Human Factors in Highly Automated Systems

A CIEHF White Paper

Professor Ron McLeod
ronmcleod10@gmail.com

Ron McLeod

- BSc Psychology - 1980
- MSc Ergonomics - 1981
- PhD Engineering and Applied Science - 1986
- 40 years experience as Human Factors Specialist

- Human Factors Global Discipline Lead - Royal Dutch Shell (to 2014)
- Independent Human Factors Consultant

- Honorary Professor of Engineering Psychology, Heriot-Watt University,
- Visiting Professor of Human Factors, Loughborough University

- IEA Fellow 2022
- CIEHF 2020 Lifetime Achievement Award
- Former CIEHF Trustee
- SPE Distinguished Lecturer
- US National Academy of Sciences Committee Member
- Board Member SPE Human Factors Technical Section


HUMAN FACTORS
IN BARRIER MANAGEMENT
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WHITE PAPER


WHITE PAPER
LEARNING FROM ADVERSE EVENTS
Chartered Institute of Ergonomics & Human Factors
CARDINUS


HUMAN FACTORS
FOR HEALTH & SOCIAL CARE
WHITE PAPER
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THE HUMAN DIMENSION IN TOMORROW'S AVIATION SYSTEM


Chartered Institute of Ergonomics & Human Factors
The role of human factors in delivering cyber security
An overview for cyber security decision-makers
WHITE PAPER
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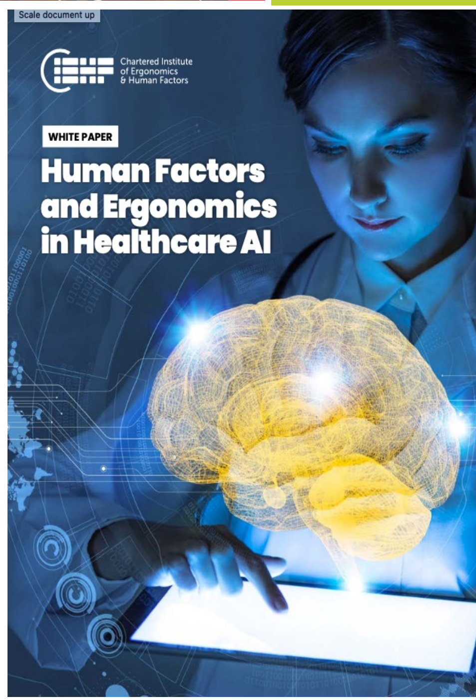
Scale document up
Chartered Institute of Ergonomics & Human Factors
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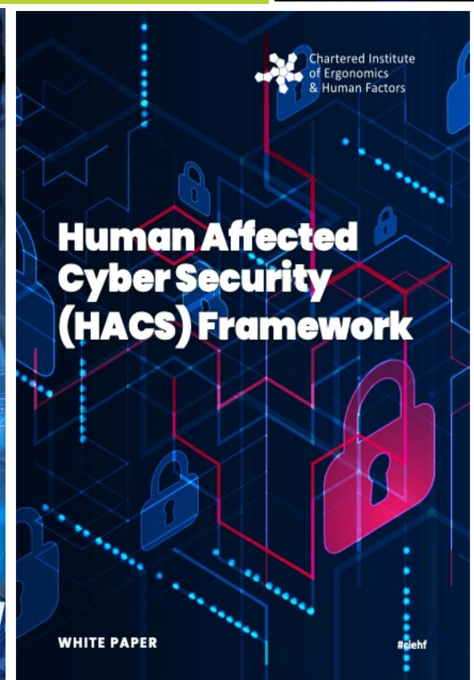
Human Factors and Ergonomics in Healthcare AI


Chartered Institute of Ergonomics & Human Factors
Human Affected Cyber Security (HACS) Framework
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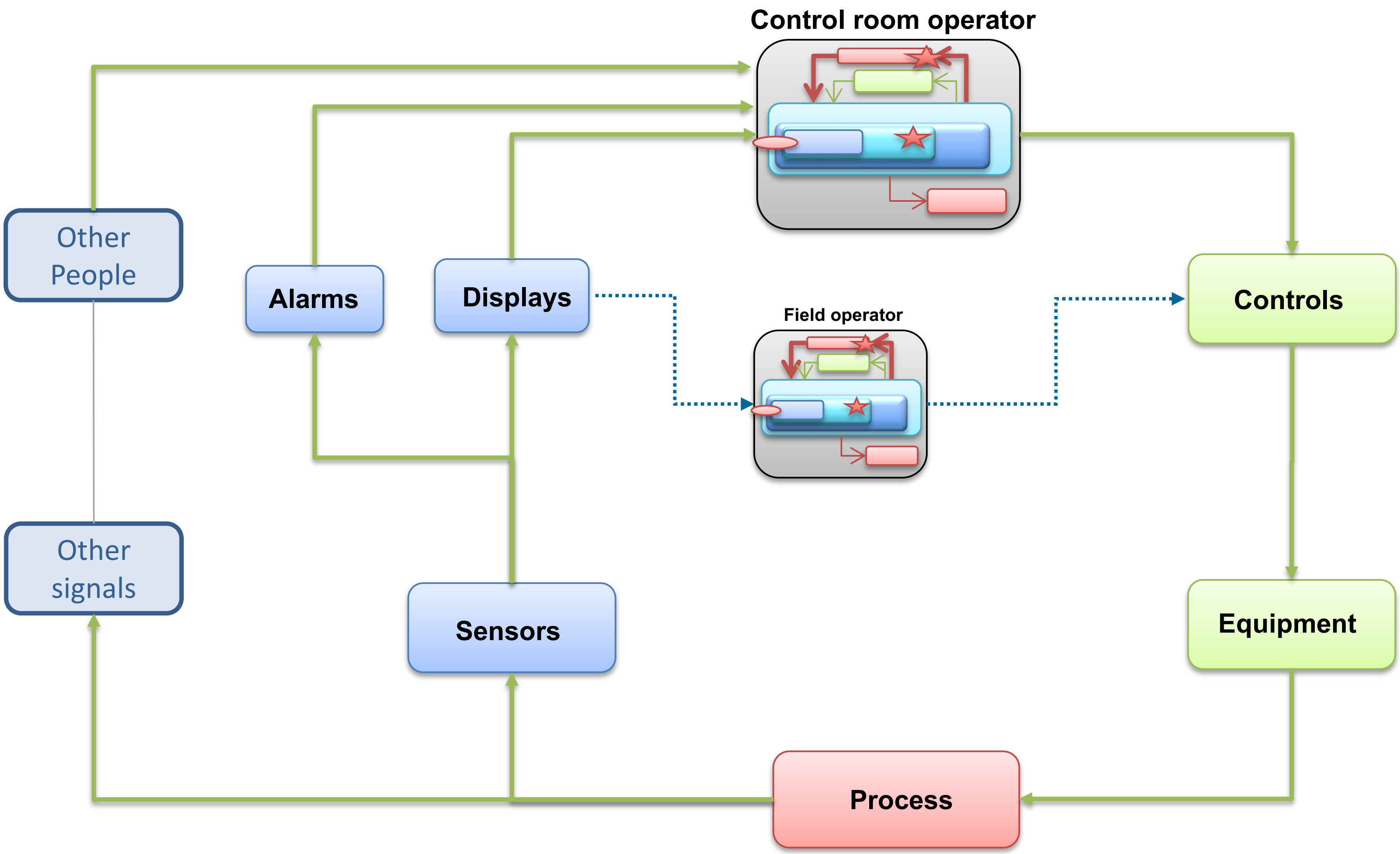
“A **white paper** is a report or guide that informs readers concisely about a complex issue and presents the issuing body’s philosophy on the matter. It is meant to help readers understand an issue, solve a problem, or make a decision”.

