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

D5.2- Plan for Integration of Empirical Analysis Techniques and Tools into the HF-RTP and Methodology

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List of abbreviations

AdCoS	Adaptive Cooperative Human-Machine System
(HF-)RTP	(Human Factors) Reference Technology Platform
ICA	Index of Cognitive Activity
MTT	methods, tools, techniques
T5.X	one of the five tasks of WP5
UML	Unified Modelling Language
WP	work package

Project partner

AWI	AnyWi
BUT	Brno University of Technology
CRF	Centro Ricerche di Fiat
DLR	German Aerospace Center
ERG	Ergoneers
HFC	Human-Factors-Consult GmbH
HON	Honeywell
PHI	Philips
REL	RE:Lab
SNV	Universita Degli Studi Suor Orsola Benincasa
TWT	TWT GmbH Science and Innovation
UTO	Universita Degli Studi Di Torino

1 Introduction

This deliverable consists of two parts. The "Integration Plan Common Part" is shared by the deliverables D2.2 to D5.2. It explains how to integrate methods, tools and techniques (MTTs) into the Human Factors Reference Technology Platform (HF-RTP). The present document details the MTTs which will be contributed by WP5 as components to the HF-RTP. Details concerning the HoliDes RTP, its methodology and the integration of components can also be found in D1.1 and the forthcoming D1.3.

Here, we will describe MTTs which the partners are developing or advancing in WP5 of HoliDes. These MTTs will eventually form the HF-RTP. They serve WP5's vision to extend and develop empirical methods, which aid the design and development of adaptive, cooperative Human-machine systems. These methods support developers to conform to existing norms and standards.

The MTTs of WP5 consist largely of empirical methods. Empirical methods are an integral part of any Human-centered systems engineering process. Their precise position and use in a workflow depends on the AdCoS under development, the organization that uses them, as well as individual considerations. These questions will determine the tailoring of the RTP for a specific use case.

Empirical MTTs are an essential part of both, early and late stages of any design process of a Human-machine system, for example during requirements analysis or verification of Human Factors related non-functional requirements. However, empirical MTTs can also be an integral part of the development phase, especially when using principles of agile requirements engineering approaches.

While in the CESAR RTP it is only software tools that manipulate data, in HoliDes various kinds of MTTs are being used. Each MTT that is part of the development and evaluation of an AdCoS manipulates data and is an integral part of the engineering environment.

2 MTTs for Integration

In the following sections the methods, techniques or tools for integration into the HF-RTP are described. These sections include the project partner working on this document.

2.1 AWI: Modelling of AdCoS data from a means-ends perspective

The method will be applied to AdCoS by AWI in T5.5.

2.1.1 Purpose

As an aid to aggregate data, this method provides functional modelling from a means-ends perspective to help analyse whether a given AdCoS helps the operator achieve key goals in the operation of the system. This type of modelling will help transform measured and observed data into information about high-level system state, thus allowing system evaluation to be performed in terms closer to actual operation.

2.1.2 Use Cases

The means-ends modelling for AdCoS can be used at different stages of the AdCoS design process, namely during system development and validation. During the former, it may be used to identify parts of the human-machine interaction in which an increase or decrease of adaptation and/or cooperation is useful. During the latter stage, means-ends modelling can identify potential causes of errors produced by unclear or weakly defined states of automation, adaptation or cooperation.

2.1.3 AdCoS Use-Cases

This method will be applied to the use cases of the health care domain (WP6).

2.1.4 Input

Successful means-ends modelling needs data providing information about how the operator interacts with the AdCoS. These data are gathered during simulator studies, expert interviews or studies with a prototype.

2.1.5 Output

Means-ends modelling applied during the design process which provides a description of the interaction between an operator and the AdCoS. For integration into the HF-RTP, this description may be transformed into a UML-like language.

2.2 BUT / HON: Operator state detection from implicit hand gestures

This tool will be developed by BUT in cooperation with HON within tasks 5.2-4.

2.2.1 Purpose

In human to human communication non-verbal cues such as hand gestures can transmit valuable information (e.g. Lausberg und Kita 2003). Especially implicit gestures, i.e., gestures that are not intended to be specialised (such as in gesture-based interaction), carry semantic meaning. For example, the operator might reach towards a knob in the cockpit, but not push it for a while. Similar to a human conversation partner, the system might benefit from knowledge that does not necessarily lead to system input but still indicates important information about the operator's mind state.

