

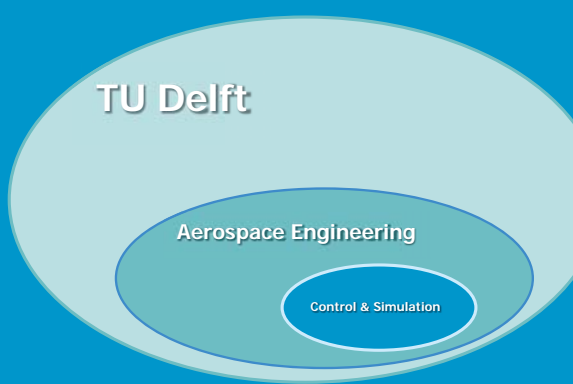
Designing for Situation Awareness

-the world behind the glass-

Max Mulder

Human Factors in Control
Oslo, October 12, 2016

aerospace human-machine systems



TU Delft

Aerospace Engineering

Control & Simulation

Oslo 2016

today

- brief recap : situation awareness
- our work : *ecological* flight deck design
- example : airborne separation assistance
- closing statements

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situation awareness

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Literature on SA

Endsley (1995): "the *perception* of environmental elements and events with respect to time or space, the *comprehension* of their meaning, and the *projection* of their status into the future"

27 definitions of SA, and this number is still growing

SITUATION

????

AWARENESS

SPAM SAGAT SART
SABARS WOMBAT

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ecological flight deck design

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why do we need to study humans in the aerospace domain?



>70 % of all accidents is attributed to *human error*

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response options

- fire the pilot
- **improve training**
- better maintenance, improve reliability
- adapt procedures
- add automation/warning systems (TCAS, EGPWS)
- **improve the interface**

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why do we need to study humans in the aerospace domain?

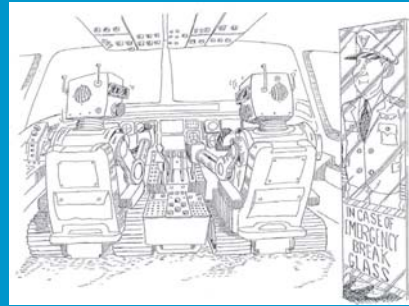


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enormous cost reductions through automation...

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why do we need to study humans in the aerospace domain?



...changing roles of humans

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the evolving cockpit



© Tony Decker

Yes, all information is presented to the pilot. But, in doing so, all cognition needs to be done by the human

High workload, low performance



© Tony Decker

Yes, most tasks are automated. But, in doing so, only a small part of the cognition needs to be done by the human

Low workload, low situation awareness

our approach: design systems in which cognition is a joint process

ISAP 2013

levels in interface design

- illumination, readability, colors, symbols
- integrated displays, configural displays, emergent features, principle of moving part
- ...so, what's next?



© Tony Decker

ISAP 2013

the flight deck is . . .

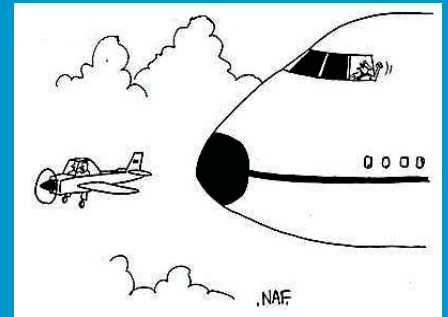
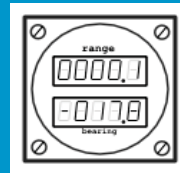
- an "OPEN" system (Vicente)
 - extensive + complex interaction with the environment
- "the airborne office"



. . . a workplace for **cognitive** (team)work

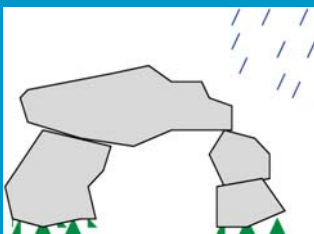
ISAP 2013

. . . is there an approach to automation and interface design that helps pilots with their (cognitive) tasks?



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human capabilities "direct perception" – Gibson



affording
specifying

perception-action
coupling

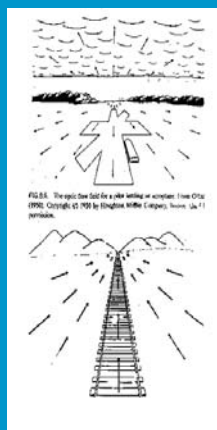


FIG. 8.8. The explicit flow field for a pilot walking on a runway. From Vicente (1992). Copyright © 1992 by Elsevier North-Holland Company, Inc. All rights reserved.

