Human Factors and AI for NDE

A Launchpad for Further Discussion

Thiago Seuaciuc Osorio

2026 NRC-Industry NDE Technical Information Exchange
Wednesday, 21 January 2026

References

1 *Human Factors in Nondestructive Examination* (NUREG/CR-7295 / PNNL-32505)
T Sanquist, S Morrow, J Harrison, C Nove

2 *Review of Human Factors Research in Nondestructive Examination* (ML17059D745)
A D'Agostino, S Morrow, C Franklin, N Hughes

3 *Human Factors in Nondestructive Examination: Manual Ultrasonic Testing Task Analysis and Field Research* (PNNL-27441)
T Sanquist, S Morrow, A D'Agostino, N Hughes, C Franklin

Leverages Previous Industry Research

EPRI

Background

The current NDE qualification process is good

"The performance demonstrations, coupled with advancements in ultrasonic examination technology, provide assurance that the ultrasonic examinations are capable of finding flaws. Today, the NRC and industry have confidence that ultrasonic equipment, procedures, and personnel that meet the requirements of Appendix VIII will be able to find flaws in components under ideal conditions"

"Although these measures help to ensure that the equipment, procedures and personnel are capable of reliably detecting flaws in a formal testing environment, notable failures have occurred during application in the field"

Failures still happen in the field

Human factors are now the main issue

"In each case, the equipment and procedures, while not always optimal, were physically capable of obtaining discernable signals from the flaws. A variety of human factors challenges present in these inspections set the stage for the failures"

"Human factors issues such as time pressures, poor communication between licensees and contractors, and cognitive errors in data analysis now often play larger roles than technology in missed detections"