Videos of the operator (pilot, driver, etc.) during task accomplishment will be recorded. Computer vision techniques will be used to enable automated analysis of the video sequences.

2.2.2 Use Cases

Deriving knowledge about the human operator can be very valuable in the system validation phase. While interacting with a prototype or some modules of the AdCoS, the operator state can be evaluated. The tool can provide feedback about the effect of the system on the operator's state.

In addition, this tool bears the potential to be used online to classify the driver's implicit hand gestures not only during testing of a prototype, but also during everyday interaction with the AdCoS. This online measure of driver state could in turn be used to adapt the degree of automation of the AdCoS.

2.2.3 AdCoS Use-Cases

Aeronautics cockpit from WP7. The computer vision techniques described below have a high relevance in this scenario, because the freedom of motion of the subject is high in this setting. At the same time, for safety, regulatory and practical reasons, it is not possible to use structured light-based approaches, such as infrared depth sensors similar to Microsoft Kinect.

2.2.4 Input

Whole-body videos of the human operator while accomplishing the task are needed as input for the tool. Videos need to be stored in a way that enables linking them to certain system states, e.g., inputs from the user to the system. Thus multimodal data integration and synchronization needs to be guaranteed.

2.2.5 Output

The tool provides a continuous description of the gestures of the operator over time of system usage.

2.3 BUT / HON: Detection of operators' head orientation

This tool will be applied in the aeronautics domain in WP7 in the use case airport diversion assistant. The computer vision techniques described above have a high relevance in this scenario, because the freedom of motion of the subject is high in this setting.

2.3.1 Purpose

Orienting attention towards new locations is normally accompanied by reorientation of the head direction. When interacting with an AdCoS, the operator may orient towards other locations in the work environment (i.e., a navigation system in a car) which can indicate distraction from the main task. Thus, automatically detecting these head movements provides valuable information about the operator’s current focus of attention and possible distraction.

Videos of the operator’s head (pilot, driver, etc.) during task accomplishment will be recorded. Computer vision techniques will be used to enable automated analysis of the video sequences.

2.3.2 Use Cases

Deriving knowledge about the human operator can be very valuable in the system validation phase. While interacting with a prototype or some modules of the AdCoS, the operator’s focus of visual attention can be evaluated. The tool provides feedback whether or not the system’s states have adverse effect on attention location.

In addition, this tool bears the potential to be used online to classify the driver’s focus of visual attention not only during testing of a prototype, but also during everyday interaction with the AdCoS. This online measure of attention could in turn be used to adapt the degree of automation of the AdCoS to the driver’s state.

A combination with the tools developed by UTO (see section 2.132.3) and TWT (see section 2.12) is possible to increase the tool’s predictive power.

2.3.3 AdCoS Use-Cases

This tool will be applied in the aeronautics domain in WP7 in the use case airport diversion assistant. The computer vision techniques described above have a high relevance in this scenario, because the freedom of motion of the subject is high in this setting.

2.3.4 Input

Videos of the human operator’s head while accomplishing the task are needed as input for the tool. Videos need to be stored in way that enables linking them to certain system states, e.g., inputs from the user to the system. Thus multimodal data integration and synchronization needs to be guaranteed.

2.3.5 Output

The tool provides a continuous description of the operator's head orientation over time of system usage.

2.4 DLR: Task analysis of different automation stages of automotive AdCoS

This service/method will be developed and adapted by DLR within T5.3 and T5.4.

2.4.1 Purpose

Current task analysis methods have been developed for use in traditional non-adaptive human-machine systems. The transition between human and machine control in modern AdCoS may not be entirely captured by these methods. We will select, adapt and apply an appropriate task analysis, so that it will be useful in the design process for AdCoS. As a welcome side effect, the task analysis will also provide a (formal) description of the interaction between the driver and an automotive AdCoS which can be used to construct (cognitive) driver models (WP2) and may also be helpful in the AdCoS design process.

2.4.2 Use Cases

The adapted task analysis for AdCoS can be used at different stages of the AdCoS design process, namely during system development and validation. During the former, it may be used to identify parts of the human-machine interaction in which an increase or decrease of adaptation and/or cooperation is useful. During the latter stage, task analysis can identify potential causes of errors produce by unclear or weakly defined states of automation, adaptation or cooperation.

