Summary of POD Study Results

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

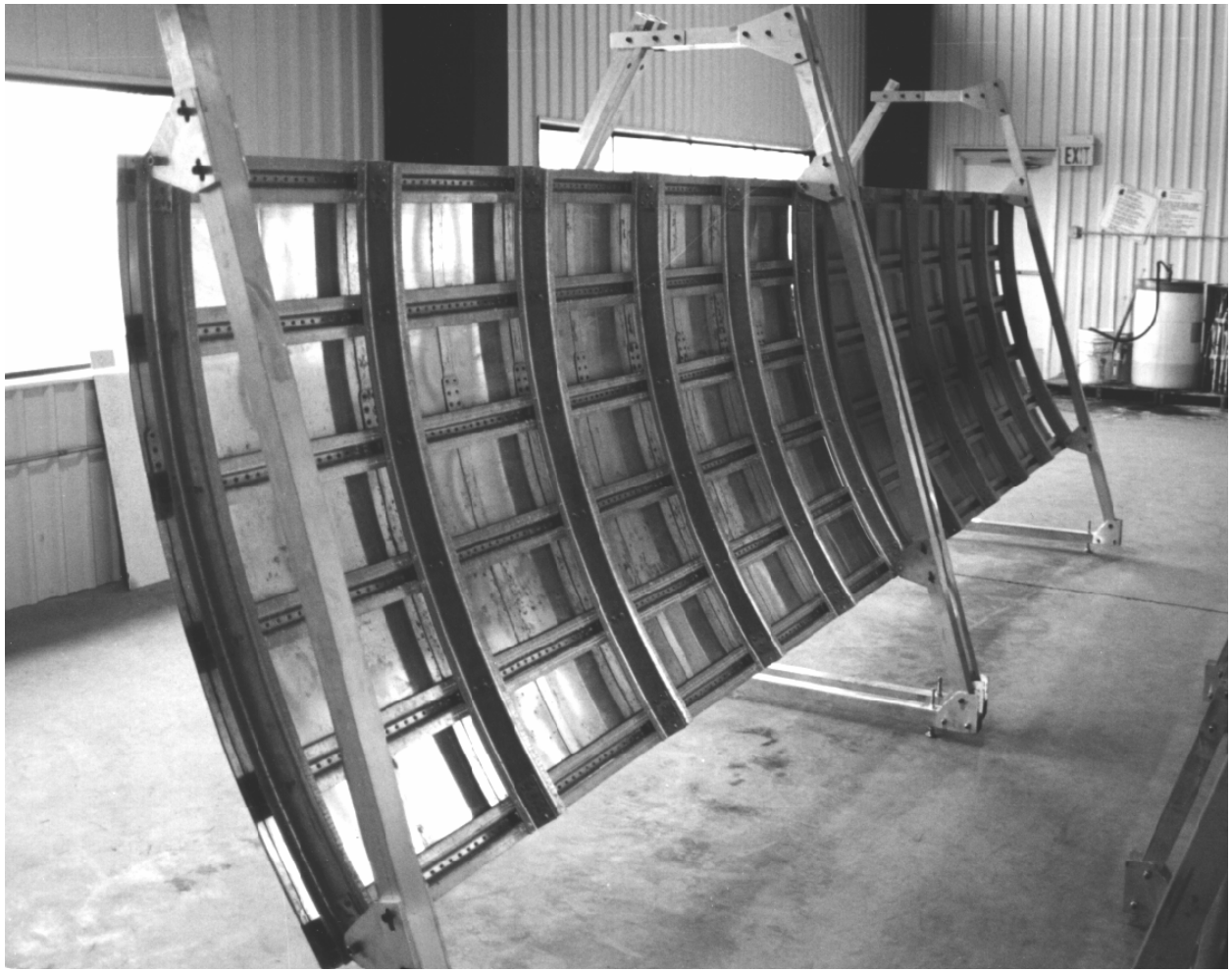
AIRLINE MAINTENANCE FACILITY EXPERIMENT

Realism of Inspection (specimens & location)

