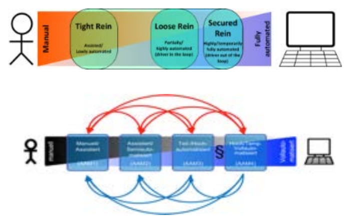
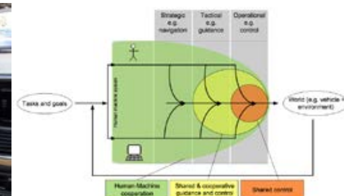
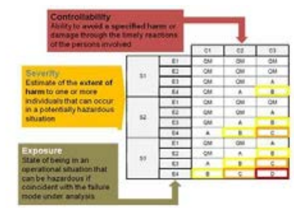
TRUST & RISK-BASED ASSURANCE: WHICH LESSONS LEARNED FROM AUTONOMOUS AND AUTOMAT DRIVING CAN BE APPLIED TO MILITARY SYSTEMS?







Prof. Dr.-Ing. Frank Flemisch

Supported by Dr. Shadan Shadegian, Marcel Baltzer

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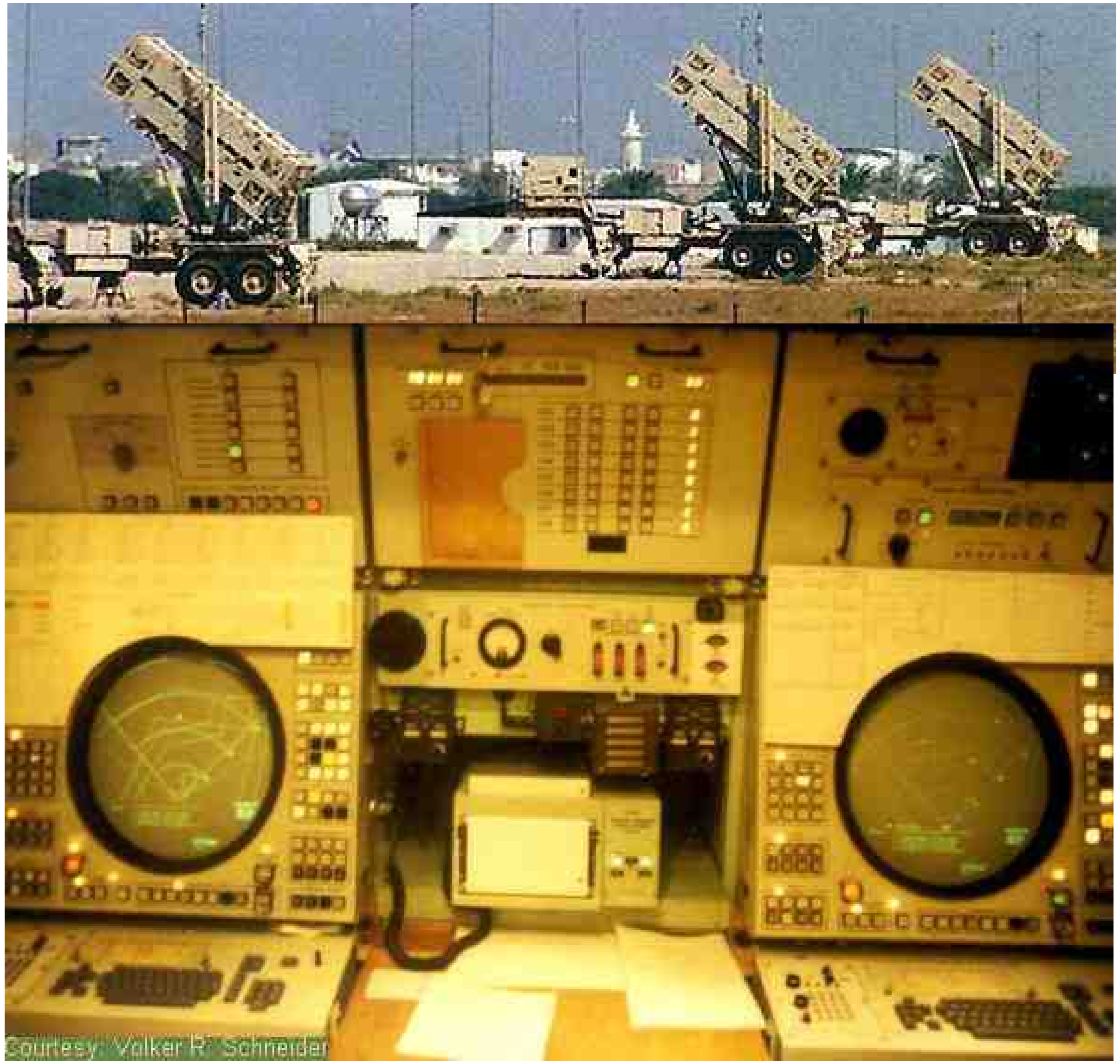

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Frank Flemisch's personal background:

VaMorS & ASPIO / Patriot / CAMA / HAVEit / Cybercar / StrAsRob / Cogas

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Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE

Network Enabled Capabilities for safety & security critical missions





Research Areas

- Sensor Data and Information Fusion
- Communication Systems
- Information Technology for Command & Control
- Ergonomics & Human Machine Systems
- Unmanned Systems
- Cyber Defense

Location	Wachtberg / Bonn
Founded	1963
Staff	>400
Annual Budget	25 Mio. €
Director	Prof. Dr. Peter Martini

www.fkie.fraunhofer.de

HFM Panel

"Optimising health, human protection, well-being and performance of the human in operational environments"

Research Area HSB Human Systems & Behavior

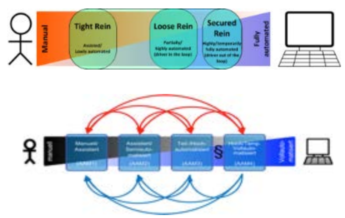
Health Medicine & Protection (HMP)

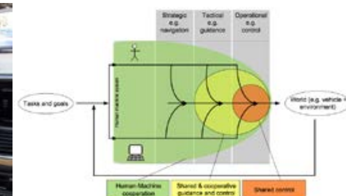
Provides the scientific basis for establishing an operationally fit and healthy force, restoring health, minimizing disease and injury, optimizing human protection, sustainability and survivability.

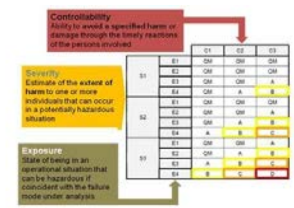
Human Systems and Behaviour (HSB)

Provides the scientific basis and explores new technology for optimizing the performance of individuals, teams and organizations and their interaction with socio-technical systems to achieve highly effective mission performance. This encompasses research in the fields of human factors, human systems integration as well as psycho-social, organizational, cultural and cognitive aspects in military action.

TRUST & RISK-BASED ASSURANCE: WHICH LESSONS LEARNED FROM AUTONOMOUS AND AUTOMAT DRIVING CAN BE APPLIED TO MILITARY SYSTEMS?







Prof. Dr.-Ing. Frank Flemisch

Supported by Dr. Shadan Shadegian, Marcel Baltzer

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Driverless & Autonomous cars:
Did everything start with the Google car?

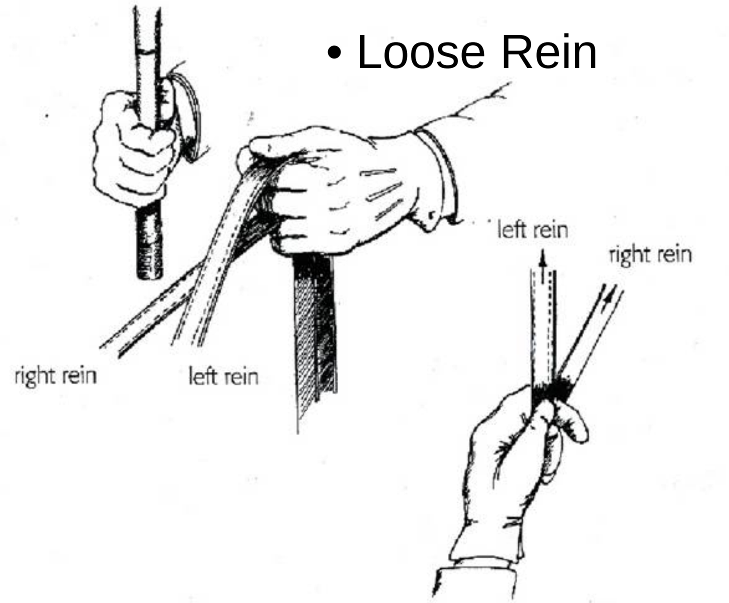
1885

2015

Autonomy: Wild stallion

Rider & Horse: Trust, Controllability and risk assurance

- Tight Rein
- Loose Rein



Reactive

Reflexes

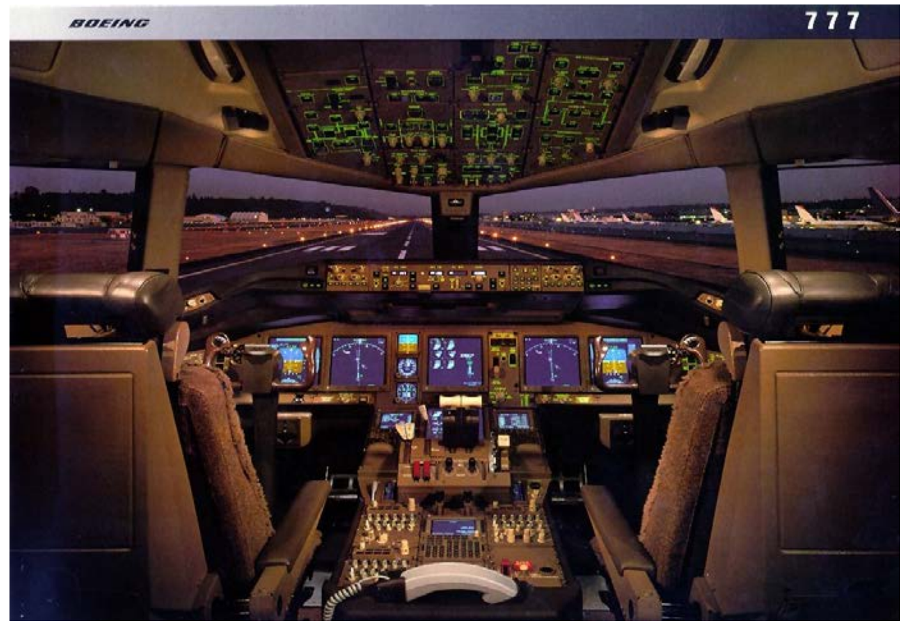
Autonomous

Cooperative!

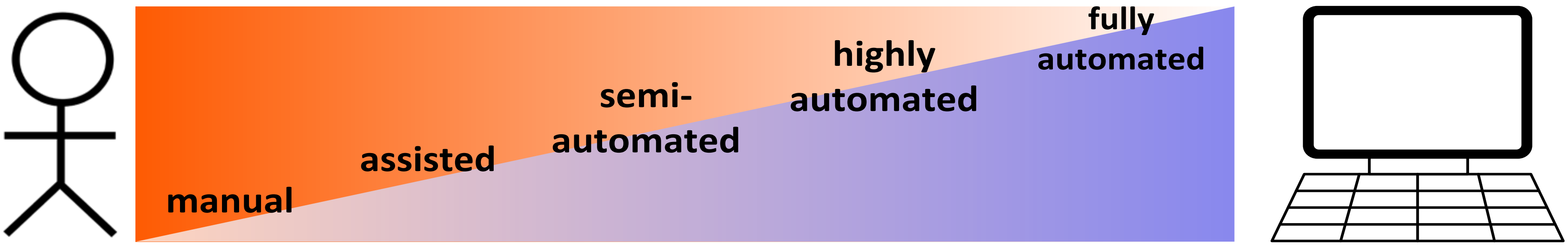
From Horse carts to cars:
Evolutions and revolutions in the past