EPRI

Humans Are…

The Weakest Link

The Strongest Link

…Not the Problem

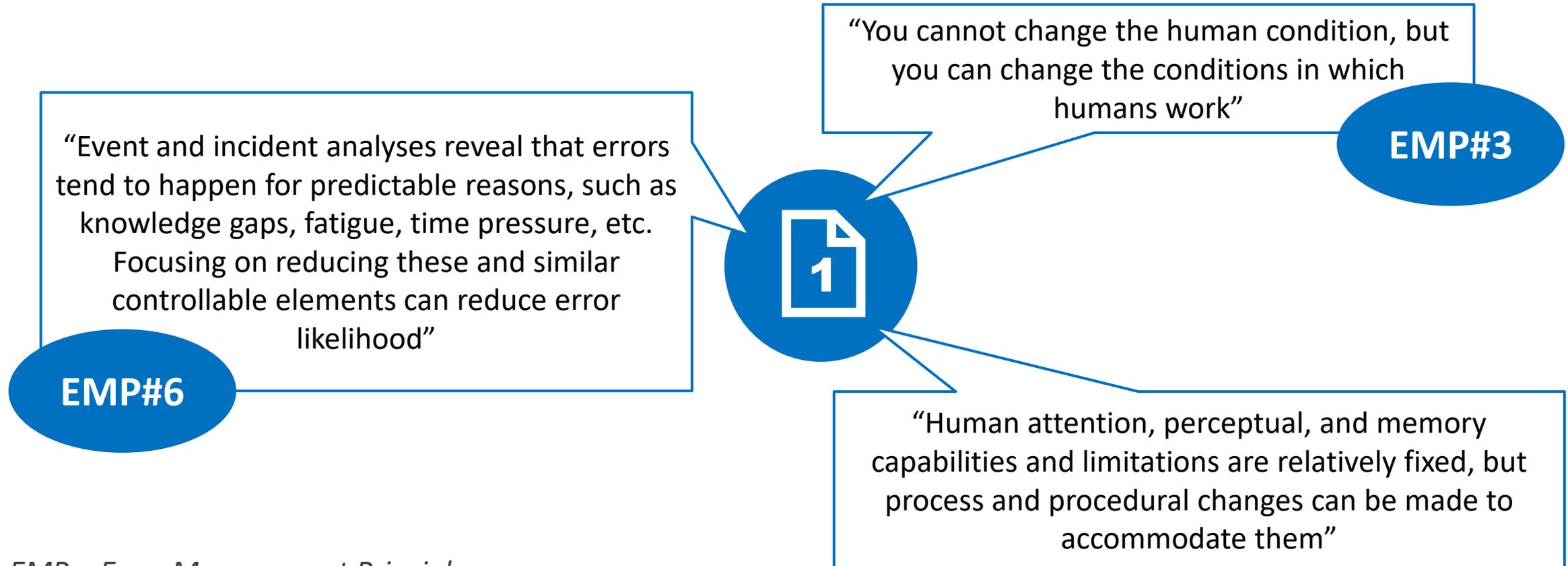## INTELLIGENCE REQUIRED

2 **Active interpretation is required**

- "NDE contains diagnostics/interpretative task demands"
- *Interpretative habits** associated with:
  - More complex tasks (sizing *vs*. detection)
  - Higher theoretical background
  - Higher experience

* Focus on personal expertise, and emphasis on the perception-action cycle with diagnostic interpretative aims

"Humans are odd... But there is grace in their failings."
Marvel's Vision, to Ultron

EPRI

The goal of AI-assistance then, is not to remove the human, but to **improve their work conditions**

"Event and incident analyses reveal that errors tend to happen for predictable reasons, such as knowledge gaps, fatigue, time pressure, etc. Focusing on reducing these and similar controllable elements can reduce error likelihood"

EMP#6

"You cannot change the human condition, but you can change the conditions in which humans work"

EMP#3

"Human attention, perceptual, and memory capabilities and limitations are relatively fixed, but process and procedural changes can be made to accommodate them"

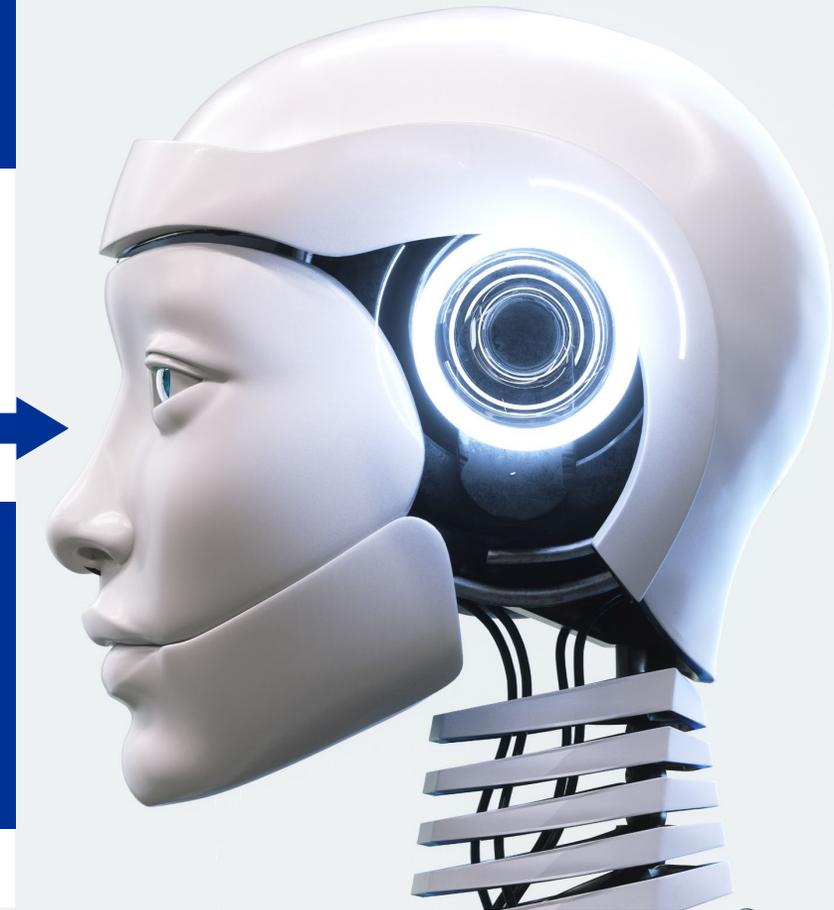*EMP = Error Management Principle*

EPRI

"Inspection is a COGNITIVELY DEMANDING task that requires CONSTANT VIGILANCE"

