The NRC's Human Factors Research for Advanced Control Room Technologies

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NRC Mission

To regulate the nation's civilian use of byproduct, source, and special nuclear materials to ensure adequate protection of public health and safety, to promote the common defense and security, and to protect the environment.

– Protect people and environment

NRC's regulatory requirement for human factors (HF)

10 CFR 50.34(f)(2)(iii):

A control room design reflects state-of-art human factors principles.

One way for the NRC to achieve the regulation is to perform HF review at different points in the application and licensing process:

- Design process document
- Prototype design
- Design Certification
- Inspection and testing

NRC's HF review guidance

The Staff Review Plan (NUREG-0800) describes the staff's review activities to verify that accepted HF engineering principles are incorporated during an NPP design process.

Human Factors Engineering Review Model (NUREG 0711) provide guidance for detailed review.

NRC also has other HF review guidance for specific topics such as

- Human-system-interface (HSI) design (NUREG-0700),
- Staffing Exemption,
- System verification and validation (V & V), and
- HF Interim Staff Guidance (ISG).

The NRC's HF activities for new control room design

Design process

Prototype design

Completed design

Inspection and testing

Design Certification

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NUREG 0711

NUREG 0700

Staffing

V &V

ISGs

⇨

Safety

Questions in the review process

- How are the general guidance applicable to specific control room technologies?
- Does a design meet the intent of a guideline?
- Have all the safety aspects in a new technology been adequately considered?
- What if a design is exempted or deviated from certain guidelines?

Research needs

1. Enhance review guidance with scientific basis for new technologies

2. Develop concrete criteria to assess safety impacts of new technologies

3. Conduct experiments to test safety aspects of new technologies with respect to human performance

4. Perform simulation and analysis to establish links between guidelines/criteria and plant safety

HF research program for advanced control room technologies

1. Enhance review guidance with scientific basis for new technologies

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Enhance existing review guidance

NUREG 0711

NUREG 0700

Staffing

V &V

ISGs

- Updating NUREG 0711 & 0700
- Develop easy-to-use methods and tools for staffing evaluation
- Develop guidelines and acceptance criteria for integrated system verification and validation (V & V) in control rooms

Expand review guidance for new technologies, design features, and concepts of operation (CONOPS)

NUREG 0711

NUREG 0700

Staffing

V &V

ISGs

Computerized procedures

Roles of automation and personnel

HSI complexity & opacity

CONOPS of modular design

Knowledge base

characterization

Guidelines

Develop concrete criteria to assess safety impacts

NUREG 0711

NUREG 0700

Staffing

V &V

ISGs

Computerized procedures

Roles of automation and personnel

HSI complexity & opacity

CONOPS of modular design

Knowledge base

characterization

Guidelines

Assessment criteria

Conduct testing and develop links to human performance measurements

NUREG 0711

NUREG 0700

Staffing

V &V

ISGs

Computerized procedures

Roles of automation and personnel

HSI complexity & opacity

CONOPS of modular design

Knowledge base

Safety aspects / characterization

Guidelines

Assessment criteria

Testing/ Benchmarking

Error of omission / commission

Reaction time

Workload

Situational awareness

Teamwork

Vigilance / engagement

Develop links to plant safety

Knowledge base

Safety aspects / characterization

Guidelines

Assessment criteria

Testing/ Benchmarking

⇨

Error of omission / commission

Reaction time

Workload

Situational awareness

Teamwork

Vigilance / engagement

⇨

Indications of task performance

Error-prone scenarios

⇨

Safety

Example project: Computerized Procedures

Operational issues:

- New plants will use computerized procedures (CPs) and operating plants may upgrade control rooms with CPs.
- NRC's previous guideline (NUREG -0700) was developed ~10 years ago; NRC currently uses Interim Staff Guideline for design review.

