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iFly

Safety, Complexity and Responsibility based design and validation of highly automated Air Traffic Management

Specific Targeted Research Projects (STREP)

Thematic Priority 1.3.1.4.g Aeronautics and Space

iFly Deliverable D2.4
Potential human factors improvements for A^3 ConOps

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Executive Summary

Background: The iFly project (iFly 2006) is planned to develop an advanced airborne self separation ATM design for en-route traffic, which is aimed to manage a three to six times increase in current en-route traffic levels providing simultaneously improved safety levels.

The present document is the fourth and the last deliverable of Work Package 2 of iFLY project. The report presents the Human Factors suggestions for potential improvements of the Autonomous Aircraft Advanced (A^3) ConOps.

Results: Most of the human factor issues presented in D2.3, identified during an analysis of D1.3, are such which could be taken into account during later stages of A^3 ConOps development. There are a comparatively small number of human factors issues identified in D2.3, which can be taken into account during the immediate course of A^3 ConOps improvement, planned for WP8 of the present iFly project. The proposed improvements include the following:

- the need to establish minimum requirements for equipment should be mentioned
- the need to establish minimal operational requirements should be mentioned
- the need to take transition issues into account in a follow-up project should be mentioned
- the possible use of voice channel in normal conditions should be considered
- the value of information from other (airborne) sources for situation awareness should also be considered
- the function congruence between the human and automation should be considered
- the need for assistance from the ground for leaving the SSA in emergency should be mentioned to be taken into account in follow-up projects
- the suggestions about ground support should be considered
- the suggestions about RBT changes should be considered

The report also gives general recommendations for integrating human factors and automation issues, which are applicable both to the iFly stage as well as to the later stages of A^3 ConOps development.

Interactions with other iFly deliverables: Key deliverables for the present document are D1.3 (iFly 2009a), prepared by WP1.3 and D2.3 (iFly 2009b), prepared by WP2.3. Previously released deliverables from WP2 D2.1 (iFly 2007b) and D2.2 (iFly 2007c) were also taken into account.

The present deliverable D2.4 provides the input for those Work Packages which will either focus on developing technologies whose requirements arise from the ConOps (WP3.2, WP4.2 and WP5.3), or will perform risk/safety assessments of the ConOps within WP7 (see iFly 2007b), or refine the A^3 ConOps (WP8). In this the present deliverable will impact the further improvements of A^3 ConOps on the second design cycle of their development.

INDEX

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1 Introduction

1.1 Objectives of the iFly project

Air transport throughout the world, and particularly in Europe, is characterized by major capacity, efficiency and environmental challenges. With continued growth in air traffic a three to six times increase is predicted for 2020. These challenges must be addressed if we are to improve the performance of the Air Traffic Management (ATM) system.

The iFly project definition begun as a response to the European Commission (EC) 6th Framework program call for Innovative ATM Research in the area of "Aeronautics and Space" (iFly 2006). The program is expected to develop novel concepts and technologies with a fresh perspective into a new air traffic management paradigm for all types of aircraft in support of a more efficient air transport system. It is aimed at supporting the integration of collaborative decision-making in a co-operative air and ground based ATM end to end concept, validating a complete ATM and airport environment, while taking into account the challenging objectives of SESAR (2007).

iFly will develop a highly autonomous and distributed ATM design for en-route traffic, which takes advantage of aircraft self separation capabilities and which is intended to manage a three to six times increase in current en-route traffic levels. Analysis of safety, complexity and pilot/ controller responsibilities, as well as subsequent assessment of ground and airborne system requirements will deliver a coherent set of operational procedures and algorithms, thus demonstrating how the results of the project may be exploited.

The aim of the iFly project is to develop advanced operational concepts of airborne self separation. Initially the Autonomous Aircraft Advanced (A^3) concept develops an approach fully based on airborne responsibility. According to this concept, all autonomous aircraft flying in Self Separating Airspace (SSA) are capable of providing self separation without the ATM support from the ground. As the result of the second design cycle, the refined concept will take into account the limitations in assigning more responsibility to airborne side, revealed on the previous design cycle and will elaborate the vision how A^3–equipped aircraft fit best within the SESAR thinking regarding future ATM.

1.2 iFly Work Package 2 (WP2)

Changes in the air traffic management system irrevocably cause changes in the role of the human involved in that system as a result of technological and systemic changes. When the system becomes more and more automated, a shift in tasks and responsibilities of the human controlling the system becomes possible. In the iFly concept the human operator (the cockpit crew) is responsible for actions and tasks related to self separation he/she performs during en-route phase of flight. This responsibility will become a core issue in aerospace operations, if decisions and actions of self separation will be carried out without being required to request permission from another actor (ATCo).

Important in this is, that many functions in autonomous aircraft operations will be supported by automation on the flight deck and there should be a balance of responsibility between automation and human made decisions. As long as the human remains responsible for the resulting actions of the human-machine system, he/she also needs to be able to control the system. When the system is fully automated and the human is out of the loop, it is not possible to hold him/her responsible for the resulting outcomes. On the other hand, human-centred automation of (parts of) a system can also support the human to maintain control over the situation, especially in complex systems like an aircraft.

Therefore, human responsibility is a key factor in determining where, how, and to what extent an iFly like system can be automated. Traditionally in air traffic management environment this responsibility has been spread across the airborne and ground side of the system. Current developments in ATM show a shift towards a more decentralized system, with increasing tasks and likely more responsibilities for the airborne side, i.e. the cockpit crew. This side forms the starting point for the current project, therefore the question that arises is: “What responsibilities should be assigned to the airborne side of the system assuming a new task distribution implied by autonomous ATM?” Work package 2 considers these issues in more detail.

Work package 2 is divided into two parts: 1.) “airborne responsibilities” and 2.) “bottlenecks and potential solutions”, both of them consisting of two sets of tasks.

<u>Part 1: Airborne responsibilities</u>

WP2.1 Identify current and new responsibilities of cockpit crew during en-route phase of flight.

WP2.2 Analyse Situation Awareness, Information, Communication and other cockpit crew tasks.

<u>Part 2: Bottlenecks and potential solutions</u>

WP2.3 To identify bottlenecks in responsibility issues.

WP2.4 To develop potential human factors improvements for A^3 ConOps.

Tasks of WP2.1 have been addressed in deliverable D2.1 (iFly 2007b), tasks of WP2.2 in D2.2 (iFly 2007c) and tasks of WP2.3 in D2.3 (iFly 2009b).

As a result of the D2.1 new and changing pilot tasks and responsibilities were identified. These pilot tasks served as an input for detailed analysis of situation awareness issues in the cockpit and pilot tasks related to them in D2.2. The results of D2.2 were used in D2.3 for critical analysis of the A^3 ConOps specified in WP1 D1.3, mainly from the angle of providing and maintaining adequate situation awareness of the cockpit crew.

The aim of the current deliverable D2.4 is to address WP2.4 issues. As the initial options for allocating responsibility to the cockpit crew have been identified in WP1.1 (iFly 2008) and WP1.3 (iFly 2009a), WP2.3 was searching for inconsistencies in these options and questioned them, to prepare the second design cycle for improvement of the A^3 concept. This is in contrast with the common way, in which first a concept is fully developed regarding the technical systems, and after this, responsibilities are assigned to the applicable actors.

After WP2.3 had identified human factors responsibility bottlenecks where improvement of A^3 ConOps is needed, the goal of WP2.4 is to develop potential mitigating human factors related measures of these bottlenecks for the A^3 ConOps. These potential mitigating human factors measures will be taken into account for the refinement of A^3 within WP8.1 (see iFly 2006, p 45).

1.3 Objective of the report

The objective of the present document is to suggest ideas for potential improvements of the A^3 ConOps for the human factor issues that have been identified in D2.3.

Most of the human factor issues identified in D2.3 as a result of analysis of D1.3 are such, which could be taken into account on the later stages of A^3 ConOps development. There is a comparatively small number of identified in D2.3 human factors issues, which can be taken into account on the nearest stage of A^3 ConOps improvement, planned into WP8.1 and WP8.3 of the present iFly project.

The report gives also general recommendations for integrating human factors and automation issues, which are mostly applicable in work packages dealing with the design of single decision support tools, like Conflict detection and resolution modules and the associated algorithms.

1.4 Document Layout

The present deliverable starts with the *Executive summary* and consists of seven sections:

1. *Introduction* gives the objectives of the iFly project, describes the iFly Work Package 2 and presents the objectives of the report and the document layout.
2. *Human factors issues contributing into A^3 ConOps improvement* describes the issues identified in D2.3, which may be taken into account on the second design cycle in WP8.1.
3. *Human-System Integration: Evolution of understanding* gives an overview of this subject matter.
4. *Human-Automation Interaction: Main Problems* describes the main problems resulting from poor automation design.

5. *Human-Automation Interaction: Strategies for Enhancement* discusses strategies which can be used to determine appropriate levels of automation considering a human-centred approach.
6. *Concluding remarks.*
7. *Appendixes, including a list of Acronyms, a list of References, and a table regarding Human System integration activity needs on the basis of HF-issues in D2.3.*

2 Human Factors issues contributing to A^3 ConOps improvement

In every system design process humans are involved as designers as well as potential users of these systems. Although the conscious and systematic application of knowledge about the human in the system design has its available history, in every new system design all this knowledge has to be reapplied as a new. Human capabilities, needs and limitations must be considered early and throughout the whole process of system design and development. The attempt of the possible seamless integration of humans into the design process from various perspectives has come to be called human-system integration (see Pew, Mavor, 2007).

As it has been always difficult to establish effective communication between system designers and human-system domain experts, in the above-mentioned book there are some valuable recommendations for overcoming these difficulties:

- To include human-system integration contributions during early development and continue this throughout the development life cycle.
- To integrate across human-system domains as well as across the system life cycle.
- To adopt a risk and opportunity-driven approach to determining needs for human-system integration activity.

These ideas have been followed in the iFly project and the present deliverable can be considered as a step towards this advisable integration. In D2.3 several human factors issues were raised, which could be considered helpful for further development of A^3 ConOps. Possible suggestions were given from a human factors point of view independently of the project life cycle. As a result there are suggestions, which may be applicable in the second design cycle in the time scale of the present iFly project and those, which may be applicable to later, follow-up, design cycles.

In WP2.4 the differentiation of abovementioned human factors issues was made on the basis of possible time scale of their applicability in A^3 ConOps. Most of the human factors issues, given in Appendix 3, belong to those, for which human-system integration activities remain beyond the iFly time and development scope. Those issues, which could, at least to a certain extent, be integrated into A^3 ConOps system design for improvement of A^3 ConOps in WP8, have been collected in Table 1. It is important to note that for making the human factors issues from D2.3 graspable in the present final WP2 document, the lengthy discussions and proposed possible alternatives in D2.3 have been reduced in the present deliverable to a reasonable extent and concentrated mostly into single sentence shape, presented in the uniform manner in three columns of the Table 1.

The numeration of the human factors issues in Table 1 and Appendix 3 follows the D2.3 content. The issues are briefly re-introduced in general, discussed from the viewpoint of their possible later use in further steps of A^3 ConOps refinement (probably beyond the iFly project scope) and then possible human-system integration actions in WP8 are suggested.

Table 1. Human Factors issues in D2.3, which could be considered contributing into A^3 ConOps improvement in WP8

Human-System Integration activity needs on the basis of HF issues in D2.3			
Issue No	**Synopsis of the issue from D2.3**	**Possible actions in further steps of A^3 ConOps refinement**	**Possible action in WP8**
4	Taking differences in the technology level of equipment into account for different actors operating in the Self Separated Airspace is an essential opportunity.	Minimum requirements for equipment must be specified in further steps of A^3 development.	No immediate action necessary in WP8, but the need to establish minimum requirements should be mentioned.
8	The level of support provided to the crew by onboard decision support tools may essentially differ for different actors, but the minimal operational requirements have to be established for all the actors in SSA.	Minimal operational requirements should be defined in further steps of A^3 development.	No immediate action necessary in WP8, but the need to establish minimal operational requirements should be mentioned.
9	Appropriate level of automation will depend both on the situation and the workload of the flight crew. More automation will not always provide higher Situation Awareness.	Minimal operational requirements should be defined in further steps of A^3 development.	No immediate action necessary in WP8, but the term "situational awareness", used in D1.3, should be replaced by "situation awareness".
11	Transitions from one type of airspace to the other may become safety critical situations which should be considered in the design process. Even if they remain beyond the border of the defined system, they should not be overlooked for this reason.	Transition issues should be developed in further refinements of A^3 ConOps.	No immediate action needed in WP8, but the necessity to take transition issues into account in more detail in the future should be mentioned.
13	Transitions from one type of airspace to the other may lead to safety critical situations which should be considered in the design process. Even if they remain beyond the border of the defined system, they should not be overlooked for this reason.	Transition issues should be developed in further refinements of A^3 ConOps.	No immediate action needed in WP8, but the necessity to take transition issues into account in more detail in the future should be mentioned.
17	The use of voice a channel for communication between the flight crew and FOC should be considered not only in emergency, but also normal conditions.	The use of voice channel in normal conditions should be considered in further steps of A^3 development.	No immediate action needed in WP8, but the possible use of voice channel in normal conditions should be considered.
23	SWIM will definitely have a major role in	The demands of the	No immediate action

	providing information to the flight crews in non-normal or emergency situations. But at the same time the value of real-time airborne information in the vicinity of the aircraft in non-normal or emergency situation for situation awareness raises more quickly than the value of distant and long-term information.	flight crew to SWIM information in normal, non-normal and emergency situations should be investigated in further developments of A^3 ConOps.	needed in WP8, but the value of information from other (airborne) sources for situation awareness should also be considered.
27	The list of minimum requirements which enables the flight crew and the aircraft to operate in SSA should be defined.	Minimal operational requirements should be defined in further steps of A^3 development.	No immediate action necessary in WP8, but the need to establish minimal operational requirements should be mentioned.
28	Human-system integration is the most important contributor to the system adaptability and resilience. This integration means the search for the right level of automation, which may vary as a function of environment and crew workload.	Human-system integration has to be taken into account at every step of A^3 development.	No immediate action needed in WP8, but the idea of function congruence between the human and automation should be considered within WP8 for keeping the human in the loop.
41	CD and CR tools failure may, but must not always cause the failure of the airborne systems ability for self separation, if the crew is able to take over the control and has the traffic information available. The self separating incapable aircraft ceasing to operate in SSA and leaving for MA may need additional assistance from the ground.	Assistance from the ground in an emergency for leaving the SSA must be considered. In further steps of A^3 ConOps development the ability of the crew to maintain self separation in CD and CR tools failure conditions, while traffic information is still available, may need further analysis.	Replace "aircraft that are aware" to "crews who are aware …" Assistance from the ground for leaving the SSA in emergency should be considered in WP8.3
42	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be considered within WP8.3.
43	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but ground support should be considered within WP8.3.
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45	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be considered within WP8.3.
46	The ground support concept in emergency and non-normal operations should be developed.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support concept for emergency and non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be considered within WP8.3.
58	The conditions, under which the RBT changes need to be initiated by the flight crew, have to be defined in a more detailed way.	In further steps of A^3 ConOps development the conditions of RBT changes initiated by the flight crew may need a more detailed definition.	No immediate action needed in WP8, but the suggestions about RBT changes should be considered.