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ecological interface design

(Vicente & Rasmussen, 1992)

Basic idea: "make visible the invisible"

Use technology to create an interface that provides meaningful information and that allows humans to directly act on the information to achieve their goals

Transfer a cognitive process into a perceptual process

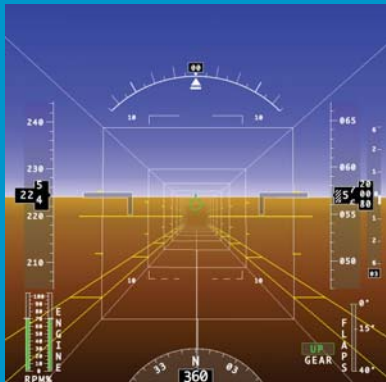
Work Domain Analysis

+ Control task analysis
Strategies analysis
Social organization and cooperation
Worker competencies analysis

Interface design

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some "Delft" ecological interfaces



Aircraft control
Total Energy Management

Oslo 2016



some "Delft" ecological interfaces



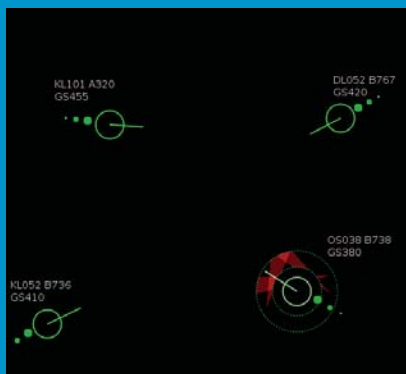
Aircraft control
Total Energy Management

Aircraft control
Separation Assistance

Oslo 2016



some "Delft" ecological interfaces



Aircraft control
Total Energy Management

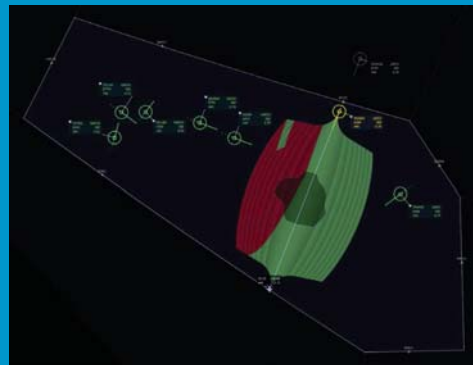
Aircraft control
Separation Assistance

Air traffic control
Separation Assistance

Oslo 2016



some "Delft" ecological interfaces



Aircraft control
Total Energy Management

Aircraft control
Separation Assistance

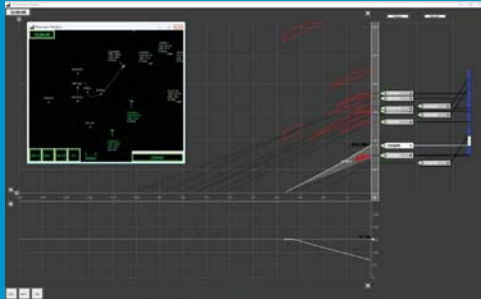
Air traffic control
Separation Assistance

Air traffic control
4D trajectory management

Oslo 2016



some "Delft" ecological interfaces



- Aircraft control**
Total Energy Management
- Aircraft control**
Separation Assistance
- Air traffic control**
Separation Assistance
- Air traffic control**
4D trajectory management
- Air traffic control**
Arrival management

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airborne separation assistance

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airborne separation assistance

Airborne Separation Assistance System (ASAS): "The equipment, protocols, airborne surveillance and other aircraft state data, flight crew and ATC procedures which enable the pilot to exercise responsibility, in agreed and appropriate circumstances, for separation of his aircraft from one or more aircraft." (source ICAO SICASP/6-WP/44)

ASAS functionalities:

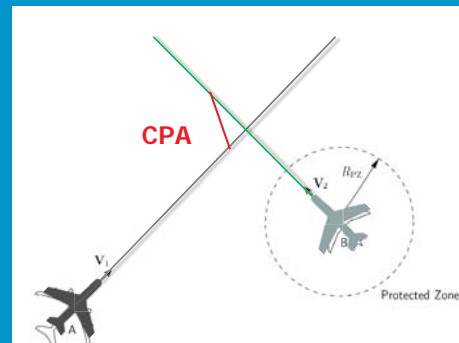
1. Maintaining an **overview** of the surrounding traffic
2. **Detecting** potential loss of separation conflicts
3. **Resolving** conflicts
4. **Preventing** aircraft to run into new conflicts

our example
2D only

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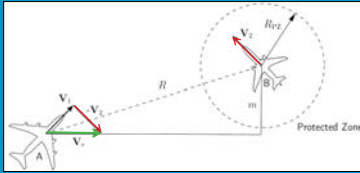
airborne separation assistance

What is the problem?



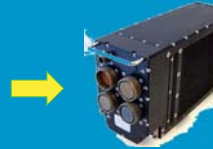
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typical engineering approach



TRAFFIC!

IF ($t_m \leq \text{look-ahead time}$) AND ($|m| < R_{PZ}$)
 conflict = TRUE
 ELSE
 conflict = FALSE



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pitfalls of automation

- hidden rationale
- intent confusion
- reduced situation awareness
- disagreement
- overreliance
- lack of trust
- ...

WHAT is it doing? WHY is it doing that? It is doing it AGAIN!??