1900 *Champs-Élysées* *1908*

1996: fully autonomous driving and highly automated flying

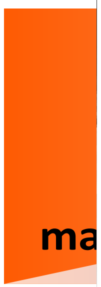


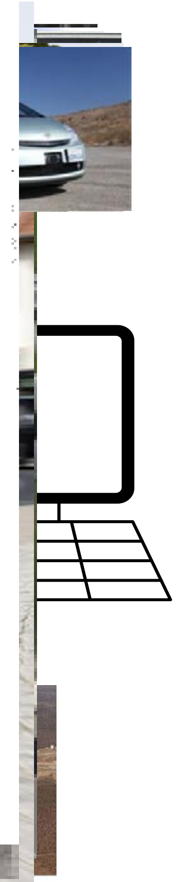
Assistance and Automation

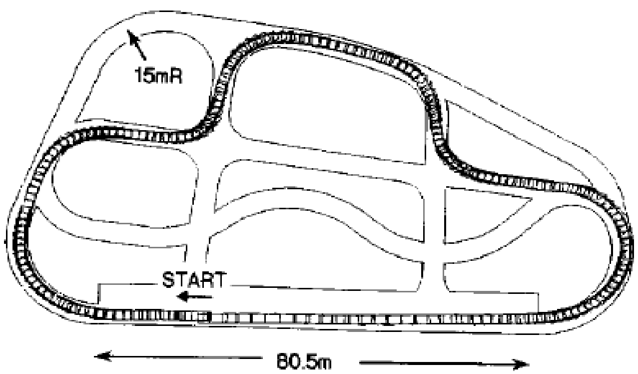


Assistance and Automation

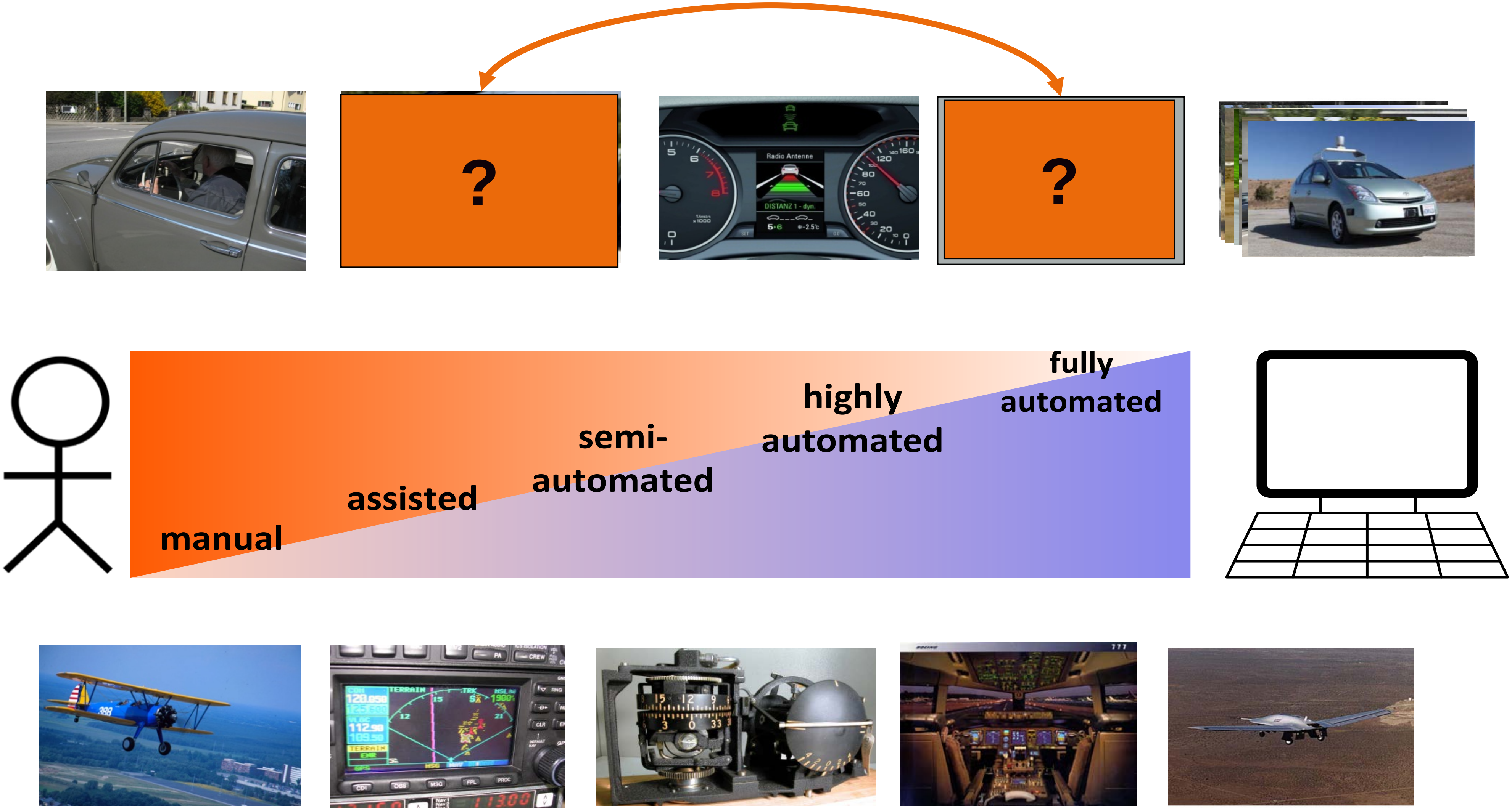
Assistance and Automation







Assistance and Automation



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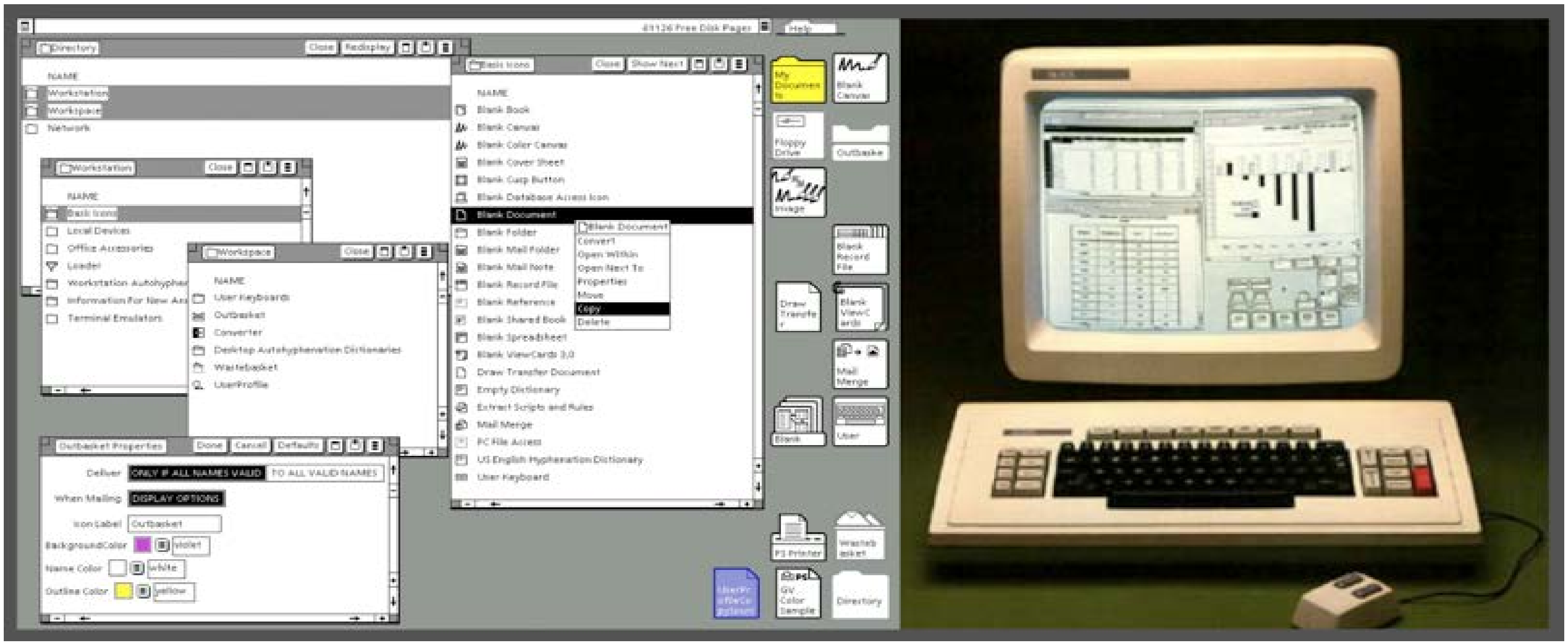
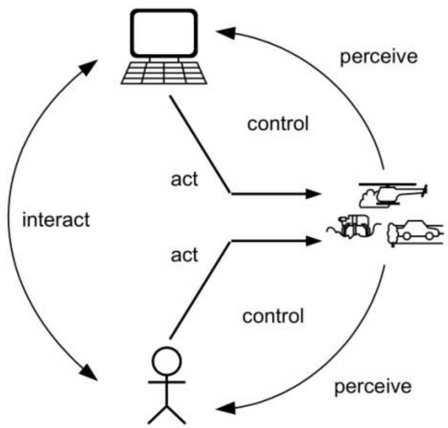
Design Metaphor: Example Desktop Metaphor



Desktop Metapher Xerox Star 1981

Cooperative Movement: Examples from nature



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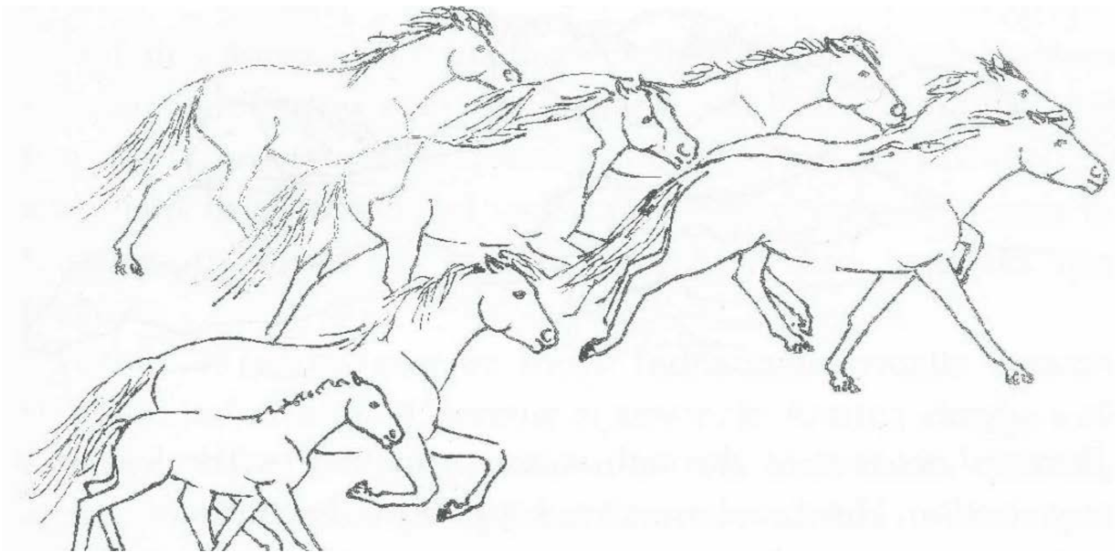
Introduction: H-Metaphor

- Horseman and Horse: H(orse)-Metaphor
  - Tight Rein
  - Loose Rein



Flemisch, F.O.; Adams, C. A.; Conway S. R.; Goodrich K. H.; Palmer M. T. ; Schutte P. C.: The H-Metaphor as a guideline for vehicle automation and interaction; NASA/TM—2003-212672; NASA Langley Research Center; Hampton, Va, USA; 2003

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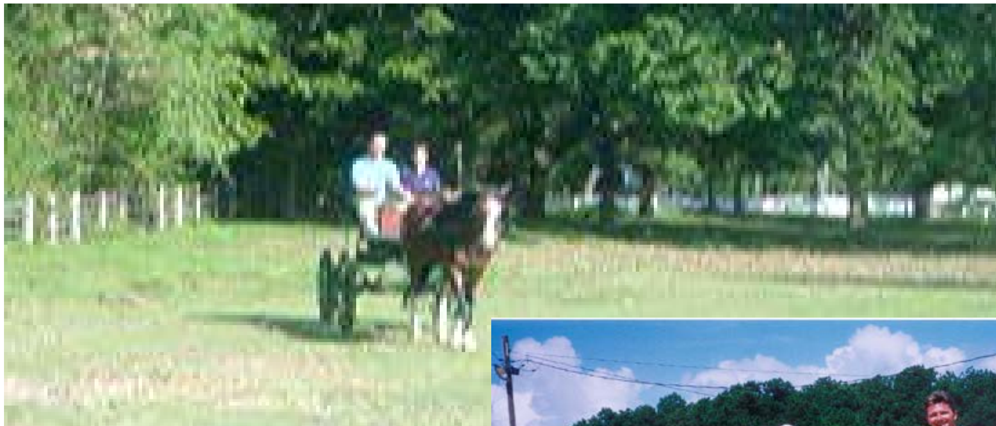
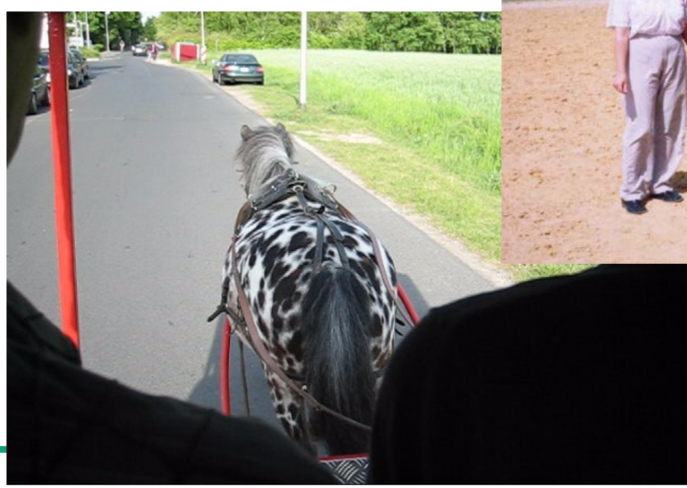
From H-Metaphor to H-Mode





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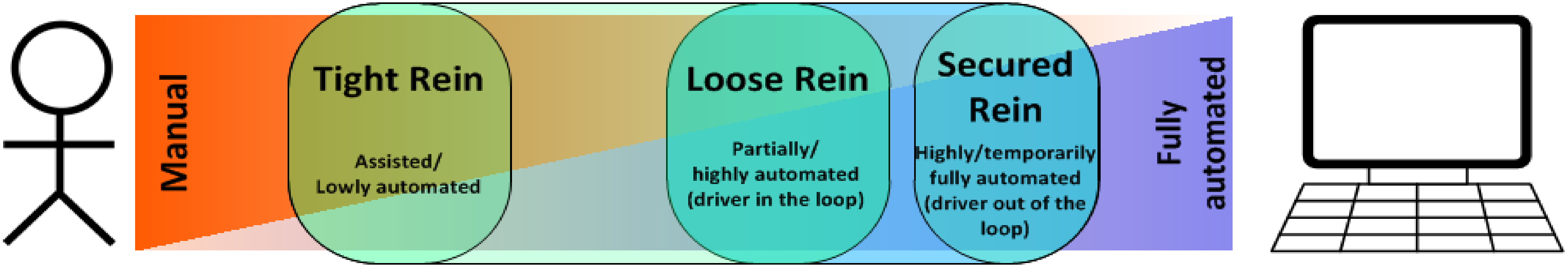
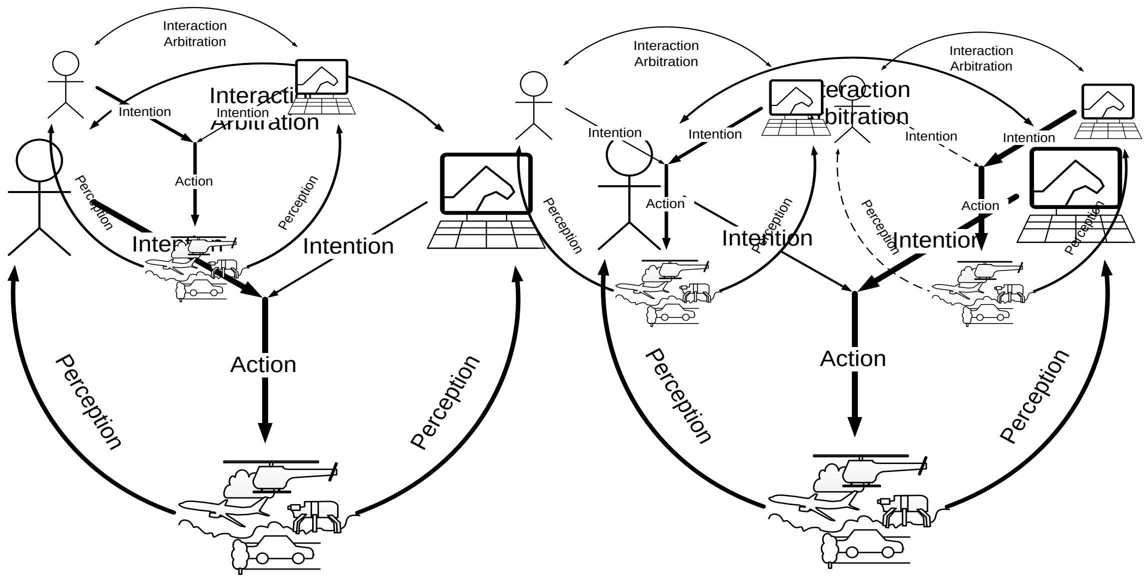
Cooperative automation, e.g. H-Mode 2d 1.1





