Probability of Detection of Computer Analysed Pulsed Eddy Current Data

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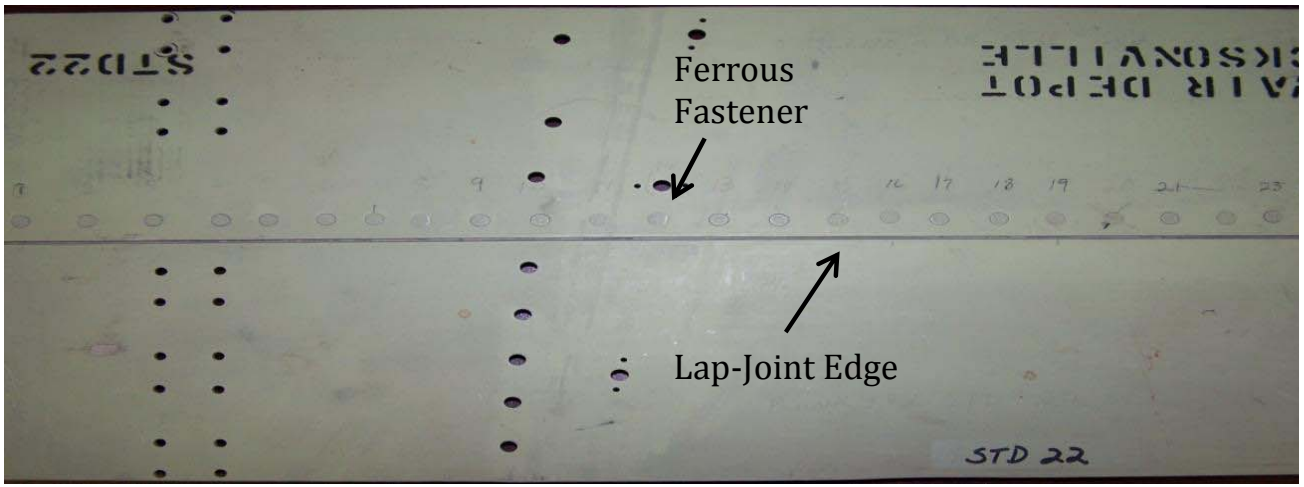
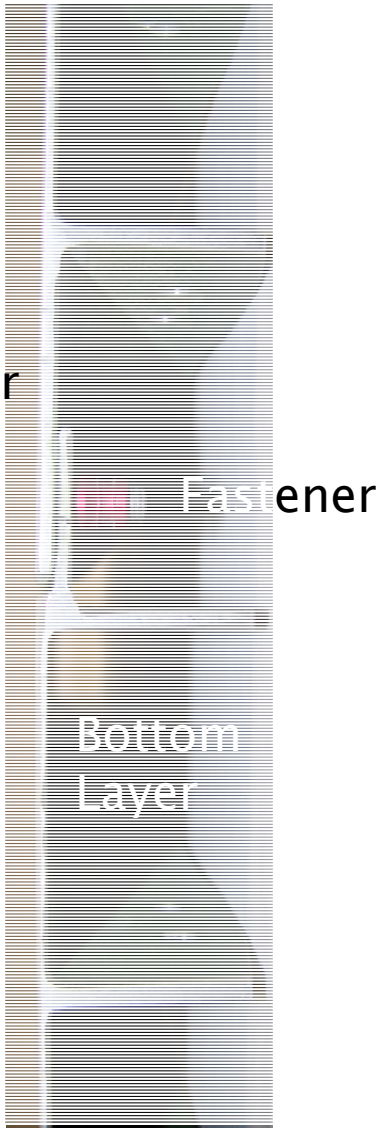
Outline

- Application
- Approach
- Intro to Hit/Miss POD
- Results
- Summary

Application

Aurora (P-3 Orion)



