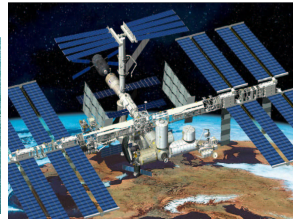


## User-Centered Design and Beyond

### Situated Cognitive Engineering

Mark Neerincx  
January 2009



## User-centered...

Who are the users?



What would they do?



What is the context?

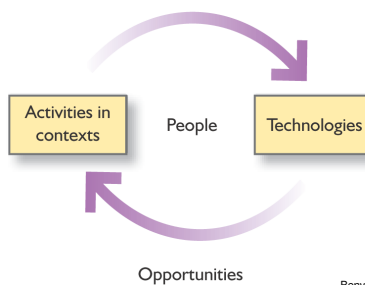


Which technologies can support them?

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Requirements



### PACT

- People
- Activities
- Contexts
- Technologies

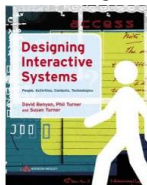


Figure 2.1 Activities and technologies.  
Source: after Carroll (2002), Figure 3.1, p. 68.

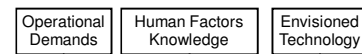
Benyon, D., Turner, P., and Turner, S., (2005). *Designing Interactive Systems: People, Activities, Contexts, Technologies*. Harlow, England: Addison-Wesley.

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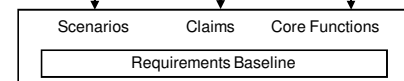


## Situated Cognitive Engineering

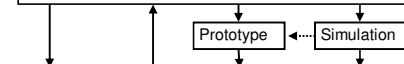
Derive



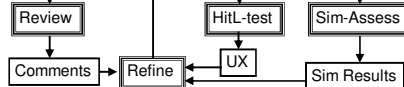
Specify



Test



Refine



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## Situated Cognitive Theories...

- ...help to establish sound support systems by accounting adequately for how context and actions are coupled and mutually dependent.
- ...apply to the specific domain or environmental description that is part of it.
- ...include accepted features of cognition such as limited processing capacity, are validated in the context of a specific domain and possibly group of task performers, and provide predictions of the task performance within this domain.

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## Derive: Work Domain & Support analysis

Operational demands

- Littoral waters
- High variability in work demands
- Smaller crews

Human factors

- **Cognitive task load (CTL)**
- Trust

Situation awareness

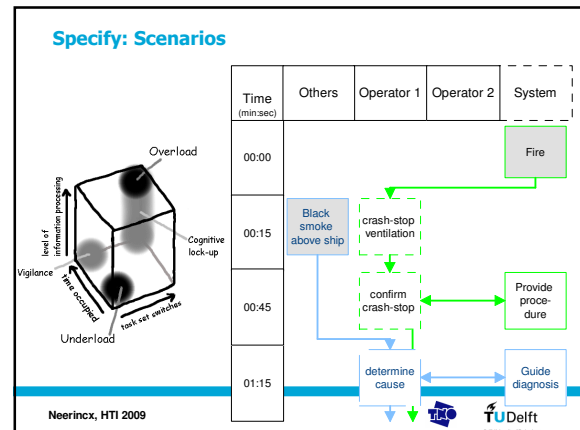
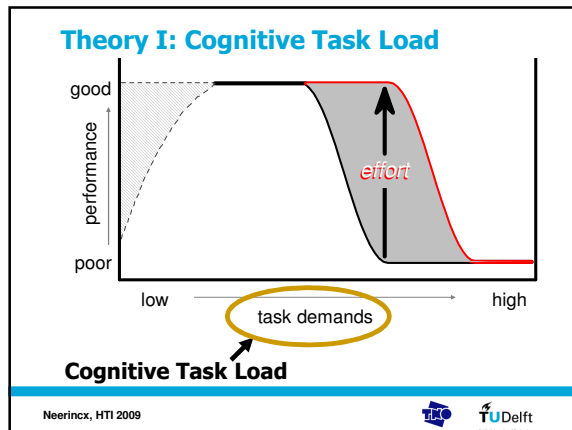
Technology

- Intelligent combat & platform management systems
- Adaptive automation
- Network-centric vs platform-centric



