Guidance Material for HP Automation Support - Annex A. List of REOAs

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Abstract

This document is an Annex to the deliverable of WP16.05.01 Task 4. It gathers twenty-six Relevant Experiences of Automation (REOAs) collected by project contributors.

REOAs represent a large amount of information on ground and airborne automated functions: they build a pool of raw data as an evidence for the derivation of the Guidelines for HP Automation Support (higher level principles).

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Executive summary

This document is an Annex to the deliverable of WP16.05.01 Task 4 – Guidance Material. It provides completion to the main deliverable by presenting the complete list of Relevant Experiences of Automation (REOA) examples.

REOA examples consist in automated solutions in support to human performance and represent an evidence-based starting point for the development of higher level principles (Guidelines in Human Performance Automation support).

Twenty-six REOA examples are introduced and presented in the current document. The entire set of REOAs is split into two groups: airborne functions (that gathers 9 REOAs) and ground functions (that gathers 17 functions).

Detailed information on each REOA is reported into a template, that provides the reference structure to organize information in a satisfactory manner. For each REOA, the focus on the kind of Human Performance automation support provided is highlighted.

Each REOA can be used as an example of a certain experience of human-machine cooperation that can be generalized as lesson learnt and applied to contexts different from the ones in which it was originally developed.

1 Introduction

1.1 Purpose of the document

The purpose of the current Annex is to provide completion to the parent document WP16.05.01 - D4 Guidance Material by reporting the complete list of Relevant Experiences of Automation (REOA) examples.

Twenty-six REOA examples are presented in order to provide the evidence-based starting point which higher level principles (Guidelines) are grounded on.

The document is divided into four chapters, organized as follows:

- *Chapter 1: Introduction.* This chapter (the current part) introduces the scope and the purpose of the document. Target readership is highlighted as well.
- *Chapter 2: Introducing Relevant Experiences of Automation (REOAs).* This chapter provides an explanation of the term "REOA" and of its scope. Plus, it describes how REOA examples have been selected and analysed.
- *Chapter 3: Overview of REOAs.* This chapter introduces the complete set of REOAs. It explains how REOA examples were split into categories, addressing respectively airborne/ground functions and flight phases. It also explains how detailed information on each REOA has been organized into templates. Last but not least, it gathers initial considerations on the distribution of REOAs with respect of the type of HP support provided: in other words, its purpose is to search for relevant discrepancies between the type of cooperation provided by REOAs related to ground functions and REOAs related to airborne functions.
- *Chapter 4: List of REOAs.* In this chapter, the twenty-six REOAs are presented.

1.2 Intended readership

This Annex is mainly targeted to HF specialists who contribute to operational and technical projects and when applying the HP Assessment Process (HPAP). Nevertheless, the document also addresses the reader being interested in better understanding the value of human factors in automation design.

1.3 Acronyms and Terminology

Term	Definition
ATM:	Air Traffic Management
E-ATMS	European Air Traffic Management System
GP	Good Practice
HP	Human Performance
REOA	Relevant Experience of Automation
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.

2 Introducing Relevant Experiences of Automation (REOAs)

This chapter is going to introduce the notion of Relevant Experience of Automation (REOA).

In section 2.1, an explanation of what REOA means will be presented; afterwards, the role of REOAs with reference to the development of Guidelines for Human Performance (HP) Automation Support will be highlighted.

Sections 2.2 and 2.3 will deal respectively with the way REOAs have been selected and described.

2.1 Operational definition and role of REOAs

The notion of Relevant Experience of Automation (REOA) involves concrete examples of automation solutions in support to the human performance. In practice, a REOA consist of a template filled in with structured information on the characteristics of the support offered by automation to the human operators, on both the ground and airborne side.

The term experience is intended to underline that the emphasis is not on the technical solution as such, but rather on the interaction between the tool and the user. In practice, the analysis is focused on the experience that the user has while managing the tool and in the kind of cooperation which is established between the two when performing certain tasks.

In order to address the type of cooperation between the human and the machine, a theoretical framework addressing classification was developed (WP16.05.01 D03 Framework for HP Automation Related Good Practices). The framework is composed of classification elements covering the context, the task, the level of automation, the cooperation type between human and system, and the maturity level of the automation. These classification elements are defined taking into account pertinent models from literature and will be presented in section 2.3.

The term relevant is referred to the selection of the automated solutions to be analyzed. A concrete experience of automation can be considered relevant if it is linked to the aim of deriving, through an analysis, examples of Good Practices (GPs) of automation support.

In order to investigate GPs through REOAs, criteria have been established to determine the relevance of the selected automation solutions (see section 2.2).

So, the selected examples of REOAs represent a pool of raw data that are considered a starting point to derive Good Practices. While the following step, based on the analysis on GPs, consists of developing Guidelines on HP Automation Support. Such process is explained in the following subsection.

2.1.1 Addressing GPs and Guidelines through REOAs: the process

The key term Good Practice is theoretically defined as follows (WP16.05.01 Project Initiation Report v00.01.01, p.4):

A Good Practice emerges in any field, with experience. Some things are shown to work better than others, or to reduce risk more than others. Helping to spread good practice therefore makes projects more effective and less risk prone than they might otherwise be. Good practice can be quite diverse. There can be more than one way to achieve the desired effects, and some might be more appropriate than others in different situations. The over-riding criterion is that the practices have been shown to deliver the desired benefits.

The previous theoretical definition has been specified and completed in the following operational definition:

A good practice is a concrete and recent experience of use of HP automation support which is expected – if reused or spread elsewhere – to positively contribute to one or more KPAs identified in SESAR and to positively manage the relevant automation issues identified in 16.05.01 Deliverable 2.

Automation experiences are proposed as Good Practices in the project if there is an expectation that important elements of the identified design solution or of the adopted design process can be used as lessons learnt for future applications in the SESAR context.

The notion of lesson learnt is linked to the HP automation issues identified in WP 16.05.01 task 2 (WP16.05.01 D02 Identification of issues in HP automation support): in practice, as it is stated in the operational definition, a REOA can be proposed as a Good Practice when it involves an experience of automation that mitigates HP automation-related issues.

Certainly the derivation of a GP requires a certain level of abstraction, consisting in the deduction about the way how things were done and in the evaluation of whether such practices can be applied in contexts different from those in which they were originally developed. This means that the information on the classification elements of all REOA has been analysed with the aim of searching for commonalities in the classification elements of different automated solutions.

Regarding this, setting GPs has the purpose of supporting the users in identifying the existing practices which can be useful for their own purposes.

Further development of the process of abstraction is to derive Guidelines for HP automation support on the basis of the GPs identified. The Guidelines represent the expected output of the collection of GPs: during a further analysis of identified GPs, information has been generalised to lead the intended guidelines, i.e. higher level principles.

The guidelines will not prescribe specific solutions to be developed but a process to identify the appropriate criteria for designing and validating automation solutions. They will be used by WP16.06.05 and X.Y.Z operational projects.

Figure 1 shows the process of abstraction that leads from concrete automation solutions (REOAs) to higher level principles (Guidelines).

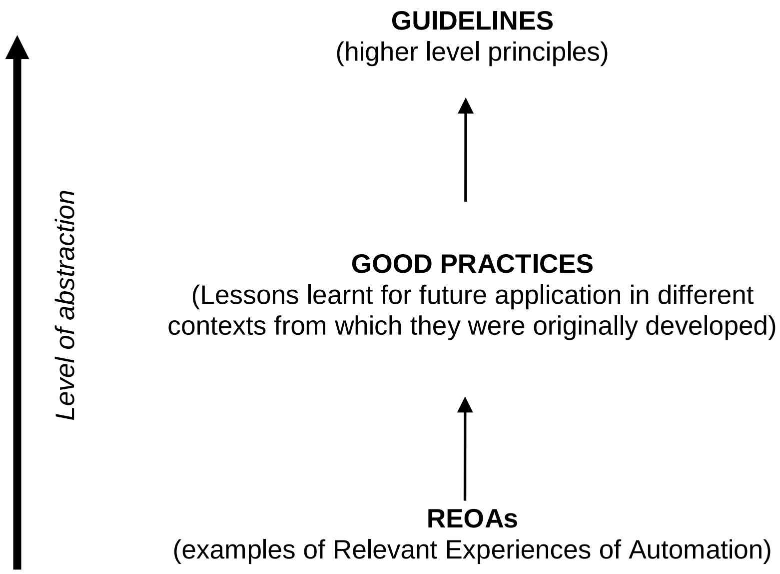


Figure 1: process of abstraction to derive guidelines from REOAs

On the basis of the previous statements, one can notice that the notion of REOAs is the key element which guidelines can be derived from; plus, they represent **experimental evidence** that permits a well-grounded anchorage of abstract principles (the guidelines) on concrete experiences.

As anticipated, in order to investigate GPs through REOAs, criteria have been established to determine the relevance of the selected automation solutions. The following subsection elaborates on such criteria.

