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Deliverable 1.1: WP1 Requirements Analysis for the HF-RTP, Methodology and Techniques and Tools

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List of Acronyms

AdCoS	Adaptive Cooperative Human-Machine Systems
AER	Aeronautics
AUT	Automotive
CTR	Control Rooms
HF	Human Factor
HF-RTP	Human Factors Reference Technology Platform
HMI	Human-Machine-Interaction
HoliDes	Holistic Human Factors Design of Adaptive Cooperative Human-Machine Systems
HTTP	Hypertext Transfer Protocol
IOS	Interoperability Specification
MBAT	Combined Model-based Analysis and Testing of Embedded Systems
OSLC	Open Services for Lifecycle Collaboration
RDF	Resource Description Framework
REQ	Requirement
REST	reStructuredText
RTP	Reference Technology Platform
UC	Use Case
WP	Work Package
XML	Extensible Markup Language

1 Introduction

This deliverable introduces to the Reference Technology Platform (RTP) and the idea of the Human Factors (HF) RTP, which will be developed during the course of this project. Whereas the RTP is a set of pre-integrated tools and services that could be compiled and installed to satisfy the needs of a particular use case, an RTP instance is a subset of RTP components that have been integrated through a stage known as tailoring, i.e., it is a choice of tools and services out of the "library" provided by the RTP. A major advantage of the RTP is that it supports the development of Adaptive Cooperative Human-Machine Systems (AdCoS) which is the target to be developed for the specific use cases. With this approach HoliDes has the aim to guarantee fluent and cooperative task achievement in situations where many humans and many machines act together, cooperatively, in a highly adaptive way. In order to elucidate the demands of supporting human factors along the whole engineering life-cycle we present some of the workflows and methodologies that are specific to human factors engineering. We reflect these insights onto the requirements that were provided in a first version from the different application areas of WP6-9 (health, aerospace, control rooms, and automotive), resulting in a collection of requirements that are specifically important across domains for the HF-RTP. Thus, these cross-domain requirements were not only important irrespective of the target application domains but also for the HF domain, creating the framework for the AdCoS. This list of requirements will be extended during the course of this project. Finally, we discuss the possibilities for the requirements management process. The discussion and decision for a common requirements management tool should be further continued across all work packages.

2 HF-RTP-Idea

This chapter shall provide basic information about the HoliDes Reference Technology Platform (RTP), the Interoperability Specification (IOS) and other interoperability technologies that will be utilized to support human factors engineering. It will clarify some of the terminology that surrounds RTP by giving succinct definitions.

2.1 Approach for human factors integration

RTP related projects funded by ARTEMIS like CESAR [2], MBAT [3] or Crystal [4] focus on classical engineering processes, methods and tools; hence the definition of the RTP focuses on those aspects. One of the main goals of the HoliDes project is to extend the existing RTP concepts with an integration of human factors methods and tools into a *Human Factors Reference Technology Platform* (HF-RTP).

To achieve the integration, it is necessary to start with a short discussion on development processes. Even if standardized processes like the V-Model [13] suggest a unique approach, the actual implementation of such processes is domain and company specific. Standards for the development of safety critical systems like DO-178C, DO330 and DO-331 in the aeronautics domain or an upcoming extension for ISO26262 (automotive) concerning tool qualification do not propose specific tools for certain process steps. Any tool which is *qualified* according to the standard can be used. As a consequence, the set of tools (tool chain) used by different industries is very often completely different, even if the systems they develop are very similar. Thus, the integration of new technologies and tools into the various workflows is a complex problem and by no means straight forward.

The main idea behind a RTP is to build on an Interoperability Specification (IOS) to simplify the data exchange through unification / standardization of the underlying data models and data exchange format. As an example, the OSLC (Open Services for Lifecycle Collaboration) standard provides a specification whose information is necessary to define a requirement. Hence, if a database server offers an OSLC service for requirements, any client tool which is OSLC compliant can process the requirements database in a unified way.

The problems of a common data model and method to exchange data were already tackled by projects like CESAR and MBAT. They decided to rely on the OSLC technology and HoliDes will go in the same direction. We will also reuse the approach of projects CESAR and MBAT to motivate the integration of new methods and tools into existing processes: they created a set of use cases motivated by specific development problems, e.g. how to integrate a certain verification method into the existing design process. Therefore, in HoliDes we will define a number of such use case scenarios for each of the four industrial application domains (WP 6-9). They will deal with the integration of specific human factor aspects into the traditional system design processes. Examples will be found in deliverable D1.2 (Review of Human Factor Integration Concepts and Regulations). Process integration issues in general are already investigated by the *human factors integration* research strand (c.f. also D1.2). HoliDes will contribute to this research with a focus on integration of methods and tools.
HoliDes addresses the development of *adaptive and cooperative systems,* which pose some specific characteristics and problems: for example the sharing and allocation of task responsibilities between system and operator to reach a common goal may change dynamically. Consequently, if a task could be done by either a human operator or a technical system or by cooperation between them, it has to be considered that each of them may need different information to optimally perform in the given situation. Overall task performance time is also likely to vary and the methods for worst case execution time analysis would have to consider human task performance as well as system performance. At this point the development from a purely technical point of view will fail and human factors need to be integrated appropriately. Therefore, in the following two sections we provide first some further background on the RTP (Section 2.2, 2.3), the role of an RTP in HoliDes (Section 2.4) followed by a discussion of human factors properties that will be considered for an extended RTP, i.e. the HF-RTP.

2.2 RTP background

An RTP by itself is a set of tools or services which are IOS compliant to facilitate the exchange of project lifecycle data during design time. IOS compliance means that the tools which exchange data do so using the principles of the IOS which in the case of HoliDes is technically based on Open Services for Lifecycle Collaboration [1]. The decision for OSLC was made, because the project on the one hand reuses results of CESAR and shall also be compatible with future developments in the project Crystal. OSLC is an open community of software developers and users which aim to improve the collaboration between software using standard internet technologies. It is only a few years old but is rapidly gathering momentum as more technology providers implement its standards. To date, it does not cover the human factors domain. By the end of HoliDes, it is hoped that enough relevant cross domain human factors concepts are identified to propose a new domain to the OSLC community, namely the human factors engineering domain.

IOS is a specification which currently is still being developed by other ongoing Artemis research projects such as Crystal [4]. Whilst the exact details of IOS are yet to be defined, the underlying principles are clear. That is, they will all share data using the same technologies which made the internet so successful. Those technologies are HTTP, RDF, XML, REST and Linked Data and will be covered in more detail in other deliverables.
The HoliDes RTP will build on the RTPs of other projects such as Cesar [2] and MBAT [3] by adding further concepts to help engineers incorporate human factors into the design of systems.