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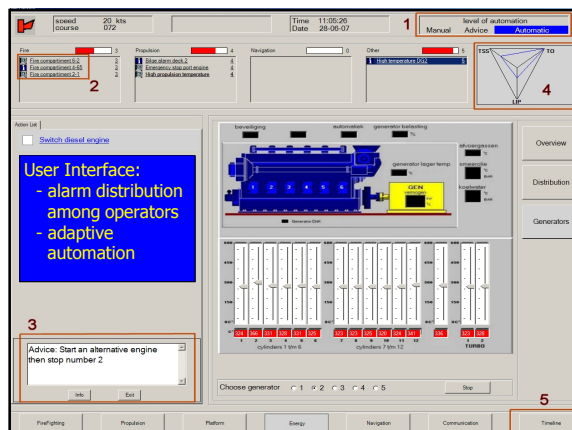
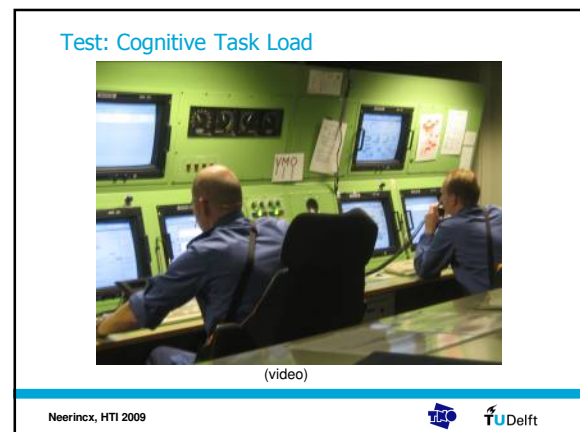




### Simulation-based assessment

4 Persons				VST-Operator			M-Officer			Total
Sup	IH	Exper		TO	LIP	TSS	TO	LIP	TSS	Time
no	no	Little		55.61	3.56	2	41.47	4.15	6	223.00
no	yes	Little		46.41	3.56	2	34.62	4.15	6	200.38
no	no	Average		54.61	2.56	2	40.78	3.15	6	217.00
no	yes	Average		44.13	2.56	1	32.96	3.15	6	201.38
DG	no	Much		52.69	1.47	2	38.88	1.75	6	213.50
DG	yes	Much		43.24	1.47	1	31.90	1.75	6	195.13
2 Persons				VST-Operator			M-Officer			Total
Sup	IH	Exper		TO	LIP	TSS	TO	LIP	TSS	Time
no	no	Little		71.40	3.65	7	45.76	4.22	5	253.50
no	yes	Little		66.26	3.65	6	42.46	4.22	5	204.88
no	no	Average		70.90	2.65	6	45.49	3.23	5	244.00
no	yes	Average		65.49	2.65	6	42.02	3.23	5	198.13
DG	no	Much		69.94	1.51	6	44.35	1.81	5	234.50
DG	yes	Much		63.04	1.51	6	39.97	1.81	5	195.13

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### Theory II: Situation Awareness (Endsley, 1995)

- The perception of the relevant information in the environment,
- the comprehension of their meaning and
- the projection of their status in the near future

8 SA demons, factors that cause loss of SA (Endsley, 2003):

- tunneling
- memory trap
- workload
- data overload
- salience
- complexity creep
- mental model
- out-of-the-loop**

A photograph showing an operator in a control room, sitting at a desk with multiple computer monitors. The operator is wearing a white shirt and is looking at the screens. The room has a green wall and a clock on the wall.

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## Specify: Core functions and Claims

- Core function: Prevent out-of-the-loop problems
- Claim 1:
  - Feature*: When the task load decreases (e.g. few tracks to handle), a lower level of automation is triggered.
  - Result*: The user does (almost) everything and handles more tracks, so that (s)he is sufficiently engaged in the current operation (e.g., adequate eye movements and medium arousal level), detects relevant objects in time (e.g., adequate identification performance) and is not involved in unrelated and irrelevant activities (e.g., mainly task-related behavior).

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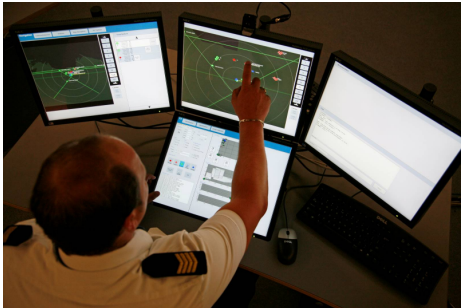