Flemisch, F.; Schieben, A.; Kelsch, J.; Löper, C.: Automation spectrum, inner / outer compatibility and other potentially useful human factors concepts for assistance and automation; In: Ed. Waard, D.; Flemisch, F.; Lorenz, B.; Oberheid, H.; Brookhuis, K. Human Factors for Assistance and Automation; Shaker, Maastricht, 2008

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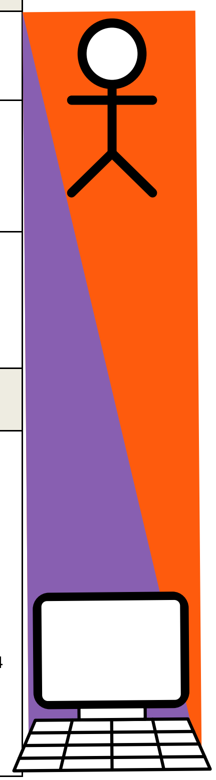
Summary of Levels of Driving Automation for On-Road Vehicles

This table summarizes SAE International's levels of *driving* automation for on-road vehicles. Information Report J3016 provides full definitions for these levels and for the italicized terms used therein. The levels are descriptive rather than normative and technical rather than legal. Elements indicate minimum rather than maximum capabilities for each level. "System" refers to the driver assistance system, combination of driver assistance systems, or *automated driving system*, as appropriate.

The table also shows how SAE's levels definitively correspond to those developed by the Germany Federal Highway Research Institute (BASt) and approximately correspond to those described by the US National Highway Traffic Safety Administration (NHTSA) in its "Preliminary Statement of Policy Concerning Automated Vehicles" of May 30, 2013.

Level	Name	Narrative definition	Execution of steering and acceleration/ deceleration	Monitoring of driving environment	Fallback performance of *dynamic driving task*	System capability (*driving modes*)	BASt level	NHTSA level
***Human driver* monitors the driving environment**								
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a	Driver only	0
1	**Driver Assistance**	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes	Assisted	1
2	**Partial Automation**	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes	Partially automated	2
***Automated driving system* ("system") monitors the driving environment**								
3	**Conditional Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task* with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes	Highly automated	3
4	**High Automation**	the *driving mode*-specific performance by an *automated driving system* of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes	Fully automated	3/4
5	**Full Automation**	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**	-	



Source SAE, 2014

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DoD Four Levels of Autonomy

Level	Name	Description
1	Human Operated	**A human operator makes all decisions**. The system has no autonomous control of its environment although it may have information-only responses to sensed data.
2	Human Delegated	**The vehicle can perform many functions independently of human control when delegated to do so**. This level encompasses automatic controls, engine controls, and other low-level automation that must be activated or deactivated by human input and must act in mutual exclusion of human operation.
3	Human Supervised	**The system can perform a wide variety of activities when given top-level permissions or direction by a human**. Both the human and the system can initiate behaviors based on sensed data, but the system can do so only if within the scope of its currently directed tasks.
4	Fully Autonomous	**The system receives goals from humans and translates them into tasks to be performed without human interaction**. A human

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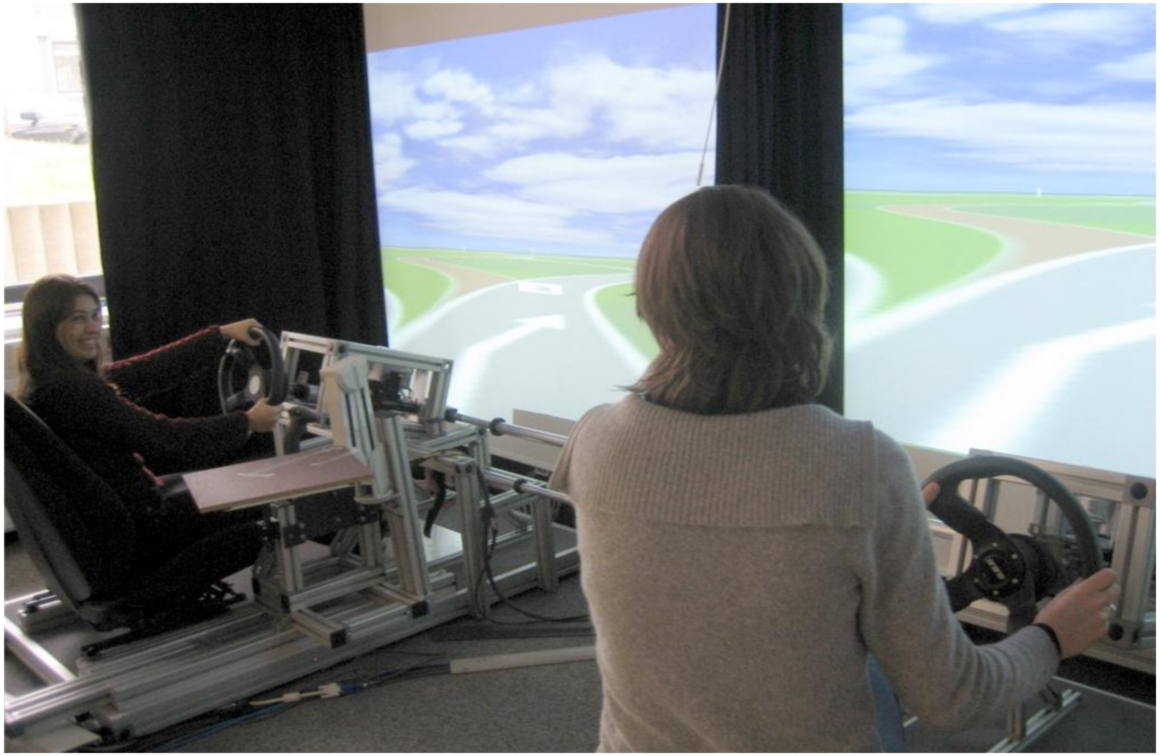
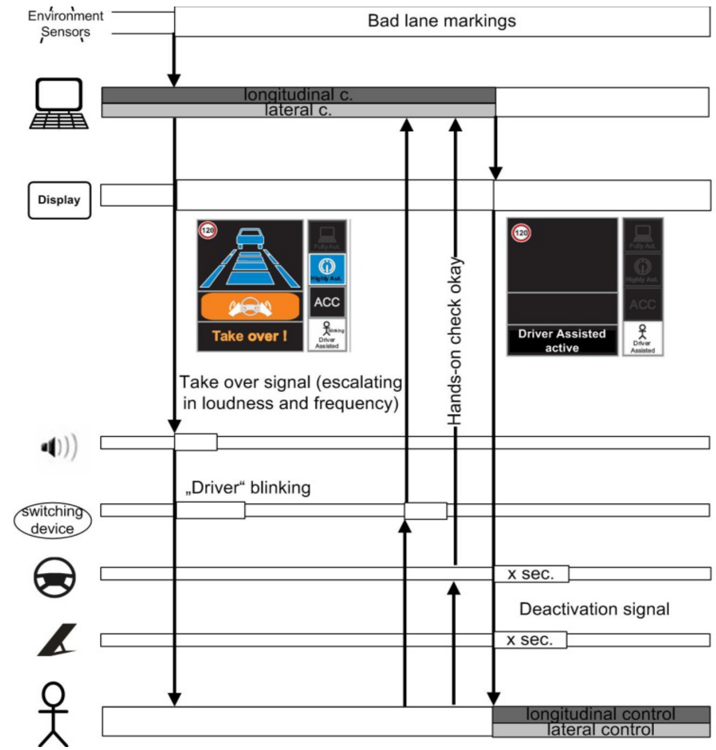
Theater method: Participatory design of the system behavior and interaction





Schieben, A.; Heesen, M.; Schindler, J.; Kelsch, J; Flemisch, F.: The theater-system technique: Agile designing and testing of system behavior and interaction, applied to highly automated vehicles; Automotive User Interfaces and Interactive Vehicular Applications (AutomotiveUI); Essen; 2009

Flemisch, F.; Semling, C.; Heesen, M; Meier, S.; Baltzer M.; Krasni, A.; Schieben, A.: Towards a balanced Human Systems Integration beyond time and space: Exploroscopes for a structured exploration of human–machine design spaces; HFM-231 SYMPOSIUM On “Beyond Time and Space”; NATO-STO Human Factors and Medicin Panel; Orlando 2013

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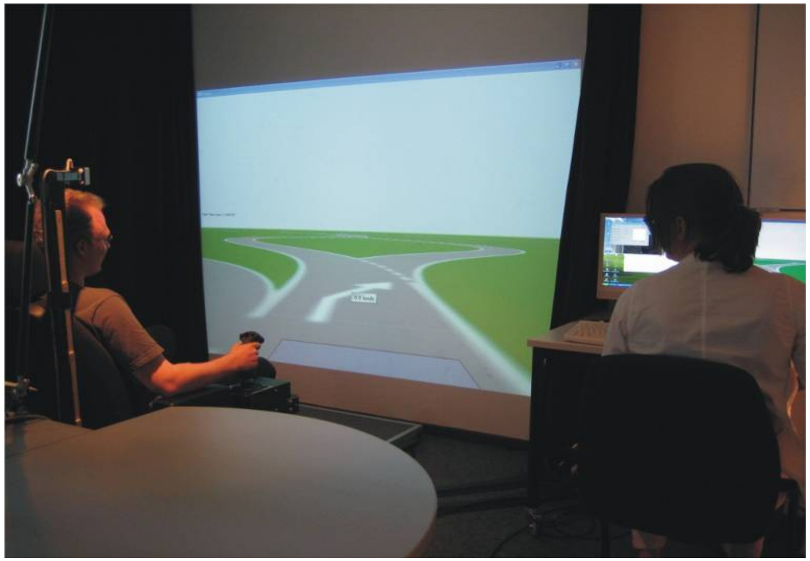
Experiments on different coupling schemes: Manual, Assisted (Tight Rein), Highly Automated (Loose Rein), Fully Automated



Exploration in SmpLab — Experiment in Dynamic Simulator

10 external subjects, Age 19 – 58, 5 male, 5 female, (5 academics, 5 non-academics)

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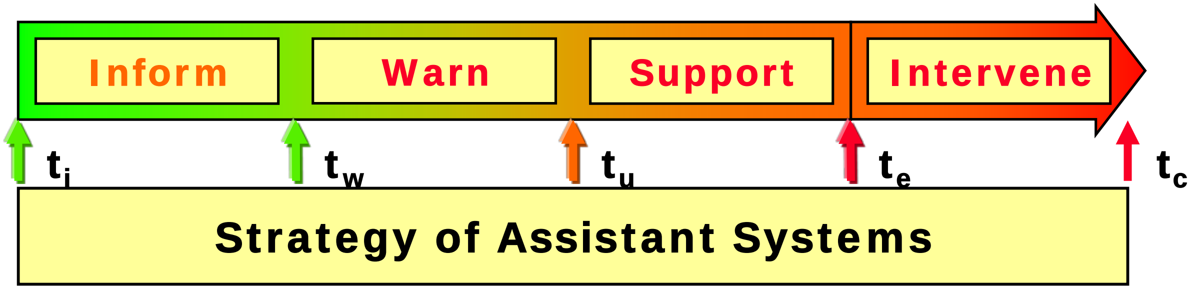
EU-Projects Prevent, SPARC → HAVE-IT

Secure Propulsion using Advanced Redundant Control



DaimlerChrysler

Centro Ricerche Fiat

EPFL
École Polytechnique Fédérale de Lausanne

ILS

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HAVEit: Assistance & Automation Scale / Spectrum



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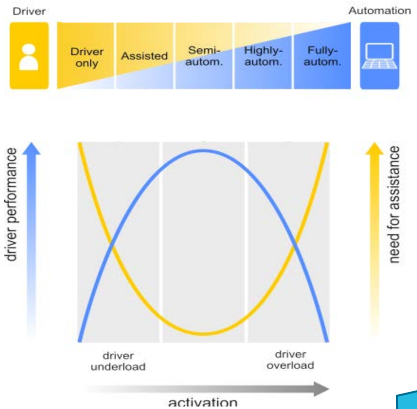
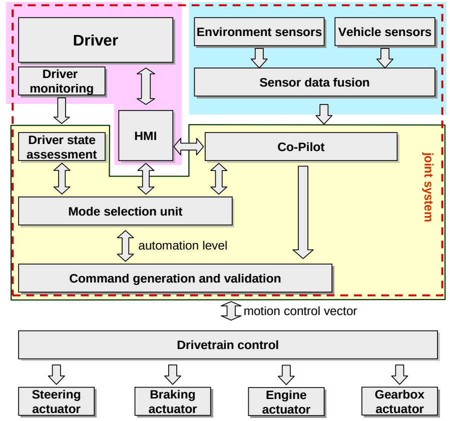
HAVEit Joint System development steps: Iterative waterfall