Accessibility

Arrangeable layouts

2nd set of Specimens



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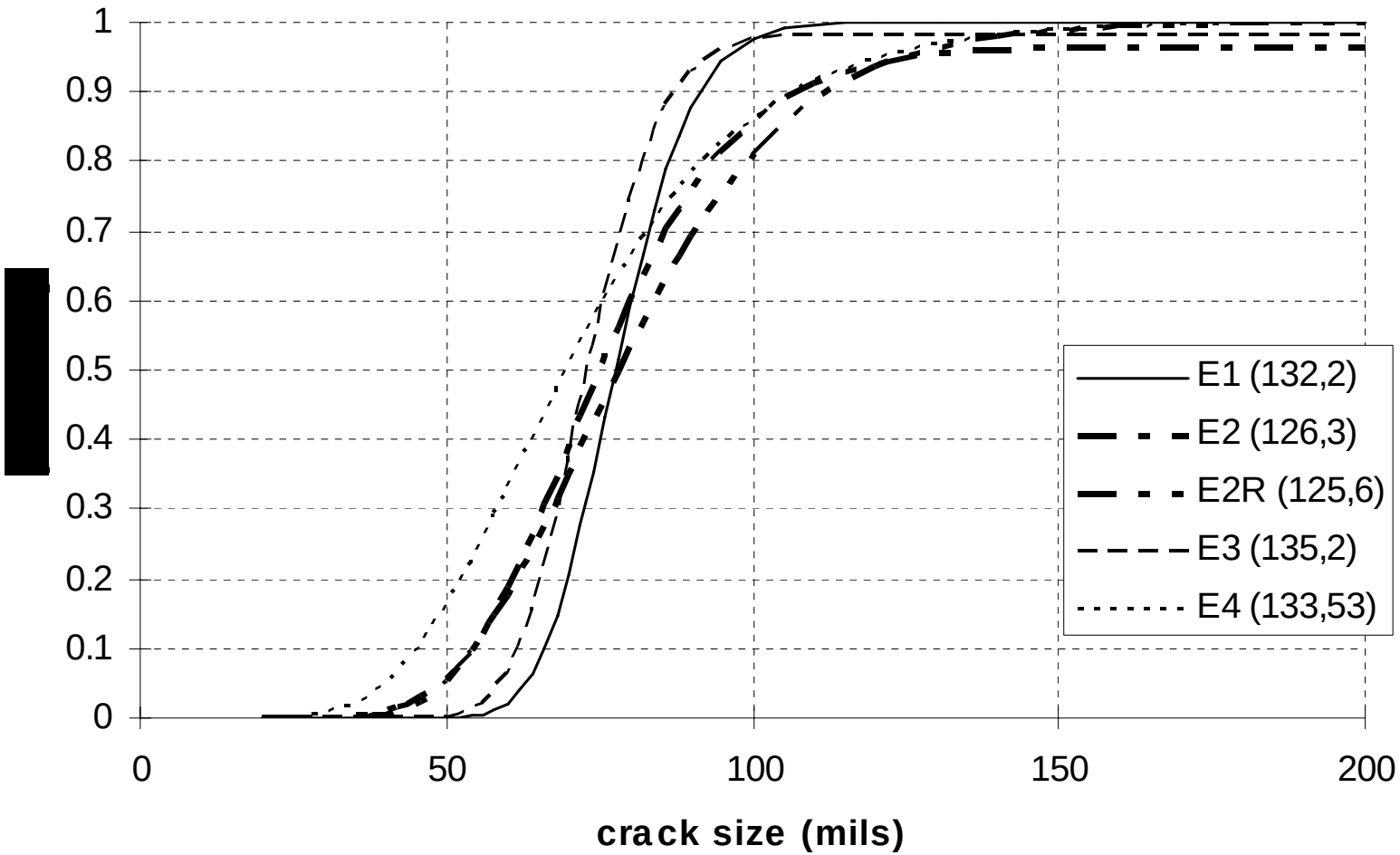
POD summary by Facility examples

Facility E - Probability of Detection Curves
(184 flawed sites in 782 detection opportunities)