Case in Point: RVUH

Operating Experience: Missed Flaws

Contributing Causes	Mitigation Strategies
• Fatigue • Distraction • Lack of independent review	• Implementation of independent review ← Costly • Reducing time pressure ← How do we do this? • Reducing distractions • Complete review of a single set without interruption ← ~90 min of focused time

Easier said than done...

EPRI

Case in Point: RVUH

Operating Experience: Missed Flaws

Contributing Causes

- Fatigue
- Distraction
- Lack of independent review

Mitigation Strategies

- Implementation of independent review
- Reducing time pressure
- Reducing distractions
- Complete review of a single set without interruption

Reduced → Fatigue

Done efficiently → Implementation of independent review

Relaxed → Reducing time pressure

Fewer opportunities → Reducing distractions

~2 min per penetration → Complete review of a single set without interruption

AI-Assisted Analysis
Full head analyzed in under 3h

AI-Assistance enables implementation of identified error mitigation strategies

EPRI

Errors & Mitigations

Error Class I: Good plan, poor execution

"The plan of action is appropriate but actions do not go according to plan. Skill-based errors—slips (*attention*) and lapses (*memory*) can occur at all levels of a system"

Error Class II: Poor plan, good execution

"Actions go as planned, but are inadequate to achieve goal. Knowledge and rule-based *mistakes* occur at the level of formulating a plan of action"

Person-Level Mitigations

"Person-level error reduction mitigations are aimed at creating conditions that are more conducive to reliable attentional, perceptual, and decision-making processes in the individuals conducting and interpreting exams"

- Shift scheduling
- **Reduce distraction & time pressure stress**
- Skill development
- Exam team composition
- **Cognitive aiding**
- **Complete read of data without interruption**

System-Level Mitigations

"System-level error reduction involves changes in organizational processes and procedures "upstream" from the specific tasks of component examination. The ownership of system processes can involve industry organizations, regulatory agencies, utilities, specific plants, and NDE vendors"

- Information accuracy
- Communication & preparation
- Inspection scheduling
- **Data review & interpretation process**
- Change management & evaluation

EPPI

This Whole Presentation Could Have Been 3 Bullets…

We have trust in the process

- NDE system is capable
- ➢ Expect to work also with the inclusion of AI as part of the NDE system

Performance is now limited by human factors

- Errors mitigation strategies have been identified
- Some have been implemented
- Others do not have a straightforward implementation

AI can improve the human working condition (EMP#3)

- Enables the industry to implement identified mitigation strategies
  - ➢ Some more efficiently
  - ➢ Some for the first time

"Great. I think I got it, but just in case, tell me the whole thing again I wasn't listening."
Emmet, in The Lego Movie

EPRI

Change Management & Evaluation

✓ AI brings benefits to NDE

✗ AI brings new issues to NDE

"Introducing new technologies, processes, and procedures with the intention of reducing one type of human factors problem generally results in new, unanticipated issues"

The Goal: ▢1

- Pro-actively review identified performance influencing factors (PIF) and error reduction approaches to:
  - Identify anticipated issues
  - Identify mitigation actions
  - Identify measures (things to watch out for)

Suggested topic for discussion in tomorrow's breakout session

EPRI

Proposed Approach

- The next slides list identified PIFs
  - Some *initial* thoughts presented for consideration
- Your homework
  - Review & make notes for tomorrow's breakout session
- Envisioned/suggested output

Issue/Factor	Mitigative Action	Observation
What can go wrong? What are undesirable behaviors?	*What controls/actions can we pro-actively employ?*	*How do we observe this in practice?*