## Specify: Scenarios Use cases

[UC_Nr]	Example: UseCase 3
[UC_name]	Increasing SA after decreasing LOA
Goal	Limit out-of-the-loop problems
Actor	Team member of Command and Control Centre
Precondition	AA is at the medium or high level; User has a limited view of tracks as some are handled by the system, limiting his situational awareness to 'dangerous' tracks.
Post condition	AA is set at a lower level More tracks will be handled by the user from now on, increasing his or her overall situational awareness.
Trigger	Amount of work (pending tracks, tracks requiring user attention) is below a preset threshold level.
Main Success Scenario	After decrease of automation level, more tracks of multiple categories will be handled by the user In doing so, the user quickly gets good situational awareness.
Alternative Scenario	.....
Satisfies claim	Claim 1, Claim 25
Satisfies requirement	Requirement 13

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## Prototype Development: Basic-T



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## Prototype evaluation

- Subjective workload*
- Observed *task load*, *situation awareness*, and *quality* and *timeliness* of the actions
- The *performance* in terms of tracks handled and reaction time on signals of the machine was measured.
- Communication* between participant and others (such as helicopter, played by experimenter in kitchen)

=> Less extreme task load; overall, improved performance

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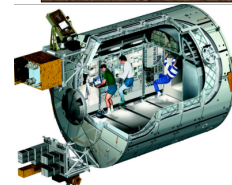
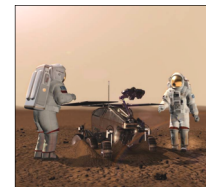
## Results and refinements


- Implementation bugs
- Users were sometimes overruled by a system decision after a user decision was already made.
- Core function: Prevent out-of-the-loop problems
- Claim 3.
  - Feature*: When the automation level is lowered, the user is made aware of tracks that have been handled by the system.
  - Result*: Tracks that were handled by the system at high automation levels are labeled as such, so that the operator can inspect them after the level of automation has lowered (e.g., user behavior) to improve his or her momentary knowledge of the situation (e.g., adequate situation reports).

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## Human-Machine Collaboration in Space





**MECA**  
Mission Execution  
Crew Assistant  
<http://www.CrewAssistant.com>





**Vision on Joint Cognitive Systems:**



- Collection of distributed, connected & personal ePartners to support the hPartners

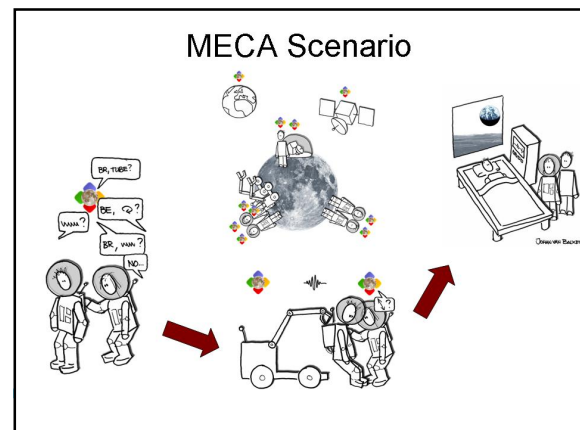
**Goal:**

- to improve human-machine team's resilience and safeguard hPartners from failures in unexpected, complex and potentially hazardous situations

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### ePartner Concept

Has **information** of its hPartner, **e.g.**



- permanent characteristics (e.g., personality)
- dynamic characteristics (e.g., experience)
- base-line state (e.g., "normal" heart rate)
- momentary state (e.g., current heart rate)
- tasks to do (e.g., alarm handling)
- task performance (e.g. time)
- current context (e.g., location)

And **interprets** this information to

- assess human's condition for current context
- identify critical situations (e.g. panic)
- apply mitigation strategies to reduce the negative effects (e.g. reschedule tasks, notify colleague, ...)





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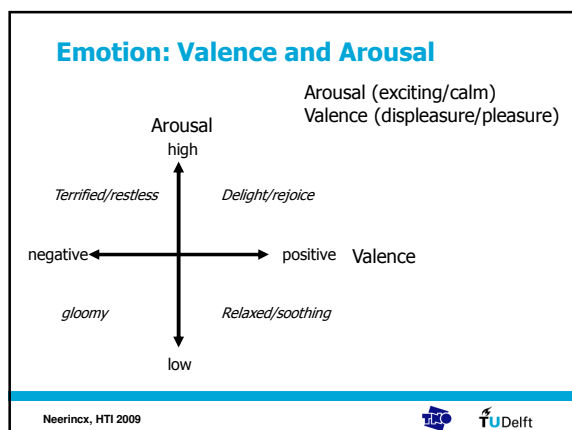
### ePartner's knowledge

- Easy to share with its hPartner
- Trustworthy
- Based on situated theories (sub-models):
  - cognitive task load**
  - emotional state**
  - fitness
  - team involvement
- Continuously updating the models via human input, and automatic sensing of human behavior, physiology and context

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### ePartner's Support

Identification of critical states per sub-model, **and** for combination of states, e.g.