As can be seen from the last column of the Table 1, of 16 human factors issues given, some are in need of WP8 improvements and most of them are suggestions, about which the WP8 system designers have to decide, if and to which extent to take these given suggestions into account in the refinement of A^3 ConOps within WP8. From the Table 1 the reader can see that several items coming from different discussion topics, take the form of identical suggestions. Partly for that reason and also for better visibility and compactness the proposals for improvements of human factors issues in iFly WP8 are summarized below once more as separate items:

- the need to establish minimum requirements for equipment should be mentioned
- the need to establish minimal operational requirements should be mentioned
- the need to take transition issues into account in a follow-up project should be mentioned
- the possible use of voice channel in normal conditions should be considered
- the value of information from other (airborne) sources for situation awareness should also be considered
- the function congruence between the human and automation should be considered
- the need for assistance from the ground for leaving the SSA in emergency should be mentioned to be taken into account in follow-up projects
- the suggestions about ground support should be considered
- the suggestions about RBT changes should be considered

Beside the above mentioned issues identified in D2.3 one major aspect needs to be discussed in more detail, due to its importance for ongoing developments of the A^3 ConOps within and beyond the iFly project: Human-Automation Issues. In the following sections of the present deliverable this topic is elaborated in more detail and contains several suggestions regarding how to deal with these issues.

3 Human-System integration: Evolution of understanding

3.1 Fitts List

In 1951 Fitts (Fitts, 1995, after Lee, 2006) created a list of strengths of humans and machines (see Table 2) with the idea behind it to help "designers" at these days to assess each function and to determine if the function would be better accomplished by humans or by machines. This strategy to enhance the Human-Machine interaction is typically known as "function allocation". Fitts held the opinion that functions which would be better performed by machines should be automated while the rest, including recovery in case systems fail, should remain under the responsibility of the human.

Table 2. A revised Fitt's List (1951, after Lee, 2006) of strengths of Human and machines related to the four Information-Processing Stages

Information-Processing Stage	Humans are better in:	Automation is better in:
Information acquisition	Detecting small amounts of visual, auditory, or chemical signal	Monitoring processes
	Detecting a wide range of stimuli	Detecting signals beyond human capability
Information analysis	Perceiving patterns and making generalizations	Ignoring extraneous factors and making quantitative assessments
	Exercising judgment	Consistent application of precise criteria
	Recall of related information and development of innovative associations between items	Storing information for long periods and recalling specific parts and exact reproduction
Action selection	Improvising and using flexible procedures	Repeating the same procedure in precisely the same manner many times
	Reasoning inductively and correcting errors	Reasoning deductively
Action implementation	Switching between actions as demanded by the situation	Performing many complex operations at once
	Adjusting dynamically to a wide range of conditions	Responding quickly and precisely

It has turned out that this (by now historical, but still in use) approach contains several weaknesses. First of all there are many interconnections between functions which Fitts didn't take into account. Such a decomposition of activities used by Fitts masks complex interdependencies, with the result, that humans will be in charge of any tasks which are just too complicated to be

automated. Another weakness concerns the situation dependence of automation and human performance. And sometimes one and the same function may require improvisation to be fulfilled under special circumstances.
Nevertheless, Fitts point of view provides some general ideas which can improve the design of automation. Due to the strengths associated with humans it is important to leave the “big picture” to the human and details to the automation. According to more recent views, designers shouldn’t focus on and identify which function should be allocated to humans or machines, but should find a way how humans and machines could complement each other in order to be successful (Lee, 2006).

3.2 Cognitive Systems Engineering

Human Factors topics in the iFly project have originated mainly from the views of Cognitive Systems Engineering (CSE). To avoid possible misinterpretations, the essence of these views needs brief introduction. The logic of development of technology has brought the human-technology or man-machine interface problems since 1970s to the cognitive domain. By that time most of negative consequences of dominance of behaviourism in psychology of the first half of the last century were overcome and cognitive psychology was developing. One of the negative aspects that was still taken over from the former psychology by several applied psychologists (engineering psychologists or human factors specialists), was the view of human information processing as a linear sequence of fixed processing stages.

An alternative approach emerged, where the advances in cognitive psychology and in the design of “intelligent” computer systems demonstrated that this approach is inadequate both theoretically and in real-world applications. An alternative approach describes human cognitive functioning as a recursive set of operations including both bottom-up or data-driven analysis, that is, analyses arising from information which comes to the operator from the environment, and top-down or concept-driven analysis, that is, analyses which start from information which the operator already has (Hollnagel, Woods, 1999). This direction of man-machine studies lead to the development of the Cognitive Systems Engineering (CSE). In CSE the man-machine systems are designed, developed and analyzed in terms of cognitive systems. The man-machine interfaces of information processing machines must be created according to cognitive principles, which underlie human cognition. In interface development it is appropriate to start from realistic prototypical cognitive functioning of an operator instead of prescribing artificial logic rules to human cognition (Rasmussen, Jensen, 1974).
By the virtue of the CSE man-machine system (MMS) is seen as adaptive, where the broad goal is to improve the functioning of the system as a whole, rather than to replace as many operator functions as possible. In Hollnagel and Woods (1999, p. 343) view:

“It is of course, quite reasonable to consider separate functions of an MMS in detail. However, one should never forget that they occur against a background of total system function. This means it is insufficient to make an a

priori assignment of functions between the operator and the machine, particularly when the criterion appears to be that the machine must compensate for the deficiencies of man, i.e., a simple extension of the principle behind traditional human engineering.

An a priori distribution of functions sees the task universe as a closed space where sub-tasks are identified and then allocated to man or machine until the space is filled [...]. This assumes that overall system performance is linear function of performance on each sub-task. However, changing task allocation qualitatively changes the nature of the man-machine interface through transformations in the underlying cognitive system, which necessarily affects overall system performance."

3.3 Joint Cognitive Systems

The Joint Cognitive System (JCS, operator and the machine part of the system taken together) is characterized by its ability to maintain control, or more specifically, to modify its behaviour on the basis of knowledge and experience. This includes goal oriented behaviour, based on symbol manipulation and using the knowledge about system and its environment. The knowledge in the cognitive system makes it able to plan and modify its actions. So the cognitive system is both data and concept driven by means of internal model or representation of its environment.

One of the consequences of introducing the concept of JCS is the changing view of accustomed function allocation ideology in human-machine systems. Instead, the search for function congruence is a preferable approach in human-machine systems compared to functions allocation between human and machine (computer):

"The principle of function congruence emphasises that the functions assigned to various parts of the system must correspond to each other and provide the ability to redistribute functions according to current needs, … keeping in mind that the primary objective is the ability of the joint system to maintain control" (Hollnagel, 1999, p. 52-53.).

When we are speaking about a system and its environment, we implicitly presuppose the existence of defined system boundaries. Hollnagel (2007, p. 412) characterizes the dependence of the boundaries of the JCS both from the purpose of the analysis and the purpose of the JCS itself:

"The point … of systems definition in general, is to emphasize that there is no 'natural' way of setting the boundary between a system and its environment: it depends on the purpose of the analysis. It follows from the principles of CSE that the boundaries may be based on systems functions rather than on systems structures, i.e. on what a system does rather than on what it is."

Accordingly, those objects of the system, which can be effectively controlled by the JCS and which are important for the ability of the JCS to maintain control, are included in the JCS. Hollnagel (2007) emphasizes that in the transition from controlled to free flight changing responsibilities of pilots and ATCos will change the boundaries of their respective JCSs.

3.4 Human-centred versus function-centred design

For some time already the principles of human-centred system design have been questioned. Winograd and Woods (1997) have explained that there is no single criterion or feature which determines human-centred design. Among many aspects of human-centeredness there are some, specific to this approach: attempts to satisfy human needs; keeping human “in the loop”, i.e. making human a substantial or main control agent of the system; making the technical part of the system to interact with human; improving human performance, be it individual or collective one.

According to Winograd and Woods (1997) the system design should be problem-driven, activity-centred and context bound. Such refocusing puts the systems with their functions into the focus of design, moving technology and human (as a user) to the background. This approach can be understood as the natural reaction of dissatisfaction with the initial technology-centred and subsequent human-centred design concepts. Technology-centred and human-centred approaches to design have not succeeded at least partly because of their inherent opposition of one to the other.

Hollnagel (2006) describes the changing situation, explaining that interest in human-centred design is usually an indication that things have got out of hand – i.e., that technology has become so complex that the human capacity for coping with the system has been exhausted both from the point of the view of the operator and the designer.

The resulting new function-centred approach shifts the functions of the system into focus of the design, positioning itself in the middle between technology-centred and human-centred approaches. The purpose of design is therefore no longer the facilitation of the interaction between human and machine, but rather to ensure the effective functioning of the joint operator-machine system. This kind of effective functioning asks for coagency rather than interaction between human and machine components of the system (Hollnagel and Woods, 2005). When taking as an example a joint driver-vehicle system design, Hollnagel (2006) states that any driver-vehicle system is designed to provide a specific function and its design should be centred on that function, with the overriding concern, how the joint driver-vehicle system can remain in control. It is obvious, that the joint pilot-aircraft system should be looked at in the similar way.

3.5 Human in command

Being in command of a socio-technical system (or joint cognitive system) means having a control over the functions of the system. To control the functions it is necessary to have a model of the system under consideration. This means that for human in control the functional model of the system is needed, which allows the human to apply both proactive control (feedforward) and reactive control (feedback) to the system functioning. It is also important to remember, that in socio-technical system the performance of the parts and of the system as a whole is not bimodal, but can vary depending on the situation and resources available (Hollnagel, 2008).

As Hollnagel explains it, the performance in a socio-technical (or joint cognitive) system may sometimes be better than normal, and sometimes worse, but the complete failure is exceedingly rare. Such situation is dependent on the fact that these systems are always underspecified to some degree. This incompleteness of the specifications can be compensated by variability in the system’s internal performance. The quality of this performance depends on how well the variability can be managed in a given situation, rather than on the suppression of variability. Accordingly, an adequate notation of a socio-technical (or joint cognitive) system must be able to describe how the system functions, rather than how it is structured. The functioning of the human in controlling the system is explained by the Extended Control Model (see below).

3.6 Extended Control Model by Hollnagel

Hollnagel has developed the idea of extended control in several publications (Hollnagel, 2003, 2006, 2007). The extended control means that control takes place at several levels simultaneously, including tracking, regulating, monitoring and targeting layers. At all these levels the control includes the current state, the desirable state, activity towards transforming the current state into desirable state and assessing the effect of activity onto achievement towards the desirable state. At lower levels of extended control compensatory control (feedback) prevails, but at higher level there is more anticipatory control (feedforward). The aim of the extended control is to explain the effective functioning of the joint human-machine cognitive system through coagency rather than through interaction. The nature of proposed extended control can be better explained graphically by Extended Control Model (ECOM, Figure 1).

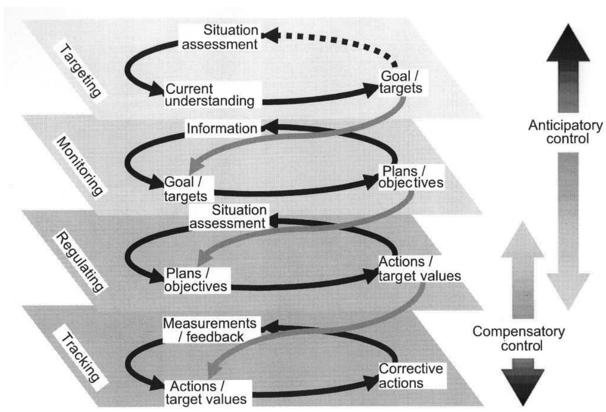

Figure 1. Extended Control Model (Hollnagel 2007, Fig. 7.)