KEEP CALM AND CARRY ON

EMP#1 — **Errors are inevitable**

EMP#2 — **Errors are not intrinsically bad**

Overall intent is to *minimize latent errors*

EPRI

Performance Influencing Factors

Organizational Factors

Physical Environment

Group Characteristics

Individual Differences

Task Characteristics
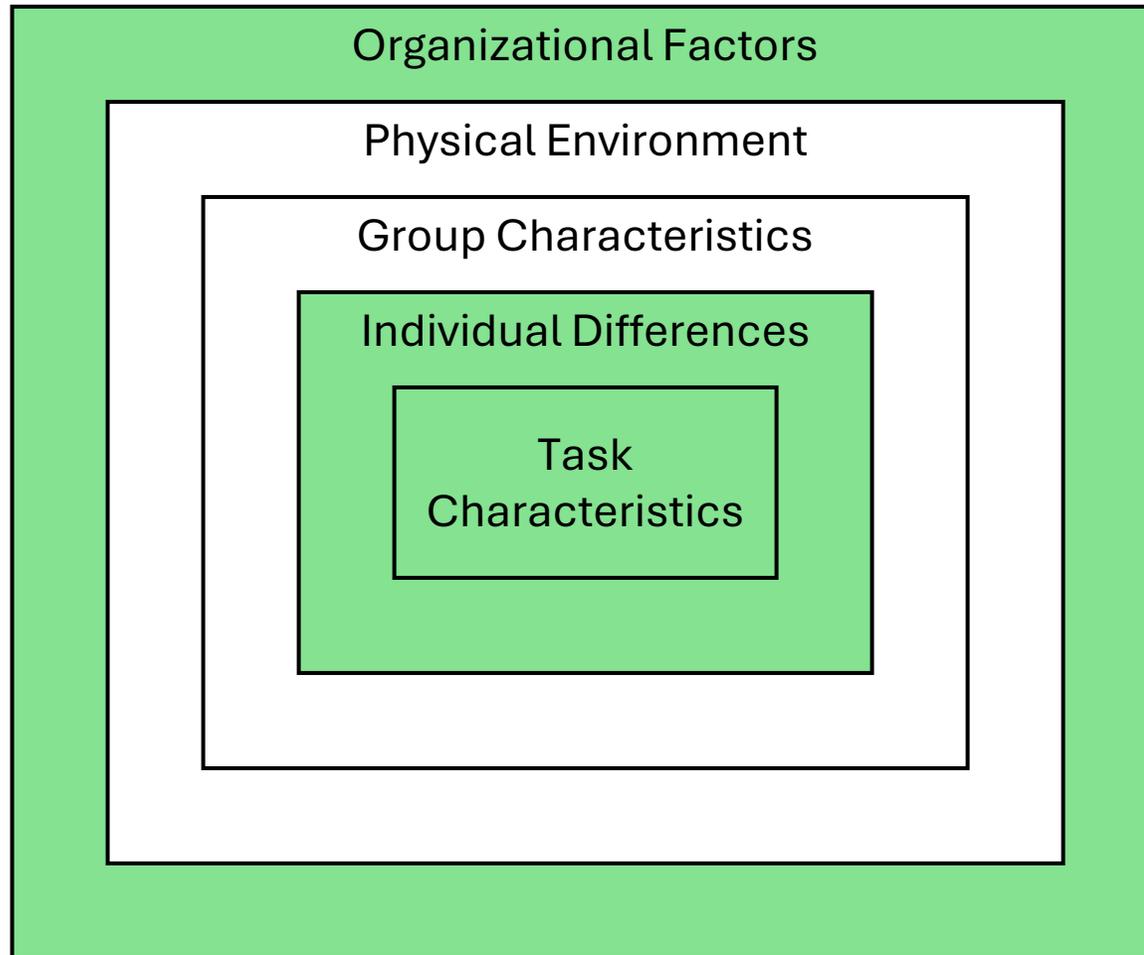
- The following tables are intended to provide starting thoughts for further consideration/discussion as adequate in the breakout session.
  - Not intended to be read in detail this presentation
- Review them at your discretion and come prepared to discuss what you find to be the most salient points
- Only categories in green are included
  - You can bring up any of the others if desired

