EXPLORING THE EFFECTS OF HUMAN FACTORS ON ULTRASONIC NONDESTRUCTIVE EXAMINATION

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Research Purpose

- The NRC Office of Regulatory Research (RES) is conducting research to identify, understand, and prioritize the human factors that are most likely to impact personnel performance during NDE in nuclear power plants.
- This research effort will assist the NRC in planning future research, evaluating whether changes are needed in regulatory requirements, and providing technical justification for regulatory decisions.

NRC Interest In Human Factors

- There have been concerns over the effects of field conditions on inspector performance for decades
- Operational Experience in some cases showed that flaws that should have been easily found were not found in the field
- A review of operational experience showed that the failed inspections had a common set of factors
  - Insufficient oversight of inspectors by licensees
  - Time pressure on inspectors
  - Scan speed or quick review of encoded data
- These issues pointed to a need for more information on human factors

Research Motivation

- Significant progress in increasing the reliability of UT through performance demonstration testing
- Recognition that performance demonstration testing is in an “ideal” laboratory-like environment, which is very different from working conditions in the field
- International interest in examining factors present in the field that can influence the reliability of UT NDE
- Sporadic empirical research efforts to study human factors (HF) that can affect inspector performance in the field

Research Goals

- Systematically evaluate the human factors that can affect UT inspectors.
- Determine the key differences between qualification performed in a laboratory environment vs. field inspections.
- Determine the highest priority human factors that may be impacting UT NDE performance in the field.

Research Approach

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Part 1: Topic Characterization

Part 2: Task Analysis

Part 3: Prioritization

Part 1: Topic Characterization

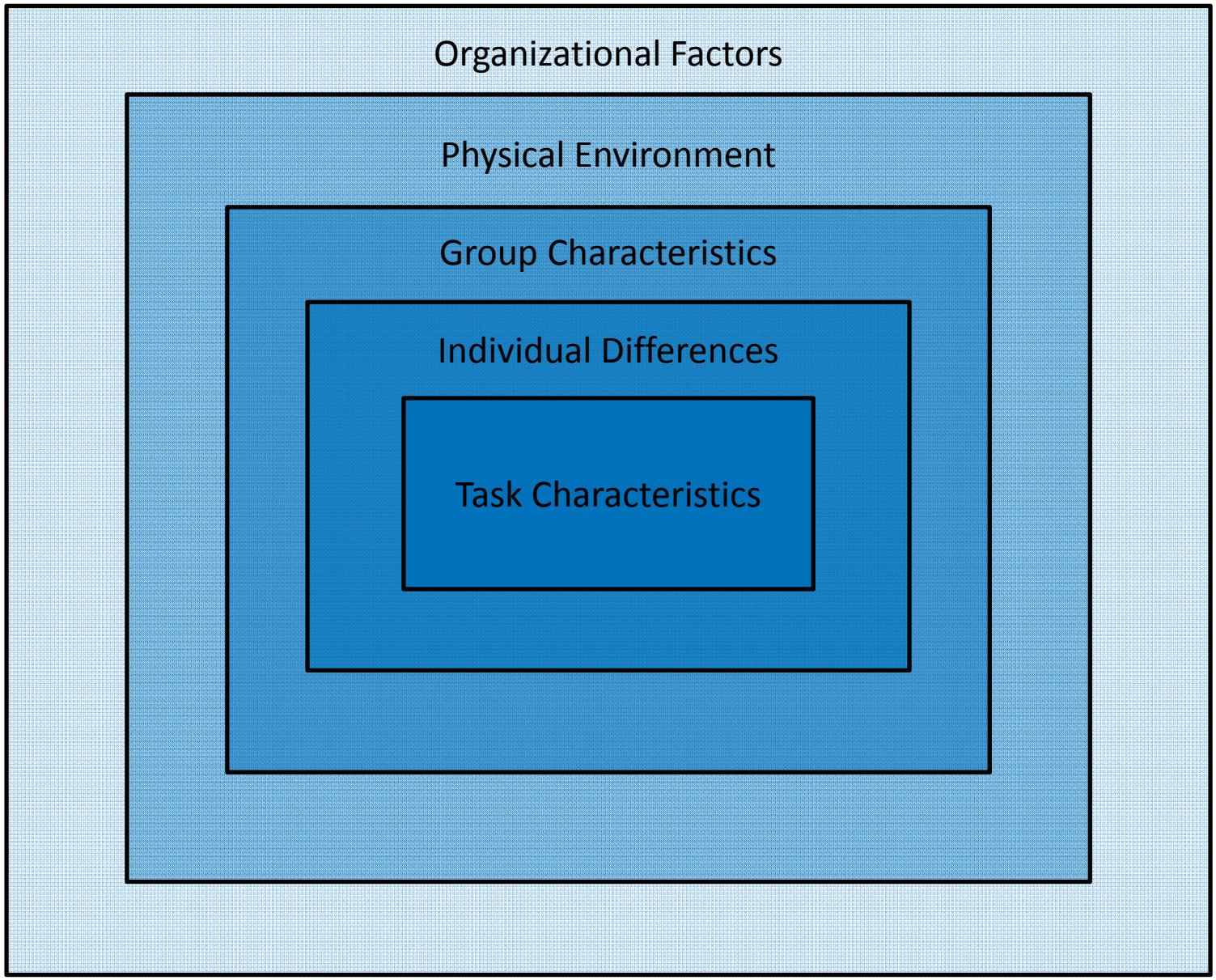
- Objectives:
  - Develop a high-level understanding of UT NDE and the potential human performance challenges.
  - Characterize the current state of human factors research in NDE.
- Activities:
  - Site visits and discussions with subject matter experts
  - Review of UT codes, standards, and regulations
  - Review of NDE operating experience
  - Review of the NDE research that addresses human factors
- Desired Outcomes:
  - Comprehensive report on the state of HF research in NDE
  - Identify human factors in NDE that require additional research

