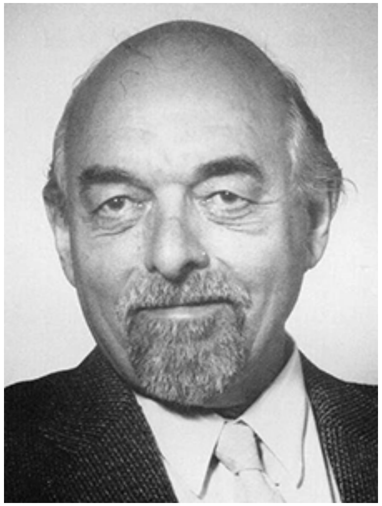
Cognitive Systems Engineering
Shaping understanding with constraints

Prof Penelope Sanderson
The University of Queensland
Australia

ODAM-NES 2014 - Copenhagen



Forthcoming Legacy of Jens Rasmussen symposium

Program committee: Patrick Waterson (Chair), Jean-Christophe Le Coze, John Paul Hansen, Henning Boje Andersen

Local organisers: Henning Boje Andersen (Chair), John Paulin Hansen, Ole Broberg, Tina Weller

Wednesday 20 August - at DGI Byen - 13:00 – 16:45

Thursday 21 August - at Risoe National Lab - 08:00 – 13:00

Outline of today's talk

- Jens Rasmussen's professional legacy
  - Facts, icons, resources, themes
- Two sample uses of Rasmussen's ideas
  - Sensor Abstraction Hierarchies
  - Ecological Interface Design for auditory displays
- The Legacy symposium

Jens Rasmussen

Some career facts

1950: M.Sc. (Hons) electronic engineering from Technical University of Denmark

1956: Joined the AEC's Research Establishment at Risø

1962-1987: Head of Electronics Department at Risø National Laboratory.

1987-1992: Research Professor of Cognitive Engineering at Risø National Laboratory and Technical University of Denmark.

After retirement: Free-lance consultant with WPAFB, EOARD, SRSA, JAERI, and many other organisations, and guest at many academic institutions.

Two honorary doctorates and multiple professional awards including:

2013: Election to the US National Academy of Engineering.

“Denmark was once at the forefront of nuclear research and had planned on building nuclear power plants.

However, in 1985, the Danish parliament passed a resolution that nuclear power plants would not be built in the country and there is currently no move to reverse this situation.”

http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/Denmark/

Major themes in Rasmussen's legacy

- Human operator activity results from behaviour-shaping constraints that we can identify and analyse.
- The human operator is a flexible and adaptive element who "finishes the design" of the technical system she or he operates.
- Human operators cope with complexity by recourse to different mental models and different modes of mental activity.
- Risk management – and safety – require an understanding of the whole sociotechnical and sociopolitical context of work.
- Profoundly functional perspective, supported by strong graphical modeling approach and powerful analytic templates.

Major influences

- Cognitive systems engineering “a conceptual marketplace”
    - Physics
    - Control engineering
    - History and philosophy of science
    - Cognitive science
    - Judgment and decision making
    - European work psychology
    - Ecological psychology
    - Sociology
    - Organisational and management science
    - Engineering design…

Top-ranked papers on Google Scholar and Web of Science

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS, VOL. SMC-13, NO. 3, MAY/JUNE 1983 257

Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models

JENS RASMUSSEN, SENIOR MEMBER, IEEE

Abstract—The introduction of information technology based on digital computers for the design of man–machine interface systems has led to a requirement for consistent models of human performance in routine task env… during unfamiliar task conditions. A discussion is pre-sen… models for representing

nature of the human task. The optimal control part of the model may not be needed if the manual acts are no longer an integral part of the control task but merely a general interface manipulation skill. In that case, independent development of a decision model may lead to a more direct … not a global quantitative model

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0925-7535/97 $17.00 + 0.00

PII: S0925-7535(97)00052-0

RISK MANAGEMENT IN A DYNAMIC SOCIETY: A MODELLING PROBLEM

Jens Rasmussen

Hurecon, Smorum Bygarde 52, DK 2765 Smorum, Denmark

Abstract–In spite of all efforts to design safer systems, we still witness severe, large-scale accidents. A basic question is: Do we actually have adequate models of accident causation in the present dynamic society? The socio-technical system involved in risk management includes several levels ranging from legislators, over managers and work planners, to system operators. This system is presently stressed by a fast pace of technological change … aggressive, competitive environment, and by changin…

Traditionally, each level of …

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS, VOL. 22, NO. 4, JULY/AUGUST 1992 589

Ecological Interface Design: Theoretical Foundations

Kim J. Vicente, *Member, IEEE*, and Jens Rasmussen, *Senior Member, IEEE*

Abstract—A theoretical framework for designing interfaces for complex human–machine systems is proposed. The framework, called ecological interface design (EID), is based on the skills, rules, knowledge taxonomy of cognitive control. The basic goal of EID is twofold: first, not to force processing to a higher level than the demands of the task require, and second, to support each of the three levels of cognitive control. Thus, an EID interface should not contribute to the difficulty of the task, and at the same time, it should support the entire range of activities that operators will be faced with. Three prescriptive design principles are suggested to achieve this objective, each directed at supporting a particular level of cognitive control. Theoretical foundations of the framework are laid out. Particular attention is paid to presenting a coherent deductive argument justifying the principles of EID. In addition, three sources of converging support for the framework are presented. First, a review… the relevant psychological and cognitiv… reveals that there is a considerable am… consistent with the principles of EID. Se… other approaches to interface design in… unique and significant contribution to n… of an initial empirical evaluation also pr… support for the EID framework. Some is… are outlined.