1 2
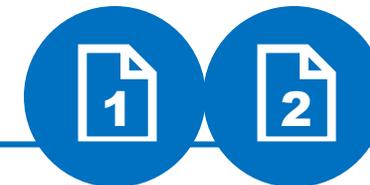
- Image adapted from [2]
- Following PIFs taken from [1]

EPRI

PIF: Task Characteristics

PIF	Anticipated Impacts/Needs/Considerations

Pre-job Preparation	• Proper pre-job briefs are identified as the key component of preparing for the examination (together with calibration) [NUREG/CR-7295/PNNL-32505]. AI-assistance can enable better pre-job brief. For instance, inspectors can efficiently review all previous inspections in the matter of hours.
	• There will be additional (new) elements, such as:
	  – Inspectors need to be aware of the scope of the AI model and its role (capacity of use) in the inspection.
	  – Ensure compatibility of AI tools with UT system

Equipment	• Additional hardware needed to process current inspection data. System complexity increases.
	  ➢ Seek "plug'n'play" setups.
	• Model is frozen (essential variable).
	  ➢ Models need to be repeatable and static, and contain identifier for validation. Stochastic models need to be assessed accordingly.
	• Opportunity for additional alarms.

Procedure	• Modified to include AI-assistance. Modification can be limited to data analysis portion. May require additional/different steps/actions from the examiner. ➢ Consider backwards compatibility. In Sweden, it was a dual procedure, allowing for assessment with and without AI-assistance.
Time Pressure	• Expected to decrease as/if analysis time decreases. ML17059D745 points out that it is the perception of time-pressure that affects inspection quality. AI may help alleviate this perception. ➢ AI-assistance process cannot increase analysis time.
Task Complexity	• Data analysis complexity should not increase as compared to non-assisted counterpart. Further analysis still expected to be completed on native software as before. ➢ Interface should be seamless and simple; cannot increase task complexity.

EPRI

PIF: Individual Differences

PIF	Anticipated Impacts/Needs/Considerations

Knowledge / Experience	• Required knowledge/experience should not change: allow inspectors to focus on their craft
	  ➢ Tools should be "transparent:" AI knowledge is not required to use it.
	  ➢ Tools do not replace human expertise. They still allow/require humans to exercise their abilities.

Examiner Process	• Will indubitably change/evolve as tools become more prevalent and inspectors more accustomed to them. How the inspector's decision criteria will be affected is a point for discussion/observation, and is likely to depend on their experience level (ML17059D745 points out that shifts in decision criteria can be attributed to a lack of confidence by the inspector). Main concern is over- and under-reliance.
	  ➢ Model-only performance should be measured to understand consequence of over-reliance.
	  ➢ Human-only performance should be measured to understand consequence of under-reliance.
	• Social loafing
	• Reducing distractions and interruptions is important to the analysts [NUREG/CR-7295/PNNL-32505]. AI-assistance can help minimize those by reducing analysis time.

Motivation / Attitude / Personality	• Personality may impact acceptance/trust/use of tools. • Boredom and the perception of "unimportance" have negative impact on performance. Maintaining meaningful human input is essential. ➢ Tool design should maintain meaningful, healthy level of human-agency.
Physical Abilities	• Can bring positive impact on visual search capabilities. "Visual search is characterized to be one of the most error-prone critical functions associated with NDE" and "Missed defects are attributable to failures in visual search" [ML17059D745]
Cognitive Factors	• Can alleviate taxation on limited cognitive resources such as memory and attention (cause of Error Class I) • Cognitive aiding is identified as one of the person-level error mitigation strategies in PNNL-27441/ML18176A055 • Cognitive abilities still need to be practiced lest they be lost. ➢ Maintenance of human-agency is required: inspectors must still have a chance to apply their skills to maintain them.

