	**HoliDes** **Holi**stic Human Factors **Des**ign of Adaptive Cooperative Human-Machine Systems	HOliDes

Review of Human Factors Integration Concepts and Regulations

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1 Introduction

The objective of this document is the review of Human Factors Integration Concepts and Regulations substantiated for the four HoliDes domains. In this way, the acquired knowledge gained about the possible HF input relevant to the development and qualification of systems, should serve as a basis for the further working steps within WP1: definition of an initial Project Base Line and draft of the HF-RTP architecture and methodology.
The present deliverable has been generated as a result of Tasks 1.2 and 1.3. The first task was dedicated to Human Factors Integration Concepts, which are understood as frameworks for systematic HF processes, conducted throughout the system development and aimed to address the HF issues relevant for the new system. Task 1.3 focussed on HF and Safety regulations and rules, defined by regulatory authorities, industry associations, or standardization boards. The regulations in many cases focus on a subset of HF or Safety issues. They often concentrate on the requirements, which have to be fullfilled (e.g. product features) and only in few cases the way to achieve it.
In the first step the involved partner collected the relevant publications: regulations and concepts. The second working step was dedicated the structured analysis (according to an established guidelines) of the gathered material. The analysis of the HF Integration Concepts and Regulations has been carried out in order to investigate certain questions:

1. Which HF issues are considered?
2. Whether and how are HF issues translated into quality criteria?
3. Are there any human factors workflows/processes for meeting the HF issues during the development purposed?
4. Do the HF workflows correspond with the system engineering stages?
5. To which extent are the HF courses of actions specified (defined stages, recommended HF activities, applied HF methods/tools)?
6. What are the strengths and weaknesses of the HF Integration Concepts? Do they sufficiently address the specific needs of AdCos and should they be integrated in HF-RTP?

The main part of the deliverable is divided into five major chapters. Four of them (3, 4, 5, 6) built as a unit, each dedicated to one of the domains: healthcare, aeronautics, control rooms and automotive. Each chapter includes the following content: reviews of HF Integration Concepts, reviews of

HF and Safety Regulations and Conclusions. Chapter 7 deals with the ISO 9241, which is an important regulation standard of HMI aspects generally. General discussion is also provided as the last part of the document (chapter 8) .

The deliverable is a comprehensive document, which includes individual reviews of a large number of publications. It is recommended to the reader, to concentrate on those concepts or regulations relevant in his particular context. In Chapter 2 a table of the reviewed concepts and regulations gives an overview of the content. The reviews are organized according to the application domains relevant in HoliDes. The table gives additional information about addressed systems and links to the subchapters dedicated to particular findings.

2 Content Overview

Table of the reviewed findings

Aeronautics

Document	Title/Name	Adressed system	Details
Concept	The Human Factors Case: Guidance for Human Factors Integration; Edition 2.0.; EUROCONTROL; 2007	ATM	3.1.1
Concept	Integrated Human Centered Systems Approach to the Development of Advances Cockpit and Air Traffic Management Systems; R.J. Hansman, J.K. Kuchar, J.-P. Clarke, S. Vakil & R. Barhydt; 1997	advanced cockpit and ATM systems	3.1.2
Concept	Engineering Process and HF Integration Concept applied by Honeywell	not defined	3.1.3
Regulation	AC-120-76B: Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags; FAA; 2012	EFB	3.2.1
Other	DOT-VNTSC-FAA-03-07: Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags; FAA; 2003	EFB	3.2.2
Regulation	NPA 2012-02: Airworthiness and operational criteria for the approval for Electronic Flight Bags; EASA; 2012	EFB	3.2.3
Other	EFB Application Design Assessment; Honeywell; 2014	EFB	3.2.4
Other	FAA project 05-02, Task Number 09-AJP61FGI-0114: Analysis of Human Performance Risks and Benefits of Adaptive Systems, Final Report; Honeywell; 2012	adaptive flight deck systems	3.2.5
Regulation	Human Factors Design Standard; Chapter 2: General design requirements; FAA; 2003	all systems in the airplane	3.2.6
Regulation	Human Factors Design Standard; Chapter 3: Automation; FAA; 2003	automation systems	2.2.7
Regulation	Human Factors Design Standard; Chapter 5: Displays and printers; FAA; 2003	displays and printers	3.2.8
Regulation	Human Factors Design Standard; Chapter 8: Computer-human interface; FAA; 2003	all systems in the airplane	3.2.9
Regulation	Certification Specifications for Large Aeroplanes CS-25; Subpart F –	all systems used	3.2.10

	Equipment; CS 25.1302 Installed systems and equipment for use by the flight crew; EASA; 2012	by the flight crew	
Regulation	Certification Specifications for Large Aeroplanes CS-25; AMC Acceptable Means of Compliance - Subpart F; AMC 25.1302 Installed systems and equipment for Use by the flight crew; EASA; 2012	all systems used by the flight crew	3.2.11
Regulation	Certification Specifications for Large Aeroplanes CS-25; Subpart F – Equipment; CS 25.1301 Function and installation; EASA; 2012	all items of installed equipment	3.2.12
Regulation	Certification Specifications for Large Aeroplanes CS-25; Subpart F – Equipment; CS 25. 1309 Equipment, systems and installations; EASA; 2012	all equipment and systems installed in the aeroplane	3.2.13
Regulation	Annex 8; PART IIIB. AEROPLANES OVER 5 700 KG FOR WHICH APPLICATION FOR CERTIFICATION WAS SUBMITTED ON OR AFTER 2 MARCH 2004; SUB-PART D. DESIGN AND CONSTRUCTION; D1 General; ICAO; 2004	all systems in the aeroplane	3.2.14
Regulation	Annex 8; PART IIIB. AEROPLANES OVER 5 700 KG FOR WHICH APPLICATION FOR CERTIFICATION WAS SUBMITTED ON OR AFTER 2 MARCH 2004; SUB-PART D. DESIGN AND CONSTRUCTION; D2 Systems Design features; ICAO; 2004	cockpit	3.2.15
Control Room			
Concept	Air Force Human Systems Integration Handbook. Planning and Execution of Human Systems Integration. Directorate of Human Performance Integration – Human Performance Optimization Division, Distribution	all types of defence systems	4.1.1
Concept	NATO Human View • Human Systems Integration for Network Centric Warfare (2010). NATO RTO Technical Report TR-HFM-155 • NATO Human View Quick Start Guide	generic AdCoS	4.1.2
Regulation	ISO 11064 Control Centre Design Standard: • ISO 11064-1: Principles for the design of control centres; DIN Deutsches Institut für Normung e.V.; 2001 • ISO 11064-2: Principles for the arrangement of control suites; DIN Deutsches Institut für Normung e.V.; 2001 • ISO 11064-3: Control room layout; DIN Deutsches Institut für Normung e.V.; 2000 • ISO 11064-4: Layout and dimensions of workstations; DIN Deutsches Institut für Normung e.V.; 2004 • ISO 11064-5: Displays and controls; DIN Deutsches Institut für Normung e.V.; 2008	control centres as a whole	4.2.1

	• ISO 11064-5: Environmental requirements for control centres; DIN Deutsches Institut für Normung e.V.; 2005 • ISO 11064-7: Principles for the evaluation of control centres; DIN Deutsches Institut für Normung e.V.; 2006		
Regulation	MIL-STD-1472G: Design criteria standard – Human engineering; U.S. Department Of Defence; 2012	control centres as a whole	4.2.2
Regulation	MIL-HDBK-759C: Handbook for human engineering design guidelines; U.S. Department Of Defence; 1995	control centres as a whole	4.2.3
Healhtcare			
Regulation / Concept	IEC 62366 Medical devices – Application of usability engineering to medical devices; IEC International Electrotechnical Commission; 2007	medical devices	5.1.1
Concept	Human-Centred Design in Medical Fields; N. Ando, N. Nakano, N, Tohyama; 2008	health care information systems	5.1.2
Concept	Usability Engineering • Evaluation in the design of health information systems: application of approaches emerging from usability engineering; A.W. Kushniruk; 2002 • Cognitive and usability engineering methods for the evaluation of clinical information systems; A.W. Kushniruk, V.L. Patel; 2004	health care information systems	5.1.3
Concept	Medical Device Use-Safety: Incorporating Human Factors Engineering into Risk Management; U.S. Department of Health and Human Services Food and Drug Administration; 2000	all systems with human interaction	5.1.4
Concept	Human Factors and Usability Engineering: • Applying Human Factors and Usability Engineering to Optimize Medical Device Design; U.S. Department of Health and Human Services Food and Drug Administration; 2011 • Human Factors Engineering: A Tool for Medical Device Evaluation in Hospital Procurement Decision Making; G. Ginsburg; 2005 • Introduction to the Human Factors Engineering Series; J. Gosbee; 2004 • Patient Safety, Potential Adverse Drug Events, and Medical Device Design: A Human Factors Engineering Approach; Lin et al.; 2001	all systems with human interaction	5.1.5
Regulation	IEC 60601-1-6 General requirements for basic safety and essential performance. Collateral standard: Usability; IEC International Electrotechnical Commission; 2010	medical electrical equipment	5.2.1

Regulation	IEC 60601-1-8 General requirements for basic safety and essential performance. Collateral standard: General requirements, tests and guidance for alarm systems in medical electrical equipment and medical electrical systems; IEC International Electrotechnical Commission; 2012	medical electrical equipment	5.2.2
Regulation	IEC 60601-2-33 Particular requirements for basic safety and essential performance of magnetic resonance equipment for medical diagnosis; IEC International Electrotechnical Commission; 2013	magnetic resonance equipment	5.2.3
Regulation	IEC 60601-2-43 Particular requirements for basic safety and essential performance of X-ray equipment for interventional procedures; IEC International Electrotechnical Commission; 2010	X-ray equipment	5.2.4
Automotive			
Concept	Code of Practice for the Design and Evaluation of ADAS (CoP); Knapp, A.; Neumann, M.; Brockmann, M.; Walz, R.; Winkle, T.; 2009	ADAS	6.1.1
Concept /Other	*Detectability Prediction for Increased Scene Awareness. David Engel,* and Cristóbal Curio. IEEE Intell. Transport. Syst. Mag. 5(4):146-157 (2013)	visual attention guidance mechanism	6.1.2
Model/Tool	ACT-R Integrated Drive Model and ACT-R Tool • Salvucci, D. D. (2006). Modelling driver behaviour in a cognitive architecture. Human Factors, 48, 362-380.	cognitive psychology model; user model.	6.1.3 6.1.4
Regulation	ISO 15005: Road vehicles – Ergonomic aspects of transport information and control systems – Dialogue management principles and compliance procedures; DIN Deutsches Institut für Normung e.V.; 2003	dialogue management	6.2.1
Regulation	ISO 15006: Road vehicles – Ergonomic aspects of transport information and control systems – Specifications for in-vehicle auditory presentation; DIN Deutsches Institut für Normung e.V.; 2012	auditory systems	6.2.2
Regulation	ISO 15007: Road vehicles – Measurement of driver visual behavior with respect to transport information and control systems;CEN European Committee for Standardization; 2002	driver assistance and driver information systems	6.2.3
Regulation	ISO 15008: Road vehicles – Ergonomic aspects of transport information and control systems – Specifications and test procedures for in-vehicle visual presentation; DIN Deutsches Institut für Normung e.V.; 2011	visual presentation	6.2.4
Regulation	ISO 17287: Road vehicles: Ergonomic aspects of transport information and control systems – Procedure for assessing suitability for use while driving; DIN Deutsches Institut für Normung e.V.; 2003	TICS	6.2.5
Regulation	DOT HS 810 697: Crash Warning System Interfaces: Human Factors Insights and Lessons Learned; U.S. Department Of Transportation NHTSA;	crash avoidance systems	6.2.6

	2007		
Regulation	Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems; Driver Focus-Telematics Working Group; 2006	advanced in-vehicle information and communication systems	6.2.7
Regulation	Legal consequences of an increase in vehicle automation; Bundesanstalt für Straßenwesen; 2012	automation systems	6.2.8
Regulation	In-Vehicle Display Icons and Other Information Elements. Volume I: Guidelines, Volume II Final Report; U.S. Department of Transportation. Federal Highway Administration (FHWA); 2004	IVIS	6.2.9
Regulation	Distraction Detection and Mitigation Through Driver Feedback; National Highway Traffic Safety Administration (NHTSA); 2013	real-time driver monitoring systems; driver-state detection and analysis	6.2.10
Regulation	Multiple Reports from the AIDE (Adaptive Integrated Driver-Vehicle Interface)-Project	ADAS; IVIS; AIDE; driver state assessment systems	6.2.11
Regulation	(EU) No 347/2012: Commission Regulation for certain categories of motor vehicles with regard to advanced emergency braking systems; European Union Commission; 2012	AEBS	6.2.12
Regulation	(EU) No 351/2012: Commission Regulation for installation of lane departure warning systems in motor vehicles; European Union Commission; 2012	LDWS	6.2.13
Regulation	HASTE Final Report: Human Machine Interaction and the Safety of Traffic in Europe; O.M.J. Carsten, N. Merat, W.H. Janssen, E. Johansson, M. Fowkes, K.A. Brookhuis; 2005	IVIS	6.2.14
Regulation	ISO 26262 Road vehicles: Funktional Satety; DIN Deutsches Institut für Normung e.V.; 2011	electronic components in a car	6.2.15
Cross-Domain			
Concept /Regulation	ISO 9241: Ergonomics of human-system interaction; DIN Deutsches Institut für Normung e.V.; 1999-2013	interactive systems	7.1
Regulation	ISO 9241-11: Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability; DIN Deutsches Institut für Normung e.V.; 1999	display and controls	7.2.1

Regulation	ISO 9241-20: Ergonomics of human-system interaction – Part 20: Accessibility guidelines for information/communication technology (ICT); DIN Deutsches Institut für Normung e.V.; 2009	ICT	7.2.2
Regulation	ISO 9241-110: Ergonomics of human-system interaction – Part 110: Dialogue principles; DIN Deutsches Institut für Normung e.V.; 2008	dialogue principles	7.2.3
Regulation	ISO 9241-143: Ergonomics of human-system interaction – Part 143: Forms; DIN Deutsches Institut für Normung e.V.; 2012	HMI: forms	7.2.4
Regulation	ISO 9241-154: Ergonomics of human-system interaction – Part 154: Interactive voice response (IVR) applications; DIN Deutsches Institut für Normung e.V.; 2013	IVR applications	7.2.5
Regulation	ISO 9241-210: Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems; DIN Deutsches Institut für Normung e.V.; 2011	interactive systems	7.2.6
Regulation	ISO 9241-303: Ergonomics of human-system interaction – Part 303: Requirements for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2012	electronic visual displays	7.2.7
Regulation	ISO 9241-304: Ergonomics of human-system interaction – Part 304: User performance test methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009	electronic visual displays	7.2.8
Regulation	ISO 9241-305: Ergonomics of human-system interaction – Part 305: Optical laboratory test methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009	electronic visual displays	7.2.9
Regulation	ISO 9241-306: Ergonomics of human-system interaction – Part 306: Field assessment methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009	electronic visual displays	7.2.10
Regulation	ISO 9241-307: Ergonomics of human-system interaction – Part 307: Analysis and compliance test methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009	electronic visual displays	7.2.11
Regulation	ISO 9241-400: Ergonomics of human-system interaction – Part 400: Principles and requirements of physical input devices; DIN Deutsches Institut für Normung e.V.; 2007	physical input devices	7.2.12
Regulation	ISO 9241-410: Ergonomics of human-system interaction – Part 410: Design criteria for physical input devices; DIN Deutsches Institut für Normung e.V.; 2012	physical input devices	7.2.13
Regulation	ISO 9241-420: Ergonomics of human-system interaction – Part 420: Selection of physical input devices; DIN Deutsches Institut für Normung e.V.; 2011	physical input devices	7.2.14

3 Aeronautics Domain

3.1 HFI Concepts in Aeronautics Domain

3.1.1 Concept: The Human Factors Case

Reference

- The Human Factors Case: Guidance for Human Factors Integration; Edition 2.0.; EUROCONTROL; 2007
- CREDOS – Human Factors Case Report; Eurocontrol; 2009

Application of the concept

Domain: Aeronautics
System: ATM (Air Traffic Management System)

Addressed HF-issues

The HF Case addressed a wide spectrum of HF-Issues, which are classified into six broad main categories. Each category is broken down in further sub-categories. The provided organisational cluster of issues is called "HF Pie" classification tool. Definitions for the HF-issues are also given by the concept.

HF-issues Main Category	**Definition**
Working Environment	The category includes the working space, general equipment/furniture used, and the physical environment in which people work.
Organisation and Staffing	The wide category covers issues related to organisational management, people management and personal factors.
Procedures, Roles and Responsibilities,	Procedures (standard and emergency/abnormal), roles (position/propose/function having in an organisation), responsibilities and working method(task demand and complexity)
Teams and Communication	A comprehensive category addressing issues related to how individuals work and communicate with each other on shared goals and tasks. There are different aspects of team interaction and communications (e.g. information requirement, communication methods) covered.
Training and Development	"The systematic development of the knowledge, understanding, skill and attitude behaviour patterns required by an individual in order to adequately perform a given task" (Eurocontrol 2007; p. 71)

Human in System	This highlights that the human is a crucial part of the system. Subcategories are: human-machine interaction (input and output devices, information requirements, alert signals, human-machine interface, allocation of function between human and machine) and system (reliability, automation and new technology)

Within the HF Case Approach, HF-issues are assessed of how they potentially impact the human performance in the system. Twelve critical HF impacts are specified: acceptance, cognitive processes, comfort, error, fatigue, job satisfaction, motivation, situational awareness, skill change, stress, trust, and workload.

Proposed course of action

The HF Case Process is well-defined and consists of five specific stages:

- Stage 1: Fact Finding:
  - objective: the project scope from an HF perspective, is to identify what will change, who will be affected, and how they will be affected.
  - steps: gather information, initial HF assessment, review meeting
  - output: Initial HF Assessment
  - support given: Fact Finding Template and Guidance for Completion; HF Pie
- Stage 2: Issues Analysis:
  - objective: identify and prioritize the project specific HF Issues and consider their potential impact on human performance and on the system, identify mitigation strategies
  - steps: identify HF Issues and their impacts (group workshop or expert interviews), prioritize the HF Issues and their impacts, Draft the Issues Analysis Report
  - output: Issues Analysis Report
  - support given: Guideline to choose the appropriate approach (group workshop or expert interview); Group Workshop Guidelines; HF Issues Descriptions; Definitions for HF Impacts on Human Performance; Issues Analysis Approach Feedback Form; Issues Analysis Report Outline; Example Criteria and Definitions for High, Medium and Low; Example of Assigning Criteria to Issues
- Stage 3: Action Plan:
  - objective: describe HF Actions and mitigation strategies necessary to address the selected relevant HF Issues (listed in Issues Analysis Report).

- steps:
  - Identify HF Actions required:
    - mitigation strategies
    - simulations
    - studies (e.g. literature review; cognitive work analysis; workload assessment; error investigations)
  - Determine monitoring arrangements for the HF effort;
  - Draft the Action Plan
- output: Action Plan
- support given: Action Plan Content and Elements

- Stage 4: Actions Implementation
  - objective: implement the actions defined in the Action Plan, validate the results, and report the HF conclusions and findings in the HF Case Report.
  - steps: carry out the Actions; validate the actions findings; draft the HF Case Report
  - output: HF Case Report
  - support given: : HF Actions Findings Template; HF Case Report Outline
- Stage 5 - HF Case Review:
  - objective: review the quality of the conducted HF Case-Process
  - steps: Review process; draft the HF Review Report
  - output: HF Case Review Report
  - support given: : HF Case Review Report Outline

The concept primarily proposes Human Factors Management activities. These are structured very clearly and described in detail. The format for drawing conclusions is also given. On the contrary, the Human Factors Engineering activities are not closely considered.

System development stages addressed by the concept

- The HF Case Concept is a management process that enables the addressing and management of HF-Issues systematically throughout a project lifecycle (8 stages) in order to improve human performance within the system.
- The HF Case process can be initiated at any stage of the project lifecycle, but it is recommended to do so as early as possible, because of greater prospects to handle HF-Issues satisfactorily and cost efficiently.

- The HF Case Process consists of 5 defined stages. The authors only point out that the HF Case Process should run in parallel to the project lifecycle. However, they do not concretize when exactly the HF Case-stages/activities should occur in correspondence with the project lifecycle processes.
- The HF Case does not refer to the V-Model, rather it only emphasises, that the application of HF is a core part of the system design evaluation and implementation.

Proposed Tools

Eurocontrol purposed a HF Case e-tool, which is a standalone application to log and track HF case data throughout the five stages of the HF Case process for any ATM project. Using the tool requires the completion of the Eurocontrol HF Case Training Course and to sign a licence agreement

STRENGTHS-WEAKNESSES Analysis

Strengths:

- The concept provides a practical framework to address and manage the HF issues systematically throughout a project lifecycle (e.g. system design, evaluation, implementation and operation).
- The concept has been composed to support a development process of complex cooperative systems (ATM), where interactions occur between a number of humans and machines. As a result of it the concept takes a wide range of HF issues under consideration:
  - An extensive structured map of HF issues (classification and representations of HF-issues at different level of details) is given.
  - The work process of how to identify the relevant HF-issues in the project is defined clearly. It establishes a basis for the HF integration process.
- The HF Case provides a well-specified and structured course of action for HF Integration process. The objectives, work steps, deliverables and outputs from each stage of the process are clarified very well. Detailed Guidelines for planned activities and templates for outcomes are given.
- The application of the concept, mainly drawing conclusions from every stage, enables for a good overview and makes the HF work status and achieved results in the project transparent for all partners/stakeholders involved in the development process.

- The concept has matured with its application. Since the first version was published in 2004, more than a dozen HF Cases have been carried out for various EATM projects. As a result, a new revised version has been composed in 2007.
- The HF Case establishes a matured process/guidance of HF integration throughout a project lifecycle that could be entirely or in large parts adopted for AdCos and be integrated in the HF-RTP. The concept as a HF management "tool" does not set a large focus on the domain- specific HF topics. A universal cross-domain application of the HF Case is conceivable.
- The concept provides a structured and comprehensive representation of various HF-issues, which could be important for the development of complex systems. It could deliver a useful reference/checklist/overview for AdCos development and be inserted in the HF-RTP.

Weaknesses:

- The objective of the approach is the HF management throughout a project. It does not deal with the human factors topics and activities/methods directly. It only emphasises that HF actions and mitigation strategies (necessary to address the selected relevant HF Issues) should be planned, implemented and documented.
- The HF Case Process does not correspond to the V-Model.

3.1.2 Concept: Integrated Human Centred Systems Approach to the Development of Advanced Cockpit and ATM Systems

Reference

Integrated Human Centered Systems Approach to the Development of Advanced Cockpit and Air Traffic Management Systems; R.J. Hansman, J.K. Kuchar, J.-P. Clarke, S. Vakil & R. Barhydt; 1997

Application of the concept

Domain: Aeronautics
System: advanced cockpit and ATM information systems.
Case studies applying the concept focussed on the following systems and procedures "intent information on cockpit traffic display", "hazard alerting and conflict probe and design issues", and "minimal noise approach and departure procedures".

Addressed HF-issues

- Automation and new technology
- input devices
- output devices
- information requirements
- alert signals
- allocation of function between human and machine

Further issues that are covered by the concept are:

- system performance (new system must improve performance of the coupled system, i.e. humans)
- situational awareness
- attentions limitations
- information and task overload
- understanding of the automation criteria
- changes in authority
- changes in communication modes
- loss of „party line" information
- unexpected compensatory behavior
- human acceptance and trust of automation
- human reliance in automation

HF-Workflow in the development process

V-Model steps	Supported by the concept (original step)	HF-Activities	Proposed Methods	Output format of methods
Requirements Engineering	✓	Model the system and operator(s) as a closed loop feedback process. Determine the information that the operator requires to perform the task.	• functional analysis • time line analysis • interviews • surveys	unformalized
System Architecture				
H-S Requirements Evaluation	✓	Use the information requirements to determine the display/automation requirements.	• information requirement analysis • assessment of technological capability	unformalized

H-S-Design	✓	Develop prototype systems. Perform simulation evaluations.	• rapid prototyping on graphical workstations	unformalized
H-S-Implementation				
H-S Integration/ Verification				
H-S Testing (Validation)	✓	Integrated simulation testing. System evaluation	• simulation studies • cost-benefit analysis	unformalized
System Integration/ Verification				
System Validation	✓	Field development phase	• field studies	unformalized

STRENGTHS-WEAKNESSES Analysis

Strengths:

The concept Integrated Human Centered Systems approach covers almost the full category 6 of human factors issues "human in system". Therefore it can be regarded as a strong concept. Moreover the authors list a variety of systems that have been developed by using this concept. These systems are now integrated in the ATM-procedures. The concept has been applied successfully and accompanies many steps of the system development process.

Weaknesses:

The concept has been applied to a narrow group of systems, namely advanced information systems. The authors do not mention whether it can be applied to other systems as well. Additionally almost only human factors activities are described. Methods that could be used are rarely given or described. There are almost no concrete methods mentioned. So it is difficult to develop a chain of action following the concept. There are also no tools given.

General evaluation and summary

The Integrated Human Centered Systems Approach is a concept that has been applied successfully in the domain of aeronautics. It accompanies many

steps of the system development process and offers different opportunities to integrated human's limitations and capabilities in the field of "human in system". The authors mention many issues that arise in the co-operation of humans and automation and that can be tackled by the usage of the concept. Even though there are only a few methods mentioned the concept can be regarded as a strong concept, since use cases show its strength. Additionally the lack of methods offers flexibility such that the concept can be applied to many different systems.

3.1.3 Engineering Process and HF Integration Concept applied by Honeywell

Engineering process

The process is described in two major phases. First is the development of the technology, which has the following steps:

1. Gather the requirements
2. Evaluate benefits/interests in the technology
3. Verify the feasibility of the technology
4. Create the realistic prototype
5. Evaluate the risks of the development and create mitigation strategies

The second phase is the product realization that turns the technology into a product applying the required safety standards. The steps are:

1. Create the product that complies with all applicable standards and restrictions
2. Undergo certification process
3. Deploy and support the product

The two phases are rather separate though interaction exists during execution of each of them.

- Development of the technology
  The development of the technology is based on the standard industrial process of manufacturing the technology readiness level, (TRA at wiki). The process is then broken down into a sequence of steps, in which the risks are identified and mitigated and the technology matures from initial ideas into a reliable prototype. The steps (technology readiness levels, TRLs) are:
  TRL 1: Basic principles observed and reported
  TRL 2: Technology concept and/or application formulated

TRL 3: Analytical & experimental critical function and/or characteristic proof-of-concept
TRL 4: Component and/or breadboard validation in laboratory environment
TRL 5: Component and/or breadboard validation in relevant environment
TRL 6: System/subsystem model or prototype demonstration in a relevant environment (ground or space)
TRL 7: System prototype demonstration in a space environment
TRL 8: Actual system completed and "Flight qualified" through test and demonstration (ground or space)
TRL 9: Actual system "Flight proven" through successful mission operations

The process is usually adjusted to the working environment of each company that applies it and the adjustment is considered confidential (such as in case of Honeywell).

HF integration concept

Maturing the technology readiness is a general process where no explicit strategies for integration of human factors are mentioned. It is up to each user of the process to define his/her own strategy. This strategy is usually considered confidential.

HF integration reflects the TRLs and usually adds specific actions to be taken and verified at each TRL. This implies that in the beginning the development team needs to identify

1. Whether there are any HF aspects in the technology
2. At which TRL the HF aspects should be addressed
3. Who are the HF experts to be contacted at respective TRLs

During execution of the development process, each TRL affected by HF issues is extended for activities the HF team should undergo. The results of the activities are documented in prescribed artefacts such as

TRL 2:
- Intended function definition
- Task analysis and functional allocation
- Preliminary test plan

TRL 3:
- Preliminary user interface
- Feedback of a representative user to the preliminary user interface

- Evaluation via simple HF assessment techniques (user survey, design walk-through etc.)
- Evaluation reports

TRL 4

- Updated user interface
- Evaluation based on more sophisticated techniques (experiments in laboratory environment with target users)
- Evaluation reports

TRL 5

- Preliminary HF certification strategy
- Continuous evaluation of user interface being developed (experiments for the integrated system, not only the interface itself)
- Evaluation reports
- Technology transition plans (describing how HF issues will affect the productization)

TRL 6

- Continuous evaluation
- Evaluation reports
- HF risk mitigation strategy
- Compliance to HF standard and regulations

Similar to the engineering process, transition to a higher TRL needs to be authorized by independent board of experts during a review process called on by the development team.

3.2 HF and Safety Regulations in Aeronautics Domain

3.2.1 Guidelines for the Certification, Airworthiness and Operational Use of Electronic Flight Bags

Reference

AC-120-76B: Guidelines for the Certification, Airworthiness, and Operational Use of Electronic Flight Bags; FAA; 2012

Application of the regulation

Domain: Aeronautics
System: Electronic Flight Bag

Addressed HF-issues

- Working Environment

- Training and Development
- Human in System

Demand of HF-activities during development process

- Regulations on design of EFB HW and SW
- Regulations on HMI aspects of EFB applications

Addressed system development stages

- System architecture
- HW-SW Design
- HW-SW Implementation
- System Validation

Additional information

There are 2 EFB hardware classes and 3 software types (A, B, C).

- **HMI Design regulations for Class 2 EFBs**
  - The system must not be used as primary source of information. The beneficial safety function may augment, elaborate, or supplement information coming from a primary information source whether it is presented in the primary field of view displays or the out-the-window view, but it must not replace it.
  - Designing the User Interface (UI) of an EFB Class 2 platform to decrease the risk of over compliance
  - Designing UI of a safety beneficial function to prevent unintended usage, and/or
  - Design the operational procedure for the safety beneficial function to prevent transfer of responsibility from the aircrew to the safety beneficial function
  - The UI of an EFB platform must be compatible with the flight deck in terms of basic design principles including consistency of colour coding, symbols, etc., but it should not elicit higher expectations related to robustness of the system functionality than the system is able to provide.
  - One of the most important concerns of the regulatory authorities is usage of the EFB Type B applications for navigation purposes. This means displaying of the own ship in relation to the navigation aids as magnetic rose, arc, navigational aids, etc. The concern of the regulatory authorities is given by the lower reliability and robustness of the EFB application to display navigational data. This is a

valid concern as using the EFB Class 2 device as primary source of information for navigation of the aircraft could impair flight safety.

- The own ship position could be used when displaying strategic weather along the route, help the pilot to avoid the impaired weather conditions, etc. The same logic as with displaying of the own ship position during the flight besides the approved display of own ship position on AMM could be applied when investigating possibilities to display other aircraft position using ADS-B In data on EFB Class 2 hardware. If the data is used for strategic purposes and displayed in a way that it prevents the aircrew from using it for tactical navigation manoeuvring, then may be even possible to host such feature on non-certified EFB hardware.

- **Class 3 EFB**
  EFBs installed in accordance with applicable airworthiness regulations. Refer to AC20-173 for guidance on the installation of EFB components. For this class read and write interaction with avionic is allowed.
  - **Type A EFB Software**
    Type A EFB SW applications include pre-composed, fixed presentations of data currently presented in paper format. Type A applications are typically intended to be used on the ground or during non-critical phases of flight. Type A application software may reside on any EFB hardware classification. These applications do not need any formal approval. The operator must possess evidence demonstrating that operational requirements are met when using Type A software applications. This means that the operator can use the application after successful completion of the user/operator evaluation (including flight crew training, checking and currency requirements).
  - **Type B EFB Software**
    Type B EFB SW applications include dynamic, interactive applications that can manipulate data and presentation for operationally required and other paper reference materials. Type B applications are applications that are intended for use during critical phases of flight. Type B application software may reside on any EFB hardware classification. These applications do not need any formal approval. The operator must possess evidence demonstrating that operational requirements are met when using Type B software applications. This means that the operator can use the application after success-

ful completion of the user/operator evaluation (including flight crew training, checking, currency requirements and FSB reports). Type B applications require a validation period to ensure the reliability of the EFB functions prior to the removal of the applicable paper documents.

- **Type C EFB Software**
  Type C EFB SW applications include intended functions for communications, navigation, and surveillance that require FAA design, production and installation approval. Type C applications are FAA approved software using RTCA/DO-178B compliance or other acceptable means. Approved software applications will have an FAA approved flight manual supplement. Type C applications are for airborne functions with a failure condition classification considered to be a major hazard or higher.

