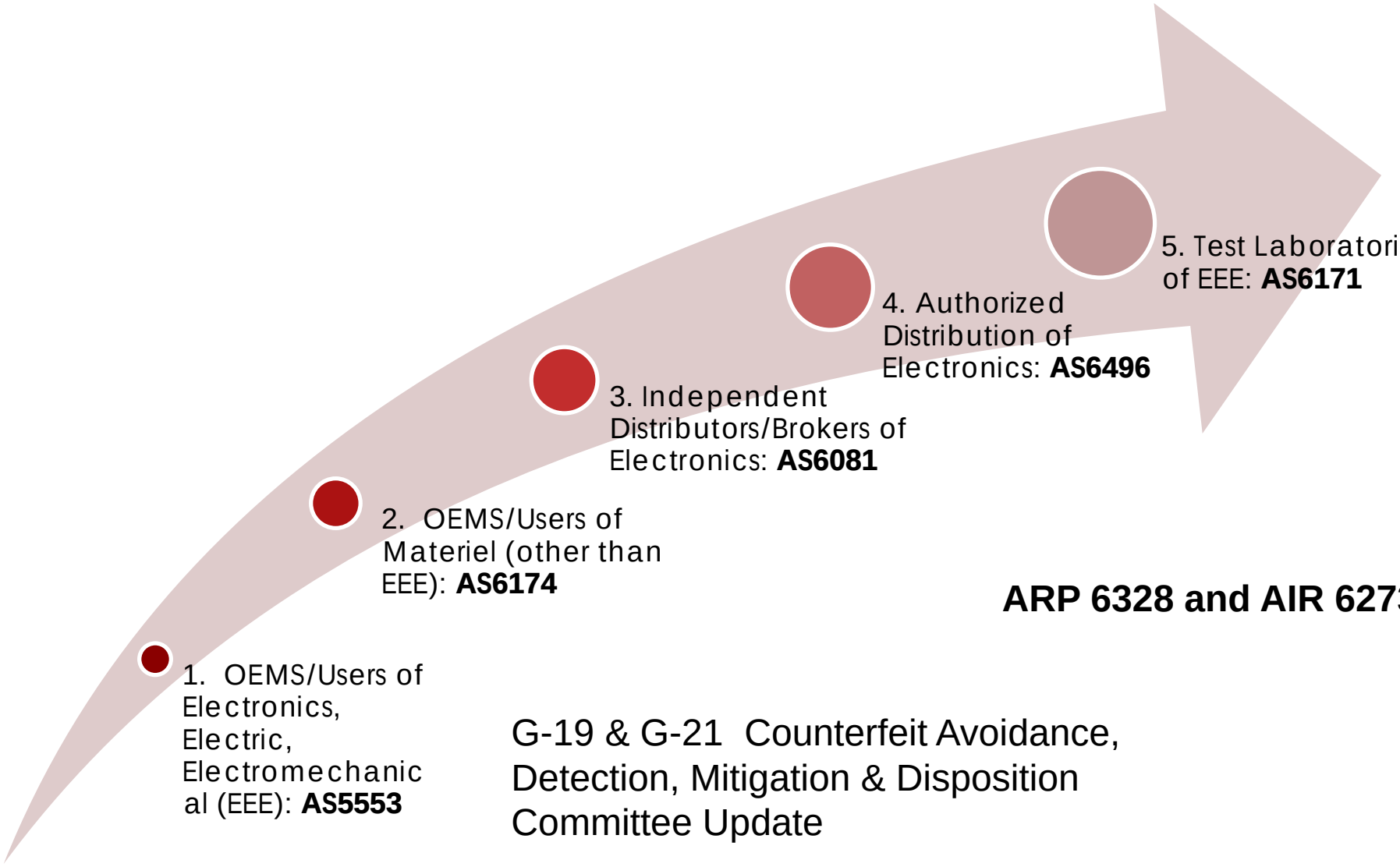
(2011): Screening for counterfeit electronic parts, Journal of Materials Science, Materials in Electronics 22:1511-1522

"Semiconductor Manufacturers' Efforts to Improve Trust in the Electronic Part Supply Chain", IEEE Transactions on Components and Packaging Technology, Vol. 30, No. 3, pp. 547 – 549, September 2007.

Possible Sources of Parts Used to Create Counterfeits



G-19 & G-21 Counterfeit Prevention & Detection Standards



ARP 6328 and AIR 6273

G-19 & G-21 Counterfeit Avoidance, Detection, Mitigation & Disposition Committee Update

Summary of SAE G-19 Aerospace Standards

Standard	Title
SAE AS5553 Rev B	Counterfeit Electrical, Electronic, and Electromechanical (EEE) Parts; Avoidance, Detection, Mitigation, and Disposition – **Published 9/2016**
ARP6328	Guideline for Development of Counterfeit Electronic Parts; Avoidance, Detection, Mitigation, and Disposition Systems – **Published 9/2016**
SAE AS6462	AS5553 Verification Criteria **– Under revision**
SAE AS6171	Test Methods Standard; General Requirements, Suspect/Counterfeit, Electrical, Electronic, and Electromechanical Parts – **Published 10/2016**
SAE AS6081	Counterfeit Electronic Parts Avoidance – Distributors – **Preparing release of revision and in discussion on the test methods**
SAE ARP6178	Fraudulent/Counterfeit Electronic Parts; Tool for Risk Assessment of Distributors
SAE AIR6273	AIR6273 - Terms, Definitions, and Acronyms - Counterfeit Materiel or Electrical, Electronic and Electromechanical Parts – **under ballot**
SAE AS6496	Fraudulent/Counterfeit Electronic Parts: Avoidance, Detection, Mitigation, and Disposition - Authorized/Franchised Distribution

Test Methods Covered in the 6171 Slash Sheets

- AS6171/2: External Visual Inspection (EVI) (incl. remarking, resurfacing, weight, dimensions, SEM)
- AS6171/3: X-Ray Fluorescence (XRF) (incl. lead finish, thickness)
- AS6171/4: Delid/Decapsulation Physical Analysis (DDPA)
- AS6171/5: Radiological Inspection (RI): X-ray imaging
- AS6171/6: Acoustic Microscopy (AM): external and internal
- AS6171/7: Electrical Test: Curve Trace, Full DC, Key Electrical Parameters for AC, Switching, and Functional Tests; ambient or over temperature (incl. environmental, burn-in, seal)
- AS6171/8: Raman Spectroscopy: materials identification
- AS6171/9: Fourier Transform Infrared Spectroscopy (FTIR): materials identification
- AS6171/10: Thermogravimetric Analysis (TGA): material analysis
- AS6171/11: Design Recovery (DR): device layout and function