Generic Concepts

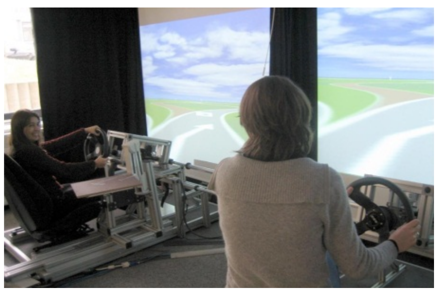




Iterative refinement

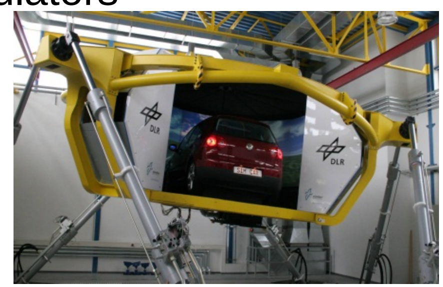
Migration to simulators

Iterative refinement



Design

with theater system



Validation by simulation

Migration to vehicle(s)

Validation in vehicle(s)

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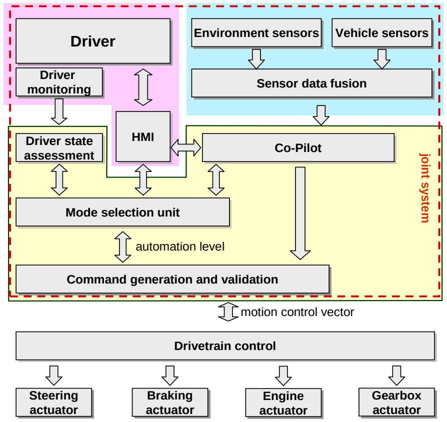
HAVEit Joint System development steps: Iterative waterfall



Iterative refinement

Migration to simulators

Validation by simulation

Iterative refinement

Migration to vehicle(s)

Validation in vehicle(s)

Final Demonstrators

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First steps towards reality: DHAS Divided Highway Assistant System

(Daimler Lenkpilot, Audi/VW Autobahnpilot, Tesla Autopilot)

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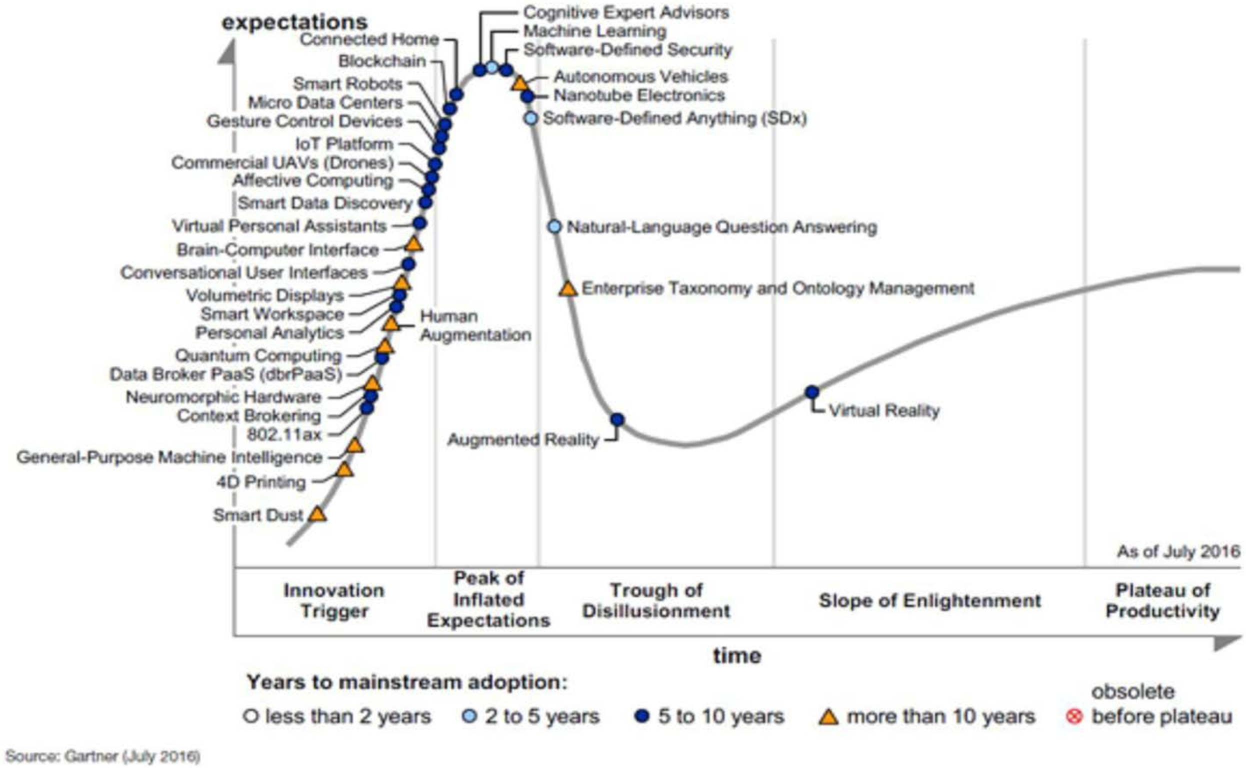
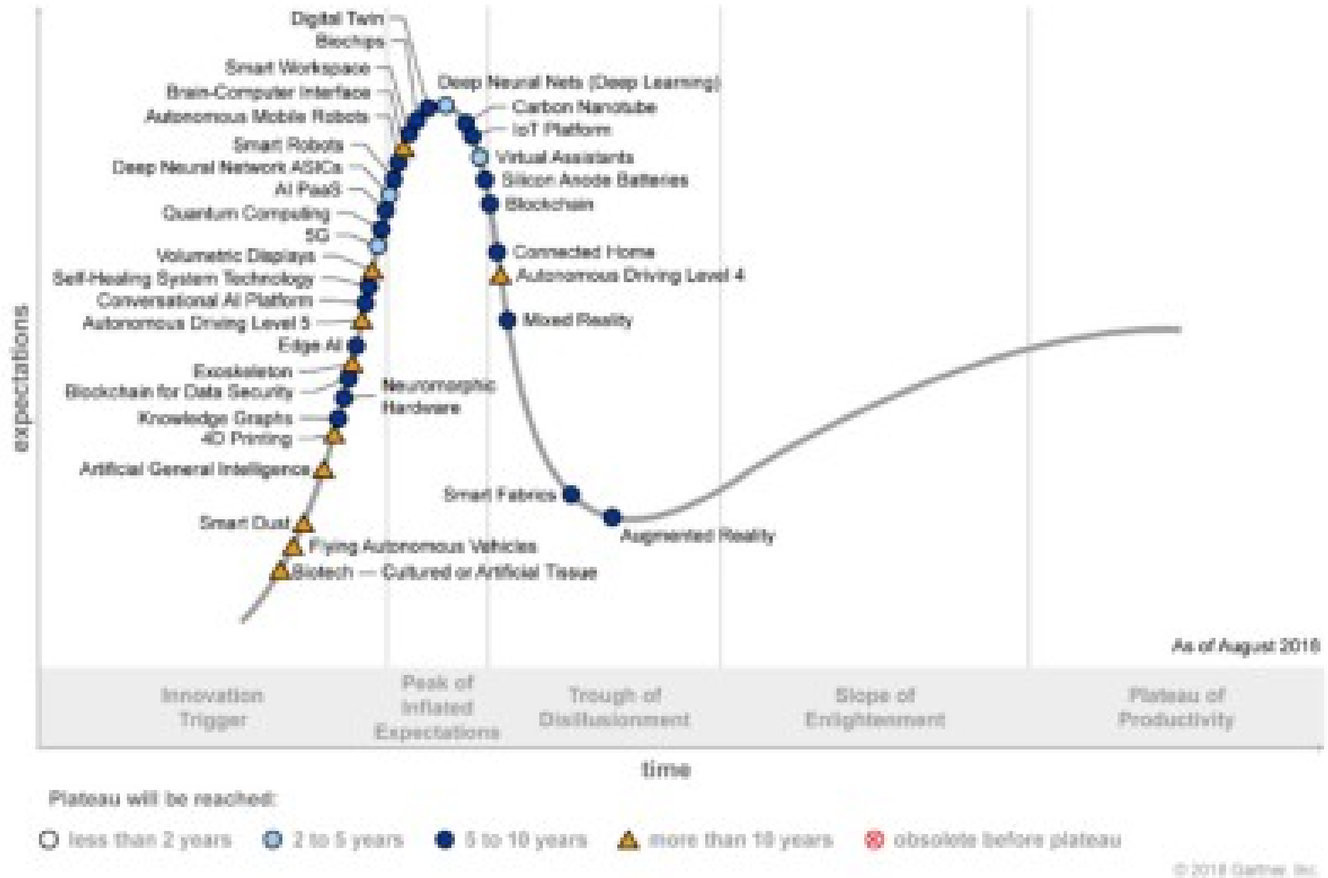
Lessons learned: Autonomous X might be a HYPE
Gartner Hype Cycle Autonomous Driving



New Gartner hype cycle on emerging technologies. http://www.gartner.com/newsroom/id/3412017, last access: 27.01.2017

Gartner Hype Cycle 2018



Source: Gartner (August 2018)

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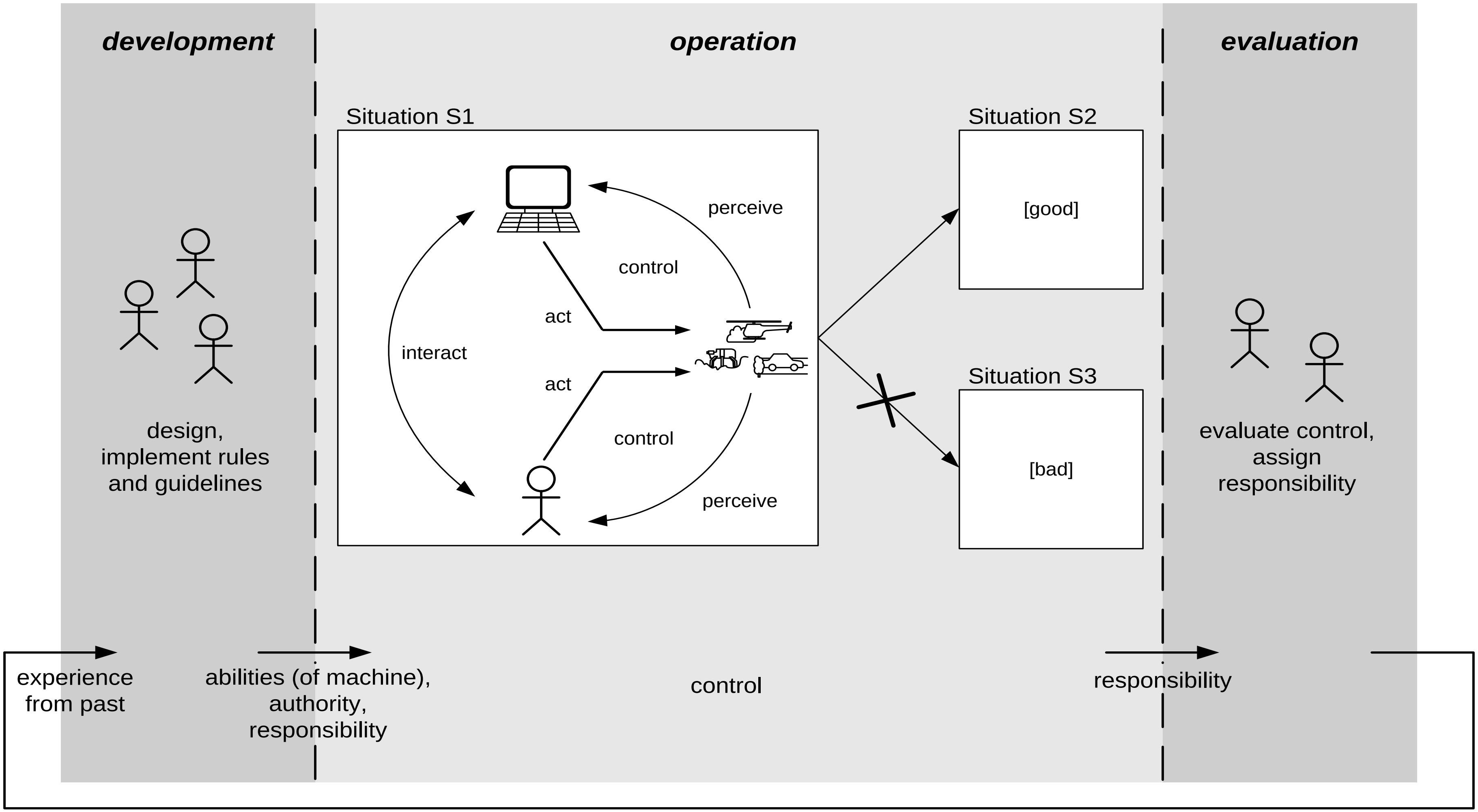
Lessons learned: Pragmatic definitions Assistance, Automation, Autonomy

- Assistance / Assistant Systems: Technical (sub-) systems which
  - support the human to do something mainly him or herself, and
  - have a minimum of intelligence
- Automation: Technical (sub-) systems which
  - do something mainly itsself, and
  - have a minimum of intelligence, and
  - still interact with the human (at least from time to time)
- Autonomy: Potential or ability of an agent (e.g. a human or technical subsystem) to do something completely by itself
- Artificial intelligence: technically generated intelligence
- **HAT Human Autonomy Teaming:** Cooperative Automation with sufficient autonomous capabilities and meaningful human control

Lessons learned: Ability, Authority, Control and Responsibility

In the human-machine system and in the Meta System (Flemisch et al. 2011)