NRC's needs for research in CPs:

- Up-to-date guidelines for conducting design review;
- Methods and tools for inspecting, testing, and analyzing HF aspects of CPs
- Acceptance criteria for CPs
- Human reliability analysis (HRA) for failure events associated with CPs.

Safety aspects in CPs

- Operator in control

  Inappropriate design may cause intrusions in the operator execution rights.

- Automation of procedure functions

  Automation may put operators out of the procedure loop.

- Transitioning to paper-based or computer-based backup

  The potential for human errors in navigation, place-keeping, and decision-making can be increased due to the transition.

- CPs failure modes

  Potential failure modes need to be identified; In particular, recovery from CPs failure in complex situations may approach to or even exceed the limits of operator capabilities.

- Specific human-system-interface (HSI) features

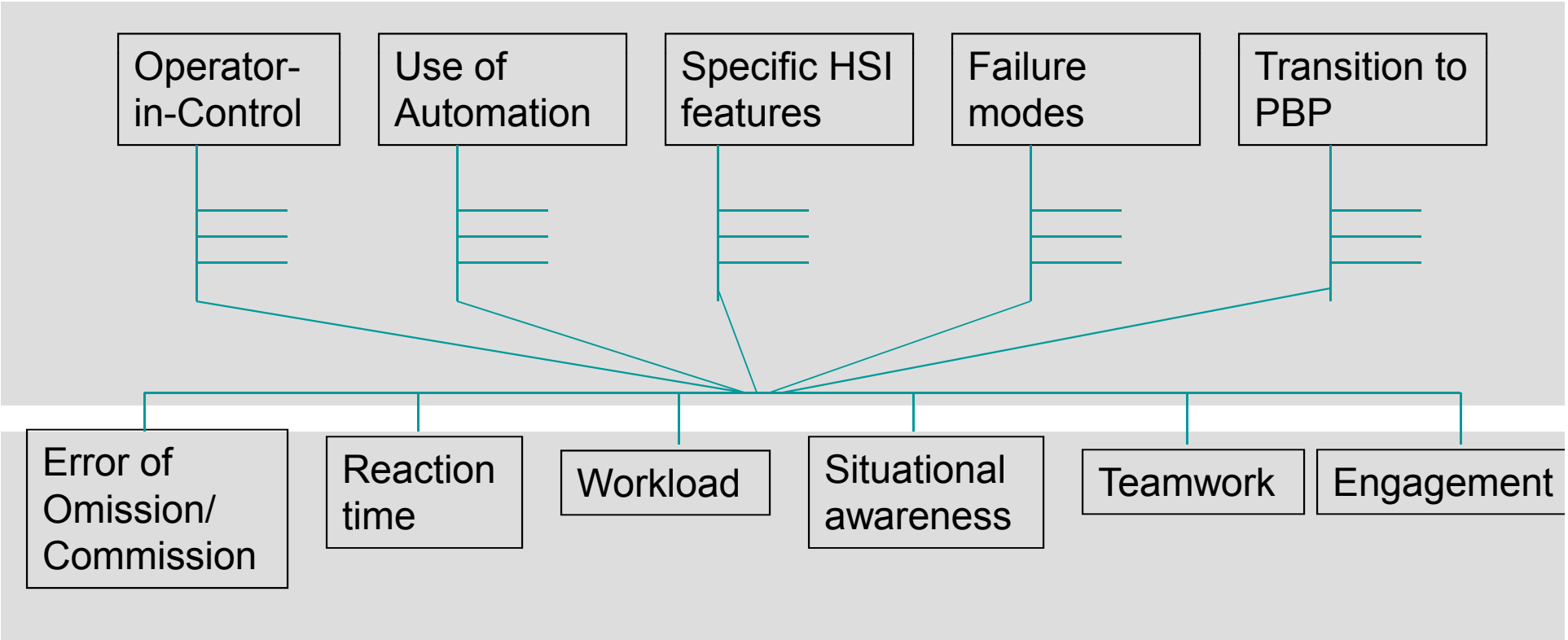
  Keyhole, navigation, complexity, and system integration.