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EID: work domain analysis

Functional Purpose	Production	Efficiency	Safety	
Abstract Functions	Absolute & relative locomotion		Separation	WHY?
Generalized Functions	Maneuvering Coordination		Obstruction	WHAT??
Physical Functions	Control units		Traffic	HOW?
Physical Form	Location & state of own aircraft		Other aircraft locations & states	

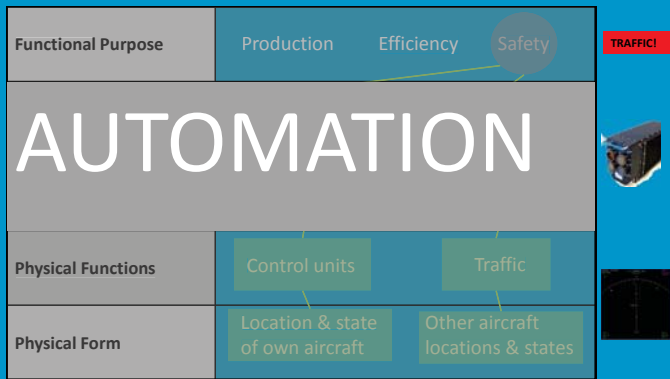
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EID: work domain analysis

Functional Purpose	Production	Efficiency	Safety
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Generalized Functions	Maneuvering Coordination		Obstruction
Physical Functions	Control units		Traffic
Physical Form	Location & state of own aircraft		Other aircraft locations & states

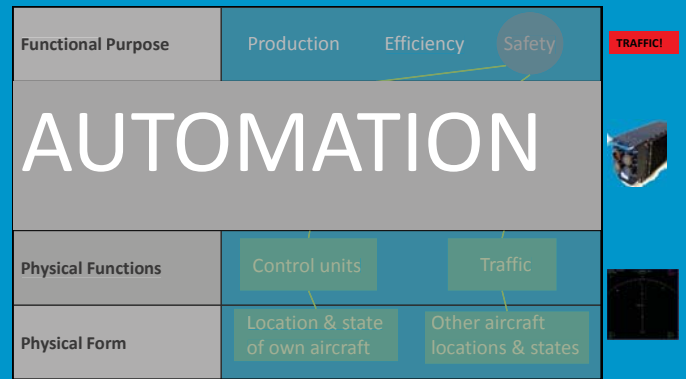
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typical automation & interface in the AH



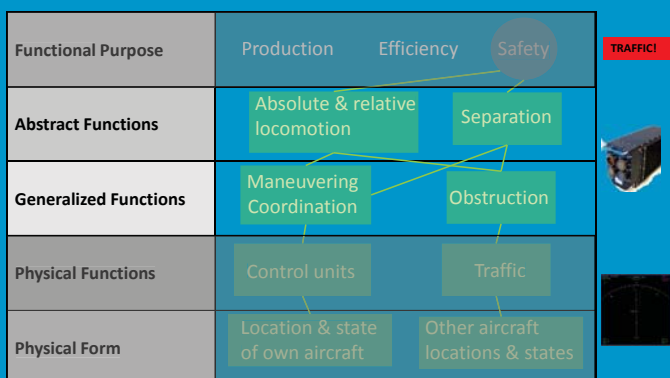
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make visible the invisible



Oslo 2016

make visible the invisible



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improve the interface: visualise the CPA

- conflict location moves when maneuvering
- affordance 'hit' is clear, affordance 'avoidance' is not
- only heading, no speed
- new conflicts triggered by manoeuvres



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improve the interface: visualise the CPA

- conflict location moves when maneuvering
- affordance 'hit' is clear, affordance 'avoidance' is not
- only heading, no speed
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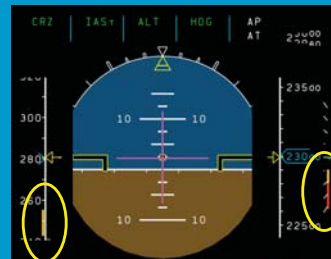
Add 'heading' and 'speed' bands, *computed by automation*

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predictive ASAS (1)

ADD "no-go" bands for

- track/heading
- vertical speed and speed



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predictive ASAS (2)

- conflict location moves when maneuvering
- affordance 'hit' is clear, affordance 'avoidance' is not
- only heading, no speed
- new conflicts triggered by manoeuvres



Add 'heading' and 'speed' bands, *computed by automation*

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predictive-ASAS issues

- yes, we can see how to avoid aircraft,
- but *we* cannot see how to do it efficiently, and
- the computer-aided optimal solution can be within a no-go heading or speed zone....
- so how can we check that the computer is right??
- no-go bands for multiple aircraft??

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we took another look at a conflict situation

assume we have two aircraft



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and created an ecological interface

...set intruder aircraft to stand still



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ecological ASAS

...then we should also change the speed of own...