- **HMI guidelines (Part 12 – EFB System Design Considerations)**
  - Legibility of Text: Text displayed on the EFB should be legible to the typical user at the intended viewing distance(s) and under the full range of lighting conditions expected on a flight deck, including use in direct sunlight.
  - Flight crew Workload: The EFB software design should minimize flight crew workload and head-down time.
  - Human/Machine Interface: The interface design (including, but not limited to, data entry methods, color-coding philosophies, terminology, and symbology) should be consistent across the EFB and various hosted applications.

3.2.2 Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags

Reference

DOT-VNTSC-FAA-03-07: Human Factors Considerations in the Design and Evaluation of Electronic Flight Bags; FAA; 2003

Application of the regulation

Domain: Aeronautics
System: Electronic Flight Bag

Addressed HF-issues

- Human in System:

- Legibility – Lighting Issues.
- General use of colours
- Legibility of Text—Character
- Legibility of Text—Typeface Size and Width
- Legibility of Text—Spacing for Readability
- Non-Text Display Elements

Demand of HF-activities during development process

- Regulations on design and evaluation of EFB SW

Addressed system development stages

- System architecture
- HW-SW Design
- HW-SW Implementation
- System Validation

3.2.3 Airworthiness and operational criteria for the approval for EFB

Reference

NPA 2012-02: Airworthiness and operational criteria for the approval for Electronic Flight Bags; EASA; 2012

Application of the regulation

Domain: Aeronautics
System: Electronic Flight Bag

Addressed HF-issues

- Training and Development
- Human in System

Demand of HF-activities during development process

- Regulations on design and evaluation of EFB SW

Addressed system development stages

- System architecture
- HW-SW Design
- HW-SW Implementation
- System Validation

Additional information

- Procedures to Mitigate and/or Control Workload: Procedures should be designed to mitigate and/or control additional workloads created by using an EFB system.
- Legibility of Text: Text displayed on the EFB should be legible to the typical user at the intended viewing distance(s) and under the full range of lighting conditions expected on a flight crew compartment, including use in direct sunlight. Users should be able to adjust the screen brightness of an EFB independently of the brightness of other displays on the flight crew compartment. In addition, when automatic brightness adjustment is incorporated, it should operate independently for each EFB in the flight crew compartment. Buttons and labels should be adequately illuminated for night use.

3.2.4 EFB Application Design Assessment

Reference

EFB Application Design Assessment; Honeywell; 2014

Application of the regulation

Domain: Aeronautics
System: Electronic Flight Bag

Addressed HF-issues

- HMI:
  - use of colours
  - legibility (lighting conditions, text, symbols, adjustment to changed human vision by older users)

Demand of HF-activities during development process

- Guidelines for graphical design of EFB SW

Addressed system development stages

- HW-SW Design
- System Validation

3.2.5 Analysis of Human Performance Risks and Benefits of Adaptive Systems

Reference

FAA project 05-02, Task Number 09-AJP61FGI-0114: Analysis of Human Performance Risks and Benefits of Adaptive Systems, Final Report; Honeywell; 2012

Application of the regulation

Domain: Aeronautics
Generic
System: Adaptive flight deck systems

Addressed HF-issues

- Training and development (training requirements)
- Procedures, roles and responsibilities
- Human in System: situation awareness, distraction, workload, user acceptance)

Proposed HF-activities during development process

- Guidelines and recommendations for architecture and design of adaptive systems

Addressed system development stages

- Requirements engineering
- System architecture
- HW-SW requirement evaluation
- HW-SW Design
- HW-SW implementation
- HW-SW testing
- System Validation

Additional information

- **Adaptive Systems, Automation, and Perception of Non-Determinism**
  - Adaptive systems that appear to be non-deterministic should be avoided. Many elements of an adaptive system can cause it to be

perceived as non-deterministic, and these elements should be assessed on a case by case basis.
  - Adaptive systems may have many of the same benefits as good full time automation, but adaptive systems carry inherently more risk related to predictability. Hence adaptive systems should be used rather than good full time automation only when the adaptive nature provides a very clear benefit over an "all the time" automation feature or function.
  - Adaptations that turn on and off too frequently or too infrequently should be avoided.
  - Triggers which are less observable by the user (e.g. operator measurement or task tracking) should be used cautiously since they may appear to be non-deterministic and carry more risk.
- **Overall Adaptive System Risks and Benefits**
  - All potential adaptations pose some risk to pilot performance in addition to potential benefits. These risks and benefits need to be considered together in determining whether an adaptive system is acceptable or not.
  - Adaptive systems should minimize negative impacts on all aspects of pilot performance.
  - Adaptive systems should maintain or improve pilot situation awareness compared to the level normally achieved without the adaptive system, except when near-term performance takes priority.
  - Adaptive systems should maintain or improve the ability of the flight crew to stay engaged and "in the loop" compared to that achieved without the adaptive system.
  - Adaptations that change control authority between pilot and automation should be avoided; if necessary, they should be done sparingly and accompanied by salient feedback.
  - Adaptive systems that provide information or recommendations, but still allow pilots to make decisions and selections are more acceptable than adaptive systems that make decisions and have control authority.
  - Adaptations that provide a last resort "safety of flight" function may be acceptable even if they have human performance risks.
  - The benefit of an adaptive system should be obvious to the pilots; if it is not, pilots will be less likely to accept the adaptive system and may consider it to be a nuisance or distraction.

- A variety of sources of potential risks of adaptive systems should be assessed before the systems are deemed acceptable.
- Adaptive system risk assessment should evaluate unintended negative consequences.
- Balancing pilot workload is one of the main drivers of adaptive systems which are designed specifically to improve pilot-system performance. However, workload should be assessed for both positive and negative changes due to introduction of adaptive systems.
- The impact of the introduction of an adaptive system on training requirements needs to be considered.
- The Adaptive systems should minimize the likelihood of adaptation-induced oscillations that would severely disrupt flight crew workflow.

- **Guidelines related to Adaptive System Components**
  - Triggers:
    - Operator measurement and task tracking triggers should be utilized with caution until the state-of-the-art is more mature.
    - All trigger types other than operator measurement and task tracking are inherently low risk and should be considered as potentially acceptable triggers for adaptive systems.
    - The number of triggers that are combined to activate any adaptation should be kept relatively small.
  - Processing Types:
    - More sophisticated processing methods (e.g., neural nets, Bayesian models) that are less transparent and more complex than other types of processing (e.g., simple production rules) can be considered if they provide more accurate, predictable, and timely adaptations
  - Adaptation Types:
    - Task sharing adaptations that are informational in nature are more acceptable from a pilot performance perspective than those that are action or control oriented.
    - Task offloading involving lower priority tasks are more acceptable from a pilot performance perspective than those involving high priority or flight critical tasks.
    - The adaptive offloading of large tasks or function chunks should be avoided because it can cause greater risk of pilots losing situation awareness and being out of the loop.

- Adaptive systems that generate a list of information to add or subtract, which pilot can select, are more acceptable than systems that automatically adding/subtracting information. However, the extra workload of systems that require pilot selection or activation of information content adaptations must be considered.
- Level of abstraction/integration adaptations are potentially both high risk and high benefit, so the acceptability must be evaluated on a case by case basis.
- Even though prioritisation adaptations are informational, to be acceptable they must assure that pilots don't over-rely on the information in safety-critical situations.
- An adaptive system that could assist pilots with returning to an interrupted task as well as remind them of a missed or forgotten action that could could turn into more serious problems, should be considered to be potentially high benefit and low risk.
- Adaptations that intentionally interrupt current pilot tasks should be used sparingly and are recommended only if the automation can unequivocally determine that there is imminent danger due to pilots not attending to key tasks or information.
- Adaptations of Interface Features are generally low risk adaptations, especially if the adaptation is implemented in a way that gets pilot attention without being overly intrusive or annoying.
- Adaptive changes from visual to aural should be minimised to avoid too much aural information on the flight deck and potential interference with other aurally presented information. Changes from aural to visual information should be assessed for the possibility of misleading pilots into assuming the problem or condition that was being aurally indicated went away.

- **Risks related to adaptive system characteristics**
  - Key adaptive system characteristics that should be assessed as risks to pilot performance include authority, complexity, accuracy, sensitivity, robustness, novelty, and pilot acceptance.

- Adaptive systems should include predictability and transparency features, which make automatic changes (and anticipated changes) as obvious to the pilots as possible.
- While a large number of adaptive system characteristics were identified that are relevant to adaptive system risk, all the characteristics are inter-related and issues with one characteristic should be assessed in conjunction with other characteristics.
- Triggers and adaptations are likely more observable by pilots than the processing. Therefore trigger and adaptation characteristics such as complexity and transparency should be assessed more carefully than processing characteristics.

- **Operational Use Factors Affecting Adaptive System Risks**
  - The type of application that the adaptive system is being utilised for should be considered in assessing its acceptability.
  - The operational situation in which the adaptive system is being utilized should be considered in assessing its acceptability
- **Implementation Considerations for Adaptive Systems**
  - All adaptive systems should regularly and saliently communicate their status, intention and any issues associated with their performance.
  - If adaptations are reversible, pilots should have a quick and easy way to override them.
  - Actions that have recently been performed by pilots should generally not be overridden with automatic adaptations.
  - The interaction style of the adaptive system should be assessed as a key component of the adaptive system; it can have a significant impact on the overall risk and benefit of the system.
  - The amount of required pilot interaction with an adaptive system should consider factors other than pilot workload.
  - Turning adaptations on and off may require different design approaches and result in different triggers for activating and deactivating the adaptation.
  - Acceptable adaptive systems should have explicit features that mitigate the potential nuisance/distraction/disruption potential of the adaptations.
  - If adaptive systems have incomplete information for triggering the adaptation, it should inform the pilot and first ask whether he/she wants it to proceed on information available or wait until all information is available to engage the adaptation.

- Utilising an operator initiated trigger will realise many risk mitigations with minimal costs.
- When tuning adaptive systems for invoking sensitivity it is advisable to bias them to minimize false positives and not misses.

3.2.6 Human Factors Design Standard: General design requirements

Reference

Human Factors Design Standard; Chapter 2: General design requirements; FAA; 2003

Application of the regulation

Domain: Aeronautics
System: all systems in the airplane

Addressed HF-issues

Knowledge, skill, and ability requirements; Personal Factors; Training; Task Demand; Human machine interaction; System Reliability Demand / Proposition of HF-activities during development process

Additional information

Chapter 2 of the Human Factors Design Standard regulates the general design requirements for systems and equipment. It describes basic design elements like the durability of systems, their reliability and the appropriate allocation of their functions. General rules for simplicity, consistency, standardization and the user-centered perspective are explained. Systems shall be designed to minimize user actions and training requirements but maximize human performance. Safety of systems is ruled in this chapter, too. A fail-safe design and the error resistance are two examples therefore. Systems shall be easy to maintain and help has to be provided in case of difficulties during operating or maintaining software, systems or equipment. There is no HF-workflow (activities during the development process) given.

3.2.7 Human Factors Design Standard: Automation

Reference

Human Factors Design Standard; Chapter 3: Automation; FAA; 2003

Application of the regulation

Domain: Aeronautics

System: all systems in the airplane using automation

Addressed HF-issues

Noise; Knowledge, skill, and ability requirements; Physiological Factors; Stress; Preoccupations; Training; Procedures; Roles; Responsibilities; Complexity; Team interaction; Human machine interaction; System Reliability, Automation and new technology

Proposed HF-Activities

1. Design of automation should begin by choosing the human-centered criteria (goals) of the system and then defining the functions that the system will perform. (analysis)
2. When new automation is introduced, the designers shall consider the possibility of negative effects on team coordination. (analysis)
3. The overall impact of automation shall be thoroughly examined before implementation to ensure that changes do not result in additional complexities, loss of situational awareness, or possibilities for error. (analysis/evaluation)
4. Contextually valid human-in-the-loop experiments and simulations should be conducted to validate and refine automated system design. (evaluation)
5. Possible interactions with other tools, system functions, and user tasks shall be evaluated when new automation is designed. (evaluation)
6. New automation components shall be tested with the complete system, including other automated components of the system, to ensure they function together as an effective whole. (evaluation)
7. Automated systems shall be tested under normal modes of operation and under failure modes of the automation. (evaluation)
8. Automated systems shall be tested in a realistic operational environment with representative users before implementation to ensure that operator performance is not compromised and workload is not increased. (evaluation)

HF workflow

Requirements Engineering; Hardware-Software Requirements; System Integration/Verification; Hardware-Software Testing

Additional information

Chapter "Adaptive automation" integrated, including hints under which conditions adaptive automation shall or shall not be implemented.

3.2.8 Human Factors Design Standard: Displays and printers

Reference

Human Factors Design Standard; Chapter 5: Displays and printers; FAA; 2003

Application of the regulation

Domain: Aeronautics
System: all systems in the airplane using displays and printers

Addressed HF-issues

- work place layout;
- physical limitations;
- Human machine interaction;
- System Reliability

Additional information

The regulation describes design and position requirements of displays and printers. There are no HF-activities or HF workflow described. This chapter only addresses visual displays used for information output. Touch screen displays and visual indicators are not regulated in this chapter. General rules outline how output devices have to be presented on the displays like the legibility, the avoidance of unnecessary markings and contrast and brightness. Location of the displays is explained in connection with the line of sight and the optimum vertical and horizontal visual fields. Specifics of different types of displays are described in the following subchapters. When printers should be used, where they shall be located and how information has to be presented on the printed tapes is the content of the next subchapter. The rule ends with the use of plotters and recorders and accommodation requirements for people with disabilities.

3.2.9 Human Factors Design Standard: Computer-human interface

Reference

Human Factors Design Standard; Chapter 8: Computer-human interface; FAA; 2003

Application of the regulation

Domain: Aeronautics
System: all systems in the airplane

Addressed HF-issues

- Physical limitations;
- Working Method;
- Human machine interaction (especially Input and Output devices);
- System Reliability

Additional information

Chapter 8 contains very detailed instructions about how information has to be presented on the display, how the menu navigation has to be implemented, how input devices shall work and similar rules with the aim to supporting the crew fulfill their task as well and easily as possible. There are no HF-activities or HF workflow described. The regulation is divided into 18 subchapters.
The first subchapter deals with screen design. Besides general principles like simplicity and a minimal information density, further rules are described like the location or highlighting of messages in context with their importance, to help the crew get the most important information as fast as possible.
Text entry and display is the next subchapter in this regulation. It rules possibilities of input devices for the crew and functions they are able to use.
The third subchapter explains the presentation specifications of graphical information on the display. Different kinds of graphs are described as well as the possibilities of the flight crew to manipulate them, like zooming in for example.
The next subchapter deals with concealed information. An indication of the suppression of information shall be provided if there is a temporary suppression.
Dynamic information update is the content of subchapter five. It regulates rates of change, updating rates and possibilities for users to temporarily stop updates.
Subchapter six rules the coding. It contains requirements like when to use coding, colors and their meanings, symbol coding etc.
The seventh subchapter defines Interaction. Several interaction types are listed in this subchapter and shall be selected according to the task, the characteristics of the system and the abilities of the users. These interaction types are further described in the rest of the subchapter.

General interactive techniques are explained in subchapter eight. They are direct manipulation, command language and queries.
The ninth subchapter contains information about user-initiated interrupts. This includes nondestructive options like Back or Cancel.
Subchapter ten is ruling file management functions. General functions like saving and retrieving graphic data and protection against exiting a file without saving are also described as file management commands for the crew to control it.
Selecting methods are explained in the eleventh subchapter. It includes selection options and highlighting to allow the applicant to manipulate the presented information.
The twelfth subchapter describes transaction options. It contains general options like the timing of the transaction or option presentation and stacked commands.
Controls are the content of subchapter 13. Different kinds of buttons are presented as well as icons, special graphical controls and cursors.
Subchapter 14 grants information about windows. It rules components window inclusions and descriptions of them. Additionally it presents different kinds of window types like data-entry windows and map windows. It classifies message windows, provides information about window states like open windows, closed windows and active windows and introduces window operations and window navigation.
The fifteenth subchapter describes system operations. The general part contains information about system support functions, system interrupts and user-specified settings. Special functions like the screen saver, system access, log on and log off or data back up options are further described in the next part.
The content of the sixteenth subchapter is Help. On-line help shall be available to give procedural aid and the ability to recover from errors and advice without requiring a user to exit from the application. Access to help shall always be granted and the user is to be reminded of its accessibility.
Subchapter 17 contains information about data communication. This includes special messages, like the interruptibility from users and the resumption of that activity after the interruption.
The rule ends with subchapter 18, which regulates accommodation requirements for people with disabilities.

3.2.10 Certification Specifications: Installed Systems and Equipment for Use by the Flight Crew

Reference

Certification Specifications for Large Aeroplanes CS-25; Subpart F – Equipment; CS 25.1302 Installed systems and equipment for use by the flight crew; EASA; 2012

Application of the regulation

Domain: Aeronautics
System: all systems used by the flight crew

Addressed HF-issues

- Support equipment and furniture required;
- Training; Procedures;
- Human machine interaction;
- System Reliability

HF Process or workflow

- Requirements Engineering,
- Hardware-Software Requirements Evaluation,
- Hardware-Software Design,
- Hardware-Software Testing,
- System Validation

Additional information

CS 25.1302 regulates installed systems and equipment for use by the flight crew while being in the airplane at their normally seated positions. These systems and equipment need to be designed so that trained and qualified crew members can safely perform their tasks. This includes providing all necessary information and the installation of flight deck controls to allow accomplishment of the tasks. Furthermore, requirements are described regulating flight deck controls and the presented information. Similar is the regulation of operationally-relevant behavior of the installed equipment and the need of enabling the flight crew to manage reasonably expected errors resulting from flight crew interactions with the equipment.
Possibilities of the realisation are described in AMC 25.1302.

3.2.11 Certification Specifications (AMC): Installed Systems and Equipment for Use by the Flight Crew

Reference

Certification Specifications for Large Aeroplanes CS-25; AMC Acceptable Means of Compliance - Subpart F; AMC 25.1302 Installed systems and equipment for Use by the flight crew; EASA; 2012

Application of the regulation

Domain: Aeronautics
System: all systems used by the flight crew

Addressed HF-issues

- Training; Procedures;
- Working Method;
- Human machine interaction;
- System Reliability

Proposed HF-Activities

The document describes a methodical approach to planning certification for design related Human performance issues, including 4 human factors activities inside the hexagon:

- Evaluate systems, components & features vs. crew tasks
- Identify degrees of novelty, complexity, and integration
- Determine applicability of requirements to systems, components, and features and which aspects of the design require substantiation
- Select appropriate Means of Compliance

Additional information

This AMC (acceptable means of compliance) advises to involve the Agency as early as possible. New systems need to be certificated by the Agency.

3.2.12 Certification Specifications: Function and installation of Equipment

Reference

Certification Specifications for Large Aeroplanes CS-25; Subpart F – Equipment; CS 25.1301 Function and installation; EASA; 2012

Application of the regulation

Domain: Aeronautics
System: all items of installed equipment

Additional information

CS 25.1301 regulates requirements for equipment. It must be of a kind and design appropriate to its intended function, must be labelled equally and be installed according to its limitations. There are no HF-issues addressed and no HF activities or HF workflow described.

3.2.13 Certification Specifications: Equipment, systems and installations

Reference

Certification Specifications for Large Aeroplanes CS-25; Subpart F – Equipment; CS 25. 1309 Equipment, systems and installations; EASA; 2012

Application of the regulation

Domain: Aeronautics
System: all equipment and systems installed in the aeroplane

Addressed HF-issues

- System Reliability

Additional information

CS 25.1309 regulates the requirements concerning System Reliability of equipment, systems and installations, including a few exceptions. It is ruled which conditions equipment and systems must be designed and installed so that they perform as intended under aeroplane operating and environmental conditions. Furthermore it describes the allowed consequences after failure for aeroplane systems and associated components, considered separately and in relation to other systems. In addition flight crew must get information about unsafe system operation conditions. There are no HF-activities or HF workflow described.

3.2.14 Design and Construction: D1 General

Reference

Annex 8; PART IIIB. AEROPLANES OVER 5 700 KG FOR WHICH APPLICATION FOR CERTIFICATION WAS SUBMITTED ON OR AFTER 2 MARCH 2004; SUB-PART D. DESIGN AND CONSTRUCTION; D1 General; ICAO; 2004

Application of the regulation

Domain: Aeronautics
System: all systems in the aeroplane

Addressed HF-issues

- System Reliability

Additional information

Content of the regulation is the Reliability of airplane systems in connection to their design and construction. All essential moving parts have to be tested under all operating conditions for such parts. The used materials have to conform to approved specifications including their effect on the people and environment. Furthermore fabrication methods must produce a consistently sound structure which shall be protected during service. Therefore inspection provisions shall be made.
*D1.1 ends with: "They shall also observe Human Factors principles", therefore all HF issues have to be checked. There are no HF-activities or HF workflow described.

3.2.15 Design and construction: D2 Systems Design features

Reference

Annex 8; PART IIIB. AEROPLANES OVER 5 700 KG FOR WHICH APPLICATION FOR CERTIFICATION WAS SUBMITTED ON OR AFTER 2 MARCH 2004; SUB-PART D. DESIGN AND CONSTRUCTION; D2 Systems Design features; ICAO; 2004

Application of the regulation

Domain: Aeronautics
System: cockpit

Addressed HF-issues

- System Reliability
- Human machine interaction

HF Process or workflow

- System Architecture
- HW-SW Design

Additional information

Content of the regulation is the design of airplane systems that effect the crew ability to maintain controlled flight. It shall minimize the possibility of jamming, inadvertent operation including prevention of misassembled and unintentional engagement of control surface locking devices, but maximize the system survivability. The crew environment shall be designed to minimize the possibility of incorrect or restricted operation by the crew due to fatigue, confusion or interference. Additionally the pilot's vision shall not be limited by the arrangement of the flight crew. Emergencies resulting from foreseeable failures shall be automatically prevented or means for the prevention shall be provided for the flight crew. There are no HF-activities described.

3.3 Conclusions

There were three HF Integration concepts for the aeronautics domain reviewed: The HF Case: Guidance for HF Integration provided by Eurocontrol, Integrated Human Centered Systems Approach to the Development of Advances Cockpit and Air Traffic Management Systems, and Honeywell internal HF integration process.
The HF Case was designed for its application in European Air Traffic Management projects within Eurocontrol and has been carried out in a number of various projects including: a cockpit tool to improve airborne traffic situational awareness, the airborne collision avoidance resolution and advisory system downlink, concepts for mixed landing system operations, A-SMGCS advanced surface movement guidance and control system, FASTI: first ATC support tools implementation, and CREDOS: crosswind-reduced separations for departure operations. The IHCSA was established for the development of advanced cockpit and air traffic management systems. It was applied in several ATM programs (experimental studies of intent information on cockpit traffic display, mode awareness in advanced flight management systems, collision avoidance alerting system conformance curing closely paced parallel approaches, and hazard alerting and conflict probe design issues). The HF integration concept of Honeywell does not specify the addressed aeronautics technologies.

All the concepts point out that the emphasis of HF is to ensure a safe and efficient overall system performance, which is simultaneously driven by technical and human capabilities coupled with operational requirements. The main focus of HF Integration is set on addressing human performance related issues throughout the system development process.
The IHCSA Concept concentrates on the human operator as a key element of the closed loop information system. It also stresses the potential overall system performance degradation resulting from the human limited capabilities. Particular attention is paid to human-automation issues emerging in the ATM and FTM Domain: system performance (comparing performance of automated and non-automated alternative in full range of potential operating conditions), situational awareness, attention limitations, information and task overload, understanding of automation criteria, changes in authority, changes in communication modes and human reliance on automation. The concept summarizes the HF-issues shortly and states a few examples of how to deal with them. However, it does not translate the issues into quality criteria.
The other concepts do not define which HF-issues are relevant and should be addressed in the system development process. It is mentioned that every development project is unique. It follows that project specific HF-issues have to be identified every time. In an optimal way this task should be accomplished during the early stage of the development. The HF Case dedicates a whole second stage (Issues Analysis) of the HF Integration process to answer the crucial question, how to identify and prioritize the project specific HF Issues and assess their potential impact on the human performance in the system. An elaborated workflow including methods (workshop/expert interviews) and aids (guidelines, templates) is provided. Another noteworthy intent given by the concept is its comprehensive classification/representation of a wide range of HF-issues, broken down in several levels of detail. The HF-issues are divided into six main categories: working environment, organization and staffing, procedures, roles and responsibilities, teams and communication, training and development, and human in system. The compilation of these issues is intended to serve as an aid to assert the project specific issues systematically and to minimize the risk of overlooking any crucial ones. It should also be pointed out that the concept highlights not only the typical HF-issues of simple systems (e.g. HMI) it also addresses the specific aspects of AdCos like the cooperation/communication between many humans and many machines, task and resource distribution across agents and the operation conditions.

The comparison of these concepts gives us new insights, which may be of importance for the development of the HF-RTP. The Human Factors Integration Concepts differ strongly with regard to their focussed aspects. The special emphasis is put either on the HF Management Process, or on HF Engineering Process/Human Centered Approach.
The first one, presented primarily in HF Case, establishes a rather generic framework that includes a well-structured and strict course of action to identify and treat HF issues systematically during a project. It delivers planning, conduction and documentation aids for the HF-Process throughout a project. This approach is not related to the specific HF-issues, with the consequence that, it does not specify the appropriate HF activities/methods to deal with the single HF issues during the development process. Furthermore, the stages of the HF Integration process do not correspond with certain stages of system engineering. For instance, the concept delivers a template for drawing an action plan and proposes a number of HF activities and methods, but any further specification of the HF-work tailored to particular issues needs to be done by the development team.
The Integrated Human-Centered-Approach is less formal and proposes a HF-workflow suited to the stages of the development process of advanced ATM information systems. The key HF-steps defined are tailored according to system level trades and form a sequence of modeling, analysis, design and evaluation activities. The concept suggests several HF-methods and techniques, but these are not strictly prescribed. These should be selected depending on the project objectives and the particular system needs.
Both of the HF Integration perspectives (Management- and Human-Centered-Approach) seem to be relevant and beneficial for AdCos dedicated development projects.
Within the framework of this deliverable a number of regulations related with aeronautics systems were reviewed. FAA, EASA, and ICAO provided the analyzed regulations and standards. Additional attention was put on the findings of project reports published by Honeywell.
A part of the regulations is dedicated to the electronic flight bag and addresses issues related to some HMI aspects (use of colors, legibility of text and symbols, lighting conditions, adjustment to changed human vision by older users), hardware and software design (e.g. position, power connection, data connectivity), and operational use conditions. It is also mentioned, that the used procedures should be designed to mitigate and/or control workload. Primarily, the regulations provide requirements, which should be fulfilled by the system. These specifications should be considered in several stages of

system development and be followed by the HW-SW design phase and the implementation phases, but also be used in further system evaluations. There is no information given of how to deal with the HF-issues during the system development process.
The analyzed regulations apply to a wide variety of systems used by the flight crew. Here again a number of HF issues are addressed but only the requirements that have to be met by the system are given. The regulations deal with the following issues: work place layout, physical limitations, human machine interaction (e.g. presentation of information, user specified settings, operations), and system reliability.
Interesting contents related to automation and adaptivity of the avionic systems are delivered by following documents: Human Factors Design Standard: Chapter 3: Automation (FAA 2003) and Analysis of Human Performance Risks and Benefits of Adaptive Systems (Honeywell 2012). There are recommendations and standards for HF architecture, design and/or evaluation provided in a comprehensive manner.
To summarise, the regulations and standards found are either electronic flight bag-specific or include more generic requirements/considerations for different avionic systems. There is rarely any information given, aimed directly at HF integration processes. Mostly there is no emphasis put on the HF course of action, activities or methods, which should be conducted within the system development process in order to execute HF-issues. Despite of it, the elaborated HF knowledge included in the regulations deliver a great support and should be applied within the development of AdCos for aeronautics. The utilization of the established human factors references and requirements for system design and evaluation is undoubtedly profitable for development projects within the domain. For this reason it is recommendable to integrate the findings (especially the Human Factors Design Standard of FAA) in HF-RTP

4 Control Rooms Domain

4.1 HFI Concepts in Control Rooms Domain

4.1.1 Concept: Human Systems Integration

NOTE: The following section describes Human Systems Integration (HSI) as a relevant HF Integration Concept for the HoliDes AdCoS domain covered by Airbus. However, elements from other, less formalised HF concepts (i.e. experience, best practice, or internal style guides) will also be applied.

Reference

- Air Force Human Systems Integration Handbook. Planning and Execution of Human Systems Integration. Directorate of Human Performance Integration – Human Performance Optimization Division, Distribution A: Unlimited Distribution.
- Booher, H. R. Ed. (2003). Handbook of Human Systems Integration. John Wiley and Sons

Application of the concept

Domain:
Within HoliDes, the HSI concept will be applied to the AdCoS scenario in the control room domain – Airbus target scenario Border Security (BS).
The scope of HSI is not limited to the Border Security domain, but covers all types of defence systems. As such, it is a management and technical approach for addressing the human element in defence system development and acquisition.
It is employed by acquisition managers to ensure that human/system performance is enhanced, operational utility and effectiveness cab be maximised and life cycle costs are reduced. It is employed by manufacturers to ensure that customer requirements are understood and met.
System:
HSI affects those parts of a system that include the interplay of hardware, software and humans (e.g. the planning and execution of missions). These system parts range from simple surveillance workstations to complex multi-party mission planning or control room applications.

Addressed HF-issues

HSI covers HF-issues/aspects in the form of nine functional areas called "domains".

Domain name	Definition
Manpower	The number and mix of personnel (military, civilian, and contractor) authorised and available to train, operate, maintain, and support each system acquisition.
Personnel	The human aptitudes, skills, knowledge, experience levels, and abilities required to operate, maintain, and support the system at the time it is fielded and throughout its life cycle.
Training	The instruction and resources required to provide (…) personnel with requisite knowledge, skills, and abilities to properly operate, maintain, and support the system.
Human Factors Engineering	The comprehensive integration of human capabilities and limitations (cognitive, physical, sensory, and team dynamic) into system design, development, modification, and evaluation to optimise human-machine performance for both operation and maintenance of a system. Human Factors engineering designs systems that require minimal manpower, provide effective training, can be operated and maintained by users, and are suitable and survivable.
Environment	Environmental factors concerning water, air, and land and the interrelationships which exist among and between water, air, and land and all living things.
Safety	Safety factors are design and operational characteristics that minimise the possibilities for accidents or mishaps to operators which threaten the survival of the system.
Occupational Health	Occupational Health factors are design features that minimise risk of injury, acute and/or chronic illness or disability, and/or reduced job performance of personnel who operate, maintain, or support the system.
Survivability	The characteristics of a system that reduce risk of fratricide, detection, and the possibility of being attacked; and that enable the crew to withstand man-made or natural hostile environments without aborting the mission or suffering acute and/or chronic illness, disability, or death.
Habitability	Factors of living and working conditions that are necessary to sustain the morale, safety, health, and comfort of the user population which contribute directly to personnel effectiveness and mission accomplishment, and often preclude recruitment and retention problems.

HSI is, therefore, a very comprehensive framework, covering the whole range of Human Factors aspects including:

- Workplace ergonomics;

- Human-computer interaction;
- Health and safety aspects; and
- Organizational and social aspects.

System development states addressed by the concept

HSI impacts the different stages of the system development process (V-Model).

Lifecycle Stage	Yes/No	Comments
Requirements Engineering	**Yes**	Provides a framework for agreeing functionalities and performance levels with the customer
System Architecture	**Yes**	Provides a framework for structuring HF aspects of the system (e.g. Enterprise Quality "Human Factors" in NAF)
Hardware Software Requirements Evaluation	**Yes**	Provides a framework for prioritising and structuring requirements
Hardware Software Design	**Yes**	Provides a framework for prioritising and selecting design options and alternatives
Hardware Software Implementation	**Yes**	Possibly minor benefits through applying the framework as checklist
Hardware Software Integration/Verification	**Yes**	Possibly minor benefits through applying the framework as checklist
Hardware Software Testing (Validation)	**Yes**	Possibly minor benefits through applying the framework as checklist
System Integration/Verification	**Yes**	Provides a framework for System integration and verification
System Validation	**Yes**	Provides a framework for System Validation

Course of action and activities

The concept explicitly names the following activities that are usually conducted in the context of the Human Factors Engineering Domain:

- Assess mental workload
- Assess physical workload
- Analyse effects of environmental stressors
- Perform human reliability analyses
- Apply HF criteria and principles
- Verify design conformance to HF specification
- Design human equipment interfaces
- Design workspace layouts
- Design software-human interfaces

- Prepare/review drawings for conformance to HF specifications

NOTE: These activities are part of any good Human Factors practice.
NOTE: Depending on the product domain or user population, not all of the criteria listed will be applied in detail.
NOTE: The descriptions of the other eight domains (other than Human Factors Engineering) list activities more or less closely related to HF activities (e.g. for the "Training"-Domain, the activity "Define instructional requirements" is listed). Those peripheral HF activities are not elaborated here.