The RTP is not a piece of software or hardware that one could pick up and install. It is a library of tools and services called RTP Components which exist in a pre-integrated state. They are not connected directly and require instantiation before use in a phase known as tailoring (Figure 1). The instantiated RTP would allow the seamless development of different AdCoS (Adaptive Cooperative Human-Machine Systems) supporting the realization of use cases (WP6-9).
The exact tools which comprise an RTP instance will be determined by the use cases in HoliDes which come out of Work Packages 6-9.
These tools do not need to be specific human factor tools per se. They could just as easily be generic applications which will be used to implement human factors methods and procedures.

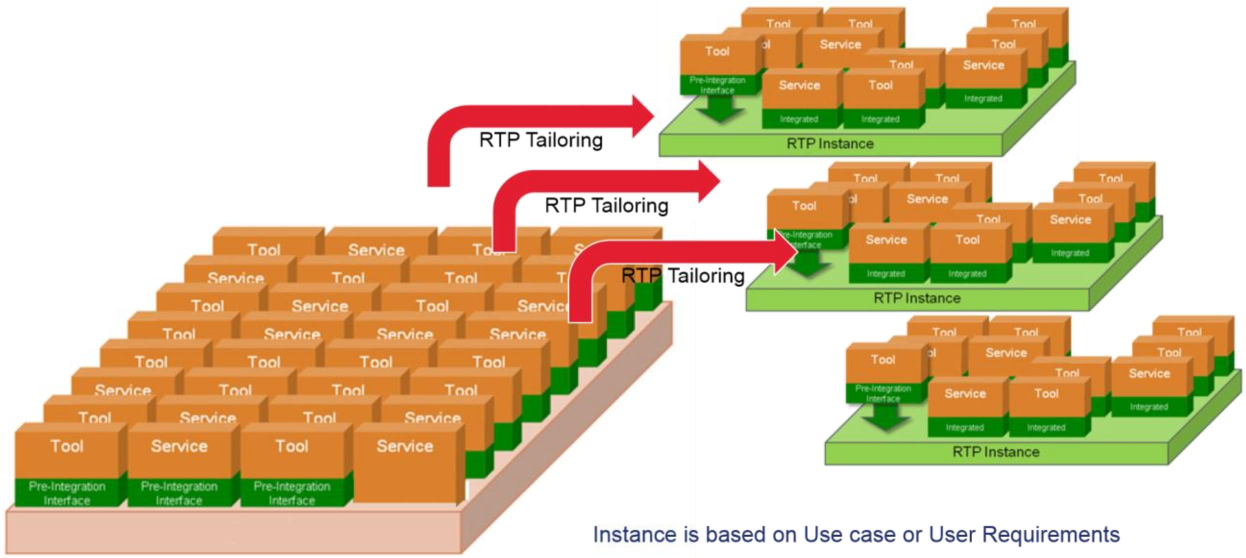

Figure 1: RTP tailoring for an RTP instance.

After defining the workflows (for example see Chapter 2.4), identifying tools and services for each use case, the tailoring process for an RTP instance will commence to integrate them. Figure 1 illustrates an example which moves from the RTP to an RTP instance.

2.3 RTP Definitions

Table 1 defines the following terms and definitions as used in HoliDes.

Term	Definition
RTP	(Reference Technology Platform) A set of pre-integrated tools and services that could be compiled and installed to satisfy the needs of a particular use case.
RTP Instance	A subset of RTP components that have been integrated through a stage known as tailoring.
RTP Component	A generic term to define an un-tailored ready to integrate component.
IOS	(Interoperability Specification) The specification which defines how the integration between RTP Components shall work.

OSLC	(Open Services for Lifecycle Collaboration) An open consortium which seeks to facilitate the exchange of data between engineering tools by using linked data. A key component of the IOS.
Use Case	The use case describes the system’s behavior under various conditions as it responds to a request from one of the stakeholders, called the primary actor. The use cases purpose is to implement the AdCoS with the help of the RTP instance.
Scenario	Illustrates the situation and the context of a use case and thereby helps explain the purpose of the system.
Tool Chain	A combination of tools or services which are used in a scenario to support a use case. The tool chain represents a particular flow of data through an engineering process.
Tool	The term tool and service are often used interchangeably. Strictly speaking, a tool represents software which an engineer will use to create data. For example to create requirements, models or documents.
Service	A service processes data and information that has already been produced by tools but is quite capable of creating new information. An example of a service could be a model transformation or an impact analysis.
Interoperability	Is defined as the ability of two or more tools or services to exchange information and then to work with that exchanged information.
Traceability	The ability to create and observe a link between information which can exist across different domains.

Table 1: RTP definitions

2.4 HF-RTP Properties

It will be important to specify what the Human Factors related properties of an RTP should be. This section therefore reflects some key aspects of the process or workflow of human-factors engineering. Even if people use machines for quite a long time, Human-Machine-Interaction (HMI) as a field of investigation is quite recent [5]. Four main principles drive the human factors work in development projects: safety, performance, comfort and aesthetics [5] and are related to four human factors lines of investigation: physical, cognitive, social and emotional aspects of HMI.

Human factors research and human centered engineering has become mandatory in the development and the design of modern technological systems. Human factors encompass the study of factors that influence the interaction of people with systems as well as using (and developing) tools and methods to support the development of systems. High quality in terms of reaching the human factors goals is not so much an attribute of the technical system developed but it is describing properties of the interaction of specified users performing a defined task in a particular environment or context using a specific system.

In a very general sense, human centered design is considered as being a cyclic process, linked to the development process. We find examples of this view in [6] or [7] as well as in the norms and standards describing the usability engineering process (ISO 9241-Part 210 which replaced ISO 13407).