2.2 Selection of REOAs

The relevance of each experience of automation and its potential for the derivation of good practices was evaluated taking into account 3 main factors:

- *The impact on human performance (HP):* automation should not be intended as technical innovation as such (for example, increasing the processing capability of a multi-radar tracking system) but rather as an improvement that changes the way the human and the machine interact and the nature of the task which is being performed;
- *The relevance for ATM and for the SESAR objectives:* the concerned automation solution should affect the way air traffic is managed and should positively contribute to one or more of the SESAR KPAs;
- *The degree of innovation:* the concerned automation should be adequately innovative, to make sure that the focus of the analysis is mainly on new HP automation issues and on the way to mitigate them, with minimum risk of replicating findings already made in older studies.

In Table 1, such factors are translated into basic positive and negative criteria to decide if a certain REOA is considered of interest (WP16.05.01-D03, Framework for HP Automation Related Good Practices v00.01.00 p.11):

Table 1: Criteria to guide selection of automated solutions.

The concerned automation solution will be considered relevant if…
… **it changes the way how the automation supports the human**, or how human and machine interact (a simple technical improvement will not suffice)
… it is **relevant for SESAR**, i.e. it has an impact on Air Traffic Management (ATM) • e.g. an improvement of the aircraft engine, with no direct impact on the way air traffic is managed will not be interesting for the project
…it is **adequately innovative** • An automated solution which was only tested in the context of R&D projects, but is not yet adopted operationally • An automated solution which is already used in real operations somewhere (e.g. in some ACCs or in some Aircraft models) but is not considered common standard yet (e.g. when the solution has already shown to provide some benefit, but this is not yet acknowledged by way of specific procedures in ICAO PAN-OPS or PANS-ATM).
… it **consists of a new procedure or a new way of using an existing automation** which has shown to be beneficial. • existing automation which are used in a different way which shows to be beneficial, • there is a different relationship between human and automation which is guided by (a) new procedure(s). • e.g. the use of a Point Merge System procedure in combination with the AMAN tool (Arrival Manager) could be considered as a relevant innovation.
The concerned automation solution will not be considered relevant if…
… it is just a technical improvement with no impact on ATM or Human Automation Interaction • e.g. a mere improvement of the multi-radar tracking performance which implies a reduced radar update time or more accurate surveillance data.
… it is something already well-established or widely standardized which cannot be considered innovative at all.

- Automations which are already in operational use since more than 10 years in different areas of Europe, with no remarkable changes (e.g. TCAS II version 7 on the airborne side or Short Term Conflict Alert on the ground side)
- Automations which have been already included and ruled in PAN-OPS or PANS-ATM ICAO procedures.

2.3 Description of REOAs: classification elements

The selected automation solutions have been described on the basis of the **classification elements** composing the Framework for HP Automation Related Good Practices (WP16.05.01 – DEL03 Framework for HP Automation Related Good Practices).

The framework explains the way how an automated solution can be analysed as Relevant Experience of Automation, providing classification elements which have the purpose of gathering detailed information about the impact that these automation solutions have on human performance.

Classification elements are based on theoretical models selected from relevant literature and described in WP16.05.01 – D03 (Framework for HP Automation Related Good Practices, p.13 – *table 1*).

Table 2 below gives an overview of the main classification elements of the framework and the respective description.

Regarding the content, classification elements are grouped into three main topics:

- *Context:* the description of context elements helps to address the operational context in which automation solution is applied;
- *Task allocation:* the description of task allocation helps to address the way how and by who tasks are performed.
- *Type of human-machine cooperation:* the description of human-machine interaction helps to address the kind of support that automation provides to human performance.

Regarding the organization of information, each classification element is presented through the related description and purpose for the scope of the analysis, i.e. how the information should be applied.

Other classification elements that are pertinent, but firstly, not based on a theoretical model and secondly, rather obvious and of a self-explanatory nature are not shown.

Table 2: Classification elements to address REOAs

Classification element	Respective description	Related purpose
1 CONTEXT		
flight phase	Flight phases taxonomy refers to the commonly used flight phases, as follows: - Taxi-out - Take-off - Climb - En-route - Descent - Approach - Landing - Taxi-in	Flight phases serve as an additional context element
task classifications for pilots and ATCOs	Following the distinction of airborne and ground actors, two respective task classifications have been developed. They cover the basic tasks of the pilot and the air traffic controller (ATCO) respectively, as follows: ▪ Pilot tasks: - Operate - Navigate	The classification of pilot and ATCO's tasks has the purpose of addressing the appropriate tasks being supported by the automation function

	- Communicate -Manage system status and surroundings ▪ ATCO tasks: - Monitoring traffic - Providing traffic information - Issuing instructions and clearances - Detecting conflicts - Resolving conflicts - Planning strategy - Assuming and transferring traffic - Ground-ground communication	
Situation	Normal vs. abnormal/emergency situations	Further contextual element concerning the kind of situation that the automation supports
2 TASK ALLOCATION		
Task changes: Roles, Responsibilities, Authority sharing and Delegation	This element provides an analysis of the task and of the actors' roles and responsibilities considering the way the task has been performed before and after the introduction of the concerned automation solution	The purpose is to evaluate whether the change in automation support brings also a change in the way the actors perform the task and how human and automation cooperate
3 IMPACT ON HUMAN PERFORMANCE		
Cognitive functions	This element covers the type of cognitive support that the machine provides to the human. Based on the human information processing model, four core functions that can be automated up to different levels are proposed: - Information acquisition - Information analysis - Decision and action selection - Action implementation	After having identified the task that is accomplished by pilot and ATCO, there is a need to classify the task performed more precisely: i.e. on the light of which cognitive function is supported by automation. The purpose is to highlight which cognitive functions are challenged on human operator side
Automation Levels (ALs)	This element describes the level up to which a single function has been automated. Regarding this, several different levels of automation have been identified on a continuum, from low level (no system assistance) to high level (complete automated system)	The purpose is to highlight that automation does not simply supplant human contribution, but rather changes it. This element is decisive to address the kind of cooperation between human and machine (What does the human? What does the machine?)

Core classification elements are related to topic (3) and consist in **cognitive functions** and **levels of automation**; in fact, addressing these elements allows enlightening the kind of support given by the concerned automation solution (REOA) to the human.

The following subsection provides detailed information on how REOAs have been addressed with reference to these two core elements. Regarding this, it introduces the Level of Automation Taxonomy (LOAT).

2.3.1 The Level of Automation Taxonomy (LOAT)

LOAT is a frame of reference for the classification of REOAs. This taxonomy has been built to meet the demand of classifying automation examples: *a)* in a satisfactory manner (with reference to the quality of information provided); and *b)* in a practical way.

With reference to the quality of information provided (*a*), LOAT delivers support to address the kind of cooperation between the human and the machine. In fact, it allows classifying REOAs on the basis of:

- The cognitive function supported by the automated solution;
- The level of automation according to which the support provided by cognitive function works.

Identification of cognitive functions is of help to analyse the **task** which is supported by automation. Moreover, addressing the level of automation within a single function helps to identify to what extent tasks have been automated and which is the impact on human performance.

In order to address the purpose of classifying information in a practical way (*b*), LOAT has been organized through a matrix-based idea.

In horizontal reading direction, the matrix includes the 4 functions identified in table 2 from information acquisition (A), information analysis (B), and decision-making (C) to action implementation (D).

In vertical reading direction, each function groups a number of Automation Levels (ALs) that was deemed suitable for each cognitive function. All columns start with a default level '0' corresponding to manual task accomplishment. The levels increase up to full automation. Level 1 is based on the principle that the human is accomplishing a task with 'primitive' external support which is not automation as such. Any means that support the human mind e.g. using flight strips to compare parameters of different aircraft and to pre-plan future traffic, could correspond on this intermediate level. From level 2 on upwards, 'real' automation is involved. The cognitive functions decision-making (C) and action implementation (D) required more levels to be specific enough. By default, the boundaries between the cognitive functions are rather blurred. This is why two categories can relate to each other, such as C4 and D2.

Actually, this taxonomy is applicable not only in the field of automation in aviation but to any domain in which automation takes place.

Table 3 shows the LOA taxonomy and is taken from D03 of WP16.05.01.