I. INTRODUCTION

A NOVEL theoretical framework fo… complex human–machine systems … per. The framework, called ecological i… is an attempt to extend the benefits o… interfaces (DMI) to complex work do… existing theories of DMI [41], [97] … developed with complex human–machine… a result, it should not be surprising to fi… do not effectively address the unique … complex work domains [88]. The first ste… a more appropriate design framework, th… important challenges associated with the… human–machine systems. The discussion … the specific context of process control, a… generalizability to other work domains wi… in the paper.

A. Unanticipated Events

One way to classify events in compl… systems is according to their …

perspective of first operators and then designers. Three broad areas along a continuum can be identified.

1) Familiar events are routine in that operators experience them frequently. As a result of a considerable amount of experience and training, operators have acquired the skills required to deal with these events.
2) Unfamiliar, but anticipated events occur infrequently and thus operators will not have a great deal of experience to rely on. However, the events have been anticipated by plant designers, who have built in means to deal with them (e.g., procedures, decision support systems, automatic controllers, etc.). These anticipated solutions provide…

IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS, VOL. SMC-15, NO. 2, MARCH/APRIL 1985

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The Role of Hierarchical Knowledge Representation in Decisionmaking and System Management

JENS RASMUSSEN, SENIOR MEMBER, IEEE

Abstract—The knowledge representation of a decisionmaker in control of a complex system can be structured in several levels of abstraction in a functional hierarchy. The role of such an abstraction hierarchy in super-… systems control is reviewed, and the difference between causal and … of the role of an abstraction … is relationship … problem-solv… gn of decision … description of … n terms of an … data bases and … s necessary to … when planning

representations of major characteristics separately, such as:

- the control requirements of the system for relevant categories of situations;
- the decision context or problem space, i.e., a systematic representation of the functional properties of the system;
- a repertoire of possible and effective strategies for the various phases of decisionmaking, such as diagnosis, evaluation, and planning; and
- a representation of information processing capabilities and limitations of the decisionmaker and of the subjective formulation of goals and criteria for choice among possible strategies, i.e., the human product and process criteria.

In the present discussion focus will be on the properties of a hierarchical representation of the problem space.

II. HIERARCHICAL KNOWLEDGE REPRESENTATION

Control of complex systems depends on the means for coping with the complexity. However, from the controller's point of view, the complexity of a system is not an objective feature of the system [1]. The complexity observed depends upon the resolution applied for information search. A simple object becomes complex if observed through a microscope. Objective complexity can only be defined with reference to a given representation of a system. Therefore the complexity faced by controllers is determined by the representation of the internal state of the system, which the interface allows the controller to develop for the variou… … conditions. This means that the apparent complexity …

…ol of complex …ituations with …priate human …or such situa-…ot apply, and … controller de-…operties of the … planning. The …ements of the …ditions. Conse-…ll be applied to … on characteris-… individual de-

…t impossible, to …predict the infor-…

Journal of Occupational Accidents, 4 (1982) 311—333 311
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HUMAN ERRORS. A TAXONOMY FOR DESCRIBING HUMAN MALFUNCTION
IN INDUSTRIAL INSTALLATIONS

Jens Rasmussen

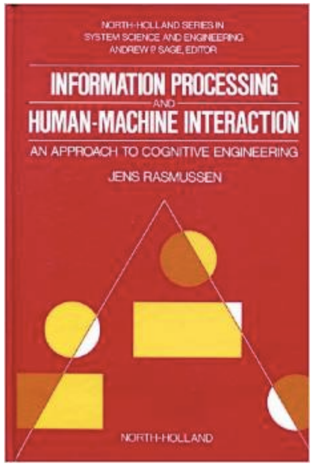
Risø National Laboratory, DK 4000 Roskilde, Denmark

(This paper has also been used for invited presentation at: European Reliability Data Association Seminar on Industrial Safety, Apeldoorn, The Netherlands, 1981)

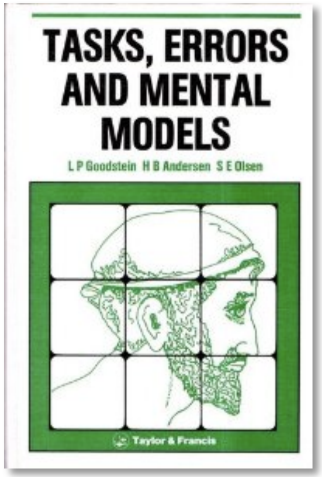
ABSTRACT

Some key outputs – and a festschrift

Rasmussen & Rouse [Eds] (1981)

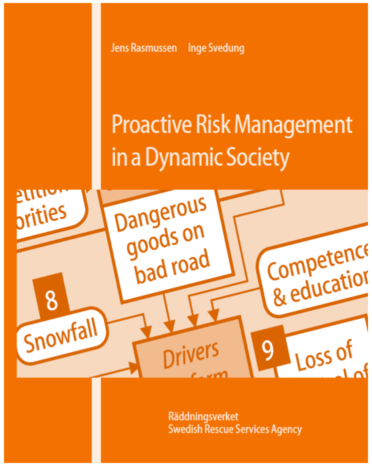


Rasmussen (1986)



Goodstein, Andersen, and Olsen [Eds] (1988)

Rasmussen, Pejtersen, and Goodstein (1994)



