System Design & Cognitive Task Load

25-02-2009

Defence, Security and Safety

TNO | Knowledge for business

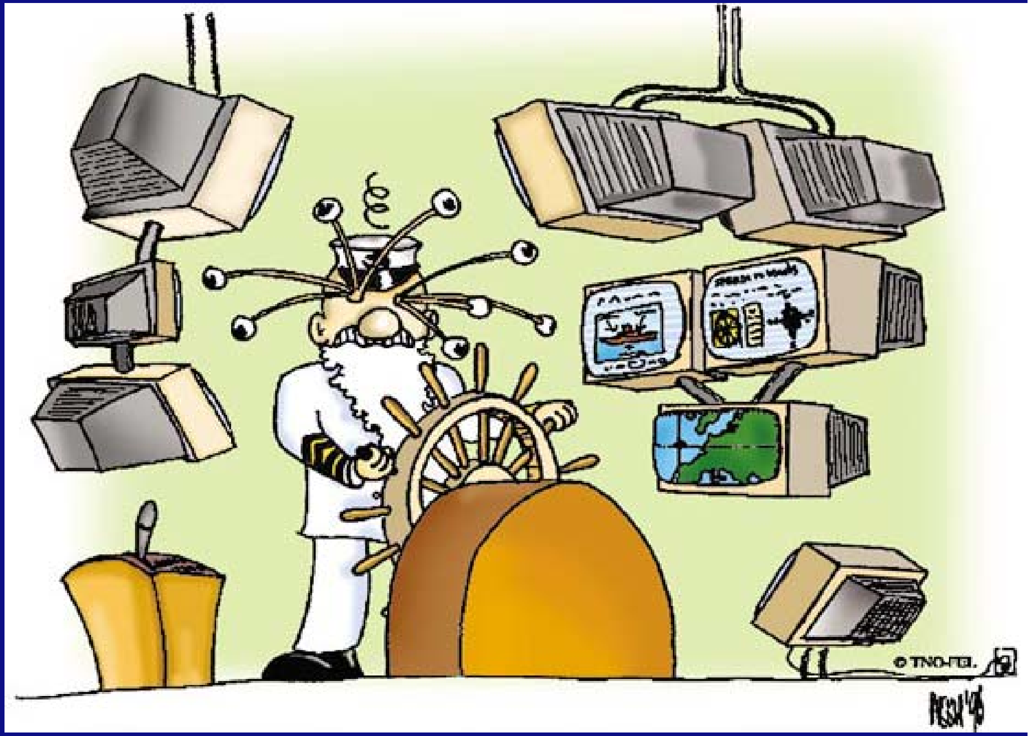
Delft University of Technology

95-00 Naval College
00-02 TNO Research Institute
02-04 Hms Tromp
04-08 TNO/TUD
08-… Platform design/project management

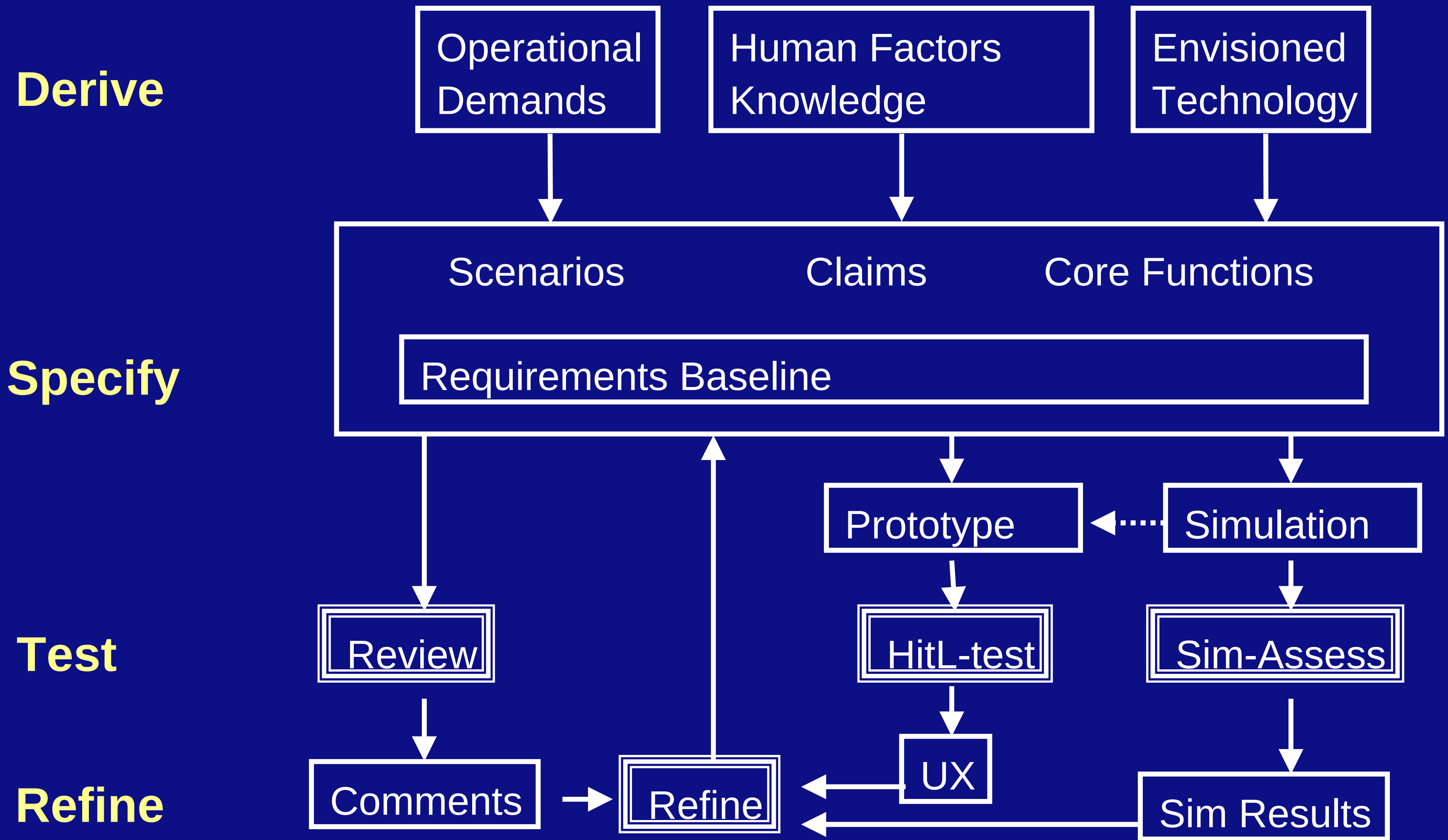
Research goals - outline

Goal: Development of complex human-machine systems

→ Situated Cognitive Engineering



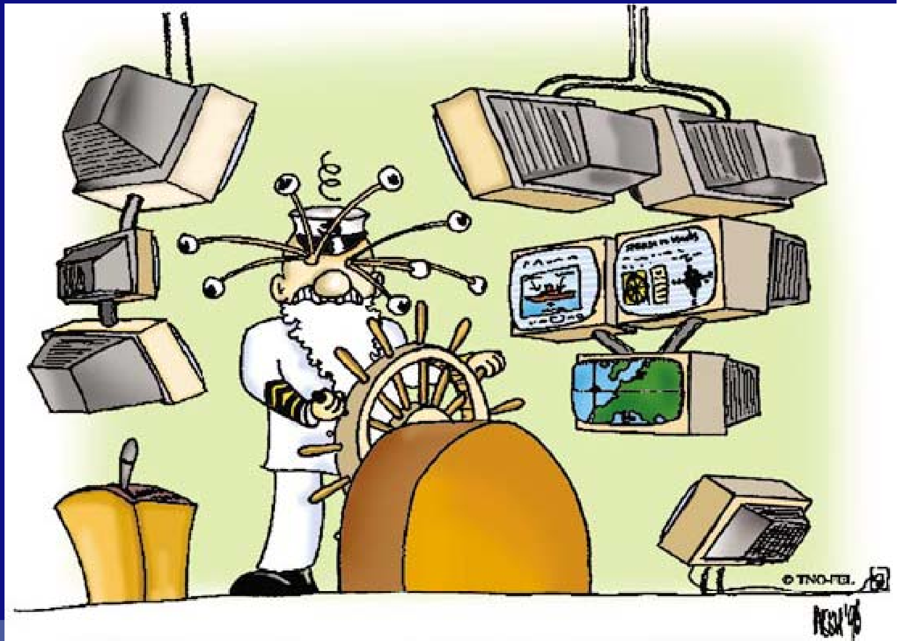
Situated Cognitive Engineering



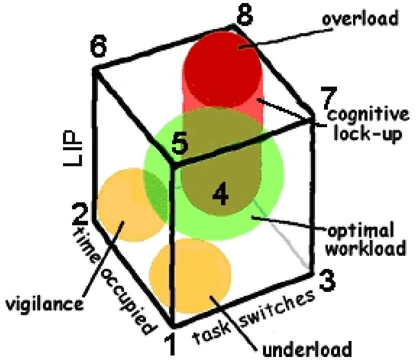
Research goals - outline

1. Measuring Cognitive Task Load (CTL model)
2. Manipulating CTL at design time (CTL method, evaluation, interface design)
3. Using CTL real time to adapt support

M. Neerincx, M.A. (2003). Cognitive task load design: model, methods and examples. In: E. Hollnagel (ed.), *Handbook of Cognitive Task Design*.