2.4.3 AdCoS Use-Cases

This method will be applied to the overtaking use case of WP9, including its decomposition (e.g. lane change, passing of vehicles, approach of vehicles).

2.4.4 Input

A successful task analysis needs data providing information about how the operator interacts with the AdCoS. These data are gathered during simulator studies, expert interviews or car drives with a prototype.

2.4.5 Output

The task analysis applied during the design process provides a (formal) description of the interaction between an operator and the AdCoS. For integration into the HF-RTP, this description may be transformed into an UML-like language.

2.5 DLR: Theatre technique for acceptance test during AdCoS design

This tool / method is adapted by DLR in task T5.3 and T5.4.

2.5.1 Purpose

Theatre technique (Schieben et al. 2009) can be used to support the collection of feedback and expectations about a system of the human operator early in the design process. So far, however, theatre technique has only been used with non-adaptive systems. Thus, the goal is to adapt and apply this technique for use during the AdCoS design process. In the theatre technique a researcher or human factors expert mimics the intended system behaviour in a wizard-of-Oz-like fashion. This is particularly useful when planned functions and interaction concepts are sought to be tested before a working prototype is ready for use. This enables the designer to evaluate (some functions of) the system very early in the AdCoS design process, thus significantly reducing cost for re-design.

2.5.2 Use Cases

When the designer/developer has a concept of an adaptive AdCoS behaviour, he or she can use the theatre technique to mimic and evaluate this behaviour during interaction with test participants. From the data collected and feedback from the participants, potential problems in the adaptation as well as undesired consequences in the interaction can be detected early in the design process and compared with the requirements. Thus the extended theatre technique can be used as method for early, low-cost validation of adaptive AdCoS functions.

2.5.3 AdCoS Use-Cases

This method will be applied to the overtaking use case of WP9 with automatic classification of driver preferences for possible trajectories as developed in WP3.

2.5.4 Input

The theatre technique needs a concept of certain functions of the AdCoS and human-factors-relevant requirements with respect to these functions. Human factors experts/researchers need to be trained to produce the desired AdCoS functions in a laboratory setting themselves.

2.5.5 Output

The theatre technique provides feedback whether or not certain system functions adhere to human-factors-relevant requirements, and if the requirements should be changed (extended, refined, abandoned).

2.6 ERG: Implementation of the index of cognitive activity (ICA)

The tool will be implemented by ERG within T5.2 and T5.4.

2.6.1 Purpose

The index of cognitive activity (ICA, Marshall 2007) provides information about the degree of a human operator’s workload based on pupil dilation as can be measured with an eye-tracker. The ICA in going to be integrated in Ergoneer's software D-Lab (which allows to integrate nearly any kind of human and environmental “data” such as eye-tracking, videos, audio, physiology, motion and so synchronously and also enables common data analysis of all that measured data).

2.6.2 Use Cases

Deriving knowledge about the human operator’s mental state can be very valuable in the system validation phase. While interacting with a prototype or some modules of the AdCoS, the operator's mental workload can be evaluated. The tool provides feedback whether or not the system's states have adverse effect on mental workload.

In addition, this tool bears the potential to be used online to classify the driver's mental workload not only during testing of a prototype, but also during everyday interaction with the AdCoS. This online measure of workload could in turn be used to adapt the degree of automation of the AdCoS to the driver's state.

2.6.3 AdCoS Use-Cases

This tool could be applied cross domain provided that an eye tracker can be used to assess the operator's pupil dilation.

2.6.4 Input

The tool requires continuous pupil dilation tracking of the operator with the eye tracker developed by ERG.

2.6.5 Output

The tool provides a temporal description of the driver's degree of mental workload over time of system usage.

2.7 ERG: Mapping of operator gaze behaviour to objects in car's vicinity

This tool is developed by ERG in T5.2 and T5.4.

2.7.1 Purpose

The goal is to automatically map eye gaze behaviour onto objects in the traffic environment which are detected by laser scanners of the automotive AdCoS. This method may also be extended to be used in a driving simulator with objects in the simulation. As it analyses the data completely automatically, this tool can provide valuable insights into the operator's eye gaze behaviour and ultimately enhance classification of the driver's visual attention and distraction.

