Institute for Energy Technology

Human Factors in Control (HFC)

Halden
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Operator Performance in Highly Automated Nuclear Plants

Gyrd Skraaning Jr.

«The machine… is a mechanism that, after being set in motion, performs with its tools the same operations that were formerly done by the workman with similar tools»

Marx, K. (1867). Das Kapital I, Ch. 15, Section 1

Automation

«The execution by a machine agent (usually a computer) of a function that was previously carried out by a human»

Parasuraman, R. (1997). Humans and Automation: Use, Misuse, Disuse, Abuse. *Human Factors*, **39**(2), 230-253

‘Automation’ first coined by Ford Motor Co. Vice President Delmer S. Harder in 1948

Origin of "AI"

A Proposal for the

DARTMOUTH SUMMER RESEARCH PROJECT ON ARTIFICIAL INTELLIGENCE

We propose that a 2 month, 10 man study of artificial intelligence be carried out during the summer of 1956 at Dartmouth College in Hanover, New Hampshire. The study is to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it. An attempt will be made to find how to make machines use language, form abstractions and concepts, solve kinds of problems now reserved for humans, and improve themselves. We

McCarthy et al. 1955

http://jmc.stanford.edu/articles/dartmouth/dartmouth.pdf

August 1956. From left to right: Oliver Selfridge, Nathaniel Rochester, Ray Solomonoff, Marvin Minsky, Trenchard More, John McCarthy, Claude Shannon.

Artificial Intelligence

«… technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy»

IBM, 2024
https://www.ibm.com/topics/artificial-intelligence

Boeing 737 MAX accidents

- Automation worked flawlessly and according to the design intentions
- Automation failed by becoming uncontrollable when fed with unreliable input
- Subsequent breakdown of the human-automation interaction
- Introducing multiple layers of advanced automation may increase the risk of systemic automation failures

Skraaning, G., & Jamieson, G. A. (2023). The Failure to Grasp Automation Failure. *Journal of Cognitive Engineering and Decision Making.*

Jamieson G. A., Skraaning G. & Joe J. (2022). The B737 MAX 8 Accidents as Operational Experiences With Automation Transparency. *IEEE Transactions on Human-Machine Systems.*

AUTOMATION-INDUCED HUMAN PERFORMANCE CHALLENGES

Elementary Automation Failures

Automatic functions are missing or lost

Failures in the automation control logic produce missing, degraded, inaccurate, or spurious output from the automatic system itself

Automation programming errors produce missing, degraded, inaccurate, or spurious output from the automatic system itself

Malfunctioning automation hardware produces missing, degraded, inaccurate, or spurious output from the automatic system itself

Loss of power supply to automation

Combinations of the elementary automation failures listed above

Systemic Automation Failures

Sensors and/or other equipment that feed information to automation are misconfigured/ faulty/unavailable and thereby trigger erratic automation behavior

Automation works as intended but operates outside its design basis without an understanding of its limitations

Automatic systems that operate in parallel compromise each other

Active automatic systems camouflage failures at the component level of the system

Failures at the component level of the system are undetected by automation, which continues pursuing generic operating goals

The automation control logic has hidden vulnerabilities that instigate propagating system breakdowns under special circumstances

Combinations of the systemic automation failures listed above

Human-Automation Interaction Breakdowns

Overly complex automation design makes it difficult to operate the system despite extensive training and adequate mental models

Automatic systems enter unexpected or hidden modes of operation that affect system behavior and/or redefine the safety envelope

Automation provides misleading support to operators

The operational concept invites misuse of automation, e.g., by portraying automation as more capable than it is

The operational concept invites disuse of automation, e.g., by implementing unreliable automation that operators cannot depend on

Automation design is based on unrealistic operational assumptions, e.g., that predefined system failure modes are always recognizable and meaningful

The responsibilities, capabilities, goals, inner workings, activities, and/or effects of automation are unsuitably hidden from operators

There is a dysfunctional distribution of taskwork, initiative, and/or authority between humans and automation

Critical operator actions are unsuitably blocked by automation

Human and Organizational Slips/Misconceptions

Faulty operator programming or setup of automation, e.g., due to poor usability

Operators presume incorrect mental models of automation, e.g., by misunderstanding the automation logic, or misinterpreting the goals, capabilities and/or effects of automation