Measuring CTL
- CTL model -

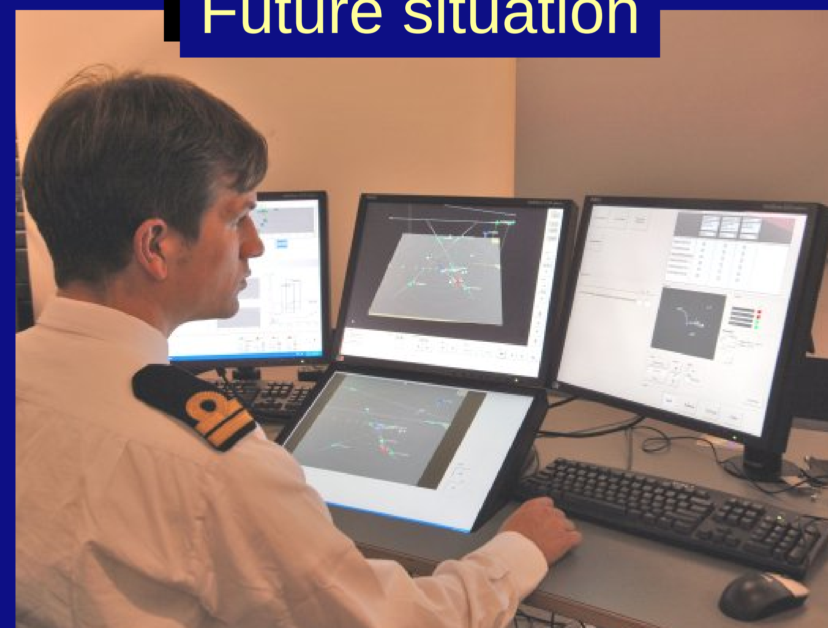


From Monitoring & Control to Supervision

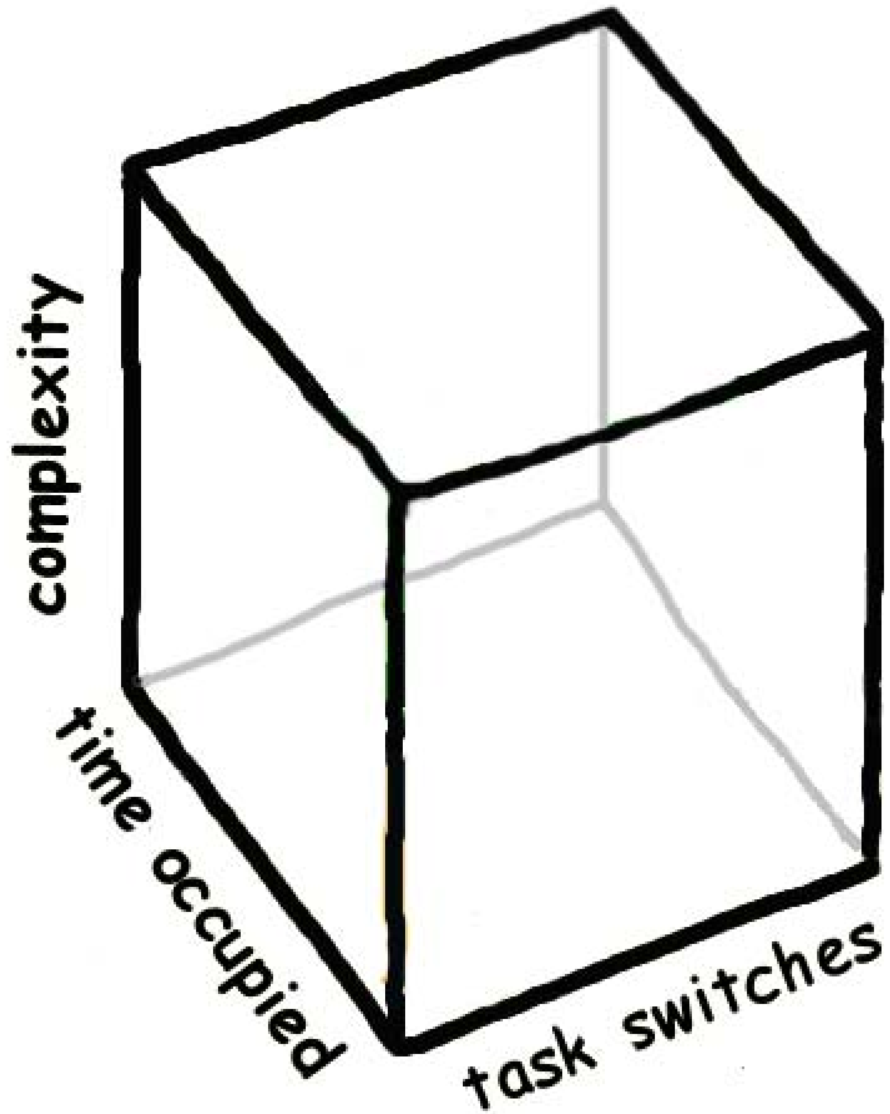
Old situation

Current situation

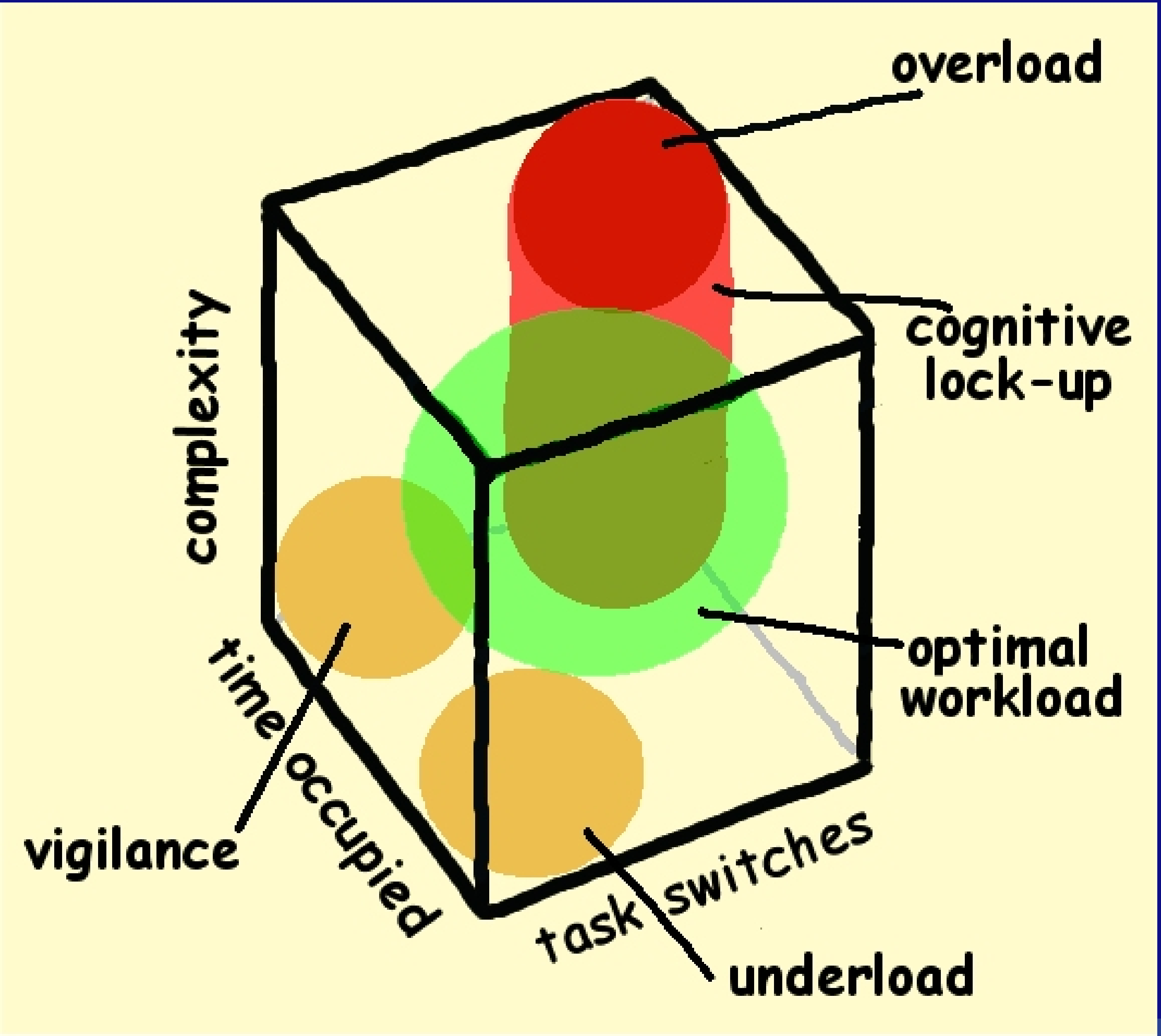
Future situation



Cognitive Task Load (CTL) Model



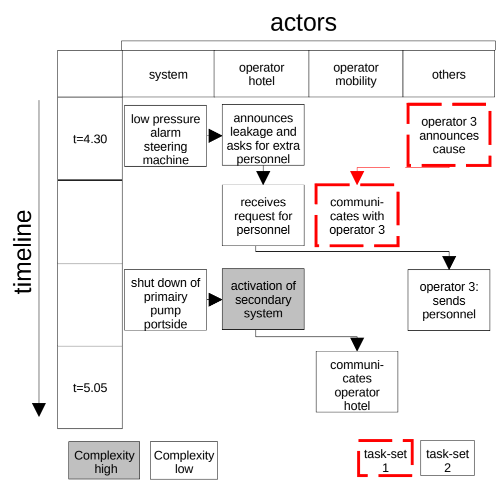
Cognitive Task Load (CTL) Model



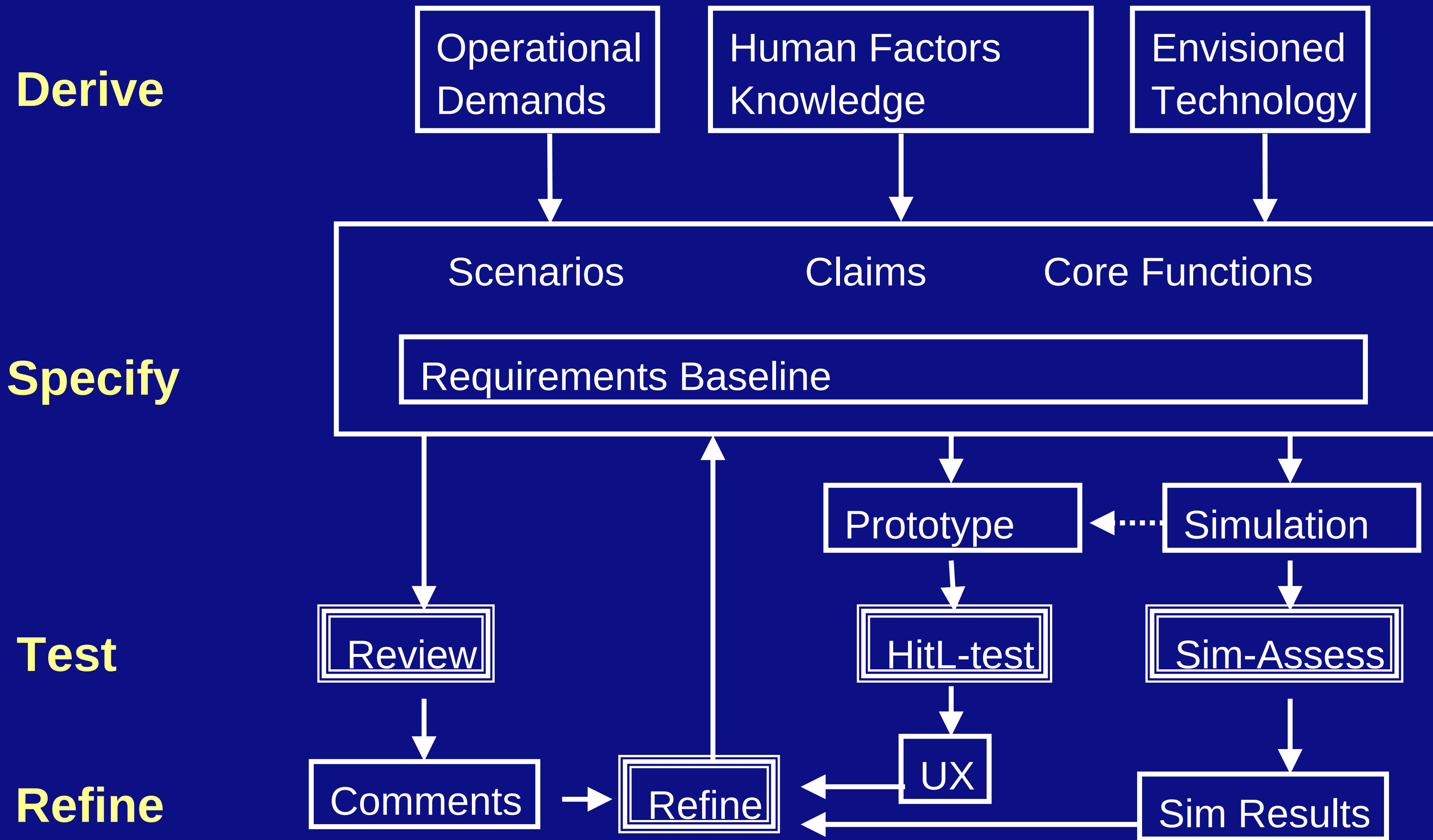