Wikipedia

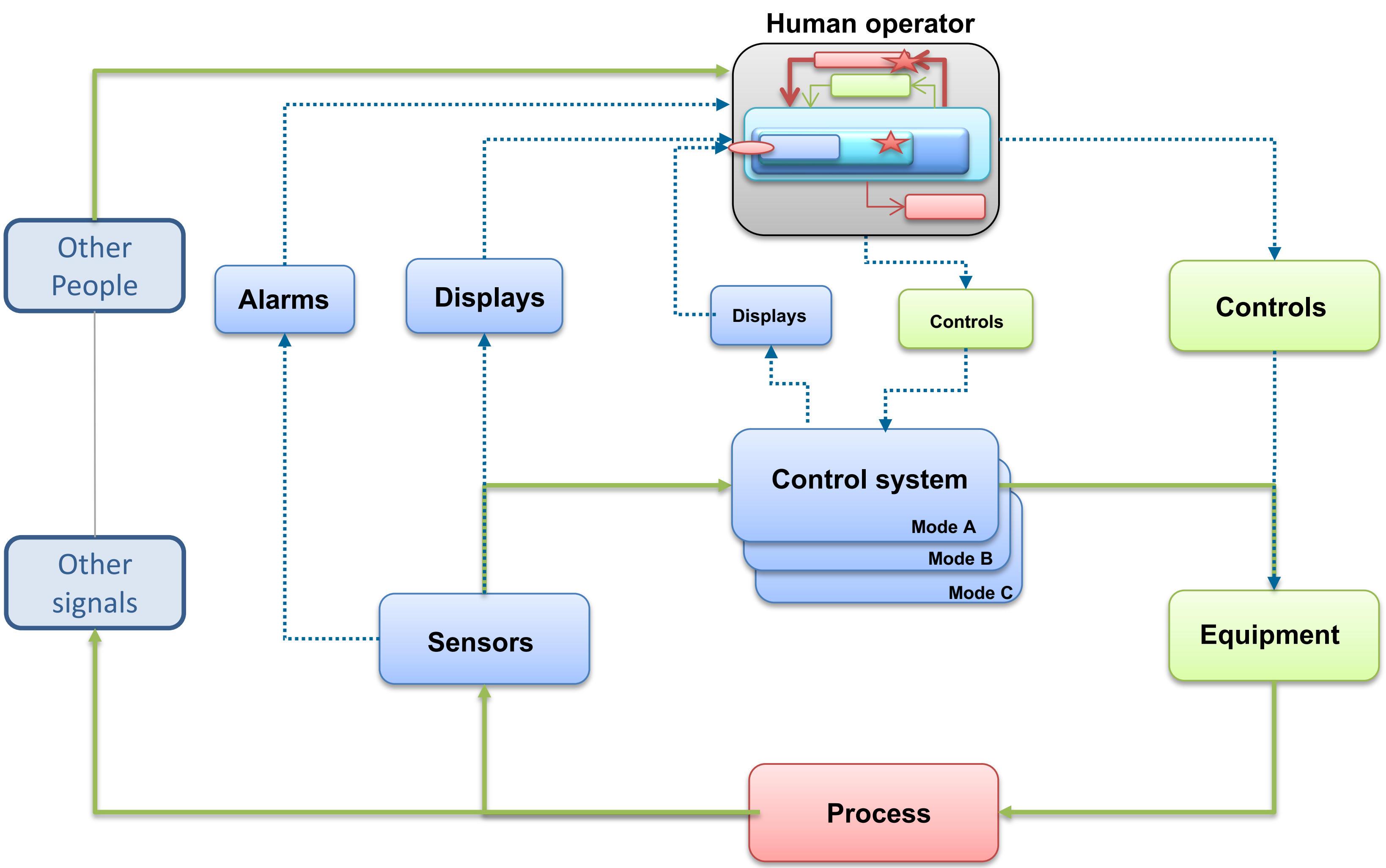
Objectives

1. Some background
2. Introduce key concepts
   - Types and Levels
   - Ability, Authority, Responsibility and Control
3. Introduce the 9 Principles
4. Introduce 2 practical HF Analysis tools
   - HF in Automation Screening Tool
   - HF Automation Analysis

Manual Control



Supervisory Control



1 June 2009

Air France AirBus A330-230, flight AF 447 crashed into the Atlantic whilst en-route from Rio-de Janeiro to Paris.

228 passengers and crew died.

- Loss of air speed indication led to failure of automatic flight systems
- Only led to the crash through the actions taken by the crew.

Published July 2012

Final Report

On the accident on 1st June 2009
to the **Airbus A330-203**
registered **F-GZCP**
operated by **Air France**
flight AF 447 Rio de Janeiro - Paris

BEA
Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile
Ministère de l'Écologie, du Développement durable, des Transports et du Logement

Learnings from AF447

Supervisory control involves significant cognitive complexity

- Maintaining real-time situation awareness of what state the automation is in, what it was doing, why it has failed, and what to do to recover;
- Maintaining the necessary skills to be able to intervene.