Rasmussen and Svedung (2001)

Risk management and safety

Recent survey of contribution

Safety Science xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Reflecting on Jens Rasmussen's legacy. A strong program for a hard problem

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Institut National de l'environnement industriel et des risques, Parc Alata, 60550 Verneuil en Halatte, France

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Safety
Model
Accident
Socio-technical view

ABSTRACT

Jens Rasmussen has been a very influential thinker for the last quarter of the 20th century in the safety science field and especially in major hazard prevention. He shaped many of the basic assumptions regarding safety and accidents which are still held today. One can see that many of his ideas underlie more recent advances in this field. Indeed, in the first decade of the 21st century, many have been inspired by his propositions and have pursued their own research agendas by using, extending or criticising his ideas. The author of numerous articles, chapters of books and books, Rasmussen had an inspiring scientific research record spreading over 30 years, expanding across the boundaries of many scientific disciplines. This article introduces selected elements of Rasmussen's legacy, including the SRK model, his theoretical approach of errors, the issue of investigating accidents, his model of migration and the sociotechnical view. It will be demonstrated that Jens Rasmussen provided key concepts for understanding safety and accidents, many of which are still relevant today. In particular, this article introduces how some principles such as degree of freedom, self organisation and adaptation, defence in depth fallacy but also the notion of error as '*unsuccessful experiment with unacceptable consequences*' still offer powerful insights into the challenge of predicting and preventing major accidents. It is also argued that they combine into a specific interpretation of the 'normal accident' debate, anticipating current trends based on complexity lenses. Overall, Jens Rasmussen defines the contours of what is called 'a strong program for a hard problem'.

THEME: Human as adaptive system element that "finishes the design"

"Brownian motion" metaphor for adaptation to forces shaping operational decisions