Task=Task-set

Complexity=LIP
Level of Information Processing

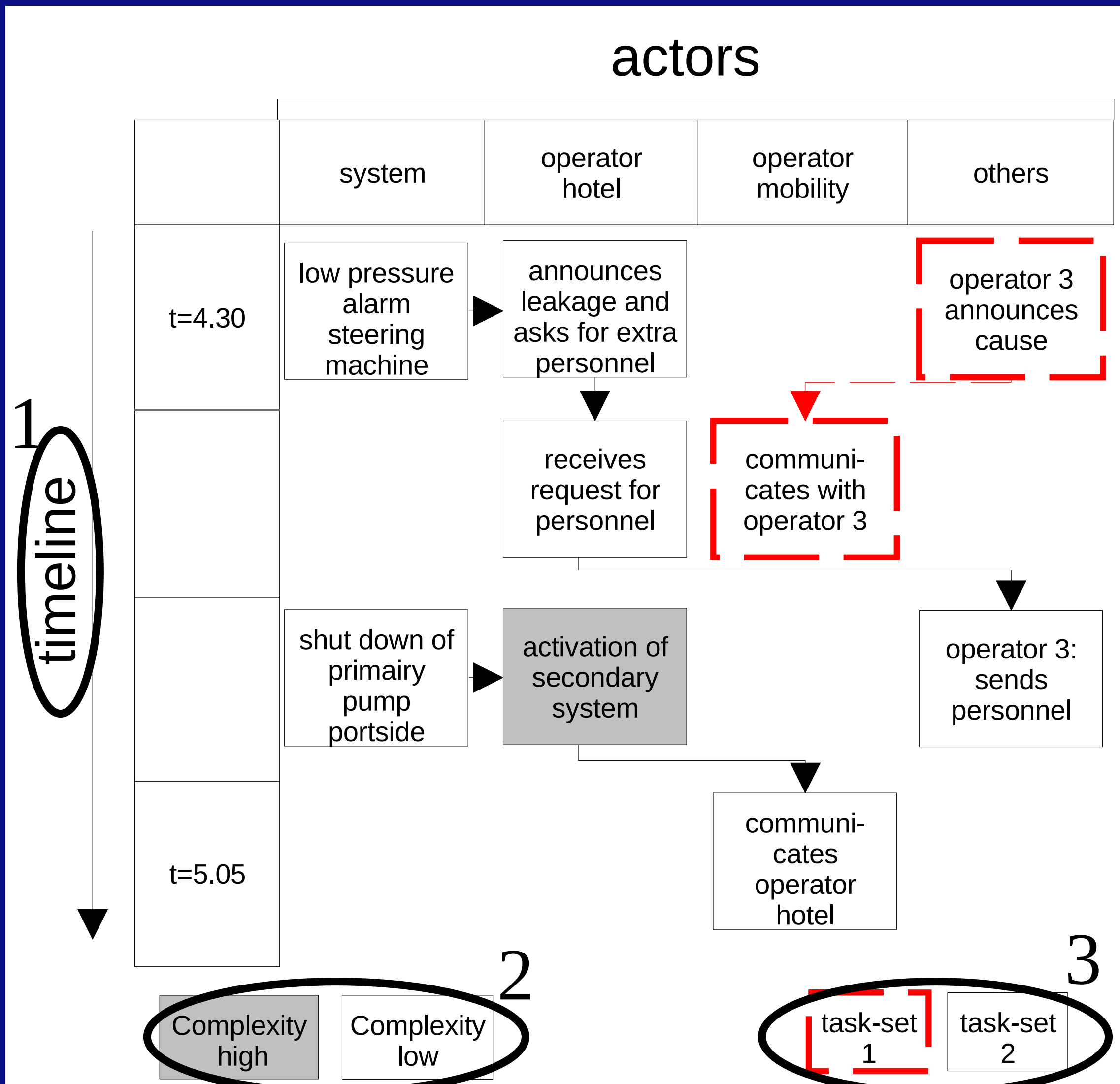
Manipulating CTL at design time
- CTL method -



Situated Cognitive Engineering



Manipulating CTL – Compound Action Sequence



CTL factors

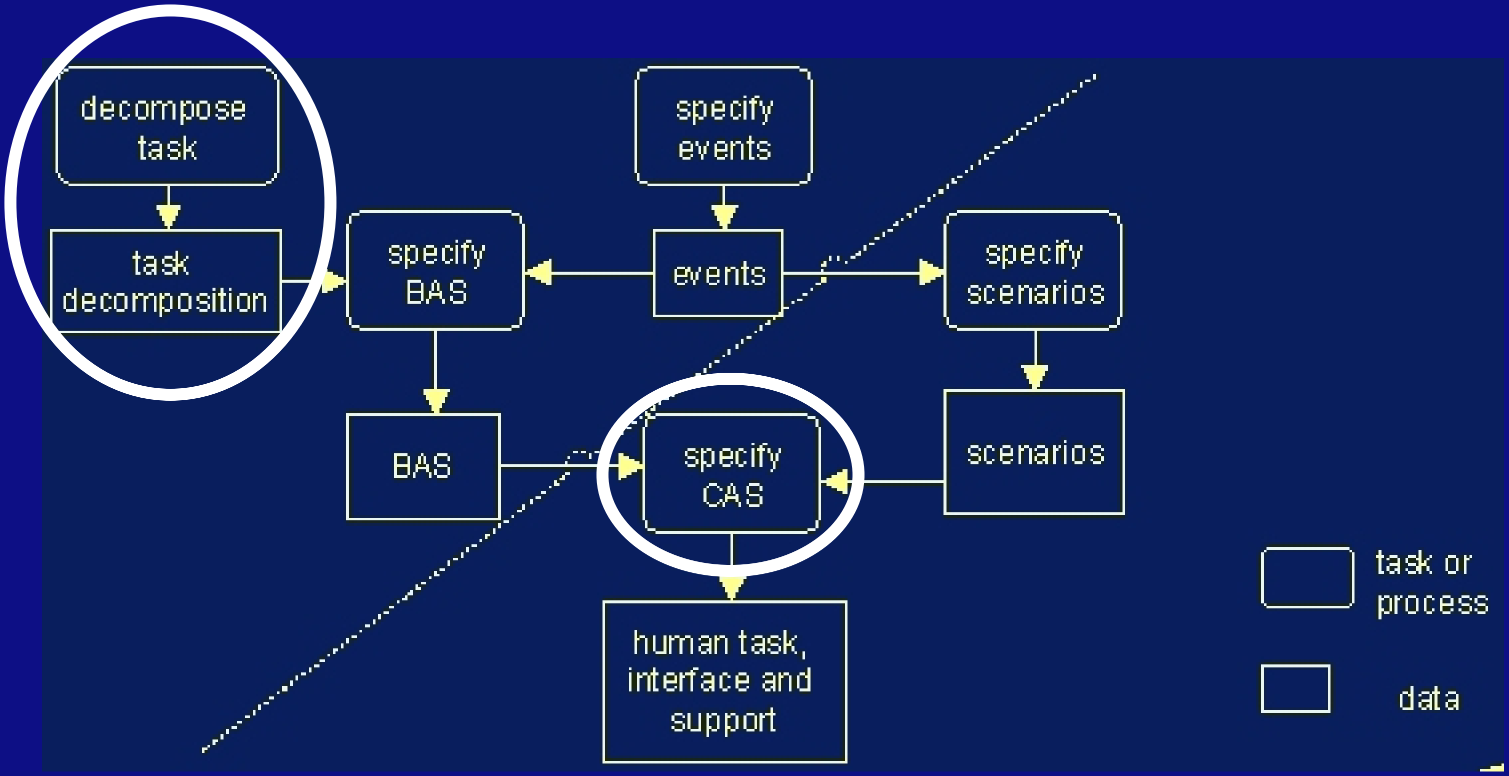
1. Time occupied
2. Complexity
3. Task switches

Tools to manipulate CTL:

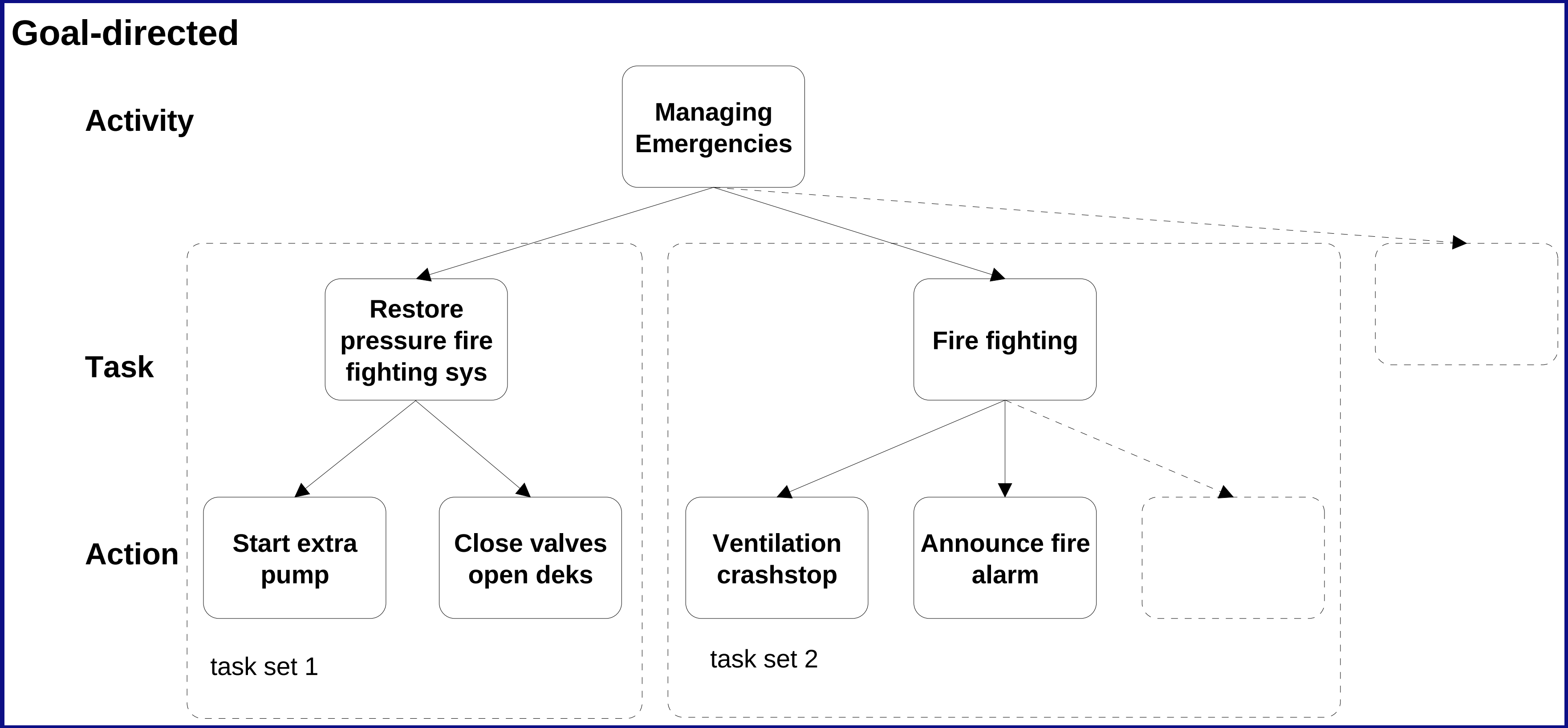
- Task allocation
- Interface support (level of automation)

The CTL Method (2)

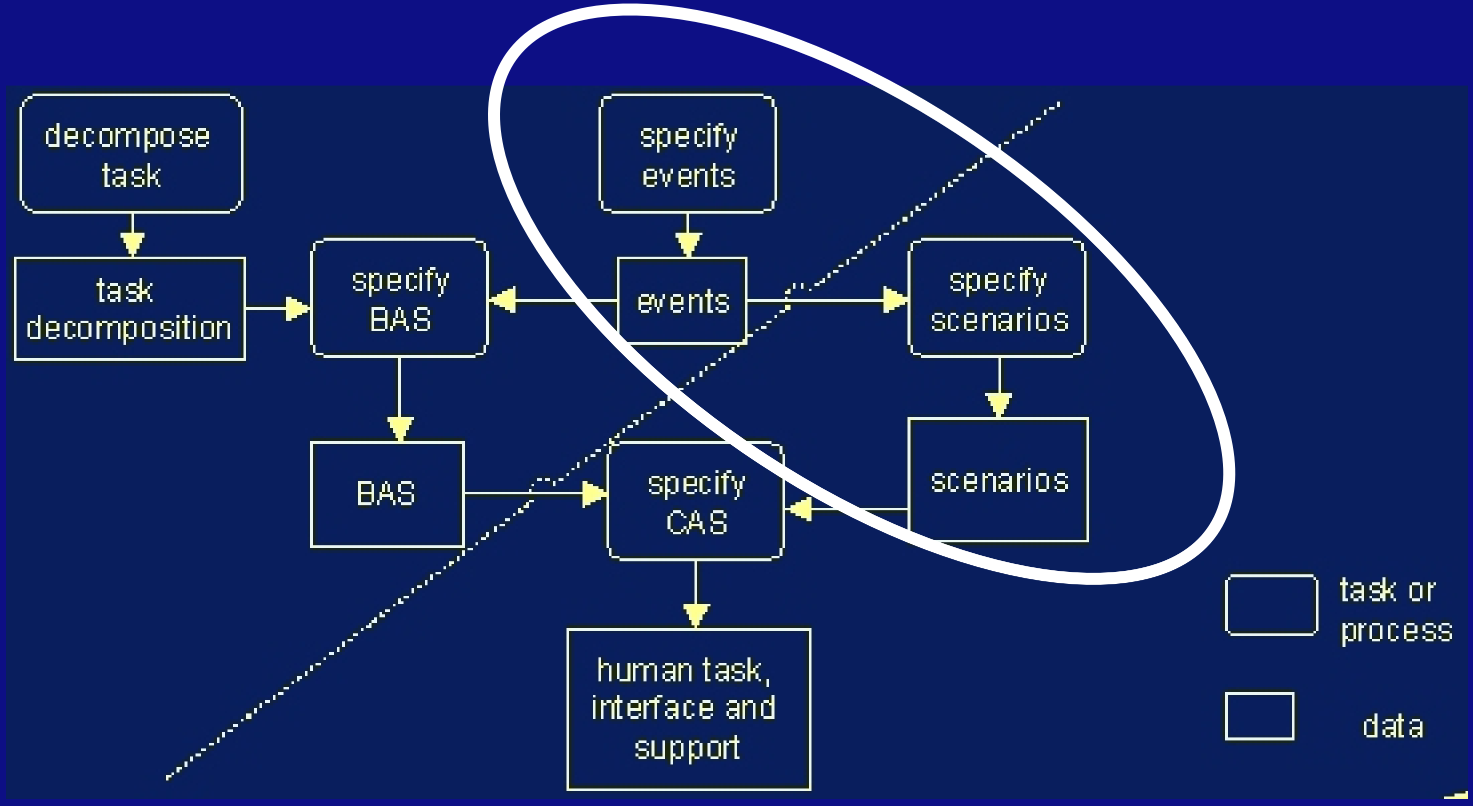
BAS= Basic Action Sequence
CAS= Compound Action Serquence



The CTL Method (3) - Task decomposition



The CTL Method (4)



The CTL Method (5) – Event list

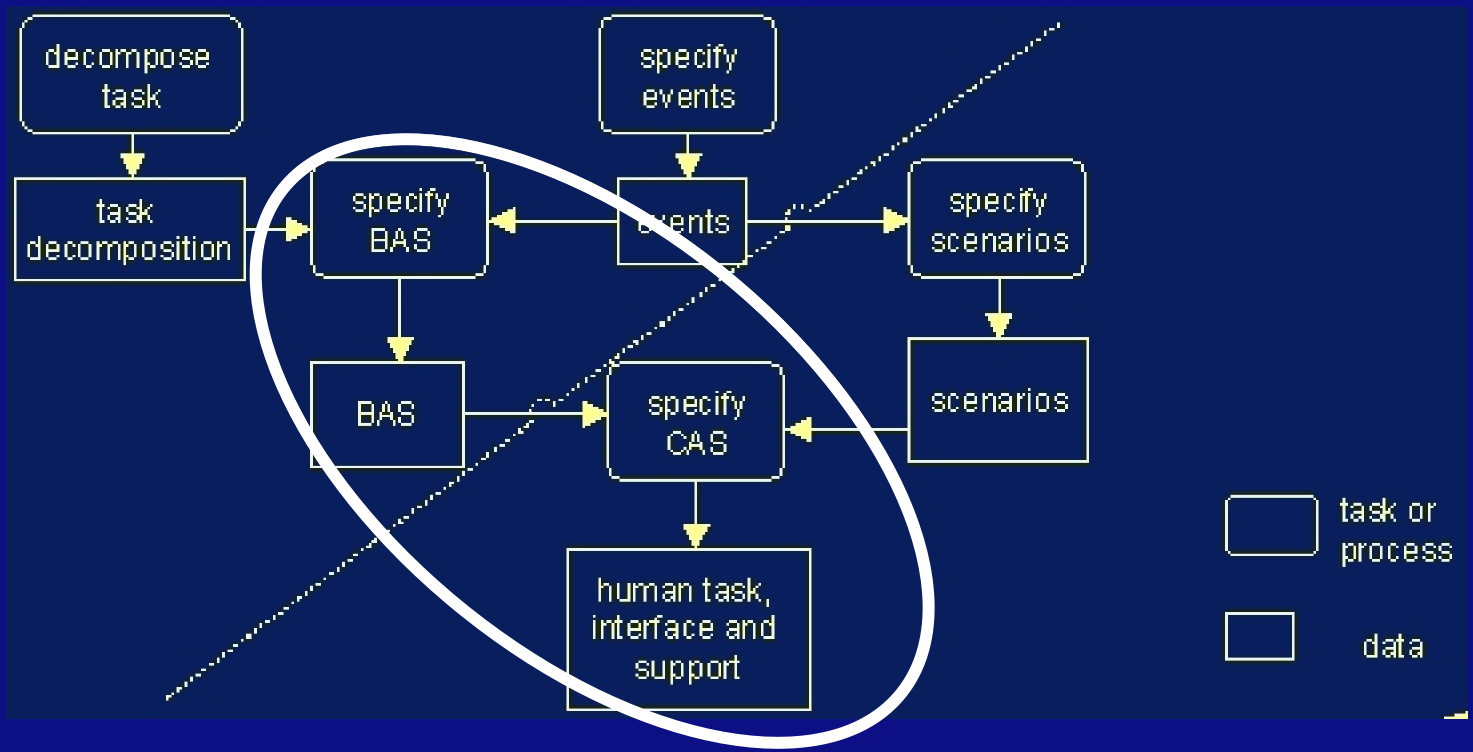
Event category			Event	Consequences
External	Weather	Current		
		Forecast	Storm approaching	Deviation of route
	Sea state	Current		
		Forecast	Sea state 8	Close all open decks for personnel
Internal				