ECOM functions on several layers of control simultaneously, through concurrent control loops. Some of these are closed (reactive), some are open (anticipatory), and some are mixed. The assumption of multiple layers of activity is crucial for the modelling approach. The author indicates that although there is no theory that formally defines the number of layers, practice has shown that four layers are sufficient for explaining JCS performance.

Each layer functions (maintains control) through basic “construct – action – event” control cycles. ‘Construct’ represents current understanding of the situation with anticipation and expectations, what happens next; ‘action’ represents the decision made and ‘event’ represents the result of the action, which gives the feedback to continue the cycle. If the events match the expectations, they reinforce the construct and if there is a mismatch, the ‘construct’ has to be modified. Besides “regular” events there may be also unexpected events, e.g., due to disturbances in the system, which may demand modifications of the ‘construct’.

3.7 The four layers of control in Extended Control Model

For better understanding of the Extended Control Model functioning, it is necessary to discuss the four control layers, which constitute the heart of the model. The control layers are explained as follows (Hollnagel, 2003, 2006, 2007):

* The tracking layer describes the activities required to keep a JCS inside predetermined performance boundaries, typically in terms of safety or efficiency. Tracking is closed-loop and activities at the tracking layer usually are performed in an automatic and unattended manner.

Examples of tracking layer activities from vehicle driving domain would be low-level driving procedures required to maintain speed, distance from other cars in front and behind, relative or absolute lateral position etc.

* The regulating layer describes the activities by which a JCS achieves short-term goals, such as specific manoeuvres relative to the environment (which need not be physical space). It also provides the goals and criteria for the tracking layer. Although regulating itself basically is a closed-loop activity, it does not always run smoothly and automatically but may require attention and effort together with some anticipatory control.

In vehicle driving example the regulating layer may be seen as maintaining or achieving target speed, specific position or movement relative to other vehicles etc. Regulating layer involves a number of tracking layer activity loops, which need the driver’s attention to what he/she is doing.

* Whereas activities at the regulating layer may lead to either direct actions or goals for the tracking layer, activities at the monitoring layer are mainly concerned with setting objectives and activating plans of actions. In flight this can involve monitoring the condition of the aircraft, although it has in many cases been taken over by automation, or monitoring the state of the environment.

In driving example the monitoring layer is used for keeping awareness of the state of the joint driver-car system (availability of resources, condition of the driver and of the car), location of the car relative to the driving environment (traffic flow, hazards), monitoring traffic signs (indications, warnings, restrictions) and generating the plans and objectives to be used at the regulating and tracking layers.

* The last type of action occurs at the targeting layer. In free flight, the targets or goals may refer to route selection, speed, flight path, and altitude. Some goals may give rise to several sub goals and activities, which possibly can be automated or supported in some way. Other goals have to do with criteria for acceptable performance. Goal-setting is distinctly an open-loop activity, and assessing the change relative to the goal is not based on simple feedback, but rather on a loose assessment of the situation – for instance, proximity to target. When the assessment is done regularly it may be considered as part of monitoring and control.

In driving example the destination and driving criteria are generated at the targeting layer. Targeting is implemented by non-trivial set of actions and may take extended period of time to complete. Targeting is better seen in irregular actions like estimating the arrival time to destination or predefined landmark, mental modelling of alternative trajectories, estimation of general progress in the journey etc.

3.8 Human-system integration perspectives

Independently of the chosen approach in the future A^3 ConOps human factors improvements it is important to map the past, the current situation and development tendencies of human-system integration views, as they mark the possible new ways of integration of theoretical concepts into the future applications.

In section 3 the changing views of human and system integration have been shown. These views include focussing on joint cognitive systems, on function-centred design instead of technology-centred or human-centred design; on function congruence instead of function allocation between human and machine; on conceptual shift from interaction to coaction between human and technology. At the same time it must be said that the function-centred design principles have not been proven to work for designing complex operations in ATM. In ATM the number of joint cognitive systems is so large that nobody has been able to capture this well in the function-centred design approach. It will be a major research effort to develop proper methodology how to do so. This means that although the function centred approach seems appealing, it also seems to be out of reach for the iFly project itself to apply the function-centred design approach in the refinement of the A^3 ConOps.

Although these developments seem very promising and may strongly influence the future approaches to human-system integration, it is premature to neglect all the work done in accepted so far theoretical framework of human-centred approach to human-automation interaction. On this purpose the next two broader sections are devoted to human-centred views of human automation interaction problems and strategies of its enhancement, which may provide useful solutions in the process of A^3 ConOps development both in iFly timeframe and beyond it.

4 Human-Automation Interaction: Main Problems

In the development of decision support tools considerations regarding automation, especially how automation can support human decision makers in the most efficient and effective way, and which level of automation is appropriate for the envisioned support tool, are of utmost importance.
Definitely, automation can bring many benefits to the aviation domain, e.g. reduced flight times, and increased fuel efficiency (Nagel 1988). It promises lower workload, decreased training effort, fewer human errors, and greater efficiency. But does it deliver what it promises? Unfortunately, the answer is: not always.

4.1 Automation-related problems

Since automation is often designed to replace the human instead of supporting the human in several tasks it often fails to provide the expected benefits as stated above, by transforming an existing job and introducing a new set of tasks, where operators receive inadequate or no feedback at all. Such automation would also fail to support the human in one of its strengths: the ability to handle unexpected situations (Lee, 2006). Humans are not able anymore to track the activities from the automated tools. Resulting questions might be: what is it doing now, why did it do that, or what is it doing next (Wiener, 1989). Some of the problems related to automation as described above are presented in the following list (see Wiener and Curry, 1980, for a more comprehensive list of automation-related problems) and discussed briefly in the subsequent paragraphs:

- Out-of-the-loop unfamiliarity
- Clumsy automation
- Automation induced errors
- Behavioural adaptation
- Complacency, automation bias, commission errors and omission errors
- Distinction between data availability and observability
- Inadequate training and skill loss

4.1.1 Out-of-the-loop unfamiliarity

Out-of-the-loop unfamiliarity describes situations where humans are not able anymore to detect automation failures and to resume manual control (Endsley and Kiris, 1995).

Even though automation can be designed to be highly reliable for several known conditions, there will always be unplanned variations in operating conditions, erroneous or unexpected behaviour of the automation or the human, malfunctions of involved systems, etc. (Parasuraman and Riley, 2000). In A^3 for example one of the main factors to be considered when designing decision support tools is the inherent unreliability of predicting the future. There will always be a number of scenarios where the automation might take an incorrect assumption or even decision. In such conditions the human operator would be required to step in and recover this situation. Would the human in such a case succumb out-of-the-loop unfamiliarity, he / she would not intervene successfully and/or in a timely manner.

In general it can be stated, that the out-of-the-loop unfamiliarity originates from intermitted feedback that decreases situation awareness, the ability to establish correct expectations, and the ability to control the system manually (Lee, 2006). Automation often comes along with reduced feedback available for the operator due to an introduced distance between the operator and the system with its inherent processes.

For example, in A^3 environment it might be important to give informal feedback about the information which is taken into account for route calculations in order to avoid a conflict, changes in the information status (e.g. intent vs. state information; accuracy of information; etc.), or about consequences of action implementation (e.g. how will the new route look like), or probably to inform the crew in case the other aircraft involved in the conflict has started to resolve this conflict.

Monitoring the performance of an automated system is also a very important task a human should be able to accomplish. Due to automation this task has changed from an active monitoring, where the gathered information actively supports control, which in turn guides the perception, to a passive monitoring, which disrupts the cycle just described. In an A^3 environment it might be important to give the crew an insight in the system status and announce the changes in the status of the system, to allow the crew to actively react on the bases of information gathered during the monitoring process in case the automation fails.

Automatic control might further lead to a disengagement of the operator while drawing direct attention to other activities, compromising further the feedback from the system. The operator might completely rely on the automation, especially when multitasking is demanded (Parasuraman et al., 1994).

Furthermore, it is important to design the automation considering control strategies and mental models of the human operator. If the algorithms are not associated with the mental model of the operator it will be difficult for the human to anticipate actions and limitations of the automation. Regarding A^3, the algorithms providing conflict resolution manoeuvres should propose manoeuvres which are within the performance limits of the aircraft, and should use manoeuvres which assure flight comfort, and are similar to those manoeuvres pilots are used to perform also during flights in a non-A^3 environment. Changes in speed, heading, altitude must be proposed within reasonable limits and should be in accordance with the mental model of a pilot. If the algorithms are consistent with the mental model, the pilot is able to detect errors in the automation much easier and faster.

4.1.2 Clumsy automation

Wiener (1989) coined the term “clumsy automation”. It describes situations in which automation makes easy tasks easier and hard tasks even harder. Very often easy tasks are automated but not the difficult ones. This involves some kind of logic: It is not easy to automate difficult tasks, and the question of how to automate these tasks often can’t be solved by the designers. This leads to the effect that workload is even more reduced in periods with already low workload, whereas workload increases even more during high workload phases. Automation of easy tasks leads, in many cases, to the fact that operators are less experienced and have insufficient knowledge about the context in order to handle difficult tasks. Bainbridge (1983) found that clumsy automation supports the bias of operators to become overconfident in automation. Operators tend to delegate tasks more often to automation in periods with low workload than in periods with high workload.

4.1.3 Automation induced errors

One of the leading thoughts behind the introduction of automation is the belief that it would reduce or even eliminate human errors. However, the sad truth is that automation-induced errors have been causal factors in several aviation accidents. “*Automation often extends the scope of human actions and delays feedback associated with these actions. As a consequence, human errors may be more likely to go undetected and do more damage*” (cf. Lee, 2006, p.1572). E.g.: In case a pilot inserts an incorrect waypoint into the FMS, this error might become apparent from several minutes to even hours later. Such a long delay between error generation and its detection increases the probability that the error is being detected too late and can’t be fixed anymore.

Especially in an A^3 environment designers should keep an eye on the possibility of “*brittle errors*” induced by automation. “*Brittle failures are typical of human-automation interactions in which novel problems arise or even simple data-entry mistakes are made with systems that completely automate the decision process and leave operators to assess the automation’s decision*” (cf. Lee,2006, after Roth et al., 1987; Roth and Woods, 1988). Such failures arise do to the fact that designers can’t anticipate and design a system which includes all possible situations and is valid for all of them. Smith et al. (1997) has shown in a design study for a flight planning tool that recommendations presented by the automation in an early phase of the operators problem evaluation phase have a significant impact on the operators’ decision process. It also influences the operators’ situation assessment and the evaluation of other possible solutions. Due to the fact that algorithms might lack the flexibility to consider real-time data and refer to e.g. weather forecasts, already published restricted areas than actual data which might differ from the forecast, can induce poor decisions.

4.1.4 Behavioural adaptation

Humans are very quick in adapting to different situations and try to take an advantage of a situation, and of the whole system they are related to. In terms of automation behavioural adaptation might lead to the effect that operators may somehow undermine the designers' intention to increase safety, efficiency or performance by reducing their own effort and giving more responsibility to the automation. With respect to decision support tools operators tend to use them rather for reducing their own effort than for enhancing their decision quality.

4.1.5 Complacency, automation bias, commission errors and omission errors

One of the main results of automation is keeping operators out of the direct control of processes. This means that the operators are often put into the position of comparatively passive observer whose main task is to monitor and control what the automation is doing. Such change of operators' functions and responsibilities from doing to monitor and control has a number of benefits, but also disadvantages. One of these disadvantages is a misuse of automation, i.e., an uncritical reliance on the proper function of an automated system without recognizing its limitations and the possibilities of automation failures. An important behavioral aspect of this misuse is reflected in an insufficient monitoring and checking of automated functions, i.e., information on the status of the automated functions is sampled less often than necessary. This phenomenon has commonly been referred to as "automation-induced complacency" or just "complacency" (Bahner et al., 2008)

This kind of complacency can include a loss of situation awareness (Endsley, 1995) and an elevated risk that operators fail to detect and manage automation failures in due time. According to Funk et al. (1999) complacency belongs to the five most important negative issues of cockpit automation and has been identified as a contributing factor to numerous incidents and accidents in civil aviation.

In the use of automated decision aids the similar "automation bias" has been described (Mosier et al., 1998, 2001). One kind of automation bias in the use of such aids involves "commission errors" which occur when operators follow a recommendation of an automated aid even though this recommendation is wrong. Commission errors can be the result of not seeking out confirmatory or disconfirmatory information, or discounting other sources of information in the presence of computer generated cues. Following the aid's recommendation without verification seems to reflect an effect, which directly corresponds to complacency in automation monitoring. The latter alternative (discounting other sources) clearly reflects some kind of bias in decision-making. Having contradictory information from different sources, the operator decides for some reason to trust what the automated aid provides, without cross-checking its validity against other available and accessible information.

Automation "omission errors" result when decision makers do not take appropriate action because they are not informed of an imminent problem or situation by automated aids. Typical omission errors happened, when the crews had delegated a task to automation, without checking other cues to catch inconsistencies or mistakes in task performance.

Results of Bahner et al. (2008) from their experimental procedure provide clear evidence for complacency, reflected in an insufficient verification of the automation, while commission errors were associated with high levels of complacency. Hence, commission errors seem to be a possible, albeit not an inevitable consequence of complacency.

The authors found that exposing operators to automation failures during training significantly decreased complacency and thus represents a suitable means to reduce this risk, even though it might not avoid it completely. Potential applications of this research include the design of training protocols in order to prevent automation misuse in interaction with automated decision aids. This result should be considered in all kinds of training for A^3 concept implementation and functioning.

4.1.6 Distinction between data availability and observability

The increased complexity, autonomy and silent automated system (at least at some detailed level of information processing) produces a gap between data that can be displayed and data that can be actually and effectively observed by the crew, integrated and understood, given their ongoing tasks and attention demands.