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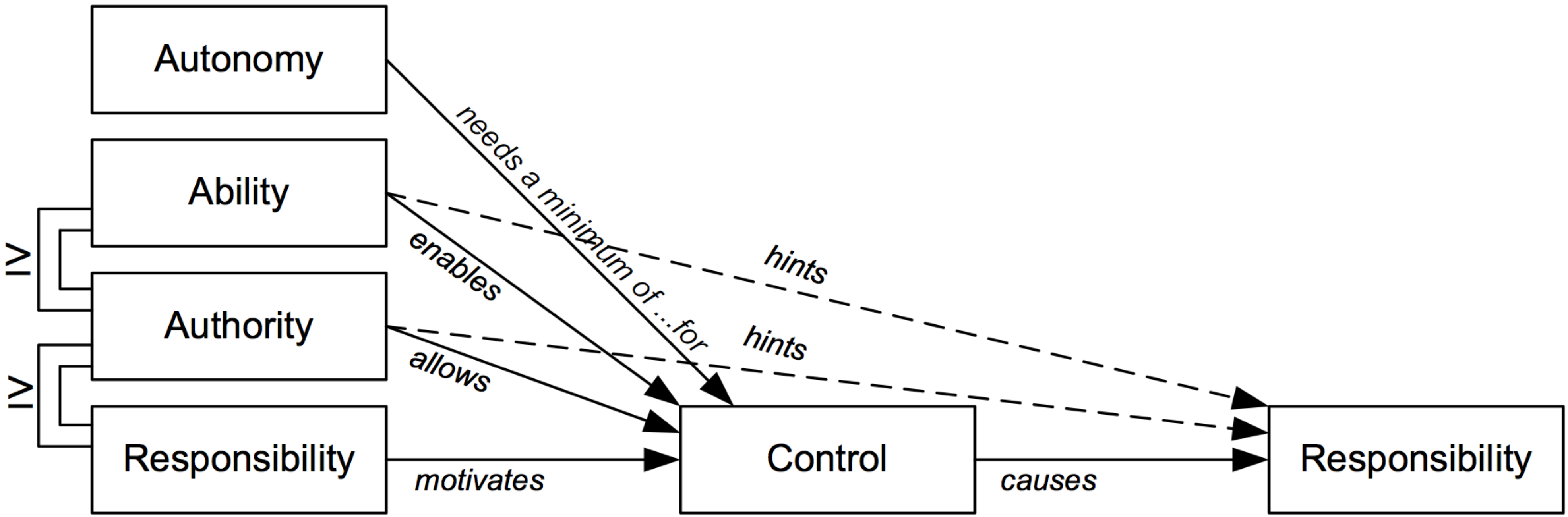
Lessons learned: Double and triple binds of

Ability, Authority, Control and Responsibility (Flemisch et al. 2011, 2016)



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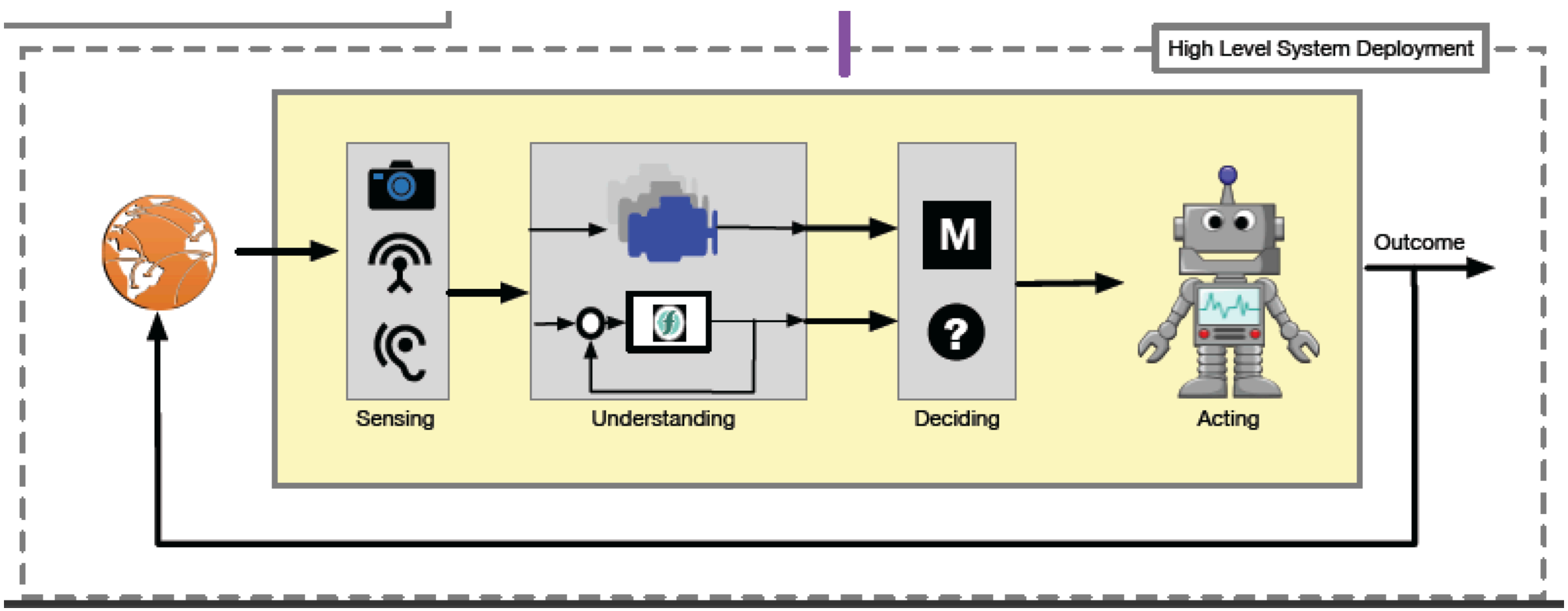
Strategies

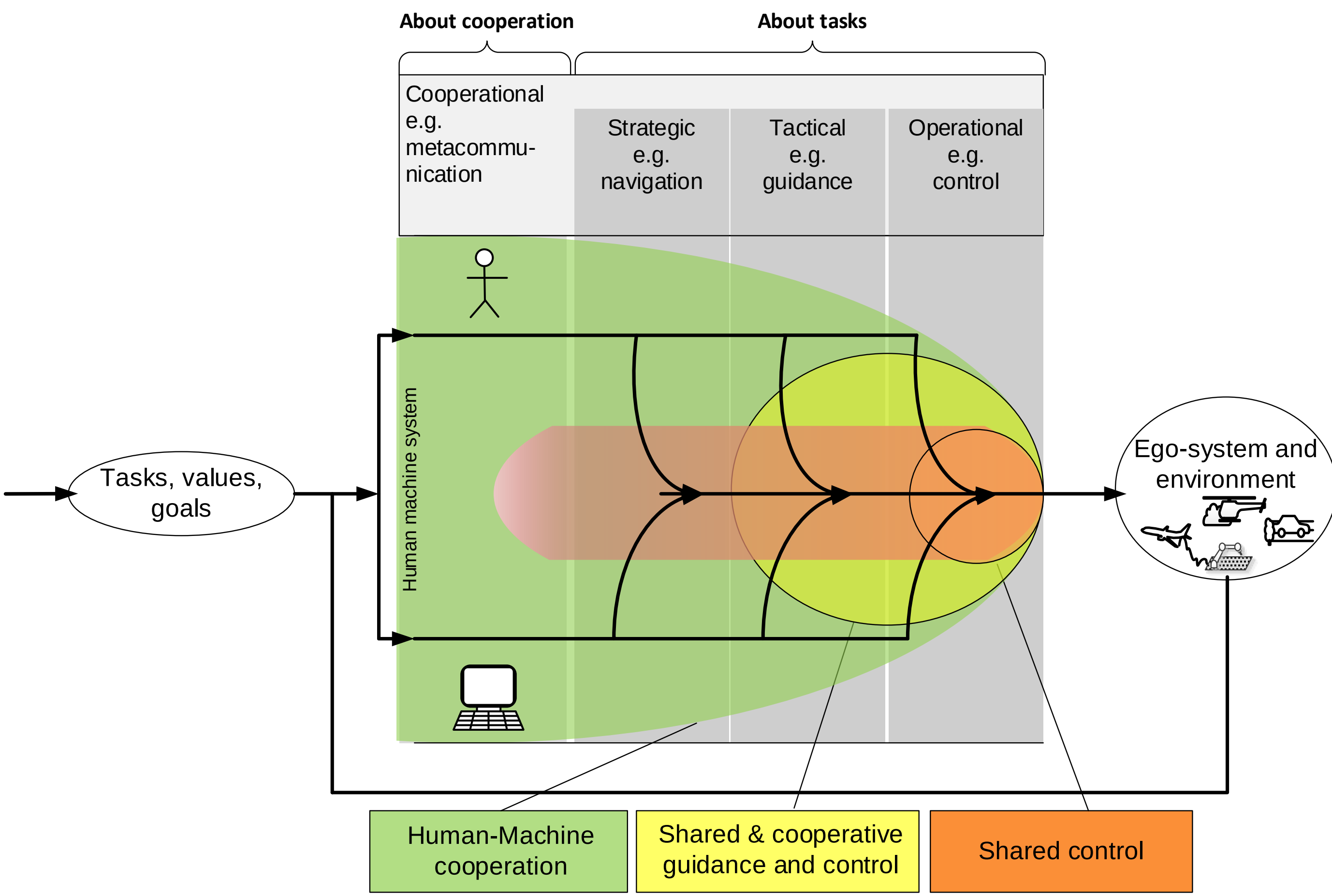
Specification

- Specify and validate what the system should do
  - Given environment, given sensor choice, is it possible to gain necessary understanding, and make safe decisions
    - e.g. recognise and avoid obstacles at night



Lessons learned:

Joint Action, Shared Control & Cooperative Automation



F. Flemisch, D. Abbink, M. Itoh, M-P. Pacaux-Lemoine, G. Weßel: Shared control is the sharp end of cooperation! Towards a common framework of joint action, shared control and human machine cooperation; , IFAC-HMS, Kyoto 2016

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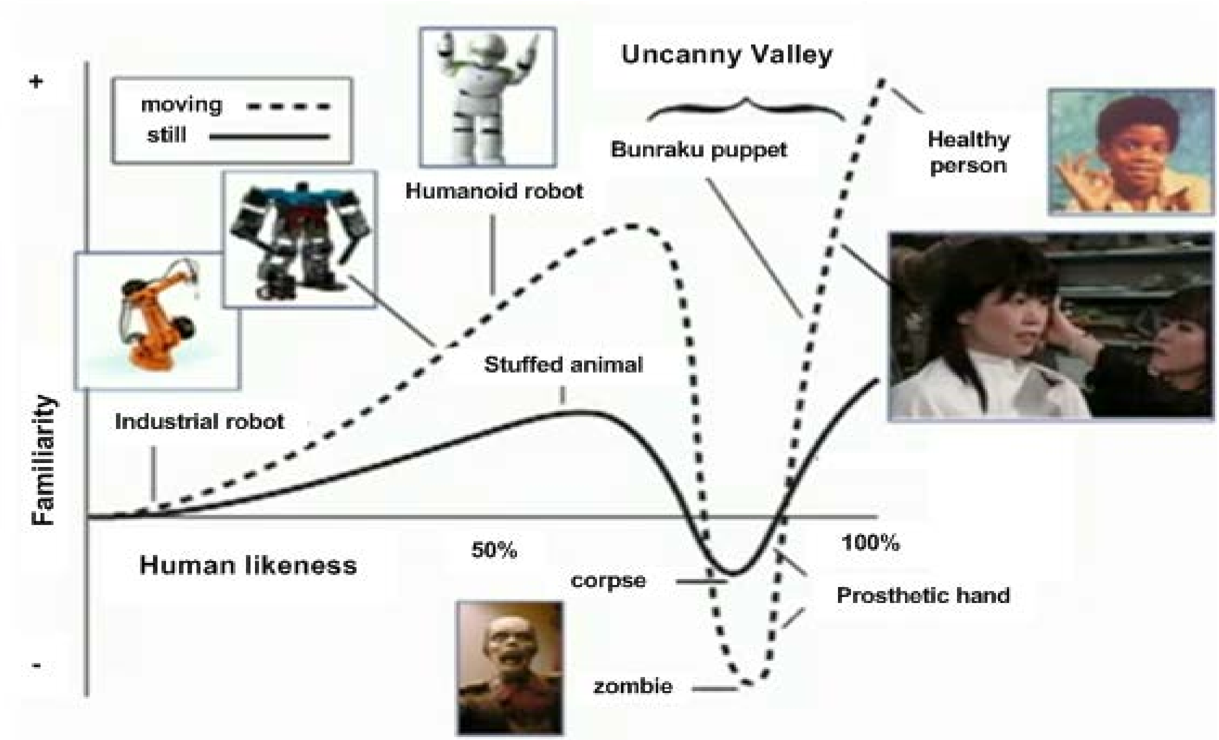
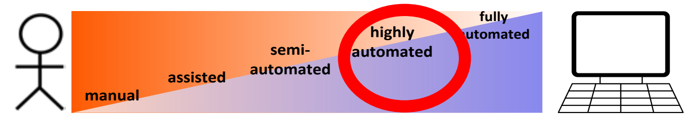
Lessons learned: From the Uncanny valley of robotics to the (uncanny and) unsafe valley of automation



[Masahiro Mori 1970, „Phänomen des unheimlichen Tals“ (jap. 不気味の谷現象 *bukimi no tani genshō)*](#)

Karl F. MacDorman: https://www.youtube.com/watch?v=geF1XO5IPc8

DFG-H-Mode(DLR): Automation Failure Partially as Highly automated



Show Video

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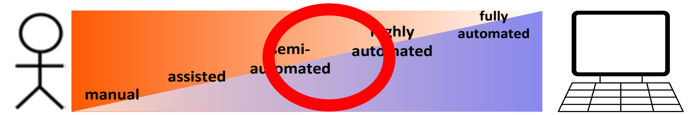
DFG-H-Mode (DLR): Automation Failure: Partially automated/ loose rein



Show Video

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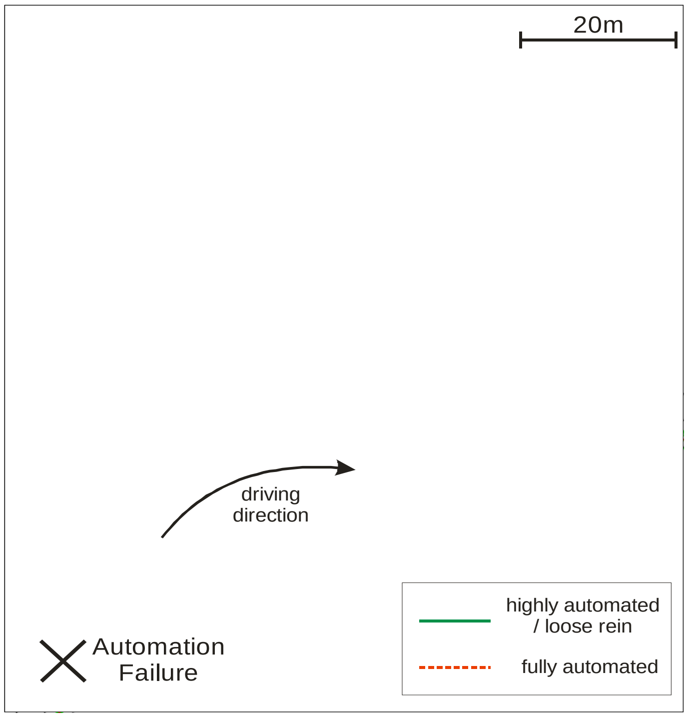
DFG-H-Mode: Automation Failure

