**MAPPS (MAINTENANCE PERSONNEL PERFORMANCE SIMULATION): A COMPUTER
SIMULATION MODEL FOR HUMAN RELIABILITY ANALYSIS***

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MAPPS (MAINTENANCE PERSONNEL PERFORMANCE SIMULATION): A COMPUTER
SIMULATION MODEL FOR HUMAN RELIABILITY ANALYSIS

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The Oak Ridge National Laboratory (ORNL) and Applied Psychological Services, Inc. (APS) under sponsorship of the U.S. Nuclear Regulatory Commission (NRC) have developed, sensitivity tested, and evaluated a computer model capable of generating reliable estimates of human performance measures in the nuclear power plant (NPP) maintenance context. The model, entitled MAPPS (Maintenance Personnel Performance Simulation), is of the simulation type and is task-oriented. It addresses a number of person-machine, person-environment, and person-person variables and is capable of providing the user with a rich spectrum of important performance measures including mean time for successful task performance by a maintenance team and maintenance team probability of task success. These two measures are particularly important for input to probabilistic risk assessment (PRA) studies which were the primary impetus for the development of MAPPS. The simulation nature of the model along with its generous input parameters and output variables allows its usefulness to extend beyond its input to PRA.

The MAPPS model represents a comprehensive framework for analyzing maintenance activities. It not only can provide a quantitative source of performance data for input to PRA and for making decisions related to maintenance activities, it will also provide the user/analyst with qualitative insights into the design and structure of maintenance tasks and the maintenance context in general.

A summary of MAPPS functional processing is presented in Figure 1. Steps 6 through 11 identify an iteration loop that simulates the entire task of interest the number of times specified by the user. A number of iterations (simulations) of a task is necessary to smooth the random effects introduced by various stochastic processes within a simulation. Various hierarchical levels of output may be generated by MAPPS (subtask, shift, iteration, and run) if requested. Output at the run level (overall task level) is the only output that is always generated for the user. Step 7 of Figure 1 points out that MAPPS will select the required maintainers for each subtask from the maintainer work group identified by the user. Step 13 indicates that MAPPS also allows shift changes to occur during task simulation. Shift changes are allowed to occur at specified times during task simulation, or following particular subtasks.

Step 8 of Figure 1 represents the heart of the MAPPS model. The logic for this step is expanded in Figure 2 and is utilized for each normal subtask for each iteration of the task of interest. MAPPS addresses 28 subtask kinds, 22 of which are considered normal subtasks and 6 are considered special. Special subtasks such as decision making and troubleshooting are not models of cognitive behavior per se, but are means of determining the time and probability of reaching a correct solution dependent on factors such as intellectual ability, goal importance, trouble report quality, etc.

The overall purpose of the logic presented in Figure 2 is to determine: (a) whether or not the subtask is performed successfully, (b) whether or not an undetected error exists in the work, and (c) how

much time is involved in completing the subtask. By way of overview, Figure 2 indicates that the simulation logic is primarily centered around the difference between the current ability levels of the maintainers and the ability requirements of the subtask to be performed. The degree of ability difference has a succinct effect upon the probability of subtask success, the average duration of subtask performance, and the total stress experienced by the maintainers. The total stress on the simulated work group is affected by the ability difference value as well as by time stress, radiation stress, and communication problems (if present). These other contributors to total stress are described as follows: time stress - when the time required to perform all remaining subtasks is greater than the time available for total task completion, time stress is assumed to be present; radiation stress - when the absorbed radiation dose for a given technician will be greater than 800 millirem (mrem) during the course of task completion, radiation stress is assumed to exist (the NRC's maximum permissible quarterly dose is 1250 mrem); communication stress - if communication is an ingredient in subtask performance, the stress resulting from any communication degradation such as elevated noise level, excessively lengthy communications or large work crews are considered.