From INFORMATION to ACTION →

INCREASING AUTOMATION ↓

A **INFORMATION ACQUISITION**	B **INFORMATION ANALYSIS**	C **DECISION AND ACTION SELECTION**	D **ACTION IMPLEMENTATION**
A0 **Manual Information Acquisition**	**B0** **Working Memory Based Information Analysis**	**C0** **Human Decision Making**	**D0** **Manual Action and Control**
The human acquires relevant information on the process s/he is following without using any tool.	The human compares, combines, and analyses different information items regarding the status of the process s/he is following by way of mental elaborations. S/he does not use any tool or support external to her/his working memory.	The human generates decision options, selects the appropriate ones and decides all actions to be performed.	The human executes and controls all actions manually.
A1 **Artefact-Supported information Acquisition**	**B1** **Artefact-Supported Information Analysis**	**C1** **Artefact-Supported Decision Making**	**D1** **Artefact-Supported Action Implementation**
The human acquires relevant information on the process s/he is following with the support of low-tech non-digital artefacts.	The human compares, combines, and analyses different information items regarding the status of the process s/he is following utilising paper or other non-digital artefacts.	The human generates decision options, selects the appropriate ones and decides all actions to be performed utilising paper or other non-digital artefacts.	The human executes and controls actions with the help of mechanical non-software based tools.
A2 **Low-Level Automation Support of Information Acquisition**	**B2** **Low-Level Automation Support of Information Analysis**	**C2** **Automated Decision Support**	**D2** **Step-by-step Action Support:**
The system supports the human in acquiring information on the process s/he is following. Filtering and/or highlighting of the most relevant information are up to the human.	Based on user's request, the system helps the human in comparing, combining and analysing different information items regarding the status of the process being followed.	The system proposes one or more decision alternatives to the human, leaving freedom to the human to generate alternative options. The human can select one of the alternatives proposed by the system or her/his own one.	The system assists the operator in performing actions by executing part of the action and/or by providing guidance for its execution. However, each action is executed based on human initiative and the human keeps full control of its execution.

A3 **Medium-Level Automation Support of Information Acquisition**	**B3** **Medium-Level Automation Support of Information Analysis**	**C3** **Rigid Automated Decision Support**	**D3** **Low-Level Support of Action Sequence Execution**
The system supports the human in acquiring information on the process s/he is following. It helps the human in integrating data coming from different sources and in filtering and/or highlighting the most relevant information items, based on user's settings.	Based on user's request, the system helps the human in comparing, combining and analysing different information items regarding the status of the process being followed. The system triggers visual and/or aural alerts if the analysis produces results requiring attention by the user.	The system proposes one or more decision alternatives to the human. The human can only select one of the alternatives or ask the system to generate new options.	The system performs automatically a sequence of actions after activation by the human. The human maintains full control of the sequence and can modify or interrupt the sequence during its execution.
A4 **High-Level Automation Support of Information Acquisition**	**B4** **High-Level Automation Support of Information Analysis**	**C4** **Low-Level Automatic Decision Making**	**D4** **High-Level Support of Action Sequence Execution**
The system supports the human in acquiring information on the process s/he is following. The system integrates data coming from different sources and filters and/or highlights the information items which are considered relevant for the user. The criteria for integrating, filtering and highlighting the relevant information are predefined at design level but visible to the user.	The system helps the human in comparing, combining and analysing different information items regarding the status of the process being followed, based on parameters pre-defined by the user. The system triggers visual and/or aural alerts if the analysis produces results requiring attention by the user.	The system generates options and decides autonomously on the actions to be performed. The human is informed of its decision.	The system performs automatically a sequence of actions after activation by the human. The human can monitor all the sequence and can interrupt it during its execution.
A5 **Full Automation Support of Information Acquisition**	**B5** **Full Automation Support of Information Analysis**	**C5** **High-Level Automatic Decision Making**	**D5** **Low-Level Automation of Action Sequence Execution**
The system supports the human in acquiring information on the process s/he is following. The system integrates data coming from different sources and filters and/or highlights the information	The system performs comparisons and analyses of data available on the status of the process being followed based on parameters defined at design level. The system triggers visual and/or	The system generates options and decides autonomously on the action to be performed. The human is informed of its decision only on request. (Note that this level is always	The system initiates and executes automatically a sequence of actions. The human can monitor all the sequence and can modify or interrupt it

items which are considered relevant for the user. The criteria for integrating, filtering and highlighting the relevant info are predefined at design level and not visible to the user (*transparent to the user* in Computer Science terms).	aural alerts if the analysis produces results requiring attention by the user.	connected to some kind of ACTION IMPLEMENTATION, at an automation level not lower than D5.)	during its execution.
		C6 **Full Automatic Decision Making**	**D6** **Medium-Level Automation of Action Sequence Execution**
		The system generates options and decides autonomously on the action to be performed without informing the human. (Note that this level is always connected to some kind of ACTION IMPLEMENTATION, at an automation level not lower than D5.)	The system initiates and executes automatically a sequence of actions. The human can monitor all the sequence and can interrupt it during its execution.
			D7 **High-Level Automation of Action Sequence Execution**
			The system initiates and executes a sequence of actions. The human can only monitor part of it and has limited opportunities to interrupt it.
			D8 **Full Automation of Action Sequence Execution**
			The system initiates and executes a sequence of actions. The human cannot monitor nor interrupt it until the sequence is not terminated.

Table 3: The Level of Automation Taxonomy (LOAT)

LOAT is of interest to identify the *change* that took place through the REOA, i.e. what was the level of automation *before* and *after* the introduction of the concerned automation solution.

Last but not least, identifying cognitive functions and levels of automation allows to determine, through a process of abstraction, when and in which operational context a certain level of automation can be considered feasible and fit-for-purpose. This kind of reasoning represent the point of departure of the process to develop of guidelines.

3 Overview of REOAs

On the basis of the criteria listed in the previous section (Table 2), twenty-six Relevant Experiences of Automation examples have been selected.

Below, the complete list of REOAs examples is reported in alphabetical order:

[1] A-SMGCS - SCA (Advanced Surface Movement Guidance and Control Systems – Surface Conflict Alerting)
[2] A-STCA (Advanced – Short Term Conflict Alert)
[3] AP/FD TCAS (Auto Pilot / Flight Director Traffic Collision Avoidance System) - mode concept
[4] ASAS – ASPA (Airborne Separation Assistance System – Airborne Spacing Application)
[5] ATSAW ITP (Air Traffic Situation Awareness in Trial Procedure in Oceanic Airspace)
[6] ATSAW SURF (Air Traffic Situation Awareness during Surface Operations)
[7] BTV (Brake to Vacate) - Auto brake
[8] BTV (Brake to Vacate) - Exit Selection
[9] BTV – ROP (Brake to Vacate – Runway Overrun Protection)
[10] BTV - ROW (Brake to Vacate – Runway Overrun Warning)
[11] CATO (Controller Assistance Tools) - What-if-probing Function
[12] CATO (Controller Assistance Tools) - ECS (Executive Conflict Search) Function
[13] CATO (Controller Assistance Tools) – flight path monitoring Function
[14] CLOU (Cooperative Local Resource Planner)/ FMAN (Flow Manager)
[15] Combined use of AMAN (Arrival Manager) and Point Merge System (PMS) Procedure
[16] DFS AMAN
[17] DSAM (Down-linked Selected Altitude Monitoring)
[18] D-Taxi (graphical route display on Airport Moving Map)
[19] ERATO (En-Route Air Traffic Organizer) Filtering and What-If Function
[20] ERATO (En-Route Air Traffic Organizer) Monitoring Function
[21] ERATO (En-Route Air Traffic Organizer) Task Scheduler Function
[22] E-TLM (Enhanced Task Load Monitoring)
[23] FAGI (Future Air-Ground integration) concept: AMAN timeline, turn-to-base advisories and air-ground negotiation
[24] PERSEO (Operational Sectorizations Network Effect Analysis Platform)
[25] SARA (Speed and Route Advisor)
[26] Tower HMI - ARR and DEP Integrated Planning Information Display

The selected REOA examples have been chosen according to the availability of relevant documentation. In many cases the REOA reflect direct experiences by one of the project members. (e.g. a ground function available in the ACC of one of the ANSPs or ATM industries represented in the project, or an airborne function available on Airbus aircraft). In other cases the project member had direct access to the documentation of interest, thanks to its participation in a dedicated R&D project. Whereas in a number of other cases the project members did not have access to relevant information regarding the automated functions. Therefore the info was either searched on-line or through establishing contacts with other companies not being 16.5.1 project members. The information owning to this last category was of course much more difficult to archive, due to confidentiality issues and commercial concerns. Therefore the sample of functions identified is not claimed to be exhaustive and it is inevitably biased by the uneven availability of the documentation of interest.

Looking at the list, it is important to notice that each REOA example does not correspond to a tool as such but rather to a single function of a certain tool. This clarification is of interest, due to the fact that different functions of a tool can be allocated to different types of HP support. (See Section 3.2, **Error! Reference source not found.**).

3.1 Operational environment

In order to get initial overview of the set of REOAs with reference to the operational environment, REOAs have been grouped according to:

- The operational domain (air/ground)
- The flight phases

The following subsections present an allocation of REOAs respectively for operational domain and for flight phases.