Communications and inter-personal skills are critical to safety

- They failed on AF447 despite many years of mandatory CRM training in commercial aviation.

Assumptions about what operators will do in emergency situations can be seriously flawed

- Commercial pilots very rarely experience an approach to stall during their career....
- ...the design of the cockpit, procedures and training assumed pilots would unambiguously recognise a situation of approaching stall, and take the necessary corrective actions.
- Mode Errors.

Death of Elaine Herzberg, March 2018

- Uber self-driving Volvo.

- Design assumed “safety driver” would take control.
- The ”driver” was watching TV on their mobile phone.

- *"We don't want people to be confused or think it was a failure of the technology…”*

- *“..if you build vehicles where drivers are rarely required to respond, then they will rarely respond when required.”*
  Peter Hancock, NTSB

Target Audience and Purpose

Target Audience;

- Primary
  - Non-specialists - little or no professional background in HF/E
  - Influential in decisions about the development and use of technology.
- Secondary
  - HF/E competent people
  - Advise or make the case for investment in HF when developing or introducing automation
  - Support automation projects
  - Identify and assess risks.

Purpose: Awareness raising;

- Depth of knowledge available in scientific and applied literature
- Learnings from adverse events
- Key HF Challenges
- Principles to guide developing and introducing highly automated systems.

Senders (1964)

Cummings (2018)

Bainbridge (1982)

Endsley (2017)

Moray & Inagaki (1999)

LEARNING FROM THE SCIENCE-BASE: PROACTIVE OPERATOR MONITORING

How do people monitor pro-actively? How do they control how they allocate their limited attention when there are many sources of information that need to be checked?

In 1964, John Senders reported what became a classic experiment to help understand how operators in a process control environment allocate their visual attention across different information displays. The work was driven by concern over information overload in nuclear control rooms. There was a need to understand how humans deal with situations where they are expected to pay attention to a number of information sources changing at different rates.

Over time, people build an internal 'mental model' of the statistical properties of the world they are expected to monitor. That mental model is used, sub-consciously, to decide when and how often to look at different information sources.

Flemisch et al (2012)

Parasuraman et al (2000)

Norman (2010)

Endsley (2003)

Digital flight strips

Work environment

Air France AF447

Train doors

Cycle computer

Drilling

Software update

Digitised forms

Apollo

In-car SatNav

Self-driving vehicle

LEARNING FROM EXPERIENCE: DIGITAL FLIGHT STRIPS

"The planned replica of paper flight strips in electronic form...did not fly with our air traffic controllers. Despite slick algorithms for moving the electronic strips and sorting them in time or by level, the controllers just closed them and developed new ways of controlling the traffic."

Tony Licu, Head of Safety Unit at EUROCONTROL, describing experience introducing automated fight strips into air traffic management system in the 1990s. HINDSIGHT 33, Winter 2021-2022

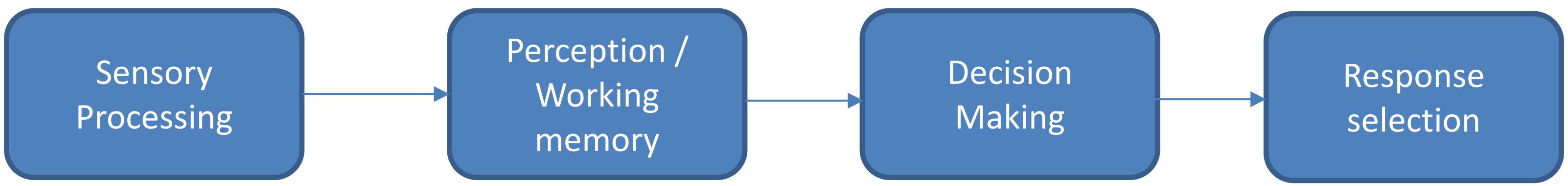
Boeing 737 Max

Golf watch

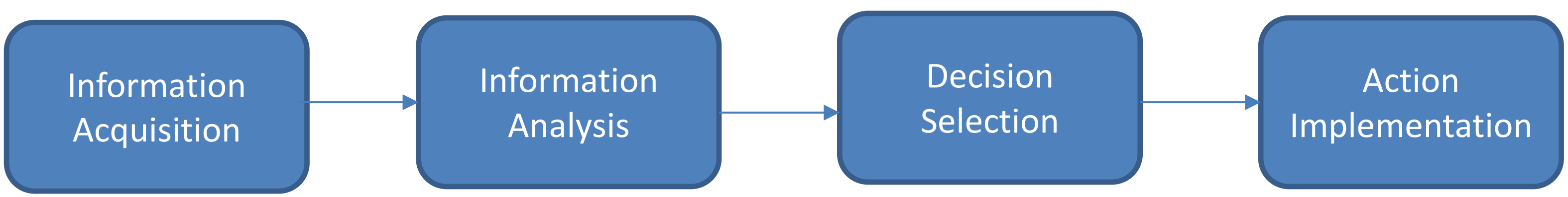

Situation Awareness
Avoiding Surprises
Skill Retention
Key HF Challenges
Trust and Complacency
Balance of Authority and Responsibility
Workload and human reliability