Methods and outputs

The concept proposes the Human Factors Engineering activities listed in Clause 2.1.5, but does not explicitly name methods for conducting them (e.g. methods for conducting the assessment of mental workload).
The concept does not specify a format for documenting or presenting the respective outcomes of specific HF activities.
The concept does not specify any tools used for conducting specific HF activities.

STRENGTHS-WEAKNESSES Analysis

Strengths:

- The concept is known to many customers (or forms even a basis for acquisition decisions) and can serve as a means for agreeing on requirements
- The concept is very comprehensive (though not all HSI domains may apply to a given product) and prevents aspects from being overseen or being introduced at a late stage in product design
- It supports the whole range of user interaction aspects (SW, HW, ergonomics) and use cases (training, operation, maintenance, support)
- It addresses safety and health-related issues, with the aim of preventing illnesses and recruitment/retention problems
- The nine HSI domains can serve as a checklist for the completeness of the HF-RTP for AdCoS

Weaknesses:

- Not all customers are familiar with it
- In some instances only very few HSI domains may apply to a given product; in those cases simpler models may be more effective
- HSI cannot be applied without some prior training

- Even though HSI can be applied to just about any product, its military background may appear offensive to some customers

4.1.2 Concept: NATO Human View

The following section describes the NATO Human View (HV) as a relevant HF Integration Concept for the HoliDes AdCoS domain covered by Airbus. However, elements from other, less formalised HF concepts (i.e. experience, best practice, or internal style guides) will also be applied.

Reference

- Human Systems Integration for Network Centric Warfare (2010). NATO RTO Technical Report TR-HFM-155
- NATO Human View Quick Start Guide

Application of the concept

The intention of the proposed approach is to define an architectural process to be used in the construction of a generic AdCoS that could be used throughout the consortium.

NOTE: this model was initially designed for use within WP8, prior to delivering it to the consortium. However, the WP1 Task 1.2 requirement requires the model to be released to the consortium as it is being defined in parallel with WP8. Therefore, this initial document has WP8 specific details and products and our aim is to construct a consortium generic one.

The four diagrams are split in to two sections. The first (HoliDes-RTP-Operational-Capabilities) defines the interaction of the Architectural products (including Human Views) with the operational layer which includes the word documents, spreadsheets etc. and requirements defined in DOORS. Note that WP8 anticipate the use of DOORS as it is the standard requirement product used within Airbus Defence and Space.

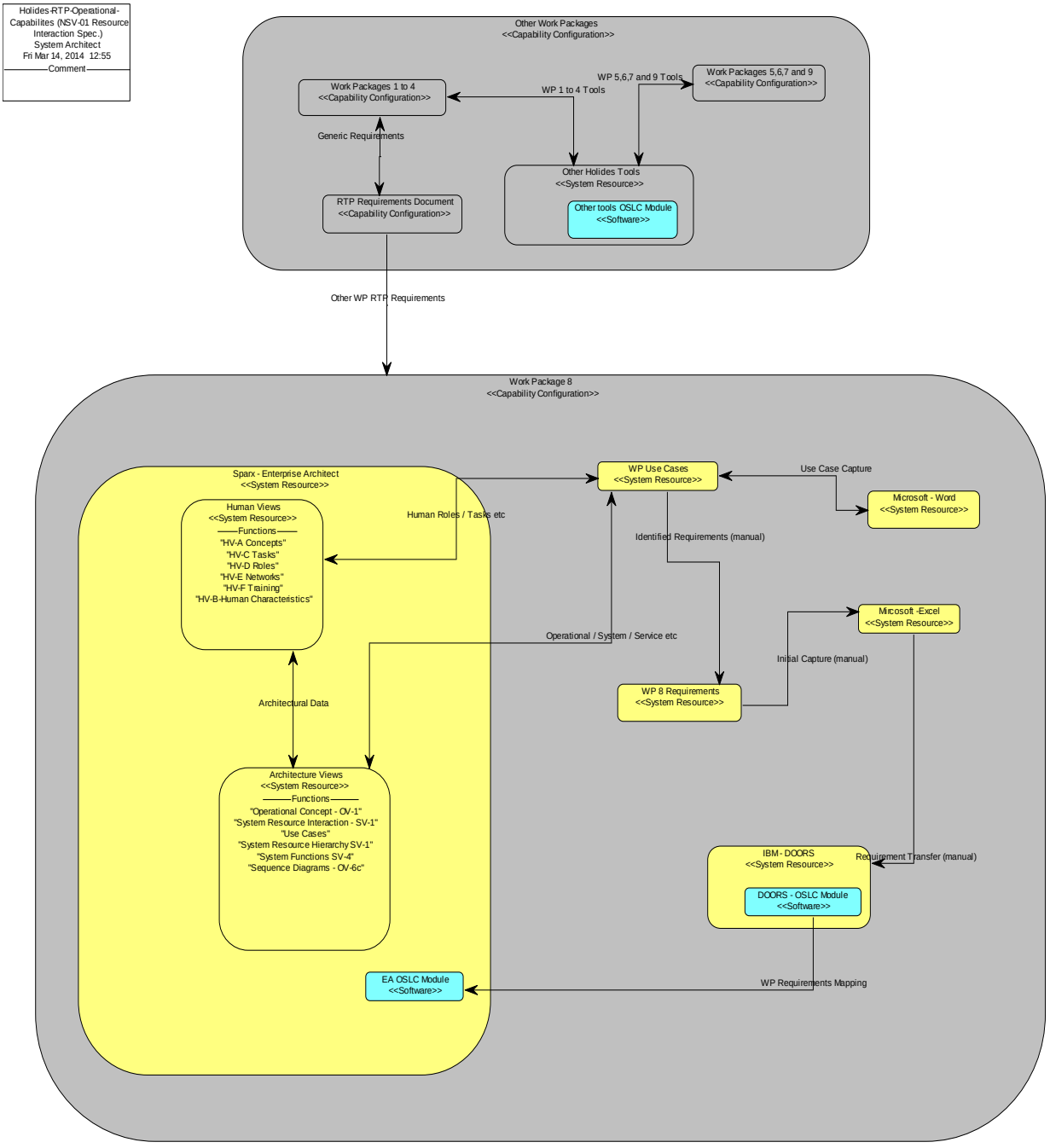
The second diagram (HoliDes-RTP-AdCoS-Design) defines an example of how the AdCoS could interact with the Operational Architecture, other tools and the 'experimentation equipment'. The diagram was designed for WP8 and should be made more generic.

The subsequent section defines two logical data models. The first (SOS-HoliDes-LDM) defines the interaction of the architectural products with the HoliDes specific Use Case definition. The second (SoS-HoliDes-Use-Case-Interaction) defines the specific interaction from the Architectural products and the HoliDes Use Case.

As Airbus Defence and Space have developed the Human Views from the NATO definition, we are using the NATO Architectural Framework (NAF) definitions. However, the definitions are a slight mix between the frameworks. This does not cause a problem, as this document is an initial draft and definitions can be re-defined when the toolset and frame have been decided.

Section 1 - Operational Capabilities

The definitions in the capability configuration "Other Work Packages" should be clear and will not be expanded. The same can be said for Word, Excel and WP8 Requirements.



4-1: HoliDes-RTP-Operational-Capabilities [NSV-01 Resource Interaction Spec.]

HF-issues covered by the concept

Human View covers HF-issues/aspects in the form of six Human Views HV-A to HV-F.

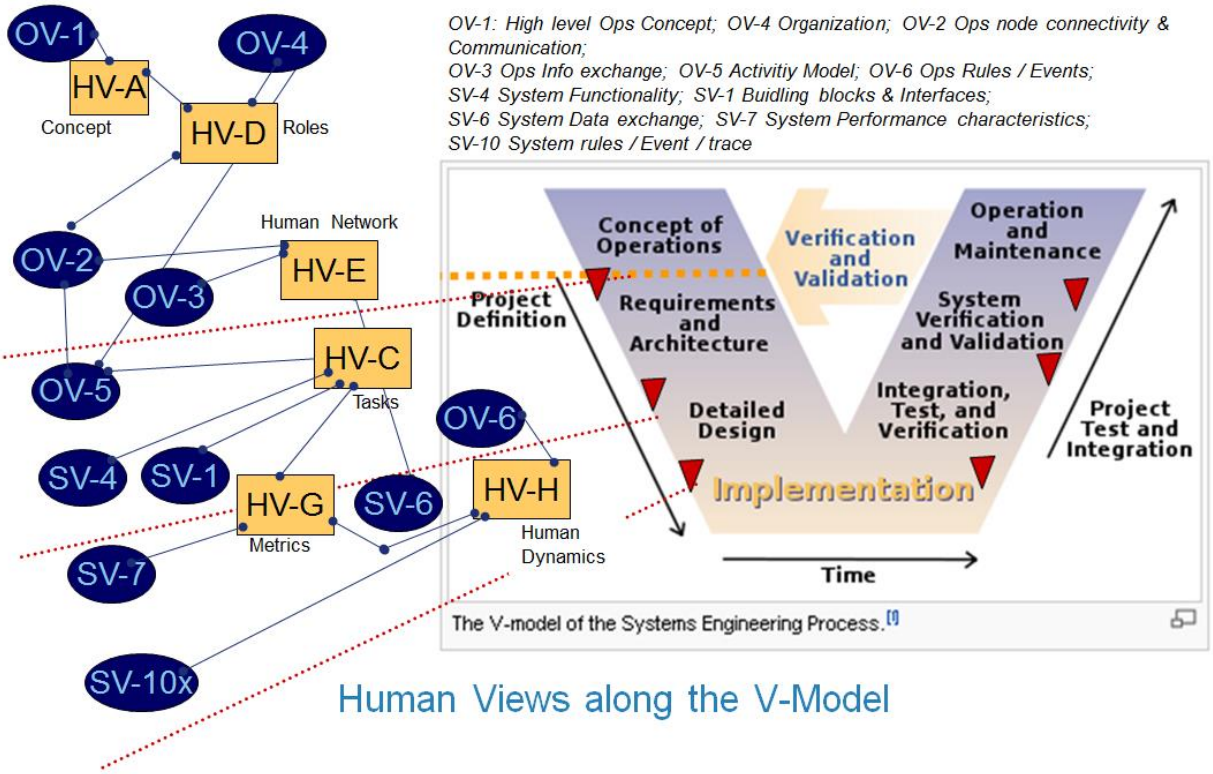
Human View	Definition
HV-A Concepts	The Concept view (HV-A) is a high-level representation of the human component of the enterprise architecture framework. Its purpose is to facilitate understanding of the human dimension in relation to operational demands and system components. It serves as a single point of reference and departure to depict how the human impacts performance (mission success, survivability, supportability, and cost) and how the human is impacted by system design and operational context (e.g. personnel availability, skill demands, training requirements, workload, and well-being).
HV-B Human Characteristics	The Human Characteristics view (HV-B) considers the physical characteristics and movement capabilities and limitations of an operator under various conditions.
HV-C Tasks	The Tasks view (HV-C) describes human-specific activities (i.e., functions assigned to humans over a system's entire life cycle). It also captures how functions are decomposed into tasks. (The term task in this product refers to a piece of work that can be assigned).
HV-D Roles	The Roles view (HV-D) describes the job functions that have been defined for humans interacting with the system. A role therefore represents a job function defining specific behaviour within the context of an organization, including the authority and responsibility conferred to the role, and competencies required to do the job. The role structure can be mapped to the HV-C task decomposition to define organizational responsibilities, and relationships between roles can be defined to provide the basis of the organizational structure.
HV-E Human Network	The Human Network view (HV-E) captures human-to-human communication patterns resulting from ad hoc or deliberate team formation, including teams distributed across space and time.
HV-F Training	The Training view (HV-F) is a detailed accounting of how training requirements, strategy, and implementation impact the human. It illustrates the educational level or training required to provide personnel with those tasks, skills, and knowledge necessary to meet job requirements.

Human View is, therefore, a very comprehensive framework, covering the whole range of Human Factors aspects including:

- Human characteristics
- Tasks and roles
- Training

Which system development states are addressed / supported by the concept

The following graph shows the relevance of the various Human Views along the V-Model of the System Engineering Process.



4-2: Human Views along the V-Model

Architectural Views Definitions

NOTE: the Architectural views are implemented in a slightly different way from framework to framework (NAF/DODAF/MODAF) and each tool vendor has a slightly different implementation. Therefore, the following definitions are generic and will require amendments dependent on the framework and tool selected.

High Level Operational View (NOV-1)

The NOV-1 describes a mission, class of mission, or scenario. It shows the main operational concepts and interesting or unique aspects of operations. It describes the interactions between the subject architecture and its environment, and between the architecture and external systems.

Operational Resource Flow (NOV-2)

The Operational Node Connectivity Specification (NOV-2) depicts Operational Nodes with Needlines between those Nodes that indicate a need to exchange information. The NOV-2 may also show the location (geographic, or Platform) of Operational Nodes, and may optionally be annotated to show flows of materiel or people between Nodes. The Operational Nodes shown in an NOV-2 Product may be internal to the Architecture, or external Nodes that communicate with those internal Nodes.

Operational Relations Chart (NOV-4) - this may be replaced by Resource Hierarchy Diagram SV-1

The Organisational Relationships Chart illustrates the command structure or relationships (as opposed to relationships with respect to a business process flow) among human roles, organisations, or organisation types that are the key players in an Architecture.

Event Trace (Sequence Diagram) (NOV-6c)

The Operational Event-Trace Description provides a time-ordered examination of the information exchanges between participating Operational Nodes as a result of a particular scenario. Each event-trace diagram will have an accompanying description that defines the particular scenario or situation.

System Interaction (NSV-1) (System Resource Interaction)

NSV-1 identifies where relationships exist between systems – i.e. the key interfaces. Sub-system assemblies may be identified in NSV-1 to any level (i.e. depth) of decomposition the architect sees fit. NSV-1 may also identify the System Nodes (e.g. Platforms) at which systems are deployed, and optionally overlay Operational Nodes that utilise those systems. In many cases, an operational node depicted in an NOV-2 product may well be the same as the System Node that is shown in NSV-1.

System Functionality (NSV-4)

The Systems Functionality Description documents system functional hierarchies and system functions, and the system data flows between them.

WP Use Case

The standard Use Case template as defined for HoliDes

Course of action and activities

The initial Architectural products defined herein are based on one of the standards Architectural Frameworks used within Airbus Defence and Space i.e. the NATO Architectural Framework (NAF) and are to be used within WP8. The course of action required within WP1, will be to define if this Architectural development, which is mandatory on all Defence contracts, can be used within the consortium to promote consistent modelling activities and re-use. The architectural development is at the front end of the system development process and integrates with the standards Use Case approach and requirements management (DOORS).

Methods and outputs

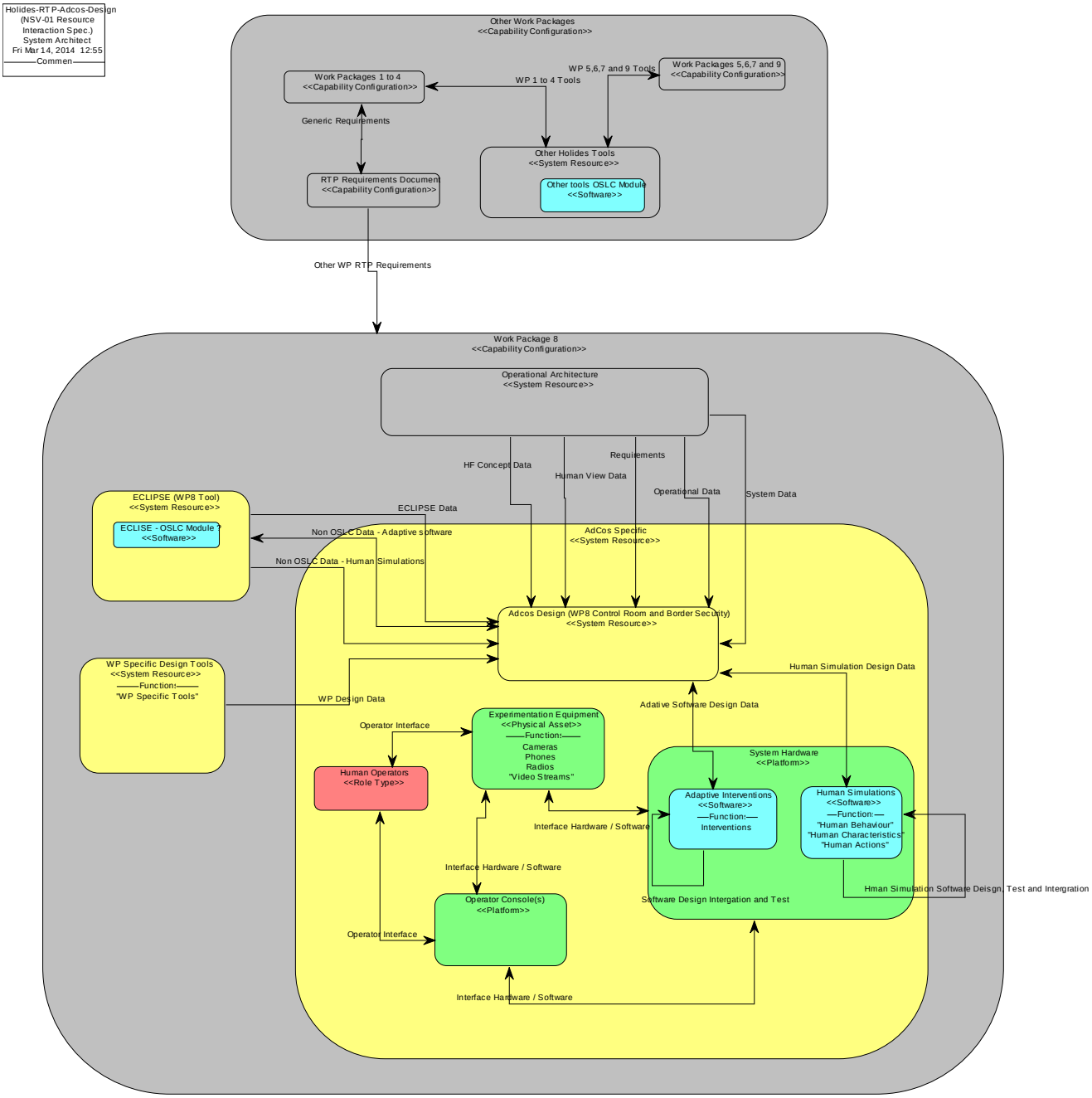
The process follows standard architectural views defined in the NATO Architectural Framework, with interpretation of said standard by each tool vendor. The output will be in standard NATO Architectural Framework format, which is standard within Europe and mandatory for all NATO projects.

Tools

The NATO Architectural Framework has been implemented by many software tool vendors, three of which have been defined: Enterprise Architect, System Architect and Rhapsody. These tools will be analysed in greater detail not here, but in the next deliverable (D1.3). However, it is possible but not recommended to define the views within Microsoft Office tools.

Section 2 HoliDes RTP AdCoS Design

The definitions in the capability configuration Other Work Packages should be clear and will not be expanded.



4-3: HoliDes-RTP-AdCoS-Design [NSV-01 Resource Interaction Spec.]

- **Operational Architecture**

See above.

- **ECLIPSE**
  WP8 specific Software tool, an OSLC interface maybe defined for interaction with other tools. If the tool defines software etc. that is used to build the AdCoS an interface or method of integration will need to de defined.

- **WP Specific Design Tools**
  Any tool that is used in the construction of the AdCoS. If the tool defines software etc. that is used to build the AdCoS an interface or method of integration will be required.

- **AdCoS Design**
  Defines the design of any specific AdCoS, with all its interfaces, input/outputs and integration.

- **Human Operators**
  All humans that will be involved in any WP experiment. This should include all humans required to run the experiment, and not just the operators (e.g. experiment designers, experiment controllers, experiment developers, observers, or Subject Matter Experts).

- **Experimentation Equipment**
  All equipment required to successfully run the experiment, together with any interfaces required.

- **Operator Consoles**
  Specific real or simulated operator consoles for each WP. For WP8 this will mean operator control consoles, other WP will require a variety of WP specific equipment.

- **System Hardware**
  Any hardware that is required to execute any WP specific piece of software e.g. simulation or adaptive, together with any interfaces required.

- **Adaptive Interventions**
  Any software adaptive intervention developed for any defined experiment, together with any interfaces required.

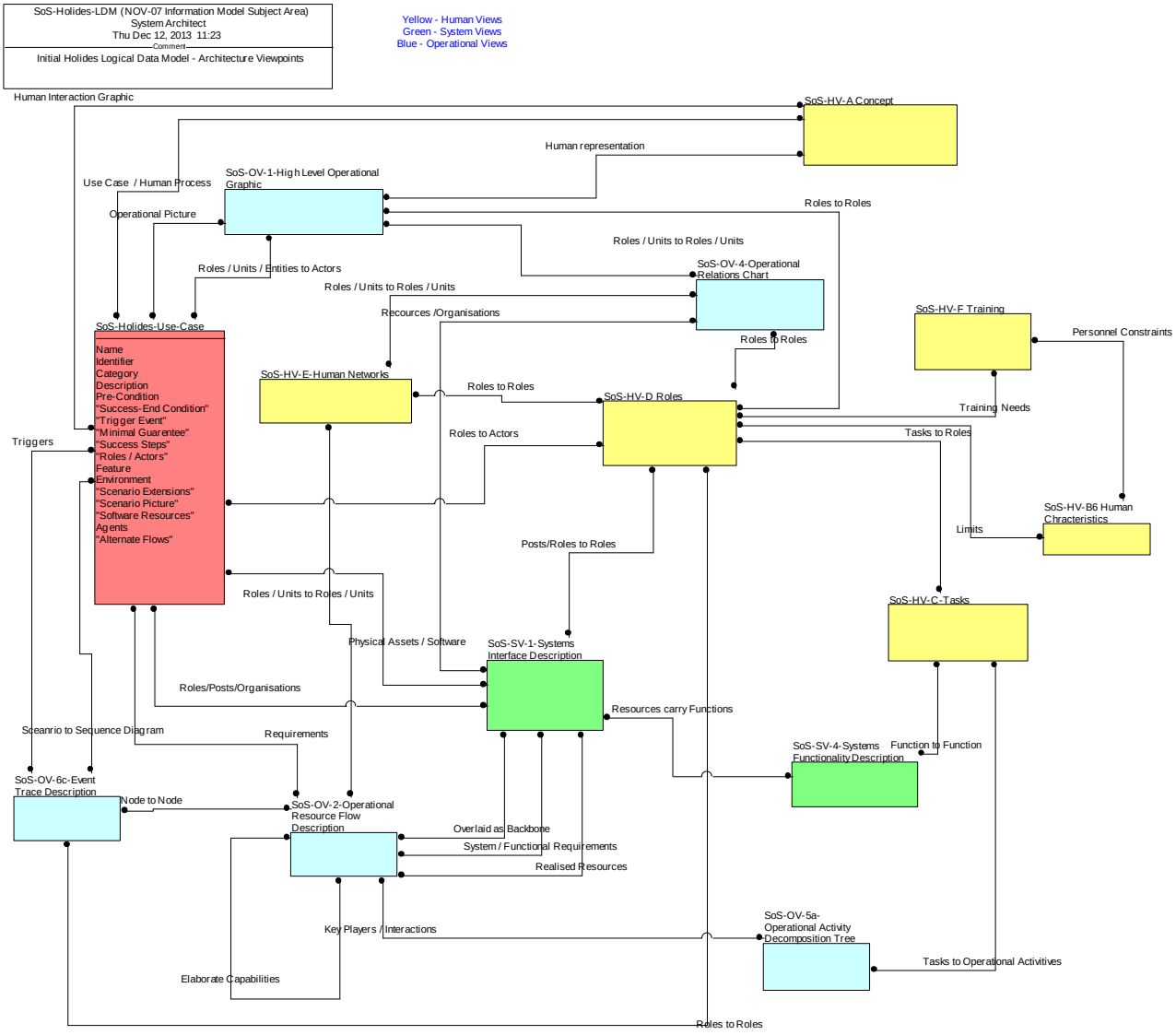
- **Human Simulations**
  Any software human simulation, together with any interfaces required.

- **OSLC**
  We need to define how we are going to use OSLC from a consortium perspective and then from the individual WP, as WP8 indicates we will look at developing a Link between Enterprise Architect and DOORS.

SoS-HoliDes-LDM Information Model

The following logical data models are generic and will require updating when we decide on the products we are going to produce. The Logical Data Model will define the overall architectural products and their data interfaces, in terms of frameworks and tools.

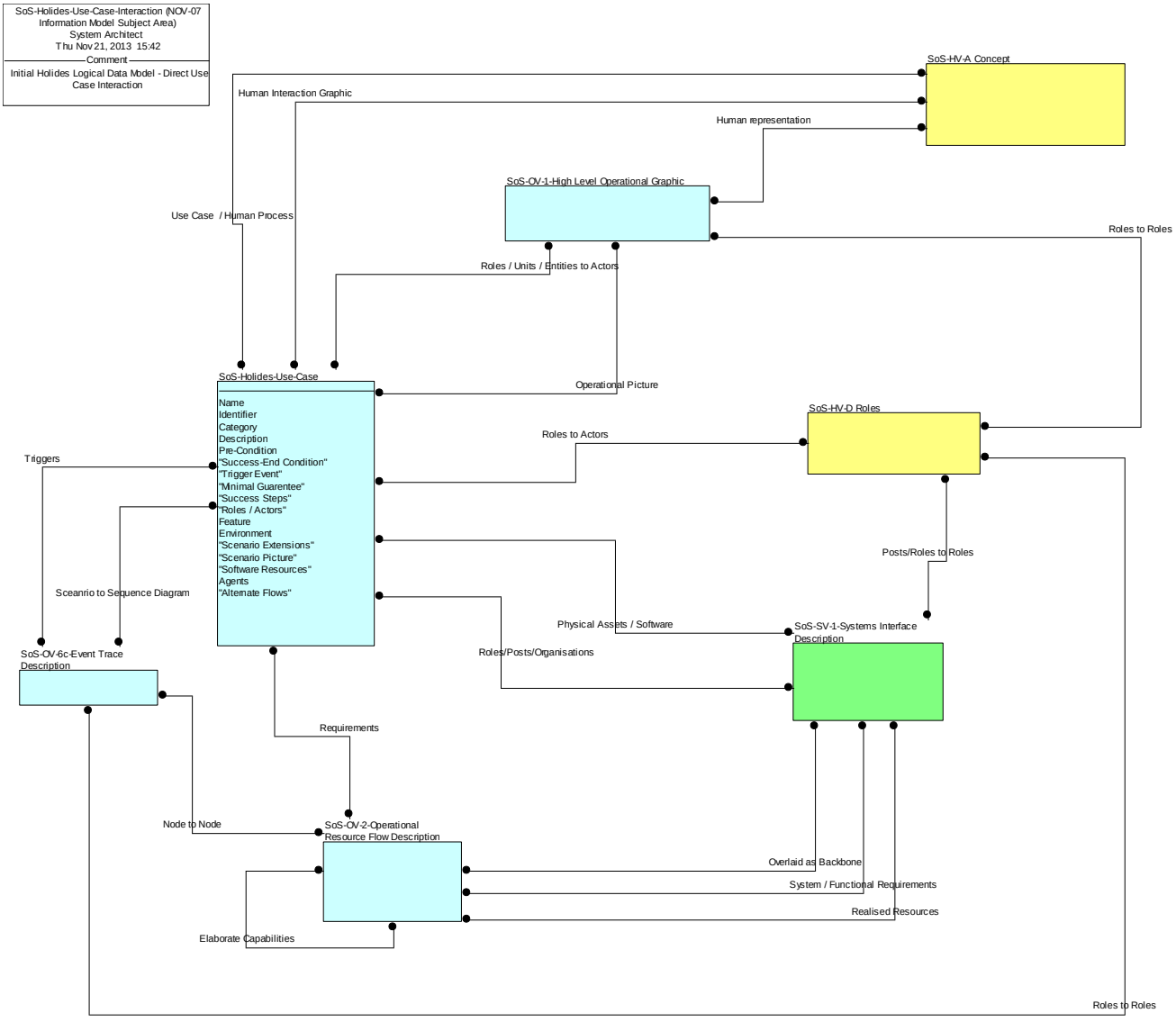
Logical Data Model (SoS-HoliDes-LDM) for the interaction for a generic architectural model for use within the HoliDes consortium.



4-4: SoS-HoliDes-LDM [NOV-07 Information Model]

SoS-HoliDes-Use-Case-Interaction [NOV-07 Inf. Model]

Logical data Model for the interaction of Use Cases with Architectural products.



4-5: SoS-HoliDes-Use-Case-Interaction [NOV-07 Information Model] activities

STRENGTHS-WEAKNESSES Analysis

Strengths:

- Based on international NATO standards - NATO Architecture Frameworks (NAF)
- Human Views based on NATO Human View Technical Report [3]
- The standards have been extensively used with Airbus Defence and Space
- The ability to produce a common Logical Data model that can be used within all HF type projects
- To provide a generic HF model that not only defines Humans in terms of their interaction with machines, system, software etc. but includes Human to Human behaviour, Human networks etc. , which will probably be a first time this has been accomplished

Weaknesses:

- This initial model was constructed to be used within WP8, it will need to be reviewed to ascertain if it capable of support the other Work Packages
- The standard is based on Military standards, therefore, a review needs to be performed if any modification can be made to provide a generic HF model for use within the consortium.

4.2 HF and Safety Regulations in Control Rooms Domain

4.2.1 Control Centre Design Standard

Introduction

ISO 11064 is concerned with an International Standard called "Ergonomic design for control centers" and it consists of seven different parts. Part 1 is the most commonly used in the Control Room domain. Part two contains some design principles. Part three contains a control room layout procedure. Part four contains a procedure for an efficient workstation design. Part five has to do with the checklist procedure for the control rooms. Part six contains a control room environmental design which takes into account the weight of sensation/perception source of stimulation. Part seven contains a description how to integrate validation and verification processes. The individual 7 parts of the Standard are reviewed in the following sections.

Reference

ISO 11064 Control Centre Design Standard:

- ISO 11064-1: Principles for the design of control centres; DIN Deutsches Institut für Normung e.V.; 2001
- ISO 11064-2: Principles for the arrangement of control suites; DIN Deutsches Institut für Normung e.V.; 2001
- ISO 11064-3: Control room layout; DIN Deutsches Institut für Normung e.V.; 2000
- ISO 11064-4: Layout and dimensions of workstations; DIN Deutsches Institut für Normung e.V.; 2004
- ISO 11064-5: Displays and controls; DIN Deutsches Institut für Normung e.V.; 2008
- ISO 11064-5: Environmental requirements for control centres; DIN Deutsches Institut für Normung e.V.; 2005
- ISO 11064-7: Principles for the evaluation of control centres; DIN Deutsches Institut für Normung e.V.; 2006
- A case study of ISO 11064 in Control Centre Design in the Norvegian Petroleum Industry, Aas A.L, Skramstad T. (2010), Applied Ergonomics 62-70.

Part 1: Principles for the design of control centres

- **Application of the regulation**
  Domain: control rooms
  System: control centres as a whole
- **HF issues**
  Taking into account the HF activities described in this standard, ISO 11064 addresses every HF-issue classified by Eurocontrol very briefly:

  1. Working environment (1.2.1 – Design)
  2. Organisation and staffing (2.1.4 – Communication and consultation, 2.3.1 – Physiological factors, 2.3.2 – Psychological factors)
  3. Training and development (3.4 – Training planning)
  4. Procedures, roles and responsibilities (4.1.1 – Prescribed working methods and individual working practices, 4.4 – Working Method)
  5. Teams and communication (5.1 – Team interaction, 5.2 – Communications)
  6. Human in system (6.1.6 – Allocation of function between human and machine, 6.2.1 – System Reliability)

- **HF activities**

ISO 11064-1 provides an 11-steps-plan for the design of control centres:

1. Clarify the objectives and background requirements:
   The goal of Step 1 is to clarify the objectives of the project, to create an overview of requirements to be met, to identify conflicting demands and to find solutions in form of compromises. Activities described include: Reviewing available documents, talking to people who are involved with leading or using comparable systems, analyse comparable systems and create an overview of technology available.
2. Determining the performance the system shall have (Task-analysis and description):
   On the basis of the results of Step 1 determine the ergonomic requirements which are needed to be met in order to ensure that the objectives can be realized by using the task-analysis-technique. The task-analysis shall include all possible system states (start up, normal operating state, partial shutdown for maintenance, shut down and emergencies) and consist of speaking/simulating possible system states, safety and reliability requirements, functional process flow charts and topology of the plant.
3. Human/Machine task mapping:
   As a result of Step 3 every task should be mapped to be done by either a human or a machine. Criteria for mapping described are: capability characteristics (men are better at/machines are better at), cognitive and affective support of the operator by keeping him in the loop and as a different option a method for dynamic task-management, which distributes the tasks to be done based on the operators current workload.
4. Determining the requirements for tasks mapped to humans:
   Based on the results of Step 3 analyse the tasks the operator shall execute, including these factors: manual/cognitive activities, frequency, duration, complexity of the task and environmental issues. The standard refers to "A guide to task analysis" by Kirwan and Ainsworth as a methodical guideline.
5. Design of the personal workload and organizational factors:
   Based on the results of Step 4 and requirements of regulations, the result of Step 5 should be a work plan with requirements needed

for communication between operators, trainings, directives as well as information about the process. Methods described are: defining a preliminary work plan and tasks that every operator has to do, by taking results of Step 4 and regulations into account.