Part 1: Current Status

- Multiple visits to EPRI's performance demonstration facility
- Reviewed NDE codes, standards and regulations
- Collected NDE-related operational experience from NRC inspection reports
- Completed Literature Review
  - Developed a human factors categorization scheme based on Neville Moray's sociotechnical systems model (2000)

PART 1: COMPLETE

Moray's Sociotechnical Systems Model



Insights from Literature Review

- Few structured, systematic studies of human factors in NDE.
- Very little discussion of group characteristics in literature.
- Organizational Factors
  - Difficult to simulate in laboratory conditions, but may be a primary contributor to NDE reliability.
  - Interactions between the NDE vendor and utility can affect quality of planning and preparation.
  - Management can influence inspector's decision criteria (i.e. propensity to make false calls versus missing defects).
  - Training strategies (e.g., use of job aids and simulations) can affect inspector's performance.
- Physical Environment
  - Degraded physical environment may have a greater impact on performance when combined with other factors, such as task difficulty.

Insights from Literature Review

- Individual Differences
  - Personality factors (conscientiousness & extraversion) found to impact NDE performance.
  - Mechanical comprehension correlated with better performance.
  - Visual capacity impacts NDE inspection success.
  - Inspector attitude & motivation influences NDE performance.
- Task Factors
  - Equipment design issues are widely acknowledged, multiple calls for design guidance.
  - Pre-job preparation can impact the quality of the NDE.
  - One strategy suggested to improve performance is more frequent and realistic practice
  - Information attended to and processed, scanning technique and speed, posture, and how one interprets signals are all process elements that can impact performance