Types and Levels of Automation

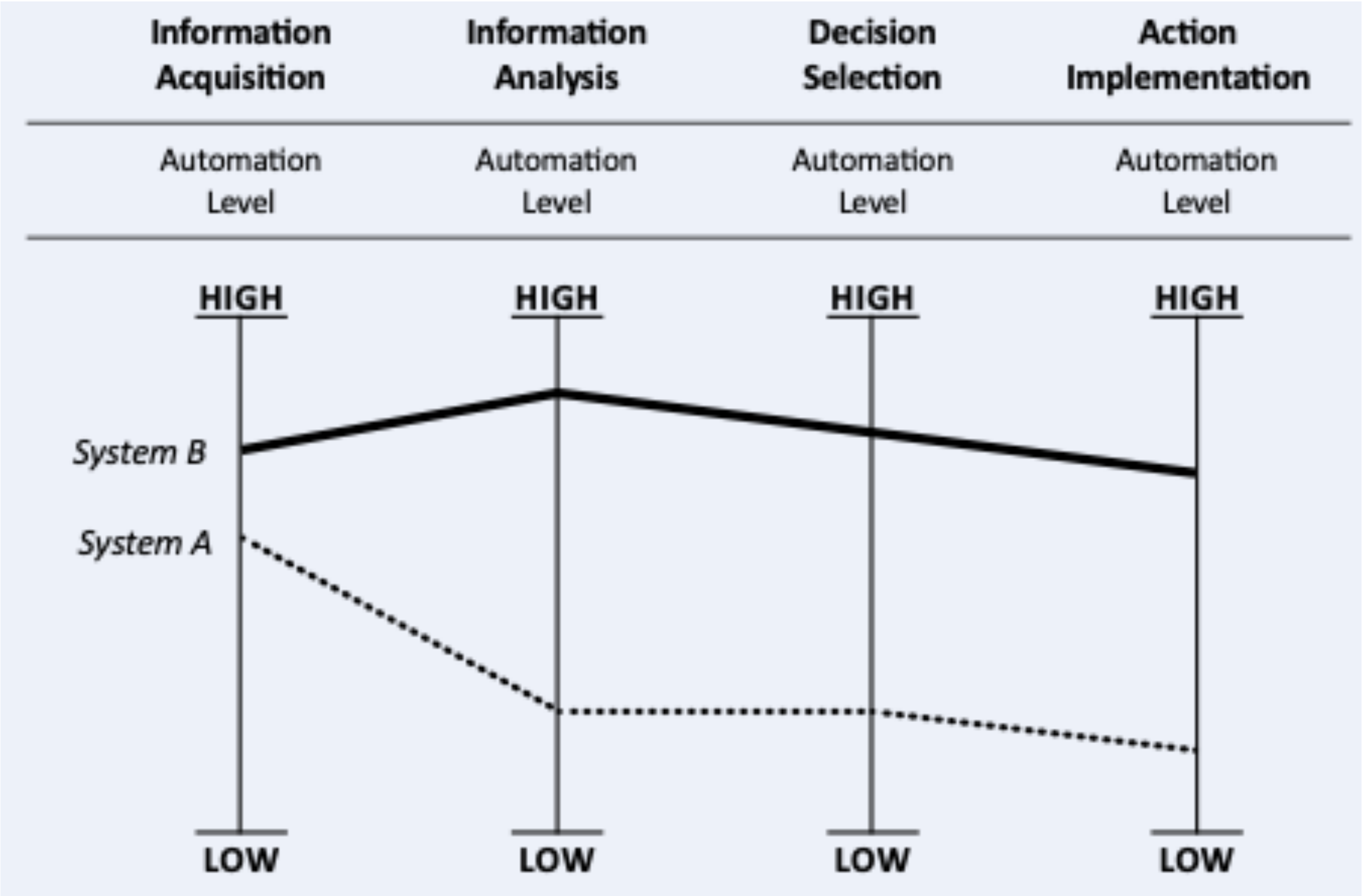
Simple 4-stage human information-processing model



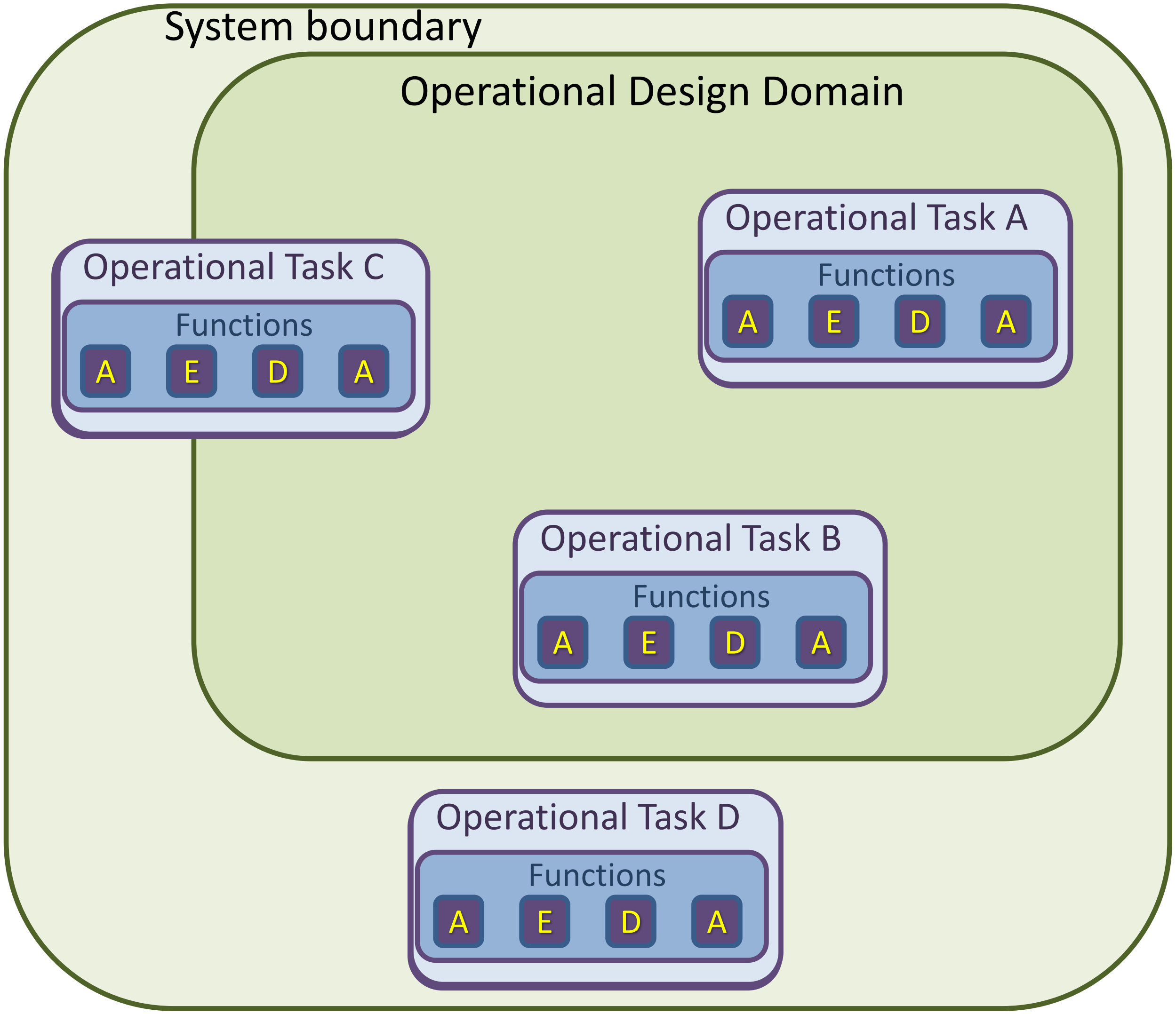
4 classes of function potentially amenable to automation