- high Cognitive Task Load & "relaxed" Emotional State
- ...

Mitigation Strategies:

- Dialogue Style
- Feedback**
- Crew Notification
- Information Filter
- Task Allocation
- Automation Level
- ...



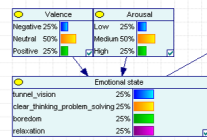

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## Modeling CTL and emotion

Bayesian network based on data from

- naval officers' actions
- astronauts' actions



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## How to Evaluate?

Provide Scenarios

Support Task Involvement

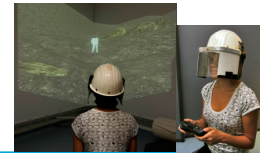
- Cognitive Load
- Situation awareness
- Presence
- Emotion

Measure

- Performance
- (Physiology)
- Opinion



In desk-top setting

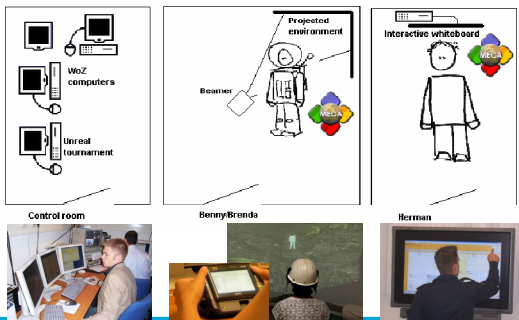


In VE setting

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## Prototyping, simulation and testing



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## Conclusions

Situated CE method proved to work well

- Scenario refined & validated (alternative scenarios, use cases)
- Claims refined & confirmed, research issues identified (e.g., acceptance of emotion sensing)
- Core functions well-appreciated, can be incrementally developed & tested

Type	Unchanged	Refined	New	Total
Generic Task Level Requirements	16	5	6	27
Functional Requirements	27	14	6	47
User Interface Requirements	25	15	5	45
Technical Requirements	8	2	6	16
Operational requirements	1	2	1	4
Interface Requirements	27	0	1	28
<b>TOTAL:</b>	<b>104</b>	<b>38</b>	<b>25</b>	<b>167</b>

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## Situated Cognitive Engineering

Customisation:

Adequate selection and application of well-founded cognitive theories, guidelines and methods.

Coherence and completeness by application of an integrated approach, e.g.

- task analysis for design and test
- complementary test methods
- correspondence theory, design specs & test methods

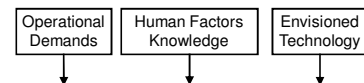
Empirical foundation in the application domain

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## Situated Cognitive Engineering

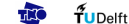
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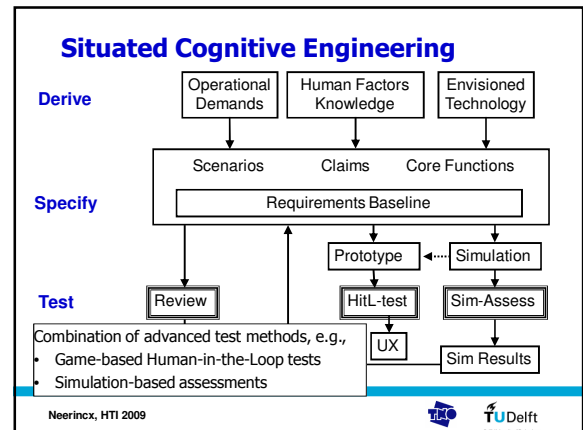
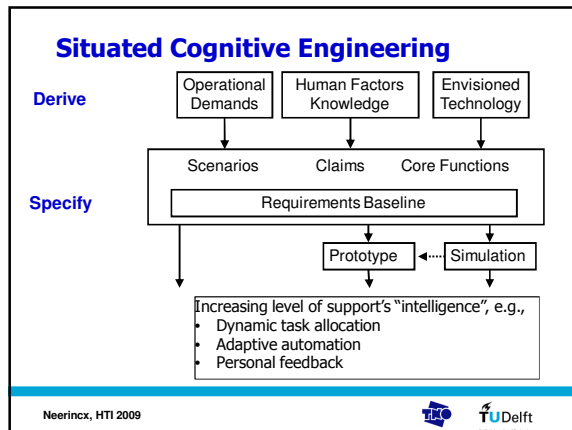


Theory development and validation, e.g.,

- Cognitive Task Load
- Situation Awareness
- Emotion

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