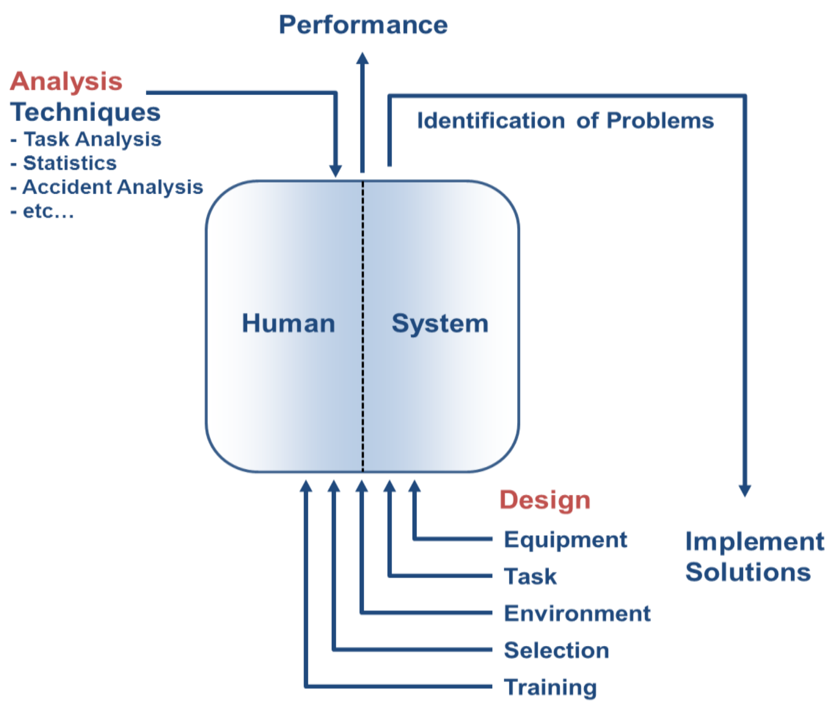

Figure 2: Human Factors Cycle (modified from Wickens et al. 2004 [7])

The goals of human factors work are accomplished through a number of procedures in the human factors cycle (Figure 2). The starting point and first phase of the cycle are often analysis activities used for a diagnosis of deficiencies of an existing human—system interaction or of a projected but not (yet) implemented case of human-machine interaction. The detected deficiencies will be translated into so called *human factors issues* to be solved in the development process.

The scope of human factors issues was broadened during the last decades from an investigation of interaction and ergonomics in a mainly physical sense towards including cognitive ergonomics as well as team related and organizational factors influencing the human-system interaction at the sharp end [7].

During the second phase, the design phase human factors work includes the procedures supposed to implement solutions to the HF issues. These activities deal with a number of relevant elements of human-machine interaction like the task, the interfaces, the planned interaction or aspects of the environment as well as selection and training of personnel.

In the third phase of human-centered development, the evaluation phase, the resulting human-machine interaction is assessed, considering quality criteria like mental workload, situation awareness, usability or user experience, and human error, depending on the issues identified in the diagnosis phase.

Analysis (1) and evaluation (3) activities often apply methods of empirical investigation while the outcome of such methods is often used to create models of the observed phenomena. The design activities (2) use formative techniques and tools to create new interfaces, task structures or interactions designs.
Typical examples for applied methods and tools during the three HF activities are:

- analysis
  - (cognitive) task analysis
  - critical incident analysis
  - accident and incident analysis
  - contextual inquiries using
  - interviews, questionnaires

    - user profiles, personas, scenarios
- design
    - interaction design
    - visual design, GUI
    - task design and task allocation
    - paper prototyping
    - wireframes
    - training design
    - selection procedures
- evaluation
    - hallway testing
    - heuristic evaluation
    - cognitive walk through
    - laboratory usability testing
    - usability questionnaires
    - simulator studies (e.g. driving or flight simulators)

This categorization of different activities within a human-centered design approach has been put forward recently in the structure of the Handbook of Human-Machine Interaction [5]. Many other publications try to connect the integration of Human Factors to the phases of a development process. Mayhew (1999) proposes three phase, that are (1) requirements analysis, (2) development and testing and (3) installation. Timpe & Kolrep (2002) suggested phases derived from a system lifecycle perspective: (1) idea (2) planning (3) development (4) implementation (5) operation (6) cessation [8].

The classification of Mayhew combines the activities development (2) and analysis (3). Engineering process models like the V-Model explicitly differentiate between development and testing and each of them is split into a number of steps during the whole process. Especially, from a regulatory point of view (system certification) the differentiation between development and analysis is mandatory in safety critical domains considered by HoliDes. Therefore, it seems not to be good practice to integrate steps (2) and (3) if the two disciplines engineering and human factors should be integrated into a holistic view.

From a generalized point of view, the three types of activities mentioned above can be performed in more than one of the lifecycle phases, e.g. error analysis is often done in the operations phase and could lead to major redesign or even to the conception or the development of a new system generation. Many usability specialists advocate for evaluation starting early in the development process (a classic is [9]). Although we acknowledge that there is no perfect congruence between HF activities and development lifecycle, our goal is to achieve a good integration of HF techniques into the standardized engineering approaches. The description of a HF workflow as practiced at Eurocontrol [10] distinguishes between project life-cycle phases and the phases of a Human-Factors case (Figure 3).