Technical approaches

1) Develop up-to-date review guidelines

2) Develop assessment criteria and human-performance related rationale to address the five high-priority HF safety aspects.

3) Conduct human-in-the-loop experiments to test the impact of CP failures on human performance.



Roles of Automation and Personnel

Operational issues

The overall level of automation in new NPPs can be expected to be much higher than in today's plants.

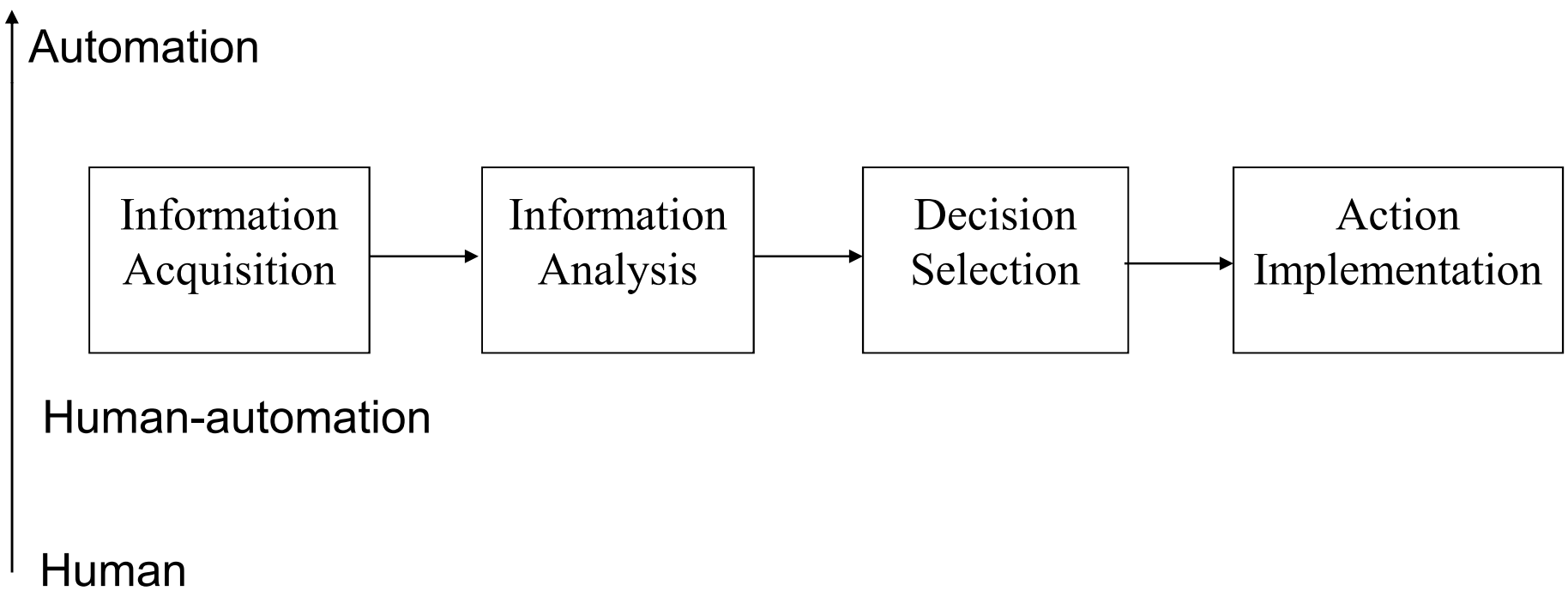
Operators play a variety of roles in the control and management of automated systems.

Research questions

- What are the safety aspects and error-prone situations associated with automation?
- What tasks should or should not be automated?
- Does the allocation of functions between automation and personnel result in safe human performance?