AS6171 – Future Test Methods

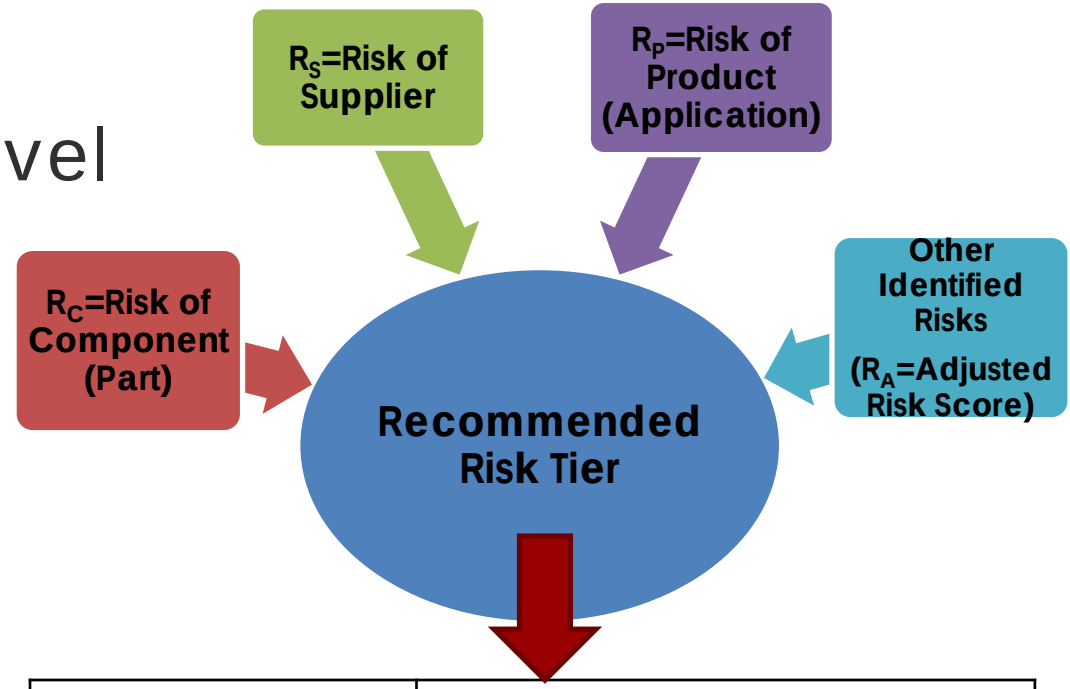
Description	Status
Acoustic Microscopy (AM) Test Method for Capacitors	Dec 2016: initial ballot
Secondary Ion Mass Spectroscopy (SIMS) Test Method	April 2017: initial ballot
Radiated Electromagnetic Emission (REME) Test Methods	In development
Packaging Test Methods	In development
Netlist Assurance Test Methods	In development
Laser Scanning Microscopy (LSM) Test Methods	In development
Thermomechanical Analysis (TMA) Test Methods	In development
Assembly Test Methods	Workgroup in formation
Scanning Electron Microscopy (SEM) Test Methods	Workgroup in formation

Each Test Method Includes:

- Processes and a description of procedures
- Apparatus needed for the test technique
- Required qualification and certification of processes and personnel
- Guidelines and requirements for reporting

AS6171 Risk Level Assessment

- Evaluating risk and recommended tier level of testing based on:
  - Risk of the receiving a counterfeit part from the supplier,
  - Risk of the part and risk of application to assess potential negative consequences of a counterfeit electronic part being installed,
  - Other offsetting risk factors.



Risk Tier Level	Target Confidence (TC)
Critical	0.90
High	0.8
Moderate	0.65
Low	0.5
Very Low	0.35

Example: Product Risk Assignment

Product Risk Factor – R_P		
Quantifies the risk of the product in which the part will be used (adapted from MIL-STD-1629A, section 4.4.3)		
Category	**Description**	**Value**
1 – Catastrophic	A failure of the product may cause death or a major system loss (e.g., aircraft, tank, missile, ship, etc.). Alternatively, product exposure on the market could result in severe monetary impact due to product recall or warranty claims.	70
2 – Critical	A failure of the product may cause severe injury, major property damage, or major system damage which will result in loss of the product's function. Alternatively, product exposure on the market could result in high monetary impact due to product recall or warranty claims.	50
3 – Marginal	A failure of the product may cause minor injury, minor property damage, or minor system damage which will result in delay or loss of availability or degraded operation.	30
4 – Minor	A failure of the product is not serious enough to cause injury, property damage, or system damage, but may result in unscheduled maintenance or repair.	10

Risk Assessment Model

$$R_A = R_P + R_C + R_S + A_P + A_C + A_S + A_G$$

- A_i = Adjustment Factors
  - A_P: based on product level testing, and like/unlike redundancy
  - A_C: based on testability/complexity of part
  - A_S: based on risk associated with supplier
  - A_G: based on additional factors including part availability, problem reports, and data from Online Aerospace Supplier Information System (OASIS)

Risk Tier Level	Score Range	Risk Category
0	0-70	Very Low
1	71-110	Low
2	111-150	Moderate
3	151-170	High
4	>170	Critical

Test Sequence Determination

- The test sequence should be determined based on the risk tier level of the part.
- AS6171/1 provides the means to calculate the Counterfeit Defect Coverage (CDC) and Counterfeit Type Coverage (CTC) for any test sequence.
  - This quantifies the effectiveness of the specified test sequence for counterfeit parts detection, and allows it to be assessed against the risk-based confidence target for detection of each defect.