6. Verification and validation of the results of steps 3, 4 and 5:
   Evaluation of function-/task-management, task requirements, tasks every operator has to do, work plan. Possible methods for evaluation described are regarding critical incidents or a computer simulation. The final step is to get the confirmation of the owner.
7. First conceptual design of the control centre:
   Defining the design principles is the next step described. After defining them, they shall be compared to user requirements (results of Step 6) and regulations in effect. Step 7 should lead to several proposed solutions.
8. Review and approval of the conceptual design:
   Methods described are talking about or playing through the proposed designs, simulation of necessary team-working aspects, visualisations through animations via PC, auditing of the regulations in effect.
9. Detailed design:
   This shall include adjoining (ISO 11064-2) and control (ISO 11064-3) rooms, workstations, displays, actuators, environmental design – each part is described separately. Methods proposed are feasibility studies taking into account common systems for realizing the project, prototyping and creating style guidelines.
10. Review and approval of the detailed design:
    Validation of the detailed design has to be integrated and iterative. The results have to deliver information, which the designer can use for correction/adjustment of his design. Safety, decrease of error margin, ergonomic design, environmental factors and job satisfaction are the most important issues for reviewing.
11. Acquisition of operational experiences after putting the control room into service:
    It is important to record ergonomic insufficiencies as help for similar projects to come. ISO 11064-1 proposes field studies, interviews, task-analysis and surveys as possible methods.

- **HF workflow**

ISO 11064-1 is a workflow in itself and it is difficult to map it to the V-Model, besides V-Model is about software and this ISO about building a control centre. If one would try to map the two workflows it might look like this:

V-Model	**ISO 11064-1**
(1)	Step 1 & 2
(2)	Step 3
(4)	Step 4, 5, 6 & 7
(5)	Step 9
(7)	Step 8 & 10
(9)	Step 11

- **Additional relevant information and notes**

ISO 11064-1 elaborates nine basic HF/ergonomic-design principles, which need to be addressed while building a control room:

1. Human-centred-Design: Human physiological and psychological limits always need to be kept in mind while designing a control room.
2. Integration of ergonomics in the technical practice: Both, the technical and ergonomic, points of view need to be included while realising a project.
3. Work iteratively: Even changing a small part can change the whole man-machine system. Therefore there has to be a test and possible correction after each change of the system.
4. Situation analysis: Analyse comparable situations and take into account ergonomic lessons learnt.
5. Task analysis: Every possible task (including start up, normal operating state, partial shutdown, shut down and emergencies) needs to be understood and therefore be analysed (ISO 6385).
6. Every system has to be fault-tolerant.
7. Include experienced users in the designing process, since their experiences are often not documented.
8. Interdisciplinary workgroups: Groups consistent of e.g. process engineers, ergonomics, architects and industrial designers should supervise and control the whole process of building a control room to ensure, that every discipline involved equally.
9. The whole ergonomic design needs to be documented.

- **General evaluation and summary**

  ISO 11064-1 is a detailed design workflow for control rooms beginning with analysing the requirements of the control room to be build and ending with evaluating the built system. It proposes a lot of general methods and activities but nevertheless lacks precise information about what has to be done and how to it should be done exactly. The standard is a guideline but one needs to have a lot of background information or experience to follow it.

Part 2: Principles for the arrangement of control suites

- **Application of the regulation**
  Domain: control rooms
  System: control- and adjoining room
- **HF issues**
  - Keep transport routes as short as possible; choose appropriate doors; etc. (1.1 Work place layout)
  - Minimize the effects of disturbing sources like noise; reflecting lights; heat; vibrations etc. (1.3 Physical environment)
  - If possible optimize the alignment of rooms for communication between operators (5.2 Communications)

- **HF activities**

In ISO 11064-2 the only activities described are methods for verification and validation of a finished layout. Validating the ways of transportation and communication can be done by analysing the connections needed. Other techniques for evaluating the design proposed are "walk through and talk through techniques", "virtual reality techniques" and ISO 11064-7.

- **HF workflow**

ISO 11064-2 proposes a workflow for designing the layout of a control room with adjoining rooms. This workflow is based on the process described in ISO 11064-1 and starts after Step 8 (Review and approval of the conceptual design).

- **General evaluation and summary**

  ISO 11064-2 addresses just a view, but very specific HF issues. The described activities are meant for validation but might also be useful from the start, if used correctly. The standard proposes a workflow filled with general activities and lists a lot of detailed aspects to be considered. It lacks precise information about what to do exactly.

Part 3: Control room layout

- **Application of the regulation**
  Domain: control rooms
  System: control room

- **HF issues**

  All issues described in ISO 11064-3 can be mapped to Eurocontrols HF-category 1: Working environment. Topics mentioned are:
  - Ceiling height, required space per workplace, door position, required space for walking/cleaning, workplace setting, minimization of possible barriers (1.1 Work place layout)
  - Line-of-sight, size of placement areas for operators (1.2.1 Operator working position design)
  - Window arrangement (1.3.2 Physical environment lighting)

- **HF activities**

  ISO 11064-3 lists a lot of general recommendations based on experienced data e.g. the required space per workplace is about 9 to 15 m². It gives formulas for calculating the line-of-sight, the required space for walking/cleaning and sets ground rules for the arrangement of windows (no windows directly in front or behind the operators).

- **HF workflow**

  Based on the results of Step 8 (Review and approval of the conceptual design) of ISO 11064-1 described this standard provides another workflow, which develops several drafts of a functional control room layout step by step. Every draft shall take into account the rules and regula-

tions described. The different drafts shall be tested in a realistic simulation. Afterwards one final draft has to be chosen.

- **General evaluation and summary**

  ISO 11063-3 gives a detailed overview about ergonomic and human factors issues that need to be addressed while designing a control room. It provides not only a workflow but also some very exact information about how to resolve some of the issues described.

Part 4: Layout and dimensions of workstations

- **Application of the regulation**
  Domain: control rooms
  System: workstations as a whole

- **HF issues**

  - Workstation layout: size; accessibility of the controls based on personal factors; working posture; maximum amount of displays to be supervised by an operator (1.2.1 Operator working position Design; 2.3 Personal Factors)
  - Visual tasks: Line-of-sight; minimum size of information provided on displays; minimum/maximum distance between the eye and displays
  - Aural tasks: informational and alarm signals (6.1.4 Alert signals)

  The standard gives a reference to ISO 11064-5 for the choosing of suitable actuators and controls.
  Accessibility of the controls, a good line-of-sight to every display and a healthy working posture can be realized by using adjustable components.
  Workstations have to be suitable for the 5 to 95 percentile of possible operators.
  Appendix A provides rules and examples of how to set multiple displays for optimized usage.

- **HF workflow**

  ISO 11064-4 provides a repetitive workflow consisting of six steps based on Step 8 (Review and approval of the conceptual design) de-

scribed in ☐ (HF activities of ISO 11064-1). To sum up: After Step 8 of ISO 11064-1 there should be a first layout of the control rooms and a detailed work plan for every operator and workstation needed. The steps of ISO 11064-4 are:

1. Determine which informational and interventional systems will be needed for every workstation.
2. Determine which equipment (displays, communication facilities, actuators, etc.) will be needed.
3. Determine the expected postures while being at work (sitting, standing) and collect anthropometric data of future users (ethnic group, male/female, disabled).
4. Design the workstation in top- and side view. Check on working postures, free line-of-sight to all sources of information needed, possibility to interact with every actuator, availability of enough space for documents and telecommunication systems needed. Also take cleaning into account.
5. Verify and validate the design by involving the future operator. Investigate the possibility of future maintenance. If something needs to be changed, start again at Step 2 or 4.
6. Document the design including limitations, alternative considerations and recommendations for future projects.

- **Additional information**

  Appendix B provides a checklist that can be used to review a finished design for missed issues which needed to be addressed.

- **General evaluation and summary**

  ISO 11064-4 is a complete overview about how to design a workstation ergonomically. It addresses the major HF issues and describes possible ways to resolve most of them. Aural tasks and alarm signals are only mentioned very briefly.

Part 5: Displays and controls

- **Application of the regulation**
  Domain: control rooms
  System: displays and controls

- **HF issues**

ISO 11064-5 lists 24 HF issues relevant for humans in systems. (6. Human in system):

1. Humans need to be in charge while working in a man-machine system.
2. Systems need to provide all information needed so men can execute their tasks.
3. Human-system interfaces have to support men in efficiently and effectively doing their jobs.
4. Human capabilities need to be considered while designing human-system interfaces.
5. Ergonomic ground rules need to be considered while designing human-system interfaces.
6. Operators need to be provided with all information needed to be able to create a mental model of the process they are supervising.
7. The created task should promote and offer both a satisfying and challenging work environment.
8. The requirements of the operators' short-term memory should not exceed known limits.
9. Information provided has to be easy and clearly understandable when observed by trained operators.
10. Items that need to be distinguished from each other need to be provided separately.
11. Only actual information shall be provided. If it isn't possible to provide accurate information that fact shall be highlighted by the system.
12. Alerts need to fit to their importance for the operator or safety of the system.
13. Information needs to be provided consistently throughout the whole system.
14. Information needs to be provided readably, clearly, precisely, consistently, observable, understandingly and discriminable.
15. Items to be controlled by the operator have to be visible at all times.
16. Human-system interaction should be configured as easy as possible.
17. The system should support the operator while he is giving input.

18. The system shall use available data and therefore minimize input needed from the operator.
19. Requirements caused by frequently occurring situations shall be minimized by the systems automation.
20. Operators need to be provided with feedback at all times.
21. The systems response time needs to be suitable for the task being executed.
22. High priority alerts need to catch the attention of the operator at all times.
23. The system has to be tolerant for mistakes being made by the operator and if possible reduce their impact.
24. Dialogues have to be structured in groups with a clear beginning, middle and end.

Each item is presented with a couple of central questions for evaluating a man-machine system.
In a later part of the standard the issue of alarm signals (general requirements, structuring, presentation, interaction and administration, documentation) is specially addressed. (6.1.4 Alert signals)

- **HF activities**

  Appendix A gives a detailed overview about possible arrangements to treat the issues described. The topics are:
  - How to display information?
  - Configuration of human-system interaction
  - The design of displays
  - Communication systems
  - Video systems and presentation of graphics
  - Alert systems

  Every topic comes with a detailed workflow based on the general process described in ISO 11064-1 and a lot of general data based on lessons-learned from former projects.

- **HF workflow**

  Based on the results of ISO 11064-1 this standard provides another repetitive workflow of 7 steps for the design of human-system interfaces (displays and controls):
  1. Analyse the transfer of information between operator and system needed for an accurate process.

2. Development of an overall framework for the design of the human-system interface. Result is a list of main topics to be considered.
3. Development of a first concept taking into account the results of Step 2.
4. Build a prototype and test it.
5. Based on the experiences of Step 4 develop the final framework. Mentioned topics should be: display of information, control actuators, prompt, menus and dialogues, navigation, alert management, standards.
6. Detailed designing of the human-machine interface by an ergonomic expert. Every decision made needs to be documented.
7. Verification and validation based on ISO 11064-7.

- **General evaluation and summary**

  ISO 11064-5 is a very detailed standard addressing nearly every HF issue possible for human-system interactions. It contains several workflows, general data and checklists useful for evaluating.

Part 6: Environmental requirements for control centres

- **Application of the regulation**
  Domain: control rooms
  System: physical environment auf workstations

- **HF issues**

  ISO 11064-6 addresses environmental issues that can have a huge impact on the operators' capability to work. Issues described are:
  - Thermic conditions (Temperature & Humidity)
  - Air quality
  - Lighting
  - Noise
  - Vibrations
  - Interior design

- **HF activities**

  ISO 11064-6 defines nine ground rules, which need to be followed while designing the environment of control room workstations:

1. The tasks to be executed by the operator and his personal comfort need to be the main focus.
2. To optimise the operator's performance and comfort he should be able to set different lightning and temperature levels.
3. If there is a conflict between different environmental issues a balance needs to be found.
4. Factors that give information for controlling need to be recognized while designing control rooms.
5. Environmental issues work interactively and need to be considered holistically.
6. The environmental factors should be used to compensate for issues of shift-work, e.g. rise of temperature in the early morning.
7. Changes that might be made in the future need to be considered. (e.g. equipment, workstations or organizational factors)
8. Environmental issues need to be integrated in the process of ISO 11064-1.
9. To achieve a balance between building, equipment and environmental issues it is obligatory to use a repetitive, and multidisciplinary workflow.

- **HF workflow**

  Based on ISO 11064-1 this standard provides the repetitive workflow mentioned in ground rule 9, which should be used when thinking about environmental issues.

  Apart from that ISO 11064-6 also provides detailed workflows for the issues of temperature, lightning and noise.

- **Additional relevant information and notes**

  Appendix A provides some exact requirements (like temperatures, luminosity etc.) based on several engineering standards.

- **General evaluation and summary**

  This standard is a good collection of the environmental issues that might have an impact on ergonomics and need to be addressed while designing a control room, but mainly lists its requirements. For each issue mentioned very briefly, there are more specific engineering stand-

ards available, which might include activities to resolve the issues described.

Part 7: Principles for the evaluation of control centres

- **Application of the regulation**
  Domain: control rooms
  System: evaluation of control centres

- **HF issues**

  Verification/validation of HF issues addressed in ISO 11064 part 1-6

- **HF activities**

  A verification and validation plan shall be drawn at the beginning of each project. The plan shall contain the HF issues; a timeline for validation of the activities being used; criteria, techniques and means for evaluating; etc.
  Appendix C lists several possible methods for validation and gives a short explanation how to use them:
  - Pen and paper methods:
    - Ergonomic checklist
    - Examination of lessons-learnt (in comparable systems)
    - Task analysis
    - Logical tree diagram
  - Observation methods:
    - Walk/talk through techniques
    - Cycle analysis
    - Performance tracking
  - Expert opinion methods:
    - Delphi technique
    - Nominal group technique
    - Pairwise comparison technique
    - Estimation of proportion technique
  - Experimental methods
  - Measuring of physical dimensions

- **HF workflow**

  Throughout the whole process described in ISO 11064 it needs to be verified and validated, starting as soon as possible. Based on the work-flow of ISO 11064-1 this part 7 defines five stages, three (analytical, conceptual, detailed design stage) of which need to be verified and validated. The workflow described is repetitive: Stages with inacceptable results need to be revised. Stage E is validation while running the control centre. That might offer some lessons-learnt that could be used in future projects.

- **Additional relevant information and notes**

  Appendix A contains a checklist which can be used to check if the workgroup for verification and validation is set up properly and gets all the information needed to do its job.

- **General evaluation and summary**

  ISO 11064-7 provides a short overview about the most important evaluation and verification techniques; a workflow which shall be considered when thinking about how to integrate evaluation in the engineering life cycle and some information about appropriate quality factors which need to be considered while evaluating a system.

Assessment of the industrial application of the ISO 11064 Control Centre Design Standard

The research of Aas & Skramstad (2010), reviewed here, was a case study aimed at assessing the industrial application of the standard. The study was conducted in the Norwegian Petroleum Sector. It applies at different dimensions and specifically it applies to ergonomics across the cognitive, the physical and the social ergonomics. These three dimensions are closely related each other. The strength of the ISO 11064 is that it is flexible and adaptive.
According to the authors, the paper, as a case study, analyses the case of Norwegian petroleum with respect to part 1 of the ISO 11064. The authors describes the main five steps in the ergonomic approach to the system design process:

a. the first step aims at clarifying the constraints through which the design process should move starting, for example, from existing situations;
b. the second step involves the analysis of the requirements related to the functions and performance of the control room in order to get a preliminary evaluation;
c. the third step is devoted to the description of the initial structure of the rooms in terms of displays, tools and interfaces which are evaluated, as necessary;
d. the fourth step consistsof a specification of the step number 3 adding, for example, contents and operational interfaces;
e. the fifth step consists of a post-commissioning review process to point out successes and shortcomings for the future actions.

The main objective of the study was to analyse the application of the ISO 11064. The method was in two parts. In the first part, a series of open-ended, semi-structured interviews were made for professionals in the oil sector regarding the application of the ISO 11064. The sample was selected from the Human Factors in Control forum. Two years later, the second part took place. An on-line survey on a seven level Likert scale was used to follow up the results of the first part, which involved both participants of the previous forum as well as new participants. The recruitment resulted in 29 participants who actually used ISO 11064 in their professional experience. The main analyses of the interviews evidenced that around the 65% of the interviewees emphasised the need to introduce adaptivity features to the standard in order to take into account the different contexts it should be applied to. In addition, half of the participants suggested to include Human Factors early in a project. Most of the sample evaluated the standard in a range from sufficient to good (around 80%). None of the participants found it excellent, poor or very poor. The data has been clearly discussed by the authors who pointed out the strengths and weaknesses of the study. The first point was about the application of standards for specific vs. general domains; how much a standard should be normative in nature and how much it should be goal based. A goal based approach should satisfy the need of adaptability of the standard to specific contextual situations. However, the risk should be a lack of generalisation, which is implicit in a standard. Another main point of the research concerns the methodological tools through which data for validation should be built. The authors, for the second part of the study, used a seven point Likert scale for the answers. The use of a Likert scale gives rise to many intermediate answers. No one used answers as excellent, poor, and

very poor. This must be taken into consideration when studying a baseline for HF studies. Finally, the paper had few participants and, as a consequence, it had some problems to generalise the results from the sample to the populations. The statistical analyses that could have been applied are at a nominal/ordinal scale given the high number of qualitative answers concerning the interview part. This issue must be taken into account for any research in standard domain.
The paper has the merit to analyse the complex domain of standards by stressing factors neglected in previous researches.

4.2.2 Design criteria standard – Human engineering

Reference

MIL-STD-1472G: Design criteria standard – Human engineering; U.S. Department Of Defence; 2012

Application of the regulation

Domain: military systems, equipment and facilities
System: control centres as a whole

HF issues

MIL-STD-1472G provides a vast number of requirements and recommendations, most of which are useful while designing a control room. Issues analysed are:

- Controls: Computer controls, display integration (6.1.1 Input devices)
- Visual displays: Content, hardware (6.1.2 Output devices)
- Speech and audio systems: Displays, speech recognition (6.1.1 Input devices, 6.1.2 Output devices)
- Labelling (1.1.1 Support equipment and furniture required)
- Environment: Illuminance, noise, vibration (1.3 Physical environment)
- Warnings: Display, visual displays, auditory displays, general workspace hazards, electrical, mechanical, fluid, toxic and radiation hazards, fire, dust, safety barriers (6.1.4 Alert signals)
- Physical accommodation: Target population, anthropometric design (2.3.1 Physiological factors)
- Maintenance accessibility (1.1 Work place layout)
- Workspace design: Workspace provision, workstation design, Illumination (1.2.1 Operator working position design)

- Physical environment design: Stairs, passageways (1.1 Work place layout)
- Virtual environments, remotely handled systems, automated systems, telepresence and teleoperations (6.2.2 Automation & new technology)

HF activities

MIL-STD-1472G lists very precise information about how issues mentioned shall be treated (e.g. maximum lux/m² for illuminance or how to design an ergonomic workstation). It focusses on the requirements and recommendations and lacks methods and tools which might be useful for someone who wants to meet the requirements/recommendations described.

HF workflow

Since MIL-STD-1472 provides a list of requirements and recommendations it might be mapped to Stage 3 and 4 of the V-Model.

Additional information

MIL-STD-1472 has not had a thorough technical review since the late 1980s. MIL-STD-1472D was promulgated in March 1989, and hence addressed the level of technology that existed through 1988 or possibly 1987. The "E" revision, promulgated in 1996, was mostly cosmetic; the text was changed to a non-proportional font in order to reduce white space. The "F" revision, promulgated in 1999, consisted mainly of moving the anthropometric data from MIL-STD-1472 to MIL-HDBK-759, but little else. As a result, requirements and design criteria contained in previous versions of MIL-STD-1472 may no longer be applicable to today's technology. The operational benefits of emerging technologies may be limited due to the out-of-date design criteria.
Tomorrow's systems will depend on greater cognitive processing on the part of the human operator, maintainer, and support personnel. Portable or wearable computers are likely to be commonplace. New display concepts such as virtual reality, haptic (touch sensing), and three-dimensional are receiving a great deal of interest, as are voice, pointing, gesture, and eye-blink control systems. Technology, if misapplied, will impose human performance requirements that cannot be satisfied. Many technologies are evolving rapidly; the human is not. The benefits of new technologies may not be realized if one fails to consider human capabilities and limitations.

The changes made in the "G" revision over the previous version are substantial. The organizational structure of the standard was revamped to group similar material in the same section of the document. Obsolete provisions (e.g., reference to dot-matrix printers) were deleted, out-of-date provisions were updated to reflect the latest research, and new provisions were added to address emerging technologies. See 6.4 for a summary of changes to the present "G" revision. (Original text from MIL-STD-1472: foreword)

General evaluation and summary

This standard is a document of 381 pages which provides a very detailed view about the most important HF issues. To list and explain every topic mentioned would go beyond the scope of this summary. The standard provides neither methods/tools nor a workflow which might be helpful for designing a control centre. It does list a vast number of different requirements and recommendations though, which should be considered and can be used as a reference.

4.2.3 Handbook for human engineering design guidelines

Reference

MIL-HDBK-759C: Handbook for human engineering design guidelines; U.S. Department Of Defence; 1995

Application of the regulation

Domain: military systems, equipment and facilities
System: control centres as a whole

HF issues

MIL-HDBK-759C provides a vast number of requirements and recommendations, most of which are useful while designing a control room. Issues analysed are:

- Control-display integration (Input devices)
- Visual displays (Output devices)
- Audio displays (Output devices)
- Controls (Input devices)
- Labelling (Support equipment and furniture required)
- Anthropometry (Physiological factors)

- Workspace design: Workspace provision, workstation design, Illumination (Operator working position design)
- Environment: Heating, illuminance, noise, vibration (Physical environment)
- Design for maintainer (Work place layout)
- Hazards and safety (Alert signals)
- User-computer interface (Automation & new technology)

Additional relevant information and notes

MIL-HDBK-759C was designed to supplement MIL-STD-1472D. Most of MIL-HDBK-759Cs content was added to the current "G"-version (described in **Fehler! Verweisquelle konnte nicht gefunden werden.**) of that standard.
Since MIL-HDBK-759C provides a list of requirements and recommendations it might be mapped to Stage 3 and 4 of the V-Model. But a HF-worklow or HF-activities are not given.

General evaluation and summary

Much like the standard described in **Fehler! Verweisquelle konnte nicht gefunden werden.** this handbook lists a lot of requirements and recommendations and to explain them all would go beyond the scope of this summary. The handbook might be used as a reference.
MIL-HDBK-759C wasn't updated since 1995 and most of its still relevant content was added to MIL-STD-1472G in 2012. Especially the issue of 6.2.2 Automation & new technology is addressed very briefly compered to MIL-STD-1472G. Because of its current release date the "G"-version might be the more proper reference when thinking/talking about AdCos.

4.3 Conclusions

In the control room domain, two different but related HF Integration concepts have been reviewed. The HSI, Human Systems Integration Concept, and the NATO Human View (HV) concept,

The HSI, Human Systems Integration concept has been developed to cover a wide range of defence systems and will be applied for the border security scenario within HoliDes. HSI is a comprehensive framework for the design and evaluation of the interplay of hardware, software and humans, covering

nine functional areas of HF issues, including workplace ergonomics, human-computer interaction, health and safety aspects, and organisational and social aspects. Although a number of HF related activities are mentioned in the concept, which are concerned with analysis, design, assessment and verification, the concept is explicit neither on methods or tools to be used nor on formats of outputs. Nevertheless, it is well established and known by many possible costumers because it is very comprehensive in terms of use-cases (training, operation, maintenance, support) and issues covered.

The NATO Human View Concept (HV) is adapting definitions from NATO architectural framework and focussed on the architectural process to be used in WP8. It includes six different human views covering human factors issues from different perspectives, general concepts (understanding the human dimension in relation to operational demands), human characteristics, tasks, roles, human network and training. The human views are allocated along the V-model of systems engineering, mainly on the left project definition and design side. It is important to note, that it has been conceived in order to comply to architectural development requirements, which are mandatory for defence contracts. The NATO Architectural Framework has been implemented by many software tool vendors, three of which have been defined: Enterprise Architect, System Architect and Rhapsody. It promises to produce a common a good level of formalisation of the output of human factors related activities and a common logical data model.

Both HF integration concepts cover a wide range of human factors issues comparable to the issues enumerated in the most elaborate aviation related concepts. They are different in their connectivity to development models (V-model) and their level of formalisation of the results of HF activities. Where the HV recommends some tools and methods (allowing adaption of others), the HSI does not specify, which methods or tools should be used.

A number of rules and regulations have been reviewed in the control room domain. ISO 11064 Control Centre Design Standard encompasses regulations for different aspects of the design of control centres. Part 1 is a detailed design workflow for control rooms beginning with analysing the requirements of the control room to be build and ending with evaluating the built system. It is a general framework describing a general workflow for the following parts of the regulations that cover different HF issues. It proposes many general methods and activities but lacks precise information about what and

how to do it exactly. Part 2 addresses only a few HF issues like workplace layout and physical environment also affecting communication. Part 3 addresses workplace layout, part 4 workstation layout and alarms. Part 5 goes more into the details of displays and controls. Part 6 is about general environmental requirements like temperature, lighting, noise etc.. Part 7 is again more generic, describing evaluation procedures and provides a list of possible validation methods. To summarise, ISO 11064 covers workflow, mainly ergonomic issues and evaluation methods for control room design.

The MIL-STD-1472G has been issued by US DoD in 2012 for military systems in control centres. It provides very detailed regulation about many HF issues focussing on classical ergonomics. The standard provides neither methods/tools nor a workflow for designing a control centre. It lists a vast number of different requirements and recommendations, which should be considered and can be used as a reference. MIL-HDBK-759C was designed to supplement MIL-STD-1472D. Most of MIL-HDBK-759Cs content was added to the current "G"-version described above..

5 Healthcare Domain

5.1 HFI Concepts in Healthcare Domain

5.1.1 Concept: Application of usability engineering to medical devices

The IEC 62366 Standard presents the Usability Engineering Process and provides guidance for its execution. Therefore, although it is a regulation, it is revealing to consider it as a Human Factors Integration Concept and review it profoundly in this chapter.

Reference

IEC 62366 Medical devices – Application of usability engineering to medical devices; IEC International Electrotechnical Commission; 2007

Application of the regulation/concept

Domain: Healthcare
System: Medical devices
Definition (ISO 13485:2003): any instrument, apparatus, implement, machine, appliance, implant, in vitro reagent or calibrator, software, material or other similar or related article, intended by the manufacturer to be used, alone or in combination, for human beings for one or more of the specific purpose(s) of:

- diagnosis, prevention, monitoring, treatment or alleviation of disease,
- diagnosis, monitoring, treatment, alleviation of or compensation for an injury
- investigation, replacement, modification, or support of the anatomy or of a physiological process,
- supporting or sustaining life,
- control of conception,
- disinfection of medical devices
- providing information for medical purposes by means of in vitro examination of specimens derived from the human body, and which does not achieve its primary intended action in or on the human body by pharmacological, immunological or metabolic means, but which can be assisted in its function by such means.

Addressed HF-issues

HMI Usability:
This International Standard specifies a process for a manufacturer to analyse, specify, design, verify and validate usability, as it relates to safety of a medical device.
This usability engineering process assesses and mitigates risks caused by usability problems associated with correct use and use errors, i.e. normal use. It can be used to identify but does not assess or mitigate risks associated with abnormal use.

HF-activities in the development process

V-Model stage	Design cycle element (IEC 1783/07)	HF-Activities (IEC 62366)
(1) Requirements Engineering	USER research /Conceptual design	5.1 Application specification 5.2 Frequently used functions 5.3.1 Identification of characteristics related to SAFETY 5.3.2 Identification of known or foreseeable HAZARDS and HAZARDOUS SITUATIONS
(1) Requirements Engineering **(2) System Architecture** **(3) Hardware-Software Requirements Evaluation**	Requirement and criteria development	5.4 PRIMARY OPERATING FUNCTIONS 5.5 USABILITY SPECIFICATION 5.6 USABILITY VALIDATION plan
(4) Hardware-Software Design **(5) Hardware-Software Implementation**	Detailed design and specification	5.7 USER INTERFACE design and implementation
(6) Hardware-Software Integration/ Verification **(7) Hardware-Software Testing (Validation)** **(8) System Integration/ Verification** **(9) System Validation**	Evaluation	5.8 USABILITY VERIFICATION 5.9 USABILITY VALIDATION 5.3.2 Identification of known or foreseeable HAZARDS and HAZARDOUS SITUATIONS

- ***Application specification***

  This usability engineering file shall include intended medical indication, intended patient population (age, weight, health, and condition), in-

tended part of the body or type of tissue to interact with, user profile, conditions of use (e.g. location) and operating principle.

- **Frequently used functions**
  List frequently used functions in the Usability Engineering File.
  - Identification of characteristics related to SAFETY
    An identification of characteristics related to safety (as part of a risk analysis) that focusses on usability shall be performed. Consider application specification and frequently used functions.
  - Identification of known or foreseeable HAZARDS and HAZARDOUS SITUATIONS
    Identify known or foreseeable hazards (as part of a risk analysis) related to usability. The identification of hazards shall consider hazards to patients, users and other persons. Consider among other things the preliminary use scenarios, possible use errors and a review of the user interface.
- **Primary Operating Functions**
  The inputs to the Primary Operating Functions shall include the following:
  - frequently used functions
  - functions related to safety of the medical device
- **Usability specification**
  The manufacturer shall develop the usability specification. The usability specification shall provide:
  - testable requirements for usability verification; and
  - testable requirements for usability of the primary operating functions including criteria for determining the adequacy of risk control achieved by the usability engineering process.
- **Usability validation plan**
  The aim is to prepare and maintain a usability validation plan which specifies:
  - any method used for validation of the usability of the primary operating functions;
  - the criteria for determining successful validation of the usability of the primary operating functions based on the usability specification; and
  - the involvement of representative intended users.

The plan shall address frequent use scenarios and reasonably worst case use scenarios.

- **User interface design and implementation**

The manufacturer should conduct iterative design and development. Usability engineering, including usability validation, should begin early and continue through the medical device design and development lifecycle.

- **Usability verification**
  As part of the medical device design verification process, the manufacturer shall verify the implementation of the medical device user interface design against the requirements of the usability specification. The results of the verification shall be recorded in the usability engineering file.
- **Usability validation**
  Usability of the medical device is validated according to the usability validation plan. The results shall be recorded in the Usability Engineering File.
  If the acceptance criteria documented in the usability validation plan are not met:
  - further user interface design and implementation activities shall be performed;
  - or if further improvement is not practicable, the manufacturer may gather and review data and literature to determine if the medical benefits of the intended use outweigh the risk arising from usability problems. If this evidence does not support the conclusion that the medical benefits outweigh the risk, then the risk is unacceptable.

Note that many of these activities commonly occur in parallel. Interaction between steps occurs frequently, rapidly, and often seamlessly

Proposed methods

HF-Activities (IEC 62366)	Proposed methods (IEC 62366)	Output format of methods
5.1 Application specification **5.2 Frequently used functions** **5.3.1 Identification of characteristics related to SAFETY** **5.3.2 Identification of known or foreseeable HAZARDS and HAZARDOUS SITUATIONS**	• market research • focus groups • user interviews • general task analysis* • cognitive task analysis* • time-and-motion studies* • Contextual inquiry and observation* • functional analysis* • questionnaires and surveys*	Unformalized
5.4 PRIMARY OPERATING FUNCTIONS **5.5 USABILITY SPECIFICATION** **5.6 USABILITY VALIDATION plan**	• use error analysis • questionnaires and surveys*	Unformalized
5.7 USER INTERFACE design and implementation	• cognitive walk-through* • design audits* • expert reviews* • heuristic analysis* • prototyping*	Unformalized
5.8 USABILITY VERIFICATION **5.9 USABILITY VALIDATION** **5.3.2 Identification of known or foreseeable HAZARDS and HAZARDOUS SITUATIONS**	• usability testing • field-testing* • workload assessment*	Unformalized

*further information concerning the method is given in the papers listed above

Additional information

The IEC 62366 describes a usability engineering process, and provides guidance on how to implement and execute the process to provide safety in medical devices. It applies knowledge about human behavior, abilities, limitations, and other characteristics related to the design of tools, devices, systems, tasks, jobs, and environments to achieve adequate usability as defined in ISO 9241. The process shall address user interactions with the medical device including transport, storage, installation, operation, maintenance and repair, as well as disposal.