The CTL Method (6) – Scenario Table

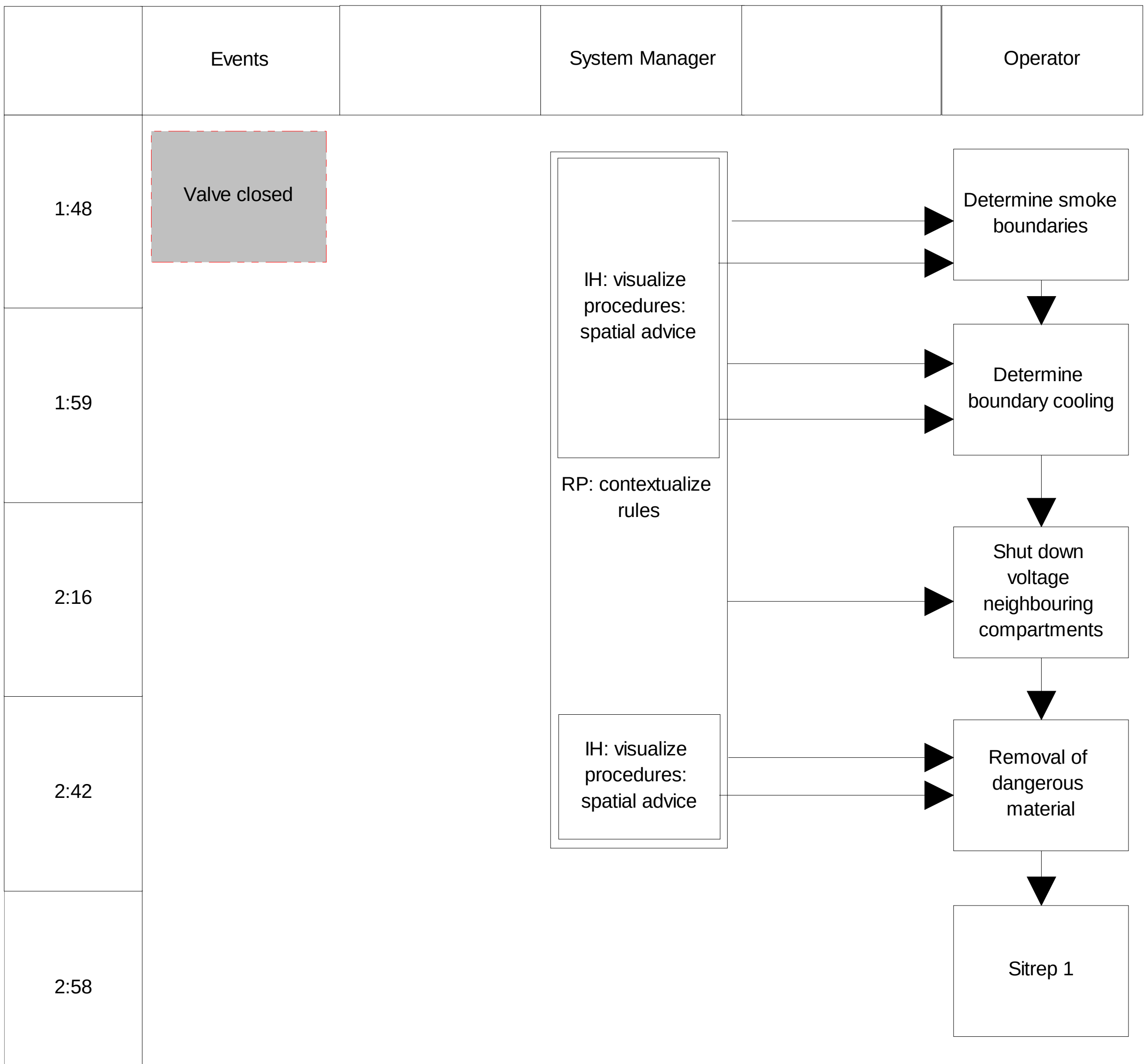
Initial state
Ship is sailing under heavy ice-conditions, clear view (13 nm), strong wind (30 knots), sea state 4

Time(min:s)	Event		
t=0:00	Fire alarm	Location	Compartment 4-65
		Details	Unknown
		Consequences	Abort current operational activities, alert fire organization
		Source	Fire sensor
t=0:42	Ventilation alarm	Location	Deck 4
		Details	Main valve in alarm
		Consequences	Oxygen supply and a violation of smoke boundary
		Source	Valve sensor
t=0:56	Fire	Location	Compartment 4-65
		Details	Too large for first attack
		Consequences	Abort current operational activities, alert fire organization
		Source	Telephone by shipmate

The CTL Method (7)



The CTL Method (8) – BAS & CAS & Support

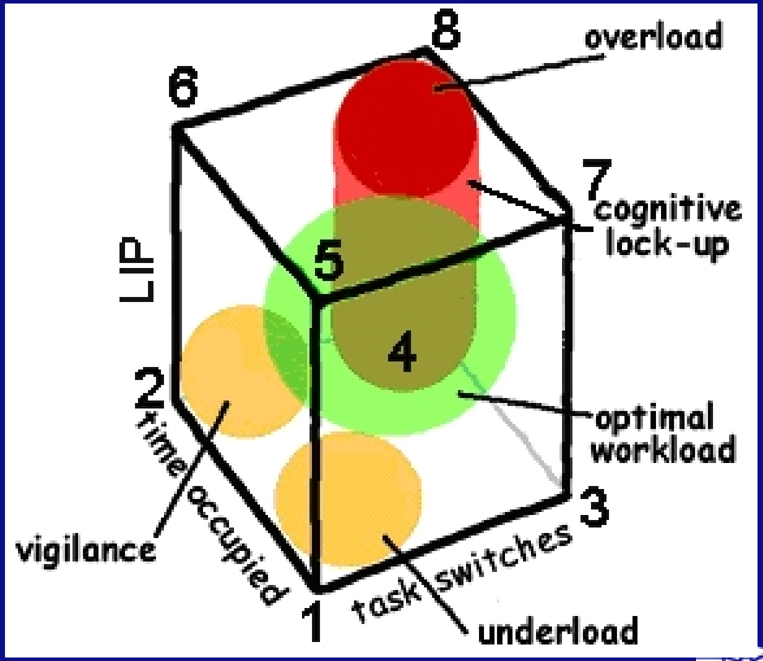


Manipulating CTL at design time
- Evaluation -

Operator Load Assessment (OLA)

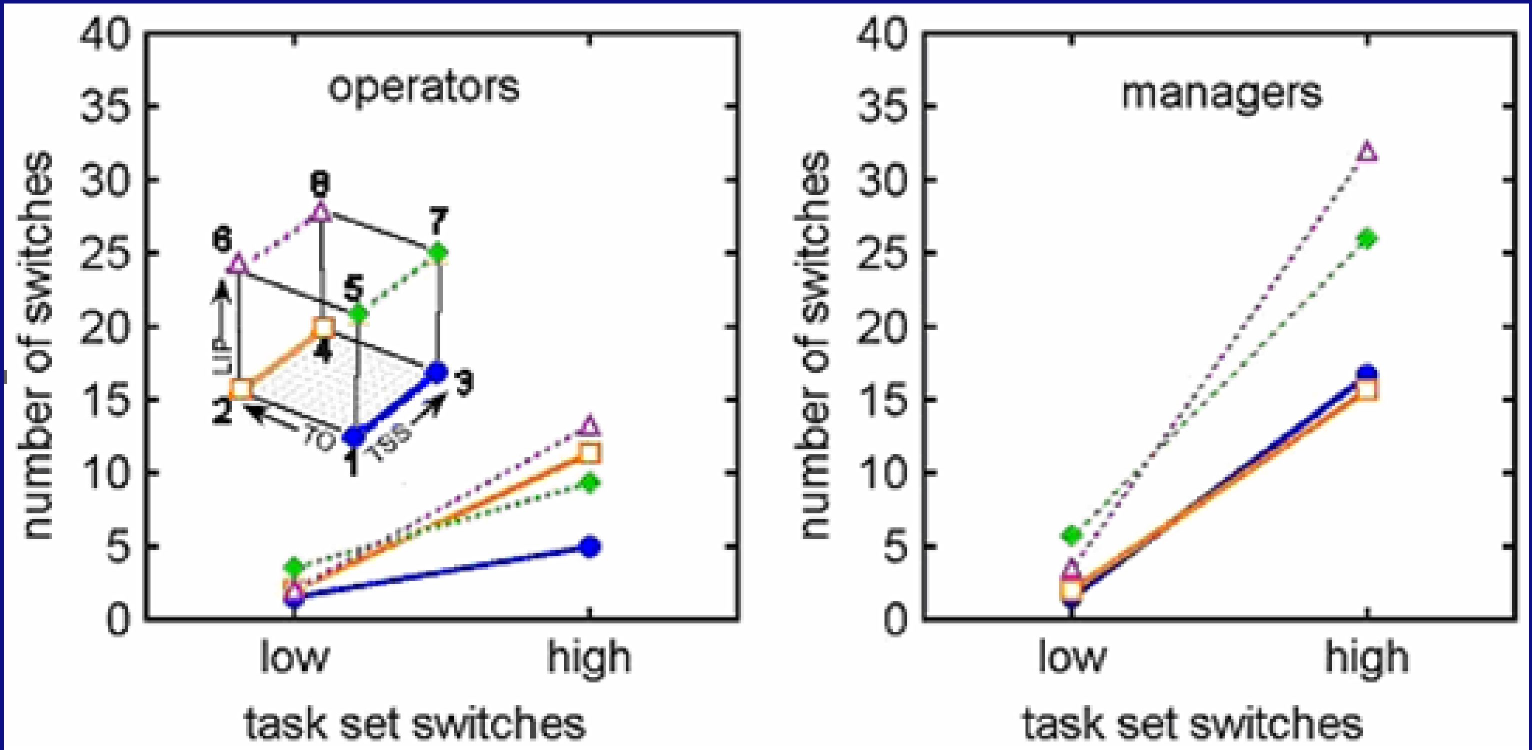
1. OLA 1: Experiment high-fidelity control centre simulator Multipurpose frigate. 8 scenarios with CTL method (high-low values)
2. OLA 2: Experiment onboard 3 ADCFs. Optimal, typical and extreme scenario.

LIP=complexity



OLA 1

- CTL method provides good prediction of the high/low values of the CTL factors.



OLA 2

Evaluation Ship Control Centre ADCF

- 3 ships
- 3 different scenarios designed with CTL method (optimal, typical, extreme).