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ecological ASAS

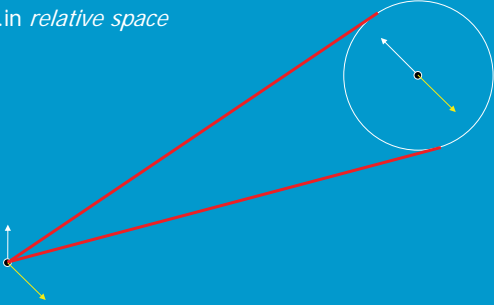
...add the protected zone...



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ecological ASAS

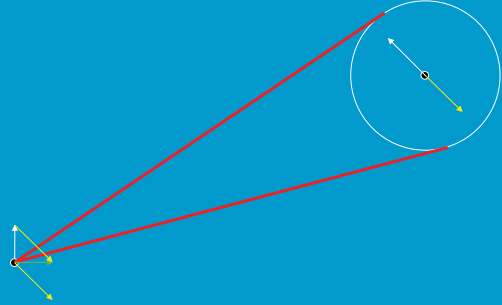
...create Forbidden Beam Zone
...in *relative space*



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ecological ASAS

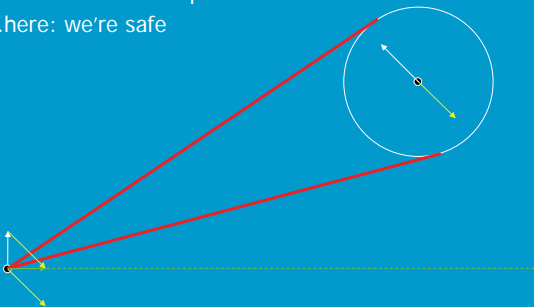
...calculate relative speed



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ecological ASAS

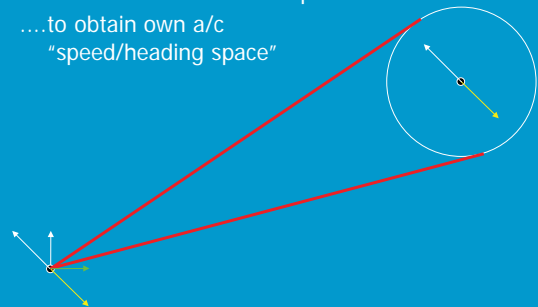
...calculate relative speed
...here: we're safe



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ecological ASAS

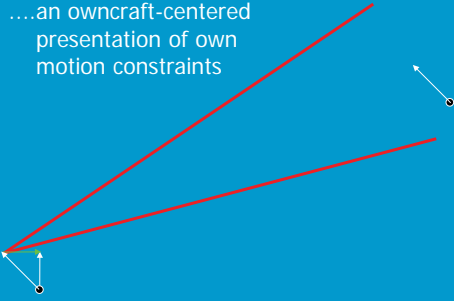
...move FBZ with intruder speed
...to obtain own a/c
"speed/heading space"



Oslo 2016

ecological ASAS

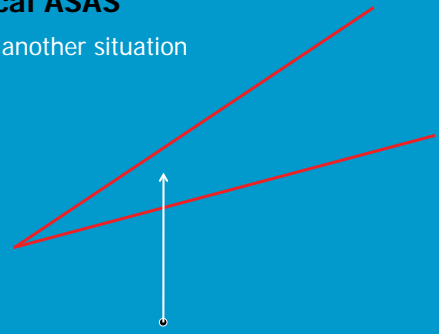
...an owncraft-centered presentation of own motion constraints