Observability refers to the cognitive work that crew needs to do to extract meaning from available data. It results from the interaction between the user which knows when to look and what to look for at what point of time. The right level of automation support requires new forms of feedback, emphasising an integrated dynamic picture of the current situation, automation activities, and how these may evolve in the future (Dekker & Woods, 1999). This means that the presented feedback to the crew should include the proper amount of information including the ‘intention of the automation’ to help them in getting the ‘big picture’.

4.1.7 Inadequate training and skill loss

It should be also mentioned that automation might degrade the operators’ ability to perform specific tasks which were previously done by the operator but then taken over by the automation. Operators would not have the possibility anymore to train their skill regarding these tasks and would not be able to step in while the automation fails. The autopilot gives a very good example for this problem. Pilots relying too much on the autopilot don’t practice their “manually flying” skills. This could have dramatic consequences in case of an automation failure. It’s important to state that reliance on automation should support, but not replace human reasoning and decision making.

5 Human-Automation Interaction: Strategies for Enhancement

Beforehand it should be said that automation is not a uniform technology. There are different types of automation with different levels of complexity which all come along with different design issues and challenges.

* * *

The preceding paragraphs focused on some problems which are highly related to automation and should be considered when designing support tools for an A^3 environment. Since this is a very ambitious task and is not as easy as it might seem on the first sight, the following paragraphs will focus on automation itself and try to provide a framework or strategies for how to enhance human-automation interaction by using a human centred design approach, suggested by ICAO.

5.1 Human Information Processing stages

In the Self Separated Airspace the aircrew will intermittently interact with a computer, will receive feedback and will provide commands to a controlled process or task environment, which is in turn connected to the aforementioned computer. The crew will act like a “Human supervisory control”. This function is mainly characterized by decisions which must be made under time pressure with little or no room for errors. But how can automation support human decision makers best, and what level of automation should be introduced into a decision support system?

Taking the above mentioned into account, it is plausible to relate to human information processing functions. Information acquisition, information analysis, action selection, and action implementation are the main information-processing functions and allow describing human and automation functions in a common language (Lee, 2006; Parasuraman and Sheridan, 2000). Different types of automation correspond to each of the four functions, whereas different degrees of automation are possible for each of them. The four types of automation, namely:

- Information Acquisition Automation
- Analysis Automation
- Decision Automation, and
- Action Automation

are described in the following subsections.

5.1.1 Information Acquisition Automation

Automation in this information processing phase refers to sensing and registration of data, complementing the operators’ sensation, perception and attention processes. An example of low level of automation might be a predetermined pattern of the ways of information acquisition. E.g. in A^3 designers might define a specific patter, when which information will be gathered and from which source. Highlighting specific aircraft on a CDTI, highlighting parts of the incoming information, or organizing incoming information regarding surrounding aircraft with reference to some predefined criteria, characterize moderate levels of information acquisition automation because organization and highlighting preserve the visibility of the raw data. This enables the crew to focus their attention to information which they perceive as the most important. By contrast, filtering of information represents a high level of automation due to the fact that the operator is forced to draw his/her attention to information which the automation determines to be relevant (Parasuraman et al., 2000).

5.1.2 Analysis Automation

Automation in this phase of the process complements cognitive functions like working memory and inferential processes, supporting situation assessment and the diagnostic analysis of the information/situation. At a low level, algorithms can be used to make an extrapolation over time, or predictions regarding incoming data. For A^3 this could mean the depiction of a projected future course of other aircraft in the neighbouring airspace.

Integration, whereby several input variables are combined into a single value, would represent a higher level of automation. An example for this level of automation would be a display with an emergent perceptual feature. With respect to A^3 this might be a change of colour of a line which depicts the trajectory of a surrounding aircraft. The yellow colour for example might indicate that the corresponding aircraft/this trajectory might cause a conflict if the “conflicting aircraft” doesn’t change its intent within a defined time period. Such a feature would augment the attention and cognition of the aircrew.

5.1.3 Decision Automation

Decision automation suggests or decides on actions by using assumptions about the state of the world, costs, and values of possible actions (mainly depending on the designers what can be taken into account).

Sheridan (1992) proposed a scale with 10 levels which refers mainly to automation of decision and action selection, or output functions of a system (Table 3).

Table 3. Levels of Automation for decision and action selection

	Automation Level	Description of Levels of Automation of Decision and Action Selection
High	10	The computer decides everything and acts autonomously, ignoring the human.
	9	Informs the human only if it, the computer, decides to.
	8	Informs the human only if asked, or
	7	executes automatically, then necessarily informs humans, and
	6	allows the human a restricted time to veto before automatic execution, or
	5	executes that suggestion if the human approves, or
	4	suggests one alternative, and
	3	narrows the selection down to a few, or
	2	the computer offers a complete set of decision/action alternatives, or
Low	1	The computer offers no assistance: human must take all decision and actions.

For example: a conflict and resolution system that notifies the aircrew of a conflict between ownship and another aircraft and suggests one resolution would qualify as level 4 automation. A Ground proximity warning system (GPWS) is positioned at level 4, in which a single manoeuvre is recommended, but the pilot can choose to ignore it. An automatic ground collision avoidance system for combat aircraft is designed at level 7, in which automation will automatically take control if the pilot doesn't (Scott, 1999). Expert systems for example are usually designed with conditional logic, e.g. there are determined rules of route planning for pilots to avoid bad weather (Layton et al., 1994).

5.1.3.1 Distinction between Decision Support Systems and Directive Decision Devices

Concerning automation and division of functions between human and automation the congruence of functions carried out by automation and human should be the aim (Hollnagel, 1999). In this aspect a useful distinction has been recently made by Sutherland (2008). Although implicitly known and by default accepted long time already, Sutherland explicitly made a distinction between well-known Decision Support Systems (DSS) and until now little discussed Directive Decision Devices (DDD). As Sutherland (2008, p. 1069) states:

"The typical DSS will have been authored at the instigation of, or at least with the accession of, its prospective users. A DSS is then expected to maintain an advisory or otherwise assistive attitude towards its users. The corollary is that resource to a DSS is volitional. Decision support systems, that is, will be

employed at the discretion of those they are designed to serve. Not so with a DDD; resource to directive decision devices is always mandatory. This follows from their origin. A DDD will have been commissioned by a higher-order administrative authority and subsequently imposed on a subordinate, with one of two ends in mind:

- enabling the replacement of human functionaries by computer-centred artefacts in the interests, variously, of consistency, economy, objectivity, compliance or any of several other criteria.

- extending the effective administrative reach (or span of control, if you will) of those sitting at the apex of organizational hierarchies. In this way, problematic though it may be, directive decision devices can propose to put automation in service to autocracy."

Considering the two types of systems described above and mapping them onto the systems which are already applied on today's flight deck, ACAS fulfils all the requirements to be qualified as a DDD. This system is designed in a way that it doesn't allow decisional scope. Regarding the resolution of a conflict, there is just one single possibility presented to the crew which they have to follow – no freedom to ponder among possibilities – as there is simply not enough time for this.

For safety purposes, it is recommended that the aircrew always remains in the decision making loop, while automation shall only serve as a decision aid. The extreme examples of DDD like ACAS above should be applied in extreme situations, for which human resources remain inadequate.

5.1.4 Action Automation

Automation at this information processing level supports the activity of an operator in implementing a decision, executing a response, respectively. It involves different levels of machine execution of the choice of action, and typically replaces or extends the functions of hand or voice of the human. Different levels of action automation may be also defined by the relative amount of manual versus automatic activity in executing the response. On a flight deck for example an uplinked flight plan can be automatically loaded into the flight management system by a single key press instead of entering the data manually (which might be very time consuming).

Olson and Sarter (2000) examined pilots' preferences for and their operational experiences with 3 different strategies: management-by-consent (automation acts only with the consent of the operator), management-by-exception (automation initiates actions on its own), and full automation. Under low up to medium workload levels pilots preferred the management-by-consent strategy, while they tended to prefer management-by-exception under high time pressure, high workload, and low task criticality.

At this point it must be mentioned that the 4-tier model of information processing (Information acquisition, Information analysis, Decision making, and Action implementation representing the 4 tiers) doesn't consider yet two very important factors: feedback and implicit control. Boyd's (1996) model of the information processing process includes these two characteristics (see Figure 2).

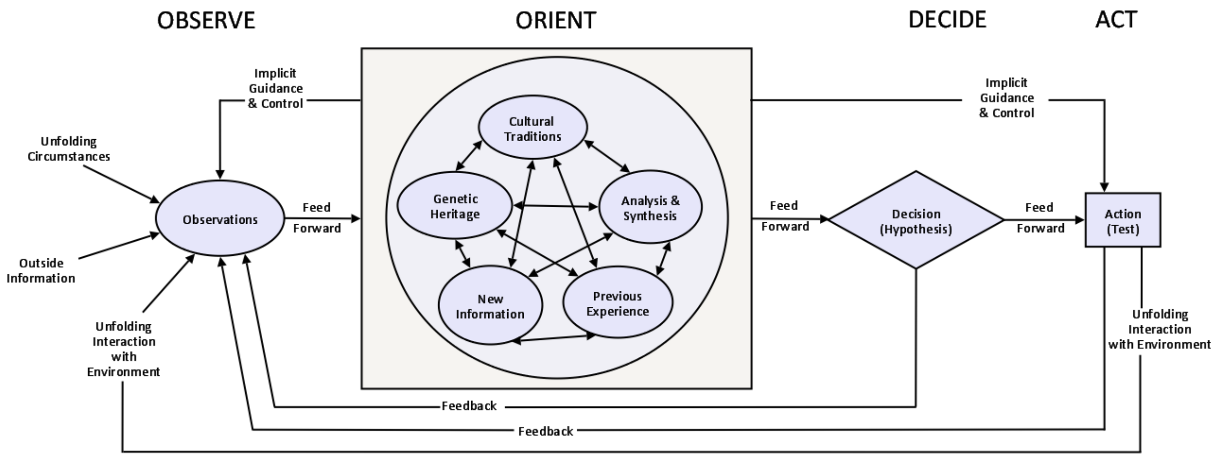

Figure 2. Boyd's OODA loop

The 4 stages in Boyd's model correspond to the four stages of information processing described before. Also, here automation can be applied in all stages and at different levels of automation. Implicit control is a background process and refers to actions based on emotion and intuition, and feedback is the concept meaning, that not every single decision has to become actions (Proud et al.). In A^3 such a feedback loop might be considered when two aircraft are involved in a conflict, and initially both aircraft are "working" on a resolution of the conflict, but due to a change (an increase or decrease in priority of one aircraft) the aircraft with higher priority is not required to implement the decision anymore.

5.2 Information processing – estimation of time

The following paragraphs shall give an impression on how much time might be needed to run through the information process, and is based on a study related to ERASMUS (Kolcarek et al., 2009).

ERASMUS is an autonomous, ground-based computer system which continuously monitors, assesses, and determines which aircraft will experience a loss of separation up to 15 minutes into the future, by using 4D (position and time) trajectory data. It is focused on using trajectory-based operations specifically in the en-route phase to provide strategic de-conflicting of aircraft and separation management. ERASMUS can be seen as a decision-support tool for conflict detection and resolution with humans directly involved in resolution and management of conflicts which ERASMUS does not address. When a loss of separation is anticipated, ERASMUS will issue clearances that will contain Required Time of Arrival (RTA) commands which will be communicated to the selected aircraft via the Controller Pilot Data Link Communication (CPDLC) channel. To meet the RTA, the pilot must modify the aircraft's vertical and/or horizontal airspeed. On the airborne side the system architecture relies on the flight management system (FMS) which can receive an up-link message from the ERASMUS solver. The whole clearance can then be directly loaded into the secondary flight plan. The CD&R services are performed periodically and each iteration is limited to 3 minute time intervals, which also mean, that the solution provided to the crew is valid for the next 3 minutes. The aircrew is directly interacting with ERASMUS (i.e. accept/reject the RTA clearance generated by ERASMUS). The success of ERASMUS highly depends on the ability of the crew to respond to and implement the messages in time. If the pilot doesn't respond in time, ERASMUS assumes that the proposed clearance was rejected. The whole process (airborne transaction time, ATT), which is limited to 3 minutes (see Figure 3) contains the following successive system and pilot tasks:

- Time required to uplink an ERASMUS generated RTA clearance to the aircraft
- T1 – Time required to notice and read the newly up-linked clearance
- Built-in delay to downlink the STANDBY response (15s)
- T2 – Time required to process the clearance and make a decision plus 5s for built-in delay of automatic loading into the secondary flight plan
- Built-in delay for downlink WILCO response (15s)
- T3 – Time required to activate the secondary flight plan

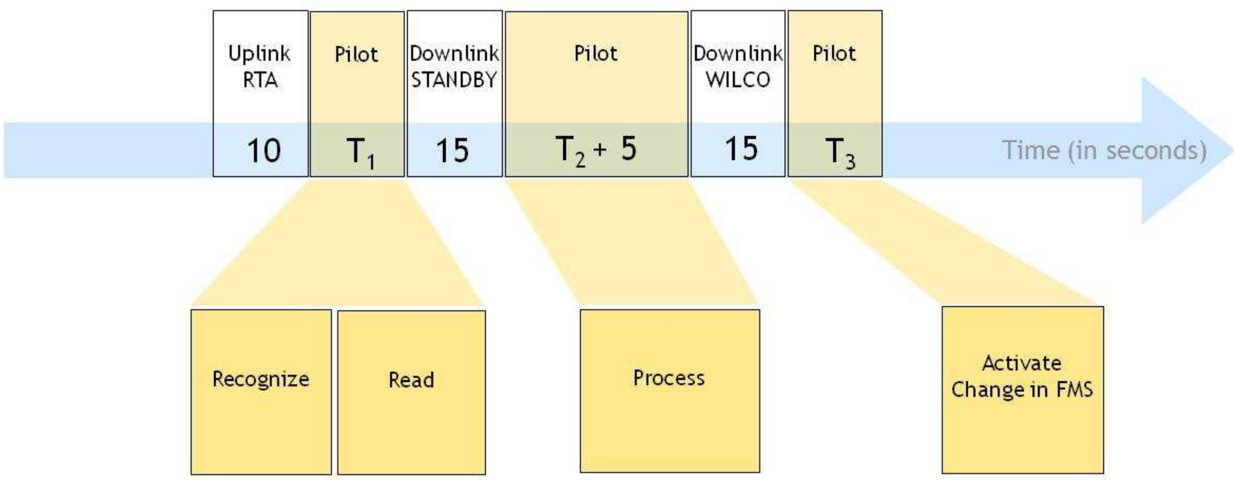

Figure 3. Depiction of the CPDLC and RTA Task Timeline

In an experiment with 11 pilots participating, T1, T2, and T3 were analyzed in detail, since they depend entirely upon human performance. Results regarding time needed for several subtasks are depicted in Table 4.