Workload / Stress / Fatigue	• Overall, fatigue is likely to be alleviated if analysis are completed in a shorter time.
	• Knowledge that utilities now can use the tool for oversight may lead to increased stress on the inspectors.
	  ➢ Needs to be addressed from an organizational level.
	• May be perceived as additional workload from the part of the vendors, especially if not part of the credited, qualified inspection.
	  ➢ Needs to be addressed from an organizational level.

EPRI

PIF: Organizational Factors

PIF	Anticipated Impacts/Needs/Considerations
Utility Planning	• AI-assistance can be leveraged for things such as pre-job briefs, inspection prioritization, inspection oversight; and can bring positive impact to all these areas if properly planned. Developing the inspection requirements is seen as the most important task in planning [NUREG/CR-7295/PNNL-32505]. Here, this includes defining and communicating the role(s) of AI-assistance and of the inspectors. ➤ There should be no surprises ➤ There should be time enough to prepare • It is necessary to ensure compatibility of the model and AI hardware with technique and other inspection equipment beforehand. • If AI enables reduces data analysis time, how should this affect inspection and shift scheduling?
Organizational Culture	• Early and throughout engagement (from development through deployment) and open discussions with all stakeholders (utilities, vendors, regulators) will be essential to minimize latent errors. • The role of the AI-assistance (in what capacity it is to be used) and of the humans (utility and vendor) should be understood by all involved. ➤ AI tools should not add to the perceived workload or pressure of the inspection activity. • Error is universal and inevitable (EMP#1), and they are not intrinsically bad (EMP#2). Everyone makes mistakes (EMP#4) ➤ Continuous OE sharing is fundamental: learning from mistakes, continuous improvement (EMP#8)
Supervision	• AI-assistance enables more efficient and meaningful site oversight. In fact, this is the way the CRDM has been used in the US. • AI output may be seen as a form of feedback or confirmation/challenge to the inspectors. (lack of feedback is identified as one of the shortcomings of field NDE) • If AI is seen as supervision or a check, it may lead to complacent behavior (social loafing)
Training	• AI can impact training (but for now, that's outside of scope) • Inspectors should be (functionally) trained in the intended use of AI as adequate. Level of training will depend on level of AI integration/use in the system.
Vendor-Utility Interactions	• Will likely be affected as utilities use–and drive the vendors to use–AI tools. Examples include: utilities using AI for oversight; or requiring open data format or the use of AI for the inspection. ➤ Early and continuous discussion is important to maintain healthy relationships, avoid surprises, and minimize latent errors. • AI-assistance may enable faster preliminary results and earlier identification of potential issues, which may be of interest to the utilities. At the same time, inspection vendors may be reluctant to discuss preliminary results prior to full confirmation amongst themselves.
Industry Challenges	• May alleviate perceived near-future workforce availability challenges • May cause stress and concern over job security by inspectors • May be perceived as decreasing job size for vendors

EPRI

Another Output: "Guiding Principles"

The collected thoughts in the discussion can also help identify "guiding principles" such as the examples below: each one comes from considerations for one of the PIFs.

For the AI tool design

- Seamless integration
- Simple & intuitive
  - No significant training or additional expertise require
  - ➤ Let the inspector focus on the NDE
- Support backwards compatibility
  - What if AI goes wrong?
- Maintain meaningful human agency
  - Sense of relevance
  - Maintain skills

For the process

- While assessment is on the entire system, it may be advisable to:
  - Maintain "human-only" performance assessment
    - This is the "under-reliant" performance limit
  - Include "machine-only" performance assessment
    - This is the "over-reliant" performance limit
- Continuous OE sharing
- Acceptance must come from all levels

EPRI

TOGETHER…SHAPING THE FUTURE OF ENERGY®

www.epri.com