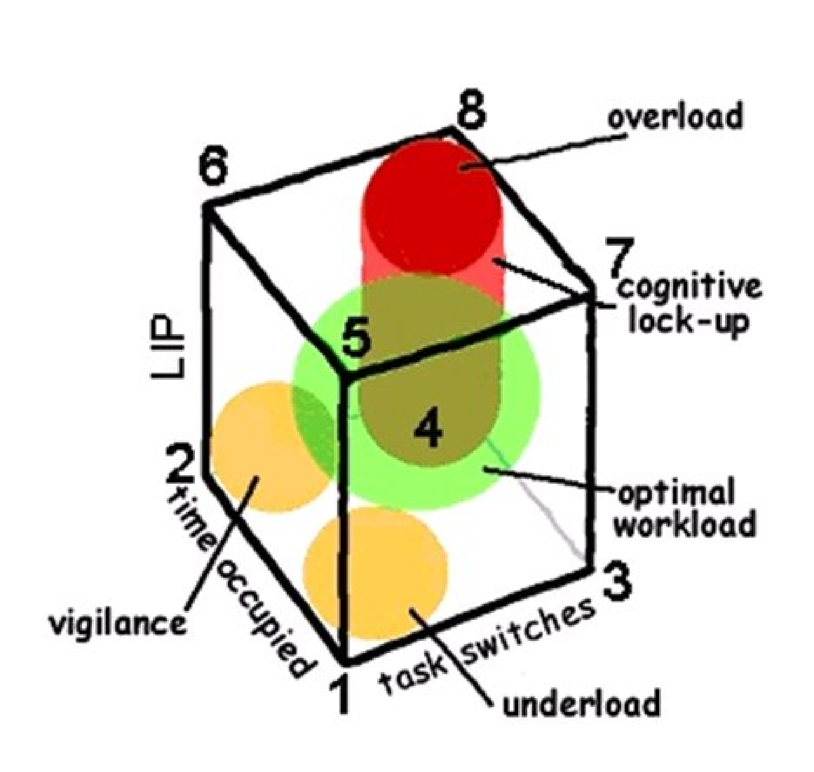
Measuring CTL

- TO,TSS,Complexity
- Subjective effort
- Performance
- Questionnaire


VMO

OLA 2

Working Condition	Scenario 1	Scenario 2	Scenario 3
	Optimal	Typical	Extreme
TO	Medium	High	High
TSS	Medium	Low	High
LIP	Medium	High	High



	Effect	Scenario optimal	Scenario typical	Scenario extreme
TO (%)	F(2, 28) = 207.89, p < .0001	48	84	79
TSS (#/min)	F(2, 28) = 25.991, p < .0001	1.57	0.78	2.14
LIP (av/min)	F(2, 24) = 26.919, p < .0001	1.62	2.75	2.93

- A numerical indication of critical and optimal CTL areas has been made

OLA 1

	Operator		Manager	
	Low	High	Low	High
TO				
TSS	0.14	0.87	0.20	1.7
LIP	1.9	2.7	2.3	2.9

OLA 2

	Operator			Manager		
	Low	Medium	High	Low	Medium	High
TO		40	79		58	86
TSS	0.35	0.77	0.97	0.25	0.89	1.3
LIP		1.7	3.1		1.6	2.7

Iterative steps during design

Using the CTL method in multiple simple iterative steps will optimize the end human-machine system.

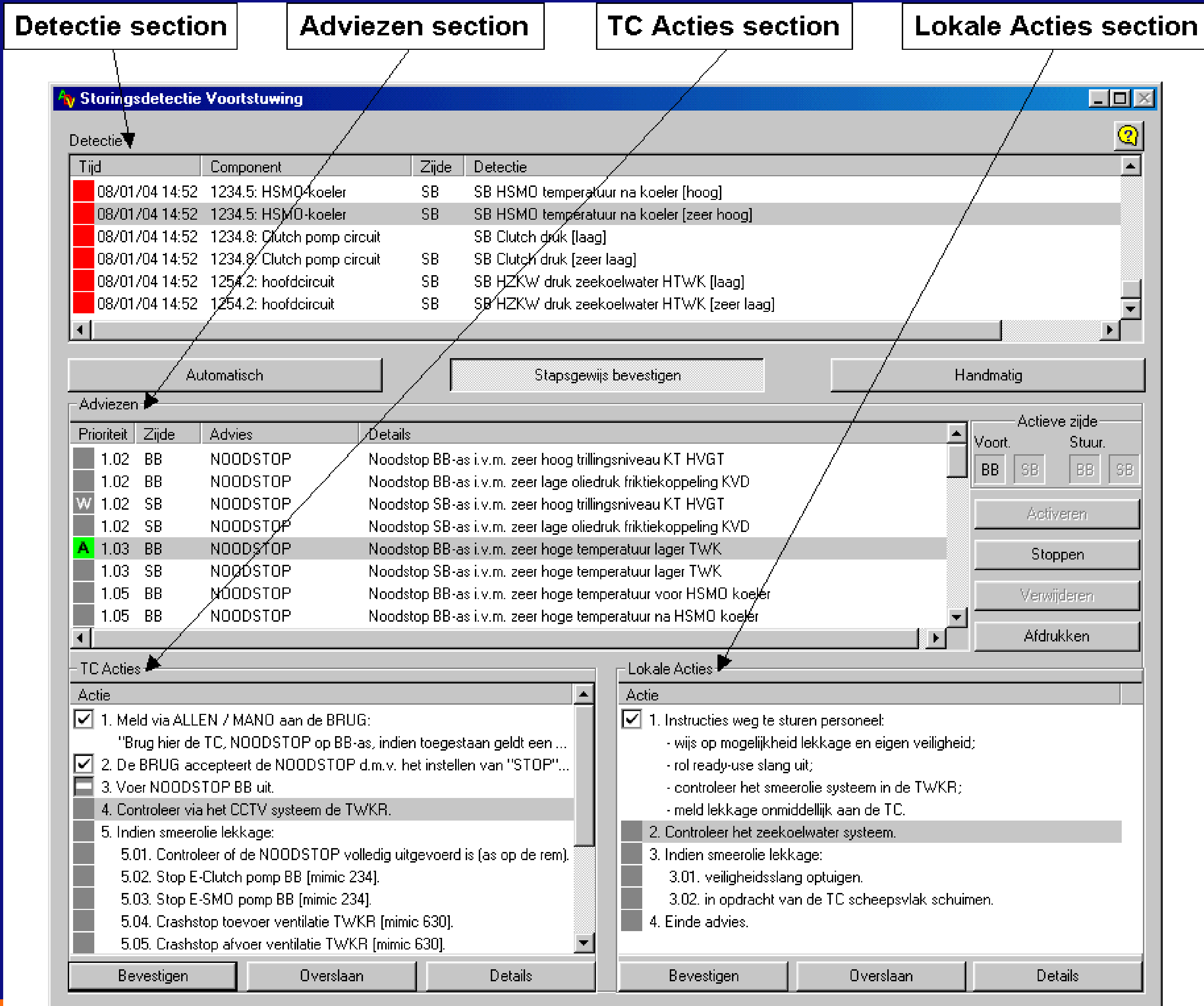
CTL method for evaluation

At which cognitive task load does the support function at an optimum level?

LOA 0 = old-fashioned manual

LOA 2 = Semi-auto

LOA 3 = Auto


Detectie section
Adviezen section
TC Acties section
Lokale Acties section
Storingsdetectie Voortstuwing
Detectie
Tijd | Component | Zijde | Detectie
08/01/04 14:52 1234.5: HSMO-koeler SB SB HSMO temperatuur na koeler [hoog]
08/01/04 14:52 1234.5: HSMO-koeler SB SB HSMO temperatuur na koeler [zeer hoog]
08/01/04 14:52 1234.8: Clutch pomp circuit SB Clutch druk [laag]
08/01/04 14:52 1234.8: Clutch pomp circuit SB SB Clutch druk [zeer laag]
08/01/04 14:52 1254.2: hoofdcircuit SB SB HZKW druk zeekoelwater HTWK [laag]
08/01/04 14:52 1254.2: hoofdcircuit SB SB HZKW druk zeekoelwater HTWK [zeer laag]
Automatisch
Stapsgewijs bevestigen
Handmatig
Adviezen
Prioriteit | Zijde | Advies | Details
1.02 BB NOODSTOP Noodstop BB-as i.v.m. zeer hoog trillingsniveau KT HVGT
1.02 BB NOODSTOP Noodstop BB-as i.v.m. zeer lage oliedruk friktiekoppeling KVD
W 1.02 SB NOODSTOP Noodstop SB-as i.v.m. zeer hoog trillingsniveau KT HVGT
1.02 SB NOODSTOP Noodstop SB-as i.v.m. zeer lage oliedruk friktiekoppeling KVD
A 1.03 BB NOODSTOP Noodstop BB-as i.v.m. zeer hoge temperatuur lager TWK
1.03 SB NOODSTOP Noodstop SB-as i.v.m. zeer hoge temperatuur lager TWK
1.05 BB NOODSTOP Noodstop BB-as i.v.m. zeer hoge temperatuur voor HSMO koeler
1.05 BB NOODSTOP Noodstop BB-as i.v.m. zeer hoge temperatuur na HSMO koeler
Actieve zijde
Voort.
Stuur.
BB
SB
BB
SB
Activeren
Stoppen
Verwijderen
Afdrukken
TC Acties
Actie
1. Meld via ALLEN / MANO aan de BRUG:
"Brug hier de TC, NOODSTOP op BB-as, indien toegestaan geldt een ...
2. De BRUG accepteert de NOODSTOP d.m.v. het instellen van "STOP"...
3. Voer NOODSTOP BB uit.
4. Controleer via het CCTV systeem de TWKR.
5. Indien smeerolie lekkage:
5.01. Controleer of de NOODSTOP volledig uitgevoerd is (as op de rem).
5.02. Stop E-Clutch pomp BB [mimic 234].
5.03. Stop E-SMO pomp BB [mimic 234].
5.04. Crashstop toevoer ventilatie TWKR [mimic 630].
5.05. Crashstop afvoer ventilatie TWKR [mimic 630].
Bevestigen
Overslaan
Details
Lokale Acties
Actie
1. Instructies weg te sturen personeel:
- wijs op mogelijkheid lekkage en eigen veiligheid;
- rol ready-use slang uit;
- controleer het smeerolie systeem in de TWKR;
- meld lekkage onmiddellijk aan de TC.
2. Controleer het zeekoelwater systeem.
3. Indien smeerolie lekkage:
3.01. veiligheidsslang optuigen.
3.02. in opdracht van de TC scheepsvlak schuimen.
4. Einde advies.
Bevestigen
Overslaan
Details