Operators are unfamiliar with the automation due to inadequate training

Operators handle automation ineffectively due to, e.g., excessive workload or fatigue

Mismatch between organizational policies for automation use and the operating context

Crew communication, coordination, and task allocation issues make working in an automated system difficult

Inadvertent activation/deactivation of automation

Skraaning Jr, G., & Jamieson, G. A. (2023). The Failure to Grasp Automation Failure. *Journal of Cognitive Engineering and Decision Making*, 15553434231189375

a

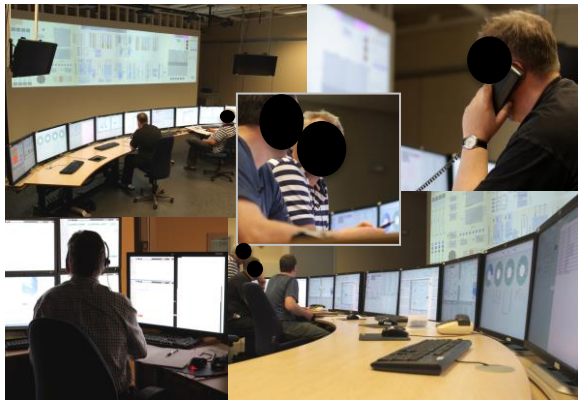
b

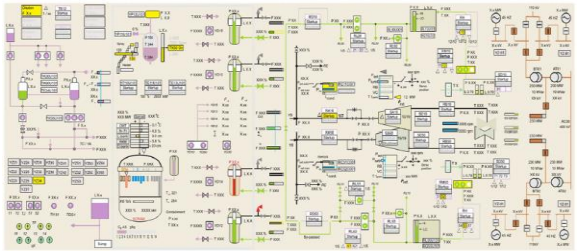
Automation in nuclear process control

- Nuclear power plants will become more highly automated in the future
  - Multiple layers of advanced automation
  - New forms of automation/autonomy
- Operator roles will change while the interaction with future automation may become a safety concern
- The Halden Project has proactively followed this development through knowledge-building and simulator experiments in the HTO laboratories

1997 2010 2017 2020 2026

HAMMLAB experiments



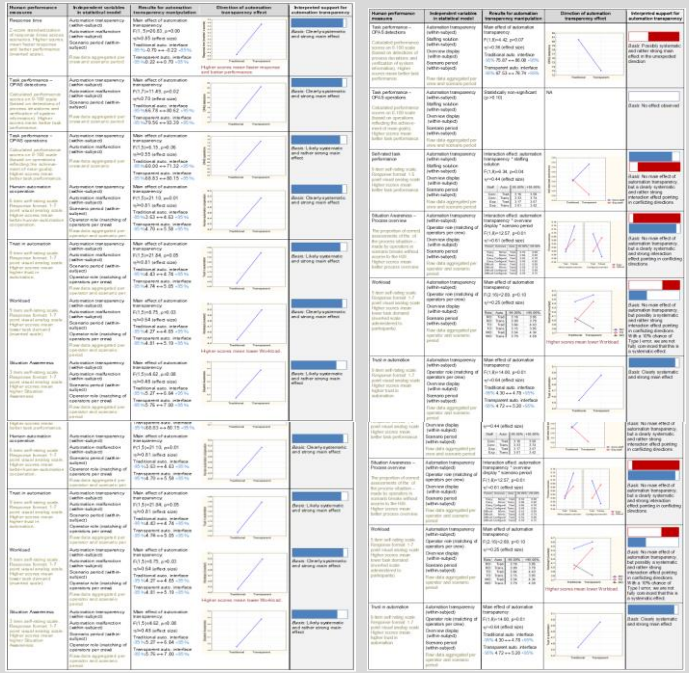


- Full-scope simulator studies based on classical experimental methods
- Focus on Automation Transparency and Levels of Automation