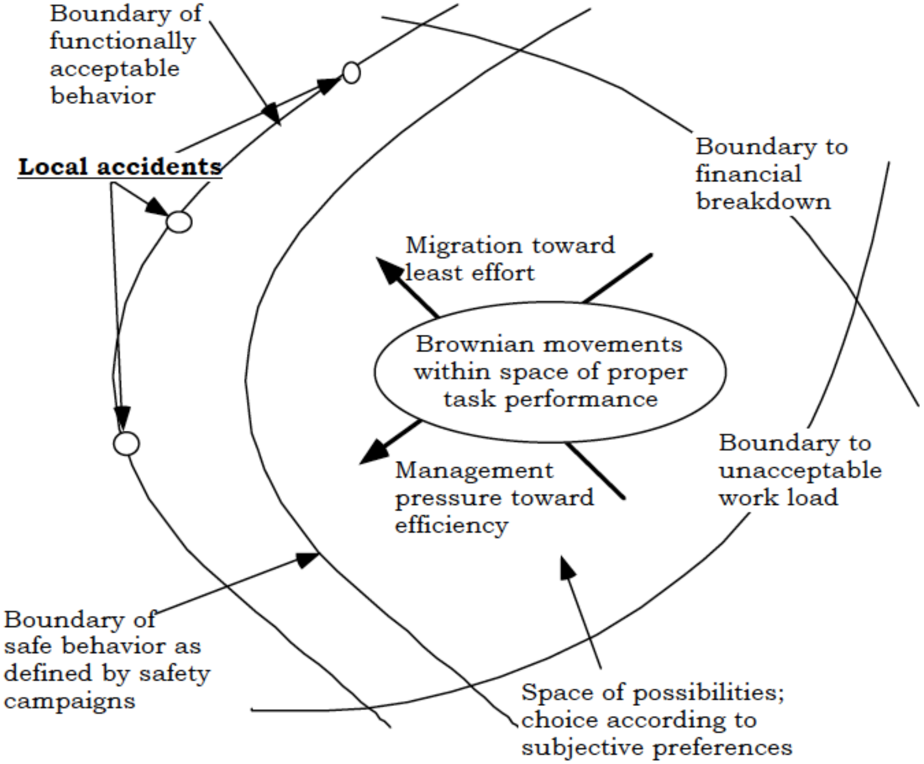


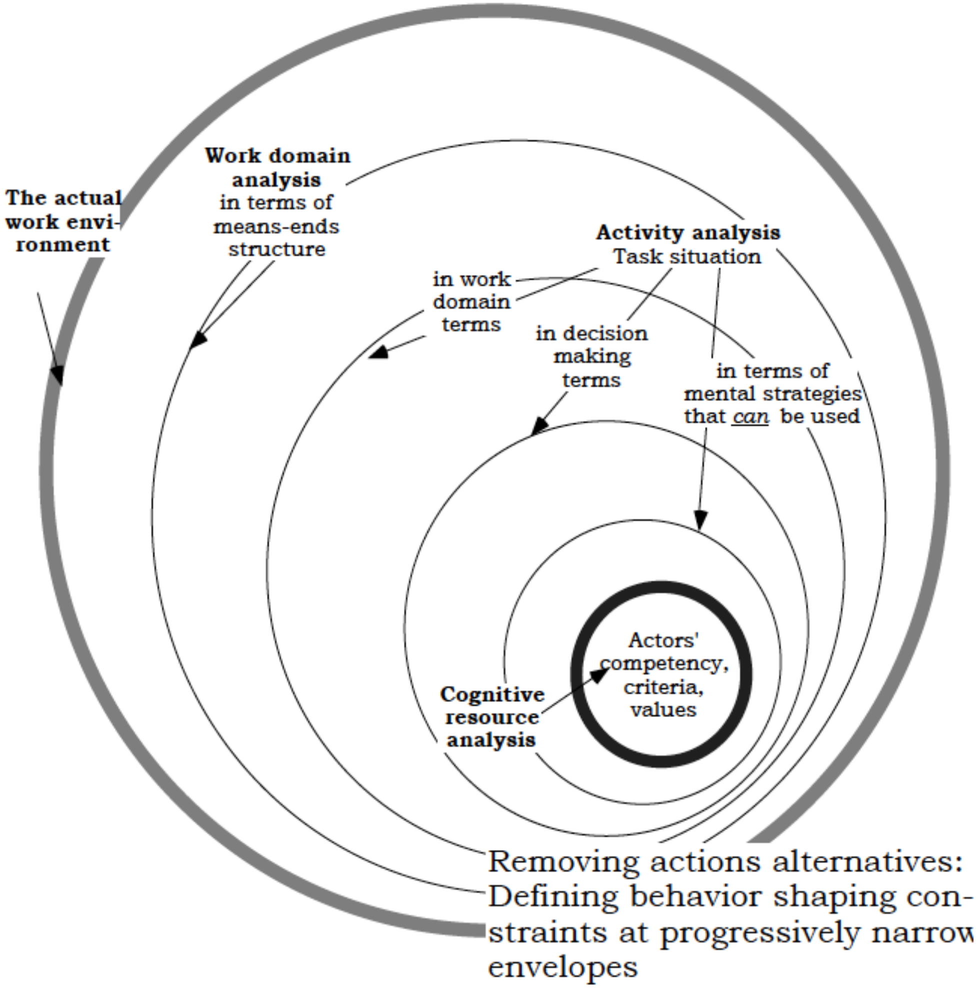
Figure 6.3. Activity can be characteristic by "Brownian movements" within the work space, subject to work load and effectiveness gradients.

THEME: Nested behavior-shaping constraints

Cognitive Work Analysis

An approach, and a framework, for analysis, modeling, design, and evaluation.

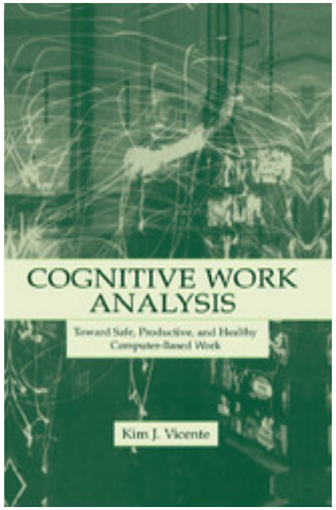
Analytical templates for capturing the constraints at each level (abstraction decomposition space, decision ladder, etc.)



Cognitive Work Analysis

Expositions and applications by “the next generations”

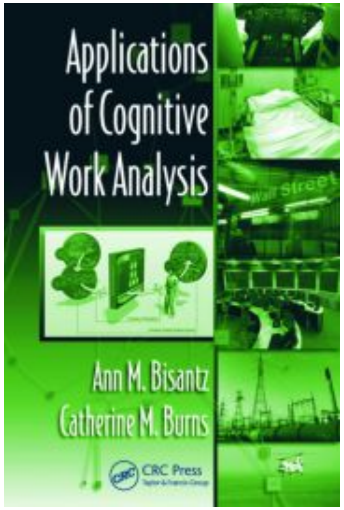
Vicente (1999)



COGNITIVE WORK ANALYSIS

Toward Safe, Productive, and Healthy Computer-Based Work

Kim J. Vicente



Applications of Cognitive Work Analysis

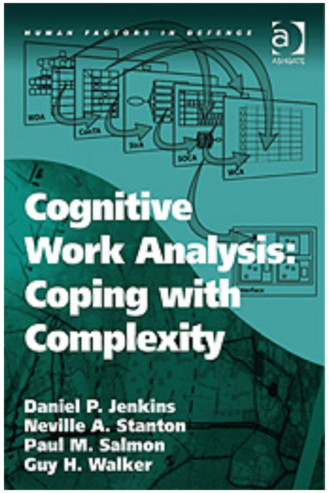
Ann M. Bisantz

Catherine M. Burns

CRC Press

Bisantz & Burns (2009)

Jenkins,
Stanton,
Salmon &
Walker (2009)

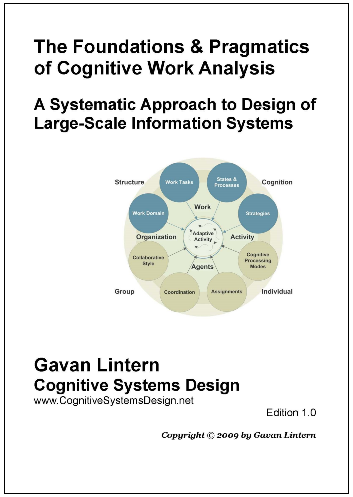


HUMAN FACTORS IN DEFENCE

ASHGATE

Cognitive Work Analysis: Coping with Complexity

Daniel P. Jenkins
Neville A. Stanton
Paul M. Salmon
Guy H. Walker



The Foundations & Pragmatics of Cognitive Work Analysis

A Systematic Approach to Design of Large-Scale Information Systems

Gavan Lintern
Cognitive Systems Design
www.CognitiveSystemsDesign.net

Edition 1.0

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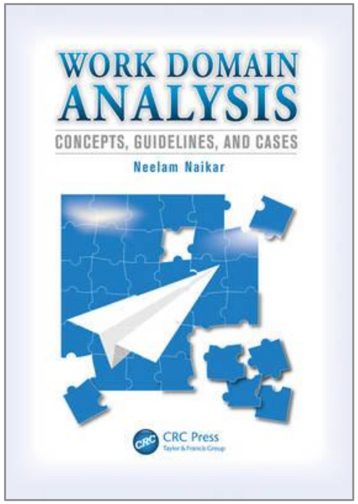