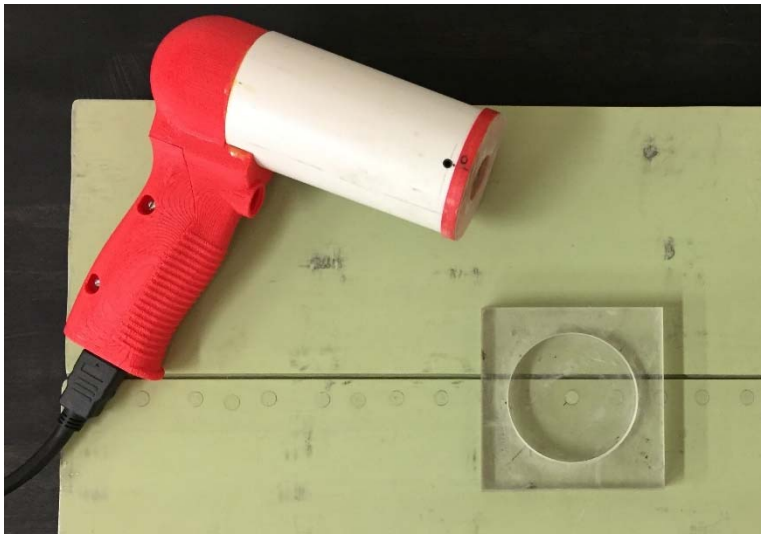


Objective

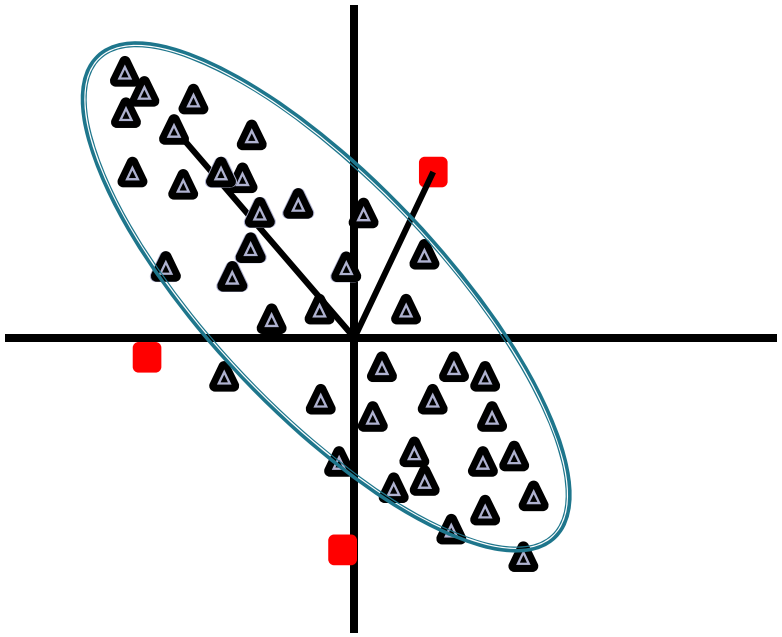
- Develop a rapid scanning technique to identify fasteners with second (and first) layer cracks without fastener removal
  - Reduce down time/cost
  - Eliminate possible damage due to fastener removal
- Use bolt hole eddy current as a confirmatory technique (sizing)

Pulsed Eddy Current Detection of Cracks

- Specially designed probe uses pulsed rather than conventional eddy current
- Generates data that is reduced to a small number of scores (5) using PCA that totally encapsulate the information



Cluster Analysis



Mahalanobis Distance

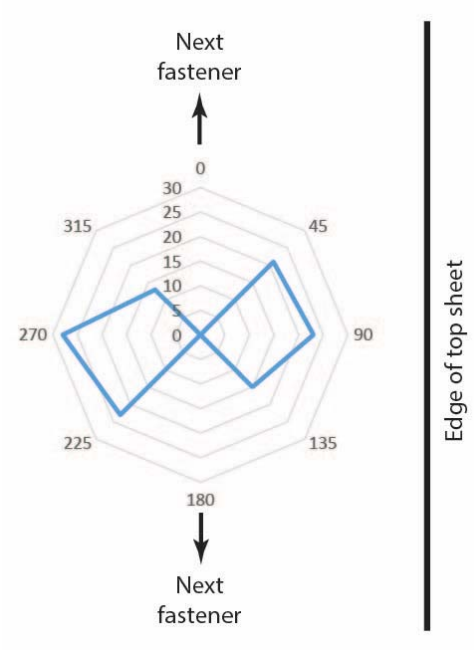
Characteristics

- Blind to the operator
- Treats the data as a group rather than fastener by fastener
- Uses robust statistics to overcome the blind inclusion of defects
- Previous work showed excellent ability to detect cracks
- Next step was to establish a Probability of Detection (POD)