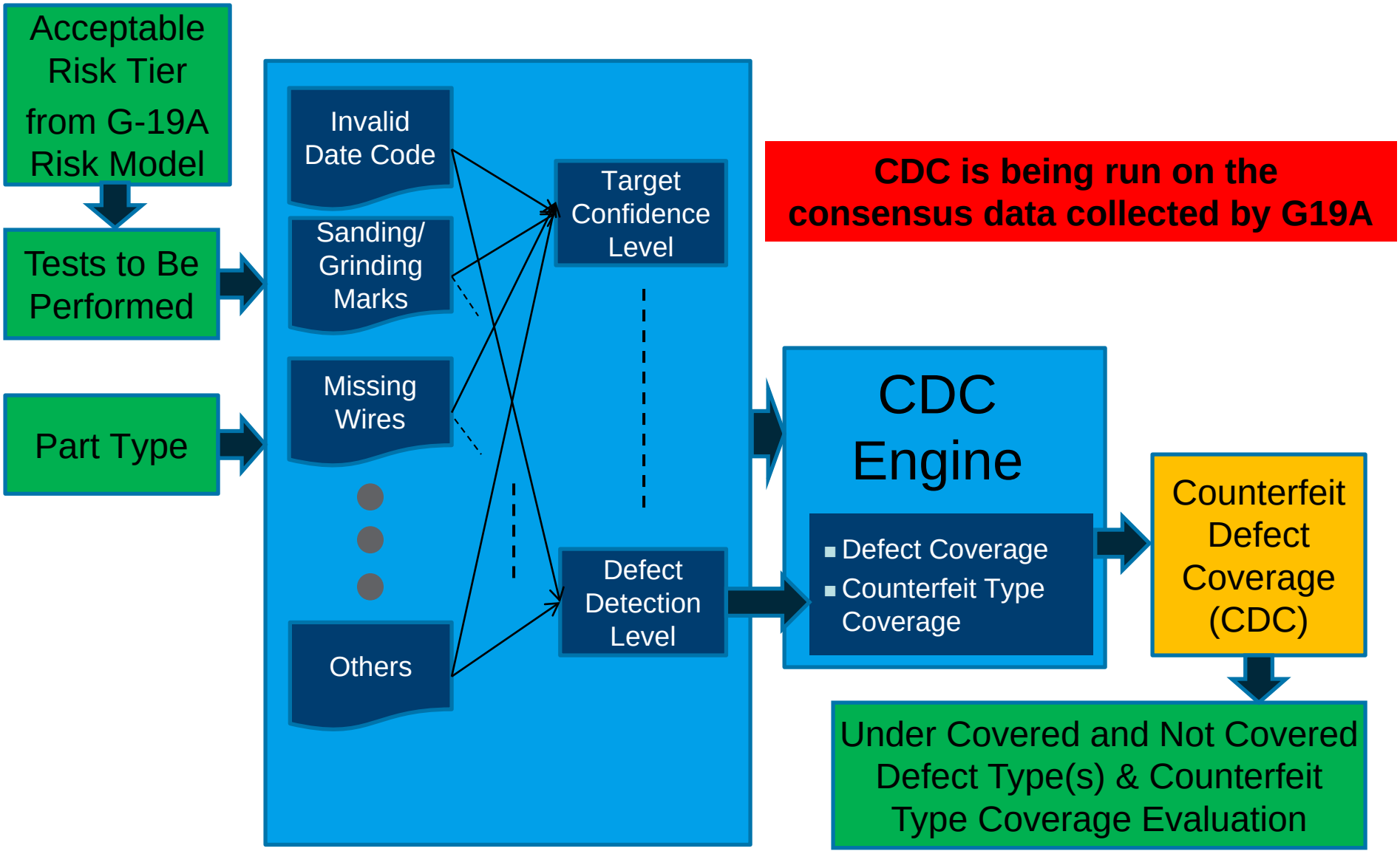
Risk Tier Level	Target Confidence (TC)
Critical	0.90
High	0.8
Moderate	0.65
Low	0.5
Very Low	0.35

Evaluation of Counterfeit Defect Coverage (CDC) for a Test Sequence

Step #	Name	Description
1	Select tier level and target confidence (TC)	Select the risk tier level for assessment and the associated target confidence.
2	Select Test Methods	Select the desired test methods per the SOW or test plan.
3	Establish Confidence Level Matrix	Establishes the confidence level of detecting a each specific defect by each specific test method
4	Determine resultant testing confidence for each defect	Calculate total confidence level of detection for each defect using the entire test plan
5	Identify any defect which is a Not-Covered Defect (NCD) or Under-Covered Defect (UCD)	If resultant testing confidence = 0, then the defect is an NCD If resultant testing confidence < TC (target confidence) then the defect is a UCD
6	Calculate CDC	Calculate Counterfeit Defect Coverage (CDC) as average of resultant testing confidence values over all defects
7	Report results	Report CDC, NCDs, and UCDs.

A Web-based CDC Model has been created by CHASE (Center for Hardware Assurance, Security, and Engineering) at Univ. of Connecticut, to facilitate these calculations.

Estimation of Test Coverage



Counterfeit Detection Test Methods

#	Test Method	#	Test Method
1	EVI, General (Full Lot)	17	AM, PEMS - External, Internal & Material
2	EVI, Detailed (Sample)	18	Electrical, Curve Trace, at ambient temp.
3	EVI, Remarking	19	Electrical, DC Test at ambient temp.
4	EVI, Resurfacing	20	Electrical, Key Parameters at ambient temp.
5	EVI, Part Dimensions	21	Electrical, DC Test and Key Parameters, over temp.
6	EVI, SEM	22	Electrical, Burn-In with Pre- and Post-Testing
7	XRF, Lead Finish Analysis	23	Electrical, Temp. Cycling with Pre- and Post-Testing
8	XRF, Lead Finish Thickness	24	Electrical, Seal (hermetic devices)
9	XRF, Material Composition	25	Raman
10	DDPA, Internal Inspection	26	FTIR
11	DDPA, Bond Pull	27	TGA
12	DDPA, Die Attach	28	Design Recovery, Lev. 1: Simple manual comparison
13	Radiological, 2D	29	Design Recovery, Lev. 2: Layout comp.
14	Radiological, 3D, Incremental	30	Design Recovery, Lev. 3: Selective functional comp.
15	Radiological, 3D, Independent	31	Design Recovery, Lev. 4: Full microcircuit comp.
16	AM, PEMS – External only	32	User/Requester

AS6171 – Examples of Test Sequences by Risk-Tier Levels – Active Parts, Complex

Steps	Physical/Environmental/Electrical Inspections/Tests	4 Critical Risk	3 High Risk		2 Moderate Risk		1 Low Risk		0 Very Low Risk	
		Ex1	Ex1	Ex2	Ex1	EX2	EX1	EX2	EX1	EX2
1	EVI, General (Full Lot)	X	X	X	X	X	X	X	X	X
2	EVI, Detailed (Sample)	X	X	X	X	X	X	X		
3	EVI, Remarking	X				X	X		X	X
4	EVI, Resurfacing					X	X	X		X
5	EVI, Part Dimensions	X	X	X		X				
6	EVI, SEM	X	X	X						
7	XRF, Lead Finish Analysis	X	X	X		X	X		X	X
8	XRF, Lead Finish Thickness	X		X						
9	XRF, Material Composition	X		X		X				
10	DDPA, Internal Inspection	X	X	X	X	X				
11	DDPA, Bond Pull	X	X	X	X					
12	DDPA, Die Attach	X		X						
13	Radiological, 2D	X	X	X	X	X	X	X	X	X
14	Radiological, 3D, Incremental	X		X						
15	Radiological, 3D, Independent									
16	AM, PEMS – External only	X	X							
17	AM, PEMS - External, Internal & Material (Incremental)	X	X							
18	Electrical, Curve Trace, at ambient temp.	X								
19	Electrical, DC Test at ambient temp.	X	X	X	X	X				
20	Electrical, Key Parameters (AC, Switching, Functional) at ambient temp.	X	X	X						
21	Electrical, DC Test and Key Parameters (AC, Switching, Functional), over temp.	X								
22	Electrical, Burn-In with Pre- and Post-Electrical Tests	X								
23	Electrical, Temperature Cycling with Pre- and Post-Electrical Tests	X								
24	Electrical, Seal (hermetic devices)	X								
25	Raman	X		X	X					
26	FTIR	X	X	X						
27	TGA	X								
28	Design Recovery, Level 1: Simple manual comparison	X								

Sample Test Sequences for Low Risk
Active Parts, Complex

Low Risk Target Confidence: 50%

Test #	Test Method	Low Risk	
		Ex 1	Ex 2
1	EVI, General (Full Lot)	X	X
2	EVI, Detailed (Sample)	X	X
3	EVI, Remarking	X	
4	EVI, Resurfacing	X	X
7	XRF, Lead Finish Analysis	X	
13	Radiological, 2D	X	X