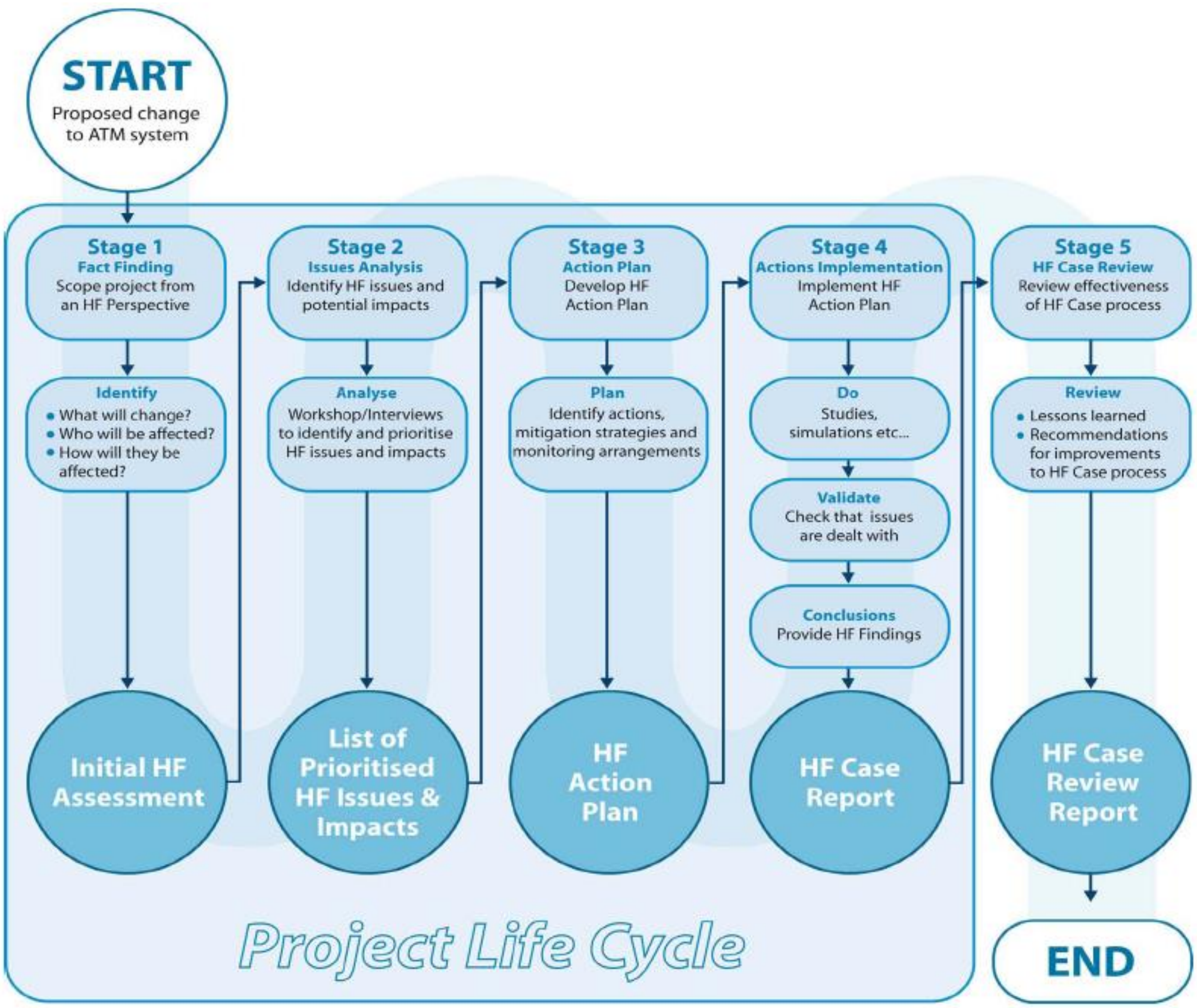

Figure 3: Eurocontrol Human-Factors case overview [10]

The Eurocontrol Human-Factors case is very much focused on identifying Human Factors issues and deriving appropriate actions to mitigate them. From a safety critical system development perspective, HF activities sometimes lack clear conceptualization and unambiguous criteria for quality and/or performance measurement. Due to this fuzziness and to possible unforeseen systemic reactions to alteration of the human-machine-interaction, it is almost impossible to predict, whether mitigation strategies will be successful or not. Therefore, one of the most often repeated postulation of HF integration concepts is their iterative nature. Evaluation has to be started early and repeated throughout the development process and might lead to repeated analysis and design of aspects of the developed system.

To describe the HF relevance of requirements within the context of HoliDes, we suggest a framework for HF related aspects in the context of development processes using three dimensions (Figure 4):

HF issues: Which HF problem is addressed?
Eurocontrol [10] defines six categories of HF issues: (1) working environment, (2) organization and staffing, (3) training and development (4) procedures, roles and responsibilities (5) teams and communication and (6) human in the system [10]. Criteria like workload, situational awareness, attention, perception, communication, error etc. can be used as quality criteria to evaluate whether goals derived from the issues have been met.

HF activities: What do the HF people do?
We categorized the activities into three groups as mentioned above, analysis, design and evaluation.

HF phases: When in the system lifecycle does it happen?
As a very simple first approach to this dimension, we distinguish just three lifecycle phases that are concept, prototype, and operation. The basic idea is that each of the phases might be iterated several times until a satisfactory intermediate result has been found before turning to the next phase. To be able to marry this cyclic idea with the V-Model of development, we refer to the idea of feedback from the ascending (testing) part of the V into the development part. If tests fail, the process has to be reiterated.

These three dimensions will be used throughout WP1 with different goals:

- They will be used in this deliverable to describe the HF related relevance of requirements from the application work-packages WP6 to WP9.
- They will be used in deliverable D1.2, where HF integration concepts as well as HF and safety regulations will be assessed and commented with respect to the three dimensions of HF relevance.
- They will be used as framework for the definition and update of HF-RTP requirements in this and the later deliverables of WP1.

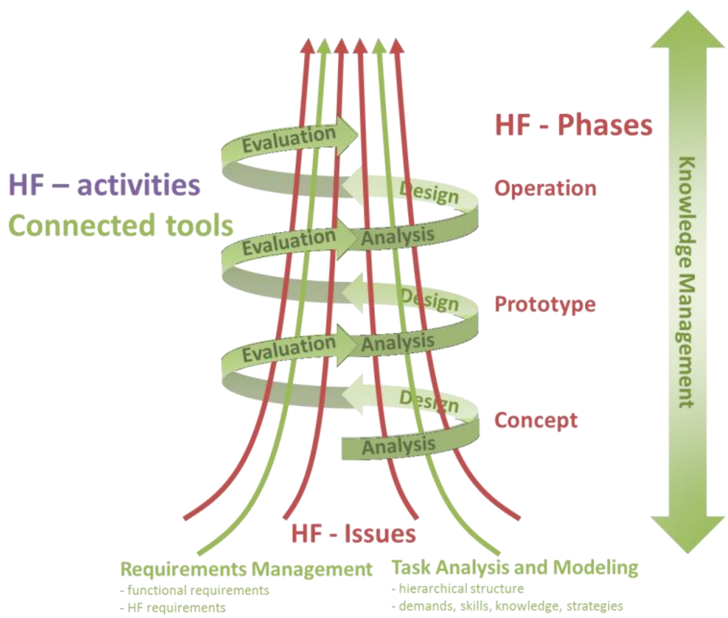

Figure 4: Three dimensions of HF relevance

The general idea of how human factors should be dealt with in the engineering process is widely known and acknowledged in several domains (aviation, automotive, process plants) and is being introduced in other domains. Human factors engineers however have to face a number of typical problems:

- Unclear HF related requirements and or fuzzy HF quality criteria:
  One role of the human factors specialists is adding human factors criteria to the list of systems requirements [7]. This step however often leads only to very general requirements ("good user experience" or "high usability of the interface" or "adequate situational awareness")

interpretable in many ways. It is important to note that most of HF related requirements do not describe intended attributes of the system to be built, but relate to properties emerging from the interaction of users with the system in a defined context to perform a task and reach a defined goal. Some of the quality criteria are heavily disputed as far as their underlying theoretical concept and their measurability is concerned (e.g. [11])

- Late involvement in the engineering process:
  This problem has often been identified in different concepts for Human-Factors Engineering [6,9,12]. Late involvement might mean that the contribution of human factors specialists is reduced to evaluation in late development phases where changes in design are costly in terms of costs and time needed.
- Disintegration of the different HF activities:
  A less severe but conceptually similar problem is the disintegration of the different HF activities, analysis, design and evaluation. In theory the analysis activity uses empirical data (e.g. from questionnaires or interviews), leads to hierarchical task analysis and derives task models as well as user preferences and requirements ([7] pp. 48ff). In practice, the translation of empirical data into task hierarchies and of task hierarchies into design decisions as well as into needed evaluation steps is not clear. It is often more an art interpretation based on the expertise and skills of the human factors specialist than a well-documented process. The overall process lacks adequate and precise translation methods between the steps. In the practical development process, this disintegration can lead to inefficient repeating of design choices that have been discarded in earlier iterations after evaluation.
- Unconnected tools in the different phases:
  The disintegration of activities might be a consequence of unconnected tools used for the different activities. The tools used in the analytic steps often support data generation or collection (e.g. tools to generate questionnaires or observation protocols). Results are often represented with simple text or table based reporting tools or tools for hierarchical task modelling. Although the notion that systems design has impacts on the tasks performed with the systems and therefore systems design is task-design is widely accepted by human factors specialists, the tools used in the design activities are not connected to the tools used in the analytic phases. And moreover, the tools used in the evaluation activities to not share data with analytic or design tools.