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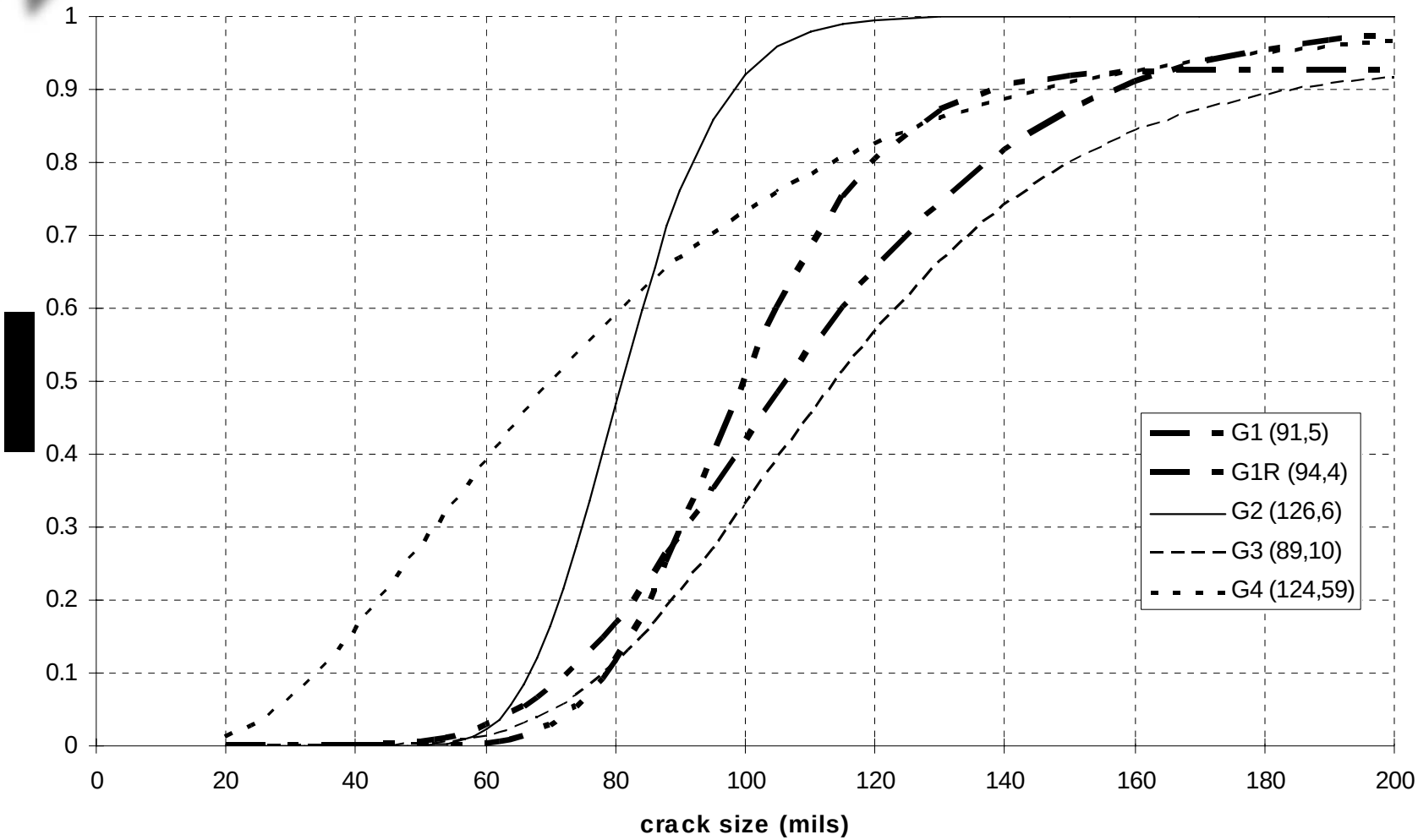
Facility G - Probability of Detection Curves
(184 flawed sites in 782 detection opportunities)