Table 4. Components of airborne transaction time

	Mean	Median	Min. value	Max. value
Notice time	8(s)	6(s)	3(s)	29(s)
Reading time	15(s)	13(s)	2(s)	60(s)
Processing time	68(s)	59(s)	26(s)	148(s)
Secondary flight plan activation time	10(s)	6(s)	2(s)	58(s)
Total	104(s)	95(s)	61(s)	200(s)

The first component, “Notice time”, refers to the time necessary to recognize the presence of the data-link clearance. “Reading time” refers to the time needed to review the clearance – this time is measured from pressing the ATC button (which is announcing a new data-link message) until the time of pressing the SEND button of the STANDBY response. The “Processing time” is the time required to load the RTA into the secondary flight plan, preview the impact of the RTA in the secondary flight plan, and making a decision (belongs to T2 interval). This time is measured from the completion of downlink STANDBY until pressing a button which down-links the WILCO/UNABLE response.

In a questionnaire after the experiment one question was dedicated to the awareness of the conflicting traffic on a display. It must be sure that the pilots are able to faultlessly identify the conflicting aircraft.

Regarding the human point of view the notice time (~8s), the reading time (~15s) and the clearance processing time (~83s) were considered as relevant. Most of the time was spent on processing the clearance, including loading the RTA into the secondary flight plan, reviewing the secondary flight plan, and making a decision whether to accept or reject the ERASMUS clearance.

From a Human factors point of view ERASMUS and the associated tasks are more or less simple to handle. ERASMUS is proposing one solution to a given problem and already provides the crew with a change to the flight plan which can be either accepted or rejected. Considering this as relative “simple” it’s important to state, that taking the maximum values for the whole information process it took about 3min to handle the ERASMUS clearance. Transferring this result to A^3 it will be very important to think about such a timeline with respect to solving a conflict. The analysis/processing time might be much longer due to the complexity of the problem. This definitely affects the algorithm behind, especially the conflict resolution algorithms. Designers of these algorithms must consider that the crew will need some time to process this information, which means, that the proposed solutions should be valid for at least this period of time and longer. One must also consider possible delays between the CDTI Alert logic and the Flight Crew, delays between Flight Crew and Aircraft Dynamic, delays between Flight Crew and Flight Crew, or even aircraft and aircraft, and especially delays between ground support (SWIM) and the onboard system. So the update-cycle of proposed resolution manoeuvres is a very critical point in A^3, critical to safety. Comprehension of the alert, base reaction time, and the impact of the alerting system on total performance should drive the design of the alert logic module as well as the conflict resolution modules in A^3.

Corker (2000) went even further when he tried to develop a better understanding of the impact of joint and distributed decision making on the size and shape of the alert zones. When modelling the alert zones he considered the shape of the warning zones for different aircraft differently to account for crew response in deconfliction. Furthermore he considered the Crew response time as determining perimeters of warning/alert zones [RT=☐(Perception t) (Decision t) (Communication t) (Neuromotor Response t) / modulation function of intent (expected (+) unexpected (-)], as well as a minimum reaction time similar to TCAS Resolution Alerts (see Corker, 2000 for details).

5.3 Determining Levels of Automation

When designing supporting tools the major question is what level of automation should be applied to each step in the information processing flow. There is no simple answer to this question and tradeoffs between anticipated benefits and costs are likely to occur.

Based on Boyd's' OODA loop, which is described above, a team at NASA Johnson Space Center developed a 8-level scale of Autonomy Assessment covering each of the OODA categories (i.e. observe, orient, decide, act – comparable to the 4-tier model described beforehand). Level 1 corresponds to complete human responsibility; level 8 corresponds to complete computer responsibility. Each level of autonomy scale is tailored to fit the tasks encompassed by the function type (Observe, Orient, Decide, or Act). E.g. the levels in the "Observe" column refer to gathering, monitoring, and filtering data; the levels in the "Orient" column refer to deriving a list of options through analysis, trend prediction, interpretation and integration; the levels in the "Decide" column refer to decision-making based on ranking available options; and the levels in the "Act" column refer to execution or authority to act on the chosen decision.

On levels1-2, the human is primary and the computer is secondary actor. On levels 3-5, the computer operates with human interaction. On levels 6-8 the computer operates independently of the human and the human has decreasing access to information and decreasing override rights. Understanding the differences between the levels is critical to interpreting them correctly. To understand a particular autonomy level requires referencing the entire scale to see how each level is different from the next, rather than focusing solely on a particular level. See NASAs' Level of Autonomy Assessment Scale in Table 5. The following paragraphs might give an idea how the scale could be applied to A^3 support tools.

Table 5. NASAs' Level of Autonomy Assessment Scale

Level	OBSERVE	ORIENT	DECIDE	ACT
8	The computer gathers, filters, and prioritizes data without displaying any information to the human	The computer predicts, interprets, and integrates data into a result which is not displayed to the human.	The computer performs ranking tasks. The computer performs final ranking, but does not display results to the human.	Computer executes automatically and does not allow any human interaction
7	The computer gathers, filters, and prioritizes data without displaying any information to the human. Though, a "program functioning" flag is displayed.	The computer analyzes, predicts, interprets, and integrates data into a result which is only displayed to the human if result fits programmed context (context dependant summaries).	The computer performs ranking tasks. The computer performs final ranking and displays a reduced set of ranked options without displaying "why" decisions were made to the human.	Computer executes automatically and only informs the human if required by context. It allows for override ability after execution. Human is shadow for contingencies.
6	The computer gathers, filters, and prioritizes information displayed to the human.	The computer overlays predictions with analysis and interprets the data. The human is shown all results.	The computer performs ranking tasks and displays a reduced set of ranked options while displaying "why" decisions were made to the human.	Computer executes automatically, informs the human, and allows for override ability after execution. Human is shadow for contingencies.
5	The computer is responsible for gathering the information for the human, but it only displays non-prioritized, filtered information.	The computer overlays predictions with analysis and interprets the data. The human shadows the interpretation for contingencies.	The computer performs ranking tasks. All results, including "why" decisions were made are displayed to the human.	Computer allows the human a context-dependent restricted time to veto before execution. Human shadows for contingencies.
4	The computer is responsible for gathering the information for the human and for displaying all information, but it highlights the non-prioritized, relevant information for the user.	The computer analyzes the data and makes predictions, though the human is responsible for interpretation of the data.	Both, human and computer perform ranking tasks, the results from the computer are considered prime.	Computer allows the human a pre-programmed restricted time to veto before execution. Human shadows for contingencies.
3	The computer is responsible for gathering and displaying unfiltered, un-prioritized information for the human. The human still is the prime monitor of all information.	Computer is the prime source of analysis and predictions, with human shadow for contingencies. The human is responsible for interpretation of the data	Both, human and computer perform ranking tasks, the results from the human are considered prime.	Computer executes decision after human approval. Human shadows for contingencies.
2	Human is the prime source for gathering and monitoring all data, with computer shadow for emergencies.	Human is the prime source of analysis and predictions, with computer shadow for contingencies. The human is responsible for interpretation of the data.	The human performs all ranking tasks, but the computer can be used as a tool for assistance.	Human is the prime source of execution, with computer shadow for contingencies.
1	Human is the only source for gathering and monitoring (defined as filtering, prioritizing, and understanding) all data.	Human is responsible for analyzing all data, making predictions, and interpretation of the data.	The computer does not assist in or perform ranking tasks. Human must do it all.	Human alone can execute decision.

Conflict Detection modules in A^3 can generally be considered to support the aircrew in the information acquisition process. The tool will be responsible to gather information regarding surrounding aircraft. To minimize visual overload of the crew it might be good to filter the data and depict only important information with respect to the situation. Unfiltered data might be available for the aircrew in case they would ask for (e.g. selecting an aircraft on the CDTI might give access to unfiltered data which might complete the picture and the mental model of the aircrew). Taking this into account, the recommended level of automation is at level 5 or 4, respectively.

The Conflict Processing Module might be considered to support the aircrew in the orientation phase. The tool might analyze the data and make some predictions regarding inherent conflicts. These predictions might be displayed to the crew. Integration, whereby several input variables are combined into a single value, would represent a higher level of automation. An example for this level of automation would be a display with an emergent perceptual feature. With respect to A^3 this might be a change of colour of a line which depicts the trajectory of a surrounding aircraft. The yellow for example might indicate that this aircraft/this trajectory might cause a conflict if the “conflicting aircraft” doesn’t change its intent within a defined time period. Such a feature would augment the predictive perceptual and cognitive abilities of the aircrew. Automation level 4 up to 6 might be taken into account for the design of this tool.

The Mid-Term Conflict Resolution module as well as the Short-Term Conflict Resolution module support the crew in their decision making stage. The most important question here is definitely the one considering how many options should be presented to the crew. Referring to Sheridan’s’ Levels of Automation for decision and action selection it is recommended to level 3 (narrows the selection down to a few) or 4 (suggests one alternative). In case designers consider the automation to be at level 3, then it is recommended to limit the options to 5 or less, based on the capacity of the working memory of humans. In case of limitations given by the situation, e.g. decreased time for decision making, which in turn might lead to emotional arousal, stress etc., 2 options might be the maximum an aircrew should handle. In extraordinary situations the presentation of only one option is recommended. With respect to the list above the automation level might be 6 or 7. It is recommended, in any case, that the action automation doesn’t exceed level 3 with respect to NASAs’ list.

According to Parasuraman et al. (2000) it is proposed that any particular level of automation should be evaluated by examining its associated human performance consequences (e.g. mental workload, situation awareness, complacency, skill degradation) – defined as the primary evaluation criteria. Furthermore secondary evaluation criteria involve automation reliability, ease of system integration, efficiency/safety tradeoffs, manufacturing and operating costs, liability issues, and the costs of decision/action consequences. These evaluation criteria should be applied to evaluate the feasibility and appropriateness of particular levels of automation. Some of the evaluation criteria are described in the following paragraphs.

5.3.1 <u>Primary Evaluative Criteria</u>

5.3.1.1 Mental workload

It is known that well designed automation can adjust the mental workload of a human operator in order that it is appropriate for the system tasks that should be performed. Even at the simplest level of automation, organizing information sources, e.g. in form of a priority list, will help the operator to pick information which is relevant to the decision, or data summaries help by eliminating time-consuming search or communication operations. Providing predictive information helps to decrease pilot workload and hazard detection performance improves with the addition of predictive information concerning the flight path of neighbouring aircraft. Data transformation, for example graphic presentation of information (CDTI) can also be beneficial. Transformation and integration of raw data into a form (graphical or otherwise) that matches the operator's representation of system operations has been found to be a useful design principle.

On the other hand automation can also increase workload. This is mainly found when automation is difficult to initiate and/or engage, thus increasing cognitive workload and if extensive data is required, also the physical workload of the operator – the result referred to as clumsy automation (Parasuraman et al., 2000).

5.3.1.2 Situation awareness

Automation of decision making function may reduce operators' awareness of the system and dynamic features of the work environment. Humans tend to be less aware of changes in environmental or system states when those changes are under the control of automation. And if a decision aid, expert system, or other type of decision automation consistently and repeatedly selects and executes decision choices in a dynamic environment, the human operator may not be able to sustain a good "picture" of the information source in the environment because he or she is not actively engaged in the information sources leading to a decision. This might occur in systems where operators act as passive decision makers monitoring a process to determine when to intervene so as to prevent errors or incidents (Parasuraman et al., 2000).

5.3.1.3 Complacency

Reliability plays a major role when discussing the phenomenon of "complacency". In case automation is highly but not perfectly reliable in executing decision choices, then the operator may be inattentive in his/her automation and information sources monitoring task. Hence the probability to fail to detect the occasional times when the automation fails is high. This effect of over trust or complacency is greatest when the operator is engaged in multiple tasks and less apparent when monitoring the automated system is the only task that the operator has to perform. Automation of information analysis can also lead to complacency if the algorithms underlying filtering, prediction, or integration operations are reliable but not perfectly reliable. Automated cuing (attention guidance) can lead the operators to pay less attention to uncued areas of a display than is appropriate. It might be the case that performance suffers much more when unreliable recommendations were given by decision automation than when only incorrect status information is provided by information automation (Parasuraman et al., 2000).