Oslo 2016

ecological ASAS

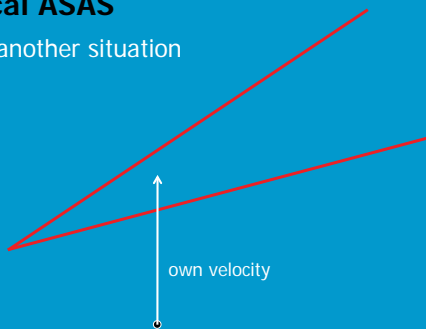
...look at another situation



Oslo 2016

ecological ASAS

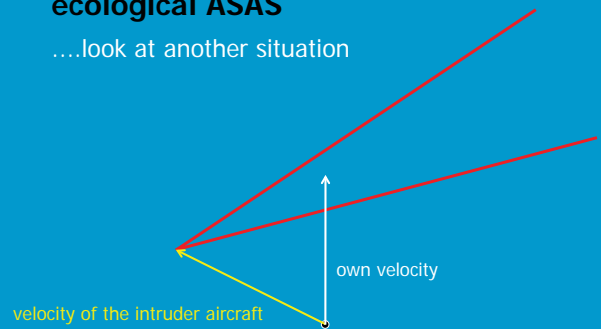
...look at another situation



Oslo 2016

ecological ASAS

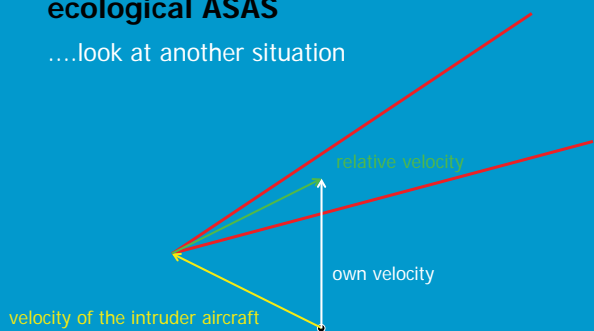
...look at another situation



Oslo 2016

ecological ASAS

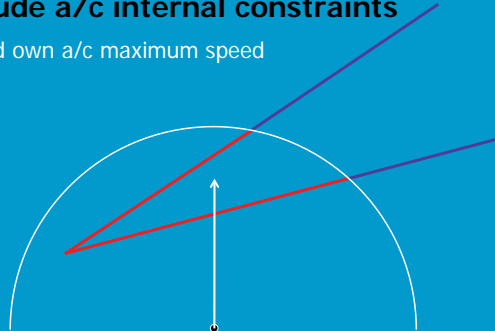
...look at another situation



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include a/c internal constraints

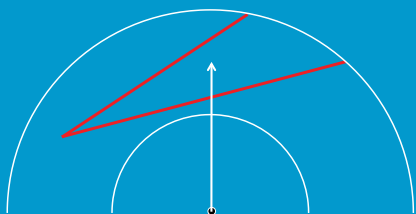
...add own a/c maximum speed



Oslo 2016

include a/c internal constraints

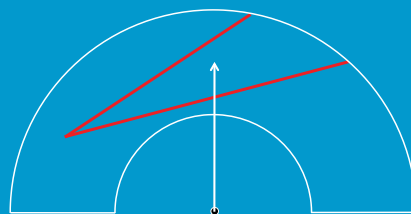
...add own a/c minimum speed



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include a/c internal constraints

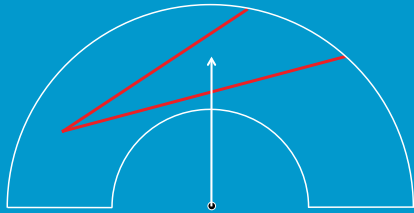
...add maximum heading changes for productivity



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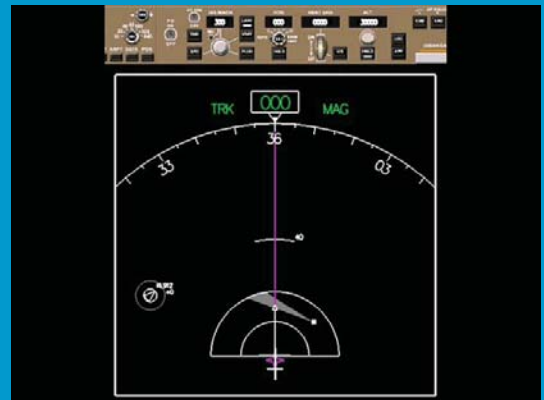
...the ecological ASAS display

...the result is the "state vector envelope" for 2D motion



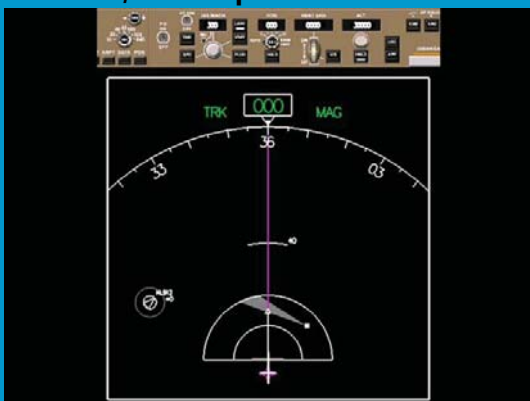
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demo: conflict with one aircraft



Oslo 2016

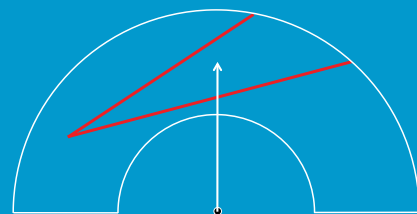
no reaction, development of conflict



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EID aims to show all constraints

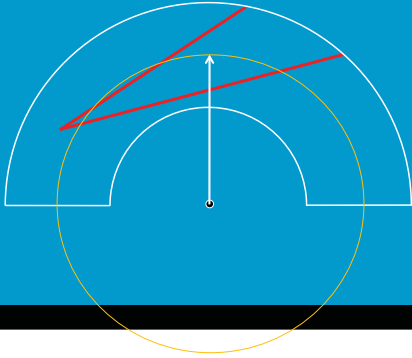
....heading bands??



Oslo 2016

EID aims to show all constraints

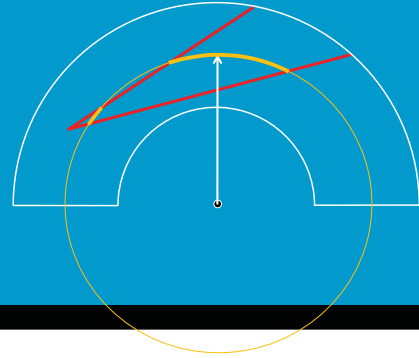
...heading bands??



