PUBLISHABLE SUMMARY

Reporting period:	1st 2008-03-01 to 2009-02-28 2nd 2009-03-01 to 2010-02-28	**Contract no:**	FP7-211988
Title:	Model-based Analysis of Human Errors during Aircraft Cockpit System Design		
Acronym:	HUMAN		
Project website:	http://www.human.aero		
List of Contractors:	**Name:**	**Short name:**	**Country:**
	OFFIS e.V.	OFF	Germany
	Airbus France	AIF	France
	Alenia Aeronautica S.p.A.	ALA	Italy
	Université catholique de Louvain Belgian Laboratory of Human-Computer Interaction	BCH	Belgium
	Deutsches Zentrum für Luft- und Raumfahrt e.V.	DLR	Germany
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Objectives:

The objective of the HUMAN project is to develop a methodology with techniques and prototypical tools supporting the prediction of human errors in ways that are usable and practical for human-centred design of systems operating in complex cockpit environments.

The current approach of analysing systems is error prone as well as costly and time-consuming (based on engineering judgement, operational feedback from similar aircraft, and simulator-based experiments). The HUMAN methodology will allow to detect potential pilot errors more accurately and earlier (in the design) and with reduced effort.

Approach:

The detection of errors will be achieved by developing and validating a cognitive model of crew behaviour. Cognitive models are a means to make knowledge about characteristic human capabilities and limitations readily available to designers in an executable form. They have the potential to automate parts of the analysis of human errors because they offer the opportunity to simulate the interaction with cockpit systems under various conditions and to predict cognitive processes like the assessment of situations and the resulting choice of actions including erroneous actions. In this way they can be used as a partial "substitute" for human pilots in early development stages when design changes are still feasible and affordable.

Model- and simulation-based approaches are already well-established for many aspects of the study, design and manufacture of a modern airliner (e.g., aerodynamics, aircraft systems, engines), for the very same objective of detecting potential problems earlier and reducing the amount of testing required at a later stage. HUMAN will extend the modelling approach to the interaction of flight crews with cockpit systems. To realize this target the main research and development work in HUMAN will produce key innovations on three complementary research dimensions:

- *Cognitive modelling*: to develop an integrated cognitive crew model able to predict human error categories with regard to deviations from normative activities (Standard Operating Procedure (SOP) and rules of good airmanship).
- *Virtual simulation platform*: to develop a high-fidelity virtual simulation platform to execute the cognitive crew model in realistic flight scenarios in order to analyse the dependencies (including the safety effect of likely pilot errors) between the pilots, a target system in the cockpit, the aircraft and its environment.
- *Physical simulation platform*: to thoroughly investigate pilot behaviour on a physical simulation platform (comprising a full-scale flight simulator) to produce behavioural and cognitive data as a basis for (1) building a detailed knowledge base about cognitive processes leading to deviations from normative activities in the complex dynamic environment of modern aircraft cockpits and for (2) validation and improving the predictions of the cognitive model generated on the virtual simulation platform.

The general idea of the virtual and physical platform is to use the same core system for both in order to ensure the functional equivalence between the two platforms (Figure 1). This equivalence is a fundamental precondition for validating the cognitive model by producing one the one hand, data sets for predicted crew activities (on the virtual platform) and on the other hand, data sets for actual crew activities (on the physical platform). Predicted and actual crew activities will be compared to assess the quality of the model predictions and to derive requirements for model improvements.

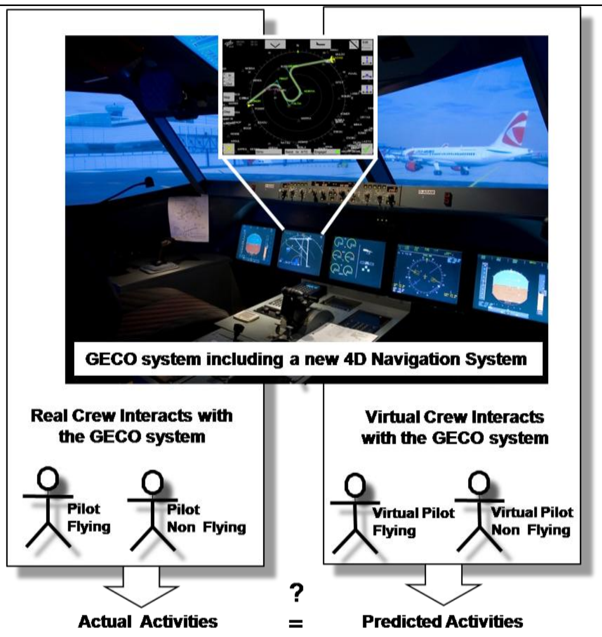

Figure 1: Physical and Virtual Simulation Platforms sharing the same core system

The core system is the GEneric COckpit (GECO), a full scale simulator provided by the DLR. In HUMAN it incorporates a target system, the AFMS (Advanced Flight Management System) with flight management functions and crew interface functionality compatible with 4D flight planning and guidance and trajectory negotiation by means of a data link connection. In the project the system is extended towards issues pertaining to the future Air Traffic Management context, like trajectory negotiation.