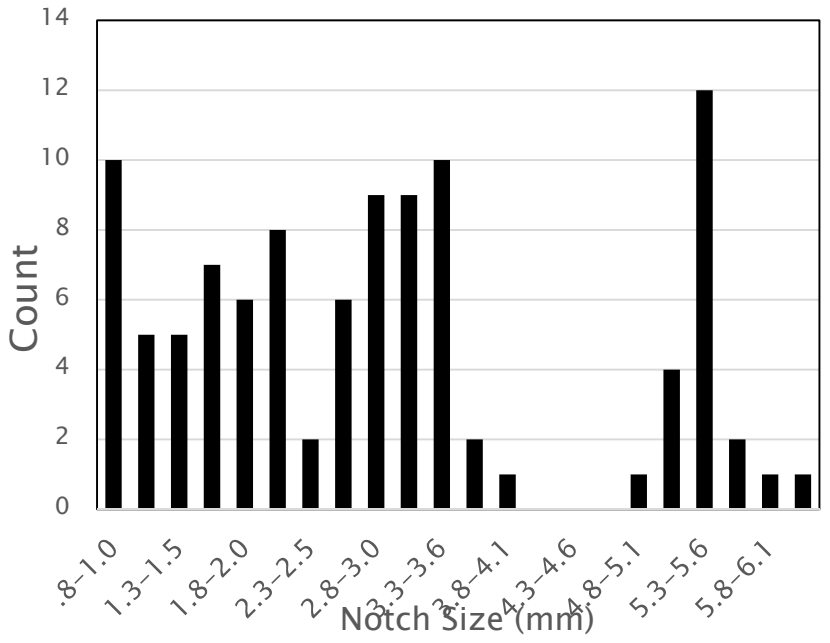
Generate a POD

Sample Size Distribution

Angular



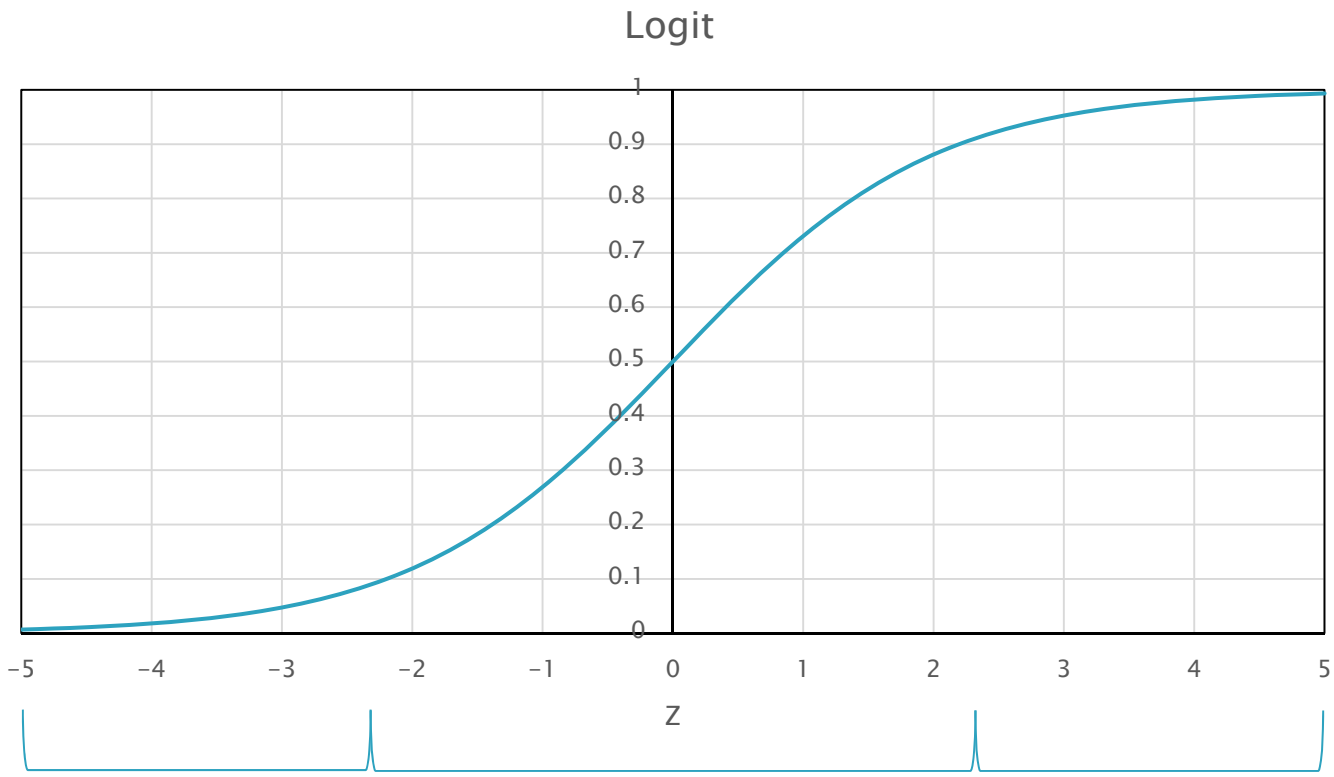
Size



Method

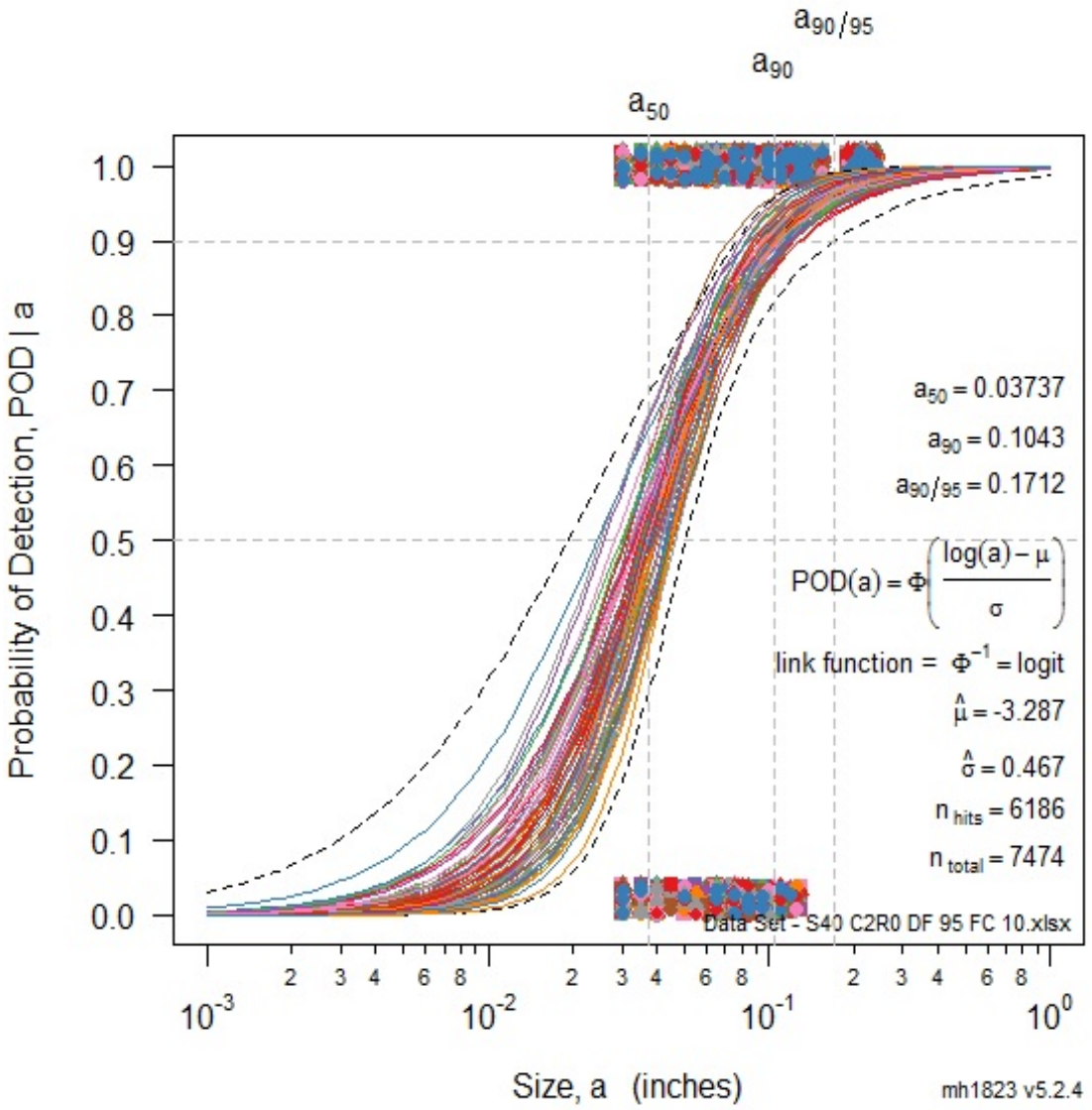
- For each sample (of 7)
  - take and process data (10 passes)
  - Use bootstrap method to generate data
  - Do robust statistics (modified smallest half volume)
  - Use a pre-set cut-off to determine hits and misses
  - Repeat so that each notched fastener appears approx. 100 times
- Combine data into one large matrix
  - Approx (101 rows (fasteners) by 83 columns (trials)
- Use MIL HBK 1823 software to do POD
  - a_{50}, a_{90}, $a_{90/95}$