The results of the Usability Engineering Process shall be recorded in the Usability Engineering File which is often part of the Risk Management File for the Risk Management Process as defined in ISO 14971. It should contain refer-

ences or pointers to all required documentation of the Usability Engineering Process. In IEC 62366 on page 24 a parallel combination of the Risk Management Process and the Usability Engineering Process can be found.
No tools are given by the concept.

STRENGTHS-WEAKNESSES Analysis

Strengths:
The concept Usability Engineering to Medical Devices has been described in detail in IEC 62366. Therefore it is rated as a promising concept that has proven its usefulness successfully. It combines the system development process with human factors activities taken form the usability engineering process. Additionally it also offers a combination to risk management. The concept offers a variety of methods and stresses that usability engineering is not necessarily a serial process. It should be seen rather flexible with many activities done in parallel and iteratively. Therefore Usability Engineering to Medical Devices is a flexible concept that can be combined with other activities. Moreover it covers the whole lifecycle of the medical devices.
The concept covers a narrow group of human factor issues. Additionally there are many different methods offered that have not been mentioned by other concepts. Therefore an adequate method can be chosen in a given situation.
Weaknesses:
This concept does not offer a workflow how to develop usability specifications and a usability validation plan. Since these specifications are the basis for further usability evaluations and validation it is necessary to conduct a complete plan. IEC 62366 comprises no guideline or standard procedure of how to derive such specifications. There is no formalized output of the methods. So it is difficult to integrate different methods into a tool chain based workflow.

General evaluation and summary

IEC 62366 describes the steps to conduct a usability engineering process for the design of medical devices. All output should be recorded in a so called Usability Engineering File. Specifics are missing and sensitive to interpretation, like the definition of a frequently used function. It requires a usability engineering background to work with this standard. Fundamentally, the Usability Engineering Process is a user-centered process. That is, it is driven by user's actual needs and is based on the premise that the user is always a critical element of the system. The concept offers an opportunity how the system development can be accompanied by human factor activities in order

to create a usable medical device that provides also safety to patients and users.

5.1.2 Concept: Human-Centred Design in Medical Fields

Reference

Human-Centred Design in Medical Fields; N. Ando, N. Nakano, N, Tohyama; 2008

Application of the Concept

Domain: health
System: health care information systems
The case study conducted by the authors focuses on the Electronic Medical Record (EMR) that allows physicians to enter medical orders such as laboratory tests, and information will then be sent to relate sections in the hospital.

Addressed HF-issues

HMI Usability, Information requirements

HF workflow in the development process

V-Model steps	Supported by the concept (original step)	HF-Activities	Methods	Output format of methods
Requirements Engineering **System Architecture** **H-S Requirements Evaluation**	✓ (Design Development)	Analyzing current status	• interviews • reviews	unformalized
H-S-Design	✓ (Evaluation)	Usability Evaluation[1]	• usability evaluation • user analysis and task analysis • design image evaluation • color analysis evaluation	design guidelines (unformalized)
H-S-Implementation **H-S Integration/ Verification** **H-S Testing (Validation)**				
System Integration/ Verification **System Validation**	✓ (Improvement Policy)	Formulation of Design Concept	• Integration of design guidelines taken from Usability Evaluations	unformalized

STRENGTHS-WEAKNESSES-Analysis

Strengths

The concept Human-Centred Design in Medical Fields covers different steps of the system development process. It also shows how the results of the usability evaluation shall be integrated into the formulation of the design concept.

The concept offers an approach of how to integrate the results of usability evaluation into the design phase. The steps listed in the method section comprise a lot of single methods that could be helpful in order to develop an adequate system in medical fields.

Weaknesses
The concept offers a restricted range of methods. Moreover the methods mentioned are rather steps that need to be done. There is no further information given what methods fall into the categories listed. Therefore the adequate method needs to be chosen by the evaluator. Likewise only two human factor issues are covered by the concept.
There is no formalized output. So it is difficult to integrate different methods into a chain of action. Only three steps of the system development process are addressed so it may be difficult to accompany the full system development process.

General evaluation and summary

Human-Centred Design in Medical Fields is a concept adopted from the general field of developing usable systems. Therefore it might also be applicable to other domains even though the authors do not mention it. In contrast to other concepts the authors introduce how the results of the usability evaluation are integrated into the design concept. Nonetheless, the concept is not yet fully integrated into the medical fields and more research needs to be done in order to be able to tackle the other human factors issues. There are-no toolsgiven by the concept.

5.1.3 Concept: Usability Engineering

Reference

- Evaluation in the design of health information systems: application of approaches emerging from usability engineering; A.W. Kushniruk; 2002
- Cognitive and usability engineering methods for the evaluation of clinical information systems; A.W. Kushniruk, V.L. Patel; 2004

Application of the Concept

Domain: health
System: health care information systems
A case study using the concept evaluated the Doctor's Outpatient Practice System (DOP). That system allows clinicians to record patient problems, allergies, and medications.

Addressed HF-issues

HMI Usability, Information requirements

HF-Workflow in the development process

V-Model steps	Addressed by the concept (original step)	HF-Activities	Proposed Methods	Output format of methods
Requirements Engineering	✓ (Planning, Requirements)	Needs and requirements analysis (assessment of user needs and system requirements)	• Workflow analysis • Job analysis • Analysis of decision making • interviews • questionnaires • focus groups • video analysis* • cognitive task analysis*	unformalized
System Architecture **H-S Requirements Evaluation** **H-S-Design**	✓ (Design)	Usability testing	• usability testing* • inspection • design walkthroughs • heuristic evaluations*	unformalized
H-S-Implementation	✓ (Programming)	Usability testing	• usability testing* • code inspections • software unit testing	unformalized
H-S Integration/ Verification **H-S Testing (Validation)**	✓ (Maintenance)	Validation (ensuring that completed software products meet predefined acceptance measures)	• outcome based-evaluations • randomized trials • summative evaluations	unformalized
System Integration/ Verification **System Validation**				

* further information concerning the method is given in the papers listed above

STRENGTHS-WEAKNESSES-Analysis

Strengths

The concept Usability Engineering covers different steps of the system development process. Moreover it offers a variety of methods to choose from.
By applying the concept the HF issues HMI Usability and Information requirements can be tackled throughout the system development.
It focusses on a narrow group of human factor issues. Moreover there are different methods offered. Depending on the situation an appropriate method can be chosen.
Due to its general form the concept might also be applied to other domains.

Weaknesses

The concept barely describes how to use the methods in an appropriate manner. Also there are no interpretation guidelines given, to help derive explicit improvements for the system in question. Moreover, it is not explained how the results shall be integrated into the next step of the system development. The outputs are also not formalised.
Another weakness concerns the focus on only two HF issues out of the group "human in system". It is neither described how the approach of Usability Engineering can also be used in order to tackle other HF issues, nor it is denied that other HF issues may be supported by applying the concept.
There is no formalised output of the methods. So it is difficult to integrate different methods into a chain of action. It is not clear how the methods may influence the use of other methods.

General evaluation and summary

Usability Engineering tries to tackle the fast development of complex information systems within the domain of health and medical equipment. Due to its young age, the methods offered are not explained in detail; however the variety of methods given allows one to adequately choose a method suitable for the system in question. Moreover, even though only one main HF issue is covered, the concept shows how it can be resolved during many stages of the system development process. This might also be done with other HF issues but further research needs to be done here. The concept provides no tools.

5.1.4 Concept: Human Factors Engineering and Risk Management

Reference

Medical Device Use-Safety: Incorporating Human Factors Engineering into Risk Management; U.S. Department of Health and Human Services Food and Drug Administration; 2000

Application of the Concept

Domain: health
System: all systems with human interaction

Addressed HF-issues

Human in System >> Human Machine Interaction with focus on safety and use-related hazards

HF-Workflow in the development process

V-Model steps	Addressed by the concept	HF-Activities	Proposed Methods	Output format of methods
Requirements Engineering	✓	Identify and describe use scenarios resulting in hazards. Prioritize and assess use-related hazards.	• Device Use Description • Standards and Guidelines* • Analytical and Empirical Approaches • Priorization and Assess-ment	unformalized
System Architec-ture **H-S Require-ments Evaluation** **H-S-Design**				
H-S-Implementation	✓	Develop and implement mitigation and control strategies for use-related hazards.	• Standards and Guidelines* • Analytical and Empirical Approaches • Mitigate and Control use-related hazards	unformalized
H-S Integration/ Verification				

H-S Testing (Validation)	✓	Verify mitigation and control strategies Determine if the risks related to the use are acceptable.	• Analytical and Empirical Approaches • Verification and Validation • Standards and Guidelines*	unformalized
System Integration/ Verification	✓	Determine if new hazards have been introduced.	• Analytical and Empirical Approaches • Standards and Guidelines*	unformalized
System Validation	✓	Validate safe and effective device use.	• Empirical Approaches • Verification and Validation	unformalized

Analytical HFE Approaches: function and task analysis*, heuristic analysis*, expert reviews*
Empirical HFE Approaches: usability testing*, walk-through*
* further information concerning the method is given in the paper listed above

Proposed tools

No tool given by the concept.

STRENGTHS-WEAKNESSES-Analysis

Strengths

The concept Human Factors Engineering and Risk Management covers different steps of the system development process and sets a strong focus on safety by recognising and eliminating use-related hazards. It comprises many different steps and offers a variety of methods that can be used. The FDA offers further information that can be used to accompany the risk analysis of a system.

This concept connects the system development process and risk management from a human factors perspective. Therefore it concentrates on one narrow group of human factor issues with a focus set on safety and use-related hazards. Moreover there are different methods offered. Depending on the situation an appropriate method can be chosen.

Since the focus is set so strictly on risk management it might also be combinable with other concepts to create a comprehensive human factors approach integrated into the system development process.

Weaknesses

The concept mostly focusses on eliminating use-related hazards and does not offer opportunities to tackle other HF-issues. Moreover there are only single methods offered. There is no explanation how these methods can be combined into an effective chain of action. Also the methods are given in a gen-

eral manner so that it can be hard to find an appropriate way of applying them to a given system.
There is no formalised output of the methods. So it is difficult to integrate different methods into a chain of action. It is not clear how the methods may influence the use of other methods.

General evaluation and summary

Human Factors Engineering and Risk Management has a strong focus on safety in contrast to other concepts. The FDA introduces a detailed concept that shall help to prevent patients and users from harm by interacting with a product and offers different methods how this can be achieved. As risk management has its own domain of analysis this concept might also be combinable with other human factors concepts out of the health domain.

5.1.5 Human Factors and Usability Engineering

Reference

- Usability Engineering in der Medizintechnik; C. Backhaus; 2010
- Applying Human Factors and Usability Engineering to Optimize Medical Device Design; U.S. Department of Health and Human Services Food and Drug Administration; 2011
- Human Factors Engineering: A Tool for Medical Device Evaluation in Hospital Procurement Decision Making; G. Ginsburg; 2005
- Introduction to the Human Factors Engineering Series; J. Gosbee; 2004
- Patient Safety, Potential Adverse Drug Events, and Medical Device Design: A Human Factors Engineering Approach; Lin et al.; 2001

Application of the Concept

Domain: health
System: all systems with human interaction

Addressed HF-issues

There are none explicitly stated but the HF-issues covered by the use cases comprise issues taken from the categories:

- 6 Human in System Human Machine Interaction.
  - HMI Usability
  - Information requirements

  - Output devices
- 4 Procedures, Roles and Responsibilities Working Method
  - Task Demand
  - Complexity

More issues might also be covered by the concept of human factors and usability engineering.

HF-Workflow in the development process

V-Model steps	Supported by the concept (original step)	HF-Activities	Proposed Methods	Output format of methods
Requirements Engineering	✓ (Process Analysis)	Process Analysis	• participative process analysis* • task analysis • field observations	process flow diagrams
System Architecture **H-S Requirements Evaluation**				
H-S-Design		Usability Evaluation of Mock-up	• focus groups* • expert reviews • questionnaires	
H-S-Implementation				
H-S Integration/ Verification				
H-S Testing (Validation)		Usability Evaluation of interface	• cognitive walkthrough* • simulated use testing* • checklists*	
System Integration/ Verification				
System Validation		Usability Evaluation of product	• heuristic evaluation* • thinking aloud technique • questionnaires (System-Usability-Scale, Nasa-TLX)	

* further information concerning the method is given in the papers listed above

Additional information

The authors introduce the concept of human factors and usability engineering as a general concept that should be applied iteratively throughout and closely coupled with the system development process. Human factors activities should be applied as early as possible. The scope of the concept embraces device users, device use environments and device user interfaces. At every stage of the system development process these factors should be kept in mind.

Nonetheless, the authors do not state which human factors activities should be performed at what stage of the development process. The HF activities listed above are taken from the use case "Produktentwicklung einer Infusionstherapiebaureihe" (engl. system development of an infusion instrument) described by Backhaus and should be seen as a possible arrangement. The methods offered for the different human factors activities are collected from the different authors.

STRENGTHS-WEAKNESSES-Analysis:

Strengths

In general the concept Human Factors and Usability Engineering as it is described by the authors can be applied to all systems that require human interaction. By applying the concept different human factors issues can be tackled, mainly of the group Human in System. Probably other issues could also be resolved by the concept.

The use cases as they are described by the authors show how it can be used as a structured schema that can be applied along the system development process and offers methods to choose from. Concerning the methods listed above, most of them can be found in different publications. Therefore they seem to be very promising in developing a sound system.

Due to its general form the concept might be applied to different human factor issues and domains. As most the methods listed above are proposed by more than one author, they are can be regarded as strong and promising tools.

Weaknesses

The authors do not describe a structured plan of action. They describe a general concept that can be realized in many ways. Moreover they are not explicitly stating what human factors issues can be solved; they are rather speaking of the development of a sound and usable system.

The methods listed are taken from different publications dealing with the concept of Human Factors and Usability Engineering. Therefore it is not clear

whether they can influence each other. Additionally only one use case offers a structured plan of human factors activities along to the system development process. Therefore other arrangements of HF-activities might be possible. The concept does not provide any tools.

General evaluation and summary

Human Factors and Usability Engineering is a concept that has been described by many authors and is commonly accepted. Therefore it can be regarded as a strong and sound concept. Most of the authors offer the same methods that are described in more detail in their publications. This again supports the strength of the concept.
All in all the concept should be closely connected to the system development process in order to create sound products and equipment and to eliminate different human factor issues.

5.2 HF and Safety Regulations in Healthcare Domain

5.2.1 General requirements for basic safety and essential performance. Collateral standard: Usability

Reference

IEC 60601-1-6 General requirements for basic safety and essential performance. Collateral standard: Usability; IEC International Electrotechnical Commission; 2010

Application of the regulation

Domain: Healthcare
System: Medical electrical equipment

Addressed HF-issues

This International Standard specifies a process for a manufacturer to analyse, specify, design, verify and validate usability, as it relates to basic safety and essential performance of medical electrical equipment.
This usability engineering process assesses and mitigates risks caused by usability problems associated with correct use and use errors, i.e. normal use. It can be used to identify but does not assess or mitigate risks associated with abnormal use.

Proposition of HF-activities during development process

The object of this collateral standard is to specify general requirements that are in addition to those of the general standards and to serve as the basis for particular standards.

HF workflow

A usability engineering process complying with IEC 62366 shall be performed.

Additional information

This document describes requirements in the following areas:

- General requirements for basic safety and essential performance
- Tests and guidance for alarm systems in medical electrical equipment and medical electrical systems
- Conditions for application to ME equipment
- Usability engineering process for ME equipment

General evaluation and summary

IEC 60601-1-6 describes in general terms the requirements and rationales for the manufacturer to analyse, specify, design, verify and validate the usability of ME equipment.

5.2.2 General requirements for basic safety and essential performance. Collateral standard: General requirements, tests and guidance for alarm systems in medical electrical equipment and medical electrical systems

Reference

- IEC 60601-1-8 General requirements for basic safety and essential performance. Collateral standard: General requirements, tests and guidance for alarm systems in medical electrical equipment and medical electrical systems; IEC International Electrotechnical Commission; 2012
- ANSI/AAMI HE48-1993, Human factors engineering guidelines and preferred practices for the design of medical devices
- BLOCK, FE. Jr. Human factors and alarms. Chapter 2 In Lake CL., ed. Clinical Monitoring for Anaesthesia & Intensive Care. Philadelphia, WB Saunders, 1994, p. 11-34.

- EDWORTHY J. Urgency mapping in auditory warning signals. In Stanton, N., Editor: Human Factors in alarm design. London: Taylor and Francis, 1994.

Application of the regulation

Domain: Healthcare
System: Medical electrical equipment

Addressed HF-issues

Visual alarm signals and information signals: Multiple-purpose computer-generated graphic displays should be designed in accordance with modern human interface design principles. Attention is drawn to IEC 62366.

Termination of inactivation of ALARM SIGNALS: It is important for an operator to be able to undo an action made in error. Patient safety requires this, as human error is inevitable and the ability to mitigate error needs to be provided.

Additional information

Medical electrical equipment and MEDICAL ELECTRICAL SYSTEMS are increasingly used in medical practice. ALARM SIGNALS are frequently used to indicate unsatisfactory physiological PATIENT states, unsatisfactory functional states of the Medical electrical equipment or medical electrical system or to warn the operator of hazards to the patient or operator due to the medical electrical equipment or medical electrical system. Information signals convey information that is independent of an alarm condition.
Surveys of healthcare personnel have indicated significant discontent with alarm signals. Problems include difficulty in identifying the source of an alarm signal, loud and distracting alarm signals, and the high incidence of false positive or negative alarm conditions.
Surveys of manufactures of medical monitors demonstrated a wide variety of default alarm settings. The leading reason for disabling alarm signals is the large number of alarm signals associated with false positive alarm conditions. Safety of patients depends on the ability of the operator to correctly discern the characteristics of alarm signals. Usability is an important element in the design of alarm signals that are readily discernible without being unnecessarily distracting or disturbing. This approach is intended to rationalize the current situation, to reduce confusion by limiting proliferation of alarm signals and their control states, and to minimize distraction for other people.

This collateral standard was developed with contributions from clinicians, engineers and applied psychologists.
This document describes requirements in the following areas:

- General requirements for basic safety and essential performance
- Tests and guidance for alarm systems in medical electrical equipment and medical electrical systems
- ME equipment identification marking, labelling/symbols documents
- Alarm systems (Visual alarm signals, auditory alarm signals, verbal alarm signals)
- Alarm system delays
- Alarm settings
- Alarm limits
- Alarm system security
- Alarm signal inactivation states
- Alarm reset
- Distributed alarm system
- Alarm logging

General evaluation and summary

IEC 60601-1-8 describes the requirements, tests and guidance for alarm systems in medical electrical equipment. This is accomplished by defining alarm categories (priorities) by degree of urgency, consistent alarm signals and consistent control states and their marking for all alarm systems. The document gives very detailed and specific requirements for alarm signals and their characteristics, but it does not provide any HF activities or workflow.

5.2.3 Particular requirements for basic safety and essential performance of magnetic resonance equipment for medical diagnosis

Reference

- IEC 60601-2-33 Particular requirements for basic safety and essential performance of magnetic resonance equipment for medical diagnosis; IEC International Electrotechnical Commission; 2013

Application of the regulation

Domain: Healthcare
System: Magnetic resonance equipment for medical diagnosis

Addressed HF-issues

- Human in system (required system behaviours, labels, controls and performance)
- Working environment (working positions, electromagnetic fields exposure)
- Training and development (i.e. warnings in Instructions for Use)

Additional information

This International Standard addresses technical aspects of the medical diagnostic MR System and the MR Equipment therein related to the safety of patients examined with this system, the safety of the MR worker involved with its operation and the safety of the MR worker involved with the development, manufacturing, installation, and servicing of the MR System.
The standard describes requirements in the following areas:

- General requirements
- General requirements for testing of ME Equipment
- Classification of ME Equipment and ME Systems
- ME Equipment identification, marking and documents
- Protection against electrical Hazards from ME Equipment
- Protection against mechanical Hazards of ME Equipment and ME Systems
- Protection against unwanted and excessive radiation Hazards
- Protection against excessive temperatures and other Hazards
- Accuracy of controls and instruments and protection against hazardous outputs
- Hazardous Situations and fault conditions
- Programmable electrical medical system (PEMS)
- Construction of ME Equipment and ME Systems
- Electromagnetic compatibility of ME Equipment and ME Systems
- Electromagnetic compatibility – Requirements and tests

General evaluation and summary

IEC 60601-2-33 does not describe a HF process, but lists technical requirements for the design of MR systems. It is quite specific, but interpreting the requirements requires extensive domain knowledge of the engineer. There are no HF activities or workflow provided.

5.2.4 Particular requirements for basic safety and essential performance of X-ray equipment for interventional procedures

Reference

IEC 60601-2-43 Particular requirements for basic safety and essential performance of X-ray equipment for interventional procedures; IEC International Electrotechnical Commission; 2010

Application of the regulation

Domain: Healthcare
System: X-ray equipment for radioscopically guided interventional procedures

Addressed HF-issues

- Human in system (required system behaviours, labels, controls and performance)
- Working environment (working positions, radiation)
- Training and development (i.e. warnings in Instructions for Use)

Additional information

This International Standard addresses technical aspects of the medical diagnostic MR System and the MR Equipment therein related to the safety of patients examined with this system, the safety of the MR worker involved with its operation and the safety of the MR worker involved with the development, manufacturing, installation, and servicing of the MR System.
The standard describes requirements in the following areas:

- General requirements
- General requirements for testing of ME Equipment
- Classification of ME Equipment and ME Systems
- ME Equipment identification, marking and documents
- Protection against electrical Hazards from ME Equipment
- Protection against mechanical Hazards of ME Equipment and ME Systems
- Protection against unwanted and excessive radiation Hazards
- Protection against excessive temperatures and other Hazards
- Accuracy of controls and instruments and protection against hazardous outputs
- Hazardous Situations and fault conditions

- Programmable electrical medical system (PEMS)
- Construction of ME Equipment and ME Systems
- Electromagnetic compatibility of ME Equipment and ME Systems
- Electromagnetic compatibility – Requirements and tests
- Radiation protection in diagnostic X-ray equipment

General evaluation and summary

IEC 60601-2-43 does not describe a HF process, but lists technical requirements for the design of x-ray equipment. It is quite specific, but interpreting the requirements requires extensive domain knowledge of the engineer. There are no HF activities or workflow provided.

5.3 Conclusions

Bearbeiten: Konzentration in erster Linie auf Usability, andere Issues werden selten behandelt. Annahne, dass Erfüllung von Usability Kriterien verspricht gleichzeitig die Erfüllung von Safety Anforderungen.
Die Regularien und Konzepte sind wenig produkt bzw. Domainspezifisch, anders als bei anderen Domänen. Die Diskussion ist eher generell und medical ist marginal.
Typsisch für AdCos: Adpativity, Intereoperabilität, Colaboration sind so gut wie gar nicht vorhanden.
The concepts for human factors integration in the domain of healthcare described above, set a main focus on HF issues that are concerned with the HMI and safety. Mostly the concepts cover issues such as interface usability and information requirements in order to develop a safe and sound system. Neither the user nor the patient shall suffer any harm. Use cases applying the concepts that were described by the authors also focussed on the interface design of output devices, task demands and their complexity.

In order to resolve the HF issues, the system in question shall be characterised by a good usability such that the system can be used effectively and safely, efficiently and with satisfaction. In general the actual end user should be included throughout the whole system development process. This can be achieved by needs and requirements analysis of the users and the system, as well as task analysis. This provides information to the interface design about essential criteria in terms of usability requirements, which need to be fulfilled by the system. Additionally all implementation steps of the system

(graphical Mock-up, prototype, full implementation) should be accompanied by usability tests on different levels suitable for the status of development (i.e. cognitive walkthroughs, heuristic evaluations or field studies with potential end users). By doing so, usability criteria and requirements can be validated. If the system does not meet the requirement a redesign can be done.

As the concepts mainly concentrate on an effective, safe, efficient and satisfactory use they do not raise extra focus on specific aspects of AdCoS such as adaptivity, cooperation, and communication as defined in T1.1. However, AdCoS in the domain of healthcare are not as complex as in other domains. Even though there are many users of a system, the main feature of these systems as described in use Case Deliverable 6.1 is displaying information and allowing functionality according to user status. These special user needs and the connected safety issues can be incorporated by following the workflows of the concept described above (i.e. conducting user and task analysis, analysis of hazards). Also the special needs of communication and cooperation within AdCoS in healthcare, can be treated like this if they can be regarded as general system requirements. Summing up, the concepts of human factors integration within the domain of healthcare do not set an explicit focus on the special HF aspects raised by AdCoS. They also seems to be more generic and less domain-specific comparing with other domains.

Like the concepts of human factors integration in the domain of healthcare, the regulations in the same domain also set a focus on issues of the category HMI, comprising of a usable design of the systems, information representation and alert signals. HF issues, which are additionally covered by the regulations are the working environment, training and development. In contrast to the concepts, almost no HF workflows are offered to resolve the issues in question. Only IEC 62366 offers a procedure on how issues can be detected and evaluated. IEC 60601-1-6 and IEC 60601-1-8 are also referring to these HF activities. IEC 60601-2-33 and IEC 60601-2-43 do not describe any HF activities. They depict technical regulations for the implementation of the systems.

IEC 62366 describes four procedures that need to be conducted: user research and conceptual design, requirement and criteria development, detailed design and specification, and evaluation of the system. The usability validation plan and the usability specification are the main documents that are necessary to evaluate and validate the system. Here the system requirements are described in a testable manner.

Similar to the concepts of human factors integration in the domain of healthcare, the regulations also do not cover the special aspects of AdCoS. Since IEC 62366 is the only regulation offering HF activities, the issues of AdCoS (adaptivity, cooperation, and communication) can only be integrated if they are explicitly added to the usability specifications and to the usability evaluation plan. The manufacturer and HF experts have to develop their own criteria on how these aspects have to be implemented and tested. There are no standards given.

Summing up, the regulations and concepts described in the domain of healthcare, offer opportunities on how various HF issues can be resolved parallel to the system development process. None of these explicitly mention how the specific aspects of AdCoS can be considered; nonetheless, these aspects are also not excluded by the concepts and regulations. It is the responsibility of the manufacturer and HF experts to include these issues in the HF activities that accompany the system development.

6 Automotive Domain

6.1 HFI Concepts and Tools in Automotive Domain

6.1.1 Code of Practice for the Design and Evaluation of ADAS

Reference

Code of Practice for the Design and Evaluation of ADAS (CoP); Knapp, A.; Neumann, M.; Brockmann, M.; Walz, R.; Winkle, T.; 2009

Application of the concept

The CoP has been produced by a group of experts within the RESPONSE 3 project, a subproject of the integrated project PReVENT (ended in 2008), a European automotive industry activity, co-funded by the European Commission, to contribute to road safety by developing and demonstrating preventive safety applications and technologies. It applies to the automotive domain and is not applicable to other domains, as the key concept and cornerstone of the CoP is the concept of *controllability*. It spans the entire development process. The CoP comprises a suitable ADAS (Advanced Driver Assistance System) description concept including specific requirements for system development. It summarises best practices and proposes methods for risk assessment and controllability evaluation.

"The Code of Practice applies to advanced driver assistance systems (ADAS). It is not specifically intended to be applied to systems providing vehicle stabilization (such as ABS and ESP) or mere information and communication systems (such as navigation, systems and telephones). It may be applicable to systems including vehicle to vehicle communication, but will not cover these completely." (p. 2)

"Focus of the CoP is the system design against the background of system controllability and the total vehicle from the field of view of Human Machine Interaction." (p. 2)

"The CoP deals with specification and assessment of advanced driver assistance systems during the entire development phase." (p. 2)

Addressed systems are Advanced Driver Assistance Systems in the form of "various vehicle types and systems with many complexity and integration levels in all ADAS" (p.3).

Due to the ADAS limits of their environmental sensing systems, the usage of the assistance functionality will also be limited. This implies that a direct in-

teraction between the driver and the system is necessary. This interaction has to be controllable also with regard to current legislation (Vienna Convention). Thus, the CoP serves as a support tool for the engineer engaged in the development of ADAS.

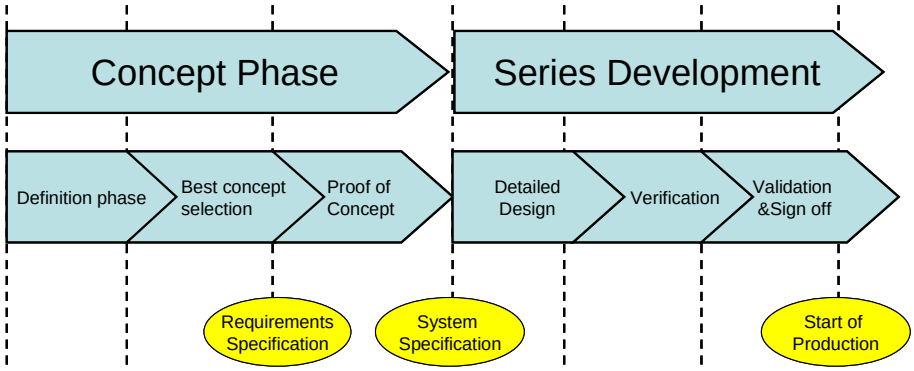
Addressed HF-issues

The current status of development makes it very difficult to describe the state-of-the-art knowledge of ADAS, because there are so many systems with different technology addressing even more different assisting functions.
Risks of ADAS may be highly complex. The term "defective product" is used in the European Product Liability Directive not only in a technical sense but it is also linked to human factors (HF) including system requirements such as dependability, controllability, comprehensibility, predictability and misuse resistance. Currently the technological safety issues are standardised within ISO TC22, while RESPONSE 3 is focussing on the human-machine interaction (HMI) safety issues of ADAS, in particular on driver controllability, an ADAS key issue.
Within the six categories of Eurocontrol (2007) categories of Human Factors issues the Code of Practice addresses category 6 *Human in System.* The CoP is explicit on the issues of 6.1 *Human machine interaction*, but also deals with aspects of 6.2 *System*. These subjects are covered partially in checklists for the single issues, but also appear as general topics throughout the CoP.
The CoP defines ADAS as systems, which (among others) require "direct interaction between the driver and the system" (p. 4). Both Human Machine Interfaces and Human Machine Interaction are therefore core issues of the CoP (primarily Annex A). System reliability is addressed in Annex C "General methods for safety analysis". For each topic extensive empirical methods are suggested

Addressed and supported development stages

The CoP defines its own development process (p. 11pp). It is not only a compilation of currently available procedures, but also offers clues for determining activities to be performed during the individual development phases. The focus is the system design against the background of system and vehicle controllability from the field of view of HMI. The CoP deals with specification, realisation and assessment of ADAS, gathering the best practices of the partner companies and also considers legal requirements.

The generic development process, describing the CoP, is provided as follows, reflecting the logical sequence of product development phases of a product development, as well as selected milestones, but not necessarily their time sequence (Figure 6-1).