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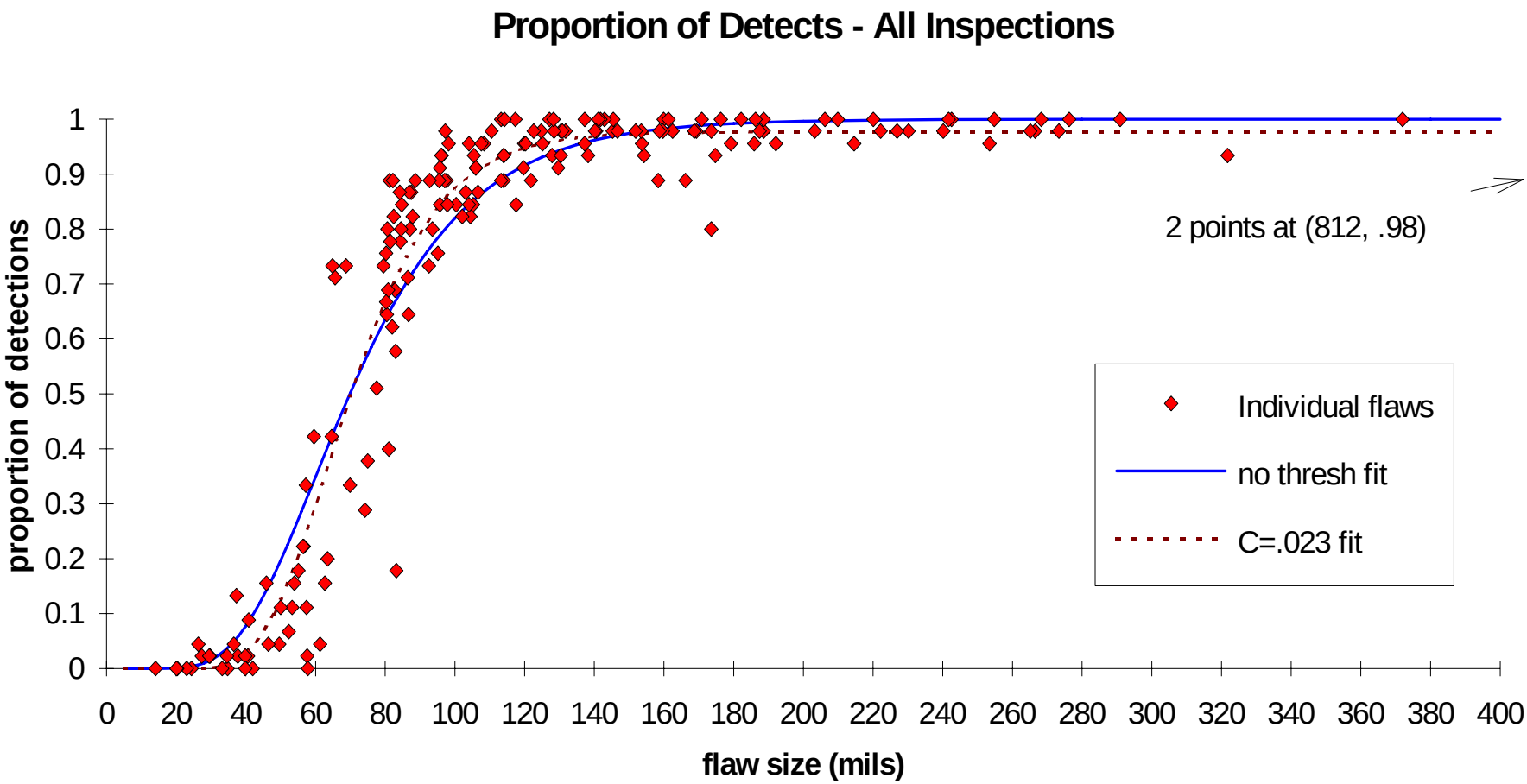
Facility Differences

- **Facility differences significant**
  - **gauged by inspection-to-inspection variances**
- **Inspection-to-inspection variation significant**
  - **gauged by repeatability within inspector**



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Model extension

Probit with fitted asymptote

$$POD(a) = (1-c)\cdot\Phi\left(\alpha+\beta\cdot\ln(a)\right)$$

Generalized parameters to include factor effects under study

$$\alpha+\sum_i \alpha_i\cdot I_i+\sum\sum \alpha_{ij}\cdot I_i\cdot I_j$$

$$\beta+\sum_i \beta_i\cdot I_i+\sum\sum \beta_{ij}\cdot I_i\cdot I_j$$

Factors modeled in the POD

	crack **ang**le (Iang)	**surf**ace conditio n (Isurf)	lap splice **pos**ition (Ipos)	**num**ber of cracks at rivet (Inum)	**proc**edur e followed (Iproc)	**dens**ity of cracked rivet sites (Idens)
level 0	11 to 22 degs.	painted	low	2	template	low (~10%)
level 1	horizontal	bare	high	1	sliding	high (~40%)

Factor Effects in mils

Values are calculated as averages across other factors. All values are in thousandths of an inch.

	level	angle	surface / facility	pos	flaw #	procedure/ facility	density
50th percentile	0	72	73	69	63	71	66
50th percentile	1	63	62	66	72	64	69
90th percentile	0	109	115	105	95	109	104
90th percentile	1	96	90	100	110	96	101