Hit/Miss POD

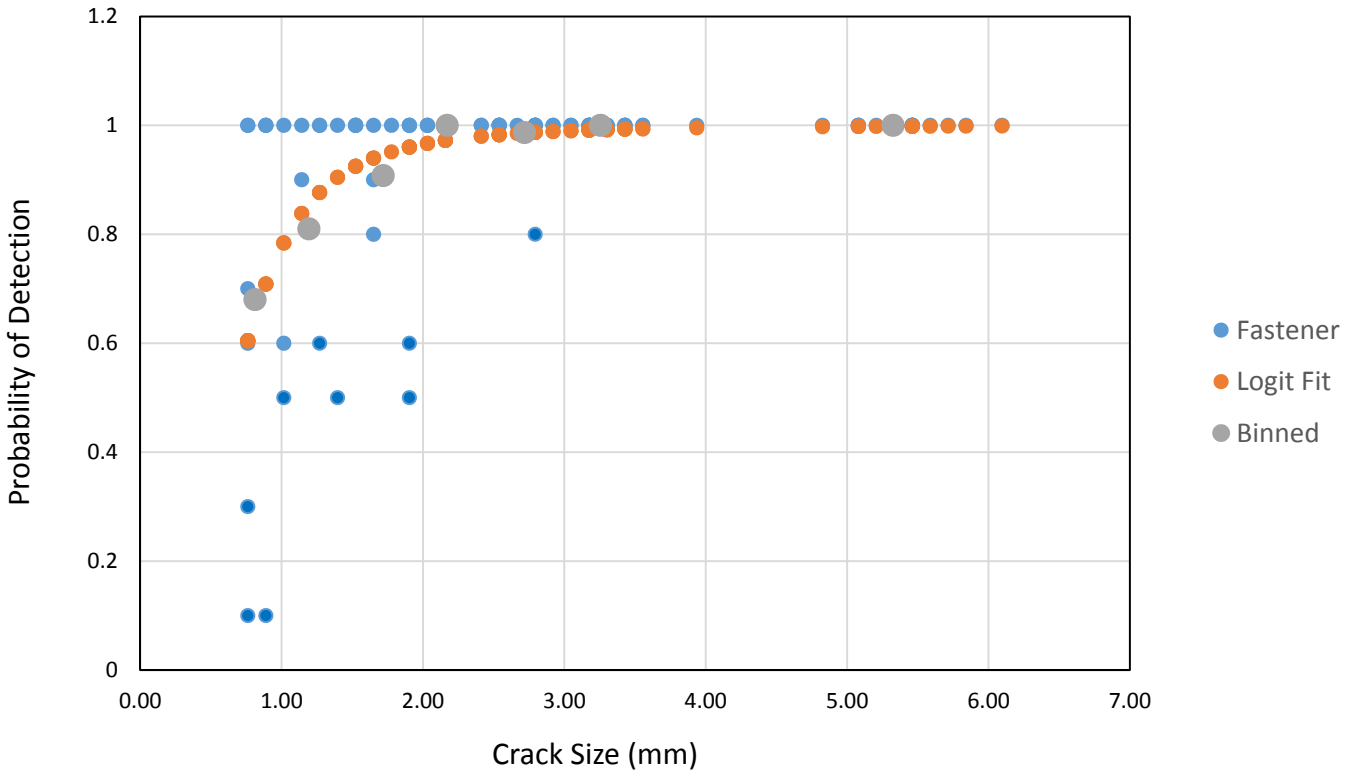


$$Z = \frac{x - \mu}{\sigma} = ln\left(\frac{p}{1-p}\right)$$

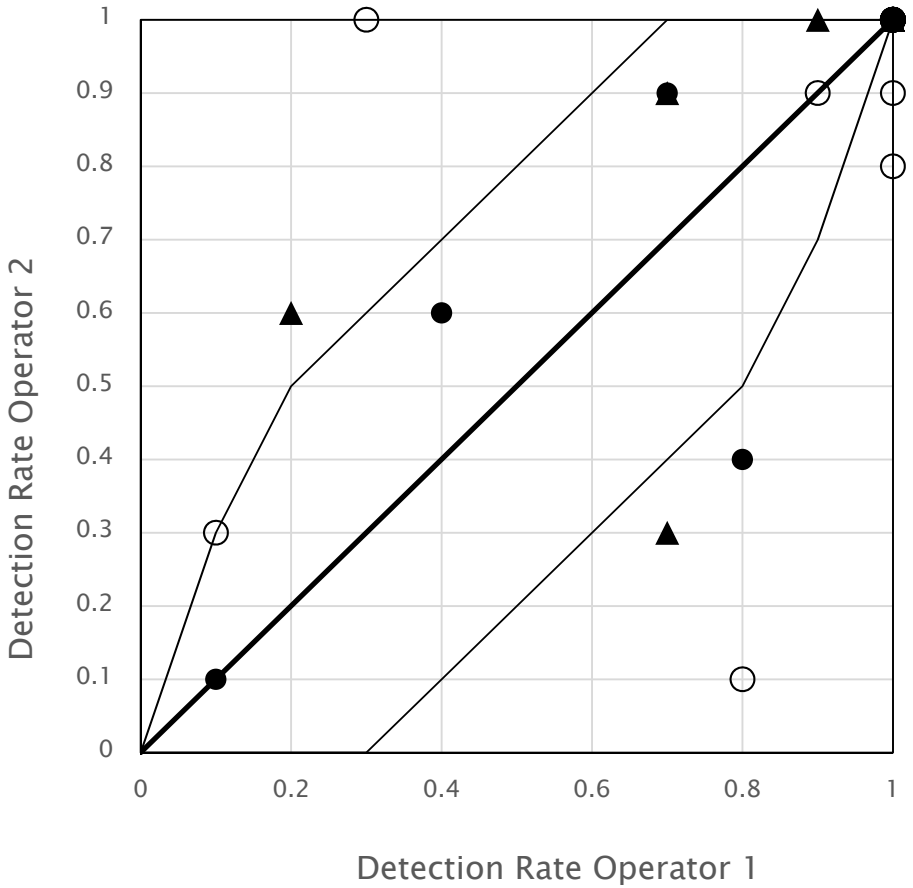
Initial Results



Appropriateness of Fit



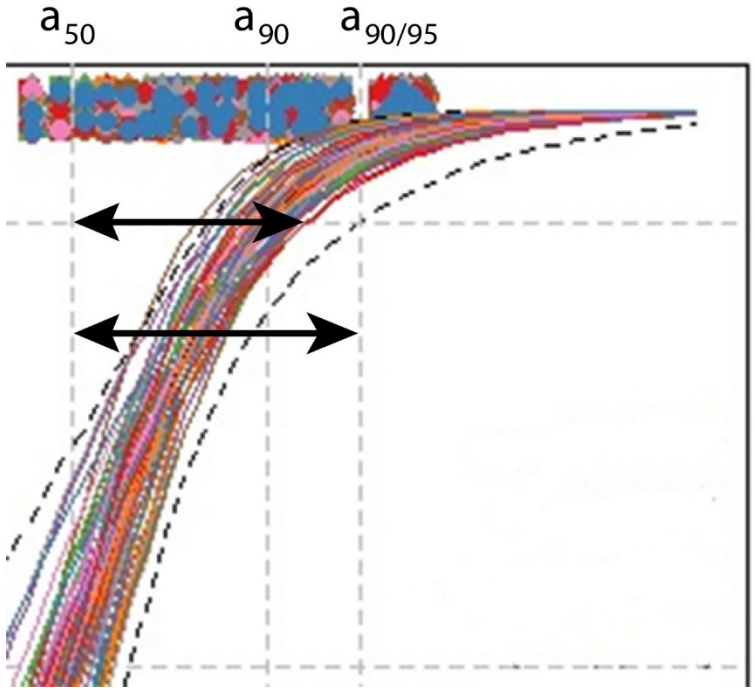
Operator to Operator Comparison



- 3 worst samples
- 45 fasteners
- 31 @ (1,1)

Empirical (marginal)

$a_{90/95}$



Empirical (marginal) $a_{90/95}$

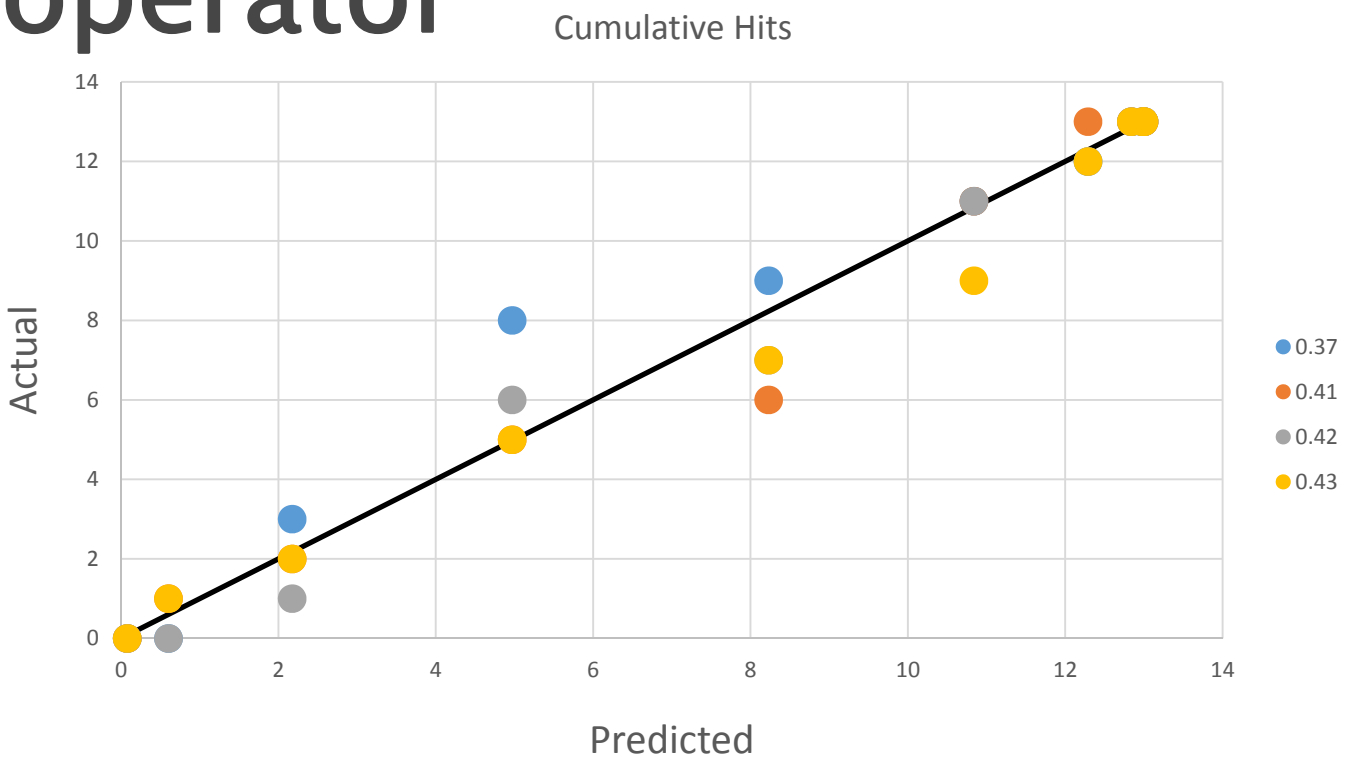
False Call Rate	Data Fraction	Number of Notches in Simulation			
		C1	C2	C3	C4
		$a_{90/95}$ (mm/inch) – Using ImageJ			
5% False Call	95%	2.72 / 0.107	2.74 / 0.108	3.00 / 0.118	3.10 / 0.122
	97.5%	2.60 / 0.102	2.67 / 0.105	2.90 / 0.114	2.98 / 0.117
	100%	2.43 / 0.095	2.75 / 0.108	3.24 / 0.128	3.53 / 0.139
10% False Call	95%	2.22 / 0.088	2.33 / 0.092	2.35 / 0.093	2.66 / 0.105
	97.5%	2.07 / 0.082	2.26 / 0.089	2.33 / 0.092	2.29 / 0.090
	100%	2.04 / 0.080	2.28 / 0.090	2.59 / 0.102	2.90 / 0.114
15% False Call	95%	1.93 / 0.076	2.05 / 0.081	2.10 / 0.083	2.11 / 0.083
	97.5%	1.91 / 0.075	2.02 / 0.080	1.96 / 0.077	2.08 / 0.082
	100%	1.71 / 0.067	1.93 / 0.076	2.28 / 0.090	2.56 / 0.101