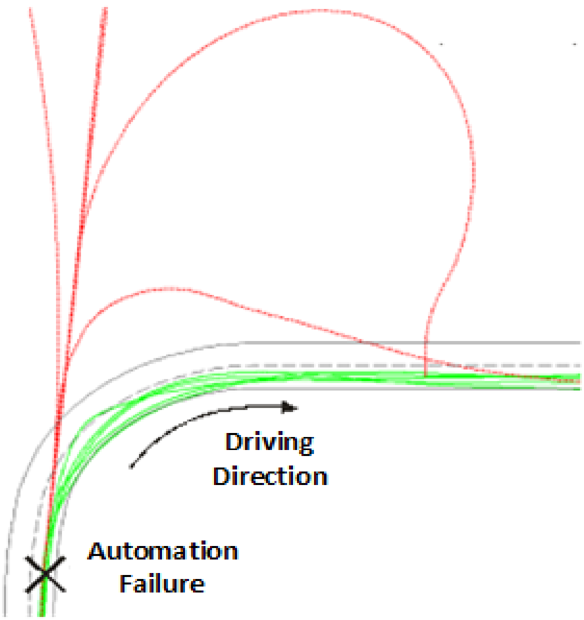


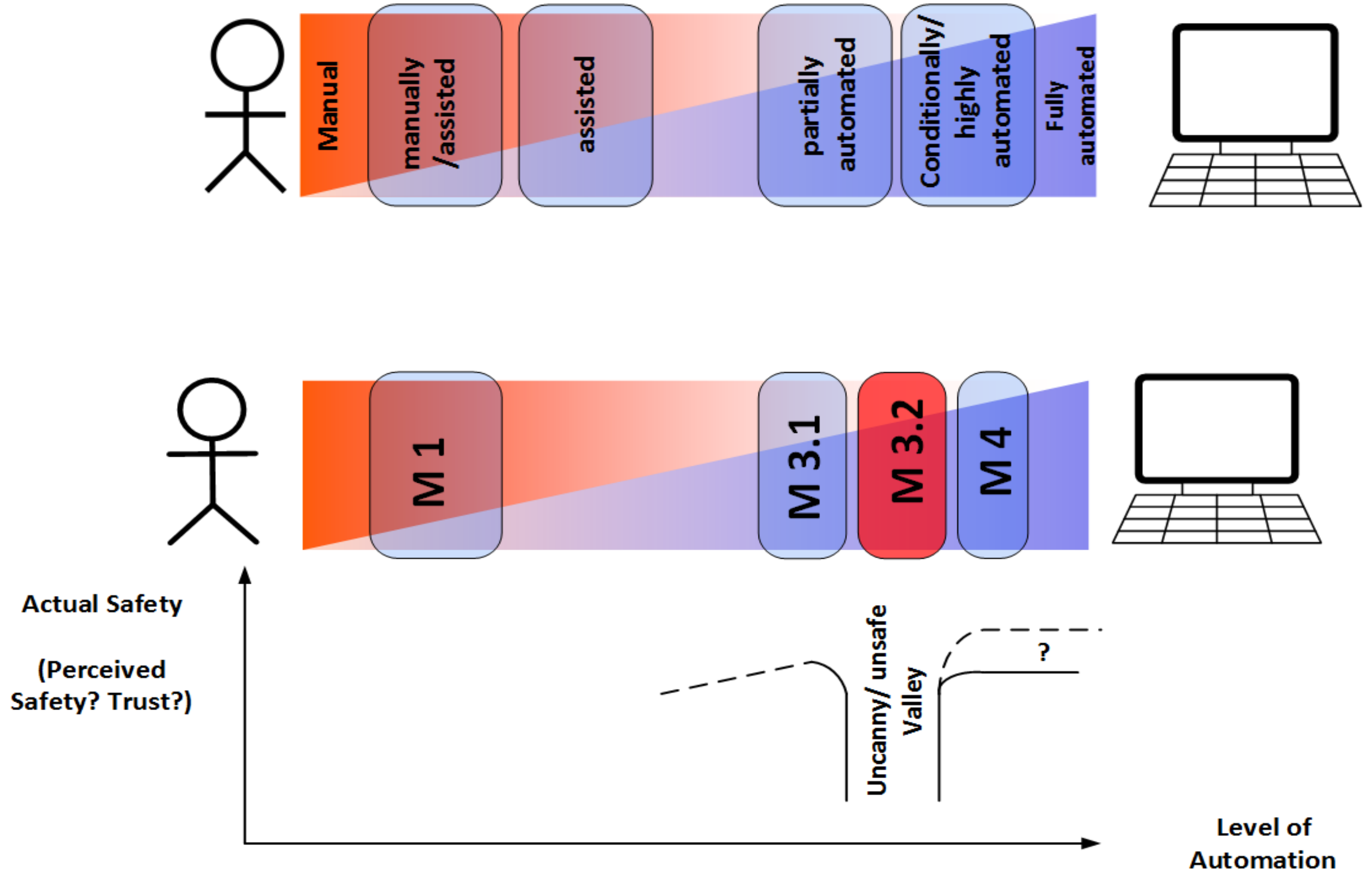
Hypothesis: In case of Partially Automated and a failure the subjects are able to take over the vehicle control more quickly and more precisely than in case of a failure in highly automated.

Highly automated:
5 of 5 subjects left the road.

Partially Automated/ Loose Rein:
5 of 5 subjects stayed on the road

Outlook: The uncanny and unsafe valley of automation





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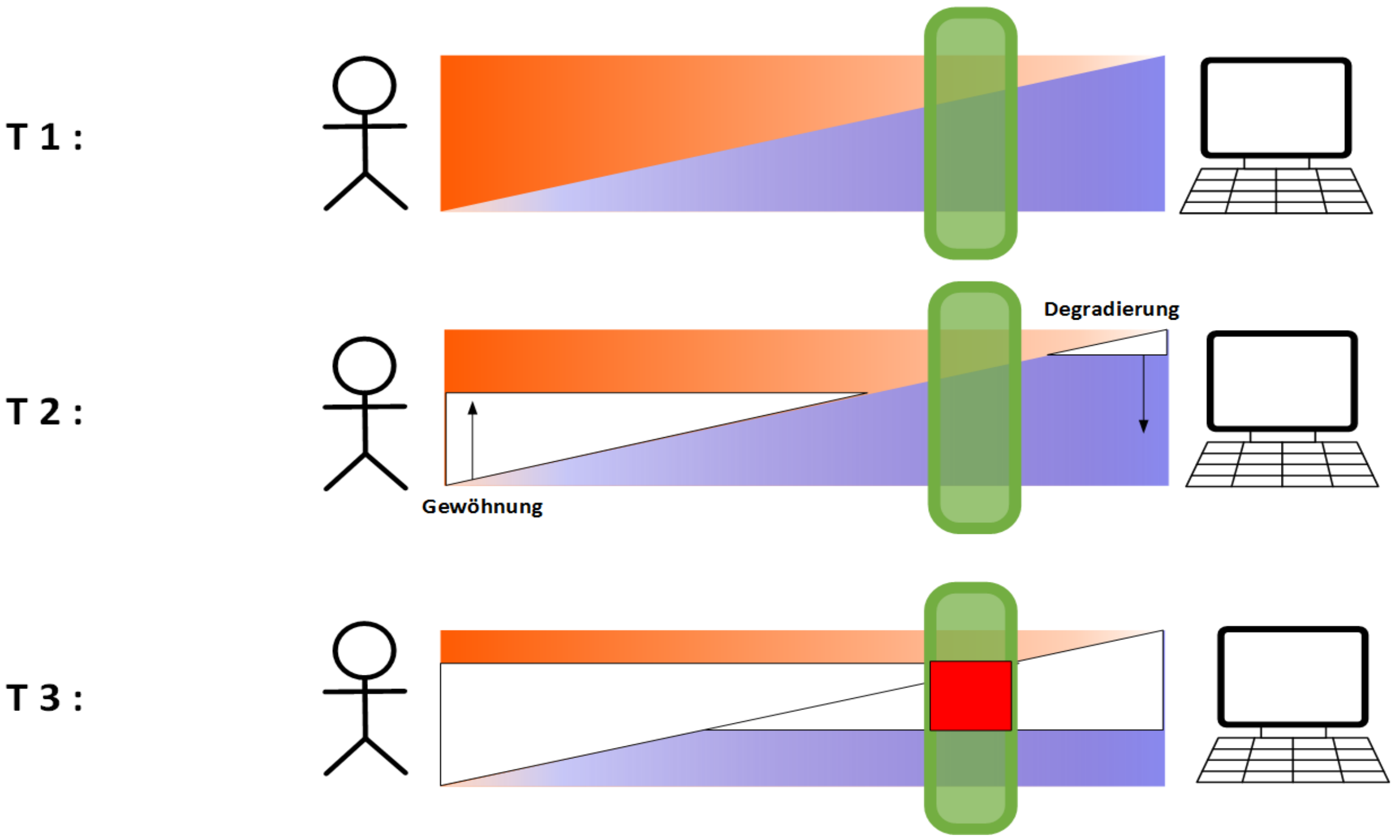
Scissor of Overtrust & Degradation?



Flemisch, F.; Altendorf, E.; Baltzer, M.; Rudolph, C.; Lopez; D.: Arbeiten in komplexen Mensch-Automations-Systemen: Das Unheimliche und unsichere Tal (Uncanny Valley) der Automation am Beispiel der Fahrzeugautomatisierung; 62. GfA-Frühjahrskongress „Arbeit in komplexen Systemen – Digital, vernetzt, human?! Aachen, 2016

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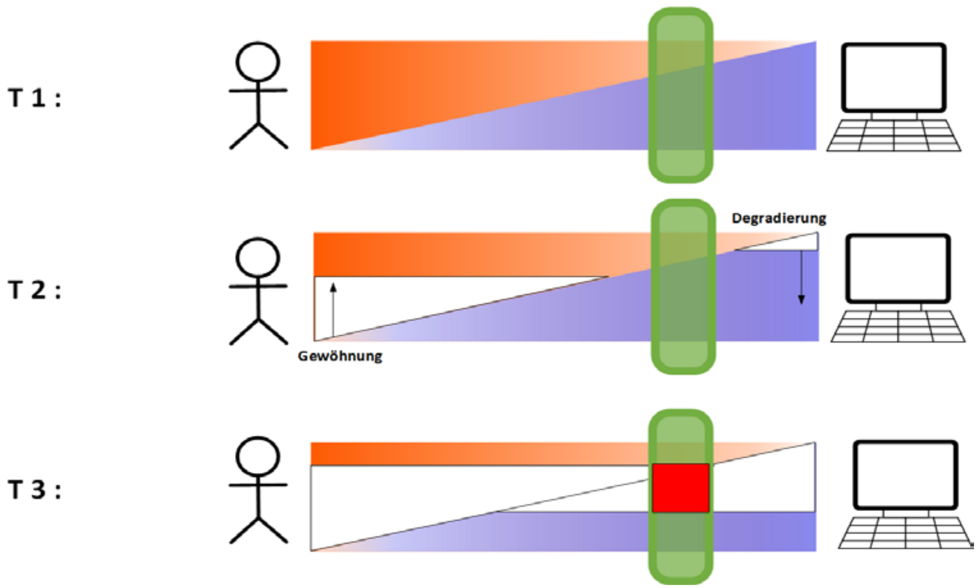
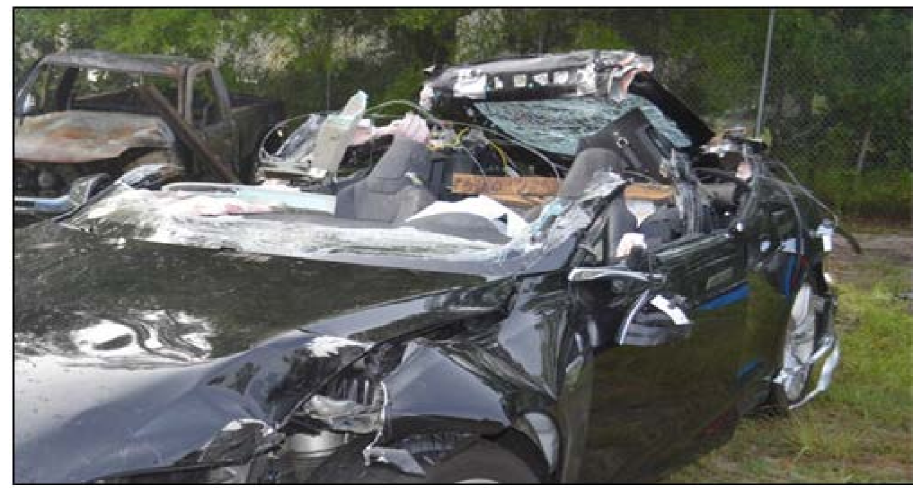
Scissor of Overtrust & Degradation?