Parasuraman et al (2000)



Parasuraman, R., Sheridan, T.B., Wickens, C.D. (2000) 'A Model for Types and Levels of Human Interaction with Automation'



A = Acquire Information

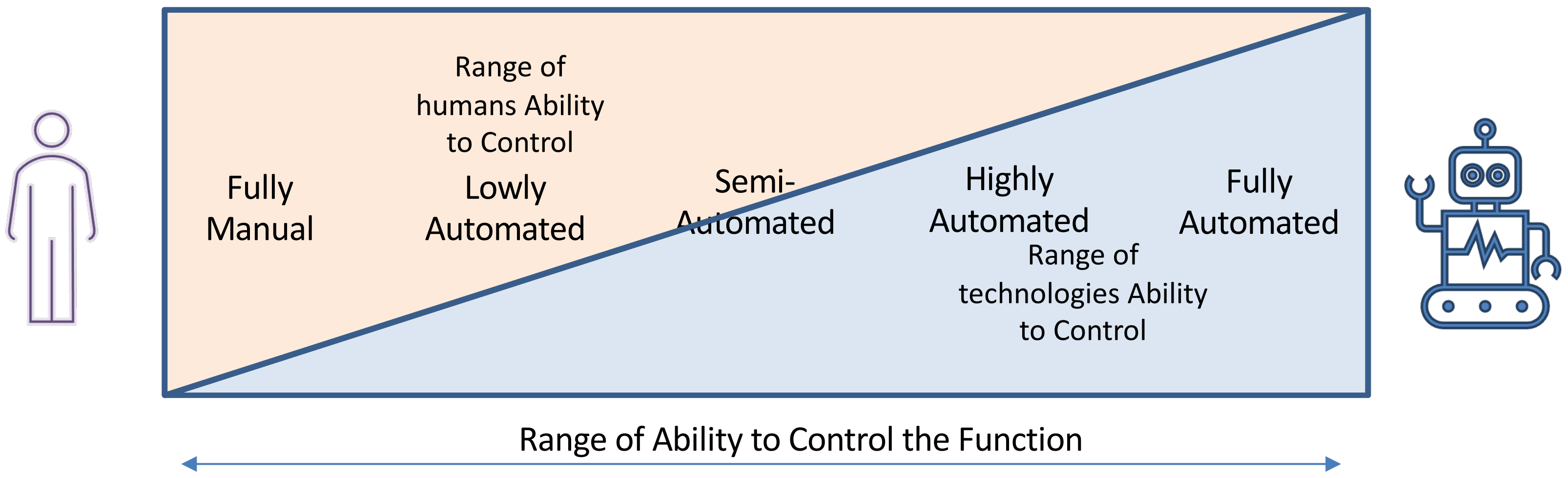
E = Extract Meaning

D = Make Decisions

A = Take Action

A2CR Diagrams

Flemisch et al (2012)