Counterfeit Defect Coverage for Low Risk Examples

- Sample

Test #	Test Method	CDC %	
		Ex 1	Ex 2
1	EVI, General (Full Lot)	17.6	X
2	EVI, Detailed (Sample)	41.34	X
3	EVI, Remarking	41.96	
4	EVI, Resurfacing	42.51	42.27
7	XRF, Lead Finish Analysis	44.11	
13	Radiological, 2D	54.32	52.61
	Overall CDC	**54.32**	**52.61**

Not-Covered Defects: Low Risk Examples

Examples 1 and 2
Bond Pull Strength
Misaligned or Missing Contact Windows
Passivation Damage
Dielectric Impurities
Interconnect Contamination
Semiconductor Impurities
Out of Specification-DC Parameters
Out of Specification-AC Parameters
Out of Specification-Functional Parameters
Out of Specification-Switching Parameters
Out of Specification-Curve Trace Parameters
Programming State
Incorrect Temperature Profile
Intermittency

Under-Covered Defects: Low Risk Examples

Example 1	Example 2
Missing or Non-functional Condition Indicator (37.5)	Missing or Non-functional Condition Indicator (37.5)
Missing or Non-functional Part Protector (15.0)	Missing or Non-functional Part Protector (15.0)
Incorrect Part Dimensions (29.6)	Incorrect Part Dimensions (29.6)
Incorrect Part Weight (37.5)	Incorrect Part Weight (37.5)
	Wrong Materials on Part Terminations (4.9)
	Interconnect Re-Attachment (46.9)
Modified Surface Texture (39.1)	Modified Surface Texture (39.1)
Defective Wire Bonds (15.0)	Defective Wire Bonds (15.0)
Die Surface Contamination (2.5)	Die Surface Contamination (2.5)
Wrong Die (37.5)	Wrong Die (37.5)
Delamination (4.9)	Delamination (4.9)
Improper Die Markings (2.5)	Improper Die Markings (2.5)
Internal Damage (15.0)	Internal Damage (15.0)
Die Surface Corrosion (2.5)	Die Surface Corrosion (2.5)
Degradation of Die Metallization (2.5)	Degradation of Die Metallization (2.5)
Contaminated Internal Cavity (15.0)	Contaminated Internal Cavity (15.0)
Not Hermetic (2.5)	Not Hermetic (2.5)
Improper Material (Internal) (37.5)	Improper Material (Internal) (37.5)

Counterfeit Type Coverage: Low Risk Examples

Example 1		Example 2	
Counterfeit Type	**CTC (%)**	**Counterfeit Type**	**CTC (%)**
Recycled	53.05	Recycled	51.18
Remarked	52.33	Remarked	50.35
Overproduced	1.4	Overproduced	1.4
Out-of-spec./Defective	21.94	Out-of-spec./Defective	21.86
Cloned	4.57	Cloned	4.32
Forged Documentation	57.97	Forged Documentation	54.1

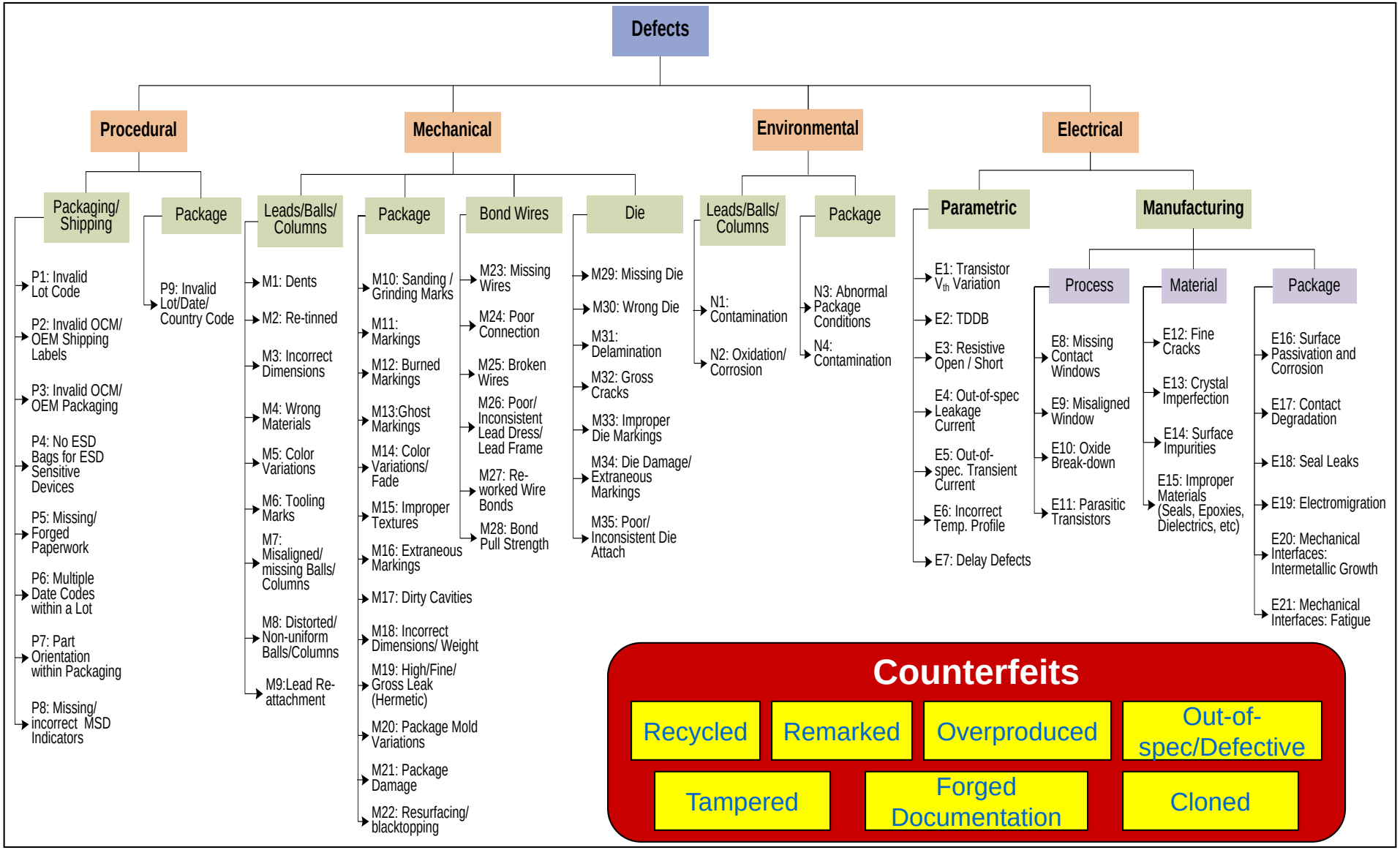
Sampling Plan

- The sampling plan is derived from the General Specification for Microcircuits, MIL-PRF-38535, Appendix D, with an accept number (c) equal to zero:
  - No indications that the part is suspect counterfeit are allowed.
- Any lot subject to suspect/counterfeit detection shall be one that is received in a single shipment (procurement lot) at incoming inspection and contains parts that all have the same lot or date code.
- The same parts can be used for more than one destructive test (e.g., remarking and resurfacing, part dimensions, DDPA)
- The standard sampling plan applies for lots of more than 200 parts. Smaller lots have modified sampling plans.