3.1.1 Allocation of REOAs for operational domain

The graph in Figure 2 shows the availability of REOAs per operational domain:

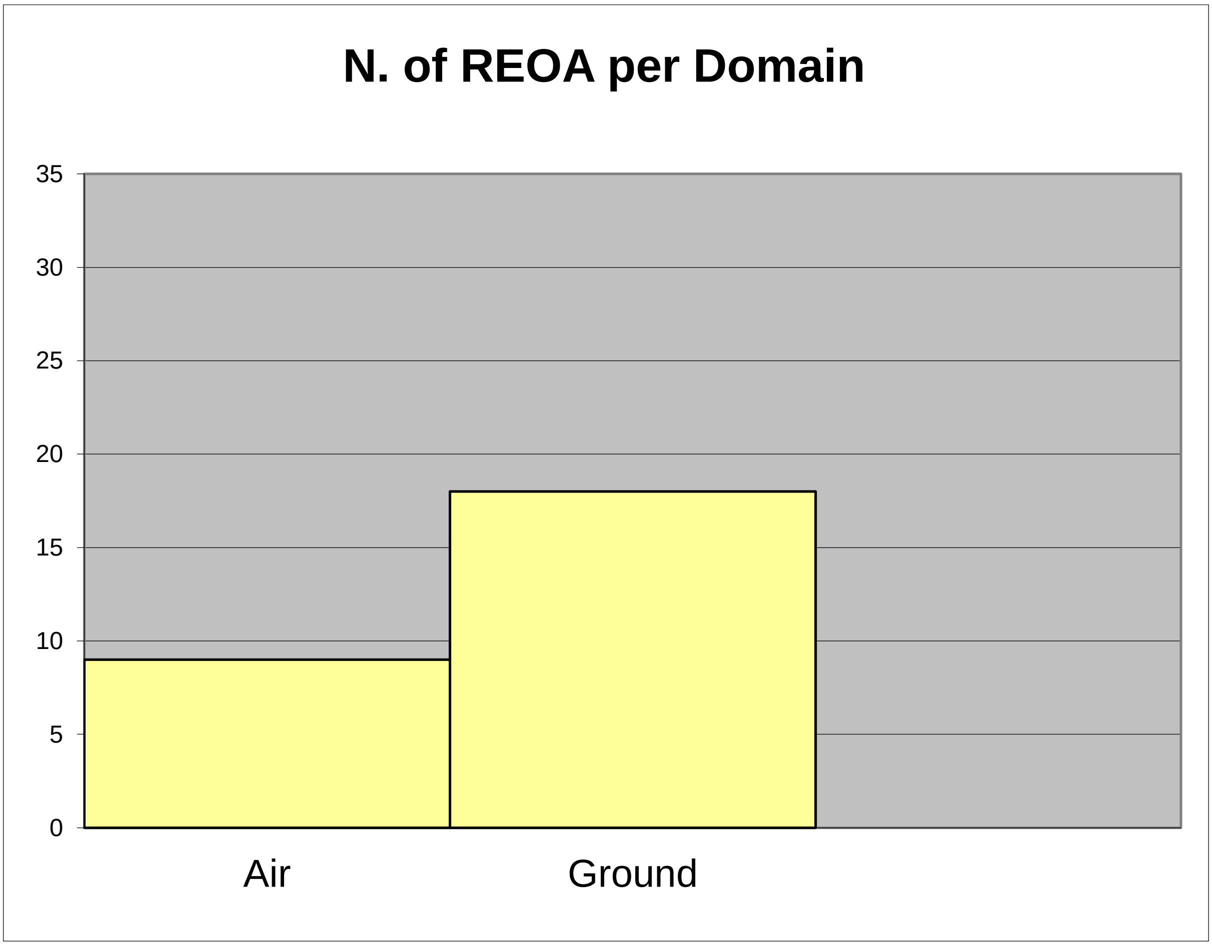


Figure 2: Number of REOAs per operational domain.

As one can notice, the majority of selected REOAs pertains to ground operational domain (16 out of 6). Such uneven distribution between air and ground is mainly due to the fact that there is only one airborne partner in the project team. Nevertheless this appears compatible with the prevalence of ground aspects which can be observed in the overall SESAR program.

3.1.2 Allocation of REOAs for flight phases

The graph in Figure 3 shows the distribution of REOAs per flight phase.

As mentioned above, the sampling of REOAs was done according to the availability of relevant information and this caused an uneven distribution of REOA examples.

In order to smooth this arbitrariness and to obtain an homogeneous distribution of examples, effort was spent to verify that concerned REOAs would cover all the flight phases.

The aim of building an homogeneous distribution of REOA examples for flight phases was partially reached, due to uneven availability of information on automated functions. This produced the results that can be seen on the graph below.

As shown in figure, the prevalence of REOA examples are referred to en-route flight phase; while automated functions referred to airport surface are poorly represented.

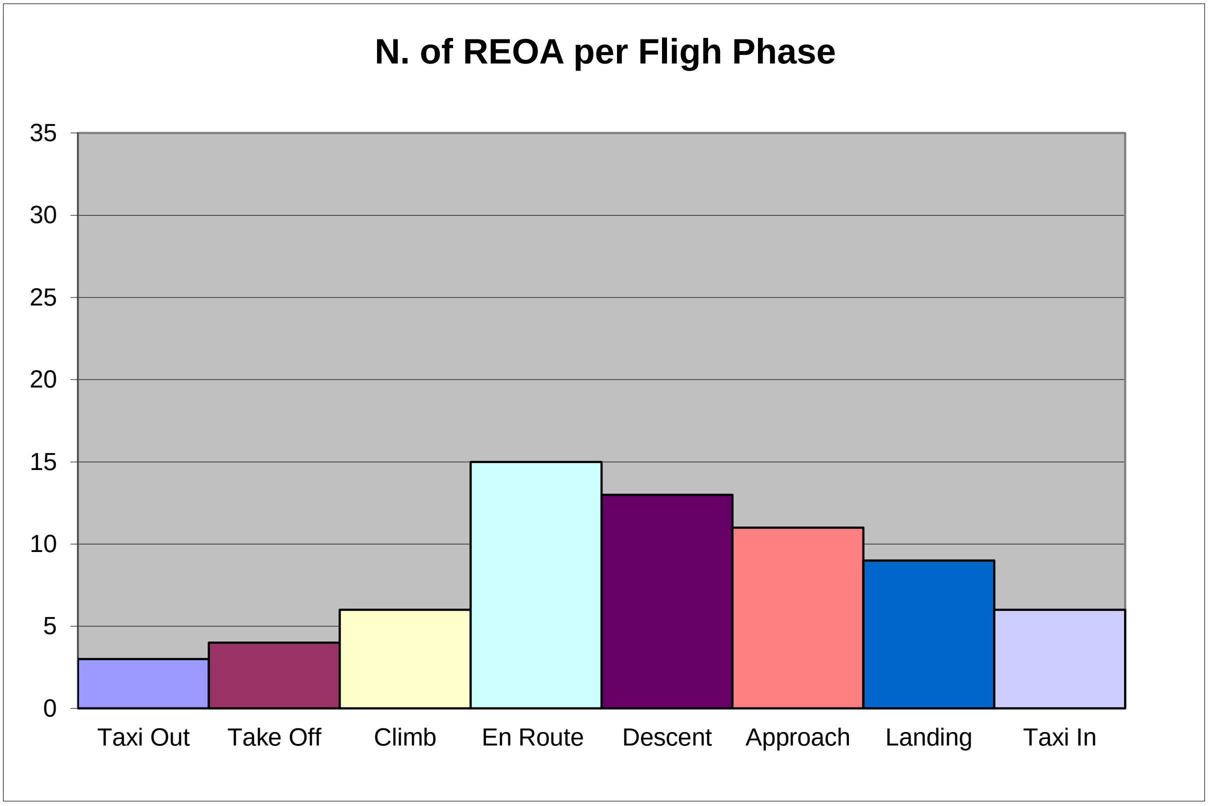


Figure 3: Number of REOAs per flight phase.

3.2 Overall observation of HP automation support provided by REOAs

This section provides an overview of the type of human performance support provided by the selected REOAs.

To derive this information, an overall observation of the information about REOAs was conducted. In particular, the observation focused on the two core classification elements described above: cognitive functions and levels of automation.

For each REOA, information on these two elements was collected.

The initial high-level hypothesis was related to one question: is it possible to detect regularities in the distribution of REOAs with respect of the type of HP support provided?

For example, is it possible to find relevant discrepancies between the type of cooperation provided by REOAs related to ground functions and REOAs related to airborne functions?

Table 4 shows the classification of REOAs according to HP support provided.

For each automated function, an alphanumeric code is associated. The coding of each REOA is based on LOA taxonomy (*see Section 2.3.1*), in which letters indicate cognitive functions, numbers indicate the level of automation.

Plus, a color-coding addresses operational domain: airborne functions are associated to white background; ground functions are associated to grey background.