After the preparation of the platforms they are used in two experimental cycles to generate a knowledge base on pilot behaviour and to validate and improve the cognitive crew model.

Work performed and main results:

Period 1:

During the **first project period** the requirement phase was finished and significant progress was made with regard to the development of the physical and virtual platform. Furthermore, a common design methodology for cockpit systems has been defined by the industrial partners and points where the concepts and tools of HUMAN are supposed to bring considerable added value have been identified.

Requirement phase

The AFMS including the AHMI (Advanced Human Machine Interface) provided by project partner DLR has been investigated in detail and has been accepted as a target system for HUMAN.

A set of a human error types (ETs) and cognitive processes by which these error might be generated (error production mechanisms, EPMs) has been defined. These ETs and EPMs have been assessed according to their relevance to the AFMS/AHMI target system with the future Air Traffic Management, according to their observability on the physical platform and according to the realism that the project partners will be able to model them with sufficient maturity given the resources of the project.

Requirements for the evolvement of the target system have been defined by the industrial partners in order to make it more representative for systems that are likely to be introduced in future aircraft. This includes features for the efficient negotiation of flight trajectories between cockpit crew and air traffic controllers via data link.

A hierarchy of flight scenarios to be tested on the simulation platform have been defined. The term 'scenario' refers to the simulator flight conditions and the simulator setup applied to a set of experimental flights performed by the subject crews. In this period the higher more generic scenario levels have been defined e.g. by specifying the phases of flight, duration and involved systems. The generic scenarios represent typical LOFT (Line Oriented Flight Training) conditions with duration of approximately 30 to 40 minutes. This approach was chosen in order investigate the performance data of the pilot acting in realistic flight situations rather than in a specific skill oriented training situation. First normative activities that the crew has to perform in these scenarios have been defined in form of flight procedures and rules of good airmanship. Scenario and normative activities include interaction with the target system and involve high level conditions that are likely to induce the ETs and EPMS identified before.

Based on the ETs and EPMs, generic scenarios and the initial normative activities, it was possible to derive the requirements for the cognitive crew model in form of needed basic capabilities.

Physical and Virtual Simulation Platform

Figure 2 shows the technical realization indicating which components are reused and which are build within HUMAN.

On the physical simulation platform new features of the target system have been implemented: a display of weather radar image, a priority system for trajectory downlink, a CAS constraint feature, and a message window for CPDLC messages.

A new technique for the formal specification of Human Machine Interfaces for cockpit systems has been defined. This methodology draws upon UsiXML (User interface eXtensible Markup Language) that was extended with new concepts relevant for the AHMI specification. A subset of the target system requirements has been formalised.

A pool of pilots for the experiments is available. A first test schedule for the first experimental cycle has been defined.