2.7.2 Use Cases

Deriving knowledge about the human operator can be very valuable in the system validation phase. While interacting with a prototype in a simulator or real car or some modules of the AdCoS, the operator's gaze behaviour in relation to objects in the vicinity can be evaluated. The tool provides feedback whether or not a new system (module) has an impact on gaze behaviour.

In addition, this tool bears the potential to be used online to classify the driver's gaze behaviour not only during testing of a prototype, but also during everyday interaction with the AdCoS. This online measure could in turn be used to adapt the degree of automation of the AdCoS to the driver's gaze behaviour.

A combination with the tools developed by BUT (see section 2.2), UTO (see section 2.13) and/or TWT (see section 2.12) is possible. Moreover, combining this tool with the assessment of the ICA (see section 2.6) potentially provides a more holistic view on the driver current cognitive state.

2.7.3 AdCoS Use-Cases

This method will be either applied to the frontal collision use case or to the overtaking use case of WP9.

2.7.4 Input

The method needs continuous eye tracking data from the operator plus location information from the objects in the car's vicinity. The latter information comes either from the car's laser scanner or the simulation.

2.7.5 Output

The method provides a description of the driver focus of gaze during the interaction with an AdCoS. Specifically, it is able to provide knowledge about which object inside or outside the car are in the driver's focus.

2.8 HFC: Human Factors and Safety regulations and guidelines for metrics

2.8.1 Purpose

To assure that metrics from Task 5.2 are compliant and well aligned with regulatory requirements (domain-specific and cross-domain). The analysis of the regulations will also help to identify the uncovered or poorly covered, but crucial HF aspects of AdCoS, for which metrics/measures are obsolete, insufficient or do not even exist. It is expected that new metrics are needed for the specific aspects of AdCoS: collaboration and adaptation.

2.8.2 Use Cases

concerns potentially every MTT

2.8.3 AdCoS Use-Cases

no specific AdCoS-UC yet

2.8.4 Input

Human Factors and Safety regulations and guidelines reviewed in WP1 (D1.2) and internal workshop.

2.8.5 Output

HFC will compile a set of analysis question and evaluation criteria.

2.9 HFC: Tests for Cognitive Task Models

2.9.1 Purpose

To test the predictions of cognitive task models, based on HF regulations and standards.

2.9.2 Use Cases

concerns potentially every cognitive task model

2.9.3 AdCoS Use-Cases

no specific AdCoS-UC yet

2.9.4 Input

Extensions of cognitive task modelling techniques from WP4 and T5.3, analysis questions and evaluation criteria from T5.2.

2.9.5 Output

Methods and techniques for testing predictions of cognitive task models for adaptive systems.

2.10 REL: Empirical validation methods in simulators

This method will be developed and applied by REL in T5.4.

2.10.1 Purpose

The aim of this method is to design empirical validation experiments by means of a simulation environment that allows validating models and also testing AdCoS from the HF and safety regulations point of view. Experiments should be tester-independent, and test cases will be designed according to the requirements and the specifications initially defined for AdCoS in the implementation domains (i.e. HoliDes WP6-9).

2.10.2 Use Cases

Empirical studies with simulators and in laboratory (i.e. with controlled experimental conditions) can be used to validate prototypes of AdCoS. The validation is accomplished with respect to the Human-Factors- safety-relevant requirements. Uses cases defined by WP6-9 as most relevant will be tested.

2.10.3 AdCoS Use-Cases

This method is particularly used for the use cases of WP8 (control rooms) and WP9 (automotive).

2.10.4 Input

The Human-Factors and safety-relevant requirements of the AdCoS are needed to afford evaluating whether the AdCoS prototype tested in the simulator adheres to them. Also use cases and scenarios need to be defined as much as possible for each domain WP6-9. Prototype of AdCoS to be tested should be available. Metrics to be tested should be clearly defined according to WP6-9 responsible partners and also all aspects of Design of Experiment should be specified. Experimental hypotheses should be clearly defined in Experimental Design.

2.10.5 Output

The method is useful to provide feedback whether or not a certain AdCoS adheres to human-factors-relevant requirements.