Sampling Plan, Standard Lot (>200 parts)

TEST / INSPECTION	TEST SAMPLE SIZE
External Visual, General Criteria	Inspect all devices in Lot
External Visual, Detailed Criteria	119 devices, c=0
Remarking & Resurfacing	3 devices, c=0
Part Dimensions	3 devices, c=0
Radiological, AM	45 devices, c=0
XRF, lead finish	3 devices, c=0
DDPA	3 devices, c=0
Electrical Tests	116 devices, c=0
Burn-In	45 devices, c=0
Thermal Shock Temperature Cycling Seal Test	22 devices, c=0

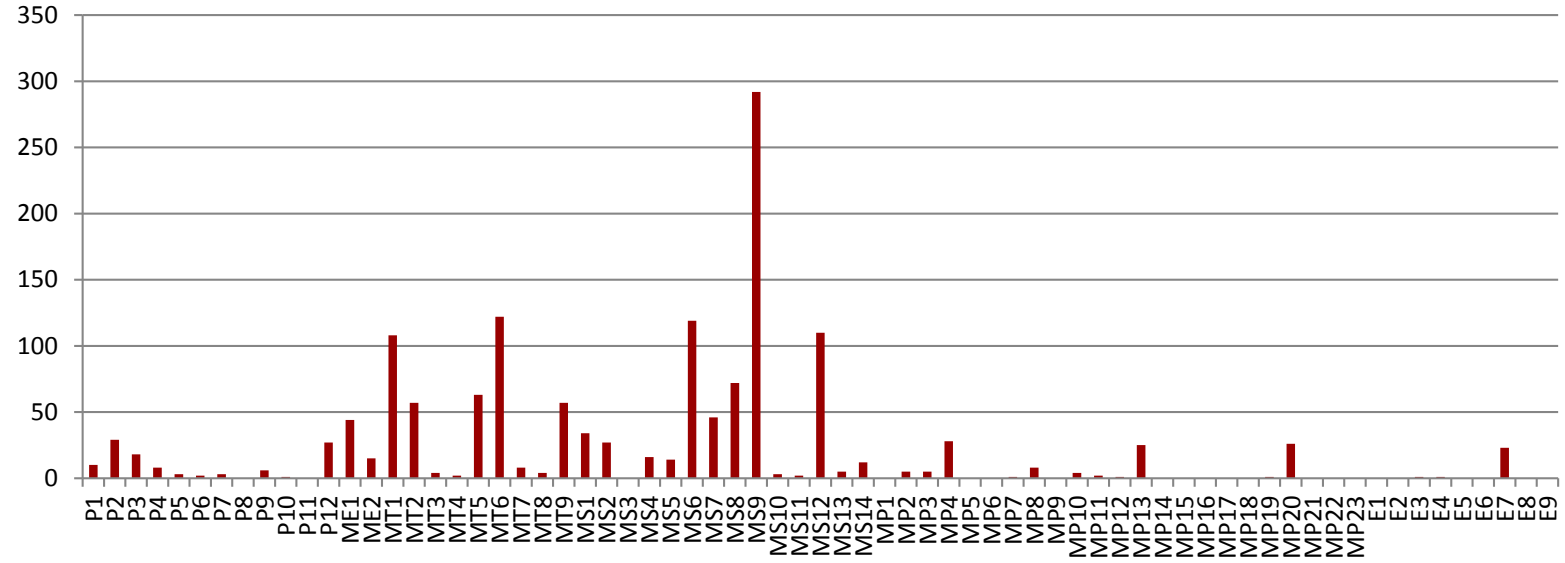
Taxonomy: Defects for Applicable Parts and Devices



Methodology and Scope of Data Analysis

- Global information services organization that monitors, investigates, and reports issues affecting global electronics supply chain
- Data collected is the time frame between February 2015 to August 2015 from ERAI
- Study is limited to observations of data

Counts of defects by Code

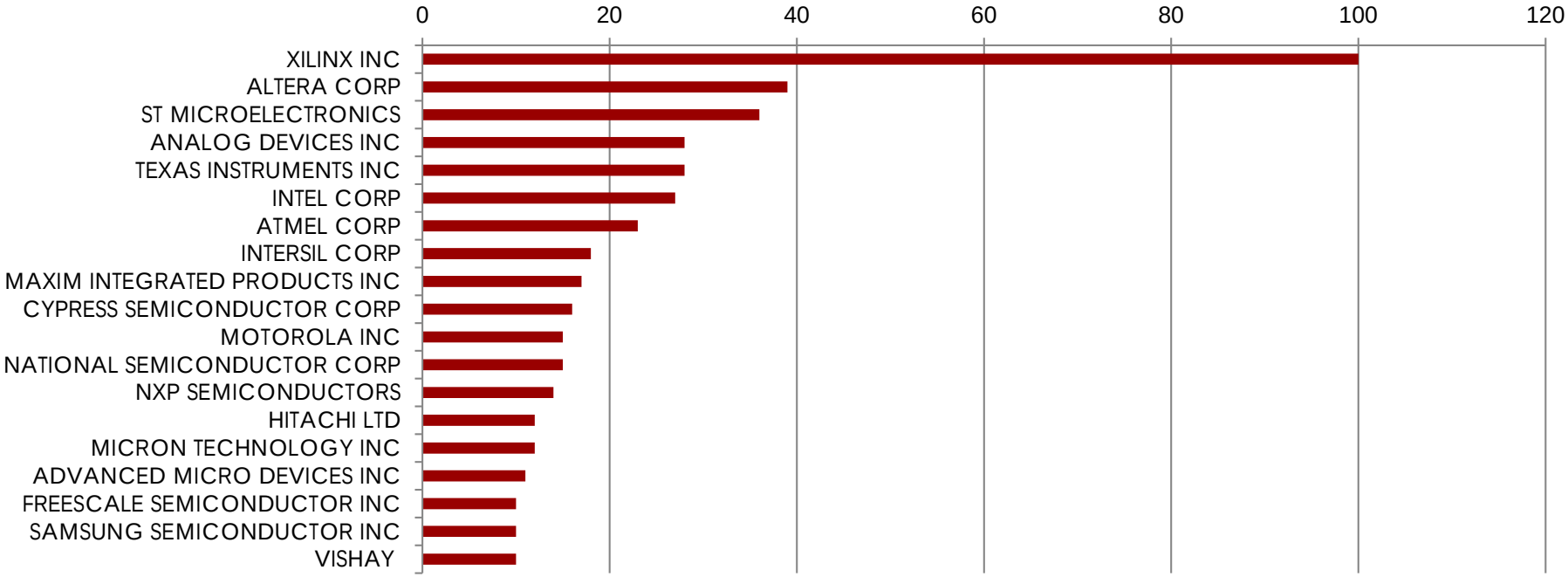


Zero Frequency Codes

P8	0
P11	0
MS3	0
MP1	0
MP5	0
MP6	0
MP9	0
MP14	0
MP15	0
MP16	0
MP17	0
MP18	0
MP21	0
MP22	0
MP23	0
E1	0
E2	0
E5	0
E6	0
E8	0
E9	0