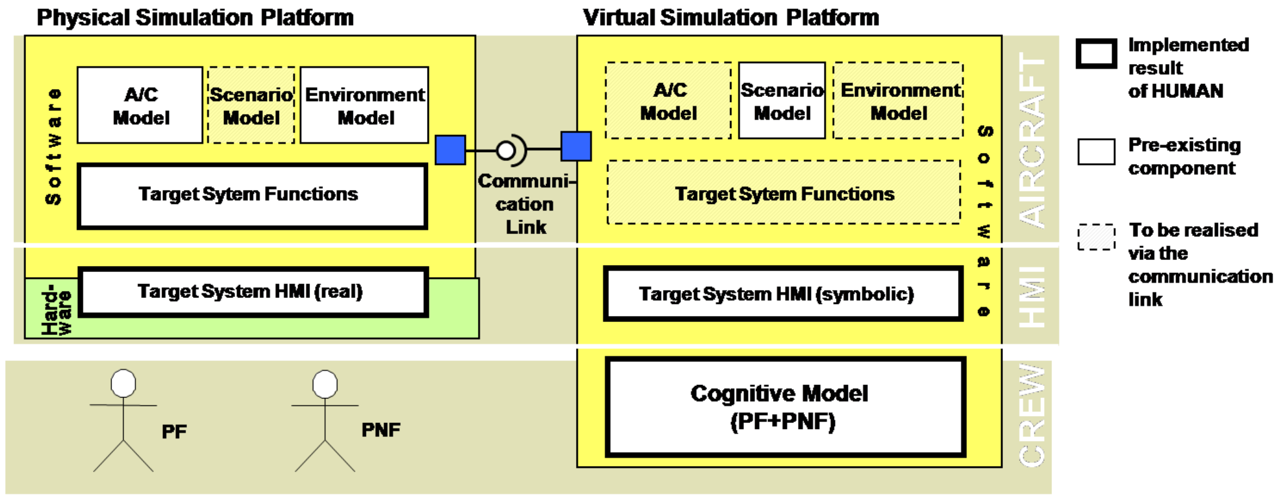

Figure 2: Realization of the Physical and Virtual Simulation Platforms

On the virtual simulation platform a first version of a new layered cognitive architecture encompassing an associative and cognitive layer has been developed. We made significant progress with regard to the realization of the capabilities to simulate human visual field including eye-movements, to simulate bottom-up as well as top-down attention, to dynamically react to external events (including visual and auditory events), to simulate crew coordination (e.g. call-outs, check list reading), to perform multiple tasks concurrently (multitasking), to interpret perceived data (translation of signs to symbols), and to handle unfamiliar situations. The implementation of these capabilities will be finished on time for the first experimental cycle.

An existing formalism and associated editor for capturing and editing normative crew activities have been extended in line with the developments of the cognitive architecture. The extensions include priorities (for multitasking), goal triggers (for reactive capabilities) and differentiation between PF and PNF (for multi-agent capabilities).

A scenario controller has been developed that starts and controls the simulation (on both platforms) in accordance with the specified scenarios. The scenario controller triggers events (e.g. system failures) and ATC communication, and stops the simulation if the scenario end has been reached. The scenario controller is able to do this for the Virtual and Physical Simulation Platform. In case of the VSP, the scenario controller starts the cognitive models, too.

A symbolic AHMI (SAHMI) is being developed that is part of the virtual simulation platform. The main purpose of the SAHMI is to allow the cognitive model access to the user interface of the AHMI. For that purpose an UI model has been created. To realize this model, UsiXML, a modern User Interface Description Language on XML basis, has been extended to specify interactive objects in high level terms expressive enough to capture the visual and auditory details relevant for the cognitive mechanisms implemented in the cognitive model. The high level terms have been semantically defined by developing a formal ontology that operationalizes their meaning based on data delivered by the GECO flight simulator (Physical Simulation Platform). Apart from the requirements posed by the cognitive model the ontology is driven by the notions required for the normative pilot activities. In addition, evaluation on the target system user interface will be performed using the output from the SAHMI.

A communication link has been implemented that allows to share models or software between both platforms to guaranty highest functional equivalence.

A new technique for analysing the data of both platforms in order to validate the cognitive crew model has been devised. The main idea of this technique is to translate the normative activities as well as the produced data in formal automata and to use model checking techniques for automatic detection of sections in the data where the (virtual) pilots deviated from prescribed behaviour. Statistical analyses are then used to compute the match between both platforms.

Finally, acceptance conditions for both platforms have been defined and will be tested before the first experimental cycle starts.

Design Methodology

A common current industrial design process for cockpit systems was described. It represents a “general” description extrapolated from the design processes at Alenia Aeronautica and Airbus France. The process encompasses 30 activities. For each activity inputs, outputs, actors, techniques, notations, tools/assets, documents and databases are specified. Based on this description preliminary aspects where HUMAN results could bring improvements were identified.

Period 2:

During the **second project period** the preparation of the physical and virtual simulation platform has been finished. The first cycle of experiments on both platforms has been performed and initial results are available. Furthermore, detailed requirements for the development of the HUMAN techniques and tools have been defined in order to guarantee their usage within a design methodology for cockpit systems.

Physical and Virtual Simulation Platform

For the physical simulation platform the AHMI specification has been formalised using UsiXML according to the requirements defined in the first project period. Based on this specification the implementation of target system improvements has been finished. As a main function to support the realism of the Advanced Human Machine Interface the simulation of a dynamic weather radar has been added to the display showing a statistically varying picture of the weather situation in front of the aircraft. The target system has been integrated into the GECO. Tools for data analysis have been defined and implemented. It was decided to realize a mainly manual approach relying on traditional statistical analysis and intensive debriefing of pilots for the first experiment cycle. The automatic approach has been started and already realized for the initial data preparation phases (e.g data synchronisation, format data integration). Automatisation of data analysis will be continued in the third project period and will be applied in the second experiment cycle. Generic scenarios (including scenario events) and normative activities for relevant flight tasks have been defined.