Technical approach

1) Develop assessment criteria to evaluate control room automation technologies;
2) Develop methods to evaluate levels of automation and experimentally test and benchmark the methods
3) provide insights into HRA for control room automation



HSI Complexity and Opacity

Operational issues:

The rapid progress of computer technologies can provide systems with many types of dynamic information to process and result in information being presented in complex ways to operators.

Complexity provided by new technologies may exceed human capacity limitations and cause performance errors.

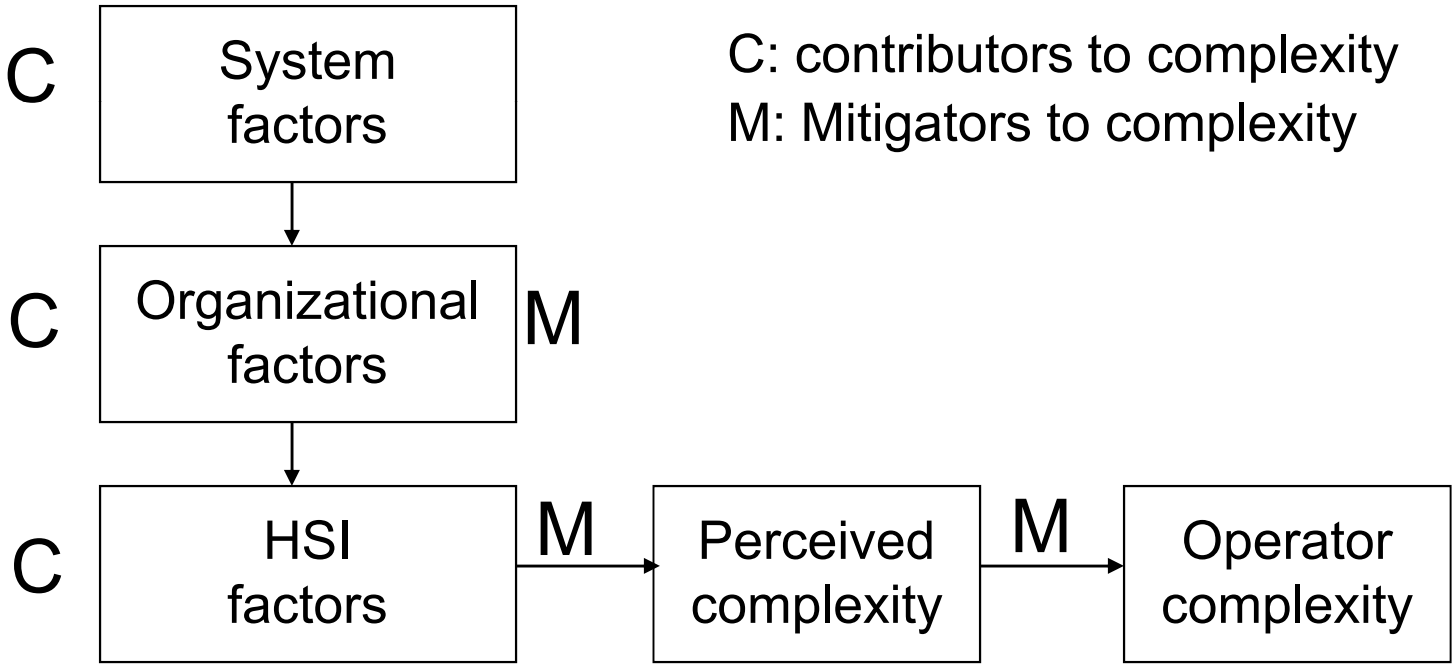
Research questions:

What attributes of control room design contribute to operator's perceived complexity?

- What is the impact of complexity and HSI opacity on operator performance?
- How can the impact be assessed?

Technical approach

1) Develop a technical basis and guidelines for evaluating HSI complexity of plant systems,
2) develop assessment tools to measure complexity, and
3) conduct experiments to elucidate the impacts of complexity on the safety aspects of human performance.