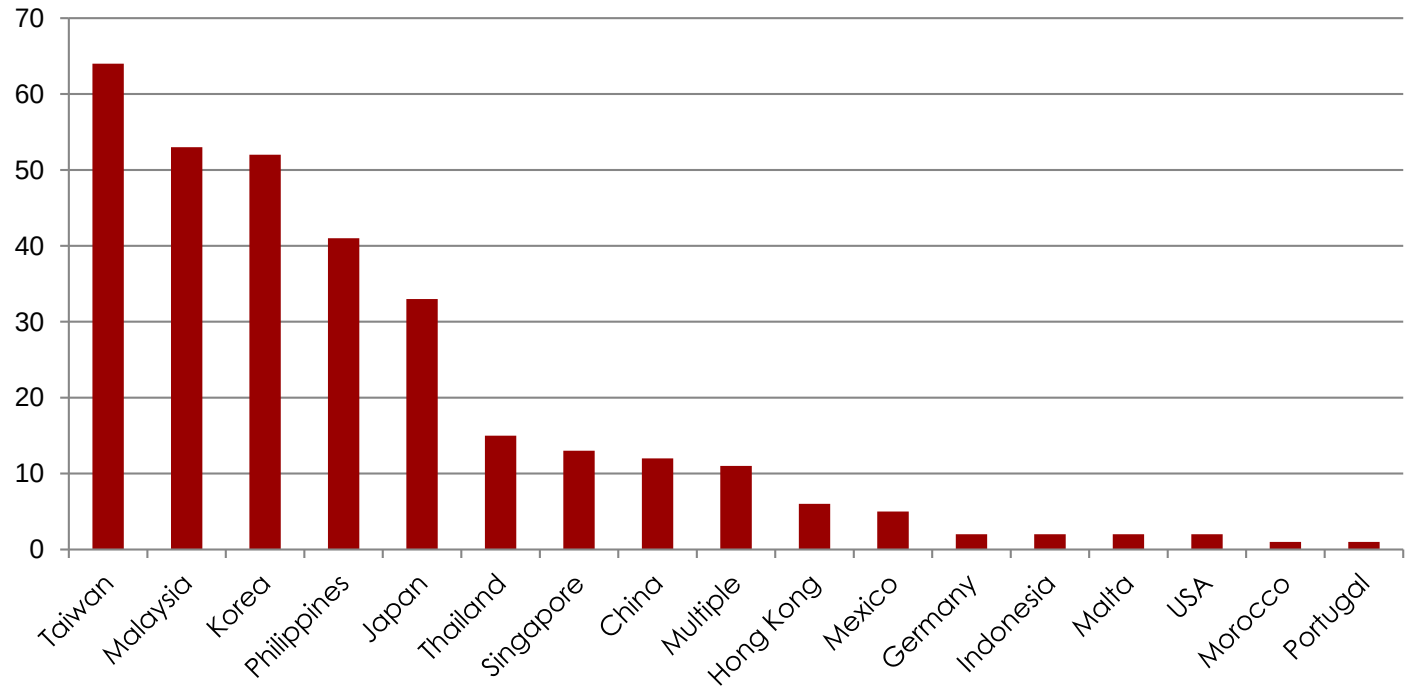
- Highest frequency of defects occurred with the physical surface category
- MS9 shows the highest amount of occurrence

Counts of Incidents by Manufacturer



- 441 defects (65.7%) of 671 for different manufacturers are list above
- Xilinx INC (100) and Altera Corp (39) account for 20.7% of the Total reported incidents
- All companies in the graph have at least 10 reported incidents

Counts of Defects by Country of Origin



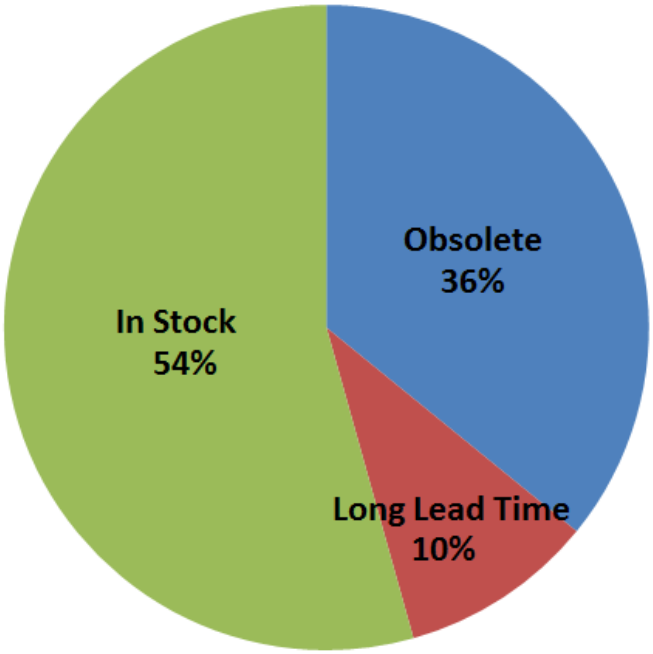
- Country of Origin is the location where the part was assembled
- Reported for 315 out of 671 parts

Multiple Incidents reported for the same Part Number

Manufacturer	Part Number	Count of Part Repetitions
INTERSIL CORP	HA7-5127A-5	5
QUALCOMM	Q1900C-1S3	4
CYPRESS SEMICONDUCTOR CORP	CY7C964-ASC	4
NXP SEMICONDUCTORS	SAA7129AH	3
SANDISK CORP	SDED7-256M-N9Y	3
ALTERA CORP	EPCS64SI16N	3
PLX TECHNOLOGY INC	PCI9030-AA60BI	3
TEXAS INSTRUMENTS INC	TMS320F243PGEA	3
HARRIS SEMICONDUCTOR	HI1-1828A-8	3
HITACHI LTD	HM628512LFP-10SL	3

- Intersil Corp had the part number HA7-5127A-5 reported as 5 separate incidents with **different Date and Lot Codes**. In this case similar results were observed for all suspect parts.
- These Part Numbers were reported at least three times

ERAI Trend Review (Capacitors)



Type	Obso %	Ave Cost	Most Often Bought
Aluminum Lytic	34%	$3.11	High value and voltage
Ceramic	52%	$0.27	High value
Film	0%	$0.87	High voltage
Porcelain	100%	---	Obsolete
Supercapacitor	0%	$9.69	High value
Tantalum	26%	$2.89	High value, low ESR

Failure Type	Pct	Al Lytic	Tantalum	Ceramic
Failed Value	34%	43%	19%	46%
Wrong Construction	32%	61%	4%	25%
Signs of Prior Use	25%	18%	33%	25%
Failed ESR/DF	22%	18%	48%	4%
Documentation	21%	25%	11%	29%
Catastrophic (Short, Vent)	11%	18%	4%	11%
Signs of Remarking	7%	4%	19%	0%
Failed in Application	3%	0%	0%	11%
Failed Voltage	1%	0%	4%	0%
Wrong Plating	1%	4%	0%	0%

Recent Trends in Counterfeit Electronic Parts, Naval Surface Warfare Center, Crane, CALCE/SMTA Symposium 2016.