Exploration in FutureLab

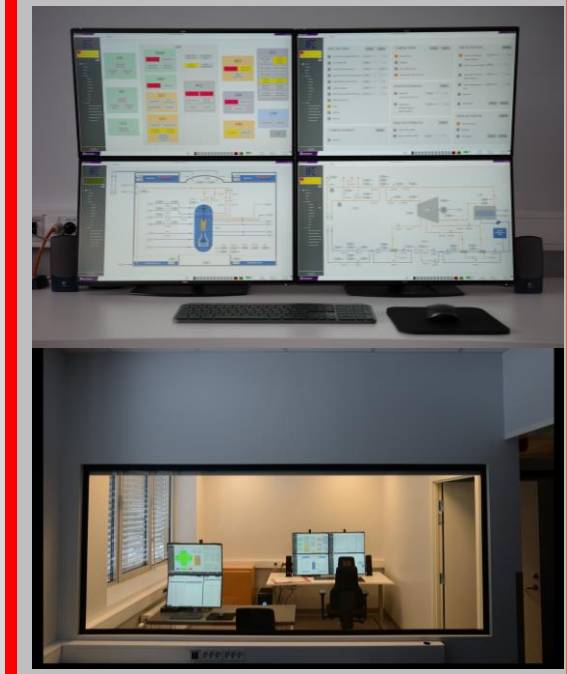
- Design-oriented prototyping and feasibility studies
- Anticipating operational concepts for highly automated future plants

Reanalysis & knowledge-building



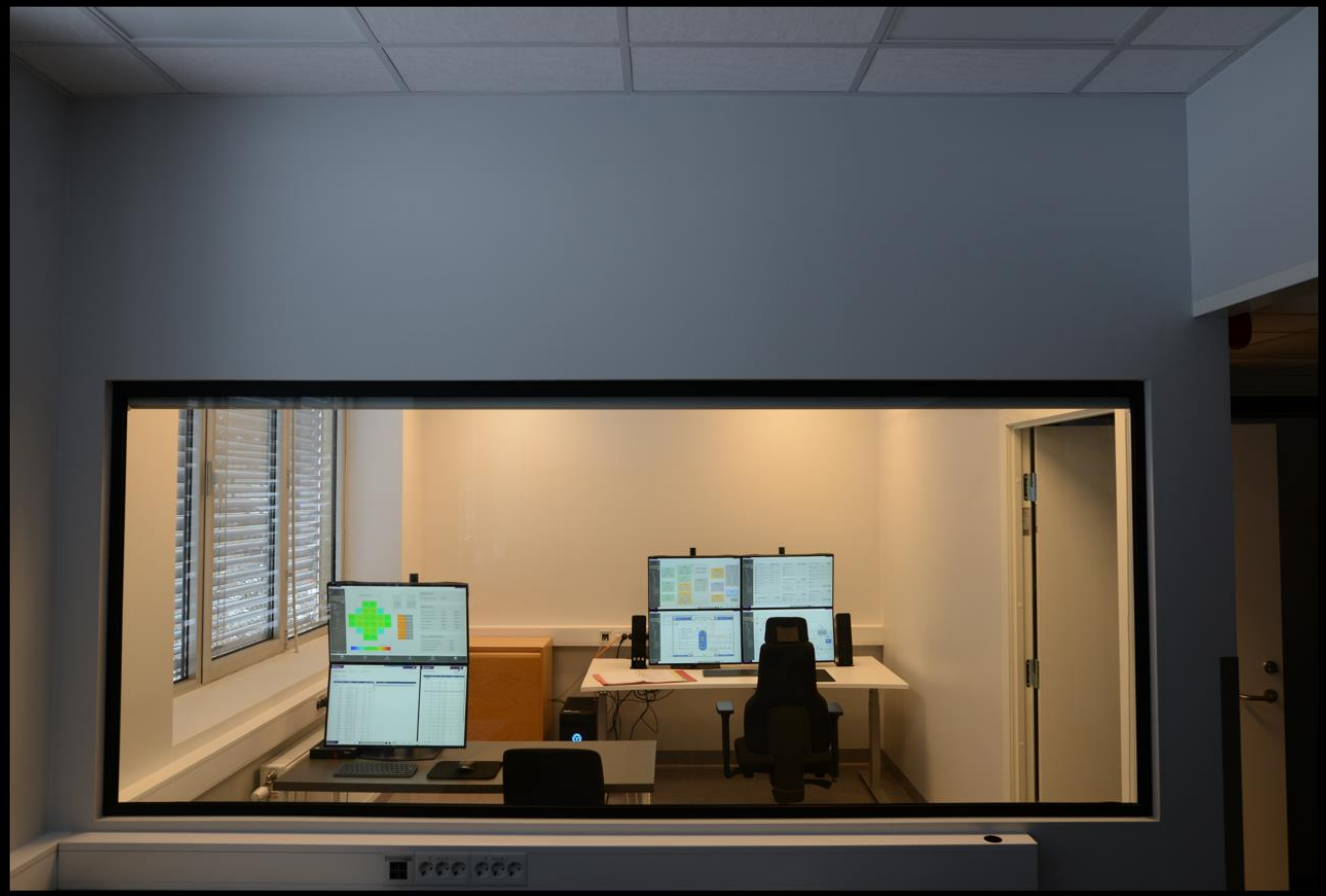
- Statistical reanalysis of HAMMLAB experiments (1997-2010)
- Literature review and knowledge transfer from safety critical industries