Oslo 2016

EID aims to show all constraints

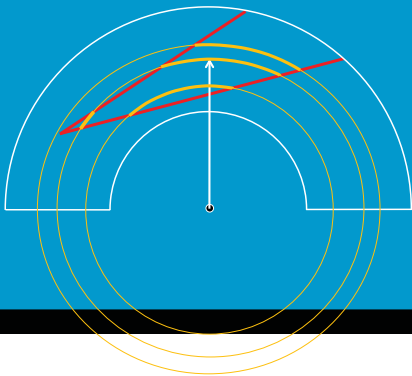
...heading bands!



Oslo 2016

EID shows all constraints

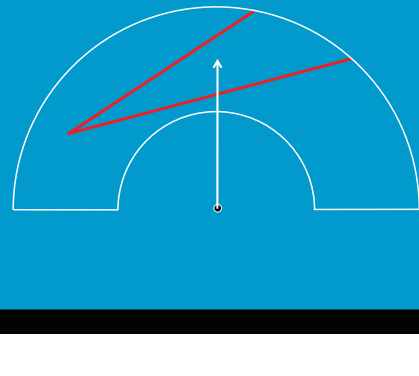
....a whole family of heading bands!



Oslo 2016

EID shows all constraints

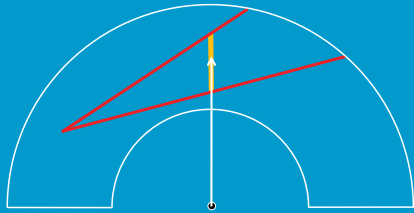
....speed bands??



Oslo 2016

EID shows all constraints

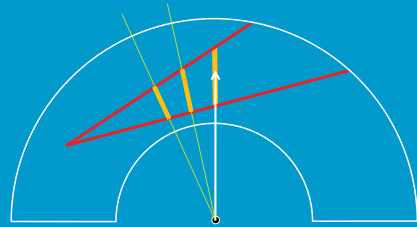
...speed bands!



Oslo 2016

EID shows all constraints

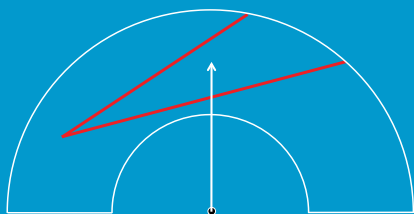
...a whole family of speed bands!



Oslo 2016

EID shows all constraints

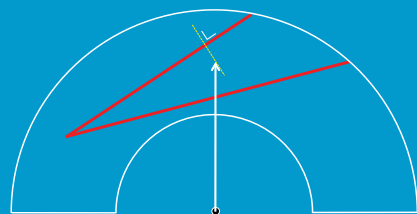
...optimal solution??



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EID shows all constraints

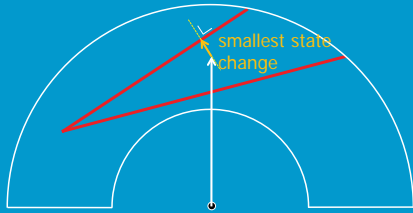
...optimal solution!



Oslo 2016

EID shows all constraints

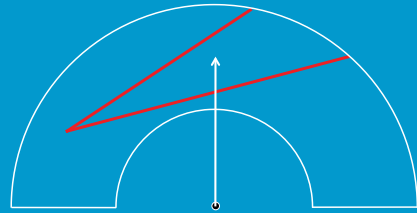
...optimal solution!



Oslo 2016

EID shows all constraints

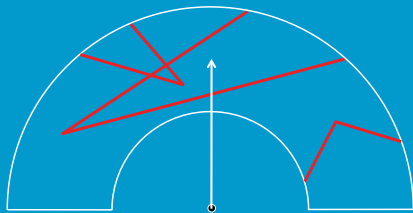
...multiple intruder aircraft??



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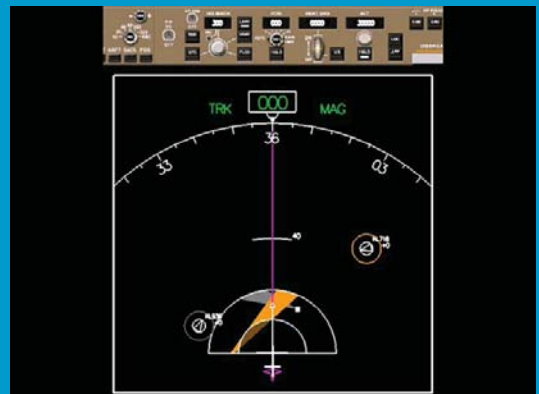
EID shows all constraints

...multiple intruder aircraft!