5.3.1.4 Skill degradation

In case the decision making function is consistently performed by automation, the human operator will not be as skilled in performing that function anymore if he/she is required to do so. There is research going on in cognitive psychology documenting that forgetting and skill decay occur with disuse (Rose, 1989). Degradation of cognitive skills may be particularly important following automation failure.

The potential costs – reduced situation awareness, complacency, and skill degradation, solidarily demonstrate that high-level automation can lead to operators exhibiting “out of the loop” unfamiliarity. Each of the above described criteria may pose a threat to safety in the event of system failure. Automation must therefore be designed that such potential human performance costs do not occur (Parasuraman et al., 2000).

5.3.2 <u>Secondary Evaluative Criteria</u>

5.3.2.1 Automation Reliability

Ensuring high reliability is a critical evaluation criterion in applying automation. The use of fault and event tree analysis helps to estimate reliability, and results are helpful as long as they are interpreted cautiously. Automation reliability cannot always be defined in probabilistic terms. Failures may occur not because of a predictable (in a statistical sense) malfunction in soft- or hardware, but because the assumptions modelled by the designer are not met in a given operational situation. The reliability may become degraded especially when the projection into the future is far in time (Long term).

Automation reliability is also an important determinant of human use of automation systems because of its influence on human trust. Unreliability lowers human trust and can therefore undermine potential system performance benefits of the automation. Automated systems might be underutilized or disabled because of mistrust (Parasuraman et al., 2000).

5.3.2.2 Costs of Decision/Action outcomes

When assessing the appropriate level of automation for a decision support tool, one should always consider possible costs which are associated with decision and action outcomes. “*The risk associated with a decision outcome can be defined as the cost of error multiplied by the probability of that error. For decisions involving very little risk, therefore, out–of-the-loop problems are unlikely to have much impact, even if there is a complete automation failure. Such decisions are good candidates for high-level automation. If human operators would have to carry out such simple decisions they would be much overloaded and would prevent them from carrying out other important functions*.” (cf. Parasuraman et al., 2000, p. 292).

Considering time-critical events designers might think of applying a high level of automation of decision selection and action because a human operator might have insufficient time and capacity to respond and act in a timely and accurate manner.

"Full automation requires highly reliable error handling capabilities and the ability to deal effectively and quickly with a potentially large number of anomalous situations. In addition to requiring the technical capability to deal with all types of known error, full automation without human monitoring also assumes the ability to handle unforeseen faults and events. This requirement currently strains the ability of most intelligent fault-management systems" (cf. Parasuraman et al., 2000, p. 292).

It's a fact that decision support tools can be engineered to be highly reliable for a lot of known conditions. But it is also a fact that the conditions an operator is confronted with when acting in the real world vary in an enormous extent. No situation resembles another due to unplanned variations in operating conditions, unexpected or erratic behaviour of other system components or human operators, system malfunctions, etc. This implies that there will always be some conditions under which automation will reach an incorrect decision. If under such conditions of system failure the human operator is required to intervene and salvage the situation, the problem of out-the-loop unfamiliarity may prevent the operator from intervening successfully or in a timely manner (Parasuraman and Riley, 2000; Endsley and Kiris, 1995).

To overcome the aforementioned problem some kind of "error trapping" might be very useful. This means, that the human operator should have at least the chance to review a decision choice taken by the automation which might be not appropriate under the given situation. This need only arises at the last action implementation stage if the previous decision selection stage has been highly automated. But again, the advantages of error trapping should be balanced against additional workload and possible error sources due to often tricky manual data entry (Parasuraman et al., 2000).

In case the resulting system reliability can be proved, high levels of information acquisition and analysis automation can be pursued and implemented.

Regarding decision and action automation, it is recommended to implement high levels of automation only in case of low risk situations.

For all other situations, the level of decision automation should not exceed the level of computer suggesting (but not executing) a preferred alternative to the pilot. For example, in risky situations, where a short term conflict is inherent, conflict resolution automation can provide alternatives to the pilot but should not select one of them without pilots' involvement. If relatively high-level decision automation is implemented in risky situations, it is recommend that some degree of human action be retained by having a moderate level of action automation.

It is recommended to keep in mind that a reduction of automation level can lead to higher workload for the crew. Nevertheless, such a reduction could also lead to a higher level of cognitive engagement of the operator which would then be a more active participant in the decision making process, which in turn would promote critical function performance and situation awareness (Endsley, 1997).

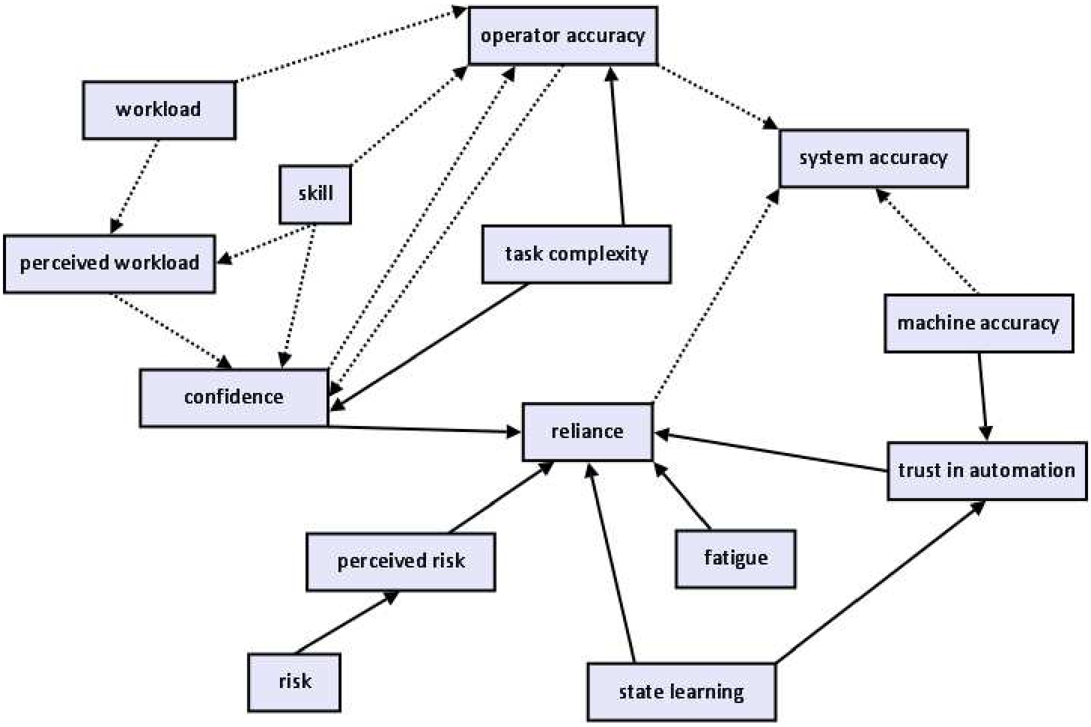

Figure 4. "Interactions between factors influencing automation use. Solid arrows represent relationships supported by experimental data; dotted arrows are hypothesized relationships or relationships that depend on the system in question". (Parasuraman and Riley, 1997, reproduced from Parasuraman R., & Mouloua, M. (Eds.) (1996))

Figure 4 gives an overview of factors and their interaction which have been identified to influence the use of automation by human operators. Designers should want to consider these factors already during development.

6 Concluding remarks

It is stated in SESAR, that

*"Humans will be central in the future European ATM system as **managers and decision-makers**; In the ATM Target Concept it is recognized that humans (with appropriate skills and competences, duly authorized) will constitute the core of the future European ATM System's operations. However, to accommodate the expected traffic increase, an advanced level of automation support for the humans will be required. » (cf. SESAR, 2007).*

The A^3 concept took up the above mentioned statement and introduced the aircrew as managers and decision-makers, supported by onboard tools which will enable them to accomplish their new/ changed tasks. Having this in mind the Human-System Integration was identified as the most important issue to be looked at already at the initial stage of the A^3 ConOps development process, expressed in iFly Project Proposal (iFly, 2006) by including WP2 tasks into the design process.

The present report concludes the tasks solved by WP2 in iFly project. Section 2 of the present report summarizes the human factors issues, which were found in iFly WP2 (in D2.3) to be developed further on in the process of the A^3 ConOps refinement beyond the iFly WP1 D1.3. Section 3 presents the evolution of views on human-system integration, which may be useful in the selection of future human factor approaches to the A^3 ConOps refinement. The sections 4 and 5 propose a framework for system designers which deals with automation issues on a very low level, e.g. with decision support tools like conflict detection and resolution modules and the associated algorithms.

Additionally, recommendations are provided in order to exemplify how the framework might be used for the further development of the A^3 ConOps, both within and beyond the iFly project, in support of the goals enlisted in the ICAO Circular 249-AN/149 "Guidelines for Human Centred Automation in Aviation":

1. The human must be in command
2. To command effectively, the human must be involved
3. To be involved, the human must be informed
4. Functions must be automated only if there is a good reason for doing so
5. The human must be able to monitor the automated system
6. Automated systems must, therefore, be predictable
7. Automated systems must be able to monitor the human operator
8. Each element of the system must have knowledge of the other's intent
9. Automation must be designed to be simple to learn and operate

In parallel with the above positive guidelines it may be useful to remember the five most important negative consequences of automation in the cockpit, found by Funk et al. (1999), discussed in the sections 4 and 5 and to be avoided or alleviated by design:

1. Attentional demands of pilot-automation interaction may significantly interfere with performance of safety-critical tasks (e.g., “head down time”, distractions etc.)
2. Automation behaviour may be unexpected and unexplained (possibly creating confusion, increasing pilot workload to compensate and sometimes leading to unsafe conditions)
3. Pilots may be overconfident in and uncritical of automation, and fail to exercise appropriate vigilance, sometimes to the extent of abdicating responsibility to it (leading to unsafe conditions)
4. Failure assessment may be difficult (resulting faulty or prolonged decision making)
5. Behaviour of automation may not be apparent (reducing the awareness of pilots about automation behaviour and goals)

In conclusion, the human in the system must not be seen as a “peripheral device”, but as an integral component of the whole system which in the end determines the success or failure of the system.

Appendix

Appendix 1: Acronyms

Acronym	Definition
A^3	Autonomous Aircraft Advanced
ACARS	Aircraft Communication Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance – Broadcast
ADS-C	Automatic Dependant Surveillance – Contract
AFR	Autonomous Flight Rules
AIS	Aeronautical Information Service
AMAN	Arrival Manager
ANSP	Air Navigation Services Provider
AOM	Airspace Organization & Management
ASACAS	Airborne Separation Assurance and Conflict Avoidance System
ASAS	Airborne Separation Assistance System
ASEP	Airborne Separation
ASP	Aeronautical Surveillance Panel
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATN/CLNP	Air Traffic Network/Connectionless Network Protocol
ATS	Air Traffic Services
ATSEP	Air Traffic Safety Electronics Personnel
CD	Conflict Detection
CD&R	Conflict Detection and Resolution
CDM	Collaborative Decision Making
CDTI	Cockpit Display of Traffic Information
CNS	Communication, Navigation and Surveillance
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf
CP	Conflict Prevention
CR	Conflict Resolution
CTA	Controlled Time of Arrival
CZ	Comfort Zone
DCB	Demand and Capacity Balancing

DL	Data Link
DST	Decision Support Tools
ECC	Error Correction Codes
EGPWS	Enhanced Ground Proximity Warning System
FFAS	Free Flight Airspace (outdated)
FMS	Flight Management System
FOC	Flight Operations Centre
GA	General Aviation
GNSS	Global Navigation Surveillance System
HF	Human Factors
HMI	Human Machine Interface
HS	Head of State
IAS	Indicated Airspeed
ICAO	International Civil Aircraft Association
IFR	Instrumental Flight Rules
IOC	Initial Operational Capability
IP	Implementation Package
LoC	Lines of Change
LoS	Loss of Separation
LTACD	Long Term Area Conflict Detection
LTAZ	Long Term Awareness Zone
MA	Managed Airspace
MET	Meteorological Service
MOC	Minimum Obstacle Clearance
MTAZ	Medium Term Awareness Zone
MTCD&R	Medium Term CD&R
NFU	Non-FOC Airspace User
NVFR	Night Visual Flight Rules
OI	Operational Improvement
OPSP	Operations Panel
PANS	Procedures for Air Navigation Services
PAZ	Protected Airspace Zone
R/T	Radio Telecommunications
RAA	Restricted Airspace Area
RBT	Reference Business Trajectory
RNP	Required Navigation Performance
RNPC	RNP Capability
RSP	Required Surveillance Performance

RTA	Required Time of Arrival
RTD	Research, Technology and Development
RVSM	Reduced Vertical Separation Minima
S&M	Sequencing and Merging
SA	Situation Awareness
SARP	Standards and Recommended Practices
SASP	Separation and Airspace Safety Panel
SBT	Shared Business Trajectory
SES	Single European Sky
SESAR	SES Advanced Research
SFM	Strategic Flow Management
SI	Spacing Interval
SM	Separation Minima
SSA	Self Separated Airspace
SSEP	Airborne Self Separation
SSR	Secondary Surveillance Radar
STAZ	Short Term Awareness Zone
STCD&R	Short Term CD&R
SVFR	Special Visual Flight Rules
SWIM	System Wide Information Management System
SZ	Safety Zone
TA	Traffic Alert
TBD	To Be Defined
TCAS	Tactical Collision Avoidance System
TIS-B	Traffic Information Service - Broadcast
TIS-C	TIS-Contract
TMA	Terminal Area
TS	Trajectory Synthesizer
TTF	Traffic To Follow
UA	Unmanaged Airspace
UAV	Unmanned Air Vehicle
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WHA	Weather Hazard Areas
WP	Work Package