For the virtual simulation platform the implementation of the basic capabilities (defined in the first project period) for the cognitive crew model has been finished successfully. Additionally, the implementation of the scenario controller and the symbolic AHMI (SAHMI) has been finished. The SAHMI allows the cognitive model to “read” and “manipulate” the target system. All components of the virtual simulation platform have been integrated.

M2 has been achieved which marks the end of the preparation phase of the physical and the virtual simulation platform which ended with the formal acceptance of the two platforms and the assessment of their functional equivalence. The acceptance test has been performed based on preparatory material (e.g. documents describing the concept and the performance of the platforms) and during an intensive two days acceptance meeting in Braunschweig, Germany according to a comprehensive list of acceptance criteria.

Experiments – Model Validation

Working hypotheses for the experiments on both simulation platforms have been defined in order to investigate and validate the cognitive crew model with regard to (1) characteristics of normative pilot behaviour, (2) errors due to Learned Carelessness and (3) errors due to Cognitive Lockup. Experiments on the physical simulation platform have been performed with 15 subject pilots. During the experiments on the virtual platform the cognitive crew model has been used to simulate each scenario several times. Initial data analysis results have been produced. For example, the analysis of pilots’ gaze distribution showed a high concentration of attention on the AHMI during the flight. Another interesting result is that pilots’ gaze distribution especially the attention to the AHMI changes during different flight levels/phases. Initial comparison between model and pilot data showed for example that the pilots perform tasks considerably slower than the model. The scanning patterns of pilots showed a greater variability then those of the model. Initial requirements for the improvement of the cognitive model have been derived and in parts already been realized. The work is ongoing: the data analysis will continue, further requirements will be derived and the model will be improved accordingly. The consortium is progressing as planned towards Milestone M3 which is defined by the availability of the Intermediate Version of the Cognitive Model after the first cycle (cognitive crew model running according to requirements derived from 1st model validation).

Design Methodology

Starting from the design process activities identified in Period 1 points were identified where the techniques and tools developed in HUMAN (e.g. cognitive model, simulation platforms, scenario controller, Procedure Editor, data analysis techniques) could improve the current state of practice. Based on the targeted design activities a detailed list of requirements for the tool development has been derived which was used in the other wok packages as a guideline for tool development.

Expected final result:

The output of the HUMAN project will be an innovative means enabling to considerably improve human centred design of cockpit systems including a cognitive crew model able to predict design relevant pilot errors, a high-fidelity Virtual Simulation Platform enabling execution of the cognitive crew model, a prototypical tool based on the virtual simulation platform supporting usability of the platform and cognitive model, formal techniques and prototypical tools for analysis of simulator data, a detailed knowledge base about cognitive processes leading to pilot errors and derived guidelines for cockpit system design, a methodology that integrates all the techniques and tools for their application during aircraft cockpit system design.

Potential impact and use:

HUMAN will have an impact on Aircraft Safety. The project will contribute to the objective to reduce the accident rate by enhancing the accuracy of pilot error prediction. Furthermore, it will contribute to the objective to achieve a substantial improvement in the elimination of and recovery from human error by reducing the design effort of active and passive safety measures and by reducing the effort of flight simulator tests for active and passive safety measures. HUMAN intends to realize these impacts by producing the expected final results described above that are finally all integrated in a new methodology for the analysis of human error based on innovative cognitive model based techniques and prototypical tools.

There is no question that cognitive modelling will be used increasingly within R&D in the coming years. There is a broad knowledge base upon which it can build and it has important applications, e.g. for improving design, training, and decision support. We claim that the gained knowledge and capability within HUMAN will give the European partners participating in HUMAN a clear advantage over competitors from abroad in human centred design of safe aircraft cockpits. Reinforcing the competitiveness will increase the market position of European aircraft and will thus create new possibilities for employment. The HUMAN project is focused on reducing the number and severity of human errors during human-machine interaction in aircraft cockpits, i.e. an interaction process in which an incorrect action could lead to the loss of human life, serious environmental damage, and/ or injuries to or illness of persons.

The methodology to be developed in HUMAN will be disseminated to other domains where human life is at stake, like the automotive domain or the railway domain. Furthermore, the project’s research results will have an influence on education at universities.