Summary

- More than just size affects the detection rate
- Automated robust analysis gives a marginal $a_{90/95}$ (80 fasteners/15% FC) 2 mm/0.08”
- Have nearly 50% detection down to 0.75 mm/0.03”
- Detection rate gets worse with smaller sample sizes (40 fasteners/15% FC) $a_{90/95}$ = 2.57 mm/ 0.10”
- Large statistical data set makes it possible to separate out some extra effects (operator)
- Statistical approach makes it possible to generate “Quality” statistics that indicate if the inspection was carried out properly and the sample conforms to the low defect assumption

Questions

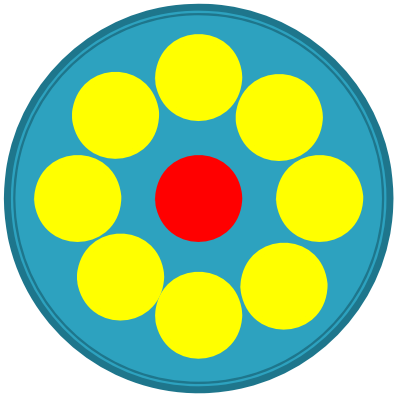
Cumulative Distribution of Results for a single operator

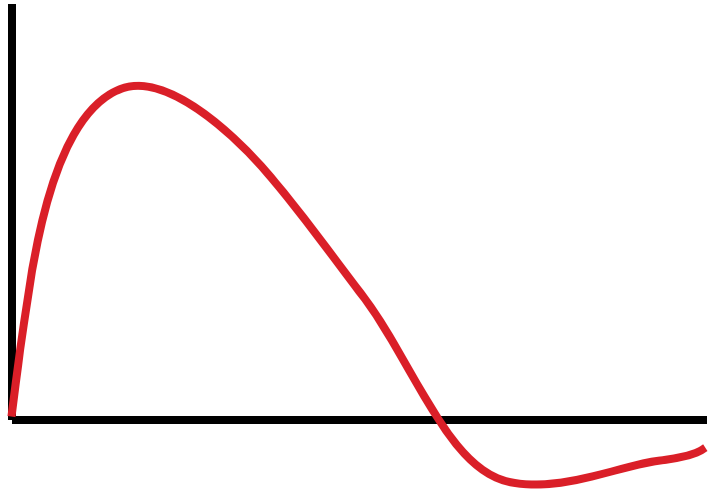


Binomial distribution for p=0.4

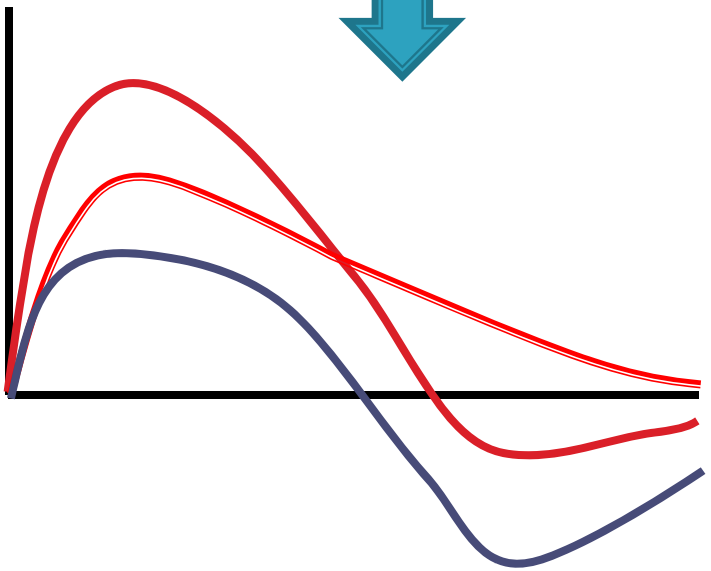
Approach

Pulsed Eddy Current





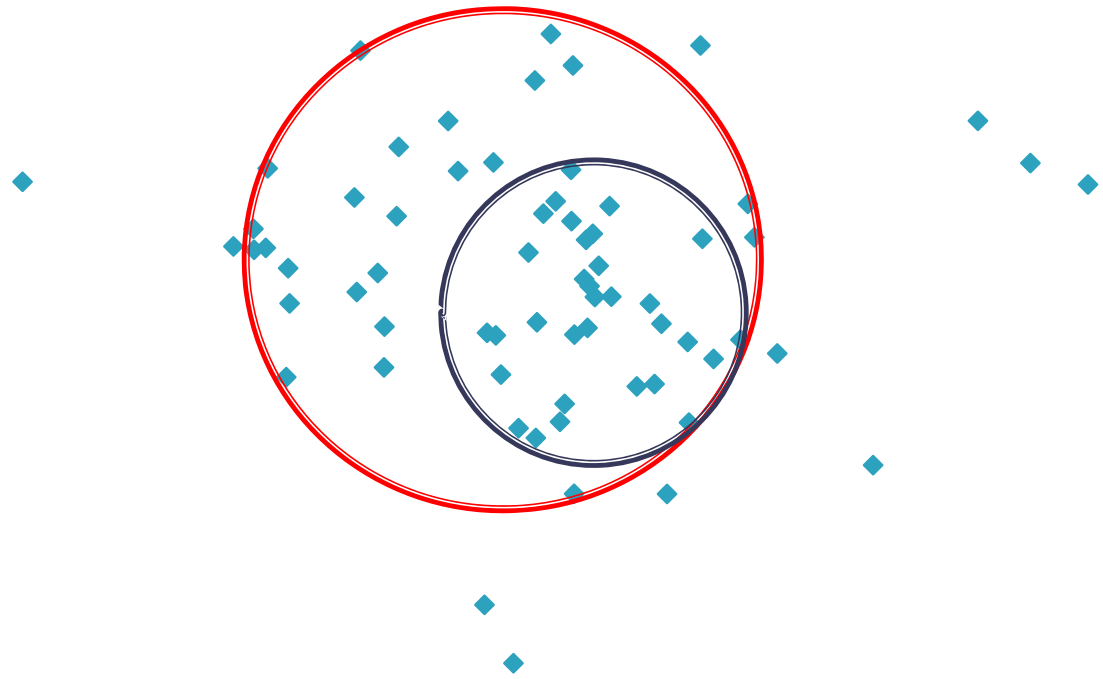
MPCA



$$S_j = S_{1j}V_1 + S_{2j}V_2$$

Robust Statistics

Modified Smallest Half Volume



Blind Detection Issues

- How to obtain an uncontaminated covariance matrix and centroid for the blanks?
- Robust Statistics
