# Description of HAMMLAB

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The HAlden Man-Machine LABoratory (HAMMLAB) is a research facility for experimental simulator studies of human-machine interaction in nuclear process control. The research activities in the laboratory include, (a) validation of control room layouts, (b) usability testing of human-machine interfaces, (c) testing and evaluation of operator support systems, (d) experimental validation of control room design principles, and (e) theory-driven simulator experiments. HAMMLAB is flexible and modifiable, meaning that it is relatively easy to alter the physical configuration of the control room and implement new operator support systems or human-system interface designs.

HAMMLAB creates a realistic operating environments with a high degree of physical and functional fidelity. Multiple nuclear plants can be simulated full scope in the laboratory, including: (i) the NORS, or NOkia Research Simulator of the Loviisa power plant near Helsinki, Finland, representing a Russian water-cooled and moderated VVER type of nuclear plant, (ii) the FRESH simulator (Fessenheim REsearch Simulator for HAMMLAB) of the Fessenheim-1 Pressurized Water Reactor (PWR) plant in Alsace, France, and (iii) the HAMBO, or HAMmlab BOiling water reactor simulator of the Forsmark-3 nuclear plant located near Uppsala, Sweden.

The simulated plant models run on a software integration platform in the HAMMLAB environment. A separate computerized human-system interface is developed for each plant model, but conventional analog displays may be emulated for experimental purposes. The human-system interface typically includes, (a) process information and control formats used by the operators to monitor and intervene with the system, (b) a spatially dedicated alarm system with intelligent processing and audible alarms, (c) trend diagrams that display the dynamic development of plant parameters, (d) a large screen process overview display, and (e) special displays for operator support systems, computerized procedures, feedback from automation etc.

There are normally three operator workstations in the HAMMLAB control room. The left station in the front of the control room is typically intended for the *Reactor Operator (RO)*, who is responsible for the nuclear energy generation of the plant. The station to the right of the RO is for the *Turbine Operator (TO)*, who manages the plant’s electricity production. The workstation at the back of the control room belongs to the *Shift Supervisor (SS)*, who has the final authority and coordinates the crew. The control room can also be set up to accommodate other crew constellations and operator roles.

During a HAMMLAB experiment, several crews of professional operators are tested in multiple test *scenarios* simulating mild transients, disturbances, and/or severe nuclear accidents. The task conditions are dynamic in the sense that the operators’ own taskwork may drive the scenario development.

HAMMLAB experiments are constituted by multiple experimental runs repeated for several operating crews. All crews will normally execute the same test scenarios and experimental conditions. The typical number of runs in an experiment is between 30 and 100. A scenario can be split into periods by interrupting the simulation, e.g. to collect Situation Awareness (SA) data. The efficient scenario time, excluding simulation breaks, typically varies from 30 to 90 minutes depending on the nature of the simulated events and the objective of the study.

Extensive amounts of raw data are collected in HAMMLAB experiments, including:

* *Simulator logs* containing all essential process parameters on a high resolution time scale, and all events that occured in the human-system interface (operator actions, alarms, discrete process events, automation activities, system malfunctions etc.).
* *Audio-video recording* through wearable microphones attached to each participant, overview cameras, close-up cameras, and operator head-mounted scene cameras.
* *Process expert comments* analysing the ongoing taskwork.
* *Real-time performance assessment* where process experts judge the operators’ taskwork during and/or after each experimental runs, using specialized assessment instruments.
* *Rating scales and questionnaires* administered electronically to the operators.
* *Eye Movement Tracking (EMT)* when applicable and practically feasible.

Experiment debriefings can be auto-confrontations where operators experience and comment on video replays of their own performance, or through semi-structured interviews.

Prior to the experiments, operators participate in training sessions focusing on (i) the familiarization to novel features in the human-system interface, (ii) technical discrepancies between the operators’ home plant and the simulated process model (if any), (iii) data collection methodologies and laboratory procedures, and (iv) the experimental conditions that the participants are working under in the experiment.

The experimental staff engaged in the data collection is located in an observation gallery during the data collection. The gallery is separated from the HAMMLAB control room by a semi-transparent glass wall. The staff usually includes the following members:

* The *experimental leader*, who is responsible for the data collection, has detailed knowledge about the experimental design, the experimental staff, and serves as the main point of contact between the participants and the staff.
* *Process experts/SMEs* (i.e. specialists on the operation of the simulated nuclear plant), who explain the scenario execution to the other experimental staff (when needed), conduct human performance assessment in real time, implement system malfunctions manually if required, perform scenario briefing and debriefing, and act as plant personnel, such as role-playing an electrician or field operator over telephone.
* *System control specialists*, who are technically responsible for running the simulated process model and human-system interface.
* A *laboratory technician* managing the audio-video recording, electronic questionnaires, data backups and other practical tasks.
* EMT-technicians to calibrate and monitor the eye-tracking equipment (if EMT is applied).

All staff members have access to a web-browser, since the information management during experiments is organized on a dedicated experiment web containing the laboratory set-up, scenario descriptions, experimental run plans, staff procedures, messages etc.