Practical Considerations in Empirical POD Study Design

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POD Studies – What about factors other than flaw size?

- **Experimental Design**
  - **Identification of factors of interest**
- **Protocols**
  - **Making sure needed inferences can be made**
- **Logistics/Dress Rehearsal**
  - **Effect on the experimental design**

Identification of Potential Impact Variables - DoEx

- ***Environmental***
- ***Inspector characteristics***
- ***Equipment***
- ***Inspection process variables***
- ***Procedures***

Environmental

- Lighting
- Noise
- Temperature
- Distractions

Inspector Characteristics

- Experience Level
  - Recency of Experience
- Training
  - Formal/recurring
  - OJT
- Physical Characteristics

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Equipment

- Controllers
- Probes
- Cables

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Process Variables

Source of variation from one inspection to the next

- Variations within calibration or setup process
  - Dwell times, scan rates, operating frequency, etc.
- Call criterion (thresholds)
  - Constant throughout inspection?

Procedures

- Usually fixed but can differ across locations/facilities
- Can extend to issues of management/supervision & task assignment

Final Study Design

- Dictated by Goal and Resources
- Identified Factors
  - Controlled
  - Uncontrolled
    - Recorded
    - Unrecorded

Protocol Development

- Assure that the objectives of the experiment are implemented.
- Assure that the experiment is carried out in a consistent manner.
- Assure that the data to be recorded are clearly defined and are gathered consistently.
- Assure that consistent information is given to the inspectors prior to their inspection.
- Assure that deviations that might arise from the original plan can be dealt with effectively
- Assure that subsequent experiments can be carried out in a comparable manner.

Protocols (continued)

- Assure that data are taken under "blind" conditions

Logistics/Dress Rehearsal

- Prior agreements with inspector population or organizational management
- Impacts Design of Experiment

Two Examples

- **Reliability at Airline Maintenance Facilities**
  - **Knowledge of existing process and procedures**
- **Fielding a Newly Developed Automated Ultrasonic Inspection**
  - **Assessing capability and transferring newly developed process to end-user**

Eddy-Current Inspection Reliability Experiment

- FAA program in mid 1990s
- Follow-up to Aloha Airline Incident

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NTSB statement

"There are human factor issues associated with visual and nondestructive inspection which can degrade inspector performance to the extent that theoretically detectable damage is overlooked."

ECIRE Primary Goals

- Provide a quantitative assessment of inspectors' performance in airline facility use of high-frequency eddy current inspection procedures specified by the OEM.
- Encompass "human factor issues" to the extent possible through the design of the test specimens and implementation of the experiment to simulate that of an actual aircraft inspection in the usual maintenance facility environment.

Incorporated Factors

- off-angle cracks
- differences in specimen definition
- accessibility of task
- time into inspection (related to "boredom")
- unpainted versus painted surfaces
- facilities (airline / 3rd party)
- work shifts

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Single Inspection

- 4 – 8 hours to complete
- 2 – levels of accessibility
- Alternating “low” & “high” flaw density (10% & 40%)
- Recorded Info
  - Rates of inspection
  - levels of calls (1, 2, 3 – confident/somewhat confident/possible)

9 Experiment Locations

- 4 major air carrier maintenance facilities
- 2 small carrier facilities
- 3 independent contract maintenance facilities
  - Six were union shops
  - Four located at large busy airports. The rest at smaller, regional airports.

Automated Ultrasonic Inspection

- C-141 Splice Joint 2nd Layer Ultrasonic Inspection
  - Sponsored by USAF Warner-Robins Air Logistics Center (WR/ALC)
  - Developed by SAIC/Ultra Image International

“Automated” image acquisition

however

The impact of the human inspector on the reliability of the process was in setting up the equipment and in interpreting the acquired data.

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POD Study Purpose

- assess basic capability of the newly developed process
- assess the ability to train an effective inspection force along with delivery of system

Phases of the Study

- **Laboratory validation**
  - **impact of major procedural variables on the resulting signals and calls were characterized**
- **Field Implementation**
  - **inspectors with a wide range of backgrounds and familiarity with the type of inspection**

Laboratory Experiment

- Five process variables likely to impact results identified
- Influence of factors studied in fractional factorial design
  - Factor levels set according to expected procedural variations

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

Field Inspections

- Use of simulated underside of wing
  - Required same movement and set- ups as actual inspection
- 14 Inspectors
  - 6 experienced & familiar with the imaging system
  - 5 experienced but not familiar with the imaging system
  - 3 inexperienced but familiar with imaging system
- Subset of inspectors (10) provided calls on common image set
  - Enabled a separation of inspector decision vs. set-up

Summary of POD Design Issues

- Purposes of POD studies often go beyond estimation of a single curve
- Expanded goals dictate the need for more general planning
  - Experimental design
  - Protocol development
  - Logistics
- Two very different programs illustrate different design elements but sharing the common element of the use of POD as the basic metric
  - Summary of results of these programs in next talk