Table 4: Distribution of REOAs per HP support provided

AUTOMATED FUNCTION	*Information Acquisition (IAC)*	*Information Analysis (IAN)*	*Decision and Action Selection (DAS)*	*Action Implementation (AIS)*
AP/FD TCAS	(A5)	B5	C4	D6
ASAS/ASPA	A5	B5		D4
ATSAW – ITP	A4	B2		
ATSAW – SURF	A5	B4		
BTV – Autobrake			C6	D6
BTV – Exit Selection	(A5)	B2		
BTV ROP			C4	D6
BTV ROW		B5		
D-TAXI	A3			D2
AMAN&PMS			C2	
A-SMGCS		B5		
A-STCA	A5	B5		
CATO – ECS	A3	B5		
CATO – Flight Path Monitoring		B5		
CATO – What-if probing	A3	B3	C2	
CLOU/FMAN		B4	C2	
DFS AMAN			C2	
DSAM	A5	B5		
ERATO – Filtering function		B3		
ERATO – Monitoring function		B5		
ERATO – Task Scheduler Function		B4	C2	
ERATO – What-if function		B3		
FAGI – AMAN timeline			C2	
FAGI – turn-to-base advisories				D2
FAGI air-ground negotiation				D6
PERSEO	A5	B2	C2	
SARA		B5	C4	
TMS/TML	A5	B2	C2	
Tower – HMI	A3	B2	C2	

Although the sampling of REOAs was not based on statistic parameters (but rather mainly based on availability of relevant documentation), it is possible to detect regularities in the way how HP automation support is distributed among air and ground operational domains.

A first remark is related to the distribution of automated support to action implementation (AIS) among air and ground side.

Looking at the table above, the selected *ground* automated functions do not have automated support with reference to action implementation (AIS) except for FAGI concept - turn-to-base advisories and air-ground negotiation (nevertheless turn-to-base advisories function remains at a very low level of automation support to action implementation –D2-, providing just a guidance as action is being executed). While on *airborne* side this kind of support is widely given even at high level of automation.

This means that the kind of support provided to the *controller* by the selected automated functions related to ground domain concerns acquiring and elaborating information and also generating options with respect of the action to be performed. While implementation of action is not represented.

Implementation of action, on the contrary, is always left up to the controller.

On the contrary, on the airborne side it is possible to notice that automation support on action implementation is given at even high level of automation (D6). This means that at a certain time the system is expected to initiate and execute automatically a sequence of actions without asking activation by the *pilot*, who can only monitor and interrupt it if needed (at level D6).

A second remark concerns the distribution of automated support to Decision and Action Selection (DAS) among air and ground side.

Looking again at the table above, the cognitive function Decision and Action Selection (DAS) is supported by a higher level of automation (from C4 up to C6) on airborne side than on ground side.

This means that, on *airborne* side, the system generates options and decides autonomously on the actions to be performed. The *pilot* is informed on its decision by default (C4) or only on request (C5), (or even not informed at level C6). In practice, the system does not show to the pilot any option but just presents the single action it has automatically chosen among alternatives (that remain hidden to the pilot).

On the contrary, on the *ground* side the automated support on DAS is tuned on lower levels of automation: in the majority of the cases at level C2 with only one automated function (SARA) at level C4. This means that freedom to generate alternative options is left to the *controller*, who can select one of the alternatives proposed by the system or her/his own one.

A last remark is associated to the distribution of automated support to Information Analysis (IAN) among air and ground side.

Looking at the table, it is possible to notice that the selected *ground* functions provides support to information analysis (IAN) in several cases: in other words, with respect to the selected ground functions, support to IAN is always present (except for one case, i.e. AMAN&PMS interoperability).

These preliminary observations represent the first - evidence-based - step from which it is possible to start a process of research for commonalities and discrepancies. This is as a point of departure for further abstraction in order to derive higher level principles (Guidelines), following the process that has been described in Section 2.1.1.

3.3 Organizing information on each REOA: the templates

To support the collection of REOAs in a practical way, a tool has been designed. Core part of this tool is a **template** which integrates all the classification elements (*see section 2.3*). This ensemble provides the support to gather information on the automation solutions and to reveal its impact on human performance.

The template consists of sections with sub-sections. The structure of the template was designed to integrate and organize in a satisfactory manner the information collected from the analysis of relevant documentation as well as from interviews with subject matter experts on the concerned automated function.

Each template is focused on the description of one specific automated function (for example ERATO – What-if function) and addresses the following topics:

- *Overview of the concerned automation*: this introductory section covers the title, the description of the overall automated system (for example ERATO) and the relevant functions included (for example ERATO – What-if function). Plus, it provides information on the concerned operational environment;
- *Description of the function:* for the specific function selected, detailed information on the applied solution, the kind of situations supported and the expected benefits on SESAR KPAs are described;
- *Context of the task and task:* this section addresses the concerned flight phases and the involved actors. Precise tasks of the actors supported by the automated function and potential consequences on task changes are also assessed;
- *Impact on Human Performance:* this section is a core part of the template, since it establishes the link to human performance. The section includes the classification of supported cognitive functions and automation level, that are rated in a matrix. Mitigated and remaining or emerging HP issues are identified as well;

- *Context of application of the automated solution:* more information on the origin of the automation example and the maturity of the concept are elaborated;
- *Final considerations:* this section includes final considerations on the lessons that could be learnt from the identified practice. It establishes a link to the HP and automation support issue(s) mentioned above and how it could be generalized to other operational contexts.

As it can be noticed looking at the list of topics above, this way of organizing information on REOAs includes not only a description of the function as such but also detailed analysis of the kind of HP support provided and a preliminary attempt to derive higher level conclusions, such as generalizations and lessons learnt.

This has an impact on the development of Guidelines: in other words, templates are organized in order to address REOAs in a manner that can be fit for the purpose of deriving higher level principles, presenting information already analysed with reference to certain main topics (for example, HP support). In this way, information on each specific function (included in each template) is ready to be generalized or compared with other functions included in the concerned templates.

4 List of REOAs

This section provides the complete list of REOAs.

As already explained (*see section 3.3*), information on each REOA is collected within a template.

It is worth pointing out that templates presented hereafter show different structures: in practice, the following presentation of REOAs is based on two different versions of the template.

This is due to the parallel work progress of template production and REOA collection and reflects the evolution of the project: in fact, the order of the items was changed in order to ease the process of filling the templates. Nevertheless, information provided is basically the same.

Templates will be presented according to a main criterion: they will be split in two categories according to operational domain.

At the beginning, templates related to airborne functions will be presented. They will be listed in alphabetical order according to the title of the concerned automated solution.

Following, templates concerning ground functions (they also will be listed in alphabetical order according to the title of the concerned automated solution).

4.1 Airborne functions

Sampling of airborne functions gathered nine automated solutions, as follows:

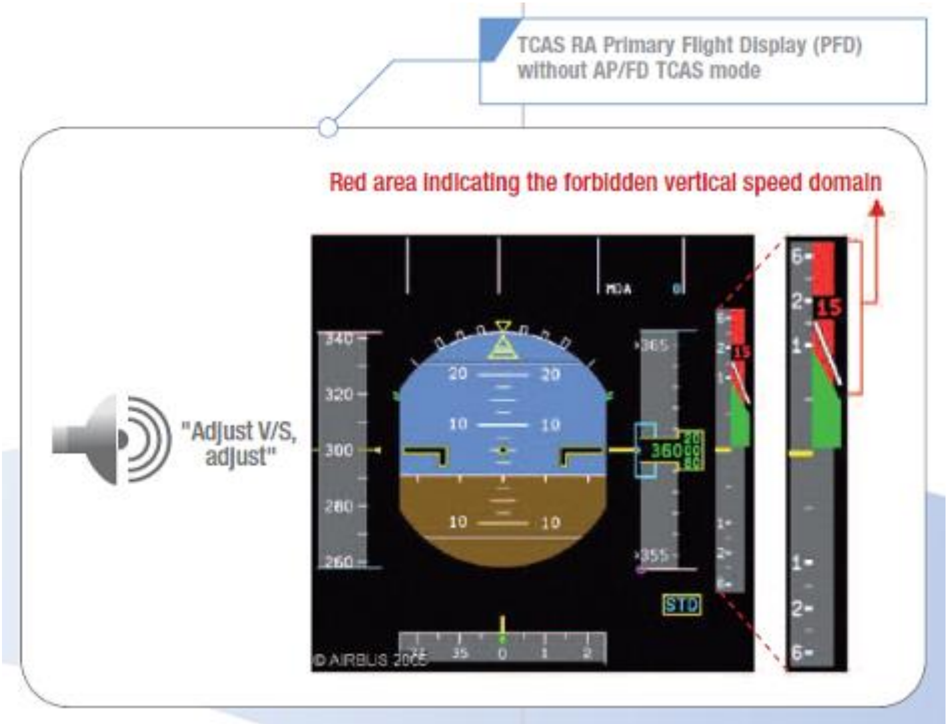
[1] AP/FD TCAS (Auto Pilot / Flight Director Traffic Collision Avoidance System) - mode concept
[2] ASAS – ASPA (Airborne Separation Assistance System – Airborne Spacing Application)
[3] ATSAW ITP (Air Traffic Situation Awareness in Trial Procedure in Oceanic Airspace)
[4] ATSAW SURF (Air Traffic Situation Awareness during Surface Operations)
[5] BTV (Brake to Vacate) - Auto brake
[6] BTV (Brake to Vacate) - Exit Selection
[7] BTV – ROP (Brake to Vacate – Runway Overrun Protection)
[8] BTV – ROW (Brake to Vacate – Runway Overrun Warning)
[9] D-TAXI (graphical route display on Airport Moving Map)