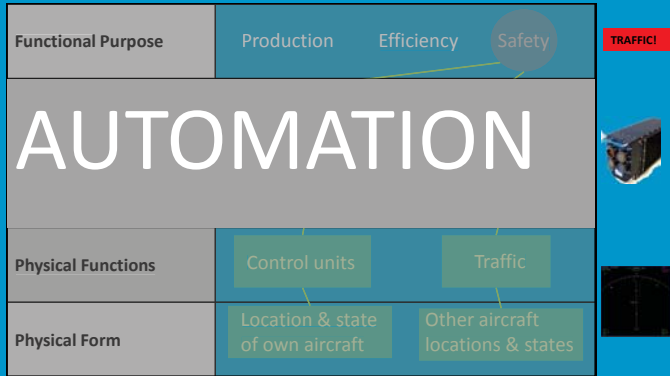
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demonstration: multiple intruders



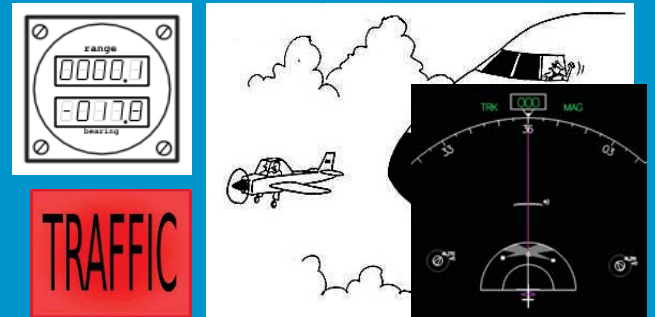
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make visible the invisible



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... is there an approach to automation and interface design that helps pilots with their (cognitive) tasks?



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the world behind the glass

TRAFFIC!

"I am in a conflict (or not)."

VS.

"Am I in a conflict?"

"Is the conflict near?"

"What are my resolution opportunities?"

"What are the relative movements?"

"Will I cross the intruder from the front or back side?"

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closing statements

Oslo 2016

closing statements

Distribute the cognition between humans and the automated systems through the interface

“strive for a joint cognitive system”

EID: transform a cognitive task into a perceptual task by providing meaningful information that humans can directly perceive and act on accordingly

“make visible the invisible”

Ecological interfaces are **not (by definition) simple, intuitive**; they reflect the complexity of the work domain!

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our approach to interface design

...usually starts out with engineering analysis, modelling and describing the system

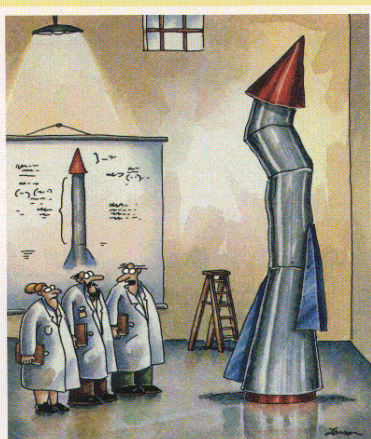
...we have learned that picking the “right” representation (state variables) is crucial to the success of the automation and interface design



There is NO RECIPE for the design itself

...but, a graph that you use to *explain the problem space* to others may very well serve as a dynamic window on the system to be controlled

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“It's time we face reality, my friends. ... We're not exactly rocket scientists.”

we go through lots of analysis and design iterations!!