- Lab samples are defect rich. How to generate large numbers of blanks like the real case?
- Bootstrap Method

Bootstrap

Blanks

S2	S3	S4	S5
0.593376	0.045519	-0.09982	-0.01491
0.500364	0.097982	-0.0933	-0.01727
0.447071	0.071758	-0.07776	-0.01358
0.490726	0.077445	-0.08257	-0.01078
0.476314	0.051395	-0.07991	-0.0113
0.48483	0.076218	-0.08172	-0.01324
0.443515	0.028313	-0.07137	-0.01277
0.446337	0.055967	-0.07361	-0.01268
0.49945			

Cracks

S2	S3	S4	S5
-0.46111	-0.01135	0.088817	-0.02026
0.307697	0.191124	0.019304	0.00513
-0.29056	-0.05131	-0.05987	-0.02391
0.180092	-0.0654	-0.04422	-0.03478
		-0.20707	

Test Data Set

0.002606	0.014639	-0.00898	-0.00704
-0.08587	0.131992	-0.00031	-0.001
-0.11465	-0.02632	0.026286	0.006772
-0.33553	-0.02745	0.009381	0.002782
-0.0343	-0.01639	0.011607	-0.00028
0.117371	-0.05911	-0.01063	-0.00201
-0.11154	0.00201	0.026094	0.000345
0.259884	-0.00134	-0.01956	-0.00196
-0.01007	-0.02041	-0.0117	-0.00295
0.080176	0.017492	0.005215	0.017656
0.48483	0.076218	-0.08172	-0.01324
-0.39145	0.072178	0.024761	0.005057
0.003998	-0.00893	-0.0153	0.002723
-0.03812	0.014792	0.013322	-0.00216