One of the driving ideas of HoliDes is that a Human Factors RTP (HF-RTP) should address at least some of the mentioned typical problems of an HF workflow. For a better integration and traceability of analytic results, design decisions and their evaluation, an integrated HF-RTP promises to be of great value:

- Human factors workflows which are already based on a number of tools have a better chance to be integrated into typical engineering processes. Tools may have to be improved with a sound concept of necessary input and output data plus the technical requirement of an OSLC adaptor. Methods which are not supported by tools so far may nevertheless be integrated conceptually if at least a formal approach is available that specifies an input-output interface and a standardized approach in between. A first list of tools used in the different domains represented in HoliDes is available and will be reported in D2.1.
- Where the backbone of an orderly engineering process is the requirements management supported by tools, a backbone for the human factors workflow has to be defined, preferably in a way that allows a conceptual link to the requirements management. We suppose that task analysis and modeling linked to human factors issues could be an important part of that backbone. Task analysis and modeling should encompass the hierarchical representation of task structures and individual strategies as well as cognitive demands, skills, knowledge connected to the tasks.
- Knowledge management should also be an integral part of the process, as it should integrate 1) rules and regulations as well as 2) expert knowledge about established strategies in terms of mitigation measures for known human-factors shortcomings and 3) known consequences of design choices for human factors issues taken from the experience made in former projects. This knowledge management should be effective within cases or projects to track analytic outcomes, design choices and evaluation results. It should also be effective across cases and projects to organize learning from experience within and across domains.

It is one goal of the HF-RTP to support the integration of the HF-workflow into standardized development processes like the V-Model approach [13]. Figure 5 shows the latest version (v1.3) of the model: the core pieces of the process are the *System Development* phases which are embedded into a larger scope of the overall project management including *Project Approval, Definition* and *Completion* steps.

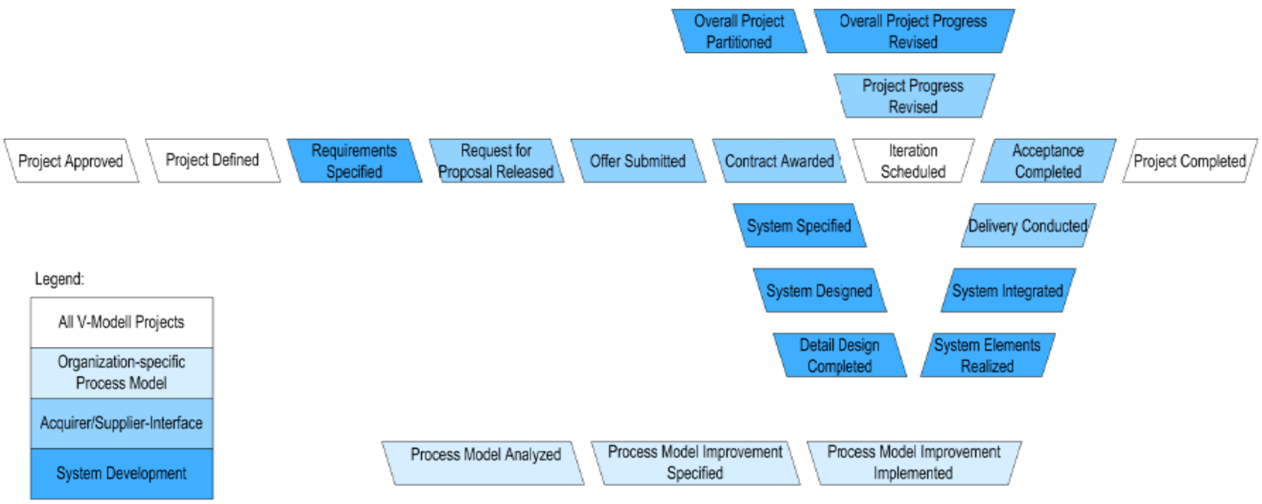

Figure 5: V-Model XT [13]

A spread misinterpretation of the V-Modell is the assumption that it leads to a static process which does not allow iterative design and prototyping phases often used by HF. In fact, this is not the case: at first *Organization-Specific Process Model* adaptations could account for such process extensions and are an integral part of the model. Furthermore, the documentation of the V-Model [13] points out that "The [...] *Iteration Scheduled* specifies the planning for the following system development steps. The planning covers the period to the next increment, but may go even further."
Such an increment can very well be a prototype version of a system which is given to the acquirer / customer for evaluation purposes. The collected feedback is fed into the next development iteration. The basic idea behind the V-Model is to rely on a formally specified development approach which is well documented and traceable. Within the given framework, process implementation details can be modified for example according to further domain specific standards, which may have to be considered for certification of safety critical systems.
In the CESAR project the V-Model was adapted to integrate specific safety aspects. They included a more detailed view on verification and validation activities. In the same way, HoliDes attempts to improve the model from a human factors point of view.