Oslo 2016

Designing for Situation Awareness

-the world behind the glass-

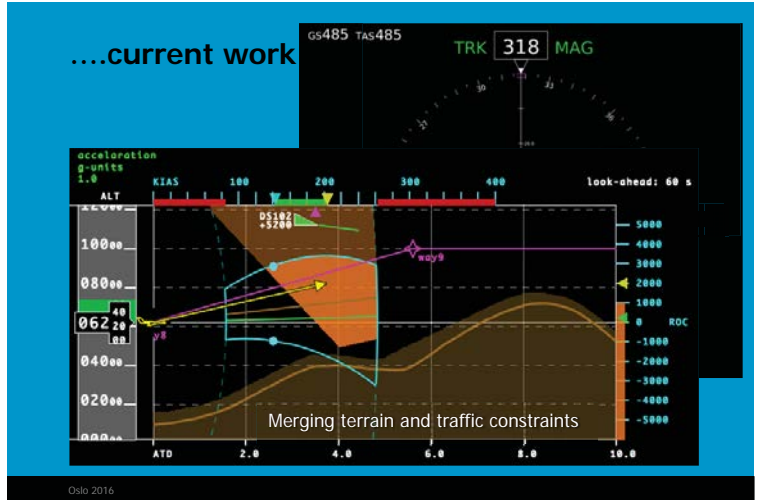
Max Mulder

Human Factors in Control

Oslo, October 12, 2016

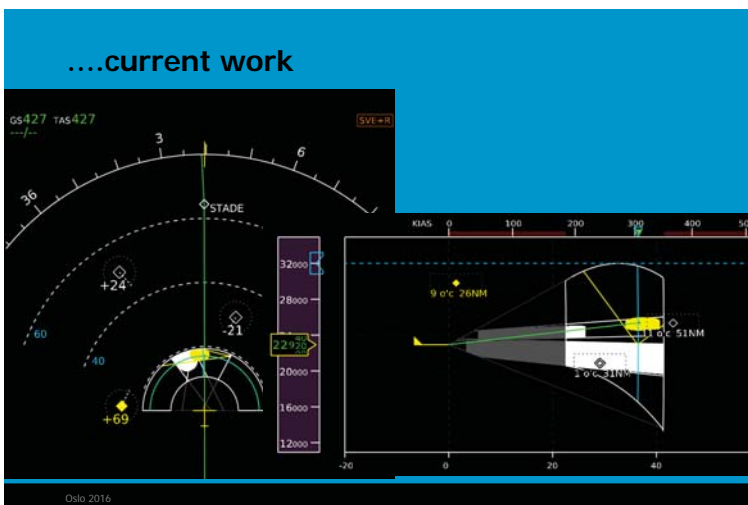


Oslo 2016



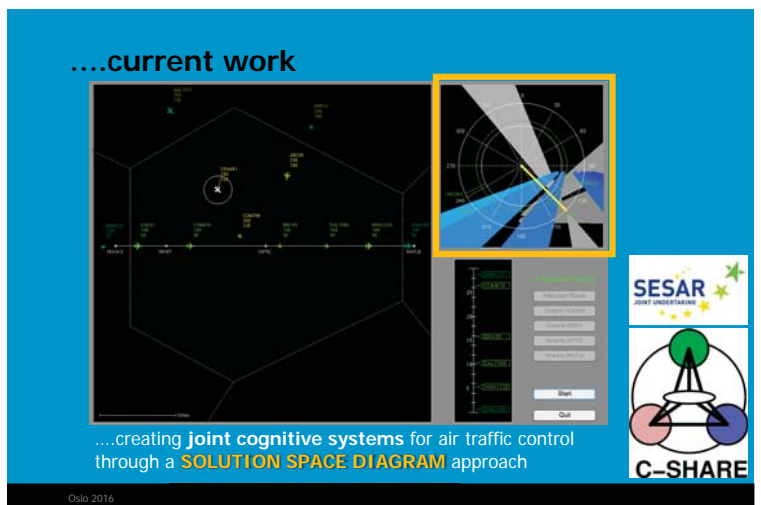
....current work

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....current work

Oslo 2016



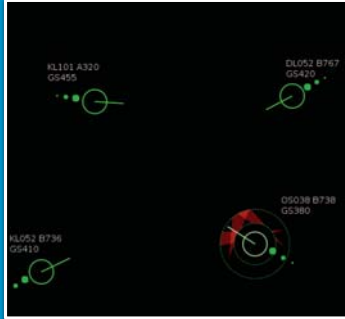
....current work

....creating joint cognitive systems for air traffic control through a SOLUTION SPACE DIAGRAM approach

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....current work



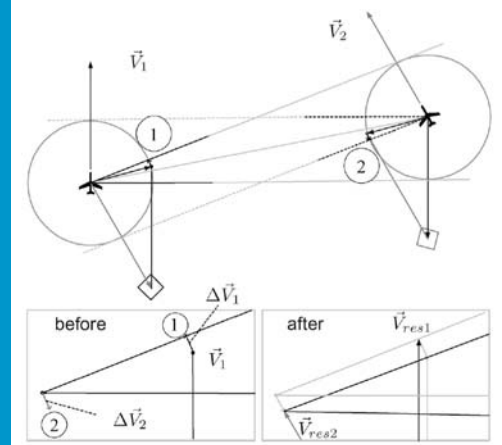
Java application

cswiki.lr.tudelft.nl

Oslo 2016

ATP

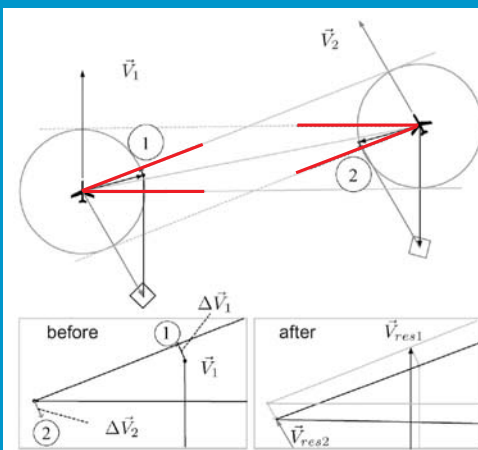
....implicit coordination!



Oslo 2016

ATP

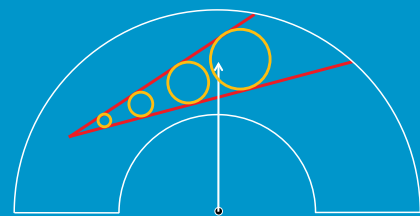
....implicit coordination!



Oslo 2016

ATP

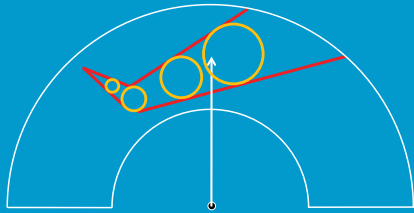
....the FBZ is a family of circles



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ATP

...that represent the intruder's 4D trajectory relative to own



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