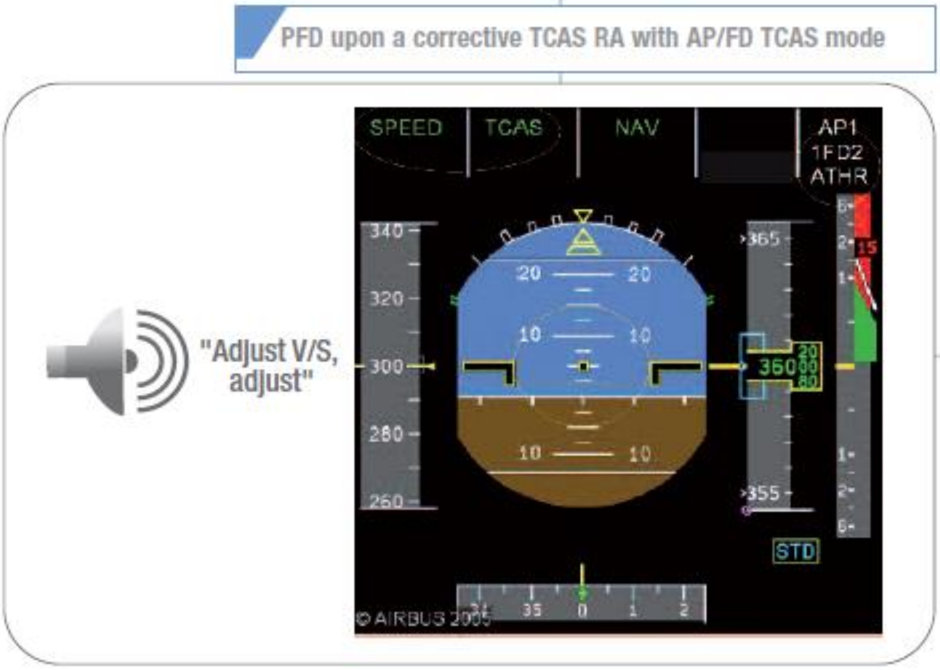
Hereafter each automated function is presented in the template.

It is worth clarifying that Brake to Vacate ROP and ROW functions are presented in the same template, even if they address different types of HP automation support (this is the reason why until now they were presented separately).

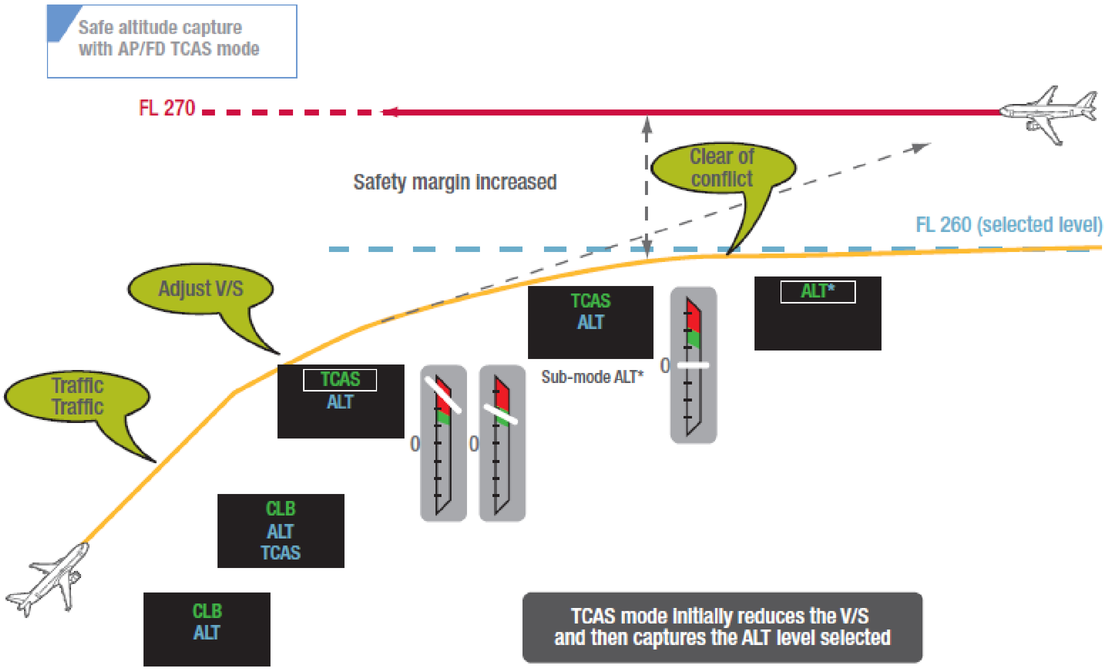
4.1.1 Auto Pilot / Flight Director Traffic Collision Avoidance System (AP/FD TCAS)

1	Title of the automated solution
	Auto Pilot/ Flight Director (AP/FD) TCAS mode concept: Auto Pilot flying the TCAS RA manoeuvre automatically
2	Short description of the concerned automation
	Traffic Alert and Collision Avoidance System (TCAS) is an onboard system that has been introduced to reduce the risk of mid-air collisions between aircraft. TCAS monitors the airspace for other aircraft equipped with a corresponding active transponder around an aircraft. TCAS scans, detects and interrogates transponders of aircraft in vicinity. In the case that TCAS detects that an aircraft is to close or the closure rate becomes critical it provides aural and visual alerts to pilots. TCAS is mandatory on all aircraft types (carrying more than 30 passengers). The TCAS display is integrated in the Navigation Display of the Cockpit and alerts the pilots of presence of other aircraft in a protected volume. [Note that, there are also non-integrated TCAS solutions existing, in case TCAS is acquired as a separate box.]

	Besides identifying potential collisions TCAS alerts the pilot by issuing the following types of aural annunciations: Traffic Advisory (TA), Resolution Advisory (RA) and Clear of Conflict.		
	2.1 Applicable domain		
	☒ Air	☐ Ground	☐ Air-Ground
	Explanation: For Air Traffic Controllers (ATC) the AP/FD TCAS mode is totally transparent in terms of expected aircraft reactions.		
3	Description of the specific function		
	The AP/FD TCAS mode enhances the existing TCAS functionality by implementing a TCAS vertical guidance feature into the Auto Flight computer. This new mode controls the vertical speed of the a/c on a vertical speed target acquired from TCAS which is adapted to each RA. The focus in this example is on the case of an Auto Pilot (AP) engaged. The pilot can fly a required TCAS RA avoidance manoeuvre automatically. The picture below shows the TCAS RA on Primary Flight Display without AP/FD TCAS mode  In the next page the TCAS RA on Primary Flight Display with AP/FD TCAS mode		



As the figure below illustrates, the AP/FD TCAS mode solution prevents undue altitude (ALT) crossing when altitude captureis compliant with the Resolution Advisory (RA).



3.1 Reason for the change

'[…] in-service feedback showed that surprise and stress induced by TCAS Resolution Advisories (RA) may lead to non-optimum crew response, resulting in undue aircraft altitude deviations injuries in the cabin, lack of proper communication with Air Traffic Control (ATC), therefore jeopardizing the aircraft and its passengers' safety.' p. 10. After the RA is triggered, the pilot has to perform the required avoidance manoeuvre which is an unfamiliar flying technique. This may increase the pilots' stress level already induced by the RA itself. The reaction of the pilot is the first factor which impacts how the quality of service will be. That is why AP/FD TCAS mode supports the RA manoeuvre.

Before the AP/FD TCAS mode employment the flying technique consists of:

- Disconnecting both AP and Flight Directors,
- Adjust pitch attitude of the a/c to reach proper vertical speed indicated on the vertical speed indicator.

Before conducting the required TCAS manoeuvres, the pilot had to disrupt his current flying technique by disengaging the AP and FD.

3.2 Applied solution

AP/FD TCAS mode supports the pilots in flying the avoidance manoeuvres requested by TCAS operational environment. It completes the TCAS vertical guidance feature into Auto Flight computer and controls the vertical speed of the a/c. In a context of continuous increase of traffic, the new proposed Airbus AP/FD TCAS mode aims at significantly enhancing safety.

3.3 Which benefits on SESAR KPAs are expected?

☐ Capacity	
☐ Efficiency	
☐ Flexibility	
☐ Predictability	
☒ Safety	In a context of continuous increase of traffic, the Airbus Auto Pilot/Flight Director (AP/FD) TCAS mode aims at significantly enhancing safety by reducing risk of collision, whilst assuring that the avoidance manoeuvre is executed in the expected way.
☐ Access and Equity	
☐ Interoperability	

4 Which kind of situation(s) does the function support?

☐ normal situations	☒ abnormal/ emergency situations The TCAS AP/FD mode comes into play when a TCAS Resolution Advisory goes off.