Appendix 2: References

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Appendix 3: Human System integration activity needs on the basis of HF Issues in D2.3

Human-System Integration activity needs on the basis of HF issues in D2.3			
Issue No	**Synopsis of the issue from D2.3**	**Possible actions in further steps of A^3 ConOps refinement**	**Possible action in WP8**
HF issues in D2.3 under the topic „Ground support“			
2	The dynamic allocation of airspace boundaries provides the human participants with new opportunities to keep the pilot in the loop, being vigilant and active. At the same time there may happen the occasions of higher than usual workload of flight crews and other parties involved due to the changing airspace boundaries.	The rare possible high workload instances due to changing airspace boundaries should be handled in further steps of A^3 development.	No immediate action needed in WP8
3	The dynamic allocation of airspace boundaries provides the human participants with new opportunities to keep the pilot in the loop, being vigilant and active. At the same time there may happen the occasions of higher than usual workload of flight crews and other parties involved due to the changing airspace boundaries.	The rare possible high workload instances due to changing airspace boundaries should be handled in further steps of A^3 development.	No immediate action needed in WP8
6	Defining the limitations of the system are essential opportunities at different phases of system development. At the same time the risk of overlooking the issues which may remain close to both sides of the border of the defined system should be avoided.	In further developments of A^3 ConOps the ground support involvement should be defined, especially in vague, ambigous, non-normal and emergency situations.	No immediate action needed in WP8
13	Transitions from one type of airspace to the other may lead to safety critical situations which should be considered in the design process. Even if they remain beyond the border of the defined system, they should not be overlooked for this reason.	Transition issues should be developed in further refinements of A^3 ConOps.	No immediate action needed in WP8, but the necessity to take transition issues into account in more detail in the future should be mentioned.
17	The use of voice a channel for communication between the flight crew and FOC should be considered not only in	The use of voice channel in normal conditions should be considered in further steps of A^3	No immediate action needed in WP8, but the possible use of voice channel in

	emergency, but also normal conditions.	development.	normal conditions should be considered.
19	Possible ATM ground support of actors in SSA should be considered together with other possible ground support actors (e.g., FOC and SWIM).	The issues of ground support should be considered for all ground actors together in further steps of A^3 ConOps development.	No immediate action needed in WP8
25	If conflicting SBT are proposed and SWIM and FOCs cannot successfully negotiate, the ANSP will have the authority to make the choices to solve the conflict.	The issues of ground support should be considered for all ground actors together in further steps of A^3 ConOps development.	No immediate action needed in WP8
38	To understand better the limitations stemming from military operations in SSA, it may be necessary to define all possible legal military operations in SSA of military conflict-free state.	The defining of all possible legal military operations in SSA of military conflict-free state may be necessary in further steps of A^3 ConOps development.	No immediate action needed in WP8
39	It may be worth of considering possible military operations in SSA in parallel as special cases of non-normal operations in SSA.	Legal military operations in SSA may be also considered as special cases of non-normal operations in further steps of A^3 ConOps development.	No immediate action needed in WP8
40	It may be worth of considering possible military operations in SSA in parallel as special cases of non-normal operations in SSA.	Legal military operations in SSA may be also considered as special cases of non-normal operations in further steps of A^3 ConOps development.	No immediate action needed in WP8
41	CD and CR tools failure may, but must not always cause the failure of the airborne systems ability for self separation, if the crew is able to take over the control and has the traffic information available. The self separating incapable aircraft ceasing to operate in SSA and leaving for MA may need additional assistance from the ground.	Assistance from the ground in an emergency for leaving the SSA must be considered. In further steps of A^3 ConOps development the ability of the crew to maintain self separation in CD and CR tools failure conditions, while traffic information is still available, may need further analysis.	Replace "<u>aircraft that are aware</u>" to "<u>crews</u> who are aware …" Assistance from the ground for leaving the SSA in emergency should be mentioned in WP8.3 to be taken into account at further stages of A^3 ConOps development
42	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be mentioned within WP8.3 to be taken into account at further stages of A^3 ConOps development
43	The ground support aspects of non-normal operations need further development in A^3	When the use of A^3 equipped aircraft within SESAR is	No immediate action needed in WP8, but suggestions about

	ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	considered, then ground support aspects of non-normal operations should be considered.	ground support should be considered within WP8.3.
44	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be considered within WP8.3.
45	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be considered within WP8.3.
46	The ground support aspects of non-normal operations need further development in A^3 ConOps. The content and the procedures of ground support must be elaborated by possible classes of non-normal operations.	When the use of A^3 equipped aircraft within SESAR is considered, then ground support aspects of non-normal operations should be considered.	No immediate action needed in WP8, but suggestions about ground support should be considered within WP8.3.
47	The idea of ceasing the use of voice channel in normal situations will diminish the crew workload considerably in comparison to current situation. Still it may be worth to investigate the positive and negative consequences of ceasing its use in normal situations.	In further steps of A^3 ConOps development the positive and negative consequences of ceasing the use of voice communication in normal situations should be considered.	No immediate action needed in WP8
HF issues in D2.3 under the topic „SWIM“			
2	Dynamic allocation of airspace boundaries will probably be achieved through the SWIM. It is important to provide the information about the changes timely to all potential actors both inside and in the close proximity of the boundaries.	In further developments of A^3 ConOps the information needs for aircraft and crews from SWIM should be specified for instances of airspace boundary changes.	No immediate action needed in WP8
3	Dynamic allocation of airspace boundaries will probably be achieved through the SWIM. It is important to provide the information about the changes timely to all potential actors both inside and in the close proximity of the boundaries.	In further developments of A^3 ConOps the information needs for aircraft and crews from SWIM should be specified for instances of airspace boundary changes.	No immediate action needed in WP8
20	It may be appropriate to differentiate between the ground support functions provided through the SWIM and the others	It may be appropriate to distinguish SWIM-provided ground support functions form the others	No immediate action needed in WP8

	provided directly to the airborne system.	in further developments of A^3 ConOps.	
21	The ground support functions of SWIM should be specified from the pilot's perspective. Scenario based design may facilitate this development.	The ground support functions of SWIM should be specified in further developments of A^3 ConOps from the pilot's perspective.	No immediate action needed in WP8
22	It has to be investigated if the source of the data (e.g. SWIM, or air-air data) must be depicted to the pilots or not. The accuracy of the data might change due their source, which may be very important for critical decisions.	The necessity of presenting the information about the data source to the pilots should be investigated in further developments of A^3 ConOps from the pilot's perspective.	No immediate action needed in WP8
23	SWIM will definitely have a major role in providing information to the flight crews in non-normal or emergency situations. But at the same time the value of real-time airborne information in the vicinity of the aircraft in non-normal or emergency situation raises more quickly than the value of distant and long-term information.	The demands of the flight crew to SWIM information in normal, non-normal and emergency situations should be investigated in further developments of A^3 ConOps.	No immediate action needed in WP8, but the value of information from other (airborne) sources should also be considered.
25	If conflicting SBT are proposed and SWIM and FOCs cannot successfully negotiate, the ANSP will have the authority to make the choices to solve the conflict.	The issues of ground support should be considered for all ground actors together in further steps of A^3 development.	No immediate action needed in WP8
26	SWIM is a key element in A3 ConOps because it provides the necessary information to support the adequate situation awareness of the flight crew, which is needed for handling their new responsibilities. But it remains to be investigated if the capabilities of the SWIM will respond fully to A^3 airborne system information needs.	In further steps of A^3 development it remains to be investigated if the capabilities of the SWIM will satisfy fully the A^3 airborne system information needs.	No immediate action needed in WP8
28	Human-system integration is the most important contributor to the system adaptability and resilience. This integration means the search for the right level of automation, which may vary as a function of environment and crew workload.	Human-system integration has to be taken into account at every step of A^3 development.	No immediate action needed in WP8, but the idea of function congruence between the human and automation should be considered within WP8 for keeping the human in the loop.
30	Airborne long term area conflict detection functionality is adjoining the possible support from SWIM. It may be appropriate for the flight crew to know, from which source which kind of information is originating.	The source of information provided to the flight crew may need specification in further steps of A^3 development.	No immediate action needed in WP8
31	The description of Medium term conflict detection and resolution	The topics of SWIM response time and	No immediate action

	module brings up the question about the possible response time of SWIM in dense traffic and full destination airport. Another question rises about the possible imprecision of information available for MTCD&R: what will happen, if the information available is not precise enough to make final CR decisions?	precision of information for MTCD&R should be analyzed in further steps of A^3 development.	needed in WP8
34	If the priority levels of aircraft will be attributed through SWIM, it needs additional analysis, when the priority levels for two adjacent aircraft will be decided and how long and under which conditions they will remain unchanged.	The conditions and timing of attribution of priority levels by SWIM needs analysis in further steps of A^3 development.	No immediate action needed in WP8
35	Although in most occasions the priority levels will be attributed to the aircraft according to their aerodynamic characteristics, there may be other considerations (e.g. the health condition of the patient) to be taken into account.	The conditions of attributing priority levels to aircraft in special occasions may need analysis in further steps of A^3 development.	No immediate action needed in WP8
36	Although in most occasions the priority levels will be attributed to the aircraft according to their aerodynamic characteristics, there may be other considerations (e.g. the health condition of the patient) to be taken into account.	The conditions of attributing priority levels to aircraft in special occasions may need analysis in further steps of A^3 development.	No immediate action needed in WP8
41	CD and CR tools failure may, but must not always cause the failure of the airborne systems ability for self separation, if the crew is able to take over the control and has the traffic information available. The self separating incapable aircraft ceasing to operate in SSA and leaving for MA may need additional assistance from the ground.	Assistance from the ground in an emergency for leaving the SSA must be considered. In further steps of A^3 ConOps development the ability of the crew to maintain self separation in CD and CR tools failure conditions, while traffic information is still available, may need further analysis.	Replace "aircraft that are aware" to "crews who are aware …" Assistance from the ground for leaving the SSA in emergency should be considered in WP8.3
47	The idea of ceasing the use of voice channel in normal situations will diminish the crew workload considerably in comparison to current situation. Still it may be worth to investigate the positive and negative consequences of ceasing its use in normal situations.	In further steps of A^3 ConOps development the positive and negative consequences of ceasing the use of voice communication in normal situations should be considered.	No immediate action needed in WP8
48	While developing the concept of ground support, the boundaries between ground originated data (in SWIM) and airborne	In further steps of A^3 ConOps development the boundaries between ground and airborne	No immediate action needed in WP8

	originated data should be considered.	originating data should be considered.	
49	Providing information to the airborne system upon request or by periodical broadcasting may influence the involvement of the crew in different ways. It may be worth to analyze the positive and negative aspects of both ways from the position of the flight crew concerning different classes of information to be transmitted.	In further steps of A^3 ConOps development it may be worth to analyze the influence of broadcasting or providing information upon request onto the performance of the flight crew.	No immediate action needed in WP8
HF issues in D2.3 under the topic „Minimal requirements“			
4	Taking differences in the technology level of equipment into account for different actors operating in the Self Separated Airspace is an essential opportunity.	Minimum requirements for equipment must be specified in further steps of A^3 development.	No immediate action necessary in WP8, but the need to establish minimum requirements should be mentioned.
8	The level of support provided to the crew by onboard decision support tools may essentially differ for different actors, but the minimal operational requirements have to be established for all the actors in SSA.	Minimal operational requirements should be defined in further steps of A^3 development.	No immediate action necessary in WP8, but the need to establish minimal operational requirements should be mentioned.
9	Appropriate level of automation will depend both on the situation and the workload of the flight crew. More automation will not always provide higher Situation Awareness.	Minimal operational requirements should be defined in further steps of A^3 development.	No immediate action necessary in WP8, but the term "situational awareness", used in D1.3, should be replaced by "situation awareness".
12	Modifications of FMS are very critical to safety. The flight crew must be aware of which information is taken under consideration in which situation, at which time point - to make sure that they are able to fly the aircraft manually any time in case of system failure.	Modifications of FMS and its integration with DST must be introduced after thorough analysis of its impact to flight crew SA in further refinements of A^3 ConOps.	No immediate action needed in WP8
27	The list of minimum requirements which enables the flight crew and the aircraft to operate in SSA should be defined.	Minimal operational requirements should be defined in further steps of A^3 development.	No immediate action necessary in WP8, but the need to establish minimal operational requirements should be mentioned.
HF issues in D2.3 under the topic „Transitions“			
2	Rare occasions of necessary replanning of the route, updating the RBT and renegotiating with FOC may challenge the SA of the crew while close to dynamically allocated boundaries of Managed and Unmanaged airspace.	The possible rare instances of crew workload increases mentioned should be discussed in further developments of A^3 ConOps.	No immediate action needed in WP8
3	Rare occasions of necessary replanning of the route, updating	The possible rare instances of crew	No immediate action

	the RBT and renegotiating with FOC may challenge the SA of the crew while close to dynamically allocated boundaries of Managed and Unmanaged airspace.	workload increases mentioned should be discussed in further developments of A^3 ConOps.	needed in WP8
7	Rare occasions of necessary replanning of the route, updating the RBT and renegotiating with FOC may challenge the SA of the crew while close to dynamically allocated boundaries of Managed and Unmanaged airspace.	The possible rare instances of crew workload increases mentioned should be discussed in further developments of A^3 ConOps.	No immediate action needed in WP8
11	Transitions from one type of airspace to the other may become safety critical situations which should be considered in the design process. Even if they remain beyond the border of the defined system, they should not be overlooked for this reason.	Transition issues should be developed in further refinements of A^3 ConOps.	No immediate action needed in WP8, but the necessity to take transition issues into account in more detail in the future should be mentioned.
13	Transitions from one type of the airspace to the other may become safety critical situations which should to be considered in the design process. Even if they remain beyond the border of the defined system, they should not be overlooked on this reason.	Transition issues shold be developed in further refinements of A^3 ConOps.	No immediate action needed in WP8, but the necessity to take transition issues into account in more detail in the future should be mentioned.
24	The differentiation and sharing responsibilities of different ground actors for providing the flight crew with the necessary information should be analyzed from the pilot's point of view.	The issues of ground support should be considered for all ground actors together in further steps of A^3 ConOps development.	No immediate action needed in WP8
37	Although strictly speaking out of present A^3 ConOps scope, the transitions from/ to SSA to/ from TMA remain A^3 related safety issues, especially in non-normal and emergency situations.	Transition issues shold be developed in further refinements of A^3 ConOps.	No immediate action needed in WP8
41	CD and CR tools failure may, but must not always cause the failure of the airborne systems ability for self separation, if the crew is able to take over the control and has the traffic information available. The self separating incapable aircraft ceasing to operate in SSA and leaving for MA may need additional assistance from the ground.	Assistance from the ground in an emergency for leaving the SSA must be considered. In further steps of A^3 ConOps development the ability of the crew to maintain self separation in CD and CR tools failure conditions, while traffic information is still available, may need further analysis.	Replace "<u>aircraft that are aware</u>" to "<u>crews</u> who are aware …" Assistance from the ground for leaving the SSA in emergency should be considered in WP8.3
HF issues in D2.3 under the topic „Human / automation relationships issues"			
5	Having intent information available is highly preferable, as the flight crews will benefit from this by obtaining higher predictive SA.	It is expected that the availability of intent information will remain in the A^3 ConOps during its further refinements.	No immediate action needed in WP8