Conclusions from Experiment

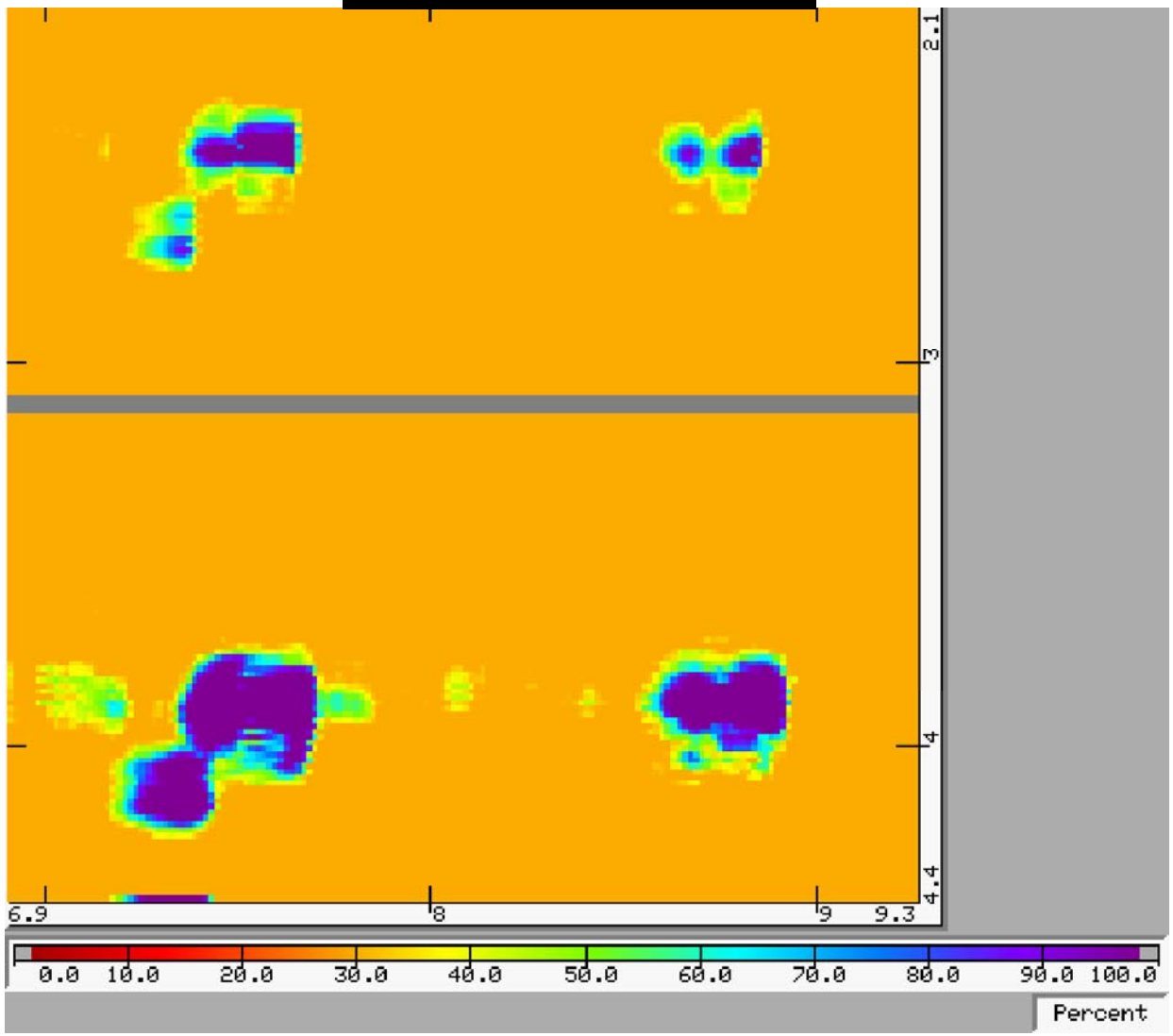
- *Individual inspector differences are a major factor affecting inspections*
- *Environmental factors can influence an inspection*
- *Inspection misses result that are independent of crack length*

Automated Ultrasonic Inspection Result Summary

General Goals were to establish

- **Capability**
- **Assurance of adequate inspection transfer to customer**

Example of image to be interpreted



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Flaw distributions

	Test sections	Inspection Sites	< 0.050 inch	0.05 to 0.10 inch	0.10 to 0.15 inch	0.15 to 0.20 inch	> 0.20 inch	not measured
Lab phase	12	356	16	18	7	9	4	4
Field phase	8	238	15	16	6	7	4	3

Experimental Variables and levels for Laboratory experiment

Variable	Low level (-1)	High level (1)	Nominal level (0)
1. time base delay	nominal - 0.005	nominal + 0.005	determined in calibration
used	0.35-ch 1 0.355-ch 2	0.36-ch 1 0.365-ch 2	0.355-ch 1 0.36-ch 2
2. depth velocity	table value for probe angle - 1 °	table value for probe angle + 1 °	tabled value determined from probe angle
used	85400 in/sec	88500 in/sec	87000 in/sec
3. receiver gain	nominal - 0.6 dB	nominal + 0.6 dB	as determined at time of calibration
used	35.6 dB	36.8 dB	36.2 dB
4. scanner skew	0.25 inch left	0.25 inch right	centered
5. probe pressure	pressure off	nominal	arbitrary
used	0 - 1 lbs. indicated	16 lbs indicated	16 lbs indicated on dial

Laboratory Results

- Variations in 2 different signal aspects (area and amplitude) quantified with respect to expected variation allowed by procedures