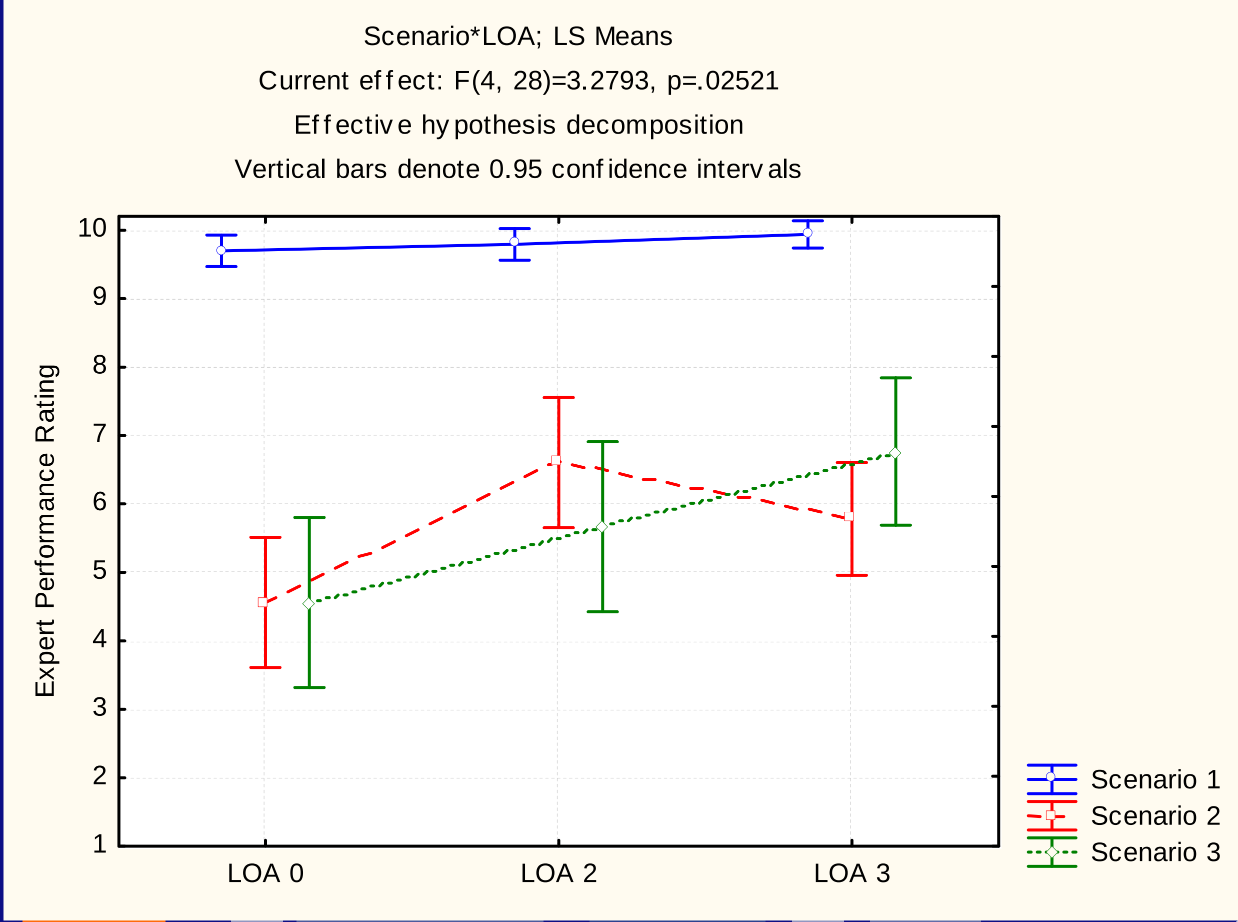
CTL method for evaluation

At which cognitive task load does the support function at an optimum level?