12	Modifications of FMS are very critical to safety. The flight crew must be aware of which information is taken under consideration in which situation, at which time point - to make sure that they are able to fly the aircraft manually any time in case of system failure.	Modifications of FMS and its integration with DST must be introduced after thorough analysis of its impact to flight crew SA in further refinements of A^3 ConOps.	No immediate action needed in WP8
17	The use of voice a channel for communication between the flight crew and FOC should be considered not only in emergency, but also normal conditions.	The use of voice channel in normal conditions should be considered in further steps of A^3 development.	No immediate action needed in WP8, but the possible use of voice channel in normal conditions should be considered.
28	Human-system integration is the most important contributor to the system adaptability and resilience. This integration means the search for the right level of automation, which may vary as a function of environment and crew workload.	Human-system integration has to be taken into account at every step of A^3 development.	No immediate action needed in WP8, but the idea of function congruence between the human and automation should be considered within WP8 for keeping the human in the loop.
31	The description of Medium term conflict detection and resolution module brings up the question about the possible response time of SWIM in dense traffic and full destination airport. Another question rises about the possible imprecision of information available for MTCD&R: what will happen, if the information available is not precise enough to make final CR decisions?	The topics of SWIM response time and precision of information for MTCD&R should be analyzed in further steps of A^3 development.	No immediate action needed in WP8
32	Potential imprecise information in MTCD&R module may shift the CR phase into STCD&R module. Although low in probability, such occasion may need to be analyzed from the pilots' point of view - how are they able to solve the conflict under time pressure.	The possible situation of shifting the CR phase into STCD&R module should be analyzed in further steps of A^3 development.	No immediate action needed in WP8
47	The idea of ceasing the use of voice channel in normal situations will diminish the crew workload considerably in comparison to current situation. Still it may be worth to investigate the positive and negative consequences of ceasing its use in normal situations.	In further steps of A^3 ConOps development the positive and negative consequences of ceasing the use of voice communication in normal situations should be considered.	No immediate action needed in WP8
50	The work of traffic proximity detector and traffic complexity predictor should be undetectable for the flight crew	In further steps of A^3 ConOps development these devices should be considered as Directive Decision Devices.	No immediate action needed in WP8
51	The work of traffic proximity	In further steps of A^3	

	detector and traffic complexity predictor should be undetectable for the flight crew.	ConOps development these devices should be considered as Directive Decision Devices.	No immediate action needed in WP8
52	The table about information communication structure does not provide links to the crew. It remains unclear, where and how the crew will be involved into information exchange, which information will be presented to the crew, which not and from which sources the information under consideration originates from.	In further steps of A^3 ConOps development it should be considered to provide an additional table about information communication with links to the crew.	No immediate action needed in WP8
53	Potential imprecise information in MTCD&R module may shift the CR phase into STCD&R module. Although low in probability, such occasion may need to be analyzed from the pilots' point of view - how are they able to solve the conflict under time pressure.	The possible situation of shifting the CR phase into STCD&R module should be analyzed in further steps of A^3 development.	No immediate action needed in WP8
56	Potential imprecise information in MTCD&R module may shift the CR phase into STCD&R module. Although low in probability, such occasion may need to be analyzed from the pilots' point of view - how are they able to solve the conflict under time pressure.	The possible situation of shifting the CR phase into STCD&R module should be analyzed in further steps of A^3 development.	No immediate action needed in WP8
HF issues in D2.3 under the topic „HMI and communication issues“			
10	The information needs of the crew (which kind of information, in which situation, when) have to be specified before deciding how to display this information.	The information needs of the crew have to be specified in further steps of A^3 ConOps refinement	No immediate action needed in WP8
17	The use of voice channel for communication between the flight crew and FOC should be considered not only in the emergency, but also in normal conditions.	The use of voice channel in normal conditions should be considered in further steps of A^3 development.	No immediate action needed in WP8, but the possible use of voice channel in normal conditions may be considered.
22	It has to be investigated if the source of the data (e.g. SWIM, or air-air data) must be depicted to the pilots or not. The accuracy of the data might change due their source, which may be very important for critical decisions.	The necessity of presenting the information about the data source to the pilots should be investigated in further developments of A^3 ConOps from the pilot's perspective.	No immediate action needed in WP8
28	Human-system integration is the most important contributor to the system adaptability and resilience. This integration means the search for the right level of automation, which may vary as a function of environment and crew	Human-system integration has to be taken into account at every step of A^3 development.	No immediate action needed in WP8, but the idea of function congruence between the human and automation should be considered within WP8 for keeping the human

	workload.		in the loop.
30	Airborne long term area conflict detection functionality is adjoining the possible support from SWIM. It may be appropriate for the flight crew to know, from which source which kind of information is originating.	The source of information provided to teh flight crew may need specification in further steps of A^3 development.	No immediate action needed in WP8
41	CD and CR tools failure may, but must not always cause the failure of the airborne systems ability for self separation, if the crew is able to take over the control and has the traffic information available. The self separating incapable aircraft ceasing to operate in SSA and leaving for MA may need additional assistance from the ground.	Assistance from the ground in an emergency for leaving the SSA must be considered. In further steps of A^3 ConOps development the ability of the crew to maintain self separation in CD and CR tools failure conditions, while traffic information is still available, may need further analysis.	Replace "aircraft that are aware" to "crews who are aware …" Assistance from the ground for leaving the SSA in emergency should be considered in WP8.3
47	The idea of ceasing the use of voice channel in normal situations will diminish the crew workload considerably in comparison to current situation. Still it may be worth to investigate the positive and negative consequences of ceasing its use in normal situations.	In further steps of A^3 ConOps development the positive and negative consequences of ceasing the use of voice communication in normal situations should be considered.	No immediate action needed in WP8
54	The maneuvering options should be presented to the crew in an intuitive way.	In further steps of A^3 ConOps development the optimal ways of presenting maneuvering options to the crew should be investigated.	No immediate action needed in WP8
55	The conflict situation should be presented to the crew in an intuitive way.	In further steps of A^3 ConOps development the optimal ways of presenting conflict situations to the crew should be investigated.	No immediate action needed in WP8
57	The maneuvering options should be presented to the crew in an intuitive way.	In further steps of A^3 ConOps development the optimal ways of presenting maneuvering options to the crew should be investigated.	No immediate action needed in WP8
59	The development of new HMI will be a difficult process and all the possible ideas and examples should be carefully analyzed from the position of providing the crew with optimal situation awareness and ability to control the aircraft.	In further steps of A^3 ConOps development the HMI will need careful analysis.	No immediate action needed in WP8
60	For presenting the information about conflict resolution a completely intuitive display format is needed. As vertical maneuvers may be easier, faster and	In further steps of A^3 ConOps development the presentation of information about conflict resolution will need	No immediate action needed in WP8

	cheaper than lateral ones, 3D or 4D solutions should be considered.	careful analysis.	
61	In CDTI development complete and intuitive cognitive integration will be necessary.	In further steps of A^3 ConOps development the ways of designing cognitively intuitive CDTI should be investigated.	No immediate action needed in WP8
62	In flight deck integration of airborne traffic management systems complete and intuitive cognitive integration will be necessary.	In further steps of A^3 ConOps development the ways of designing cognitively intuitive airborne traffic management systems should be investigated.	No immediate action needed in WP8
HF issues in D2.3 under the topic „FOC / flight crews relations issues“			
14	Changing A^3 environment may demand the changes in the reporting culture in case of detecting regular violations by competing actors in the airspace.	Possible changes in the reporting culture should be analyzed in further steps of A^3 ConOps refinement.	No immediate action needed in WP8
15	Pre-flight Strategic Flow Management will be a challenging opportunity for the FOCs in successful flight preparations. But any deviations from the planned SBT may demand extensive renegotiations before or even after the departure between the actors involved, causing possible challenges to the flight crews and FOCs.	Possible ways of handling the deviations from the planned SBT should be analyzed in further steps of A^3 ConOps refinement.	No immediate action needed in WP8
16	In-flight traffic monitoring by the FOCs will obtain higher importance and they will need more information than today.	The changing information needs of the FOCs should be analyzed in further steps of A^3 development.	No immediate action needed in WP8
17	The use of voice a channel for communication between the flight crew and FOC should be considered not only in emergency, but also normal conditions.	The use of voice channel in normal conditions should be considered in further steps of A^3 development.	No immediate action needed in WP8, but the possible use of voice channel in normal conditions should be considered.
18	Non-FOC airspace users may benefit from joining the services provided by FOCs but they may also become "unwelcome minority" among the SSA users.	Costs and benefits of non-FOC airspace users for joining FOC services should be considered in further steps of A^3 development.	No immediate action needed in WP8
25	If conflicting SBT are proposed and SWIM and FOCs cannot successfully negotiate, the ANSP will have the authority to make the choices to solve the conflict.	The issues of ground support should be considered for all ground actors together in further steps of A^3 development.	No immediate action needed in WP8
29	Simple and intuitive autonomous flight rules will facilitate the development of self separated flying. If the flow management	The renegotiation process as a detail of the autonomous flight rules may need explanation elsewhere in further steps	No immediate action needed in WP8

	constraints will not be met, the renegotiation process may need explanation elsewhere.	of A^3 development.	
33	Consequences of giving different priorities to FOC-related and non-FOC normal aircraft may be worth of investigation for the purposes of reducing the possible ambiguity in attributing priority.	Principles of attributing priority may need further development during A^3 ConOps refinement.	No immediate action needed in WP8
35	Although in most occasions the priority levels will be attributed to the aircraft according to their aerodynamic characteristics, there may be other considerations (e.g. the health condition of the patient) to be taken into account.	The conditions of attributing priority levels to aircraft in special occasions may need analysis in further steps of A^3 development.	No immediate action needed in WP8
36	Although in most occasions the priority levels will be attributed to the aircraft according to their aerodynamic characteristics, there may be other considerations (e.g. the health condition of the patient) to be taken into account.	The conditions of attributing priority levels to aircraft in special occasions may need analysis in further steps of A^3 development.	No immediate action needed in WP8
41	CD and CR tools failure may, but must not always cause the failure of the airborne systems ability for self separation, if the crew is able to take over the control and has the traffic information available. The self separating incapable aircraft ceasing to operate in SSA and leaving for MA may need additional assistance from the ground.	Assistance from the ground in an emergency for leaving the SSA must be considered. In further steps of A^3 ConOps development the ability of the crew to maintain self separation in CD and CR tools failure conditions, while traffic information is still available, may need further analysis.	Replace “aircraft that are aware” to “crews who are aware …“ Assistance from the ground for leaving the SSA in emergency should be considered in WP8.3
47	The idea of ceasing the use of voice channel in normal situations will diminish the crew workload considerably in comparison to current situation. Still it may be worth to investigate the positive and negative consequences of ceasing its use in normal situations.	In further steps of A^3 ConOps development the positive and negative consequences of ceasing the use of voice communication in normal situations should be considered.	No immediate action needed in WP8
58	The conditions, under which the RBT changes need to be initiated by the flight crew, have to be defined in a more detailed way.	In further steps of A^3 ConOps development the conditions of RBT changes initiated by the flight crew may need a more detailed definition.	No immediate action needed in WP8, but the suggestions about RBT changes should be considered.
HF issues in D2.3 under the topic „Other issues“			
1	Human-system integration is the most important contributor to the system adaptability and resilience. Well prepared human factors will	Human-system integration has to be taken into account at every step of A^3 development.	No immediate action needed in WP8

	enable to catch and and recover from possible errors and to adapt to both anticipated and non-anticipated changes.		
63	The development of procedures for contingency and emergency situations will be very critical to safety.	In further steps of A^3 ConOps development the procedures for contingency and emergency need careful analysis.	No immediate action needed in WP8