Performance Influencing Factors

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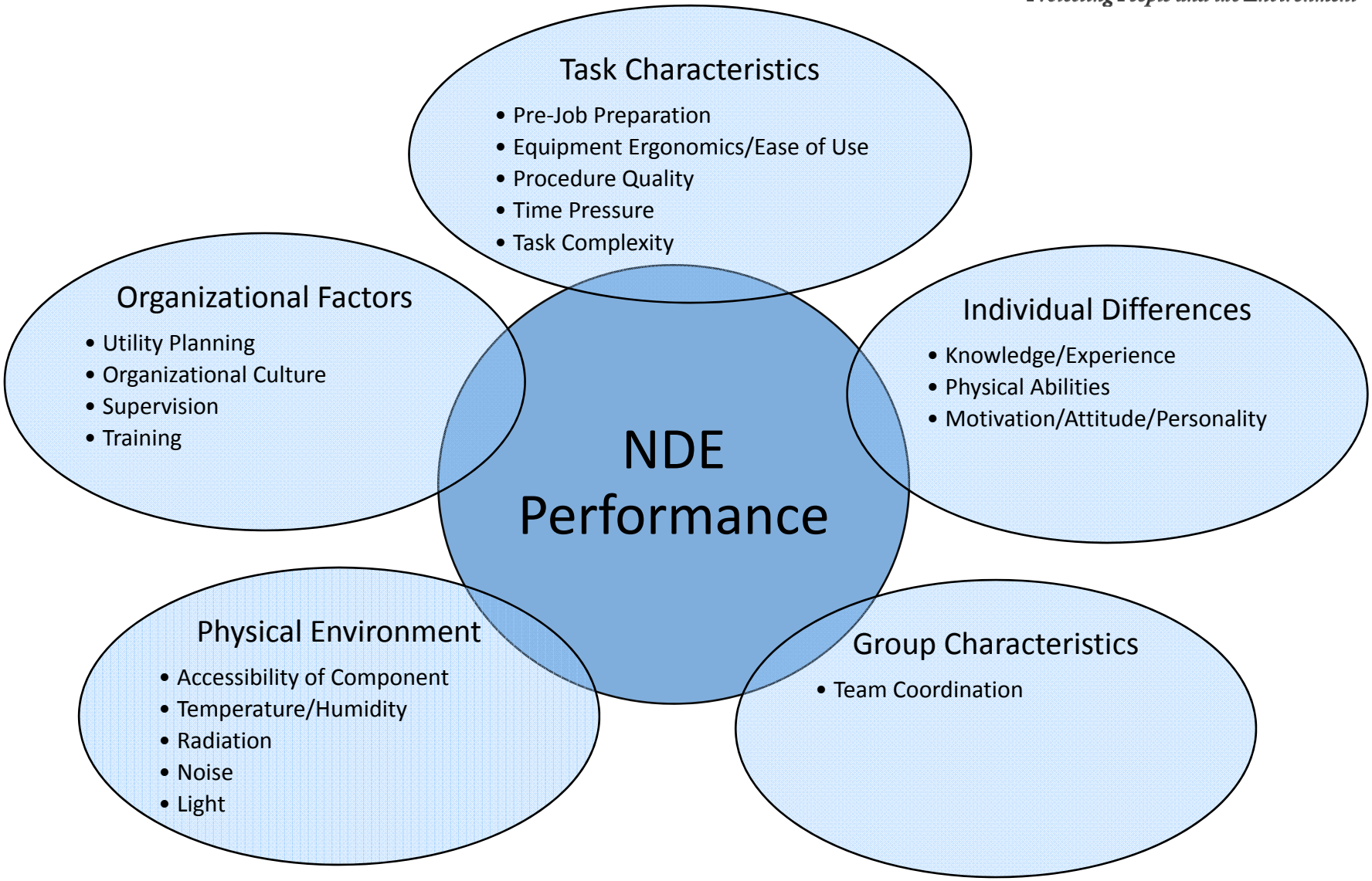

Part 2: Task Analysis

- Objectives:
  - Develop a deep understanding of what UT inspectors do, the environment they do it in, and the challenges they face.
  - Understand the differences between manual conventional UT NDE in the lab and the field.
- Activities:
  - Collect data via interviews with subject matter experts, observations, tabletop discussions, procedure analysis, and document reviews.
- Desired Outcomes:
  - Accurate characterization of manual conventional UT NDE (e.g., tasks, workflow, equipment, working environment, etc.).
  - Identification of primary differences between the lab and field environments that may affect performance.

Part 2: Current Status

- Developed list of functions comprising manual UT
- Expanded functions to specific tasks, subtasks, display and control elements
- Completed Tabletop Analysis at EPRI to validate and expand initial task list with 11 subject matter experts
- Visited three nuclear power plants to observe UT NDE in the field
- Completed face-to-face interviews with 10 subject matter experts and two focus groups (N=32)
- Additional data collection with subject matter experts ongoing

Manual Ultrasonic Testing Task Analysis

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FUNCTION: A group of activities generally performed together to accomplish an overall goal.