WORK DOMAIN ANALYSIS

CONCEPTS, GUIDELINES, AND CASES

Neelam Naikar

CRC Press

Naikar (2013)

Lintern (2013)

THEME: Support different modes of mental activity
Ecological Interface Design

Rasmussen and Lind (1981)
Vicente and Rasmussen (1990; 1992)

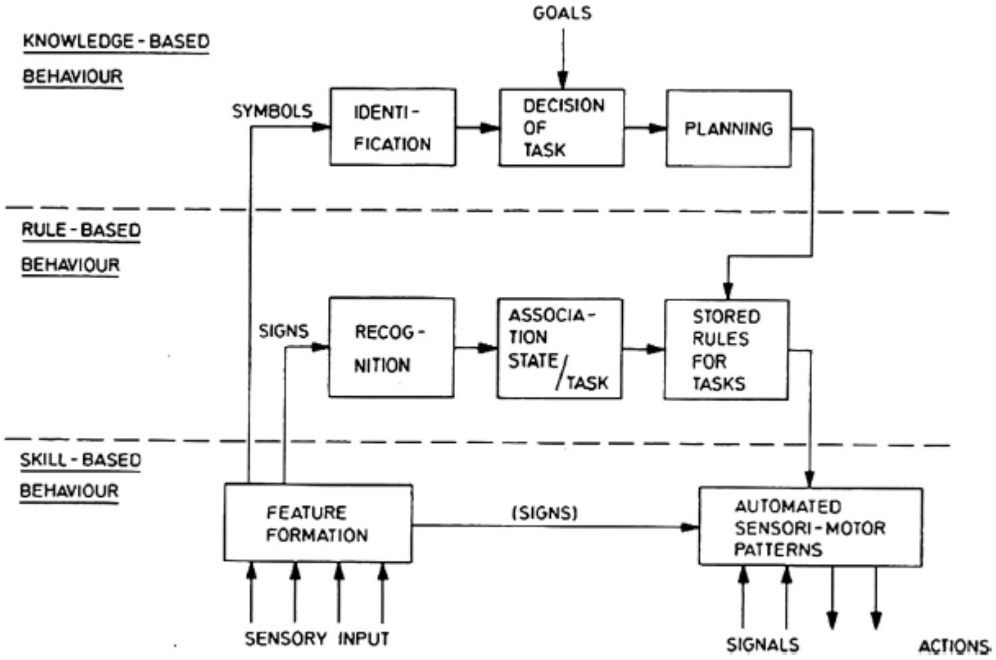
Convey veridical model of the system to operators/users

Support skill, rule, and knowledge based behaviour

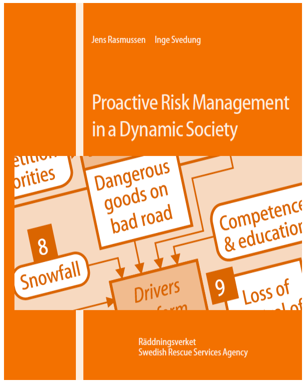
Show safety boundaries.

Burns & Hajdukiewicz (2004)

Bennett & Flach (2012)



THEME: Risk and safety emerge from dynamics of sociotechnical/sociopolitical systems



Rasmussen and Svedung (2001)