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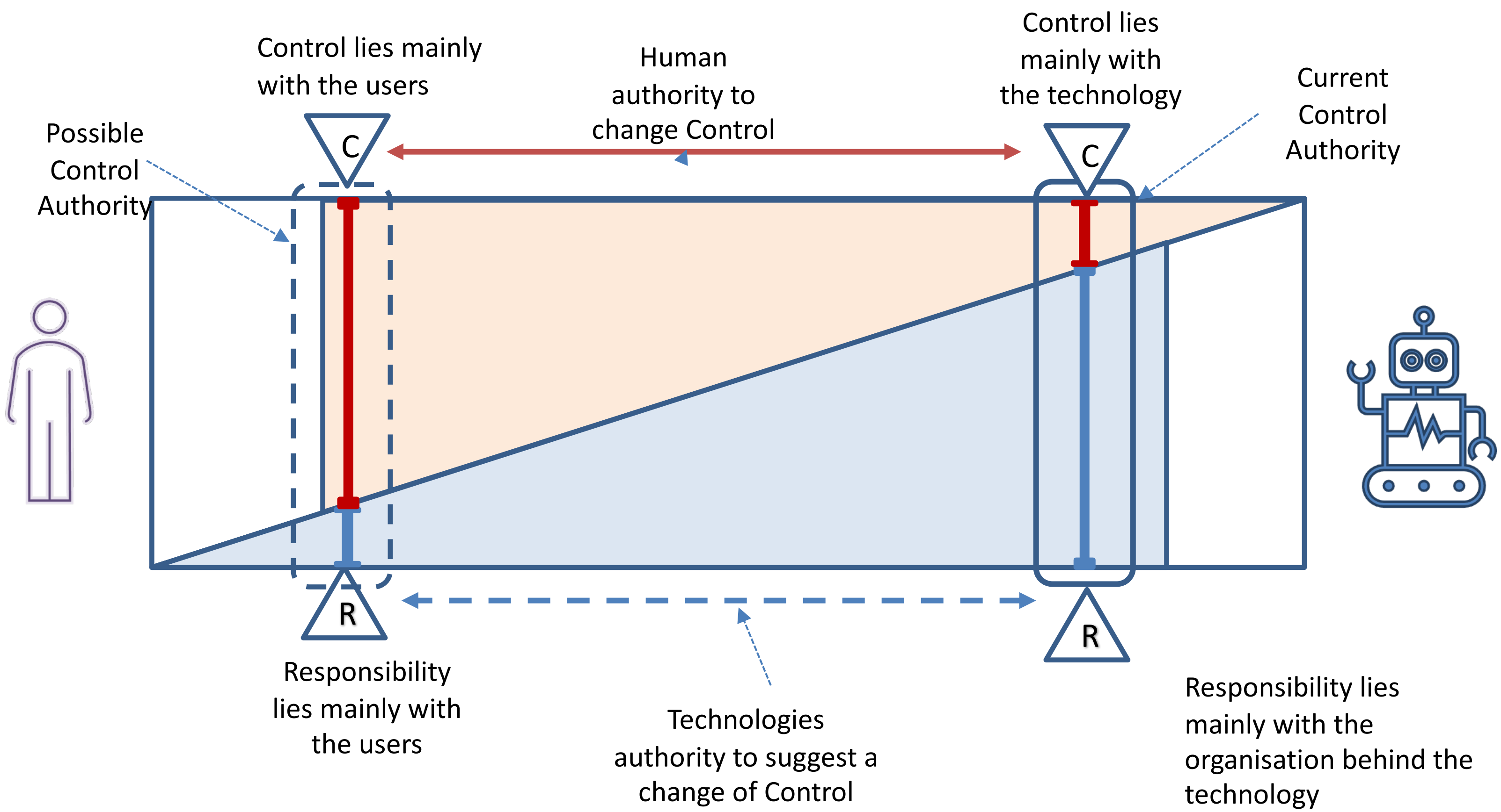
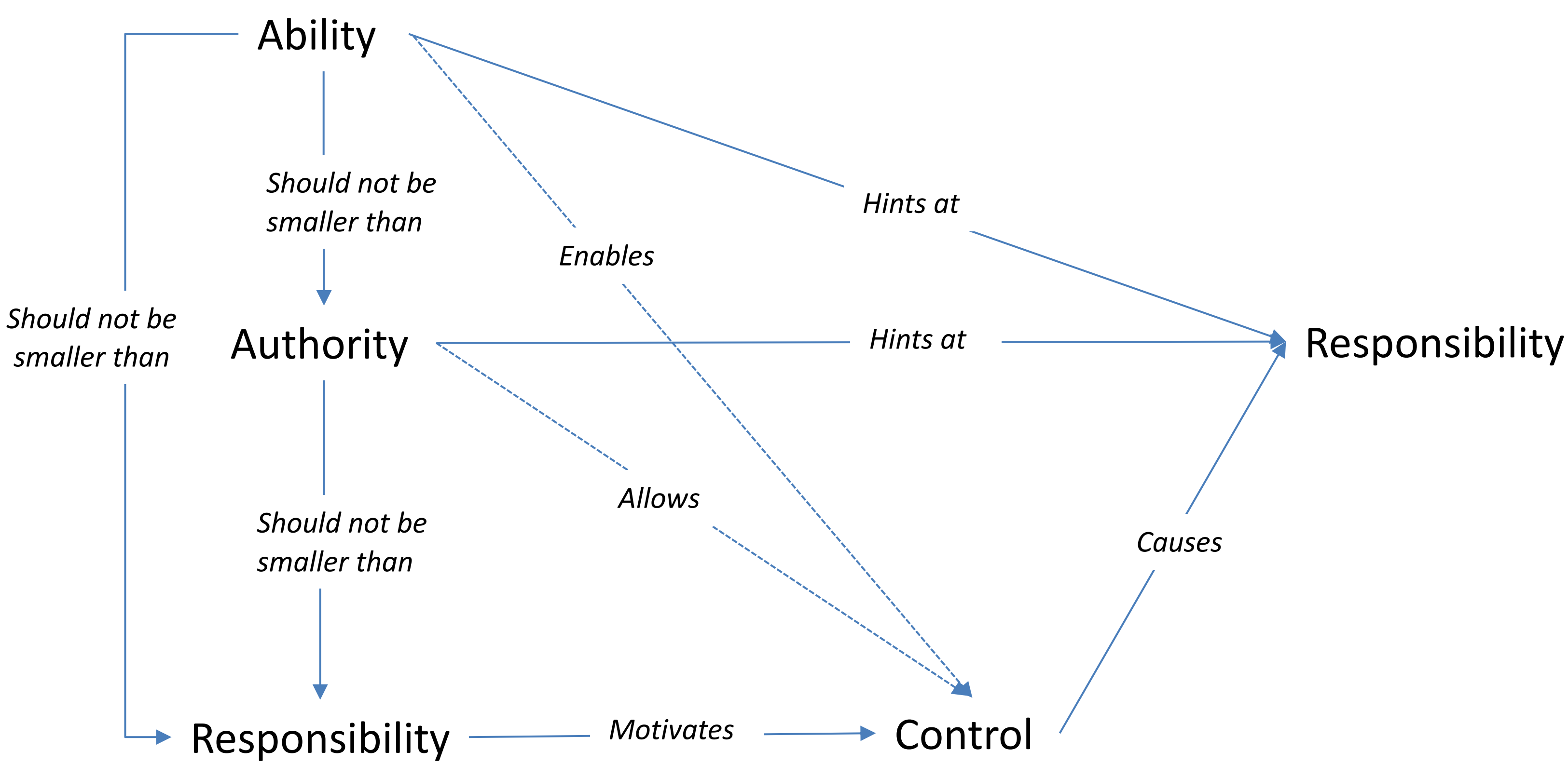
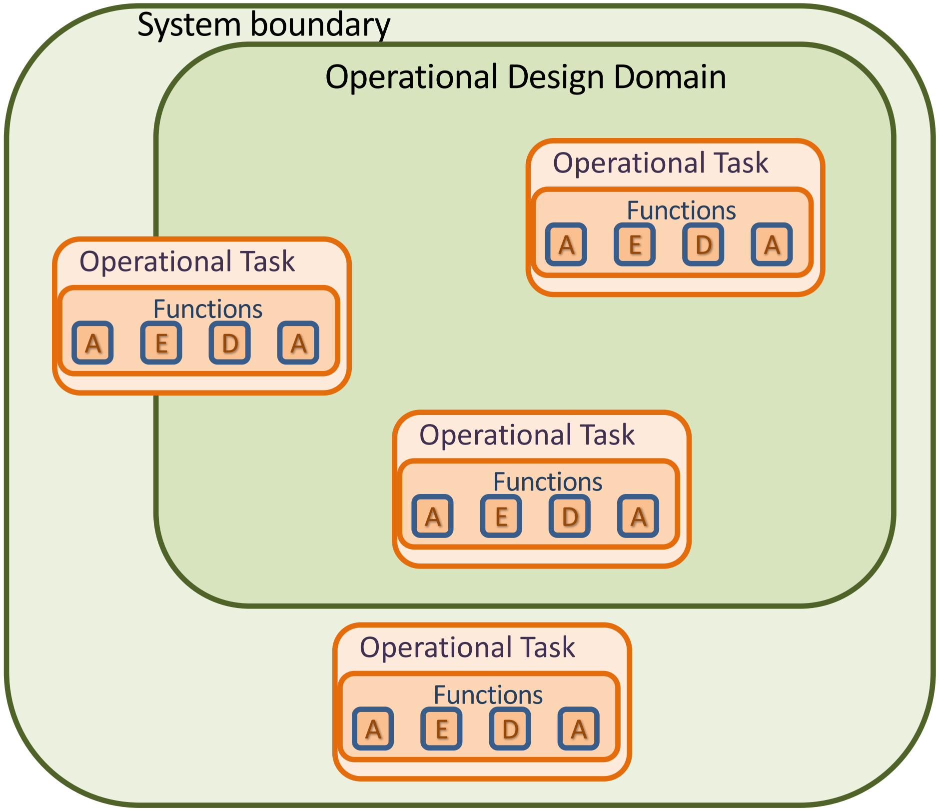