LOA 0 = old-fashioned manual

LOA 2 = Semi-auto

LOA 3 = Auto

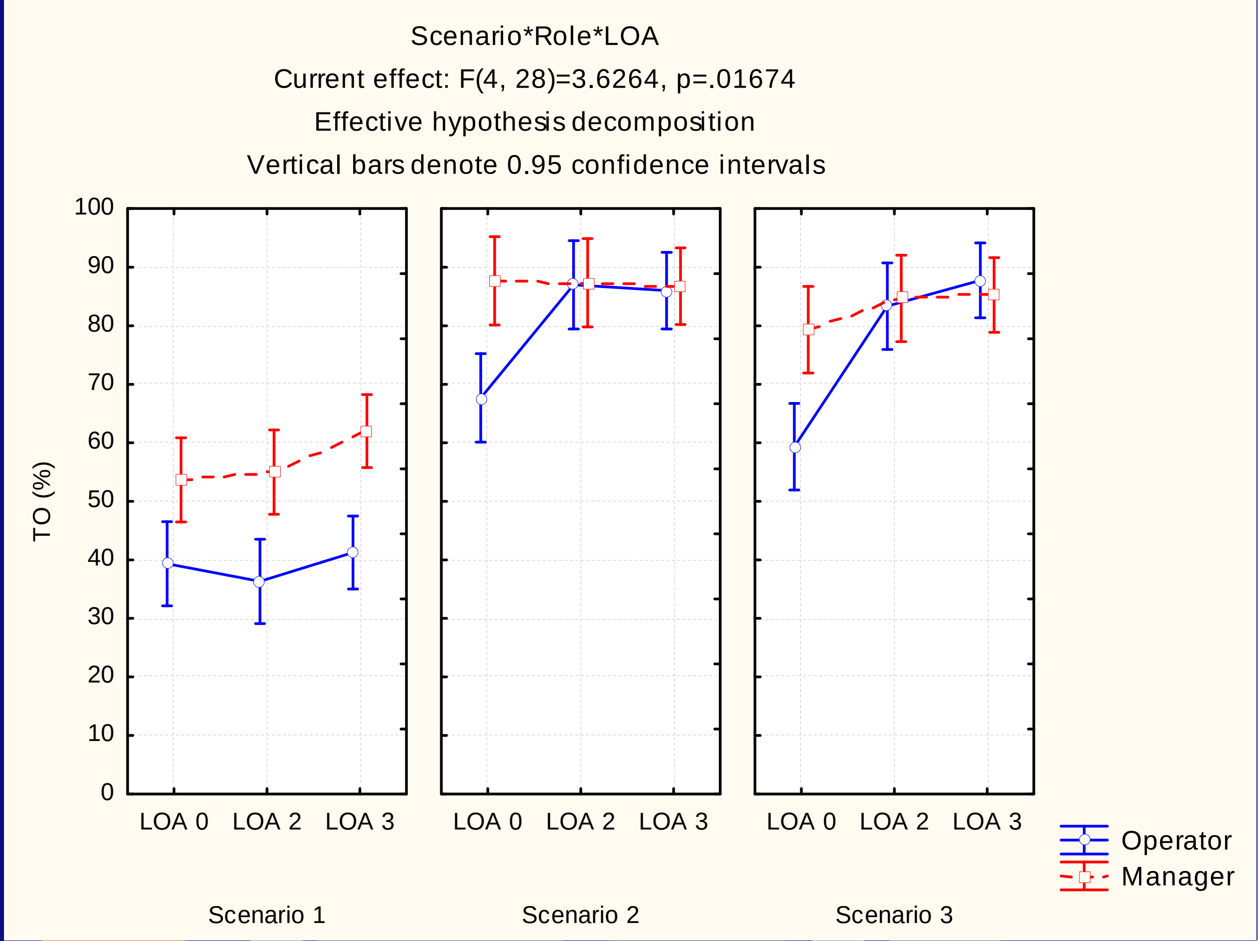


CTL method for evaluation

LOA 0 = old-fashioned manual

LOA 2 = Semi-auto

LOA 3 = Auto

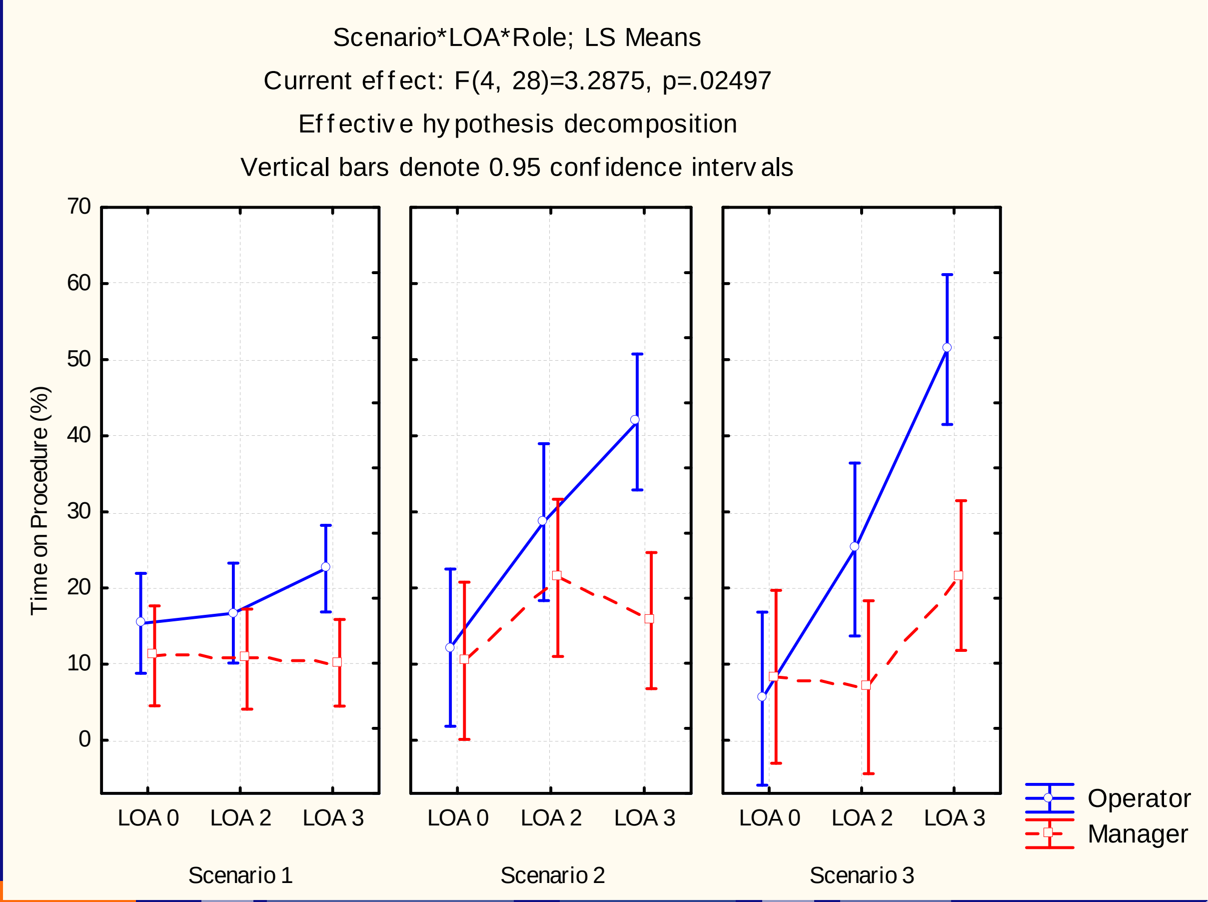


CTL method for evaluation

LOA 0 = old-fashioned manual

LOA 2 = Semi-auto

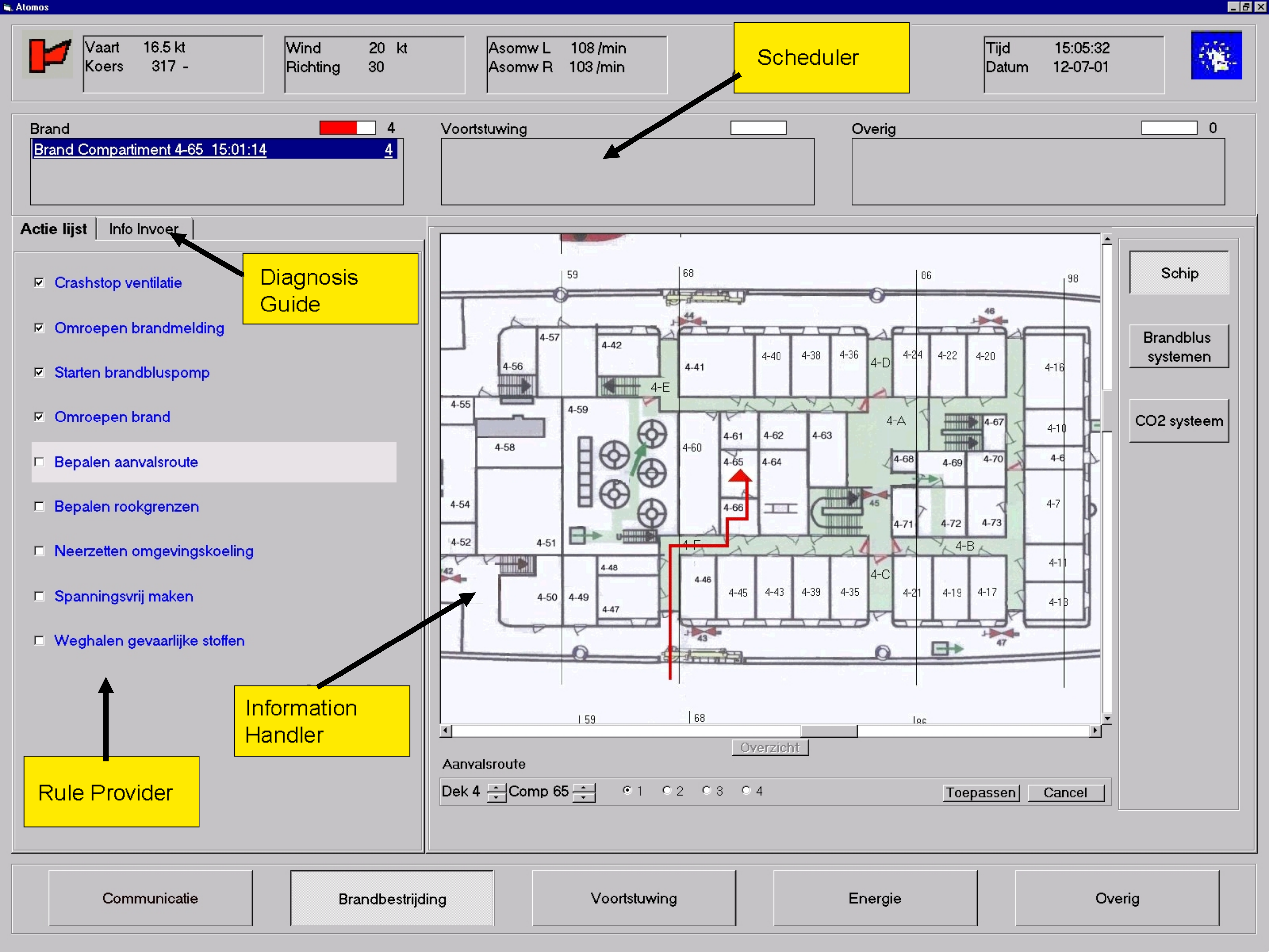
LOA 3 = Auto



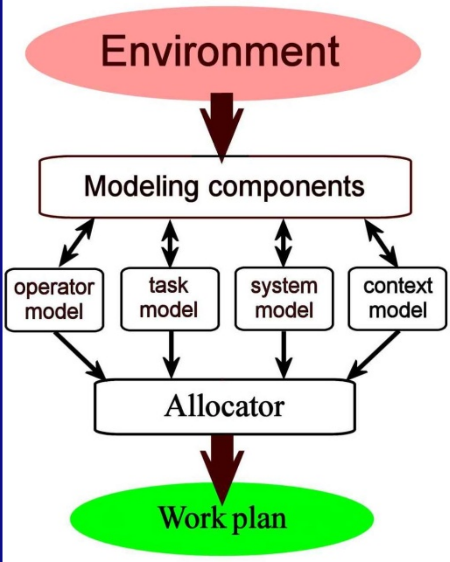
Summary CTL method

1. Powerful design and evaluation tool for user centred design
2. Values determined in several evaluations can be used in the design of new systems in this domain
3. Using the CTL method in multiple simple iterative steps will optimize the end human-machine system

Manipulating CTL at design time
- Interface support -


Atomos
Vaart 16.5 kt
Koers 317 -
Wind 20 kt
Richting 30
Asomw L 108 /min
Asomw R 103 /min
Scheduler
Tijd 15:05:32
Datum 12-07-01
Brand 4
Brand Compartiment 4-65 15:01:14 4
Voortstuwing
Overig 0
Actie lijst
Info Invoer
Diagnosis Guide
Crashstop ventilatie
Omroepen brandmelding
Starten brandbluspomp
Omroepen brand
Bepalen aanvalsroute
Bepalen rookgrenzen
Neerzetten omgevingskoeling
Spanningsvrij maken
Weghalen gevaarlijke stoffen
Information Handler
Rule Provider
Schip
Brandblus systemen
CO2 systeem
Overzicht
Aanvalsroute
Dek 4
Comp 65
1
2
3
4
Toepassen
Cancel
Communicatie
Brandbestrijding
Voortstuwing
Energie
Overig

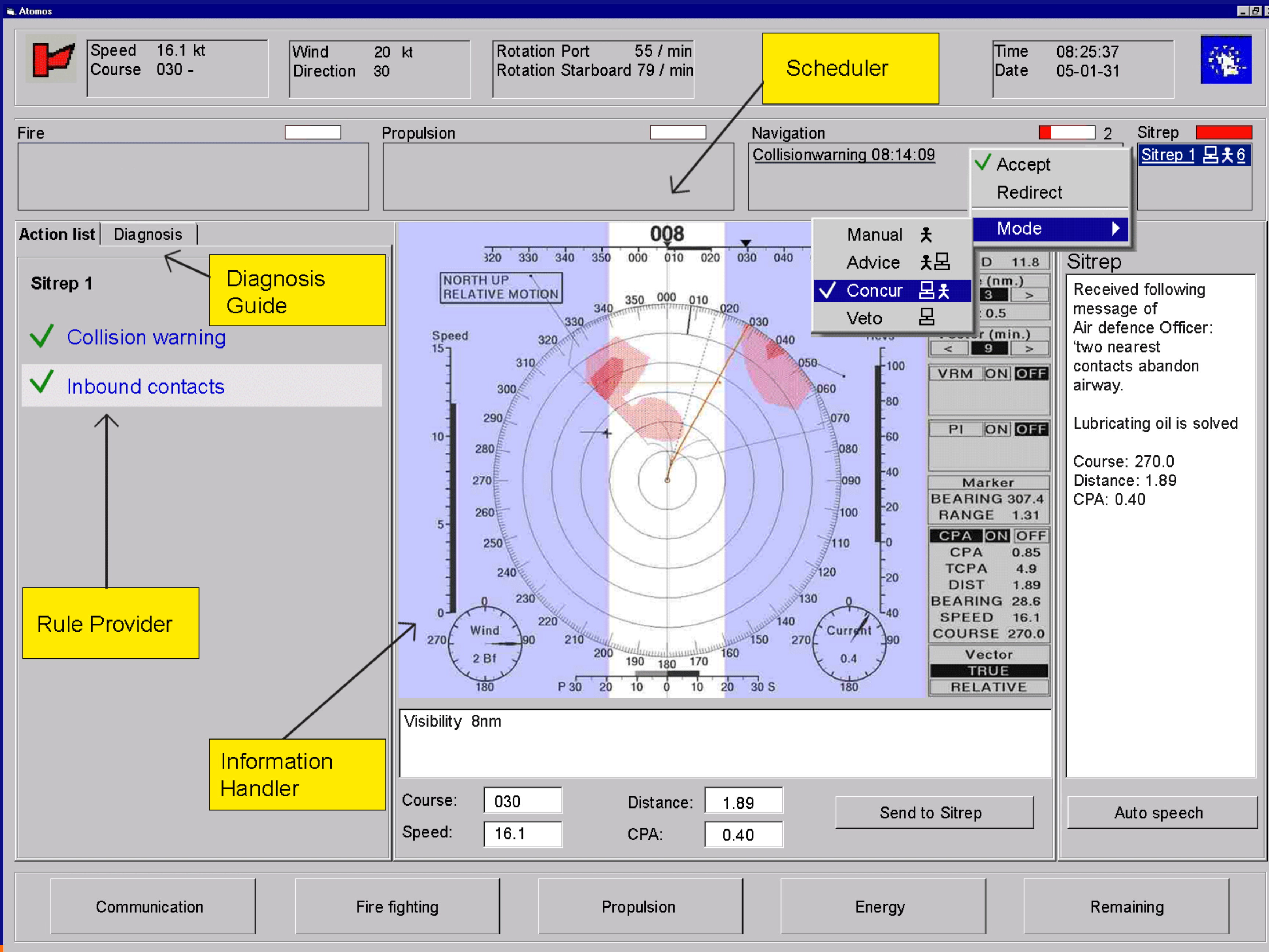
Using real-time CTL to adapt support
- ADIOS -



Real-time CTL to adapt support

1. Can we detect operator taskload (time occupied, task switches & complexity) real time?
2. can we identify critical regions (performance & effort)?
3. can we use this information to adapt support (task allocation & level of automation) to the actual CTL of the user?

ADIOS: Adaptive Interface for Operational Support



ADIOS 3

Can we create an adaptive system, where support is based on the actual task load of the operator.

Experiment in Rotterdam, STC

+- 60 participants

Using maritime scenarios (bridge and platform)

2 conditions

- Advice
- Adaptive (switching between Manual-advice-auto)

ADIOS 3

1. Measuring Complexity (manual – advice)
2. Condition 1: Advice mode
3. Generation task load areas (SOWAT)
4. Condition 2: Adaptive support mode

5. Extra: Workload feedback, Situational awareness display

Measuring

- Cognitive task load
- Performance
- Subjective effort
- Questionnaire (Usability, trust, Situational Awareness)

ADIOS 3

Film

Summary

1. We can generate critical regions of performance and effort and use these areas in combination with real time CTL to adapt support. Important issues are situational awareness and trust.

Summary

Summary

Goal: Development of complex human-machine systems
→ Situated Cognitive Engineering

1. Measuring Cognitive Task Load (CTL model)
2. Manipulating CTL at design time (CTL method, evaluation, interface design)
3. Using CTL real time to adapt support

Contact & More information

- Marc@Grootjen.nl
- http://mmi.tudelft.nl
- http://www.augmentedcognition.org/
- http://yukon.twi.tudelft.nl/weblectures/Usability/CT%20Analysis%20and%20Adaptive%20Interfaces%20in%20Process%20Control_files/Default.htm