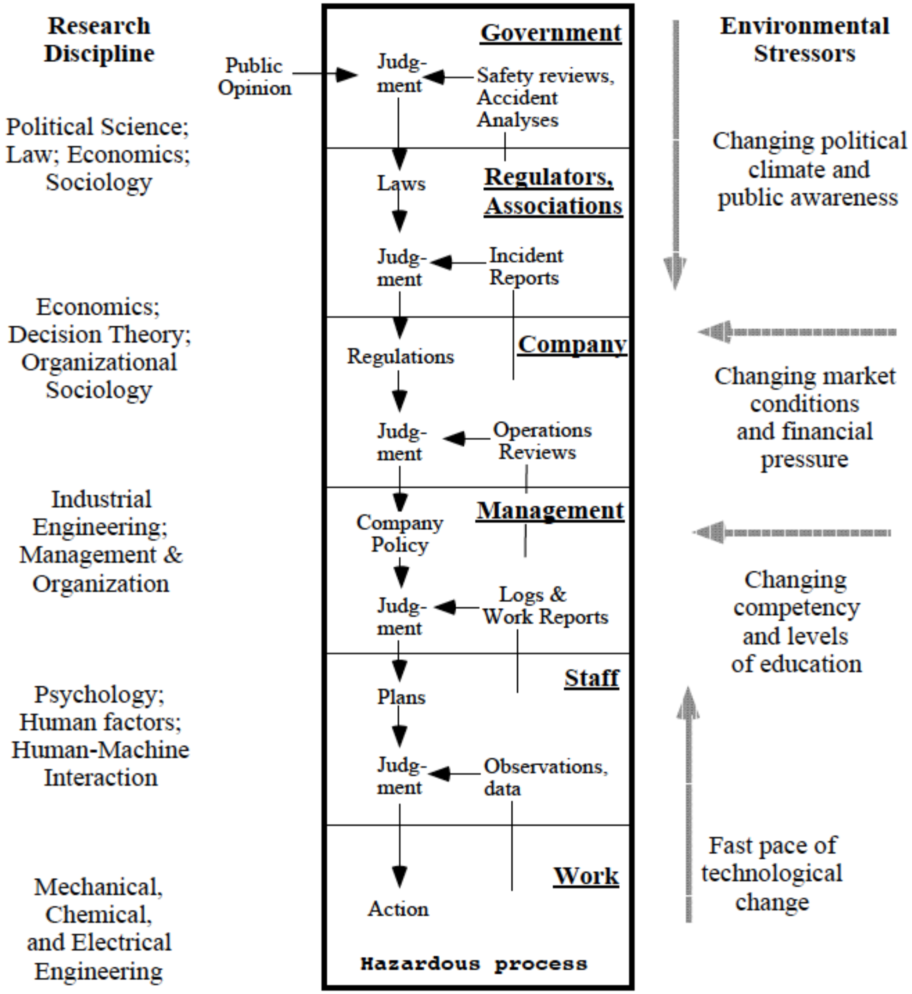
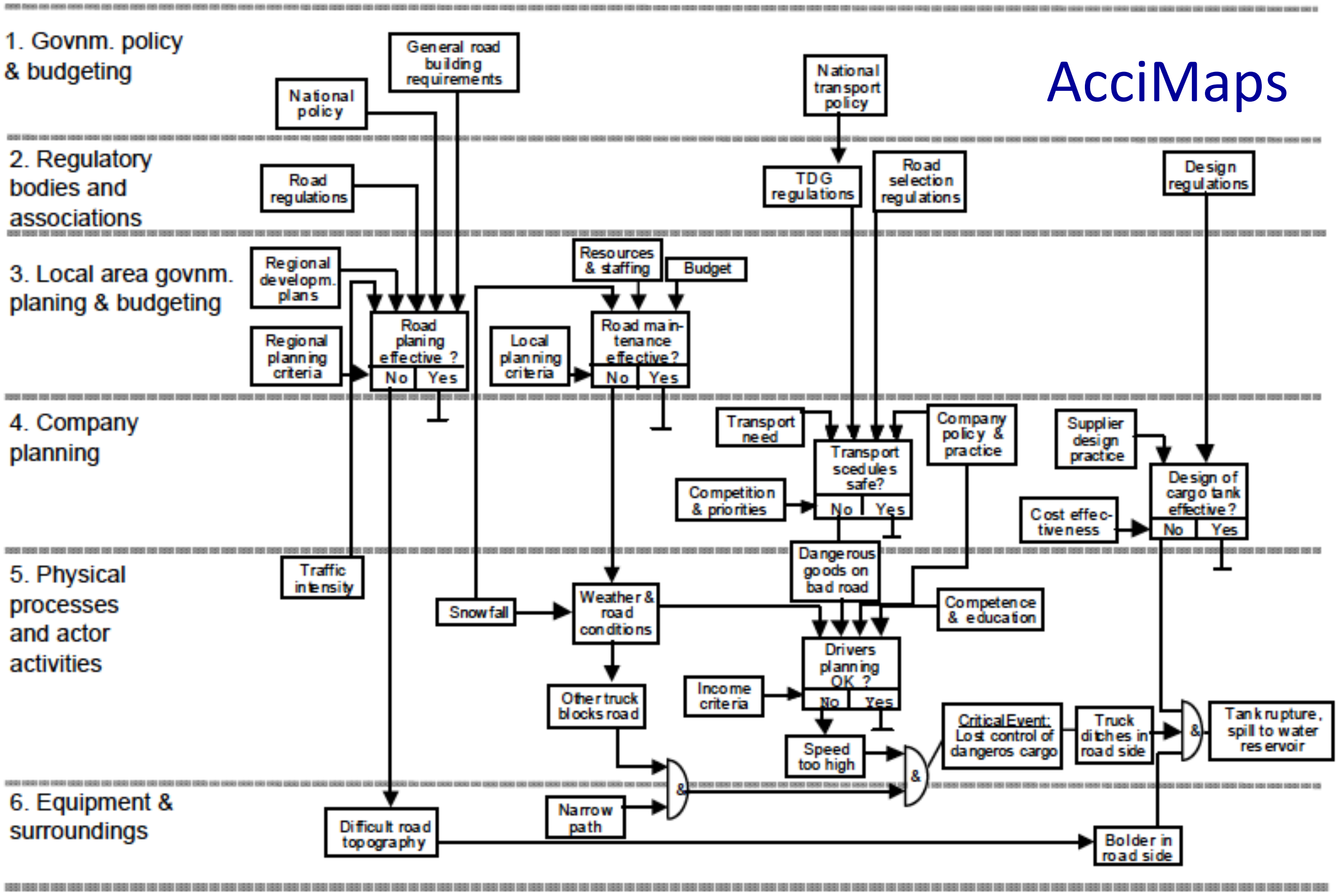


Figure 1. The socio-technical system involved in risk management.

Rasmussen (1997)

Risk and safety emerge from dynamics of sociotechnical/sociopolitical systems



AcciMaps

Figure 5. A map showing the results of the analysis of a traffic accident involving oil-spill to a drinking water supply.