6-1: Phases of COP development process

Therefore, it corresponds to a simplified presentation of reality. Possible iteration loops accompanying individual development phases are not shown.
It consists of a Concept Phase and a Series Development phase. Both phases are rather self-explanatory: The Concept Phase consists of the Definition Phase, the Best Concept Selection Phase and the Proof of Concept Phase. The Series Development starts with a Detailed Design, which probably reflects the need for a product moving towards series development to be specified in a way suitable for mass production. This stage is followed by Verification and Validation, consisting of proofs of the correct system functions' execution and the safety of the functions themselves.
The Concept Phase and Series Development Phase equate roughly the downward and the upward arrow of the V-Model. This relation deviates concerning the Detailed Design phase, though. In the V-Model it comes necessarily before the implementation. This discrepancy probably reflects the specific needs of the auto industry: a full-fledged product specification for mass production differs from the making of a single piece of software. In a certain sense the CoP's cycle therefore consists of two V-Models, one for the Concept and the other for the Series Development phase.
This development process is applied completely with regard to a new development of an ADAS (or AdCoS in our case) application. Hence, in case of modifications (derivate or change) of existing systems, an impact analysis

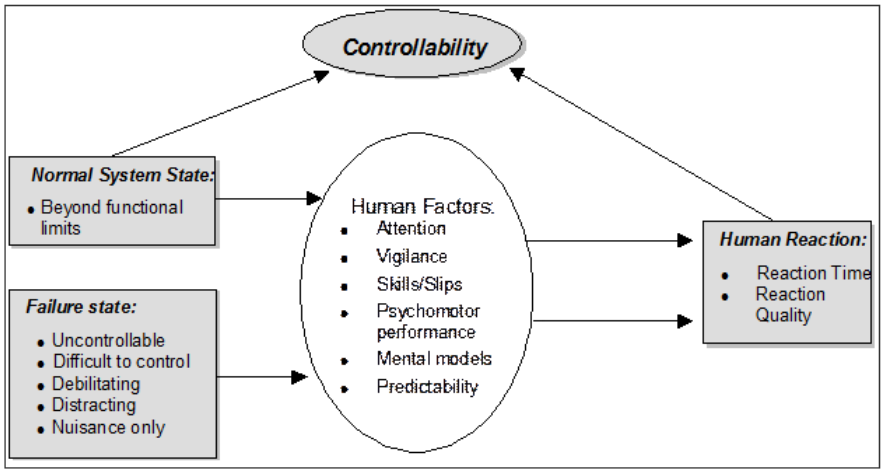
should be performed to assess the relevant areas affected by the modification. Each car manufacturer is responsible for the application and documentation of the COP, taking into consideration, that for a system with safety implications, additional safety related activities are necessary (for the automobile industry requirements there is the ISO TC22/SC3/WG16).
Finally, the concept of controllability in the COP is a key requirement. Controllability refers to the entire ADAS-driver-environment interaction (or AdCoS-driver-environment interaction, in our case) comprising of:

- normal system use within system limits,
- usage at and beyond exceeding system limits and
- usage during and after system failures.

Controllability is dependent on:

- the possibility and driver's capability, to perceive the criticality of a situation
- the drivers capability to decide on appropriate countermeasures (e.g. override, system switch-off)
- the driver's ability to perform the chosen countermeasure (e.g. reaction time, sensory-motor speed, accuracy).

Controllability is a basic parameter in the automotive risk assessment (as proposed in the draft of the functional safety standard ISO WD 26262-3). The schema is the following:



6-2: Architectural scheme of controllability

The RESPONSE 3 COP assists early controllability estimation and later confirmation by providing checklists and references to state-of-the-art evaluation methods.
At the end of the system development process, the COP recommends a Controllability Final Proof, to confirm that sufficient controllability is achieved for the production version of the system, in particular for intervening systems. This means that the development team has to verify that drivers will react as previously anticipated or in an appropriate way in relevant scenarios.

Proposition of HF-activities during the development process

The CoP describes very concrete different process stages and the corresponding sub-stages at a high and detailed level. Parts of the detailed description are proposed activities, which could be conducted during the system development (p.12). Correspondingly, the CoP recommends a concrete workflow of the entire process based of one possible example (here: "controllability", see p. 14). Furthermore, there are very specific recommendations of corresponding actions, belonging to each stage in the process. The actions can be performed in each corresponding stage of the process and are precisely defined in an instruction-based form of the CoP (see p. 16pp).
As an example, the use of the checklist procedure assists in the specification of ADAS in order to consider aspects which may not be obvious right from the beginning. The hazard and risk analysis procedure provides assistance in setting up a systematic analysis of driving situations in order to determine potential risks.
To sum up, the CoP aims at serving as a guideline assisting persons involved in ADAS development, in order to adhere to the state-of-the-art knowledge with respect to risk identification and risk assessment, as well as methodology for the evaluation of driver controllability, following the process of RESPONSE 3 project.

Proposition of methods

Based on the CoP development-process and the corresponding stages of the process in combination with the resulting specific action-recommendations, the CoP links a proposed method to each action-recommendation. Thus, for each step and corresponding action-recommendations of the CoP a linked method exists. Consequently, check lists are existing in the CoP, so that the realization of each addressed issue can be ensured (see p. 16 and A2). Unfortunately, the CoP does not provide a formalized result or output of these methods, allowing more variability in results or outputs.

Proposition of tools

The CoP does not recommend or propose specific tools. Based on the methods, tools could be derived and developed in a next step if necessary.

Additional information

Based on the lack of formalized results or outputs the CoP enables a dynamic usage in the system-development process of the automobile domain.

STRENGTHS-WEAKNESSES-Analysis

Strengths

The CoP focusses very explicit on safety and controllability. Correspondingly, the CoP is very useful for functional safety. It is very detailed and explicit on the subjects it covers with good and specific material in the annex (e.g., checklists). Furthermore, the CoP is very easy to understand, which is due to the clear specification of the stages of the development process. Its structure is clear and comprehensible. The CoP can be a basis for requirements integration and relevant concepts could be taken into account for other domains. The CoP takes standards and some HF-concepts into account, which are applicable for the automobile domain and operationalize these issues. One big strength is that the CoP makes specific recommendations for actions in the development process with an HMI section, ergonomic information, the use of other standards, and an extensive glossary (p A75pp).

The application of the CoP is a possibility to demonstrate that state-of-the-art (SOA) procedures in ADAS development have been applied, including risk identification, risk assessment and evaluation methodology. It can be used as guideline for the AdCoS development, taking into account the risk identification and risk assessment; in particular for these areas of application:

- Use of the checklist for the HMI design and development
- Application of the Controllability concept both for "Alarming AdCoS" (in CRF demonstrator) and for "Autonomous AdCoS" (in IFS demonstrator).

The CoP is a very good basis for the development of a more generic concept and development-process stages, which in turn are not specific for particular domains. Furthermore, the specific actions and methods can deliver a useful body of knowledge for the HF-RTP and AdCos development. Especially, the concrete methods in the annex (e.g., checklists) can be useful in the next steps.

Weaknesses

In particular it is not certain how big the HF aspect of the CoP is. Furthermore, the verification and validation of the issues are addressed very late in the entire process and thus may not have an impact any more. In the CoP, there is no concrete operationalisation of HF issues at all (e.g. workload). Sometimes the language is very vague when it comes to the point (e.g. "… the HMI should be designed in such a way that the driver will not solely rely on the system, but will also double check the situation"). Additionally, the CoP is very weak on empirical issues (e.g. "The design of the test trials needs to be carefully considered" - p A64). The arrangement of phases and corresponding processes are strongly influenced by economical considerations, not by science. Furthermore, there are not enough explicit feedback loops connecting the different development stages. The issue "Planning validation scenarios" is mentioned too late in the entire process. The definition of use cases or scenarios should be addressed earlier in the development process. Maybe the CoP is too industry related: economic considerations are paramount - first concepts, then detailed development (e.g. details only occur in the serial development phase). Finally, in the CoP it is not mentioned how requirements exactly fit into the entire development process.
The main limitations of CoP are:

- Full autonomous systems are not foreseen.
- Communication is not explicitly considered
- Information regarding on-board systems (such as navigator or phone) are not addressed.

The major risk is that the CoP does not at all fit for a proper deployment related to the HF-RTP or AdCos. Furthermore, the CoP is too domain specific for a general HF-deployment. Additionally, there is the risk that the phases, recommended actions and methods could not fit for HF-RTP and AdCos. Finally, the effort of implementing useful issues related to the HF-RTP or AdCos based on the CoP could be too high.

General evaluation

RESPONSE 3 has developed the CoP to provide the vehicle industry with the tools and common understanding to overcome and to help manage the problems about safety concerns and the liability of Advanced Driver Assistance Systems (ADAS). It is an exactly-worded guide, useful for the needs of research and development of ADAS within the automotive industry. Thus, the CoP primarily serves the needs of the automotive industry, which is the whole idea behind it. The advantage of the CoP lies in the specific action recommendations and the corresponding methods, mentioned in the annex. The

development process is reduced to its essential steps and stages, resulting in the concept, which is handy to realise. All the check lists mentioned in the CoP are useful methods, supporting the entire development process. Furthermore, the CoP is valuable as a framework under the concept of controllability. Other than that, parts could be used to get an overview of applicable methods and standards for ADAS. The focus on the issues of "controllability", which are in fact the key concept of CoP, restricts purposeful driver assistance functionality. So nothing would be developed, that violates that concept. Furthermore, the CoP only integrates requirements under the umbrella of system controllability from a driver's point of view. And it only has limited value as a tool for the broad exploration of possibilities for ADAS. Nonetheless, the CoP is a useful framework, which can be used as a starting point for the development of more generic concepts and development-process stages, which are useful for different domains at the same time.
RESPONSE 3 project has a follow-up at the moment, which is named RESPONSE 4, inside the Integrated Project ADAPTIVE (started in January 2014, web-site not yet available). The main objectives of RESPONSE 4 are:

- legal aspects to facilitate the introduction of automated driving functions
- additional requirements for safety validation to ISO26262 and other safety standards
- provision of a harmonised glossary

To sum up, legal aspects, human-vehicle integration and evaluation methodologies will be investigated; these aspects should be taken into account also inside HOLIDES.

6.1.2 Detectability concept

Detectability (Engel and Curio,2013) is a concept from recent research and is maintained by HoliDes Partner TWT GmbH Science & Innovation. In HoliDes we are working on similar human centered development concepts. The original focus of the detectability was in the visual domain for guiding attention. But it could have its applications in other perception modalities, or combinations thereof, as well.

Reference

Detectability Prediction *for* Increased Scene Awareness*. David Engel,* and Cristóbal Curio. IEEE Intell. Transport. Syst. Mag. 5(4):146-157 (2013)

Application of the concept

Domain: Automotive; applicable to other domains, like aeronautics and many others as well, generic
System: Visual attention guidance mechanism; complexity of the system approach is reflected by a trained non-linear support vector regression machine approach.

Adressed HF-issues

Demonstrated in Physical Environment but also relevant for Work place layout, Operator Working Position, Personal Factors: Physiological Factors, Physiosocial Factors and Human in System:HMI, System.

Adressed and supported development stages

- Hardware-Software Integration/Verification
- Hardware-Software Testing (Validation)
- System Integration/Verification
- System Validation

Proposition of HF-activities during development process

Object detectability performance are required to be collected through specific experimental dual task designs. The human performance, i.e. to visual detect certain objects/ events, can be tested after a general human-centered system calibration step (across or within subject), e.g. during real-driving. The goal is to automatically predict detectabilities which can be exploited for attention guidance HMIs.

Proposition of methods

Psychophysical simulations/ experiments to gather detectabilities under different levels of distraction, driving conditions, scene variability.

Experimental detectabilities (simple performance measures for each "situation") are going to be predicted by measurable context information, i.e. through the help of computer-vision methods (that could describe local imaging conditions) but also relational situation information. These dependent variables are used to predict, after the appropriate relevance selection, corresponding human detectabilities performance data. Gaze is a dependent variable and can be optimised for optimal detectability.

Proposition of tools

Computer-Vision measures off-line labeled scene databases and machine learning algorithms, like non-linear support vector machines.

STRENGTHS-WEAKNESSES-Analysis

Strengths

From the beginning, it combines both visual factors, which might determine human scene awareness and uses them to predict human performance, and to provide feedback to improve human performance even more, which by design the system is specifically trained for.

It further allows the determination of features in visual space that might be relevant to the design of technical recognition algorithms that further allow the specific determination/classification of visual scenes. It is furthermore intended to work in open, unconstrained envrionments, as the system is based on robust statistical learning.

The approach avoids overload by only rendering relevant information or by guiding users to specific spots in the visual environment to accomplish specific tasks.

The concept requires several tools that determine human perceptual states (eye-gaze, head-gaze). It could profit from simulation environments with reproducible visual conditions. Machine-Learning algorithms, especially non-linear regression, would be beneficial to collect real experimental data in order to trigger some sort of attentional feedback (acoustic displays, directive blinking, Head-Up-Displays).

Weaknesses

Further establishment needed.

General evaluation

Considering the detectability concept to be part of a HF-RTP could be exploited as a point to address needs in the area of attention modeling, distraction modelling, performing efficient search, and provide guidance mechanisms to relevant information in interactive settings. It is intended to work in the visual domain, but could be extended to other perceptual domains, like audio, as well.

6.1.3 ACT-R Integrated Drive Model

Reference

Salvucci, D. D. (2006). Modelling driver behaviour in a cognitive architecture. Human Factors, 48, 362-380.

Application of the concept

Domain: The discussion of the paper and the research can be applied to the automotive domain, but some of the issues, as attention distribution, safety control, can be generalized to the other domains, like Aeronautics

System: Cognitive Psychology model; Interface usability; User model.

Adressed HF-issues

- Human in system >>Human – machine interaction>> Allocation of function between human and machine

Adressed and supported development stages

- System Architecture
- System Validation

Proposition of HF-activities during development process

The concept simulates some HF activities in a series of tasks and sub-tasks. Simulation is a good way to formulate hypotheses to further test in a real scenario. The main goal of the ACT-R driver model is to facilitate rigorous evaluation and validation by having the model drive in the same environment as human drivers.

Proposition of methods

The model proposes to simulate human behavior in a driving task before testing it.

The output of the model consists of a series of measures of behavior: steering angle, lateral position and eye movements (as a surrogate for the locus of visual attention) in the form of aggregate results and time-course profiles.

Proposition of tools

ACT-R Tool

Additional Information

The ACT-R (Active Control of Thought – Reflexive) INTEGRATED DRIVE MODEL is a computational model developed with the aim of simulating driver behavior in a cognitive architecture ACT-R.

The model is explainable in a framework ETA, an acronym, which emphasises the effort to integrate three main aspects of driving processes:

1. TASK – the task a driver is going to execute;
2. ARTIFACT – the artifact, with which a driver needs to perform the task;
3. EMBODIED COGNITION – the integration of the processes that a driver has to implement to manipulate the artifacts and to execute the tasks.

The main goal of the model is the rigorous identification and explanation of the interaction between all of the three aspects. In order to do this, the model was designed with a three-components architecture:

1. the "control" component inherits perceptive processes; all perceptive variables are employed to manipulate the vehicle. In a highway driving simulation context, control is a "two-level" process based on the perception of two points, a near point, to judge how far the vehicle is to the centre of the way, and a far point, to evaluate the curvature of the way, before operating the maneuver in order to remain in the current lane. The model first concentrates on the near point, then on the far point to estimate the visual angle between the two points. Control component non only intervenes in lane keeping and curve negotiation tasks but also acts in lane changing task: to change the lane the driver begins to use the near and the far points, not from the current lane, but from the destination lane; the visual angle increases, initiating a large steering maneuver in direction of the destination lane.
2. the "monitoring" component concerns the awareness of the surrounding environment. Particularly, in a highway context, awareness is also the knowledge of other vehicles behind the driver vehicle. Monitoring is based on a model, which checks four areas, left or right lane, forward or backward. When the model decides to check a lane and a direction, it moves its visual attention to that area and establishes if a vehicle is present. If a vehicle is detected information about the position, the direction and the speed of that vehicle is stored in the declarative memory.
3. the "decision making" component makes tactical decisions about the operating maneuvers based on the knowledge about the surrounding environment. In a highway driving simulation scenario, the more important decisions concern if and when a lane change operation takes

place in a safe way. If the driver vehicle is in the right lane, the model checks for the presence of a lead vehicle and (if any) estimates its speed. If the estimated speed of the lead vehicle drops below a desired threshold the model decides to change the lane to pass the vehicle. If the vehicle is on the left lane, the model simply checks for the presence of a lead vehicle. If any, the model decides to stay on the current lane (assuming that the lead vehicle is also passing another vehicle), otherwise it decides to return to the right lane. Another crucial decision is about when to operate the maneuver in safe conditions. To do so the model recalls information about the surrounding vehicles from the declarative memory. In this way the vehicle can avoid the impact with another vehicle in its blind spot, even when it cannot view that vehicle. If there is a vehicle nearer than the safe distance, the maneuver is immediately aborted. However, the model can also forget information about other vehicles if they stay in the blind spot for a long time. In this case, the model needs to update information about the environment, checking again for surrounding vehicles.

To work properly, the model needs a lot of information that can be stored in two interacting knowledge stores:

1. a declarative memory, based on chunck or symbolic information. As described above, a chunck can encode a target (to change the lane) or an information about surrounding environment (there is a car on my left). In addition, a chunch can also specify a property of another chunck: e.g., the property "availability" indicates how easily an information can be recalled. During simulations, a learning mechanism can occur to modify these properties.
2. a procedural memory, made up by production rules representing procedural skills to manipulate declarative knowledge and, consequently, the surrounding environment. A procedural rule is a condition-action rule, which specifies what action to execute in case a condition is satisfied.

STRENGTHS-WEAKNESSES-Analysis

Strengths

The possibility to execute more processes in parallel makes the model particularly adapted to predict real world data and facilitates the validation of the model, by means of the comparison between simulation and real behavior. The possibility to integrate perceptive and motor processes to simulate the interaction with the environment.

Weaknesses
Poor sensibility to the context, completely identified with surrounding vehicles; negligence about inter-individual differences.

General evaluation

The model is not a proper HF Integration Concept because it does not describe any workflows or activities during the several stages of the system development process. However it is worth describing ACT-R in deliverable 1.2, because the model is one of the most popular in the automotive domain. The value of the model is the predictive power respect to driving behavior in safe conditions in real scenarios.

6.1.4 ACT-R Tool

Application of the tool

Domain: Automotive
Cognitive Psychology model; Interface usability; User model.

Addressed HF-issues

- Human in system >>Human – machine interaction>> Allocation of function between human and machine

Addressed development stages

- System Architecture
- System Validation

Interoperability

The tool is not conceived for interoperability with other tools.

Nonetheless, OSLC Support

The tool is not conceived for supporting OSLC and no support for OSLC has been developed up to now. Nonetheless, the output is a textual trace consisting in a sequence of timed production firings that can be easily used as an input for statistical analysis tool. Metrics such as the time to complete a task and the accuracy in the task are delivered as well.

Commercial Availability

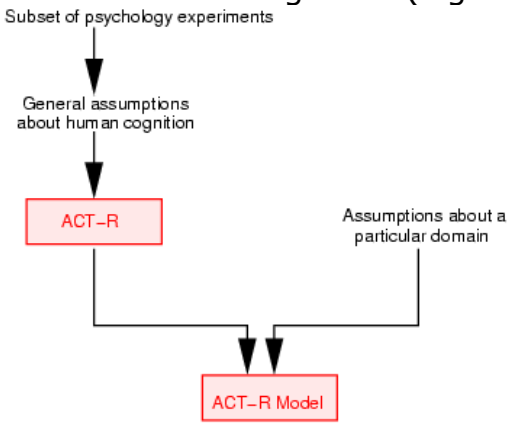
Free.

Additional Information

ACT-R is an open source, free software tool that can be easily run on Windows and Mac-OS platforms. It is composed by a set of functions and algorithms implemented in Common Lisp that embody the ACT-R cognitive theory.

All ACT-R assumptions about human cognition are derived from psychological experiments.

In the ACT-R framework, for different tasks (e.g., Tower of Hanoi, memory for text or for list of words, language comprehension, communication, aircraft controlling), researchers create "models", that are programs written in ACT-R programming language and that add their own assumptions about the particular task to the ACT-R's view of cognition (Figure 6-3).

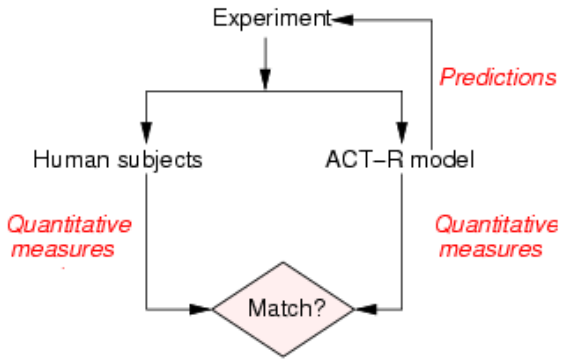


6-3: Creation of an ACT-R model

As suggested before, researchers' assumptions can be tested by comparing the results of their model with the results of people doing the same tasks according to the following cognitive psychology metrics:

- time to perform the task,
- accuracy,
- neurological data, such as those obtained from FMRI.

Indeed, one important feature of ACT-R is that it allows researchers to collect quantitative measures that can be directly compared with the quantitative measures obtained from human participants (Figure 6-4).



6-4: Testing of researchers' assumption embodied in the ACT-R model

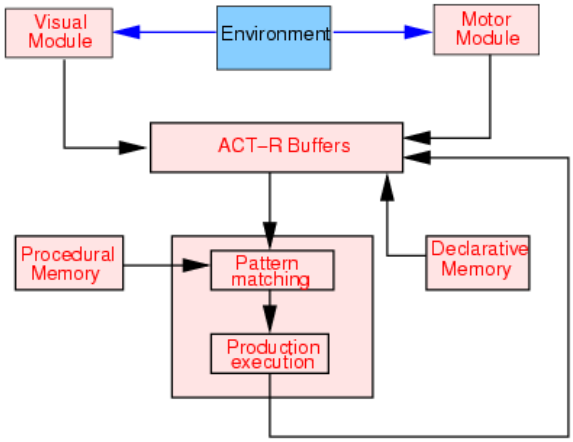
The ACT-R architecture is represented in Figure 6-5.
The main components are:

- Modules
- Buffers
- Pattern matcher

Modules are divided into two main categories:

- Perceptual – motor modules, taking care of the interface with the real world. They includes:
  - Visual module
  - Manual module

- Memory modules, grouped into:
  - Declarative memory module, dealing with the storing of "facts";
  - Procedural module, dealing with the knowledge about doing things like driving, typing letters, etc.;



6-5: ACT-R architecture

Buffers are the interface between the ACT-R modules (except for the procedural memory modules) and the ACT-R engine. Each module has a dedicated buffer. The content of the buffers at any given time represent the state of ACT-R at that moment.
The Pattern Matcher looks at the state of the buffers and searches for a "production" to be executed. The production can change the state of the buffers.
In ACT-R, cognition is seen as a succession of "production firings".

6.2 HF and Safety Regulations in Automotive Domain

6.2.1 Road vehicles: Dialogue management principles and compliance procedures

Reference

ISO 15005: Road vehicles – Ergonomic aspects of transport information and control systems – Dialogue management principles and compliance procedures; DIN Deutsches Institut für Normung e.V.; 2003

Application of the regulation

Domain: automotive
System: Dialogue management

Adressed HF issues

The three issues described in this standard can be mapped to Eurocontrols category 6.1.5 Human-Machine Interface Usability:

1. *Transport Information and Control System* (TICS) dialogues need to fit their purpose – Being used while driving:

TICS are not allowed to intervene with driving; therefore they have to be as simple to use as possible and understand and support the priorities of the driver.

2. Dialogues need to be suitable for TICS-tasks:

TICS dialogues have to be consistent and manageable at all times.

3. Suitability for the driver:

TICS dialogues need to be self-explanatory, conform with the drivers expectations and fault-tolerant.

Proposed HF activities

ISO 15005 lists a couple of requirements and/or recommendations for each issue mentioned. The requirements vary from very exact information (e.g. TICS required input has to be manageable in shorter than 1,5s) to general statements (e.g. TICS dialogues need to divide the presented information in small units to ensure that it can be perceived easily).
It refers to the standards ISO 3958, 15008 and SAE J 1050, which should give an inside of how to position the displays and controls needed.
It lacks helping methods and tools for meeting the requirements described.

HF workflow

Since the standard lists requirements and recommendations it might be mapped to Stage 3 and 4 of the V-Model.

General evaluation and summary

ISO 15005 might first serve as an overview about the topic of designing dialogues. It only provides general information about requirements and recommendations and lacks both the methods and tools, which might help during the design process.

6.2.2 Road vehicles: Specifications for in-vehicle auditory presentation

Reference

ISO 15006: Road vehicles – Ergonomic aspects of transport information and control systems – Specifications for in-vehicle auditory presentation; DIN Deutsches Institut für Normung e.V.; 2012

Application of the regulation

Domain: automotive
System: auditory systems

Adressed HF issues

ISO 15006 focusses on in-vehicle auditory signals (alert signals). Issues described are:

- Signal spectrum and level
- Timed codification of signals
- Non-verbal auditory signals
- Verbal auditory signals
- Prioritization of signals
- Requested redundancy of signals

Proposed HF activities

Appendix A refers to ISO 45631, 45681, 5128 and provides a method for measurement of the signal level and judgment of audibility.
There is a reference to ISO/TS 16951 which should provide a method for prioritization of alarm signals.
Apart from that ISO 15006 provides some general guidance for presentation of auditory signals.

HF workflow

The procedure for measurement of the signal level and judgment of audibility is a method for evaluation. Therefore this standard might be mapped to Stage 8 of the V-Model.

General evaluation and summary

ISO 15006 is a short standard on the topic of auditory signals. It provides a method for measurement of signal levels and judgment of audibility. It also refers to other standards which might be useful for correct prioritization of alarm signals. Apart from that the standard remains at a very general level of information.

6.2.3 Road vehicles: Measurement of driver visual behavior with respect to transport information and control systems

Reference

ISO 15007: Road vehicles – Measurement of driver visual behavior with respect to transport information and control systems;CEN European Committee for Standardization; 2002

Application of the regulation

- Domain: automotive
- System: Driver assistance and driver information systems; eye-/gaze-tracking systems;

Adressed HF issues

HMI Usability

Proposed HF activities

Assessment and evaluation of human-machine-interaction using eye-/gaze-tracking devices; assessment of eye-on/off-road times, gaze-durations, gaze-directions during interaction between driver and driver assistance and driver information systems

- these HF-activities belongs to the categories: analysis, evaluation

HF workflow

- Hardware-Software Testing (Validation)
- System Integration/Verification
- System Validation

General evaluation and summary

This standard provides definitions and defines parameters for the analysis of drivers' gaze-behavior. It can be used for lab-based studies as well as experiments in a real driving environment. The methods described in this standard can be used to evaluate drivers' eye-gaze behavior, not only related to driver assistance systems, but also to general in-car applications.

6.2.4 Road vehicles: Specifications and test procedures for in-vehicle visual presentation

Reference

ISO 15008: Road vehicles – Ergonomic aspects of transport information and control systems – Specifications and test procedures for in-vehicle visual presentation; DIN Deutsches Institut für Normung e.V.; 2011

Application of the regulation

- Domain: automotive
- System: visual presentation

Adressed HF issues

ISO 15008 lists requirements and recommendations which need to be considered to ensure that the driver of a car is able to recognize information provided via TICS (6.1.2 Output devices):

- Contrast/illuminace of displays: used in different lightning conditions; looked at from different angles of vision
- Colour combinations
- Size of characters
- Reflection and mirroring
- Characteristics of presentation: flicker, blinking

Proposed HF activities

Contrast should be adjustable by either automation or the driver to match every possible lightning condition. If it is impossible to create a satisfying contrast between background and characters additional contours shall be used.
Appendix B provides a table that evaluates possible combinations of colour.

HF workflow

The standard refers to SAE J1757/1:2007 which provides a method for the measurement of contrast/illuminance.
Appendix A defines a method for the measurement of the size of used characters taking the position of the eye of the beholder into account.

General evaluation and summary

ISO 15008 provides a general overview of physical characteristics which need to be fulfilled to ensure that the beholder [driver of a car] doesn't encounter problems when trying to see/read information provided by a visual display. It provides some general guidelines as well as some methods for measurement of a product. It lacks workflows that might be helpful while designing a display.

6.2.5 Road vehicles: Procedure for assessing suitability for use while driving

Reference

ISO 17287: Road vehicles: Ergonomic aspects of transport information and control systems – Procedure for assessing suitability for use while driving; DIN Deutsches Institut für Normung e.V.; 2003

Application of the regulation

- Domain: automotive
- System: Transport Information and Control System (TICS)

Adressed HF issues

This standard focusses on the usability of TICS (6.1.5 Human-Machine interface usability):

- Disturbance while driving caused by TICS
- Controllability
- Efficiency
- Operator convenience while learning to work with TICS

Proposed HF activities

Appendix C provides a detailed list of possible test methods including:

- Stress (Visual attention, introspection, second-task-paradigm)
- Accomplishment of driving (Longitudinal/diagonal control of the vehicle, perception of the environment)
- Reactive change of behaviour (Readiness to brake, use of controls, used lane, manoeuvre)
- Applicability (Time needed to execute a task, mistakes made while executing a task, TICS' response time)

HF workflow

The purpose of the standard is to support evaluation of a product before extensive distribution. It can be used in different stages of a project: concept, prototype, finished product. Therefore it might be mapped to several Stages of the V-Model: Stage 4 & 7.
To assess suitability of TICS for use while driving the precise requirements need to be defined. ISO 17287 provides some guidance to do that: A short guideline containing relevant issues and explaining them.
Based on the sufficiently described requirements a 7-step-procedure for assessment of suitability should be followed:

1. Define the assessment procedure
2. Choose between possible TICS-representations (e.g. concept, prototype, finished product, different parts of TICS)
3. Define the relevant context of use (including personas, environmental settings, relevant situations)
4. Define the evaluation criteria (ISO 15008 Visual Displays and ISO 15005 Dialogue management might help)
5. Selection of assessment methods based on the evaluation criteria defined.
6. Run the test.
7. Compare the results with the criteria defined. If necessary run re-tests.

The results have to be documented.

Additional information

Appendix A provides examples of user-centred descriptions of different TICS.
Appendix B provides examples of descriptions of possible TICS tasks.
Appendix D provides examples of executed assessment tests.

General evaluation and summary

ISO 17287 provides an assessment procedure including methods and tools that will help run an evaluation test. Combined with the requirements and recommendations described in ISO 15005-8, it somewhat completes the other standards, since they are lacking the methods and tools that might help realise a product that meets all the criteria described.

6.2.6 Crash Warning System Interfaces: Human Factors Insights and Lessons Learned

Reference

DOT HS 810 697: Crash Warning System Interfaces: Human Factors Insights and Lessons Learned; U.S. Department Of Transportation NHTSA; 2007

Application of the regulation

- Domain: automotive
- System: crash avoidance systems, especially forward collision, lane change and road departure warnings

Adressed HF issues

Issues described within this document include:

- Warning signals including selection, prioritization, integration, compatibility with drivers response, prevent false or nuisance warnings and timing (6.1.4 Alert signals)
- Auditory warnings (6.1.4 Alert signals)
- Visual warnings (6.1.4 Alert signals)
- Haptic warnings (6.1.4 Alert signals)
- Controls used in collision warning systems (6.1.1 Input devices)

Proposed HF activities

Every issue described comes with an abstract of 2007's current state of research. Furthermore a short guideline stating ways to resolve the issue based on either expert judgment or empirical data or sometimes even both is provided.

Additional relevant information and notes

Additional to the topics described in 0 the report provides four chapters which deal with particular systems and corresponding issues:

- Forward collision warning systems
- Lane change warning systems
- Road departure warning systems
- Application to heavy trucks and buses

Tutorial 1 discusses the 2007's state of technology used in these systems in three parts: 1) an overview of current technologies, 2) a technology review, and 3) a synthesis of CWS technology implementation.
Tutorial 2 focusses on the activation and operation of crash warning system devices.
Tutorial 3 provides some further inside on the topic of heavy trucks and buses.
Since there is very little directly applicable data that can be used to develop specific, comprehensive guidance for the integration of collision warnings Tutorial 4 provides some additional discussion and perspective on the topic.

General evaluation and summary

This handbook can be used in any number of ways. For example, it can be read through, from start to finish, if one desires an overview of human factors issues, principles, data sources, and guidelines associated with the design of crash avoidance warning systems. Also, individual chapters can be reviewed, if one would like to focus on specific topics, such as Forward Collision Warning (FCW) systems or Heavy Vehicle applications. Finally, one may simply refer to specific guidelines, equations, terms, and references as their individual needs warrant.

6.2.7 Driver Focus – Telematics Guidelines

Reference

Statement of Principles, Criteria and Verification Procedures on Driver Interactions with Advanced In-Vehicle Information and Communication Systems; Driver Focus-Telematics Working Group; 2006

Application of the regulation

- Domain: automotive

- System: advanced in-vehicle information and communication systems

Adressed HF issues

The authors of this regulation distinguish five sections of design principles:

1. Installation Principles (Working environment):
    a. The system should be located and fitted in accordance with relevant regulations, standards, and the vehicle and component manufacturers' instructions for installing the systems in vehicles.
    b. No part of the system should obstruct the driver's field of view as defined by applicable regulations.
    c. No part of the physical system should obstruct any vehicle controls or displays required for the driving task.
    d. Visual displays that carry information relevant to the driving task and visually-intensive information should be positioned as close as practicable to the driver's forward line of sight.
    e. Visual displays should be designed and installed to reduce or minimize glare and reflections.
2. Information Presentation Principles (Output devices):

    a. Systems with visual displays should be designed such that the driver can complete the desired task with sequential glances that are brief enough, as not to adversely affect driving.

    b. Where appropriate, internationally agreed upon standards or recognised industry practice relating to legibility, icons, symbols, words, acronyms, and abbreviations should be used. Where no standards exist, relevant design guidelines or empirical data should be used.

    c. Available information relevant to the driving task should be timely and accurate under routine driving conditions.

    d. The system should not produce uncontrollable sound levels liable to mask warnings from within the vehicle or outside or to cause distraction or irritation.