C: contributors to complexity
M: Mitigators to complexity

Human Factors in CONOPS of Modular Design

Operational issues

Example of CONOPS: Operation of multi-modular reactors by a single crew; Changing the operator's role to a supervisor with little hands-on control responsibilities.

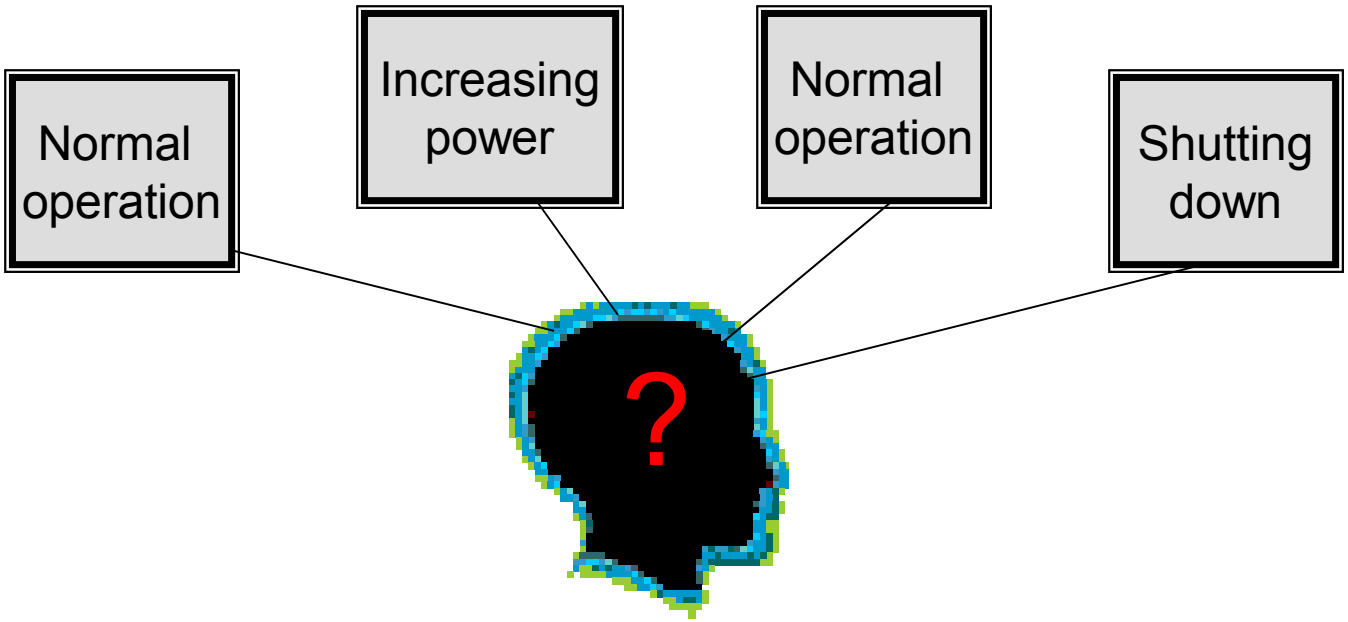
The CONOPS introduce new safety-critical human performance considerations for the NRC staff to determine the acceptability of new design.

Research questions

- Will the workload or allocating attention among multiple modules affect safe operation?
- Will a single crew be able to cope with the work during abnormal conditions that may concurrently impact more than one module is of specific interest?
- How will crew reliability of performance be affected by multitasking?
- Will the training and work procedures sufficiently prevent the "wrong unit/train" errors that have occurred at dual unit NPP sites?

Technical approach

1. Review trends of new design and operational experience of modular operations in nuclear and other industries;
2. Identify safety-focused human performance considerations in modular design;
3. Assess the applicability of NRC's regulatory documents in reviewing modular design.



The world without Human Factors

Thank you!

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