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Change Control and Notification

- ***Change control*** is the procedure used by part manufacturers to propose, qualify, approve, and implement changes made to parts.

- ***Change notification*** is the procedure used by the part manufacturers to notify their customers of changes made to the parts.

"Tracking Semiconductor Part Changes Through the Supply Part Chain," *IEEE Transactions on Components and Packaging Technologies*, Vol. 25, No. 2, pp. 230-238, June 2002.

Change Notification Standard

- The product change notice (PCN) is a document sent to customers describing part or process changes, the reasons for the change, and the projected impact of the change.
- Industry standards on change control and notification for electronics have been developed by the Joint Electron Device Engineering Council (JEDEC), the standards development arm of the Electronic Industries Association (EIA).
- These standards form the basis of many change notification procedures.
- The new standard J-STD-046 is a joint result including the ECIA and the IPC.

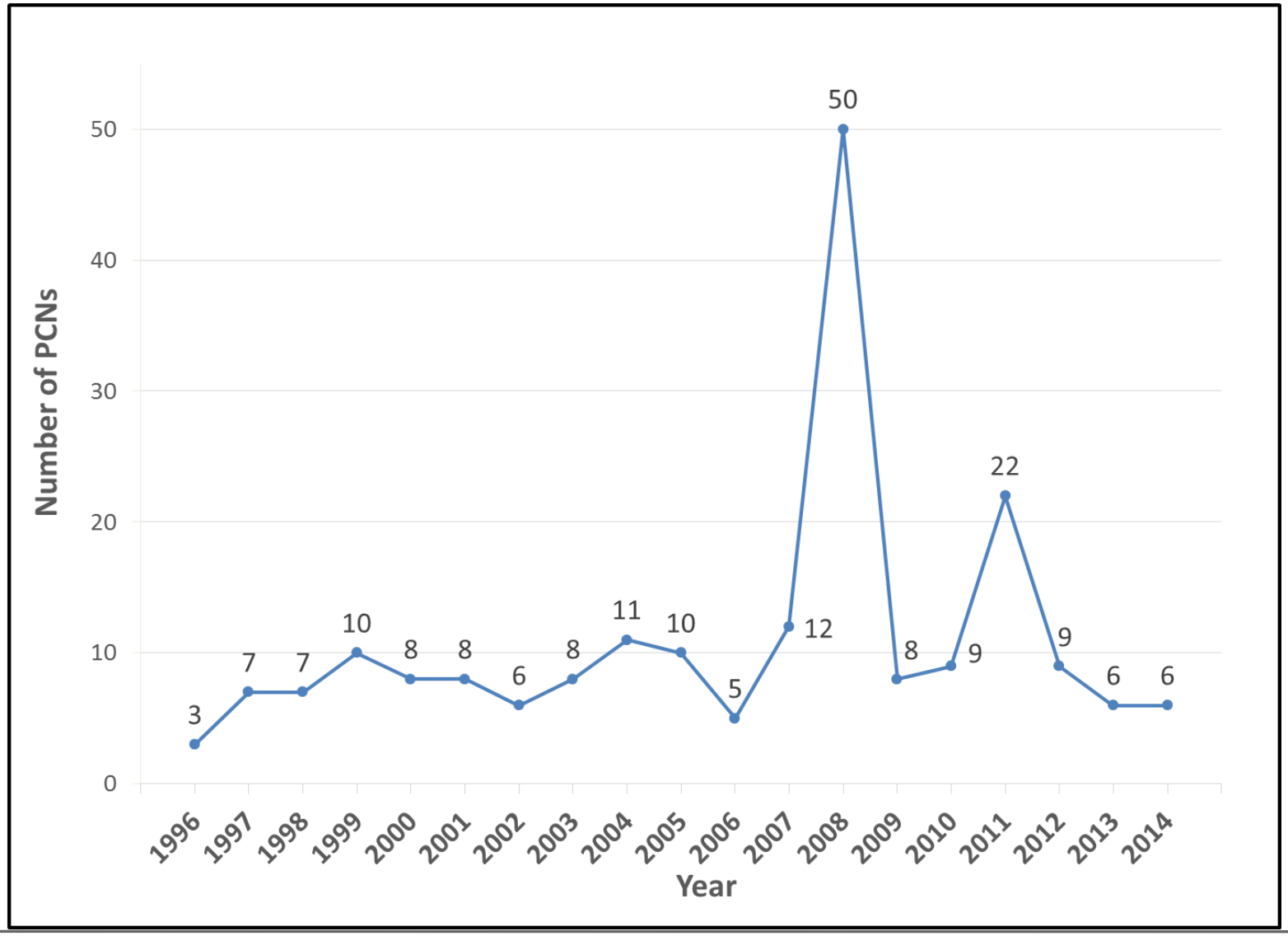
J-STD-046 Minimum Elements of Supplier's PCN Procedure

- Method of identifying and documenting the customer's unique PCN requirements.
- Definition and classification of proposed changes. (Note: This could be a reference to a separate controlled document, e.g., Engineering Change Notice.)
- Notification timing.
- Deliverables to customer – contents of change notification.
- Record retention requirements.

J-STD-046 Generic Types of Major Changes That Require Customer Notification

Design	• Change in external dimension • Change of critical material/component • Changes in process technology affecting critical process steps • Change of product marking technology
Manufacturing/Test Location	• Site transfer to a site not previously qualified (fabrication, assembly, or test site of the finished product)
Packing/Shipping	• Change in carrier type (tube, reel, tray, etc.) or dimensions • Change of product orientation within shipping media • Significant change of labelling • Dry pack requirements change • Reduction in environmental storage conditions
Datasheet	• Change of datasheet parameters, electrical specification • Elimination of final electrical measurement or burn-in (if specifically stated in the datasheet as being performed)

PCN History (Altera): 1996-2014



Cumulative PCNs: 1996-2014

Temperature range change	1
Lead finish	3
MSL change	6
Design change	11
Package material change	**14**
Change in marking or date code	*17*
Mold compound	**21**
Miscellaneous (including external packaging)	26
Die revision or addition	27
Addition or change of Fab facility	*35*
Addition or change of assembly/test facility	*37*

Material Transition Maps from PCNs

	2002	2003	2004	2005	2006	2007	2008
OLD	Shin Etsu	Sumitomo EME 6300	Sumitomo EME 7320	Nitto MP 8000	Nitto HC 100	Sumitomo EME 6300HJ	Sumitomo G770
NEW	Nitto HC-100	Nitto MP 8000	Sumitomo G700L	Sumitomo G600	Sumitomo G770	Sumitomo G600	Hitachi CEL-9750ZH F10AKL