2.11 SNV: Empirical analysis and validation methods of cognitive and communicative processes in automotive and control room domain

2.11.1 Purpose

This methods will be applied to experimental design to investigate cognitive and communication processes in WP8 and 9 in order to improve cognitive performances and interactions.

2.11.2 AdCoS Use-Cases

This method will be used first in lab simulating automotive and control room environments, then in driving and control room settings (WP8). The first series of studies aim at collecting a baseline to compare to the ecological settings. In addition, such a method can be applied to an WP9 AdCoS.

2.11.3 Input

In the WP9 framework two series of experiments have been designed. The first series of experiments will investigate the cognitive distraction. Data coming from the literature are not homogeneous. It has not been clarified, in the classic situation of someone talking to the phone, which aspects of the conversation act as distracters to the main task of driving. So far, in the first series of experiments, predictions have been formulated taking into account which aspects of the secondary task can really interfere in the primary task of driving. The experiments have been designed to be applied in the lab and in ecological situations. In addition, visual distraction has been object of many debates among researchers. Two aspects have been considered central in the study of visual distraction: first, under which conditions a driver can be considered distracted by visual stimuli (choice of a sensitive experimental paradigm); second, how cognitive and visual distraction can be considered two separate phenomena as some experimental paradigms for visual distraction involved more central cognitive processes. On this respect, a series of experiments have been designed to test visual distraction under the presentation of different stimuli involving different stages of processing.

Interactions and communications as they are currently carried out between control room's operators and customers calling for an emergency by means of an ad hoc questionnaire. A questionnaire has been created to assess the lexical and the pragmatic aspects of the interaction. The preliminary results evidence the need of a more common, formalized grid to interact with costumers to speed up the process with a minor effort. The same kind of baselines will also be collected in a cross-cultural perspective.

2.11.4 Output

A series of methods to provide feedback if and to what extent a given AdCoS match human-factors requirements.

2.12 TWT: Detection of driver distraction based on in-car measures

This tool will be developed by TWT within tasks T5.2-3.

2.12.1 Purpose

Distraction during driving leads to a delay in recognition of information that is necessary to safely perform the driving task (Regan und Young 2003). Thus, distraction is one of the most frequent causes for car accidents (Artho et al., Horberry et al. 2006). Four different forms of distraction are distinguished while they are not mutually exclusive: visual, auditory, biomechanical (physical), and cognitive distraction. Human attention is selective and not all sensory information is processed (consciously). When people perform two complex tasks simultaneously, such as driving and having a demanding conversation, the brain shifts its focus. This kind of attention shifting might also occur unconsciously. Driving performance can thus be impaired when filtered information is not encoded into working memory and so critical warnings and safety hazards can be missed (Trick et al. 2004). Sources for distraction of the driver can be located within and outside of the car.

An acoustic analysis including the detection of the number of speakers, the degree of emotional content, information about the driver's involvement in the conversation (e.g., whether the driver himself is speaking), is used for the prediction of the driver's degree of distraction. In addition, eye-tracking signals such as temporal measures of eye movements, and face movement information such as mouth movement will add to the reliability of distraction prediction. A computational and empirical cognitive distraction model is used for analysing the different signals computing a distraction degree of the driver. The effect of cognitive distraction based on different audio scenarios on driving performance will be empirically tested in a parallel task in order to assess the impact of auditory stimuli on distraction.

2.12.2 Use Cases

Deriving knowledge about the human operator can be very valuable in the system validation phase. While interacting with a prototype or some modules of the AdCoS, the operator's degree of distraction can be evaluated. The tool provides feedback whether or not a new system (module) increases or decreases the operator's degree of distraction.

In addition, this tool bears the potential to be used online to classify the driver's distraction not only during testing of a prototype, but also during everyday interaction with the AdCoS. This online measure of distraction could in turn be used to adapt the degree of automation of the AdCoS to the driver's state.

A combination with the tools developed by BUT (see section 2.3) and UTO (see section 2.13) is possible to increase the tool's predictive power.

2.12.3 AdCoS Use-Cases

This method will be either applied to the frontal collision use case or to the overtaking use case of WP9.

2.12.4 Input

In-vehicle information is needed. This includes but is not limited to in-car audio recordings and eye-tracking data from the driver. These data need to be stored in way that enables linking them to certain system states, e.g., inputs from the user to the system. Thus multimodal data integration and synchronization needs to be guaranteed.