Ability, Authority, Control & Responsibility

Flemisch et al (2012)




System boundary
Operational Design Domain
Operational Task
Functions
A E D A
Operational Task
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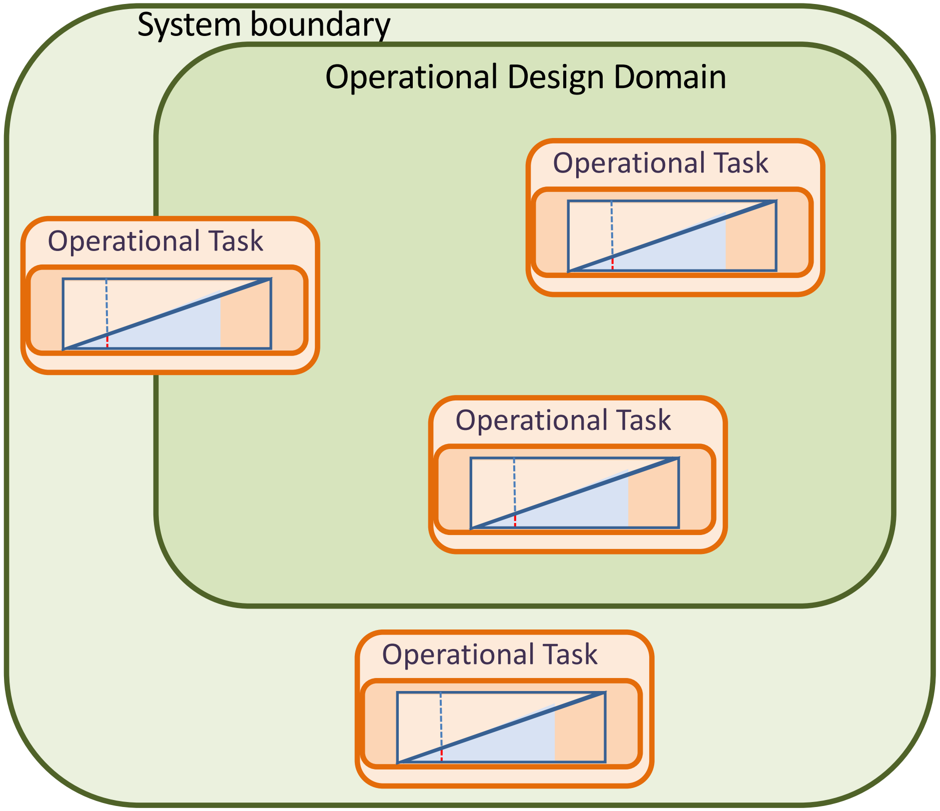
System boundary
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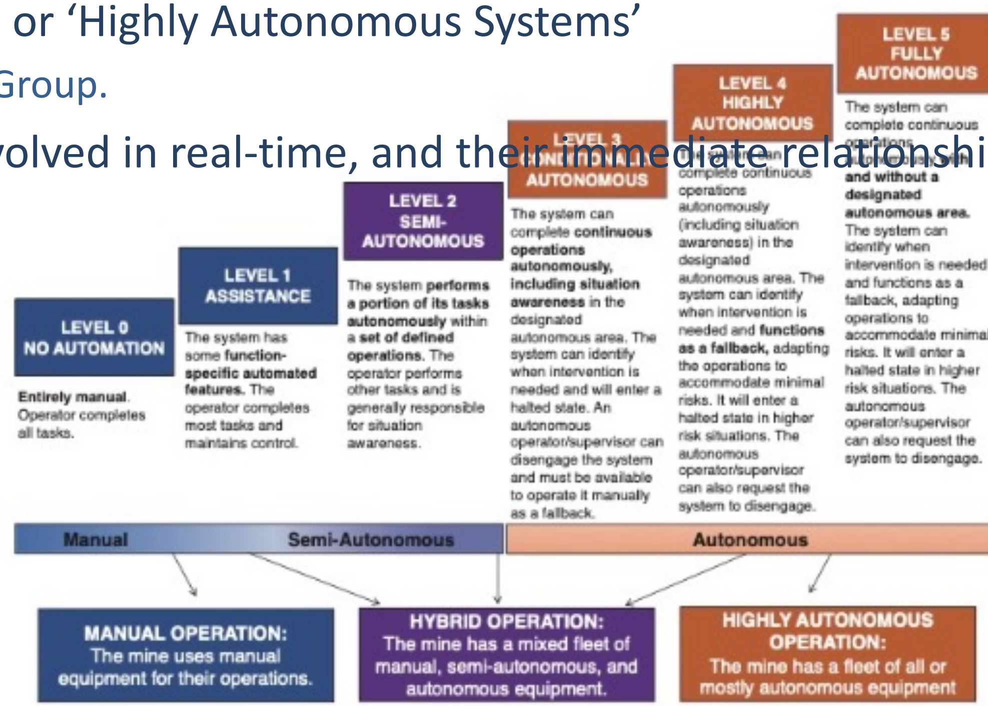
Constraints

- Continuous, real-time control tasks in an industrial context. Critical.
- Early stages of thinking about development and implementation.
- Up to and including Level 4, or ‘Highly Autonomous Systems’
  - Global Mining Guidelines Group.
- Individuals most directly involved in real-time, and their immediate relationship with the system.