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Tesla accident (05/16)

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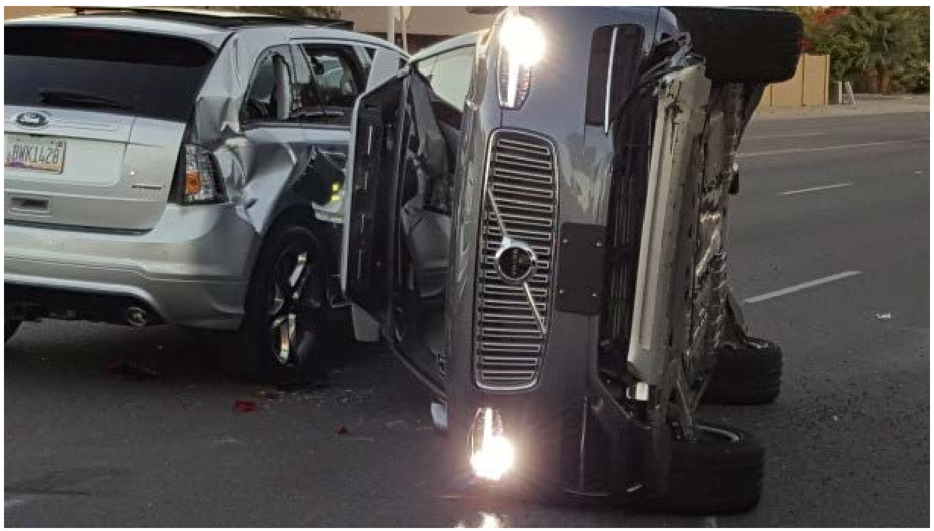
Assistance and automation: Balancing Chances and Risks!

- Chances: Safety, Performance, Usability / Ease & Joy of Use
- Risks: Safety, Usability, Joy of Use

http://planphilly.com/articles/2014/11/13/vision-zero-what-it-is-and-why-philly-mayoral-candidates-will-be-talking-about-it

The Uncanny and Unsure Valley of Automation : Uber 2018



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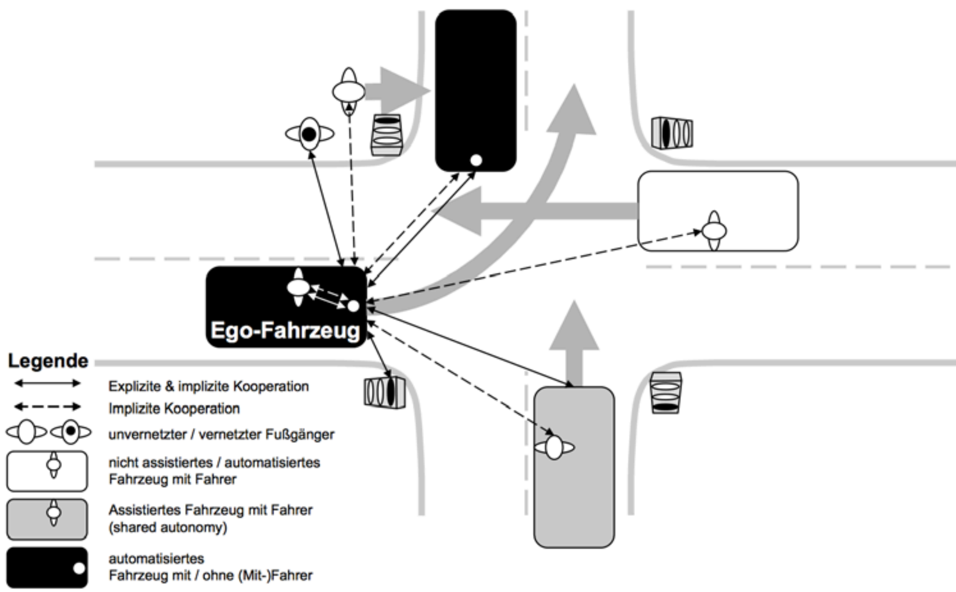
Lessons learned: System Fate is determined at system limits and transitions to failure states



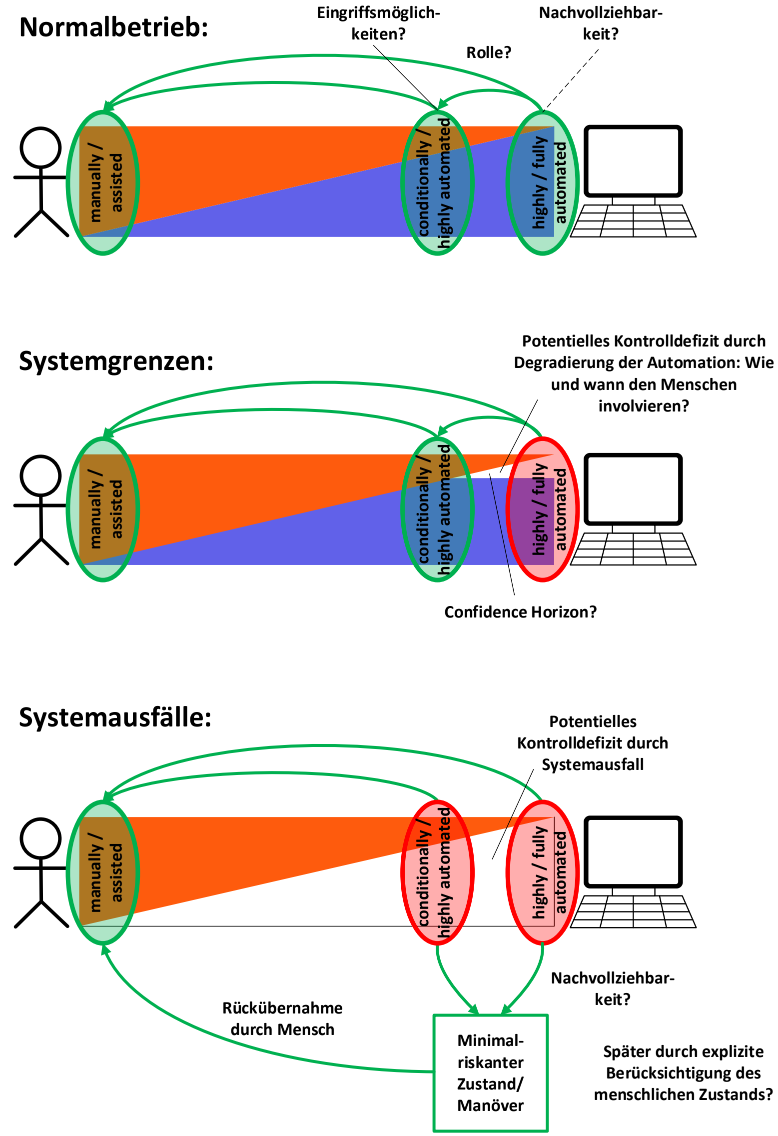


Abbildung 6: Assistenz- und Automationsspektrum bei Normalbetrieb (Oben), an Systemgrenzen (Mitte) und bei Systemausfall (Unten)

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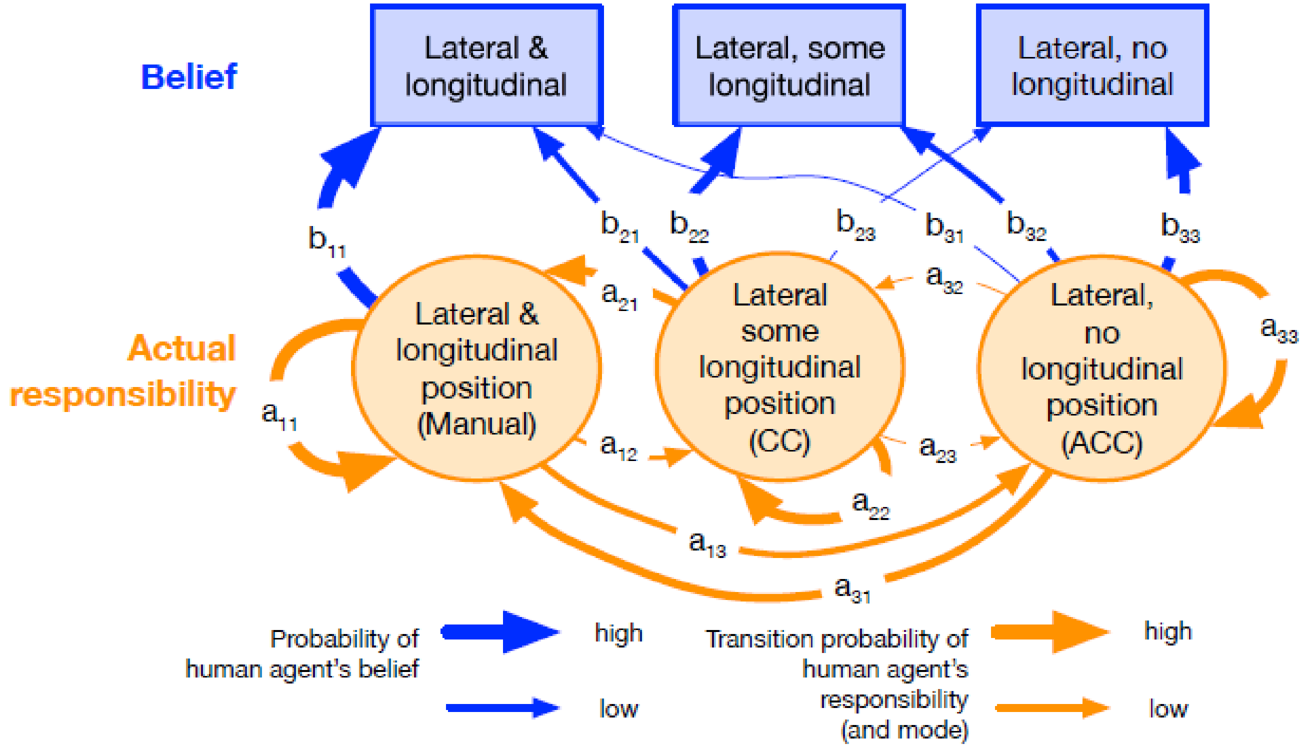
Lessons learned:
Transitions and Mode Awareness are crucial (Mode Confusion)



$$For\ all\ modes\ of\ i,\ \sum_{j=1}^{3} aij = 1$$

Janssen, C.P., Boyle, L. Ng, Kun, A.L., Ju, W., and Chuang, L. (2018)

Lessons learned: Trust is pivotal

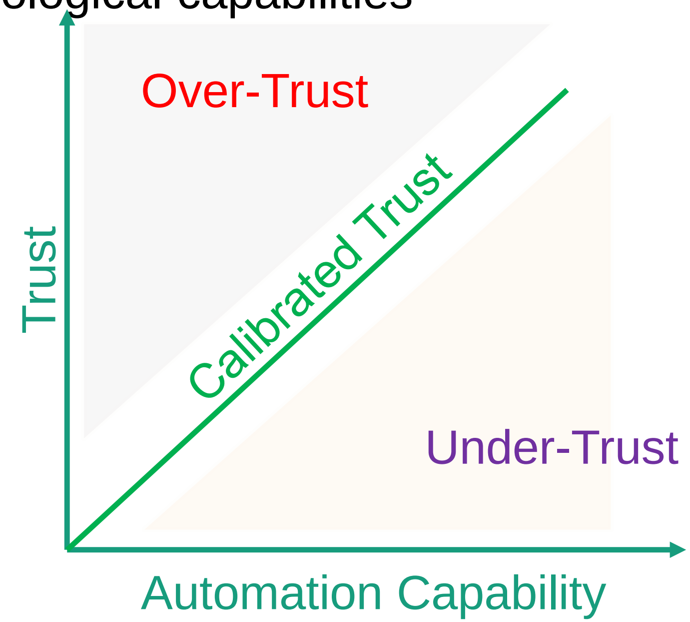
"Once lost, trust in automation, like interpersonal trust, can be hard to reestablish."

Hoffman et al. 2013

Trust in Automation

- **Over-trust**: unjustified trust in computer systems or taking advice because it comes from a computer that is called an “expert system”

- **Under-Trust**: not placing enough trust in computer systems, or failure to rely on useful technological capabilities



Lee 2012, Hoffman et al. 2013

Lessons learned:
Controllability (ISO26262) versus failure mode (e.g. IEC 61508)

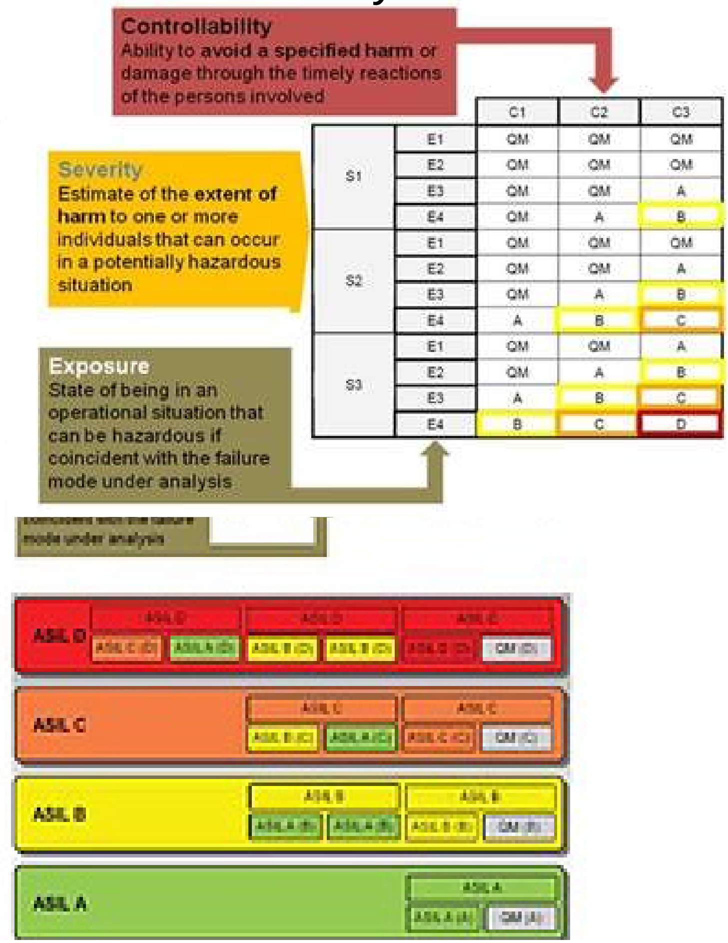
Part of ISO26262

- ASIL A, B, C, D = Severity X (Exposure x Controllability)
- ASIL is calculated for a *function* not a component
- The ASIL associated with the *function* is then inherited by the HW, SW and System Processes that deliver it.
- ASIL can be decomposed into lower levels i.e. 2 x ASIL B if offering functional redundancy can offer ASIL D

- ASIL-A has 1000 FIT
- ASIL-B has 100 FIT
- ASIL-C has 100 FIT
- ASIL-D has 10 FIT

FIT - FailureInTime - failures per 1 billion hours usage

Controllability



Automotive Safety Intergrity Levels

Topics		ASIL			
		A	B	C	D
1a	Enforcement of low complexity	++ ✓	++ ✓	++ ✓	++ ✓
1b	Use of language subsets	++ ✓	++ ✓	++ ✓	++ ✓
1c	Enforcement of strong typing	++ ✓	++ ✓	++ ✓	++ ✓
1d	Use of defensive implementation techniques	o	+ ✓	++ ✓	++ ✓
1e	Use of established design principles	+ ✓	+ ✓	+ ✓	++ ✓
1f	Use of unambiguous graphical representation	+ ✓	++ ✓	++ ✓	++ ✓
1g	Use of style guides	+ ✓	++ ✓	++ ✓	++ ✓
1h	Use of naming conventions	++ ✓	++ ✓	++ ✓	++ ✓

"++" The method is highly recommended for this ASIL.
"+" The method is recommended for this ASIL.
"o" The method has no recommendation for or against its usage for this ASIL.