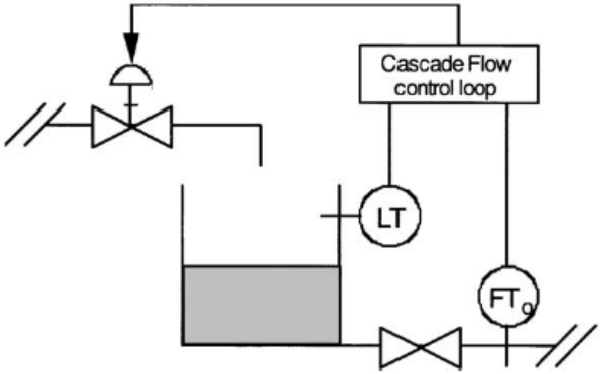
Rasmussen (1997) Rasmussen and Svedung (2001)

EXAMPLE: Cognitive Work Analysis

Reising (1999)
Reising & Sanderson (2002a; 2002b; 2004)

Using Rasmussen's Abstraction Hierarchy to determine the sensor requirements for an interpretable and trustworthy visual interface

Simple example; later example with pasteurisation plant.



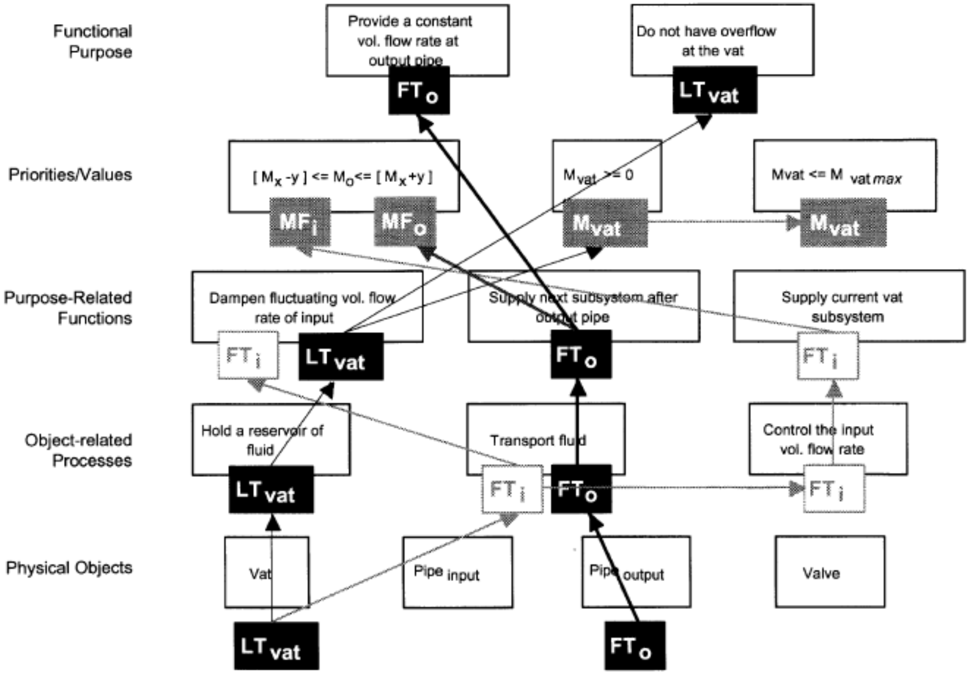
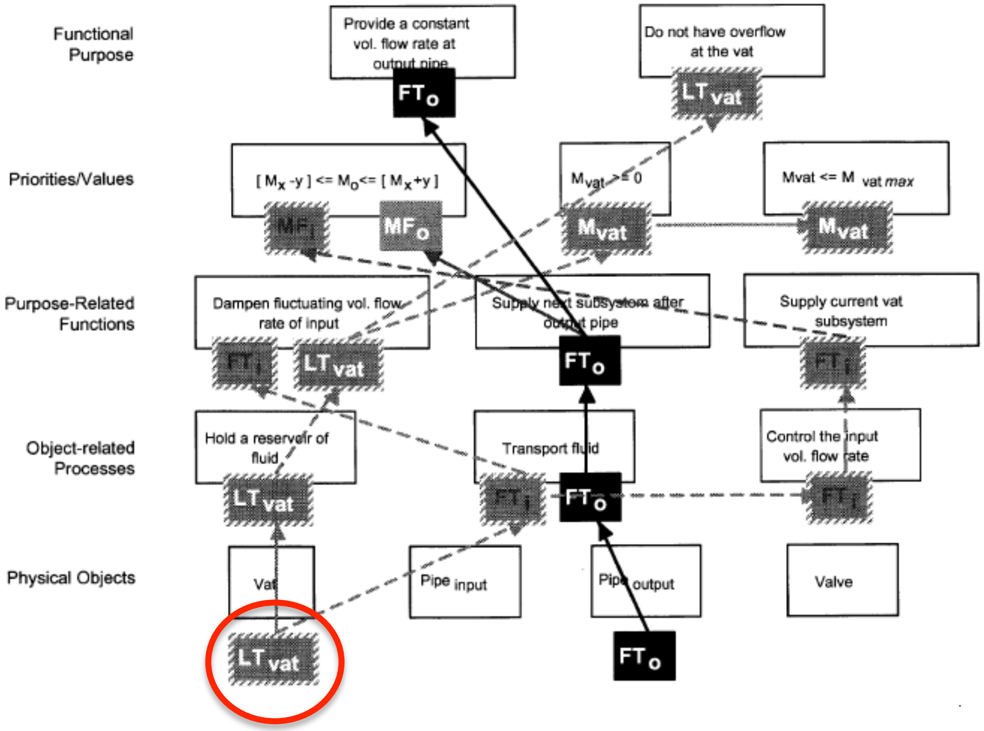
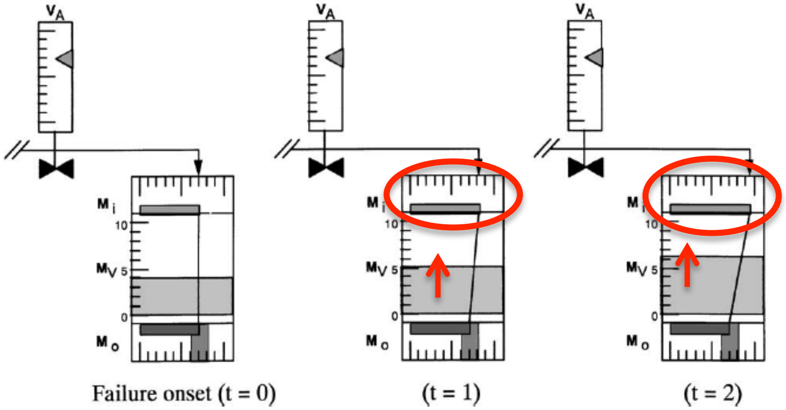