3 HF-RTP related requirements analysis

3.1 General HF-related requirements with cross-domain relevance

Examining the requirements for the use cases from WP6 to WP9, we identified some general issues being important for the HF domain irrespective of the target application domains (health, aerospace, automotive or control rooms) (Figure 6). We rate the following HF issues as major objectives for developing an adaptive cooperative human machine system:

- Application of cognitive models for predicting human decisions and (re)actions. Since cognitive models are an active research topic, we expect that the integration of cognitive models into the RTP and their meaningful combination with other techniques will be a major challenge of this project.
- Adaptive support functions and organization of general tasks according to the user's cognitive state (e.g. distraction, workload, inattention, mood) and to the user's personal profile, such as operator skill and experience level
- Usability adaptation according to the user's cognitive state and personal profile and sharing of UI elements between team members (with different profiles)
- Usage of an adaptable knowledge base in order to learn from experience and to form expertise
- Unambiguous human-machine interactions and interpretations
- High priority of safety (protection functions using alarms, intelligent prioritization of information according to the situation)
- Multimodal data integration with semantic processing for finding necessary synchronizations, interactions and prioritizations of tasks/ information/ reactions

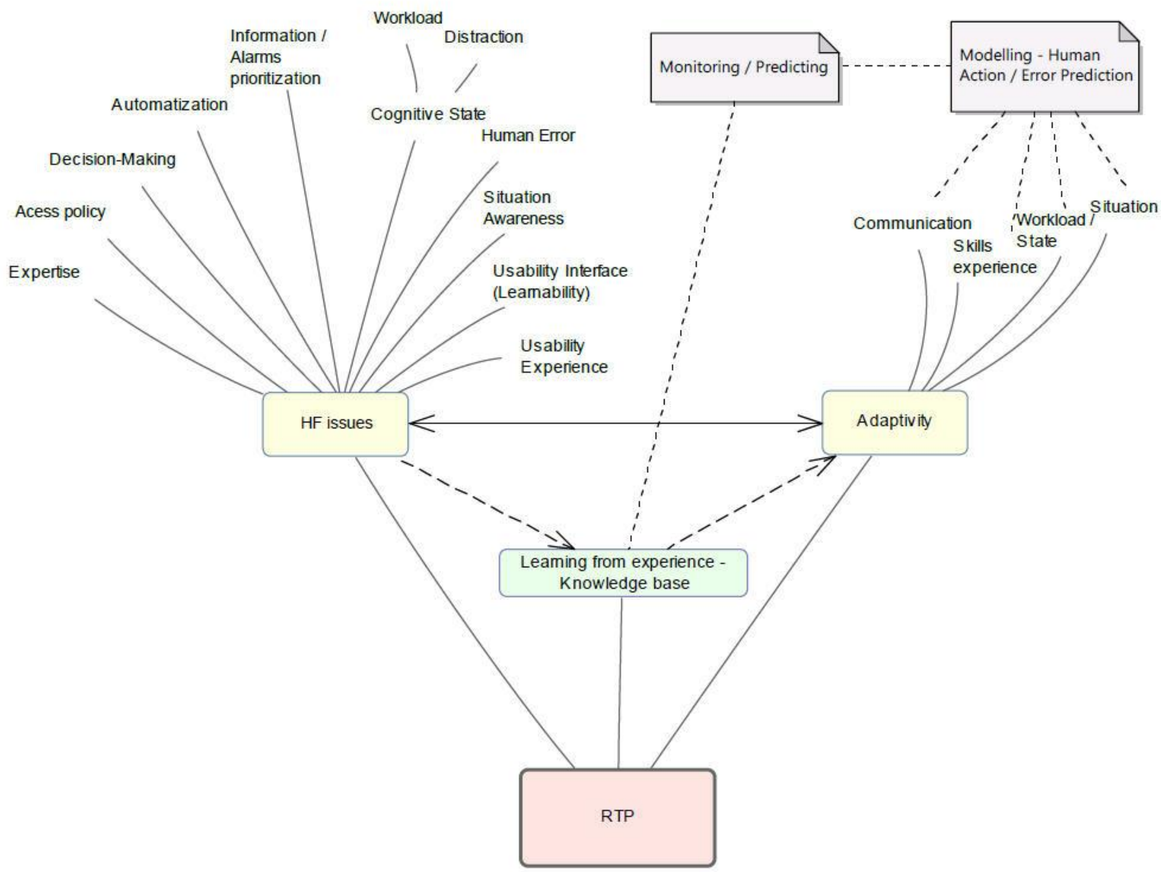

Figure 6: Mind map of Human Factor issues with respect to the RTP.

The requirements analysis revealed several requirements that might have a direct relevance with respect to the HF-RTP. They are summarized in Table 2 and should be further tracked and modified during the HF-RTP development. Further HF-RTP relevant requirements will be developed specifically with respect to the technological issues during the course of this project and will be added to this list in further iterations.

ID	REQ Description	Prio-rity	Stake-holder	Original REQ ID
WP1_HFRTP_REQ1	Different data sources must be processed in a synchronized manner.	High	WP9	e.g., WP9_TWT_AUT_R EQ13_v0.1, WP9_CRF_AUT_RE Q27_v1.0, WP9_IFS_AUT_UC1 _v1.0-1, WP7_HON_RTP_REQ74_v0.1
WP1_HFRTP_REQ2	Data logging and tracing.	High	WP7	e.g., WP7_HON_AER_REQ54_v0.1, WP7_HON_AER_REQ55_v0.1
WP1_HFRTP_REQ3	Multiple devices consistency and cooperation: Obviously of high importance when dealing with mobile devices as secondary units to a main console.	High	WP7	e.g., WP7_HON_AER_REQ51_v0.1
WP1_HFRTP_REQ4	Accessibility of experimental data – efficient storage and format.	High	WP7	e.g., WP7_HON_RTP_REQ77_v0.1
WP1_HFRTP_REQ5	Matching of ambiguities, alerts and reminders in the background – quality	High	WP7	WP7_TRS_AER_REQ_27

ID	REQ Description	Prio-rity	Stake-holder	Original REQ ID
	feature during design.			
WP1_HFRTP _REQ6	Switch on/off function by the operator: the system is always controlled by the user (even when the system controls the situation the user is able to obtain the control if it is required).	High	WP9	e.g., WP9_CRF_AUT_RE Q2_v1.0,
WP1_HFRTP _REQ7	Transparency on user monitoring: in order for the user to remain in control, the user should be aware of what the system thinks about him/her and the user should be able to overrule this.	Medium	WP9	e.g., WP9_CRF_AUT_RE Q8_v1.0
WP1_HFRTP _REQ8	System availability status/ failure status For a mobile device this is of high priority as a remote user may not have access to other contextual information about the system state.	High	WP7, WP9	e.g., WP9_CRF_AUT_RE Q4_v1.0, WP7_HON_AER_REQ45_v0.1
WP1_HFRTP _REQ9	Relevant information should be clearly visualized and easily identifiable by the user.	High	WP7	e.g., WP7_HON_AER_REQ61_v0.1, WP7_HON_AER_REQ63_v0.1