9 Principles

"Basic generalizations that are accepted as true and that can be used as a basis for reasoning or conduct"

1. Automation must be seen in the context of the overall socio-technical system it exists in.
2. Recognise that automation nearly always changes, rather than removes, the role of people in a system.
3. Be clear about which of the four core functions automation will have the ability to perform.
4. Recognise that people are going to have to monitor, supervise, and hold responsibility.
5. Ensure effective, transparent and unambiguous communication.
6. Be explicit about where the balance between authority, responsibility and control lies.
7. There should be no automation surprises
8. Avoid making unrealistic assumptions about the ability of people to monitor and intervene
9. Recognise that automated systems can increase task difficulty, workload and need for human reliability.

"A basic generalization that is accepted as true and that can be used as a basis for reasoning"
Vocabulary.com

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1. Acquiring Information
2. Extracting Meaning
3. Decision and action selection
4. Action implementation.

Parasuraman et al (2000)

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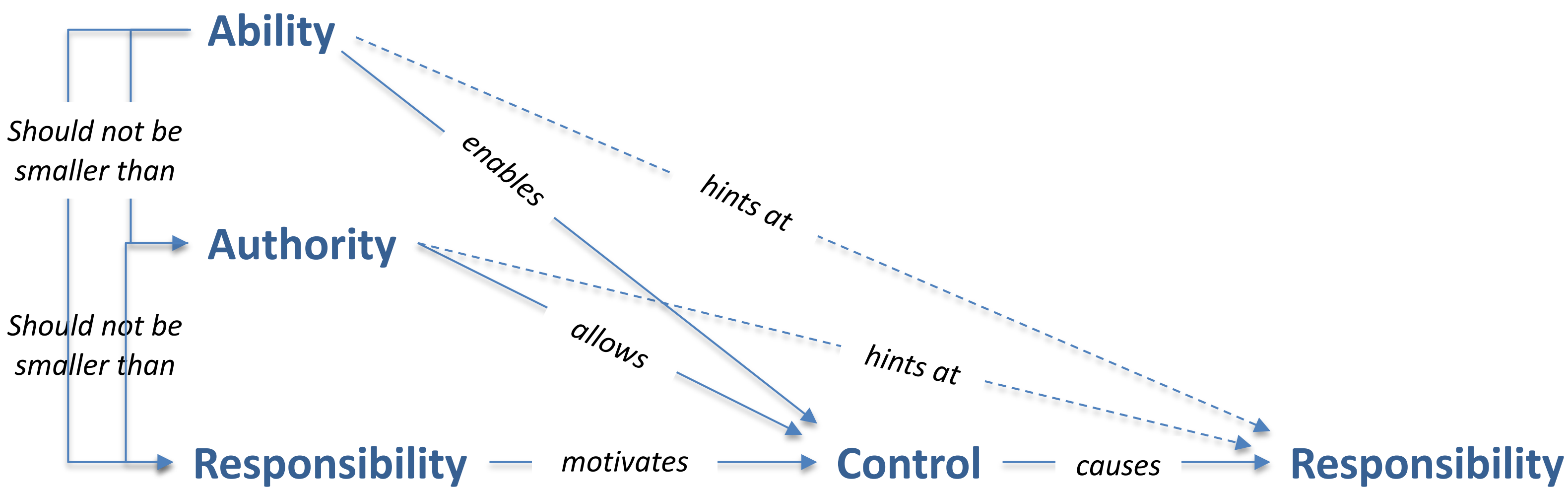

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“Simple little tools” – Harrie Rensinke

- Credible and detailed analyses of the problem space.

- Value often lies in the attention to detail and questioning they promote.

- It can be difficult to ignore or deny the issues if they can be made clear and explicit.

A HF Screening tool for automation projects

Seven Themes

1. System criticality
2. Impact on the roles and tasks performed by people.
3. Where responsibility will lie, and how it might change.
4. Balance of Ability between the human and automation.
5. Extent of authority to perform tasks given to automation.
6. Extent of control delivered by people.
7. Transition.

Seventeen Challenges

A HF Screening tool for automation projects

Themes	Challenges	Could it apply? (Definitely No … Definitely Yes)					Implications
Roles and Tasks	…will significantly change some of the tasks currently performed by people, or change how existing tasks are performed…						A suitable analysis of operator roles and tasks…
	People will be expected to be active in monitoring and supporting the automation over extended periods.						…designed to support proactive monitoring… …Alertness? …how will it keep the user informed of its projections?
Authority	… intention to give the automation authority to one or more core function without any human involvement.						…Function and task analysis… .. Risk assessment…
	…might be conditions when it may not have the ability ….						
Transitioning to Automation	Introduction of the automation will represent a significant change…						…Change management…

A method for analysing highly automated systems

1. Locate the automation within the overall socio-technical system
   - Understand the System Boundaries
   - Understand the overall System Goals
   - What human and technical elements are involved?
2. Identify and understand the Operational Tasks
   - Criticality
   - Level of Automation
   - Responsibility
3. What Generic Functions are involved for each Task?
   - Acquire Information
   - Extract Meaning
   - Make Decisions
   - Take Action
4. Understand the balance between people and technology
   - Ability
   - Authority
   - Control

McLeod, R.W. & Balfe, N (2022) *A Human Factors approach for analysing highly automated systems.* CIEHF Annual Conference.

Example: Automated Lane Keeping

Purpose: Transport people safely over national highway network within the law

System Goals: Stay in lanes….Observe speed Limits…Avoid collisions…avoid discomfort….

Elements: Vehicle; Driver; Highway; Other Vehicles; pedestrians; Environment…

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Operational Tasks:	Maintain vehicle position in lane	Detect approaching ODD limits
Criticality:	*Very High*	High
LoA:	*4*	3
Responsibility:	*Driver*	Manufacturer
Acquire Information:	Current position; Curr heading; Speed limit a	it markings; Light levels…
Ability (Tech/Human):	*Complete /*	*oderate / Moderate*
Tech has Authority:	*By defau*	*When delegated*
Human Control:	*Up to 25%*	*Up to 25%*
Extract Meaning:	Projected position in x secs	Is ODD likely to be breached?
Make Decisions:	Need to change?	Revert to manual control?
Take Action:	Implement change	Prepare driver

1 = Entirely human
2 = Low level automation
3 = Medium
4 = High
5 = Fully automated

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Thank you

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