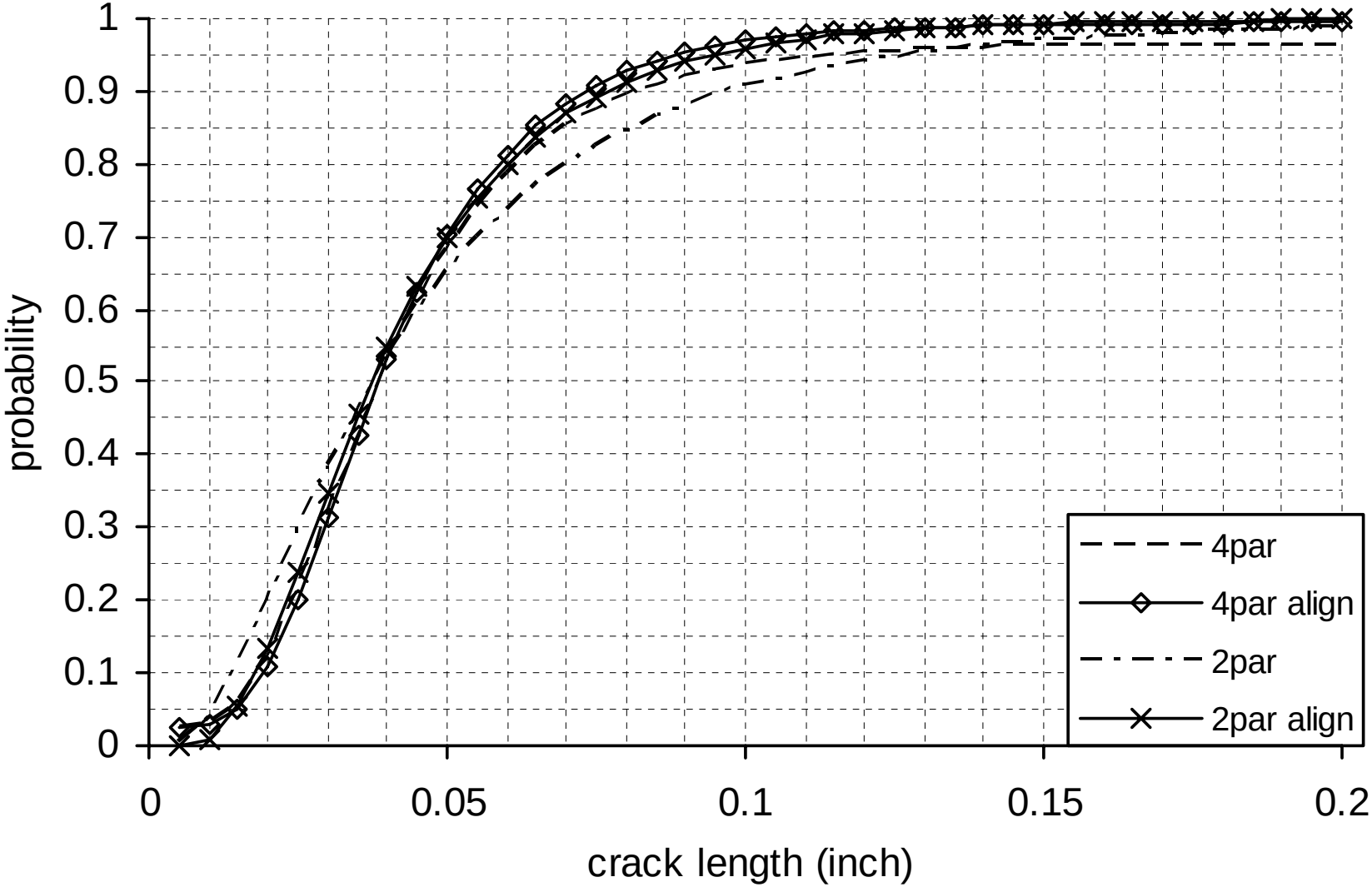
Table 3. Effects of Experimental factors on selected signals – as % of nominal

			Experimental	Factors		
Response	time delay	depth velocity	gain	skew	probe pressure	time delay * depth vel.
Inner Transducer						
Average signal strength	in interaction		7.8		1.2	2.9
Area of flaw signal		11.2	17.0			
Average signal strength of flaw area	in interaction		7.1			15.4
Outer Transducer						
Average signal strength		4.4	9.1	2.9	6.3	
Area of flaw signal	in interaction					19.8
Average signal strength of flaw area		4.7	9.9		4.6	