ID	REQ Description	Prio-rity	Stake-holder	Original REQ ID
WP1_HFRTP_REQ10	Regulation overlap between domains – system status message prioritization.	High	WP7	e.g., WP7_HON_AER_REQ42_v0.1
WP1_HFRTP_REQ11	Classifying user patterns (interaction) as, e.g., expertise level.	Medium	WP8, WP9	e.g., WP8_IRN_CTR_REQ009_v0
WP1_HFRTP_REQ12	Complex visualization GUI. However, when this regards a functionality that is intended to be accessible on a mobile device, a simplified visualization is needed, or the functionality should not be applied to the mobile device.	Medium	WP7	e.g. WP7_HON_RTP_REQ66_v0.1
WP1_HFRTP_REQ13	Different HMI strategies depending on the operator's state (internal & external): The system has to take into consideration the user location and user role, as well as user state (psychological and/or physiological state). The information should be presented in a situation-dependent manner, based on	High	WP9, WP8	e.g., WP9_CRF_AUT_RE Q8_v1.0

ID	REQ Description	Prio-rity	Stake-holder	Original REQ ID
	knowledge about what is relevant and critical in a given situation.			
WP1_HFRTP_REQ14	Different multimodal sensor data recordings must be analyzed and integrated to build an overall conclusion for predictions and decisions during online actions as well as during the development phase.	High	WP9	e.g., WP9_[TAK]_AUT_R EQ15_v1.0, WP9_ATO_AU T_REQ01_v0.1, WP9_ATO_AU T_REQ02_v0.1, WP9_CRF_AUT_RE Q6_v1.0, WP9_TWT_AUT_R EQ14_v0.1,
WP1_HFRTP_REQ15	Evaluation of importance of information sources relative to the situation: categorization / prioritizing / weighting with the help of machine learning. The user's attention should be captured (only) to highly relevant priority alarms. The system should be able to distinguish the relevance of the	High	WP9	e.g., WP9_[TAK]_AUT_R EQ17_v1.0, WP9_ATO_AU T_REQ01_v0.1,

ID	REQ Description	Prio-rity	Stake-holder	Original REQ ID
	information. This is especially important on mobile devices (scarcity of screen space, remote usage).			
WP1_HFRTP _REQ16	Monitoring cognitive/ processing load of operator or operating team.	High	WP8	e.g., WP8_ADS_CTR_ REQ015_v0, WP8_ADS_CTR_ REQ018_v0, WP8_IRN_CTR_ REQ003_v0
WP1_HFRTP _REQ17	Classification of the operator's cognitive state (e.g. attention). Especially valid with a mobile device which is often used remotely, in noisy environments or even left behind.	High	WP8, WP9	e.g., WP9_CRF_AUT_ RE Q3_v1.0, WP9_TWT_AUT_ R EQ04_v0.1
WP1_HFRTP _REQ18	Adaptive workload function: Workload management for multi-step tasks during specific time phases for flight crews and control room teams.	High	WP7	e.g., WP7_HON_AER_ REQ49_v0.1
WP1_HFRTP _REQ19	Generic questionnaires to create/ adapt tools to create defined statistics.	Medium	WP7	e.g., WP7_HON_RTP_ REQ67_v0.1

ID	REQ Description	Prio-rity	Stake-holder	Original REQ ID
WP1_HFRTP _REQ20	Scenario modeling (HF) although scenarios are specific for domains; scenarios should interact with other tools calling correct scenari os, choosing specific displays, and choosing appropriate reactions etc.	Medium	WP7	e.g., WP7_HON_RTP_ REQ68_v0.1
WP1_HFRTP _REQ21	A specific knowledge base should be storable within some repository specific for the HF-RTP although checklists are different for each domain, and thus a knowledge base is needed for specific scenarios and should allow adaptive certification (learning from experience).	High	WP7	e.g., WP7_HON_RTP_ REQ69_v0.1, WP7_HON_RTP_ REQ72_v0.1, WP7_HON_RTP_ REQ73_v0.1

Table 2: HF-RTP relevant requirements with cross-domain focus. Priorities marked based on the original requirements' priority judgements. Last column indicates the original requirements ID-numbers as provided from workpackages WP6-9.

4 Process for requirements management

Installing a requirements analysis and management process facilitates requirements management across all partners and work packages. For the time being no final decision has been made for a specific requirements engineering tool. The general advantage over excel spreadsheets is the tracing of requirements across versions, use cases, scenarios, test cases and defects. HF-RTP relevant requirements can simply be marked with additional attributes which enables filtering and visualization.

4.1 Traceability of requirements and tools to support it

The CESAR approach

CESAR addresses traceability by defining a framework for requirements management. Improved traceability is achieved across the entire development process back and forth between requirements, modelling elements and derived artefacts like for example test cases [14].
During the design process, high level requirements are refined into more detailed and more formal requirements. During this process it is important to keep track of how the requirements relate to each other so that if a higher level requirement is changed all the corresponding lower level requirements can be found. It may also occur that it turns out a detailed requirement is extremely costly to fulfil. In that case it is important to be able to trace back to the higher level requirement and the user goal, use case or standard behind it.
Furthermore requirements are linked to design concepts, parts of the code base, test cases and documentation and training materials.
Changes in the requirements of a safety critical embedded system typically require the revalidation of huge parts of the design. Especially in late development phases this revalidation effort can be extremely expensive.
CESAR and Crystal show how formalized requirements can be used to limit the costs of revalidation through systematic tracing of related system components and limiting the number of components that need to be revised. Big parts of the system can be eliminated from re-evaluation if the RTP can prove they are not affected by the change.

Dedicated requirements tools versus generic spreadsheets

Keeping track of requirements gathering and refinement is a complex and precise task. Doing so in a spreadsheet requires a lot of time and attention and if there are many parties involved it becomes impossible to keep track of all the changes let alone document them or link them to other components for automated support. The likelihood of inconsistencies grows with the number of requirements, versions and document files. The use of a requirements server prevents these problems.
The Crystal [4] project agreed on Rational DOORS by IBM [16] which is a de facto standard in safety critical engineering domains. Besides DOORS, the IBM rational suite offers a very complete set of tools for enterprise software developers. The target audience for the HoliDes project is (Human Factors) system developers. To ease the process of Human Factors designers and developers into more formal requirements management we are exploring different tools that have a relative ease of entry and are easy to link to other tools so that we can mix and match tools to support the HoliDes RTP.

The Atlassian toolset

The life cycle management tool suite of Atlassian offers a modular, integrated toolset with a focus on ease of use and simplicity. As a drawback, the reporting capabilities are less developed in the Atlassian toolset compared to other solutions.

Jira is developed for bug- and issue tracking but can also be configured for requirements tracking. It can be configured for requirements management and administrate a large numbers of agile story hierarchies. Requirements are modelled as issues which can be linked with each other. Dependencies can be drawn in a tree-like structure instantiating the concepts of child nodes or subtasks [15].
Each requirement gets a unique requirement identifier (URI) that makes it possible to link requirements to versioning systems and testing tools as well as ontology tools or wiki’s. Distributed deployment makes it possible for each partner to maintain their own requirements while exchange via OSLC makes it possible to get a complete overview.