2.12.5 Output

The tool provides a temporal description of the driver's degree of distraction. We will thus use a continuous measure provided by a regression analysis. The metrics used to quantify the driver's distraction based on in-car information are developed in T5.2. The different measurements will be integrated in RTMaps provided by INTEMPORA. Personal components of the cognitive model and computations are intended to be mobile, e.g., via a Smartphone App. The core of the App, the personal model, should be exchangeable between the mobile device and an on-board system.

2.13 UTO / CRF / SNV: Detection of driver distraction based on data on vehicle dynamics

This tool will be developed by UTO in cooperation with CRF within tasks 5.2 and 5.3.

2.13.1 Purpose

Driver distraction and inattention are an important safety concern (Regan und Young 2003). The purpose of this system is to classify driver distraction based on vehicle dynamics using machine learning techniques.

2.13.2 Use Cases

Deriving knowledge about the human operator can be very valuable in the system validation phase. While interacting with a prototype or some modules of the AdCoS, the operator's degree of distraction can be evaluated. The tool provides feedback whether or not a new system (module) increases or decreases the operator's degree of distraction.

In addition, this tool bears the potential to be used online to classify the driver's distraction not only during testing of a prototype, but also during everyday interaction with the AdCoS. This online measure of distraction could in turn be used to adapt the degree of automation of the AdCoS to the driver's state.

A combination with the tools developed by BUT (see section 2.3) and TWT (see section 2.12) is possible to increase the tool's predictive power.

2.13.3 AdCoS Use-Cases

This method will be applied in the frontal collision use case from WP9, but may also be used in the overtaking use case of the same WP.

2.13.4 Input

Data from the system dynamics during driving are needed. System dynamics need to be stored in way that enables linking them to certain system states, e.g., inputs from the user to the system. Thus multimodal data integration and synchronization needs to be guaranteed.

2.13.5 Output

The tool provides a continuous description of the driver's degree of inattention. The metrics used to quantify the driver's inattention based on vehicle dynamics are also developed here.

3 Summary

WP5 plans to generate thirteen empirical MTTs that will serve the AdCoS development at multiple stages of a holistic Human-centered design process. In the course of the project, we will conceptualize, develop and eventually integrate these MTTs into the HF-RTP and report the status of each MTT in the upcoming deliverables.

4 Overview over the MTTs

Table 1. Overview of the MTTs developed in work package 5. Please refer to the text for more information.

MTT	Purpose	Use Case	AdCoS UC	Input	Output	Partner
means-ends modelling	functional modelling	development + validation	WP6 health care domain	data of user interacting with AdCoS	(formal) description of interaction	AWI
operator state detection	operator gesture classification	validation	WP7 aeronautics	whole-body videos of operator	continuous measure of operator state	BUT
operator state detection	operator attention classification	validation	WP7 aeronautics	videos of head of operator	continuous measure of operator's attention focus	BUT
operator state detection	operator distraction classification	validation	WP9 automotive	vehicle dynamics	continuous measure of operator distraction	UTO
operator state detection	operator distraction classification	validation	WP9 automotive	in-car recordings	continuous measure of operator distraction	TWT
task analysis	functional modelling	development + validation	WP9 automotive	data of user interacting with AdCoS	(formal) description of interaction	DLR
Theatre Technique	low-cost system evaluation	development + validation without prototype	WP9 automotive	AdCoS concept	evaluation of AdCoS w.r.t. requirements	DLR
operator state detection	operator mental load classification	validation	cross domain	pupil tracking of operator	continuous index of cognitive activity	ERG
mapping bw. gaze behaviour and objects	classification of operators focus of attention	validation	WP9 automotive	eye tracking of operator / sensor for objects	continuous measure of operator focus	ERG

simulator studies	empirical validation of AdCoS	validation	WP8 control rooms	Requirements, simulator, AdCoS prototype	evaluation of AdCoS w.r.t. requirements	REL
simulator studies	empirical validation of AdCoS	validation	WP9 automotive	Requirements, simulator, AdCoS prototype	evaluation of AdCoS w.r.t. requirements	REL
Improvement of communication and interaction	improvement of control room AdCoS	development	WP8 control room	ad hoc questionnaire results	tailored method for the control room domain	SNV

Note. bw. = between, w.r.t. = with respect to.

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