Field Inspection Results

- Gain and time base delays observed in the field data exceeded the range studied in the laboratory phase
- Misidentification of hole from the image not uncommon
  - Able to be determined from saving inspectors images and comparing to calls made

Average PoDs



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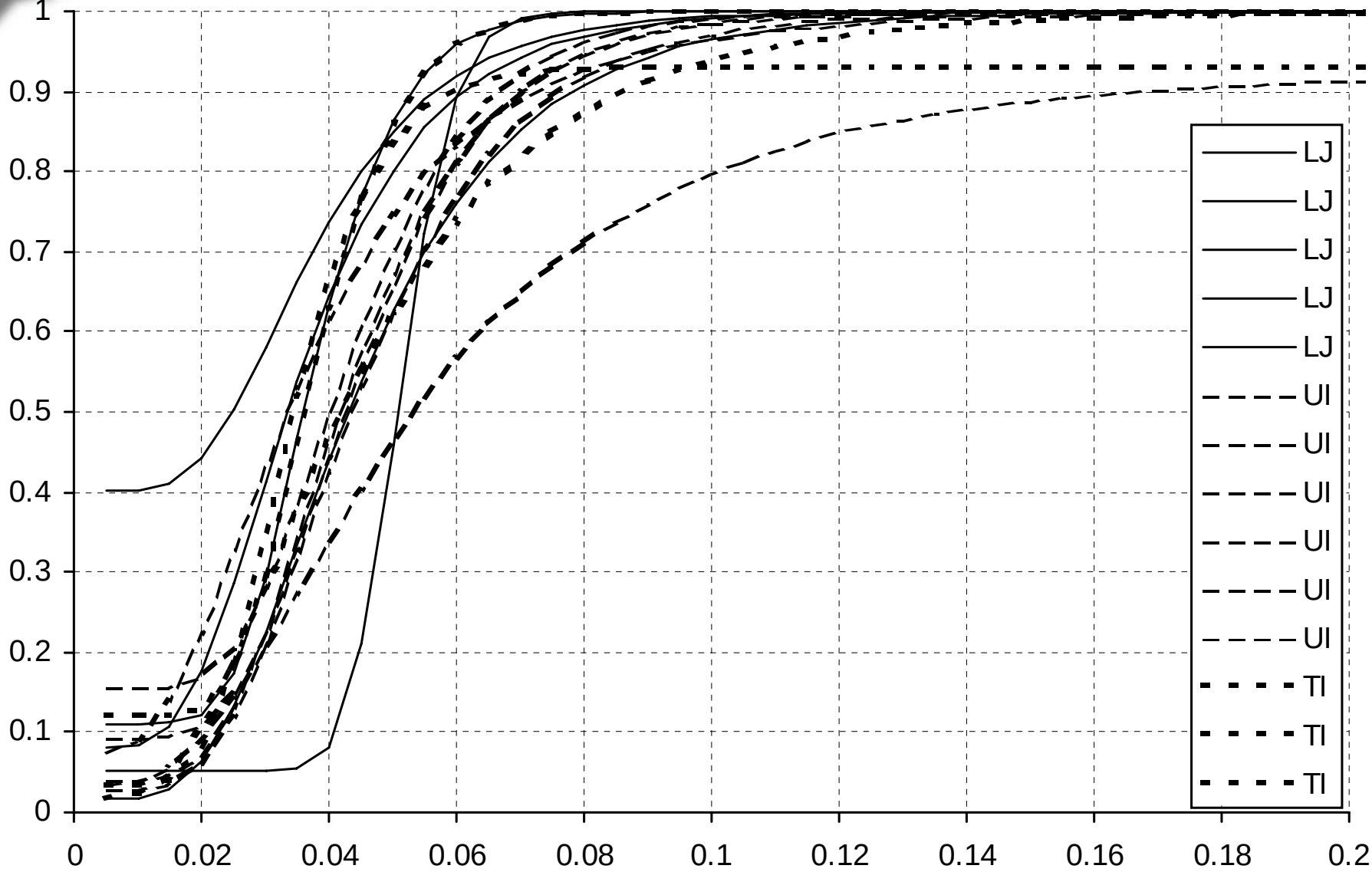
PoD Curves fit to individual inspections