HP Quality Center

Quality Center is a quality management software from HP. HP quality Center offers features to perform the following activities: requirements management, test and defect management and business process testing.
HP Requirements Management allows distributed teams to collaborate with shared requirements, identify their relationship to tests, and evaluate related defects. Using the HP test and defect management allows to define, manage, and track all kind of tests (functional, performance, and security). Business process testing provides a repository of reusable test modules that allow for changes to be made once then propagated across your distributed agile teams to all impacted tests.
An advantage of the HP Quality Center is the integration with automatic software tools and the easy creation of reports. The tool is very flexible and customizable. The drawbacks of HP Quality Center are that it is a commercial tool with prices not affordable for all type of organizations. The integration with some test tools can be very complicated and therefore Quality Center has a lot of options that are not being used due to a lack of knowledge. Moreover, customization can be a very time consuming task.

Tool recommendation for the HoliDes requirements management

From an RTP point of view DOORS, HP Quality Center as well as Jira support the requirements engineering needs of the OSLC standard (Table 3). Hence both could be integrated as client software into “RTP conform” workflows. It is up to the individual project partners to decide which tools should be used for requirements engineering.

We would suggest the use of Jira as the first choice: the tool offers the necessary capabilities to specify requirements (including versioning). License costs are acceptable, which is an important factor for the mixed academic and industry consortium of this project. For accessibility, visibility, and changeability of the current version for all partners we suggest using a joint server installation. JIRA also provides an export function for requirements ensuring compatibility with other tools like e.g. DOORS, which might be useful at a later stage of the project. The discussion and decision for a common requirements management tool should be further continued across all work packages.

	IBM Doors	Atlassian JIRA	HP Quality Center	Microsoft Excel
Versioning of requirements	Yes	Yes, with configuration and/or scripting	Yes	No
Tracking of requirements	Yes	Yes	Yes	No
Dependency illustration of requirements	Yes, requirements can be linked	Yes, requirements can be linked	Yes, requirements can be linked	No, only by adding extra-columns
Collaboration capabilities	Yes	Yes	Yes	No
Reporting Capabilities	Yes	Yes	Yes	No
Costs	High	Low	High	Low / Available

Table 3: Comparison of capabilities for different requirements management tools

4.2 Requirement Dependencies

Some requirements can be interrelated or linked with each other. The requirements team has to bear in mind these dependencies when planning the project due to the fact that a requirement with a high priority could be delayed because it depends on a lower priority requirement. This situation can be avoided if the priorities are consistent; the requirements management process should ensure that the requirements have similar priorities.
For this reason it is also useful to document the links, relationships and dependencies between individual ones. A column could be added to the requirements table indicating the dependency (Table 4).

ID	Requirement Description	Prio-rity	Stake-holder	Original Requirement ID	Depen-dency
WP1_HFRTP_REQ1	Different data sources must be processed in a synchronized manner.	High	WP9	e.g., WP9_TWT_AUT_REQ13_v0.1, WP9_CRF_AUT_REQ27_v1.0, WP9_IFS_AUT_UC1_v1.0-1, WP7_HON_RTP_REQ74_v0.1	WP1_HFRTP_REQ2

Table 4: Exemplary table for linking dependencies across requirements

After identifying all the dependencies in the table of the requirements, a requirements dependency matrix can be constructed.
This matrix shows all the identified requirements in the row and column headings. The dependencies are highlighted in the cells, the matrix helps to find dependencies easily.
This tool can also be used to identify requirements conflicts (requirements mutually exclusive or representing opposing views). These conflicts have to be discussed and solved between the requirements manager and the main stakeholders. Once an agreement has been reached, the requirements are more organized and structured.

Requirements conflict

Change is inherent to requirements. During the project life cycle the requirements change, and these changes may cause conflicts between the existing requirements. When a requirements conflict arises, the description of the conflict, its main features, the stakeholders involved, and the potential consequences of the conflict on other requirements within the project have to be recorded, in order to ensure that an audit trail is kept of all these conflicts and any later action carried out, the conflicts will be registered in the Requirements Issue Log.

Requirements dependency matrix	WP1_HFRTP_REQ1	WP1_HFRTP_REQ2	WP1_HFRTP_REQ3	WP1_HFRTP_REQ4	WP1_HFRTP_REQ5	WP1_HFRTP_REQ6	WP1_HFRTP_REQ7	WP1_HFRTP_REQ8	WP1_HFRTP_REQ9	WP1_HFRTP_REQ10	WP1_HFRTP_REQ11	WP1_HFRTP_REQ12	WP1_HFRTP_REQ13	WP1_HFRTP_REQ14	WP1_HFRTP_REQ15	WP1_HFRTP_REQ16	WP1_HFRTP_REQ17	WP1_HFRTP_REQ18	WP1_HFRTP_REQ19	WP1_HFRTP_REQ20	WP1_HFRTP_REQ21
WP1_HFRTP_REQ1																					
WP1_HFRTP_REQ2																					
WP1_HFRTP_REQ3																					
WP1_HFRTP_REQ4																					
WP1_HFRTP_REQ5																					
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WP1_HFRTP_REQ18																					
WP1_HFRTP_REQ19																					
WP1_HFRTP_REQ20																					
WP1_HFRTP_REQ21																					

Figure 7: Requirements dependency matrix for HF-RTP relevant requirements

5 Conclusion

The purpose of this deliverable is to provide the seed point for the development of a Human Factors Reference Technology Platform (HF-RTP) with the focus on human factors issues and the resulting challenges. The development of this platform itself is an ongoing activity. Besides providing background on the general RTP-idea we highlighted human factors issues that we deemed crucial for further consideration in the extension of the RTP idea.

We compiled a first collection of requirements from application work packages that are on the one hand applicable across application domains and on the other hand specific for the human factors approach of the RTP. These requirements will be extended during the course of this project and will be added to this list in further iterations. With the development of the RTP and a growing understanding of the principles behind we will also be able to formulate more specific HF-RTP requirements that aid both its development and will provide useful services to implement the use cases in WP6-9.

The general challenge related to HF issues into an RTP is the integration of different information flows. Integrating HF issues, system adaptation and cooperation aspects will be a challenge as well. It is anticipated that with the analyzed requirements in the context of Methodology and Tools work packages (WP2-WP5) the requirements will become more specific. A general challenge will be the integration of modelling artefacts and tools to the RTP. Many models are not compatible with tools yet and need to be adapted. They need to be integrated using an OSLC-standard.

6 Literature

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