✓ Satisfied by the LDRA tool suite

Mapping the capabilities of the LDRA tool suite to "Table 1: Topics to be covered by modelling and coding guidelines" offered by ISO/DIS 26262 Part 6

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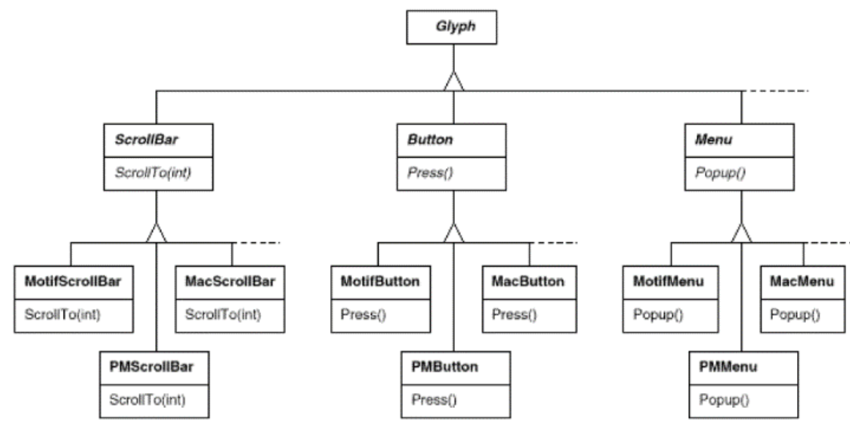
Lessons learned: Pattern help to control risks

- A pattern is a proven solution to a recurring design problem
- Christopher Alexander et al. (1977):
  A pattern language: towns, buildings, construction
- Gamma, Helm, Johnson, Vlissides (1995):
  Design Patterns: Elements of Reusable Object-Oriented Software

Baltzer, López, Flemisch, 2018a

Alexander et al., 1977



Gamma et al., 1995

HFM-247 RTG on Human-Autonomy Teaming: Supporting Dynamically Adjustable Collaboration

Mentor: Frank Flemisch DEU, Maris Vikmanis USA

Team leader(s): Dr Mark Draper (US), Prof. Dr Mark Neerincx (NL)
Members: FRA, GBR, DEU, NLD, US, ESP
Partners: SWE

Duration: Jan 2014 – Dec 2017

Co-ordination: JOINT CAPABILITY GROUP UAS

Related Activities: HFM-078, 170, 217

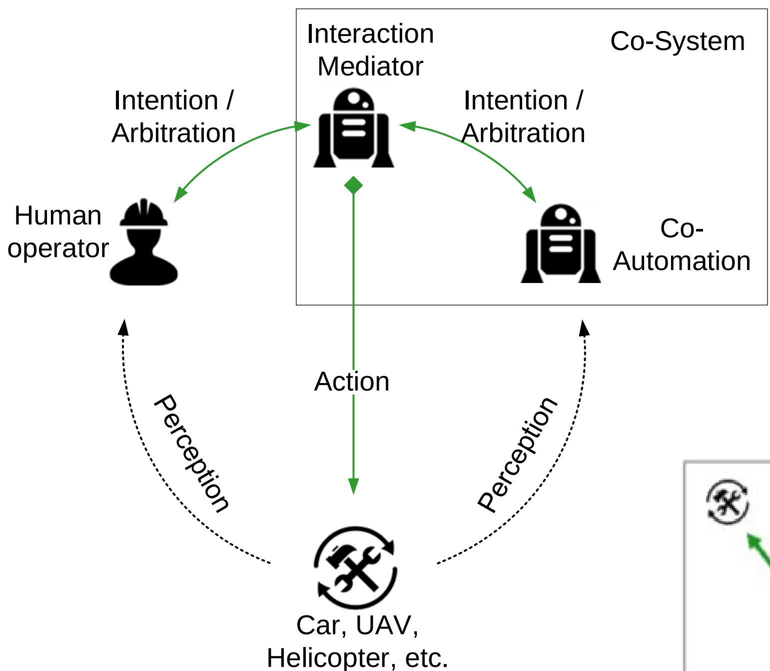
Objectives:
•Explore rapidly growing area of human-autonomy teaming
•Leverage knowledge of human-human teaming for concepts, methods metrics for human-autonomy teams
•Identify & demonstrate successful teaming methodologies and interface design practices

Topics covered:
1) Adjustable & adaptive interaction methods
2) Authority sharing architectures and interface concepts
3) Bi-directional conveyance of intent
4) Goal-based control
5) Human-autonomy problem solving / cooperative dialogue
6) Intelligent aiding for time critical decision-making

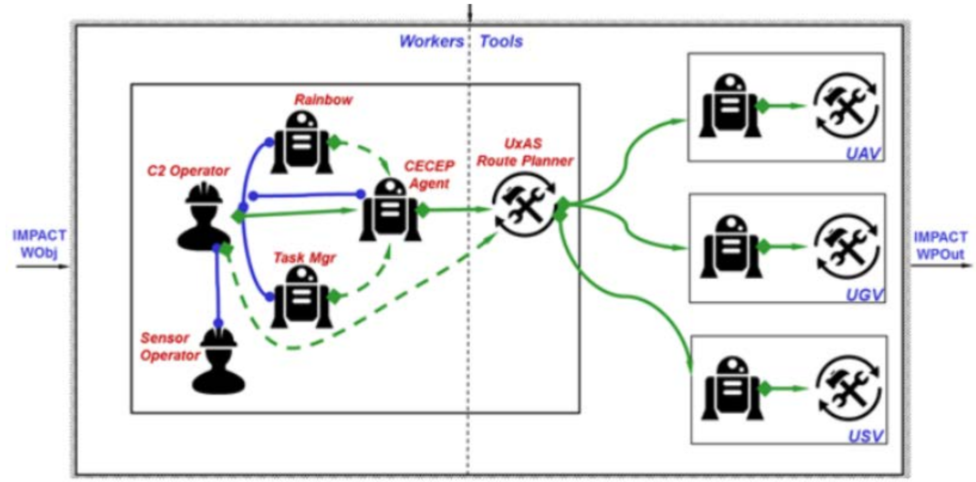
Impact and Exploitation:
•Documentation of tracked technology activities related to human-autonomy interaction across RTG participants -Increased collaboration across RTG participants on identified technical activities wherever possible - Guidelines that support other NATO activities (e.g., STANAG activities, military interoperability committee) - Human-Autonomy Teaming design patterns for developers - Priorities for future research in the area - Fall 2018 Symposium and Technology Forum in conjunction with HFM PBM

Progress:/Actions
•On track, extension to Dec 2017 approved
•Fundamental Teaming Design Patterns developed
•Final Report Outline and authoring schedule defined

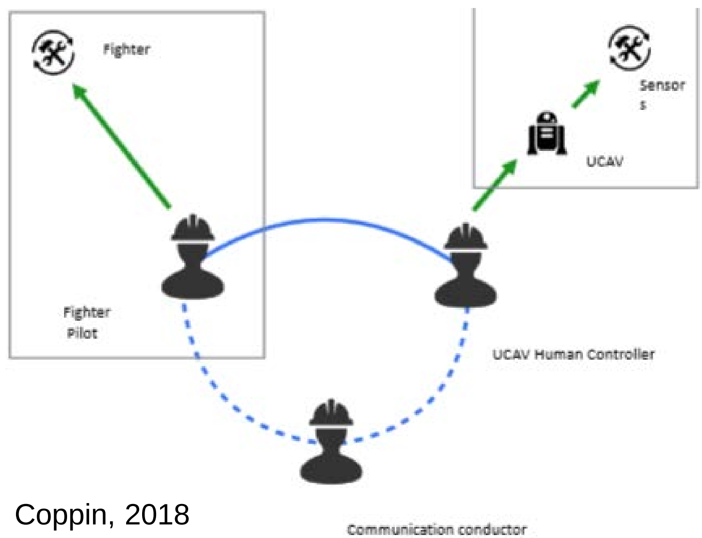
Lessons leanred: Human Automation/Autonomy Team Examples



Baltzer, López, Flemisch, 2018a



Draper, 2018



Coppin, 2018

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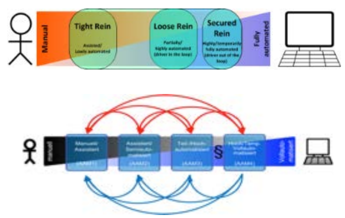
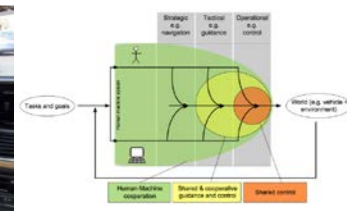
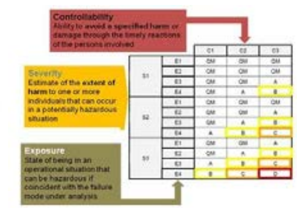
Lessons learned: Controllability is crucial (HFM-ET)

TRUST & RISK-BASED ASSURANCE:

WHICH LESSONS LEARNED FROM AUTONOMOUS AND AUTOMAT DRIVING CAN BE APPLIED TO MILITARY SYSTEMS?







Prof. Dr.-Ing. Frank Flemisch

Supported by Dr. Shadan Shadegian, Marcel Baltzer

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Literature

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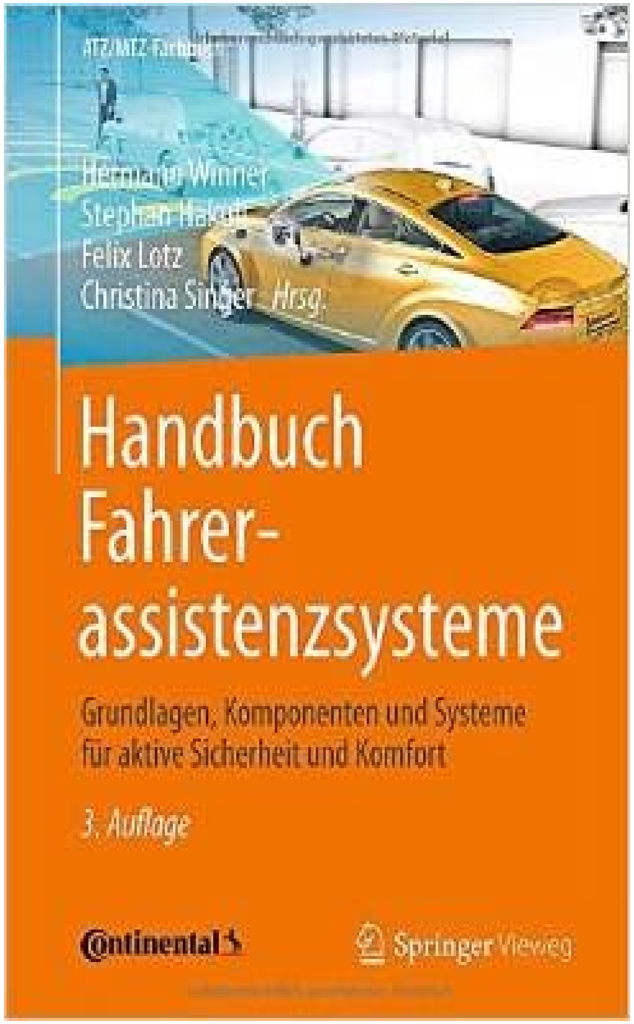

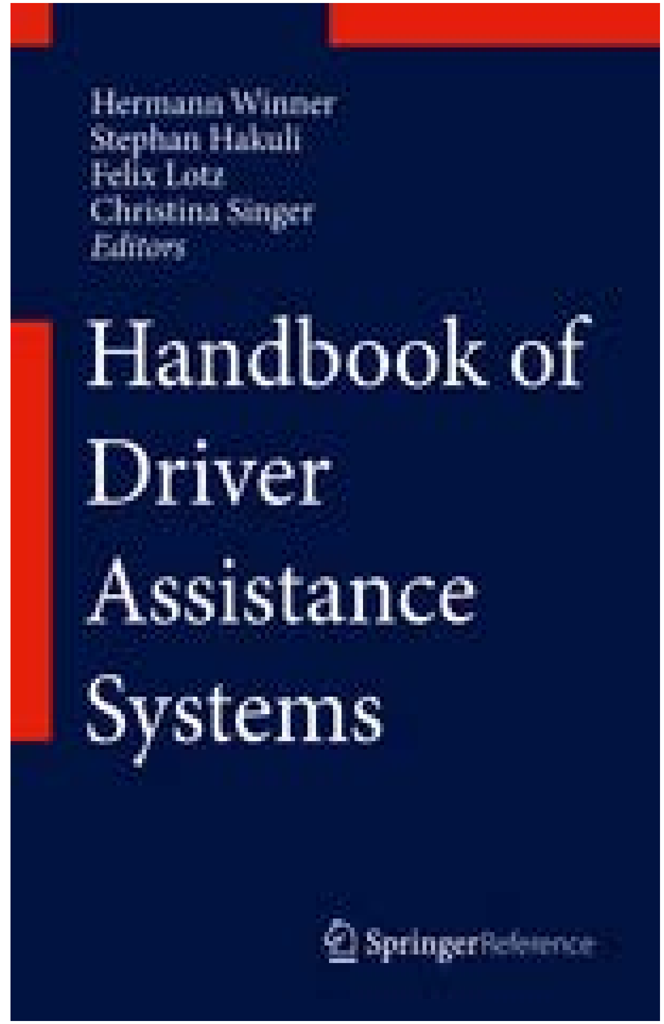

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