PLAN INSPECTION → PREPARE FOR EXAMINATION → CONDUCT EXAMINATION → REPORT EXAMINATION RESULTS

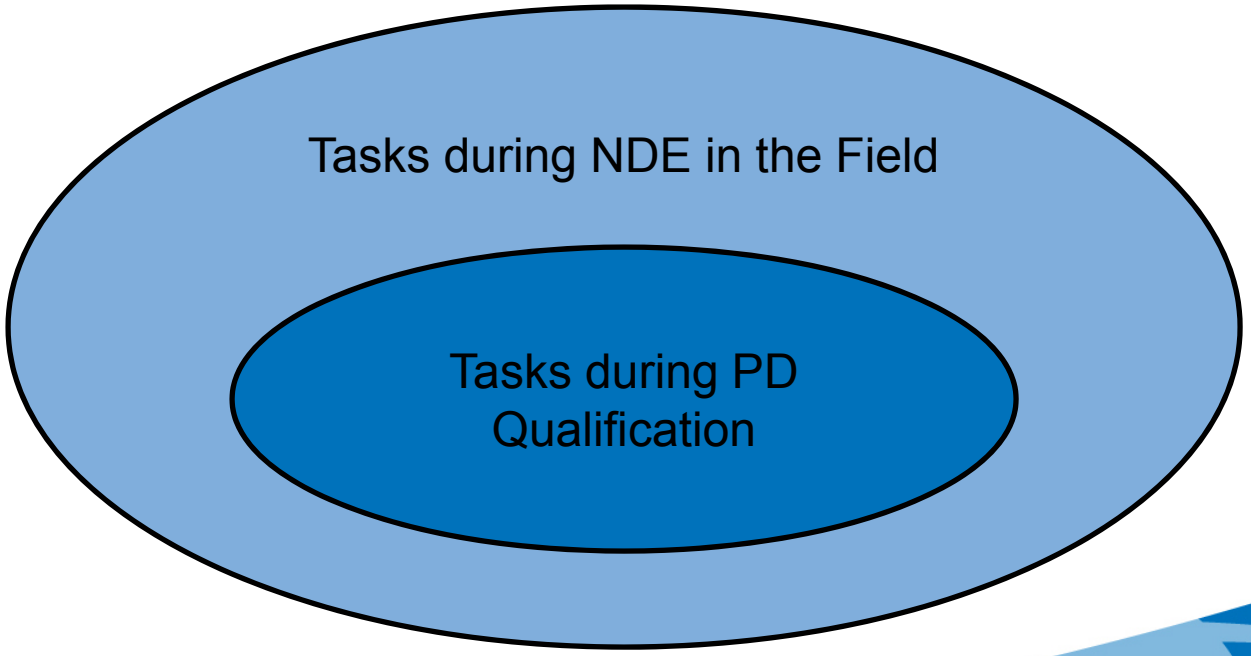
TASKS

1. Receive plant orientation and training
2. Review work documentation and procedure
3. Assemble equipment and materials
4. Perform calibration
5. Attend pre-job briefing and ask questions if needed
6. Pack equipment and materials
7. Prepare to enter area for exam

TASK: A smaller unit of behavior that provides information about the human-information processing demands, communication requirements, instrument interactions, etc.

NDE in the Field vs.
NDE in Performance Demonstration

The PD qualification process represents a sub-set of the inspection process in the field.



Field Observations

- Many personnel are not employed year-round performing NDE
  - Fall and Spring outage seasons
- Time pressure comes in varieties
  - Overall schedule, shift limitations, task-specific radiation exposure limitations
- Working conditions can vary widely
  - Heat, noise, ease of access, space restriction
- Significant coordination required to ensure the inspection can be performed
  - Coordinate surface preparation, scaffolding, radiation work permit, etc.
- Identifying the correct weld for inspection can be difficult
  - Nearby tags difficult to find or nonexistent
  - May have to identify based on pipe configurations

Images from the Field

- Industrial work environment
- Radiological concerns
- Awkward postures
- Variable lighting
- Hand-eye coordination to scan pipe while viewing UT instrument

Images from the Field

- Surface conditions must be adequately prepared (e.g., removal of insulation)
- Must hold a small transducer with hands covered in slippery couplant
- Risk of dropping equipment

Images from the Field

- Placement of components not necessarily designed for inspector access
- Lack of visual feedback when scanning underside of component

Part 3: Prioritization

- Objectives:
  - Identify the most critical human factors that can affect UT inspector performance.
- Activities:
  - Meetings with key stakeholders to develop prioritization criteria (e.g., risk, feasibility of intervention).
  - Collaborative workshops with key stakeholders to prioritize human factors in UT NDE.
- Desired Outcomes:
  - Prioritized list of human factors that can affect UT inspector performance to use as an input for future research and strategy planning.

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Thank you!

If you have questions, please email:

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