3. Principles on Interactions with Displays/Controls (Input devices):
    a. The system should allow the driver to leave at least one hand on the steering control.

b. Speech-based communication systems should include provision for hands-free speaking and listening. Starting, ending, or interrupting a dialog, however, may be done manually. A hands-free provision should not require preparation by the driver that violates any other principle while the vehicle is in motion.
c. The system should not require uninterruptible sequences of manual/visual interactions. The driver should be able to resume an operator-interrupted sequence of manual/visual interactions with the system at the point of interruption or at another logical point in the sequence.
d. In general (but with specific exceptions) the driver should be able to control the pace of interaction with the system. The system should not require the driver to make time-critical responses when providing input to the system.
e. The system's response (e.g. feedback, confirmation) following driver input should be timely and clearly perceptible.

f. Systems providing non-safety-related dynamic (i.e. moving spatially) visual information, should also be capable of functioning without providing information to the driver.

4. System Behaviour Principles (Information requirements & Human-Machine Interface Usability):
    a. Visual information not related to driving that is likely to distract the driver significantly (e.g., video and continuously moving images and automatically-scrolling text) should be disabled while the vehicle is in motion or should be only presented in such a way that the driver cannot see it while the vehicle is in motion.
    b. System functions not intended to be used by the driver while driving should be made inaccessible for the purpose of driver interaction while the vehicle is in motion.
    The system should clearly distinguish between those aspects of the system, which are intended for use by the driver while driving, and those aspects (e.g. specific functions, menus, etc.) that are not intended to be used while driving.
    c. Information about current status and any detected malfunction within the system, which is likely to have an adverse impact on safety, should be presented to the driver.
5. Principles on Information about the System:

a. The system should have adequate instructions for the driver covering proper use and safety-relevant aspects of installation and maintenance.

b. Safety instructions should be correct and simple.

c. System instructions should be in a language or form designed to be understood by drivers in accordance with mandated or accepted regional practice.

d. The instructions should distinguish clearly between those aspects of the system that are intended for use by the driver while driving, and those aspects (e.g. specific functions, menus, etc) that are not intended to be used while driving.

e. Product information should make it clear if special skills are required to use the system or if the product is unsuitable for particular users.

f. Representations of system use (e.g. descriptions, photographs, and sketches) provided to the customer with the system should neither create unrealistic expectations on the part of potential users, nor encourage unsafe or illegal use.

Proposed HF activities

Principles are presented in four sections: Rationale, Criterion/Criteria, Verification Procedures and Examples. While the Rationale is a general explanation of the principle presented, the Criterion/Criteria provide clear guidelines/recommendations, which should be considered while designing a relevant product. Often a Verification Procedure is stated, which should be executed by a suitable expert, since most of the times it is not described any further than naming it, e.g.:

- Design to conform to applicable regulations and verify by appropriate means.
- Design to conform and validate by appropriate means (e.g., analysis, inspection, demonstration, or test).
- JAMA Guidelines (downward viewing angle)
- ISO 15008 In-Vehicle Information Presentation
- ISO 2575 Symbols for Controls, Indications and Tell-tales

- Verify by inspection or demonstration.

Some Examples are given for further elaboration.

HF workflow

The whole guideline is not only usable after designing a product but also for use by automotive manufacturers and telematic devices during product development. Nevertheless it lacks precise information on chronological placement of the activities presented what makes it difficult to map to the V-Model.

Additional information

Alliance of Automobile Manufacturers members have voluntarily committed to design production vehicles to these Guidelines within specific designated timeframes.

General evaluation and summary

The intended application of the Guidelines is to provide criteria and evaluation procedures for use by automotive manufacturers and manufacturers of telematic devices during product development. It is presumed that those applying the Guidelines have the technical knowledge of the products under evaluation, as well as access to resources necessary to carry out the specified evaluation procedures. To the extent that one uses this document for post facto evaluation, for certain test and assessment determinations, appropriate product knowledge and test facilities are needed, as is the case for many federally developed safety standards. These Guidelines are not suitable as the basis for an informal inspection-based evaluation. While scientifically based, these Guidelines do not represent a self-contained academic work.

By virtue of their different purpose, these guidelines do not to apply to driver assistance systems and associated HMI elements such as audio/visual alerts and cues, haptic displays and cues and head-up displays that may intentionally be used to attract the driver's attention. As recognised by the ESoP draft dated June 2005, Advanced Driver Assistance Systems (ADAS) are "fundamentally different and require additional considerations in terms of Human Machine interaction."

6.2.8 Legal Consequences of an increase in vehicle automation

Reference

Legal consequences of an increase in vehicle automation; Bundesanstalt für Straßenwesen; 2012

Application of the regulation:

Domain: Automotive; appropriate only in (German) automotive domain
Systems: Automation systems for fully, highly, or partially automated driving beyond Driver Assistance Systems

Adressed HF issues

- Automation & new technology;
- Allocation of function between human and machine;
- Resilience, Robustness, Recovery from System failure

Proposed HF activities

Classification of level of automation; description of levels of automation; legal implications of vehicle automation; product liability of manufacturers; liability of drivers; Misuse and abuse of automation; Technical realisation and requirements of automated driving; HMI usability; Control allocation human and machine; Long-term research demands.

HF workflow

Relevant to all stages of development (V-Model).

General evaluation and summary

The BASt-project group "Legal consequences of an increase in vehicle automation" has identified, defined and consequently compiled different automation degrees beyond Driver Assistance Systems. These are partial-, high- and full automation.
According to German regulatory law, i.e. the German Road Traffic Code, it has been identified that the distinctive feature of different degrees of automation is the permanent attention of the driver to the task of driving as well as the constant availability of control over the vehicle. Partial automation meets these requirements. The absence of the driver's concentration to the traffic situation and to execute control is in conflict with the use of higher degrees of vehicle automation (i.e. high and full automation). Their use is thus

not presently compatible with German law, as the human driver would violate his obligations stipulated in the Road Traffic Code when fully relying on the degree of automation these systems would offer. As far as higher degrees of automation, which imply hands-free driving, further research in terms of behavioural psychology is required to determine whether this hinders the driver in the execution of permanent caution as required by sec. 1 para. 1 StVO (German Road Traffic Code).
As far as liabilities according to the StVG (German Road Traffic Act) are concerned, the presently reversed burden of proof on the driver within sec. 18 para. 1 S. 2 StVG might no longer be considered adequate in case of higher degrees of automation that allow the driver to draw attention from the task of driving (in case making use of such a system would be permitted by the German Road Traffic Code). The liability of the vehicle "keeper", according to the German Road Traffic Act, would remain applicable to all defined degrees of automation.
In case of partial automation, the use of systems according to their limits is accentuated. The range of intended uses must be defined closely and unmistakeably. Affecting user expectations properly can immensely help to maintain safe use, but in case design-measures that exclude overreliance are not available according to the current state of the art (otherwise such measures would have to be applied primarily). In case of the higher degrees of automation that no longer require the driver's permanent attention (under the presupposition their use would be permitted by the German Road Traffic Code), every accident potentially bears the risk to cause product liability on the side of the manufacturer. Liability of the manufacturer might only be excluded in case of a breach of traffic rules by a third party or in case of overriding/oversteering by the driver. In so far aspects of German procedural law and the burden of proof are of great importance.
The project group has identified the need for further continuative research not only to advance legal assessment but also to improve basic technical conditions for vehicle automation as well as product reliability.

6.2.9 In-Vehicle Display Icons and Other Information Elements

Reference

In-Vehicle Display Icons and Other Information Elements. Volume I: Guidelines, Volume II Final Report; U.S. Department of Transportation. Federal Highway Administration (FHWA); 2004

Application of the regulation:

Domain: Automotive
Systems: In-Vehicle Information Systems (IVIS), in-vehicle visual symbols and other information elements

Adressed HF issues

Output Devices

Proposed HF activities

Guidelines to analyse, design and evaluate the appropriateness of symbols for in-vehicle use; issues such as the legibility, recognition, interpretation of graphical and text-based icons and symbols are addressed; guidelines for the design in-vehicle auditory information; Driver Information, Design Guidelines, Icon Design, Visual Symbols, Icon Interpretation, Icon Legibility, Auditory Messages, General vs. Specific Icons, Icon Recognition, Icon Evaluation.

HF workflow

Relevant to all stages of development (V-Model)

General evaluation and summary

These guidelines are intended for use by anyone responsible for the conceptualisation, development, design, testing, or evaluation of in-vehicle display icons and other information elements.
Chapters 2 through 7 contain the preliminary design guidelines produced through this effort. Chapter 2 provides general guidelines for icon design, and focusses on issues associated with the development of icons, when to use icons, and icon comprehension. Chapter 3 provides design guidelines for icon legibility, and focusses on issues associated with contrast, luminance, and the use of color. Chapter 4 provides design guidelines for icon recognition, and focusses on issues associated with the level of detail, the level of realism, and principles of perception to follow for the design of effective icons. Chapter 5 provides guidelines for icon interpretation, and focusses on the use of icons to convey system status and the effect of actions, as well as identifying icons as part of a group. Chapter 6 provides guidelines for presenting auditory in-vehicle information, and focusses on the design of simple tones, earcons, auditory icons, and speech messages.

Chapter 7 provides guidelines for the evaluation of in-vehicle icons, and focusses on the tests recommended by the International Organisation for

Standardisation (ISO) (i.e. production test, appropriateness ranking test, comprehension/recognition test, and matching test). Chapter 8 includes a collection of icons for many messages. A tutorial describing in detail the process necessary for converting rank orders to scale values when evaluating icons using the appropriateness ranking test is provided in chapter 9. A design tool, useful for determining the sensory mode for presenting in-vehicle information, is provided in chapter 10.

6.2.10 Distraction Detection and Mitigation Through Driver Feedback

Reference

Distraction Detection and Mitigation Through Driver Feedback; National Highway Traffic Safety Administration (NHTSA); 2013

Application of the regulation:

Domain: Automotive
Systems: real-time driver monitoring systems; driver-state detection and analysis

Adressed HF issues

- Allocation of function between human and machine;
- Alert signals;
- Stress/anxiety;
- Preoccupations

Proposed HF activities

Driver Distraction, Real-time Driver Monitoring, Driver Feedback, Evaluation Protocol, System Specification, Acceptance.
These HF-activities belongs to the categories: evaluation

HF workflow

Relevant to following stages of development:

- Hardware-Software Testing (Validation)
- System Integration/Verification
- System Validation

General evaluation and summary

This report identifies evaluation techniques to characterise and assess these emerging technologies, presents results of their application, develops a framework for estimating systems' safety benefits, and provides safety relevant information to guide technology development. A standardised language for describing and differentiating systems was created, and its application revealed key trends in the design landscape. A novel approach to detection that provides prospective indications of safety-critical vehicle state changes is described. Two evaluation protocols were developed and to provide empirical assessments of (1) detection algorithm performance and (2) the effect of mitigations on driver performance and acceptance. The protocol included driving on different types of roadways and performing secondary tasks in the high-fidelity NADS-1 driving simulator. Four progressively complex distraction detection algorithms were compared to evaluate the ability of vehicle-based systems to distinguish between distracted and non-distracted drivers. Algorithm performance varied across road types and distraction tasks. A safety benefits framework appropriate for distraction mitigation systems is proposed that expands on past benefit analyses.

6.2.11 Adaptive Integrated Driver-Vehicle Interface

Reference

Multiple Reports from the AIDE (Adaptive Integrated Driver-Vehicle Interface)-Project:

- Driver workload and distraction assessment methods and tools
- Review of existing HMI guidelines and standards
- Review and taxonomy of IVIS/ADAS applications
- Review of existing techniques and metrics for IVIS and ADAS assessment
- Review of existing Tools and Methods

- Provider: Information Society Technologies (IST) Programme/AIDE-Project
- Year: 2004 - 2008

Application of the regulation:

Domain: Automotive

Systems: Advanced Driver Assistance Systems; In-Vehicle Information Systems; Adaptive Integrated Driver-vehicle Interfaces; Driver State Assessment Systems;

Adressed HF issues

- HMI Usability;
- Allocation of function between human and machine;

Proposed HF activities

- Assessment of vehicle control metrics (driving performance);
- Assessment of driver workload and driver distraction during use of IVIS and ADAS;
- Message prioritization; Model and simulate behavioral effects of ADAS and IVIS;
- Evaluate HMI-Safety;

HF workflow

Relevant to all stages of development (V-Model)

General evaluation and summary

The AIDE-Project's main focus is on HMI integration and adaptation. The key challenge for AIDE was to develop methods and HMI concepts that minimise driver distraction. The project reports on the behavioral effects of ADAS/IVIS usage and the modelling of driver-vehicle-environments. Evaluation and assessment methods were researched and reviewed and an Adaptive Integrated Driver-Vehicle Interface was designed and developed.

6.2.12 Commission Regulation: AEBS

Reference

(EU) No 347/2012: Commission Regulation for certain categories of motor vehicles with regard to advanced emergency braking systems; European Union Commission; 2012

Application of the regulation

Domain: automotive
System: advanced emergency braking system (AEBS)

Adressed safety issues

- General requirements (e.g. AEBS shall not be adversely affected by magnetic or electrical fields)
- Performance requirements
- Interruption (of signals/performance) by the driver
- Means to deactivate the AEBS function
- Warning indication
- Technical inspections

Proposed safety activities

Test procedure regulations provided are:

- Test conditions (e.g. ambient temperature)
- Test vehicle conditions
- Test targets
- Warning and activation test with a stationary target
- Warning and activation test with a moving target
- Failure detection test
- Deactivation test
- False reaction test

Safety workflow

The regulation provides requirements for admission of finished AEBS, therefore every activity and/or test described shall be used after designing an AEBS. It lacks methods/tools, which might be helpful while designing.
Stages 8 and 9 of V-Model.

Additional information

Appendix 1 and 2 provide tabular information about warning and activation test requirements for different vehicle categories.
Annex 3 defines the special requirements for documentation, fault strategy and verification with respect to the safety aspects of complex electronic vehicle control systems.

General evaluation and summary

The regulation defines obligatory safety requirements and provides a detailed test procedure for testing an AEBS.

6.2.13 Commission Regulation: LDWS

Reference

(EU) No 351/2012: Commission Regulation for installation of lane departure warning systems in motor vehicles; European Union Commission; 2012

Application of the regulation

Domain: automotive
System: lane departure warning system (LDWS)

Adressed Safety issues

- General requirements
- Performance requirements
- Means to deactivate the LDWS function
- Warning indication
- Technical inspections

Proposed Safety activities

Test procedure regulations provided are:

- Brief documentation shall be provided by the manufacturer.
- Test conditions (e.g. Visible lane markings)
- Test vehicle conditions
- Optical warning signal verification test
- Lane departure signal verification test
- Failure detection test
- Deactivation test

Safety workflow

The regulation provides requirements for admission of finished LDWS, therefore every activity and/or test described shall be used after designing an LWDS. It lacks methods/tools which might be helpful while designing.
Stages 8 and 9 of V-Model.

Additional information

Appendix provides different identified visible lane markings for each country of the EU, which shall be used during the test of a LDWS.

General evaluation and summary

Within this regulation obligatory safety requirements for LWDS and a test procedure to evaluate LWDS are described.

6.2.14 HASTE Final Report

Reference

HASTE Final Report: Human Machine Interaction and the Safety of Traffic in Europe; O.M.J. Carsten, N. Merat, W.H. Janssen, E. Johansson, M. Fowkes, K.A. Brookhuis; 2005

Application of the regulation

Domain: automotive
System: in-vehicle information systems (IVIS)

Adressed safety issues

Issues, that might have an impact on the safety of using IVIS while driving, identified and considered in the HASTE methodologies and guidelines for the assessment of IVIS are:

- Impact of different IVIS task loads (visual and cognitive) on driving performance, attention and workload
- Scenario parameters:
  - Urban, rural and motorway environments
  - Critical events, or road complexity level
  - Junctions as a parameter of road infrastructure
- Individual parameters:
  - Average and older drivers
  - Nationality

Safety workflow

The HASTE project provides a test regime for the assessment of IVIS, which can be applied once a design has become solidified so that at least a proto-type is available (V-Model stage 6/7: HW-SW Integration/Verification). Major constituents of the test regime are:

- Driving in at least a medium-level driving simulator with a relatively small number of subjects (15 subjects are thought to be sufficient)

- A rural, two-lane road, driving situation and a duration of approximately one hour
- Assessment needs to take place at the level of specific tasks on the IVIS, since an IVIS may have a combination of comparatively easier and relatively harder tasks
- A small number of dependent variables (indicators) are sufficient. At the moment, a set of 6 indicators are recommended. They are: subjective ratings, mean speed, high frequency steering, minimum headway, Percent Road Centre and Peripheral Detection Task (PDT) reaction time.

HASTE also refers to existing procedures such as:
- Expert assessment via TRL checklist (Stevens, et al., 1999)
- Safety lifecycle (ISO 61508)

Additional information

HASTEs test regime wasn't fully defined while the HASTE project lasted. Issues unresolved were:
- Scoring and weighting Issues
- Test re-test reliability
- Applying the HASTE protocol to the older driver

General evaluation and summary

HASTE claims that its test regime is applicable to any in-vehicle information system, including nomadic devices and the use of mobile phones during driving. It is technology-independent (which means that it does not depend on any particular use of hardware or technology in system design); it uses safety-related criteria; is cost effective; appropriate for any system design and validated through real-world testing.

6.2.15 Road Vehicles: Funtional Safety

Reference

Road vehicles: Funktional Satety; DIN Deutsches Institut für Normung e.V.; 2011

This section gives an overview of the international safety standard *ISO 26262 – Road vehicles – Functional safety* and its relevance for AdCos

development. The standard shall be applied for the development of all electronic components in a car. All components are classified in Automotive Safety Integrity Levels (ASIL). Different requirements apply to the different safety integrity classes.
Human factor issues are not directly addressed as this is a safety standard. They are taken into account implicitly. For example, the assignment of integrity levels for individual components is based on the impact and probability of potential failure on humans. The standard does not demand/propose any HF activities but focusses on the system itself. Any development of automotive AdCos needs to respect this standard, which makes it highly relevant for WP9.
The ISO 26262 standard is comprised of 9 chapters. In the following, we will provide a brief summary for each of them and provide relevant information with respect to AdCos development.

ISO 26262-1 Vocabulary

This chapter defines terms that are used throughout ISO 26262 and should be used as a reference. This part does not contain any requirements.

ISO 26262-2 Management of Functional Safety

A high-level overview of the safety life cycle covering the concept, product development and operation/production phases is provided. The AdCos development process needs to be adapted to follow the requirements stated here and be in line with the ISO 26262 safety life cycle.

ISO 26262-3 Concept Phase

This chapter addresses the concept phase. It covers hazard analysis and risk assessment based on the impact on human beings, exposure probability and controllability. These are parameters that need to be identified when developing safety-relevant AdCos. Based on these parameters systems are classified in ASILs. ASILs range from A to D where ASIL A is the lowest and ASIL D the highest integrity level. In addition, ASIL QM is defined, which implies that there is no requirement to comply with ISO 26262. For all AdCos components in an automotive environment, ASIL classification is necessary.

ISO 26262-4 Product Development at the System Level

Requirements for product development at system level (higher degree of abstraction than hard- and software levels; considers system as a whole) cover:

- Technical safety requirements and safety mechanisms: requirements management and specification
- Safety mechanisms: definition of safety mechanisms; they need to take into account human factors as stimuli
- System design specification: requirements on specifying the system design and on the technical safety concept
- Avoidance of systematic failures: deductive (such as FTA) and inductive (e.g., FMEA) methods are proposed here; properties of modular system design to be followed
- Allocation of requirements to hard-/software: safety requirements need to be allocated to either hard- or software components or both. This can involve another refinement step.
- Hard-/software interface specification: requirements on HW/SW interfaces
- Verification of system design: concrete methods are recommended dependent on ASIL classification
- Integration and testing at system level: HW/SW integration, vehicle integration, recommended methods dependent on ASIL
- Safety validation: definition of the process for safety validation
- Functional safety assessment, release for production (not relevant in the context of HoliDes)

ISO 26262-5 Product Development at the Hardware Level

Hardware safety requirements (system safety requirements are allocated to HW and SW) play a role, even though HW development is not considered within the project. HW safety must be ensured by the HW manufacturer/designer who must prove that the HW conforms to the safety requirements. The specification of HW safety requirements must be done in accordance with this part of the standard.

ISO 26262-6 Product Development at the Software Level

This part of ISO 26262 is highly relevant for AdCos development in the context of HoliDes as we focus on software. It covers:

- SW development phases and recommended coding guidelines (dependent on ASIL)
- SW safety requirements: allocation of system level requirements at SW level, requirements management at SW level
- SW architectural design: design and V&V methods for SW design are proposed (ASIL-dependent); in addition, also mechanisms for error de-

tection handling at SW architecture level are recommended (ASIL-dependent)
- SW unit design and implementation: in addition to the process requirements, ASIL-dependent methods for SW unit design, implementation and verification are listed
- unit testing: methods for unit testing, deriving test cases and coverage metrics (ASIL-dependent)
- SW integration testing: integration-process at SW level, ASIL-dependent recommendations for SW integration testing methods, deriving test cases and coverage metrics
- Verification w.r.t. SW safety requirements: how to check that the software is correct w.r.t. SW safety requirements; testing on target hardware

ISO 26262-7 Production and Operation

Production and operation requirements are out of scope for HoliDes since no market-ready products will be developed.

ISO 26262-8 Supporting Processes

Various additional requirements, of particular interest for AdCos development in the HoliDes project are:
- Specification and management of safety requirements: guideline on processes and methods to be used for specifying and managing safety requirements; this includes the recommendation of concrete methods
- Configuration and change management requirements
- Requirements on the verification process
- Documentation requirements
- Tool qualification: SW tools are classified with respect to tool impact (TI) and tool error detection (TD) to determine a tool confidence level (TCL) from 1 to 3. Different measures are recommended for tool qualification dependent on their TCL. In additional, the "proven in use" argument for tools is covered.
- Qualification requirements for developed software

ISO 26262-9 ASIL-Oriented and Safety-Oriented Analyses

Requirements can be decomposed according to their ASIL; this enables to separate parts of a system to have a potentially lower ASIL (as a system is always classified with the highest ASIL of all subsystems). ASIL decomposition has to be aligned with the system, HW and SW architecture. In addition,

this chapter covers the analysis of dependent failures and safety analyses to examine causes and consequences of faults and failures (concrete methods are proposed).

6.3 Conclusions

Two "real" concepts have been reviewed: The Code of Practice (CoP) and the Detectability concept. Both concepts focus on one issue, namely Human Machine Interaction (HMI): The Detectability concept mainly focusses on visual output devices; The CoP mainly on safety/controllability related issues. Additionally the CoP also provides some guidance for the System reliability issue.
Focussed on Advanced Driving Assistance Systems (ADAS) the CoP provides a development process including corresponding activities, which can be used as a method to ensure the realisation of each issue addressed. For process guidance, checklists are provided within the CoP. The Detectability concept, on the other hand, focusses on means of validation and verification for visual displays. However, the activities mentioned might also be helpful for other perceptual tasks. The concept describes a computer based model of human perception and performance with high predictive power, which enables the system to prepare for interactive actions (e.g. directive warndisplays) in a human-centered way. Neither one of the concepts specifies tools to be used.
Needs or requirements specific for AdCos, which are the main focus of the HoliDes-project, are not addressed satisfactorily within any of the concepts reviewed. In particular the CoP is not foreseen to be of use for fully autonomous systems. The issue of communication is not explicitly considered; Information on-board systems (such as navigator or phone) are not addressed. The issue of task allocation is addressed within the CoP, but mainly from a safety/controllability perspective. Nevertheless the CoP might be a useful baseline, whose contents need to be extended to AdCoS. The Detectability concept on the other hand could be exploited as a starting point to address needs in the area of attention modelling, distraction modelling, performing efficient searches and guidance to relevant information. Having machine learning as one ingredient, it also could serve aspects like adaptivity to optimise itself through the life-cycle of system functions under operation in the real-world and with a constrained number of users.
An established and tool that is currently used, which should be considered in this project, is ACT-R. ACT-R is a computer model predicting driver behaviour in safe conditions in real scenarios. Therefore it might be used for early development stages of AdCoS.

Regulations of the automotive-domain can be separated in two groups: Standards and official Guidelines (Regulations).

The HF-Standards have reviewed focus on the issue of Human Machine Interaction (HMI), mainly on HMI Usability. Therefore some ISOs provide information on a specific topic (Dialogue Management; Auditory Signals; Eye-/Gaze-Tracking-Systems; Transport Information and Control Systems) while another describes tools for evaluation, based on previously defined requirements. Thus, complying with the HF-Standards is not supported by the standards in other ways aside from providing means for evaluation. The ISOs lack methods and/or tools that might help during the design process. Apart from that most HF-issues that are relevant for AdCoS (e.g. task allocation, automation, adaptivity and communication) are not covered by the ISOs reviewed.

Other HF-Guidelines like the Driver Focus or the 'In-Vehicle Display Icons and Other Information Elements' state HF-principles for systems more simple than AdCoS or focus on a specific part rather than a complex system. The DOT-HS 810 697 as well as the 'Legal Consequences of an increase in vehicle automation' on the other hand address AdCoS relevant HF-issues like alert signals and automation. Although these documents are either outdated (2007) or limited to German traffic rules, they are highly relevant for the HoliDes-project. Nevertheless they both lack methods and tools that might help during the design process, focus on stating requirements and providing means of evaluation.
The safety related Standard reviewed (ISO 26262), on the other hand, includes the description of a safety life cycle, safety requirements for systems used while driving, safety verification and validation methods, guidelines for hard- and software development, etc. Since every system, which is built to be used while driving, needs to respect this standard, it is highly relevant for HoliDes.
Safety regulations reviewed include two Commission Regulations for specific systems (AEBS and LDWS) and the HASTE Final Report. While the Commission Regulations focus on obligatory requirements and an assessment method to test a product for compliance, the HASTE-project developed a safety test regime that is applicable to any in-vehicle information system (including nomadic devices and the use of mobile phones during driving). The HASTE Final Report might especially serve as a baseline for the HoliDes-project, whose results have to be enhanced for AdCoS.

In summary: There is no HF-concept or HF-regulation (that we know of), which fits perfectly to AdCoS. There are several that might serve as a base-line but have to be improved and appended to be applicable for adaptive systems. Most regulations focus on a specific system, AdCoS on the other hand combines different systems. Therefore the regulations have to be combined to fit the purpose of the HoliDes-project. Furthermore most concepts and regulations focus on the issue of Human Machine Interaction. Issues relevant for AdCoS (Automation & New Technology) are rarely considered.

Most of the time compliance to the stated requirements is reached through evaluation. There is a general lack of methods and/or tools that might be helpful during the design process.

7 Cross-Domain

7.1 ISO 9341: Ergonomics of human-system interaction

Reference

ISO 9241: Ergonomics of human-system interaction; DIN Deutsches Institut für Normung e.V.; 1999-2013

part	entitled	year
11	Guidance on usability	1999
20	Accessibility guidelines for information/communication technology	2009
100	Human Factors of software-systems	2008-13
200	Human-centred design for interactive systems	2011
300	Electronic visual displays	2009-12
400	Physical input devices	2007-12
500	Ergonomics of workstations	intended
600	Ergonomics of work environment	intended
700	Control rooms	intended
900	Tactile and haptic interaction	2011

Application of the concept/regulation

Domain: general
System: interactive systems: information/communication technology (ICT); Software-systems; Interactive voice response (IVR) applications; electronic visual displays; physical input devices

Adressed HF issues

Issues described in ISO 9241 include:

- Usability of human-machine interaction (HMI usability)
- Accessibility of ICT Human-Machine Interface Usability)
- Information Input and Output Error
- Human-centred design
- Presentation of information via electronic visual displays
- Usability of physical input devices

HF workflow

User-centred design shall be integrated in every stage of a product life-cycle possible, that means conception, analysis, design, implementation, evaluation and maintenance (Stage 1-9 of the V-Model). Topics relevant for sched-

uling of human-centred design and described further in the standard are: Importance of ergonomics within the project, content of planning, integration of human-centred design into the project plan and timing and resources.
Human-centred design should be realised in four iterative steps:

1. To understand and describe the context of use. This includes:
    a. The future users and others that might be interested
    b. Characteristics of users/groups
    c. Users' ambitions and tasks
    d. Environmental factors
2. Defining the users' requirements including:
    a. Context of use
    b. Requirements that can be derived from the future users and the context of use
    c. Requirements based on relevant insights of ergonomics/human-machine interfaces, standards and regulations
    d. Requirements of usability
    e. Organizational requirements.
3. Design of a concept by:
    a. Designing of the users' task, human-machine interaction and interface, while considering user experience
    b. Substantiation of the design (e.g. prototyping or simulation)
    c. Assimilation of the design based on user-centred evaluation
    d. Send the finished design to those who are responsible for realizing it
4. User-centred evaluation of the concept:
    a. Allocation of available resources for feedback about the product in early project stages and evaluation of achievements in later project stages
    b. Scheduling of user-centred evaluation
    c. Evaluation of the system-as-a-whole for significant results
    d. Analysing the results, choosing focusses, proposing solutions
    e. Communication of the solutions in a proper way as to ensure that they can be understood and used effectively by the designing team

Proposed HF activities during the system development

Every series (e.g. 300 or 400) starts out with a list of general recommendations and requirements relevant for the system, which is the main topic of

the series. Those recommendations and requirements should be considered during Step 1 and 2 (Understand and describe the context of use. Define the users' requirements.) of the user-centred design workflow. Sometimes a Checklist based on the recommendations/requirements is provided, which will help evaluate if a product/prototype complies with the criteria provided. These Checklists shall be used in Step 4: User-centred evaluation of the concept.
For further information consider the reviews of each part of the ISO 9241.

Proposition of methods

The higher standards of each series usually provide test methods, which shall be used for system evaluation – Step 4: User-centred evaluation of the concept.
Since most of the test methods presented are technical measuring methods the results are defined by the used measuring tools. How the results shall be treated, while further analysing them is not formalised.

Proposition of tools

ISO 9241 lacks tools, which might help to meet all the recommendations/requirements described.

Additional information

For further information consider the reviews of each part of the ISO 9241.

STRENGTHS-WEAKNESSES-Analysis

Strengths
ISO 9241 provides a general workflow and a detailed list of recommendations/requirements for each topic considered. A lot of evaluation methods are introduced. Parts like ISO 9241-307 combine these different elements and develop a specific compliance test method for several systems that include an electronic visual display.
Especially when combining every available Part of ISO 9241, this standard is a very powerful tool for HF peoples. ISO 9241 is the first and thus far only standardised HF concept.
If the intended additional Parts are realised, this standard will cover every major HF topic. It might be useful to develop more Parts like ISO 9241-307 that combine the different topics described, to ensure that requirements are reached more easily.

Weaknesses
The standard lacks proper tools that will help during the design process. It focusses on listing the requirements and evaluation methods.

7.1.1 General evaluation and summary

ISO 9241 is the first and thus only standardised HF concept. It includes a general workflow (user-centred design) and a lot of requirements/recommendations and measuring methods for every topic dealt with. Sadly, it does not provide any tools, which might help during the design of a product. It focusses on naming the requirements and does not provide any further guidance for people who want to meet the criteria described.

7.2 Individual parts of ISO 9241

7.2.1 Guidance on usability

Reference

ISO 9241-11: Ergonomic requirements for office work with visual display terminals (VDTs) – Part 11: Guidance on usability; DIN Deutsches Institut für Normung e.V.; 1999

Application of the regulation

Domain: general
System: display and controls

HF issues

Usability of human-machine interaction (HMI usability)

HF workflow and activities

1. Define the context in which the product will be used: Appendix A provides a list of possible characteristics for the following dimensions: User, task, equipment, environment (organisational, technical and physical).

2. Choose which indicators of usability shall be measured: Appendix B provides a list of possible indicators (effectiveness, efficiency and users

satisfaction), defines them and gives examples. Also define the criteria, which need to be reached by the system.

3. Measurement of the indicators chosen: Appendix B gives a short explanation about what needs to be measured but lacks information about what to do exactly.