CONTEXT OF THE TASK AND TASK

5 What are the concerned flight phases?

☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☒ Climb
☒ En Route	☒ Descent	☒ Approach	☐ Landing	☐ Taxi-in

Explanation

The flight phases concerned are the ones in which TCAS is active. In APP it will be active only until a certain threshold.

6 Involved Actor(s)

Air: Pilot	Ground: ATCO ☐ EC ☐ PC ☐ GND ☐ RWY ☐ Apron Controller ☐

	☒ PNF ☒ PF	Supervisor
	6.1 Rationale	
	The Pilot Flying (PF) should immediately respond to the RA. However, the PNF is also involved supporting the PF and verifying of actions is an important task.	

	Pilot tasks	ATCO tasks
7	Operate: ☒ Control the aircraft ☒ Manage the autopilot ☒ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication

7.1 Rationale

The AP/FD mode executes the manoeuvre and based on alerts the pilot is supposed to let the AP perform by precisely not 'acting' but letting the AP act.

7.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

The change in responsibilities does not change; the crew is responsible to execute the RA manoeuvre.

7.3 Would you expect that procedures change?

☒ Yes ☐ Likely yes ☐ No ☐ Likely no

Explanation:

Procedures for AP/FD TCAS have been defined. The conventional procedure for manually controlling the vertical speed remains unaltered.

8 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation			
	A	B	C	D
	Information acquisition	Information analysis	Decision and action selection	Action implementation

	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA				B5	C4	C4	D1	D6

8.1 Rationale

The judgment above refers to the specific action of **flying the required RA avoidance manoeuvre**. However this is also related to Decision and action selection by TCAS RA.

After the change with the AP/FD TCAS mode concept, the pilot is supported in flying the RA manoeuvre (D6). The pilot has the possibility to disconnect the AP and FD at any moment and to respond to the RA by flying the avoidance manoeuvre according to the conventional procedure.

There is also information analysis involved since the system corrects the manoeuvre based on a constant check of the a/c position.

IMPACTS ON HUMAN PERFORMANCE

9 Human Performance and automation issues expected to be prevented or mitigated

With the AP/FD mode concept the crew's workload and stress level by conducting the RA manoeuvre is expected to be reduced. Moreover a disruption in the flying technique when an RA is received can be eliminated. The pilot no longer needs to disengage the Auto Pilot or Flight Directors before conducting the TCAS manoeuvre. This support in executing the avoidance manoeuvre will help to avoid inappropriate reactions in case of RA (late, over, or opposite reactions) or other misbehaviour when the aircraft is clear of conflict. The following HP and automation issues can be prevented:

- **Issue n.9**: Progressive shift from skill/rule-based task to knowledge-based tasks may result in increased response time or increased risk of errors by operator
- **Issue n.10:** Automation may increase task demand and cognitive workload
- **Issue n.14:** Loss of flexibility in automated systems will reduce the human potential to adapt to normal and abnormal situations

Since the AP/FD TCAS mode supports the execution of the RA flying manoeuvre it is expected to reduce pilots' stress and workload in such an abnormal situation. The flying manoeuvre is adjusted to the severity of the RA and thus expected to reduce the risk of overreaction of pilots.

10 Human Performance and automation issues potentially not mitigated by design

The following issues from HP and automation issues from DEL02 could not be mitigated by design

- **Issue No. 2:** Lack of user involvement in automation assisted processes may lead to loss of skills and proficiency
- **Issue No. 12:** Poorly designed automation may lead to simultaneous tasks competing for user attention or causing interruptions of high workload activities, reducing efficiency and increasing the risk of human error
- **Issue No. 14bis.** Systems that do not consider unexpected events nor update the planning may lead to loss of situation awareness and to increased decision times.
- **Issue n.22**: Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness

CONTEXT

11	In which kind of organisation was the automation practice applied?		
	The function has been developed in Airbus with means of cockpit simulators (depending on function maturity) and real flight tests. Air-ground collaboration was involved.		
12	How often was the good practice applied in the past?		
	Aircraft equipped with TCAS AP/FD mode are in operation since November 2009.		
13	What were the required technical means and human resources to test/validate the practice?		
	The AP/FD TCAS mode was developed and tested by different technical means, such as cockpit simulator (aircraft -1), aircraft with real equipment (aircraft 0) in test flights, and modelling tools. Aircraft simulators differ in terms of maturity: aircraft -1 is the simulator with equipment differing from the real equipment which is implemented on an a/c 0. Various experts were involved in the development and certification process: e.g. engineers, pilots, test pilots, operational experts, HF experts.		
14	Integration of the concerned automation into a system or an ensemble of systems		
	If considered relevant, please elaborate on how the integration of the concerned automation into a system and in an ensemble of system went. How does the introduction of the concerned automation support or change the philosophy of the overall ensemble of functions or systems? The function is integrated in TCAS which is integrated in existing cockpit displays.		
15	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☒ V5: Deployment	☐ V6: Operations
	16.1 Rationale		
	Aircraft equipped with TCAS AP/FD mode are in operation since November 2009.		
FINAL CONSIDERATIONS			
16	What can be learnt from the proposed change in HP automation support?		
	AP/FD TCAS mode provides support in an abnormal situation, by precisely executing the manoeuvre which can be prone to suboptimal handling by pilots due to the criticality of the situation.		
REFERENCES			

Airbus (2009). Airbus new Auto Pilot/Flight Director TCAS mode. Retrieved from http://www.airbus.com/fileadmin/media_gallery/files/brochures_publications/FAST_magazine/fast45-04-new-auto-pilot.pdf

4.1.2 Airborne Separation Assistance System (ASAS)

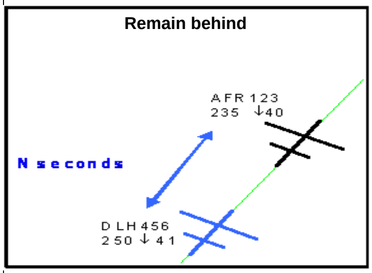
1	Title of the automated solution		
	ASAS (Airborne Separation Assistance System) ASPA S&M (SPAcing Sequencing and Merging)		
	Short description of the concerned automation		
	ASAS concept covers all kind of applications based on ADS-B (Automatic Dependent Surveillance - Broadcast) and allows acquiring and maintaining either spacing or separation. This includes different applications: - ATSAW: Airborne Traffic Situational Awareness applications; - ASPA: Airborne Spacing applications; - ASEP: Airborne Separation applications; - SSEP: Airborne Self-separation applications. These applications aim at: - Increasing capacity (sequencing traffic and maintaining the sequence thus avoiding stacking); - Reducing costs (mainly by reducing stacking thus reducing fuel burns); - Reducing emissions; - While maintaining or increasing safety.		
	2.1 Applicable domain		
	☒ Air	☒ Ground	☒ Air-Ground
	Explanation: If more than one domain is concerned, please describe how the other domain might be affected by the change. Each domain is affected by ASPA S&M. Both controllers and pilots interact or benefit from the ASPA S&M. Role of the actors is described in section 6.1.		
3	Description of the specific function		
	The ASPA S&M function allows the acquisition and the maintaining of a time spacing instructed by the ATC controller, between the trailer aircraft (or ownship) and a given target aircraft. For that purpose, the ASPA S&M function provides three manoeuvres. - 1st manoeuvre: Remain behind manoeuvre The two aircraft are following the same lateral flight plan. Following ATC instruction, the trailer aircraft has to acquire and maintain a time spacing (with a +/- 5s tolerance). - 2nd manoeuvre: Merge then Remain behind manoeuvre, This manoeuvre applies for two aircraft having their trajectory merging at a given waypoint		

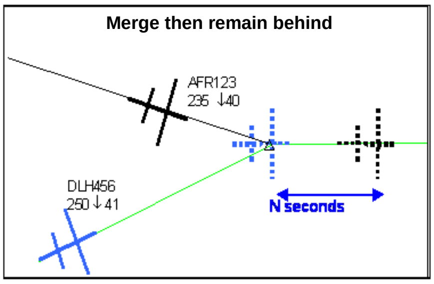
(merge waypoint). After ATC instruction, the trailer aircraft has to engage a maneuver to over fly the merge waypoint with the instructed time spacing. This spacing has to be maintained with a +/- 5s tolerance.

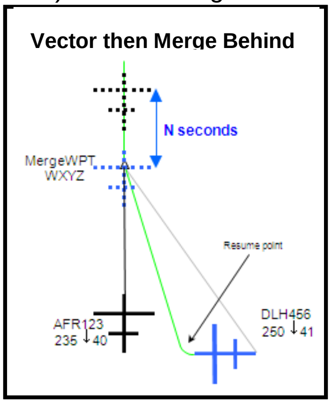
- 3rd manoeuvre: Vector then merge behind manoeuvre.