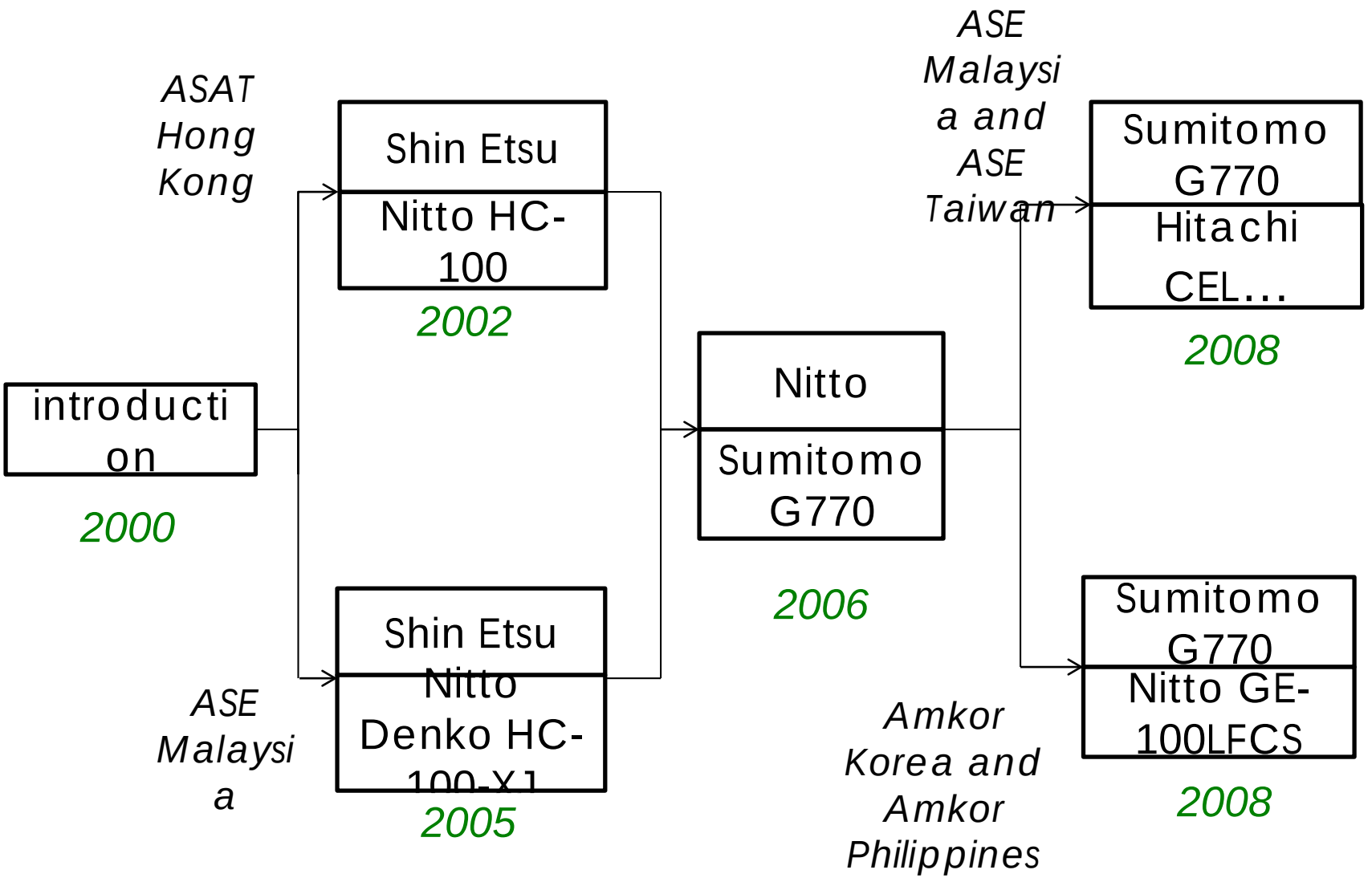
Sample Map:

Shin Etsu > Nitto HC-100 > Sumitomo G770 > Hitachi CEL-9750ZH F10AKL

2008 Sumitomo to Hitachi

	Sumitomo G770	Hitachi CEL-9750ZHF10AKL(LSA)	Equipment	Comments
Specific Gravity	**2.01**	**2.00**	Lab tools	No change
Water Absorption (24 hr) (%w)	**0.15**	**0.32**	Lab tools	50% increase
Glass Transition Temperature(°C)	**130**	**130**	DSC or TMA	No change
Thermal Conductivity (Watts/m °C)	**3.7**	**-**	Laser Flash	
Volume Resistivity (Ω·m)	**1×10^{12}**	**1×10^{16}**	Parallel Electrodes, Multimeters and Test Chambers	large increase
Thermal Expansion (T<Tg))(1e-6/°C)	**8**	**8**	TMA	No change
Thermal Expansion (T>Tg))(1e-6/°C)	**37**	**34**	TMA	8% decrease
Extracted Na+ (ppm)	**1**	**1**	IC	No change
Extracted Cl- (ppm)	**5**	**25**	IC	5 times increase

Sample Timeline: Altera FPGA – EPF6016AFC100-1



Technology Solutions – Tagging and Tracking

- Taggants can help verify origin and monitoring the supply chain of components
- CALCE investigated three taggant technologies of the following companies took place: Applied DNA Sciences, DataDot, InfraTrac
  - To determine whether the marking withstands extreme working conditions
  - To determine whether the marking has any impact on the electrical, physical and/or chemical properties of the part
- All three passed the evaluation performed by us

Technology Solutions – Feature Comparison

- Surface image based
- Die feature based
- Physically “unclonable” features
- Inserted dielets (DARPA)

Technology Solutions – Tagging and Tracking

- Power Consumption Waveform Analysis – Battelle Barricade
- Electromagnetic Emission – Nokomis ADEC
- Power Spectrum Analysis – Sandia National Lab
- …

Symposium on Counterfeit Electronic Parts, Materials and on Electronics Supply Chain – 2017

https://smta.org/counterfeit/

Sessions include:

- Concerns and Response
- Standards: SAE and Others
- Panel Discussion on Role of Test Laboratories in Reporting
- Future Technologies for Tracking and Detection
- Counterfeits Lifecycle
- Detection of Counterfeit Parts
- Tracking Parts through Supply Chain
- Views Across Supply Chain

Keynote Talks

- "Cloned" Devices - How Similar or Different Are Those from Originals
- Overview of Historical Trends Relating to Suspect Counterfeit, Non-Conforming and High Risk Electronic Components

Workshops at Symposium on Counterfeit Electronic Parts, Materials and on Electronics Supply Chain – 2017

WS 1	Implementation Process of SAE 6171	*CALCE*
WS 2	Use of Component Documentation and Supply Chain for Counterfeit Avoidance	*CALCE*

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