4. Evaluation of the results by taking into account the defined criteria of 2.

5. If necessary re-engineer the product

Appendix C describes a detailed example for evaluation of usability.

General evaluation and summary

This standard lacks exact information about possible actions and methods for increasing or even measuring product usability. It provides a general workflow, defines usability and possible indicators and provides some examples that might be useful to understand the concept. In other words: This standard is an introduction to the topic of usability.

7.2.2 Accessibility guidelines for ICT

Reference

ISO 9241-20: Ergonomics of human-system interaction – Part 20: Accessibility guidelines for information/communication technology (ICT); DIN Deutsches Institut für Normung e.V.; 2009

Application of the regulation

Domain: general
System: information/communication technology (ICT)

HF issues

Accessibility of ICT (Human-Machine Interface Usability):

a) If ICT-systems are used by public or based on a "walk up and use"-concept potential users should not have to configure or connect any parts of technology.

b) Otherwise ICT-systems should be configurable freely since every user works with ICT-systems differently.

c) If a) and b) are not possible or not suitable: Users should be able to choose from a series of ICT. Each part of the series should be accessible for a different kind of user. The series should provide a part suitable for every kind of user imaginable.

d) Even if a), b) and c) should cover most of the people, there still might be some who have to use support tools to use ICT. There should be a way for those people to connect their tools.

HF activities

To ensure accessibility, the following steps should be considered:

1. Understanding and definition of the context of use including future user characteristics, task, tools and environmental factors that might have an impact on accessibility.
2. Identification and definition of user demand for accessibility.
3. Designing a product while considering aspects of accessibility.
4. Evaluation of design accessibility with participation of users whose characteristics reflect the targeted user group.

ISO 9241-20 provides recommendations for:

- different user characteristics
- different tasks
- installation and service features
- environmental factors

HF workflow

ISO 9241-20 states generally that the best results and lowest costs can only be achieved, if accessibility is considered from the beginning to the end of the engineering life cycle. Therefore Stage 1-9 of the V-Model.

Additional information

ISO 9241-11 provides guidance for identifying the context of use.
Appendix A provides a complete list of every usability standard (ISO 9241) available.
Appendix B provides an exemplary checklist to judge the accessibility of a system.

General evaluation and summary

ISO 9241-20 provides a long list of recommendations, which should be considered when designing an ICT-system. Nevertheless the recommendations remain at a very general level and no methods/tools or workflows, which might help to achieve the recommendations, are provided by the standard.

7.2.3 ISO Dialogue principles

Reference

ISO 9241-110: Ergonomics of human-system interaction – Part 110: Dialogue principles; DIN Deutsches Institut für Normung e.V.; 2008

Application of the regulation

Domain: general
System: Dialogue principles

HF issues

Dialogue relevant HF issues described are:

- Suitability for the task to be done – Dialogues should be based on the tasks' characteristics rather than on the technology used.
- Self-explanatory dialogues – The user shall be provided with information needed to understand what he is doing and how he has to do it at any time during a dialogue.
- Conformity with users' expectations and standards in effect.
- Suitability for learning – A dialogue is suitable for learning if it provides guidance while learning.
- Controllability – Dialogues are controllable if the user is capable to start, influence the course/tempo of it until the interaction is finished.
- Fault tolerance – A result is achieved without/with a very short delay even if the input done by the user was incorrect.

- Customisability – Users are allowed to customise the dialogue in ways that might support their personal skills and needs.

These issues can be mapped to 6.1.5 Human-Machine Interface of Eurocontrols categories.

HF activities

ISO 9241-110 provides some general recommendations, which when fulfilled, might help to ensure that the issues described are resolved. Each recommendation is explained further by descriptive notes and use of examples.

It lacks requirements that have to be fulfilled since those depend on the context of use in which the interactive system shall be used. Given a context of use this part of ISO 9241 will help to develop these requirements.

HF workflow

Since this part of ISO 9241 provides only general guidance on the principles of dialogues it shall be combined with other parts of ISO 9241 and different standards. ISO 9241-110 provides two workflows, which elaborate which standards might be worth considering and when:
As described earlier, the first workflow defines the context of use as the main reference for the dialogue principles. Recommendations for design of a dialogue can be found in ISO 9241 part 110 (which is a general framework), part 12 (which provides further guidance on the topic of information representation), part 13 (prompt), part 14, 15, 16 and 17 (dialogue technique) and further literature. These recommendations support the specification and formulation of dialogue principles. The final design is based on and has to answer to the dialogue principles.
Three examples are provided for further elaboration.
The second workflow suggests that ISO 9241 part 12 shall support part 110 which on the other hand supports part 11 of ISO 9241.

General summary

This standard is a general starting point when thinking about dialogue principles. The workflows provided will definitely help to understand which parts of ISO 9241 are relevant for the design of dialogues.

7.2.4 Forms

Reference

ISO 9241-143: Ergonomics of human-system interaction – Part 143: Forms; DIN Deutsches Institut für Normung e.V.; 2012

Application of the regulation

Domain: general
System: forms

HF issues

Issues described in this standard can be mapped to 6.1.5 Human-Machine Interface (HMI) (Eurocontrols categories):

- Forms: General requirements and recommendations
- Information representation:
  - Layout
  - Names and Labels
  - Visual cues
- Interaction:
  - Navigation
  - Navigation with tab and scroll
  - Focus of input and cursor
  - Input of data
  - User control
  - Feedback
  - Access to forms and dialogue boxes
  - Present parameters
  - Standard-actions

HF activities

The standard provides means for the selection of different elements of forms: basically a list of recommendations for each element. The more items from each list that are met, the better the chosen element. Elements discussed are:

- Button
- Switch

- Panel for text input
- Option panel
- Check box
- Button for
- Select form element (single selection)
- Select form element (multiple selection)
- Pop-up-/Drop-down-menu
- Combined panel (text input and selection)
- Hierarchic list (single selection)
- Hierarchic list (multiple selection)
- Analogue elements (e.g. scroll bar, control dial)
- Tabbed elements

Furthermore some guidelines for the design of different elements of forms are provided. Elements discussed in this part of the standard are:

- Elements for alphanumeric text input
- Elements for selection
- Elements for selection based on lists
- Tabs
- Scroll bars
- Buttons and palettes

Appendix B provides an exemplary checklist based on the requirements and recommendations of this standard, which might help in evaluating form dialogues. The checklist is basically a table naming requirement, than asking whether it is applicable and fulfilled and leaving some space for comments.

HF workflow

This part of ISO 9241 does not include a workflow or process. Still it provides information, which might be helpful in different project stages: the means for selection and design of forms will most likely be helpful in the early stages of a project (Stage 4 of the V-Model). The checklist and general description of HF issues might be helpful during evaluation (Stage 8 and 9 of the V-Model).

General evaluation and summary

This standard provides information for both design/selection and evaluation of forms. It focusses on general information and lacks the tools and workflows, which will help during the process.

7.2.5 Interactive voice response applications

Reference

ISO 9241-154: Ergonomics of human-system interaction – Part 154: Interactive voice response (IVR) applications; DIN Deutsches Institut für Normung e.V.; 2013

Application of the regulation

Domain: general
System: Interactive voice response (IVR) applications

HF issues

Issues described are:

- Information Input and Output
- Assistance of the system
- Support
- Feedback
- Error management

Additional relevant information and notes

Appendix B provides further information on possible errors that are relevant while working with IVR-systems.

General evaluation and summary

This standard focusses on requirements and recommendations for IVR-systems. It lacks the methods, tools and workflow, which might help to match the requirements.

7.2.6 Human-centred design for interactive systems

Reference

ISO 9241-210: Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems; DIN Deutsches Institut für Normung e.V.; 2011

Application of the regulation

Domain: general

- System: interactive systems

HF issues

Human-centred design (Human-Machine Interface)

HF activities

Regardless of the used design process, the allocation of the project's six ground rules, should be followed while trying to achieve a human-centred design:

1. The design should be based on an extensive knowledge about the future user, tasks to be done by the system and environmental factors.
2. The future user shall be included in the design process.
3. The design should be adapted and refined constantly by the results of the user-centred evaluation.
4. The design process shall be iterative.
5. The user experience should be considered as a whole.
6. The design-team should include people with multidisciplinary knowledge and perspectives.

HF workflow

User-centred design shall be integrated in every stage of a product life-cycle possible, that means conception, analysis, design, implementation, evaluation and maintenance (Stage 1-9 of the V-Model). Topics relevant for scheduling of human-centred design, which are further described in the standard are: importance of ergonomics within the project, content of planning, integration of human-centred design into the project plan as well as timing and resources.

Human-centred design should be realised in four iterative steps:

5. Understanding and describing the context of use. This includes:
    a. The future users and others that might be interested
    b. Characteristics of users/groups
    c. Users' ambitions and tasks
    d. Environmental factors.
6. Definition of the users' requirements including:
    a. Context of use
    b. Requirements that can be derived from the future users and the context of use

c. Requirements based on relevant insights of ergonomics/human-machine interfaces, standards and regulations
d. Requirements of usability
e. Organizational requirements.

7. Design of concepts by:
   a. Designing of the user tasks, human-machine interaction and interface, while considering user experience
   b. Substantiation of the design (e.g. prototyping or simulation)
   c. Assimilate the design based on user-centred evaluation
   d. Send the finished design to those who are responsible for realizing it.
8. User-centred evaluation of the concept:
   a. Allocation of available resources for feedback about the product in early project stages and evaluation of achievements in later project stages
   b. Scheduling of user-centred evaluation
   c. Evaluation of the system-as-a-whole for significant results
   d. Analysis of the results, selection of focusses, proposal of solutions
   e. Communicating the solutions in a proper way as to ensure that they can be understood and used effectively by the designing team.

   Methods for evaluation proposed and explained in ISO 9241-210 are: evaluation by the user; introspection (without users); long-term observation.

Additional information

Appendix B provides a checklist, which can be used to review and match the requirements described in ISO 9241-210. Therefore it systematically lists all the requirements and recommendations described in the standard.

General evaluation and summary

ISO 9241-210 provides a general overview about requirements of user-centred design and proposes recommendations, which might be helpful while designing. The standard does not provide any detailed methods or tools, which are needed for user-centred design. Although project management is mentioned not all aspects of project managing are discussed.

7.2.7 Requirements for electronic visual displays

Reference

ISO 9241-303: Ergonomics of human-system interaction – Part 303: Requirements for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2012

Application of the regulation

Domain: general
System: electronic visual displays

HF issues

Issues described in ISO 9241-303 are

- Visual conditions
- Luminance
- Specific physical environments
- Visual artefacts
- Legibility and readability
- Legibility and information coding
- Legibility of graphics
- Fidelity

of electronic visual displays.

HF activities

Each issue described comes with some general guidelines, which should be considered while designing a corresponding system which includes an electronic visual display. The standard provides recommended values for:

- Visual conditions: Intended viewing distance; Intended viewing direction; Angle of view
- Luminance: Intended illuminance; Luminance of display; Balance of luminance and glare
- Specific physical environments: Oscillation; Wind and rain; Exaggerated temperature
- Visual artefacts: Imbalance of luminance; Imbalance of colour; Balance of contrast; Geometrical distortion; Defect of display and frame; Temporally instability; Local instability; Moiré-effect; Other instabilities; Unwanted reflexions

- Legibility and readability: Contrast of luminance; Polarity of the image; Character height; Font size; Character format; Character pitch; Word pitch; Vertical spacing
- Legibility and information coding: Luminance-; Blink-; Colour-; Geometric Coding
- Legibility of graphics: Size of monochrome and multicolour objects; Contrast for legibility; Colour for graphics; Number of colours
- Fidelity: Range of colours and reference white; Gamma and grey scale; Displaying of moving images; Response time; Resolution

General evaluation and summary

ISO 9241-303 provides very exact values recommended for a lot of issues connected to the usage of electronic visual display. The standard does not provide any methods, tools or workflows, which might help to accomplish the presented requirements. The following standards (ISO 9241-304-7) should provide some measuring tools, which might help to record the data needed to judge a visual display after the criteria introduced by ISO 9241-303.

7.2.8 User performance test methods for electronic visual displays

Reference

ISO 9241-304: Ergonomics of human-system interaction – Part 304: User performance test methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009

Application of the regulation

Domain: general
System: electronic visual displays

HF issues

Usability (effectiveness/efficiency/user satisfaction) of electronic visual displays.

HF workflow

It is impossible to create one generally accepted test procedure for user performance while working with electronic visual displays, since every display executes a different task. Furthermore, new displays cannot be tested by the

procedure described in ISO 9241-305, since new technologies might complicate the application of those tests. Therefore ISO 9241-304 provides a guideline, which helps develop a specific test procedure meant for displays in a given context of use. The standard describes four steps, which should be completed one after another:

1. Defining the visual and ergonomic objectives of the test procedure including:
   - Description of the criteria to be tested.
   - Test procedures that shall be used.
   - Performance criteria that shall be fulfilled.
2. Defining the test procedures.
   The procedure used should be aligned to the task to be executed by the display. The tests described in ISO 9241-304 are meant for alphanumeric displays. Procedures for graphic displays (e.g. navigation systems) still need to be developed.
3. Running the test.
   ISO 9241-304 provides a detailed description of a test procedure, which includes a sign search task and a subjective evaluation comparing an already tested display to a new one, which is the main objective of the test. The standard provides information about potential test persons, displays, environmental settings, execution of the test procedure, briefing and dependent variables.
4. Analysis of the collected data.
   The standard provides some basic information about statistical tests and procedures that might be helpful for the determination of the significantly better display.

This standard provides means for evaluation, which is Stage 8 and 9 of the V-Model.

General evaluation and summary

The standard provides information about a possible test procedure for novel alphanumeric displays, which cannot be tested by the procedure described in ISO 9241-305. Considering this standard might help to ensure that, given a context, a display meets the minimum requirements for visual ergonomics. ISO 9241-304 does not consider the product as a whole, rather just the display. Furthermore it provides a general guideline, which might be useful while creating a test procedure for a specific display in a specific context of use.

7.2.9 Optical laboratory test methods for electronic visual displays

Reference

ISO 9241-305: Ergonomics of human-system interaction – Part 305: Optical laboratory test methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009

Application of the regulation

Domain: general
System: electronic visual displays

HF issues

HF issues are described in ISO 9241-303. This part provides laboratory test methods.

HF activities

Part 305 provides test methods for electronic visual displays, which shall be used in a laboratory context. Laboratories have to decide if the visual display tested conforms to the regulations of ISO 9241. This part of the standard was released to support laboratories in their decision-making. It does not provide any regulations and/or recommendations for test values of displays (for that information take a look at Part 303). The standard focusses are on test methods, which might be helpful while evaluating a display.
Part 305 starts with some guidance on how to set up appropriate test settings. Topics described here include:

- Measurement conditions
- Preparations and procedures
- Additional equipment for testing
- Test pattern
- Position of the field of view and the measurement device
- Photometer
- Field of view
- Angle of the measurement device
- Temporal response of the device
- Illumination during testing
- Other environmental conditions during testing

Afterwards a lot of different test methods are introduced. Each method is structured in the same way:

a. Description of the purpose and the measured variables.
b. Application: Which devices might be tested by the method?
c. Preparation
d. Procedures
e. Evaluation
f. Reporting – describes the report format
g. Comments

Part 305 provides laboratory test methods for the following topics:

- Basic photometry
- Measurements of luminance profiles
- Directional photometry
- Measurements of temporal features
- Measurement of reflections
- Luminance measurements
- Contrast measurements
- Colour measurements
- Dimensions and geometries
- Geometries and defects
- Orientation of displays showing virtual images

Each topic consists of several methods, which are discussed one after another. Appendix C provides a detailed list naming every test method introduced including its references.
Appendix E states a guideline, which should be considered since it includes clues for the evaluation of measurement uncertainty and how to deal with it.

HF workflow

Since ISO 9241-305 provides laboratory test methods for the assessment of electronic visual displays and the means for evaluation, it might be mapped to Sage 8 and 9 of the V-Model.

Additional information

Throughout the whole standard, methods are separated into 2 categories: basic measuring methods and procedures. Appendix B explains how measurements were categorised.

General evaluation and summary

This part of ISO 9241 is a very detailed explanation of laboratory test methods. It provides information about a lot of measuring procedures. Combined with the requirements and recommendations described in Part 303 this seems to be a very powerful standard, which will definitely help evaluate the pros and cons of different electronic visual displays.

7.2.10 Field assessment methods for electronic visual displays

Reference

ISO 9241-306: Ergonomics of human-system interaction – Part 306: Field assessment methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009

Application of the regulation

Domain: general
System: electronic visual displays

HF issues

This part of ISO 9241 refers to every issue described in Part 303.

HF activities

Structured exactly like ISO 9241-303, this part of the ISO recommends field assessment methods for every issue described earlier in Part 303. The methods should be used to review the electronic visual display considered for the criteria described in Part 303.

After conducting the assessment methods provided, it should be possible to classify possible problems into three categories:

a. The display itself (including graphic board)
b. Software
c. Physical environment

HF workflow

Since ISO 9241-306 provides means for field assessment of electronic visual displays, in other words means for evaluation, it might be mapped to Sage 8 and 9 of the V-Model.

General evaluation and summary

A short standard, which nevertheless mention every HF issue described in ISO 9241-303. It provides at least a name of an assessment method, at best a description. The standard might be very helpful when combined with the Part 303.

7.2.11 Analysis and compliance test methods for electronic visual displays

Reference

ISO 9241-307: Ergonomics of human-system interaction – Part 307: Analysis and compliance test methods for electronic visual displays; DIN Deutsches Institut für Normung e.V.; 2009

Application of the regulation

Domain: general
System: electronic visual displays

HF issues

The HF issues relevant for electronic visual displays are described in Part 303.

HF activities

This standard combines requirements (described in Part 303) and measurement methods (described in Part 304-306) and develops analysis and compliance test methods based on them. There are five different chapters and therefore topics discussed:

- CRT-displays for indoor use
- Emissive LCDs for indoor use
- Plasma displays for indoor use
- Front projection displays (fixed resolution) for indoor use

- Emissive, reflective or transflective LCDs (portable display direction) for indoor use

Each chapter starts presenting the context of use (including users, environmental, tasks and technological factors), followed by basic physical characteristics of the corresponding visual display. The last and longest part of each chapter is the description of the compliance test method, which includes naming the object, pass/fail-criteria, measurement methods as well as statements and clues useful for evaluation and documentation.
Throughout the whole standard information is provided in tables.

HF workflow

Appendix C provides a 4-Steps-process which should be followed while evaluating a system not described in ISO 9241-307. Steps are:

1. Description of the context of use including:
   - Specification of the user
   - Specification of the environment
   - Specification of the task to be done
   - Specification of the use of technology (site/method of application)
2. Collection of information about the technology.
   Specification of the applicable technical parameters related to evaluating.
3. Defining pass/fail-criteria.
   ISO 9241-303 defines recommended criteria for electronic visual displays. Since these values are defined without consideration for the technology to be used, the task to be done nor environmental factors, it might be necessary to redefine the pass/fail-criteria while considering those factors.
4. Evaluation and documentation.
   Use ISO/IEC 17025 as a guideline for documentation.

Appendix B provides critical values for displaying of natural colours.

General evaluation and summary

The standard combines parts 303-306 of ISO 9241 and therefore provides a detailed list of criteria to be met by different systems and test methods, which might help to evaluate these criteria. If one wanted to analyse the compliance of a system, including an electronic visual display that is not de-

scribed within this Part of ISO 9241, they might use Appendix C, since it provides a 4-steps-process, which might help them. All in all a very helpful standard.

7.2.12 Principles and requirements of physical input devices

Reference

ISO 9241-400: Ergonomics of human-system interaction – Part 400: Principles and requirements of physical input devices; DIN Deutsches Institut für Normung e.V.; 2007

Application of the regulation

Domain: general
System: physical input devices

HF issues

Usability (effectiveness/efficiency/users satisfaction) of physical input devices

HF activities

This standard provides a list of requirements, which should be considered while designing an input device or choosing it/several for usage in human-machine systems. The main topics discussed are:

- Adequacy
- Manageability
- User compatibility
- Feedback
- Controllability
- Biomechanical stress

Additional information

ISO 9241-400 is the introduction of the ISO 9241-400-series. It provides:

- Definitions which are relevant for all standards on the topic of physical input devices,
- A typology of input devices,
- A list of features which will be discussed in the 400-series

General evaluation and summary

The standard is a first introduction, which also gives a short and general overview about HF issues and requirements, which need to be considered when designing an input device or choosing one for a human-machine system. Part 410 and 420 will provide more accurate information on both topics based on the definitions within this part.

7.2.13 Design criteria for physical input devices

Reference

ISO 9241-410: Ergonomics of human-system interaction – Part 410: Design criteria for physical input devices; DIN Deutsches Institut für Normung e.V.; 2012

Application of the regulation

Domain: general
System: physical input devices

HF issues

Usability (effectiveness/efficiency/users satisfaction) of physical input devices

HF activities

The standard recommends a procedure, which should be followed while using the ISO. It consists of four steps:

1. Determine features, which are relevant for the usability of the device: That means features, which affect the device's effectiveness and efficiency and the users satisfaction. Possible categories, that need to be considered are:
    - Features
    - Technical characteristics
    - Electrical characteristics
    - Maintenance-related characteristics
    - Safety and health-related characteristics
    - Interaction with software
    - Interaction with environment
2. Appliance of generic design requirements categorized in:
    - Adequacy

- Manageability
- Controllability
- Biomechanical stress

3. Based on the features determined in Step 1 define and apply device-specific design requirements.
4. Evaluation of the design concept based on the collected criteria.

ISO 9241-410 provides a long list of both device-specific and generic design criteria for the following physical input devices:

- Keyboards (Appendix B)
- Mouse (Appendix C)
- Puck (Appendix D)
- Joysticks (Appendix E)
- Trackball (Appendix F)
- Touchpads (Appendix G)
- Tablets and Overlays (Appendix H)
- Pen and Light Pen (Appendix I)
- Touch-Screens (Appendix J)

Furthermore Appendix K offers some guidance on the topic of: Design of input devices for different types of users.
It is obligatory to document all relevant ergonomic information about the designed product.

HF workflow

Since this standard provides requirements and design criteria it might be mapped to Stage 3 and 4 of the V-Model.

Additional relevant information and notes

ISO 9241-411 defines a test procedure which should help determining the compliance of a product with this part of ISO 9241.

General evaluation and summary

This part of ISO 9241 provides detailed information on the issue of usability of different types of physical input devices. It nevertheless lacks processes and/or workflows that might help in fulfilling the requirements discussed. Still it might be very helpful if a designer already knows, which input device shall be used and needs a list of requirements to be considered.

7.2.14 Selection of physical input devices

Reference

ISO 9241-420: Ergonomics of human-system interaction – Part 420: Selection of physical input devices; DIN Deutsches Institut für Normung e.V.; 2011

Application of the regulation

Domain: general
System: physical input devices

HF issues

Usability (effectiveness/efficiency/users satisfaction) of physical input devices

HF activities

While the generic requirements, described in ISO 9241-410 as design criteria of input devices, are based on the anticipated context of use, this part of ISO 9241 describes several methods for selection of physical input devices based on the actual context of use. Therefore different device-options are tested in realistic settings to evaluate their fitting.

HF workflow

Part 420 provides a detailed test procedure for selections and evaluating of input devices for specific tasks. Therefore every process described in this standard can be mapped to System Integration, Testing, System V&V (Stages 8 and 9) of the V-Model.

Before starting the test procedure, it is obligatory to analyse the task, which the input device has to work on, taking into account the potential user and the environmental setting. Results of the task analysis should be:

- Elementary tasks
- Critical incidents
- Oder of importance of the tasks
- Required degree of effectiveness and efficiency

Next, suitable products shall be selected based on their documentations. Because of ISO 9241-410, documentations have to provide information about relevant ergonomic properties of the products. Appendix H provides detailed

information in tabular form, which should be considered while choosing a product based on its documentation.
If the products documentation does not provide sufficient information it might also be reasonable to conduct some extra user based testing. Examples of situations that might require test are:

- Use of two input devices that were not designed for combined usage
- Choice of drivers or options for an input device in a new environmental setting
- Choosing between different products of the same kind

Afterwards a product based on the characteristics of the elementary task shall be chosen. The standard provides several lists and graphics showing available input devices and their pros and cons.
ISO 9241-420 also provides some guidance for setting up a proper test environment. Topics mentioned are:

- Number of test-subjects
- Qualifications and skills of test-subjects
- Environmental setting
- Test work station
- Allocation of input devices
- Length of test-episodes
- Confidentiality and ethics

Test procedures that might be helpful described in this part of ISO 9241 are:

1. Appendix B: Trace test – for evaluation of tracing abilities, freehand-input
2. Appendix C: Drag test – for evaluation of dragging abilities, i.e. clicking on an object and dragging it to e.g. another window
3. Appendix D: Evaluation of users satisfaction
4. Appendix E: Tip test (1 direction) – for evaluation of cursor movement along an axis
5. Appendix F: Tip test (multiple directions) – for evaluation of cursor movement in different directions
6. Appendix G: Input of text via mobile products – for evaluation of speed and accuracy of text-, data- and numeric inputs
7. Appendix I: Usability-test for keyboards – there is just a reference to ISO 9241-411 provided

General evaluation and summary

As expected ISO 9241-420: Selection of physical input devices does provide a detailed test procedure, which should be used when choosing an input device. Most of the procedures proposed compare two different products to one another. The standard does not provide any requirements or recommendation but refers to other parts of the 400-series for that matter. Part 420 is useful for evaluating of different products.

8 General Discussion and Conclusions

In the previous sections a huge number of different concepts, standards and regulations were introduced. Some of them propose very concrete HF-activities, but the tool support is not a direct issue tackled by those standards. As introduced by deliverable D1.1, previous RTP projects like CESAR or MBAT focussed on a safety-oriented, model-based system development. From a development process point of view, those projects relied on the V-Model approach for systems engineering and integrated new methods and tools within specific steps of the process. HoliDes will follow the same direction and also rely on the V-Modell approach with the focus on specific HF related aspects.

8.1 Review related conclusions

The review of Human-Factors integration concepts and standards and regulations in the four application domains showed many similarities of but also some important differences between domains.

8.1.1 Human Factors Issues

Different Subsets of human factors issues are covered in the different domains. In the health domain, issues covered focus on usability and safety and no difference is made between human-machine-interaction (including basic ergonomics) and usability. We found broadest coverage and an impressing range of **human-factors issues** covered in the aviation and control room domains. Some of the concepts, like the Eurocontrol Human Factors Case or the HSI Human Systems Integration Concept, provide a collection of HF issues that might be used as a point of reference for AdCos development. Moreover the scope of HF issues covered seems to be somewhat broader within aviation, as the concepts in that domain, more specifically in Air Traffic Management cover not only system development but also operations and therefore include a different and broader view on communication, safety and training issues, which is expected to be more useful for AdCos development. Although automation and human capacity and attentional limits are important, issues in the automotive domain as well as in control rooms and aviation, issues specific for adaptation should still be considered more thor-

oughly and eventually added to a reference list of HF issues to be defined for HoliDes.

8.1.2 Human factors activities

In the review a disintegration of the different HF activities, analysis, design and evaluation has been observed. The analysis activities use empirical data and lead to user preferences and human factors requirements. In some concepts a list of possible evaluation methods is provided in all four domains, to be used to verify whether the requirements are met. However most concepts do not describe design steps or methods and tools to be used for design activities. The translation of analysis affecting design decisions and much-needed evaluation steps is not clear in most concepts.

The disintegration of activities might be a consequence of unclear indications about methods and tools to be used or of unconnected tools used for the different activities. Most of the concepts do not clarify which methods and/or tools should be used for the human factors activities.

8.1.3 Human factors workflow

As a general observation, the concepts more readily describe the human factors workflow or the connection with development processes as compared to current regulations. In the control room domain, a close relation to the V-model integrates the human factors workflow into development-processes. Concepts in the health domain take up ideas from unspecific usability engineering putting forward the ideas of user participation and early involvement in development. The claim to start the human factors integration early in the development process is common to the four domains reviewed.

The regulations reviewed often focus on parts of the workflow only. Some regulations in the control room and the automotive domain provide very detailed guidelines on implementation aspects. Others, in the health care domain, describe implementation steps and tests needed, derived from usability engineering processes.

The domains differ in the scope of the HF concepts put forward. In the control room domain concepts build upon regulations and concepts relevant for defence systems and include detailed regulations for ergonomics and HMI related topics. The health domain takes up the usability engineering process.

The automotive domain provides, among others, detailed description of requirements as well as related test regimes for in-vehicle information systems (HASTE Final report). The most comprehensive concept has been found in the aviation domain, applicable both for development projects and operations and thus being more a human-factors management concept.

8.1.4 Gaps

Some gaps have been identified in the concepts and regulations however.

- In all domains issues connected to the adaptivity needs are not sufficiently covered. Automation and subsequently situational awareness and workload are hot topics the four domains. However the specific requirements for AdCos are not fully addressed.
- Many concepts and regulations provide guidelines on issues or requirements to meet. But most of them are unclear about methods or tools to use.
- Subsequently the level of formalization of results of HF activities is low. Data formats are left open.

8.2 RTP related discussion

To integrate new methods and tools from work packages WP 2-5 into existing development processes, we will use a set of RTP Use-Cases descriptions. They will describe the "as-is" situation in system development and come up with a sound explanation as to why proper extensions with human factor methods are necessary to cope with the new challenges of adaptive systems. Each use case will be described using the template below. The RTP-Use-Cases will be specified incrementally in the upcoming deliverables D1.3 - D1.7. This approach is very similar to the RTP related project MBAT, which specifies a large number of safety related use-cases.

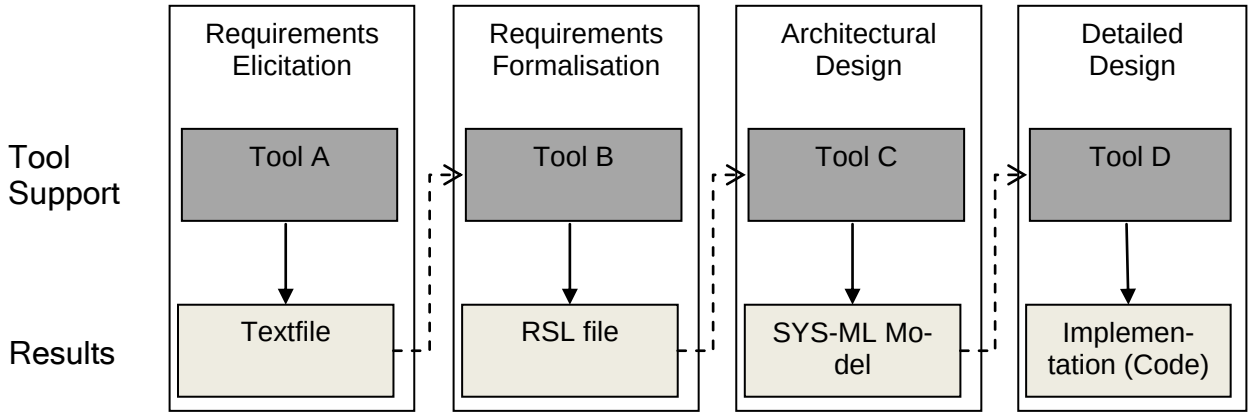
Involved Partners lists the partners involved in this use-case.

System under consideration names system or sub-system, might also be an HMI or a part of it. Short description about the system under consideration should be given here. It is important to mention that each application domain work package develops a more or less large scale demonstrator. These demonstrators are the source for a number of such RTP Use-Cases.

Specific Design & Analysis Question defines the actual "Use-Case": during development of the system under investigation, some very specific HF

problems arise, which cannot be solved adequately with the existing methods and tools. If regulations play an important role, please mention them here also.

Involved process steps and tools The V-Modell will be used as a reference model for the naming of the different development steps. Please refer to the figure 8-1 below.



8-1: Steps of the development process and tools

Development which can be of very different nature

- Missing methods & tools for integration of human factors
- Human factors regulations which are not considered adequately
- Tool interoperability problems
- Traceability problems between the process steps

Problem Solution HoliDes partners in WP 2-5 offer a number of human factor related method and tools, ranging from task analysis and human modelling to specific HMI design tools, as well as specific analysis tools and empirical methods. Each use case will deal with the integration of one or more tools to fill the gaps identified in the "as-is" process. This section will be incrementally updated throughout the deliverables D1.3 - D1.7. The first versions will mainly outline the targeted solution, which may change due to results obtained during the project.

- The solution will have to describe the general approach to deal with the problem and will also propose a possible tool chain development.
- The solution should include a second diagram based on the previous one, which shows the extensions that are going to be made to successfully integrate the HF activity / tool.

- At the end of the project the final solution for the use-case should be briefly evaluated

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10 List of figures