FIGURE 8. The sensor-annotated AH for the reservoir sub-system in Figure 7, showing the "location" of sensors at the Physical Object level, and the propagation of information from those sensors up through the AH. Black boxes show good information and dark gray boxes correspond to information that is normally derived. White boxes represent information that, if needed, must be derived by other means.

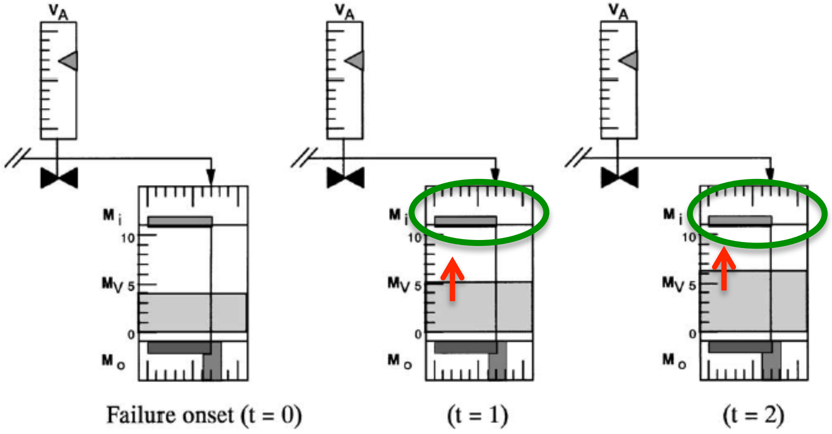
Human operator information needs should drive the design of the sensor instrumentation (not vice-versa)

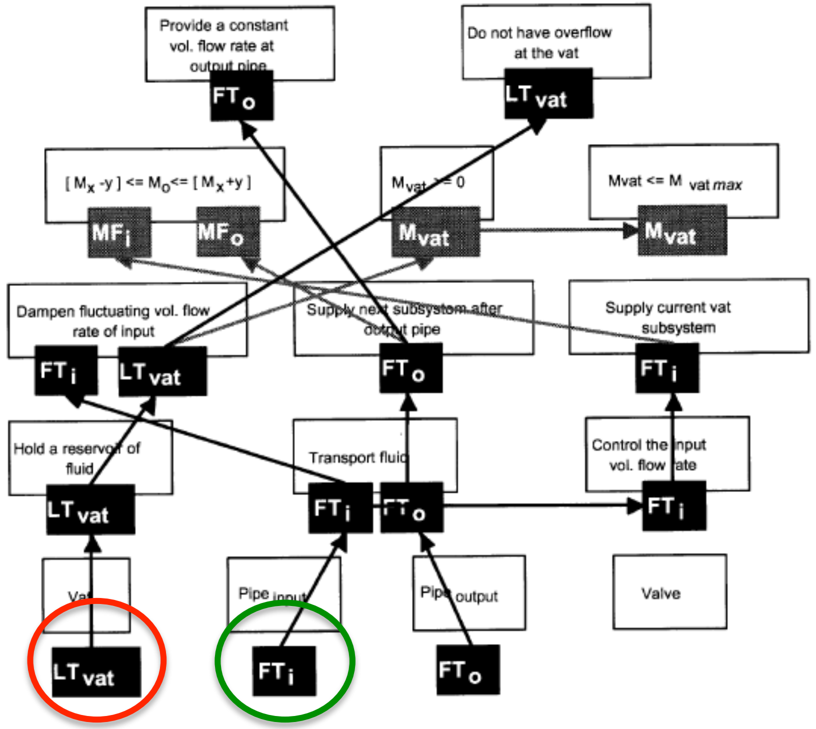




1. With faulty sensor, display gives misleading indications (valve reading stuck?)

2. Add the needed sensor and anomaly is easier to see (level reading wrong?)





EXAMPLE: Ecological Interface Design
…in the auditory modality

Watson and Sanderson (2004; 2007)
Sanderson et al. (2008)

- What information is needed to meet priorities and values?
- What aspects of monitoring should be skill, rule, or knowledge-based?
- How to increase sensitivity to approach to boundaries, but not burden user’s attention with continual monitoring?
- Example from neonatal pulse oximetry monitoring.

END