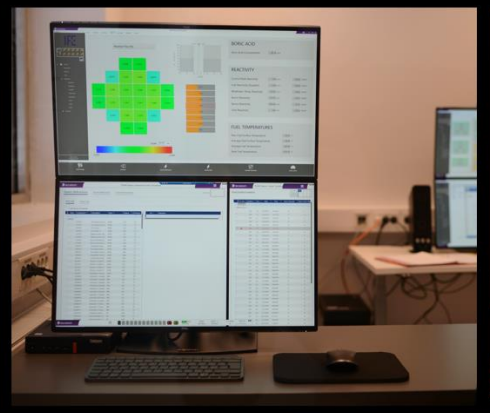
HAMMSAT experiments

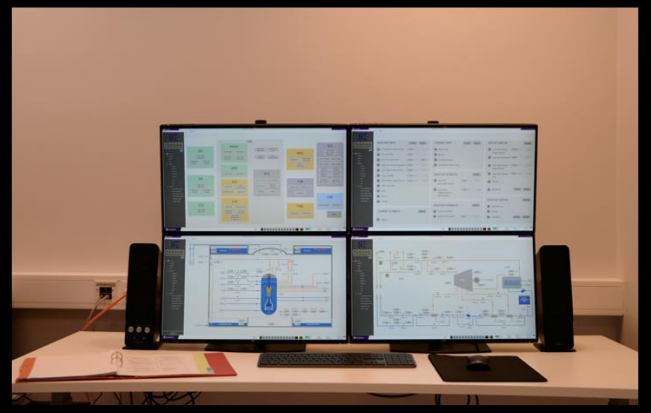


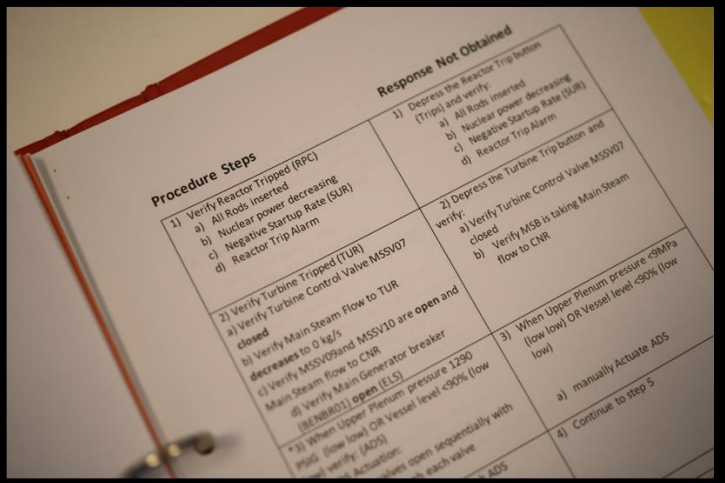
- SMR simulator experiments about Automation Failure
- Small-scale studies with single operators as participants

HAMMSAT









Human-System Interface by Tecnatom

HAMMSAT Laboratory

- HAMMLAB satellite laboratory (HAMM**SAT**)
- Compact test environment dedicated to human-automation interaction studies
- Single-unit version of the Halden SMR simulator
- Operators are tested individually with a scenario-based method to investigate automation failures
- Utilizing the original HSI that came with the simulator
- Relying on built-in automated features

Experimental purpose

- Study how systemic automation failures affect human performance and operational safety
- Identify and test interventions that may support operators in the handling of systemic automation failures

Example of systemic automation failure scenario in nuclear process control

- Automation pursues its own goals without knowledge of process failures that affect the functioning of the plant
- Process failures are hidden by automation
- Automatic systems work against each other
- Automation is unaware of its limitations

Q&A

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