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The Procedure Performance Predictor (P3): Application of the HUNTER Dynamic Human Reliability Analysis Software to Inform the Development of New Procedures

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The Human Unimodel for Nuclear Technology to Enhance Reliability (HUNTER) software has been designed to provide a simplified framework for modelling dynamic human reliability analysis (HRA). HUNTER essentially creates a virtual operator (i.e., a digital human twin) that controls and responds to a virtual power plant (i.e., a digital twin or full-scope simulator) according to a procedural script. HUNTER has successfully modelled control room operator performance for nuclear power plant incidents, producing realistic human error probabilities, courses of actions, and time durations. Recent engagement with U.S. nuclear industry stakeholders has identified uses for HUNTER and dynamic HRA beyond traditional probabilistic safety assessment. As nuclear power plants upgrade to new digital control rooms, or as control rooms are built for advanced reactors like small modular reactors, there emerges a unique situation for the operating procedures at plants. Existing procedures for legacy plants have been vetted and validated across numerous iterations. Yet, as new technologies emerge in control rooms, there is often little operating experience to inform the development of the new procedures. A Revision Null operating procedure is of concern for both procedure writers and plant safety personnel. Building on HUNTER's handling of procedures, a special variant of HUNTER is being developed, called the Procedure Performance Predictor (P3). HUNTER-P3 allows procedure writers to script a novel procedure to simulate operator and plant performance in the use of that procedure. HUNTER-P3 identifies potential error traps with the novel procedure, thereby creating a way to screen procedures for suitability and safety. HUNTER-P3 also includes consideration for deviations from the procedures to flag potential disparities between work as imaged vs. work as done.

Keywords: HUNTER, human reliability analysis, dynamic, procedure, work as imagined, work as done

1. Review of HUNTER

The Human Unimodel for Nuclear Technology to Enhance Reliability (HUNTER; Boring et al., 2022) is a dynamic human reliability analysis (HRA) tool designed to be simple to use. Initially based on an effort to create a dynamic implementation of the Standard Plant Analysis Risk-Human (SPAR-H; Gertman et al., 2005) HRA method, HUNTER grew to become a standalone software package that allows analysts to use procedures and a linked nuclear power plant model to create a realistic simulation of human performance that can be considered a virtual operator. The basic structure of HUNTER includes three functional modules:

- *Task*—which is driven by plant operating procedures
- *Individual*—which is those factors, specifically performance shaping factors (PSFs), that affect the operator
- *Environment*—which is a model of the virtual world of the simulation, typically a simulator

The software implementation of HUNTER includes additional modules necessary to execute HUNTER as standalone software. These include software modules such as a scheduler, which coordinates the interface between the task, individual, and environment, and coordinates Monte Carlo runs to produce distributions of performance outcomes.

Recent versions of HUNTER (Lew et al., 2022) include the use of the Rancor Microworld

Simulator (Rancor; Ulrich et al., 2017), a simplified pressurized water reactor simulator that has been used in a variety of studies with student and licensed reactor operators (e.g., Park et al., 2023). The advantages of Rancor center on its simplicity, which allows it to be more readily used than a full-scope and full-scale simulator for studies to collect operator-in-the-loop data, and which features a reduced number of parameters compared to full-scope training simulators. In other words, Rancor is easier to interface with HUNTER than conventional simulators for proofs of concept while also allowing ready collection of empirical data to validate HRA models.

2. Introducing HUNTER-P3

HUNTER includes a procedure authoring system that makes it straightforward to input procedures to drive the Task Module. A prototype tool called HUNTER-Gatherer uses natural language processing to automate the process of inputting procedures from existing libraries.

In recent industry forums to discuss uses of HUNTER, a strong use case has emerged outside traditional applications in HRA for risk assessment. Given the focus in HUNTER on running procedures with a plant simulator, there is a much-needed application of HUNTER to evaluate new procedures. Existing operating procedures at plants benefit from extensive operating experience, industry benchmarking and lessons learned sharing such as through the Pressurized Water Reactor Owners Group (PWROG), and continuous improvement through procedure revisions. However, two new situations challenge this process:

- Plant upgrades that introduce new digital systems in the main control room that require new procedures
- New plants that feature entirely neoteric main control rooms that likewise require new procedures.

These Version Null procedures present potential safety and efficiency concerns for operator performance.

To address this challenge, HUNTER is incorporating a new function called Procedure Performance Predictor (P3). HUNTER-P3 uses HUNTER's built-in Monte Carlo tools with human performance variability to identify where in procedures there might be error traps. In this manner, HUNTER-P3 can be used to flag deviations between work as intended and work as done. HUNTER-P3 will serve as a screening tool for novel procedures to help iterate and refine them prior to deployment. Identified error traps serve to prioritize scenarios where empirical evaluation is warranted. HUNTER-P3 is being validated using historic version histories of procedures from a nuclear power plant.

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