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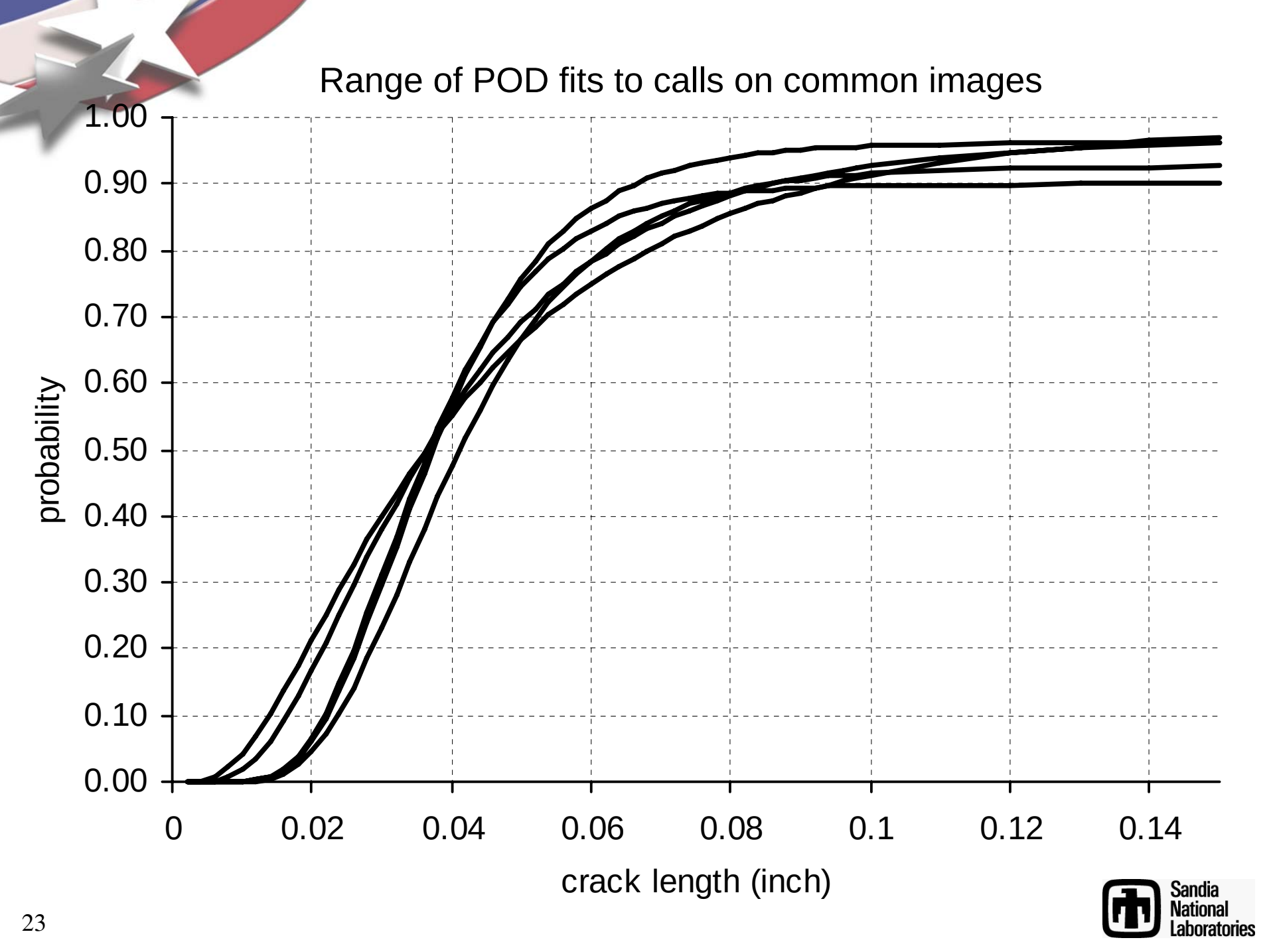
Common Image Set

- Nominal run of Laboratory phase
- 10 inspectors made calls
  - on 356 images



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Conclusions

- Target flaw size (0.050 inch) estimated to have average detection rate of 0.70
- Set-up variation in the field higher than expected
- Decision process a large contributor to observed variation
  - Lead to development of automated decision process (neural net)

References for full reports

- Spencer, F. and Schurman D., “Reliability Assessment at Airline Inspection Facilities, Volume III: Results of an Eddy Current Inspection Reliability Experiment,” DOT/FAA/CT-92/12,III, May 1995.
- Mullis, R. and MacInnis, T., “C-141 Spanwise Splice Advanced NDI Method,” The First Joint DoD/FAA/NASA Conference on Aging Aircraft" in Ogden, Utah, July 10, 1997. (NDTnet – November 1997, Vol.2 No. 11)
- Andrew, G., MacInnis, T., and Mullis, T. “Second-layer ultrasonic inspection of C-141 splice joints,” *Nondestructive Evaluation of Aging Aircraft, Airports, and Aerospace Hardware,* eds Rempt, R and Broz, A, SPIE Proceedings Vol. 2954, 1996.