The MAPPS model allows the user to specify if an acceptability check is made of the work performed by the simulated maintainers. If so, a supervisor or quality assurance check is simulated in addition to the normal checks made by the work group. Four subtask outcomes are possible: (a) success - the subtask was completed in an acceptable manner without any uncorrected errors; (b) false alarm - the subtask was completed without any uncorrected errors but was found to be

unacceptable by a supervisor/quality control check; (c) detected error - uncorrected errors existed at the end of subtask performance and were detected by a supervisor/QC check; and (d) undetected error - uncorrected errors existed at the end of subtask performance but were not detected by a supervisor/QC check. Perceived work crew failure on a subtask (e.g., false alarm, detected error) leads to re-performance of the subtask which in turn leads to higher subtask performance time, higher time and radiation stress, and a greater fatigue level. Sequences of subtask failures or successes will also lead to a respective decrease or increase in the maintainers, motivation (aspiration) levels. Under the circumstances of high time stress the MAPPS model will allow subtasks of low importance (e.g., clean up subtasks in some instances) to be skipped by the work crew.

The previous several paragraphs have presented a relatively mechanistic view of the functioning of the simulation modules as presented in Figure 2. Additional qualitative insight into the operation of the model are summarized in the following set of axioms upon which the subtask simulation is based:

1. Subtask success probability and performance duration vary as a function of the difference between the ability requirements of a subtask and the actual ability of the maintainers. As the abilities of the maintainers approach or exceed the ability requirements of a subtask, the subtask success probability increases and the performance time decreases.
2. Stress on the maintainers affects success probability and performance duration. "Moderate" stress increases subtask success probability and decreases performance time. "High"

stress (i.e., stress above the stress thresholds of the members of the simulated work group) decreases the success probability.

3. When the workplace temperature exceeds 80 degrees Fahrenheit, performance will degrade as a function of the level of heightened temperature.
4. When maintainers know that the radiation level to which they will be exposed during task performance is such that their total absorbed dose will be greater than their quarterly allowance, they will tend to increase their work pace (to decrease their exposure).
5. Poor component accessibility, inferior procedural aids, and protective clothing tend to make maintainer performance slower and less accurate.
6. Fatigue and non-recent performance of a task negatively affect performance time and work quality.
7. The supervisor's requirements relative to work quality will determine whether or not a work group's performance of a subtask is "acceptable" or "unacceptable."
8. Work groups with high levels of aspiration working for supervisors with high levels of aspiration will perform more quickly and thoroughly.
9. A favorable organizational climate reinforces productivity.
10. If communication is required during the course of the performance of a subtask, subtask performance will degrade as a function of conditions which fail to support communication.

The implementation, ultimate widespread use, and overall value of a model such as MAPPS is dependent upon a number of critical issues. In order to ensure that MAPPS meets the goals for which it was designed and in order to gain a broader perspective of its potential applications, a comprehensive effort focused upon model evaluation was undertaken. These efforts addressed critical issues within four general areas: practicality, acceptability, usefulness, and validity. Practicality refers to such issues as the feasibility of implementing MAPPS on a computer installation other than that on which it was developed (i.e., transportability), the cost of implementing the model, ease of developing input data, and training requirements for potential users. Acceptability is reflected in the users attitudes toward MAPPS and the information it produces, i.e., the sum of positive and negative responses to MAPPS and its characteristics. Usefulness refers to the compatibility of the model's diverse outputs and capabilities with the needs of its various potential user categories (i.e., NRC personnel, NPP maintenance management, architect/engineers), along with its convenience and economy as an analytic tool. Validity refers to the extent to which: (1) the simulation is internally consistent (internal validity), and (2) predicts NPP maintainer performance (empirical validity).

A number of different methods including case studies, consensus estimation, and actual observation of nuclear power plant maintenance activities were used to generate data used for model evaluation. Results of the evaluation efforts were favorable for all issues examined.

This paper will describe further the contents and structure of the MAPPS model and will provide details concerning the assessment of model practicality, acceptability, usefulness, and validity.

Figure 1. MAPPS functional processing.

Figure 2. Overview of logic flow within MAPPS model.