This maneuver applies for two aircraft having their trajectory merging at a given waypoint (merge waypoint). The goal, for the trailer aircraft, is to lose time by following a ground heading instruction, before the merging point. This spacing has to be maintained with a +/-5s tolerance.

The choice of the manoeuvre is done by the controller and instructed to the flight crew. This choice depends on the relative position between the ownship (DLH456) and the target aircraft (AFR123) as illustrated in the pictures below.







In terms of operational environment, the ASPA S&M application concerns end of en-route, descent and approach environment.

There is no specific relation between ASPA S&M application and traffic level. Nevertheless partial equipage can have an impact on Air Traffic Controller use of the application.

3.1 Reason for the change

The number of flights is projected to increase at mid-term, consequently runway and airspace will be congested in most of airports. Associated controller workload affects the efficiency and capacity in such high density context. A solution is to introduce the ASPA S&M application and air-ground data link.

The objective of the automated management of the speed is to reduce controller workload, for example by reducing the number of instructions. Indeed, it is no more needed to send individual instruction to each aircraft. Therefore the controller may be in charge of more aircraft. At the same time special attention is put on pilots' workload impact. Indeed, the system is not intended to reduce their workload. At worst, it may not increase pilots' workload.

3.2 Applied solution

Within ASPA S&M application future operational concept will evolve towards a more strategic approach. In addition to Arrival Management (AMAN), Initial 4D (I4D) or Controlled Time Arrival (CTA) techniques, automation and advanced surveillance techniques will be used to implement advanced ATM to improve situation awareness. Transfer of the separation function from the ground to the cockpit will be a standing objective leading ultimately to more autonomous operations. Indeed the airborne part of the ASPA S&M application is initiated by the flight crew upon instruction from the ATC but at all times, the ATC remains responsible of the separation between aircraft.

In terms of tasks, the ASPA S&M maneuver can be sequenced in different step (*as described in the OSED*):

- **Initiation - Set up:**
  - Initiation of ASPA S&M: Ensure that applicability conditions are satisfied before proceeding.
- **Initiation - Target Identification:**
  - Initiation of procedure: Nomination and identification of target aircraft.
- **Initiation - S&M Instruction:**
  - Initiation of procedure: ASPA S&M instruction by the controller and assessment of feasibility by crew.
- **Execution of S&M instruction:**
  - The flight crew complies with ASPA S&M instruction and advises controller if not possible.
- **Termination:**
  - ASPA S&M procedure is terminated and conventional operations are resumed.
- **Exception**:
  - Exception procedure: Revert to conventional operations.

The ASPA S&M concept is proposed to optimize aircraft spacing in preparation for arrival to the airport. This advanced concept will contribute to reducing the effect of congestion, while accommodating efficient descent paths and increasing runway throughput.

	3.3 Which benefits on SESAR KPAs are expected?	
	☒ Capacity	One of the main objective is to increase capacity (sequencing traffic and maintaining the sequence thus avoiding stacking).
	☒ Efficiency	Benefits are also expected because of the ability of pilots and controllers to perform their job more efficiently so that the traffic would be more fluid (sequencing traffic and maintaining the sequence thus avoiding stacking).
	☐ Flexibility	
	☐ Predictability	
	☐ Safety	
	☐ Access and Equity	
	☐ Interoperability	
4	Which kind of situation(s) does the function support?	
	☒ normal situations	☐ abnormal/ emergency situations Please elaborate.
CONTEXT OF THE TASK AND TASK		

5	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb

	☒ En Route	☒ Descent	☒Approach	☐ Landing	☐ Taxi-in
6	Involved Actor(s)				
	Air: Pilot ☒ PNF ☒ PF	Ground: ATCO ☒ EC ☒ PC ☐ GND ☐ RWY ☐ Apron Controller ☐ Supervisor			
	6.1 Rationale				
	Description of the different actors: ○ En route controllers monitor flight progress and maintain separation in en route airspace, issue descent clearances, and ensure that instructions for sequencing and spacing are maintained. ○ Once the flight crew reaches cruise altitude, the various conditions that could affect the flight are monitored in order to optimize aircraft performance and arrival schedule. Throughout the flight, the crew relies on ATC to maintain an appropriate spacing interval from the target aircraft and other surrounding traffic. The crew monitor the spacing time form the target aircraft. Once the aircraft begins the arrival phase of the flight, crews adhere to ATC instructions such as altitude changes, radar vectors, and speed reductions to achieve the appropriate sequence and interval required.				
7	Pilot tasks	ATCO tasks			
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☒ Flight planning/ trajectory management Communicate: ☒ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☒ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☒ Monitoring traffic ☒ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication			
	7.1 Rationale				
	ASPA S&M function introduces **new additional tasks for the flight crew and the controllers**. Indeed flight crew has to: - Communication with ATC regarding ASPA manoeuvres - Identification/Selection of the target - Entry of manoeuvre parameters - Activation of manoeuvre - Monitoring of manoeuvre				

- Management of non nominal cases (unable) and contingence procedures

Task sharing between pilots and controllers may be modified, the following description is a potential solution:

- If the spacing is missed during the maintaining phase, the pilot is in charge of detecting it (supported by the system which triggers a message) and of informing the controllers who will be in charge of stopping the manoeuvre. The controllers have no immediate information on the missed spacing situation; they will be able to see it later.

On ATC side, several routes may be merged in order to fly along a single horizontal route. To reach this objective, controller has to assure separation by:

- Vectoring aircraft (SESAR should contribute to facilitate this task);
- Controlling aircraft speed;
- Directing aircraft to flight level (for vertical separation assurance);
- Using visual separation late in the arrival process (if certain conditions are met).

Controller also has to maintain an order of traffic by:

- Building a sequence of traffic along individual routes;
- Merging multiple individual traffic flows into a single flow;
- Prevent potential aircraft conflicts or resolve them;
- Anticipating and delivering required spacing based on altitude, aircraft performances and environmental conditions;
- Managing the spacing of aircraft on final approach to enhance runway throughput.

7.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

If the concerned automation led to a change of the nature of the task and thus, to a transformation of roles, please explain (potential) changes of responsibilities, authority sharing and delegation in ATM.

The flight crew engages ASPA S&M manoeuvres only on R/T or datalink instruction from the controller. There is a task delegation to the flight crew for monitoring the manoeuvre but there is no delegation in terms of responsibility, the separation between aircraft must be guaranteed by the controller who is in charge of deciding to stop the manoeuver.

7.3 Would you expect that procedures change?

Please choose using ☒

☐ Yes ☐ Likely yes ☒ No ☐ Likely no

Explanation:

Please explain why.

Roles and responsibilities will be unchanged.

Nevertheless, roles and responsibilities between ATCO and Flight Crew will have to be clearly established in non-nominal situations (unable spacing for example) or for the contingency procedures (failures, specific weather situations…).

8	Classification of supported cognitive functions and automation level			
	Associated cognitive function being supported by automation			
	A	B	C	D
	Information acquisition	Information analysis	Decision and action selection	Action implementation

	Before change	After change	Before change	After change	Before change	After change	Before change	After change
	A1	A5	B1	B5	C1	C3	D1	D4

8.1 Rationale

- **Information acquisition**: A1→ A5. Before change crew was only able to compare its speed with the target speed and position (ATSAW) in order to have a global awareness of traffic surroundings. There was no information about the spacing time because pilots didn't have to maintain the spacing themselves. After change, spacing time to respect is always displayed and the crew can monitor the data at discretion. If the required spacing time is not possible anymore, a message informs the crew.
- **Information analysis and decision**: B1 →B5 /C1→C3. Before the change the crew could only use information on a dedicated display to have a representation of the situation. Now information is provided to the crew to analyse the situation and answer the controller about the instructed manoeuvre possibility. Information computed and displayed on a dedicated display informs the crew when an instructed manoeuvre is possible or not. During the acquisition phase the pilots know when the spacing will be reached (all manoeuvres) or they can visualize the new flight plan for the 3rd manoeuvre.
- **Action implementation:** D1→ D4. Before the change the crew had to change speed, heading and follow the flight plan using existing tools (manually or managed by the FMS) for example. After activation by the crew, ASPA S&M manages automatically the speed and the trajectory without crew intervention. The crew can monitor the system and interrupt it during the execution. The system is automatically disengaged under certain conditions, e.g. under a given altitude or if autopilot is disengaged.

IMPACTS ON HUMAN PERFORMANCE

9 Human Performance and automation issues expected to be prevented or mitigated

- **Issue 1: Lack of implication in tasks of Trajectory Management**
  ASPA S&M allows the acquisition and the automatic maintaining of a time spacing instructed by the ATC controller without any crew intervention. Nevertheless, flight crew will have to monitor the manoeuvre and the system proposes some alerts if the spacing time cannot be maintained.
- **Issue 10: Task demand increase due to cognitive treatment**
  ASPA S&M manoeuvres requires some crew actions, but the LOAD possibility facilitate required pilots actions and the system provides all the necessary information to facilitate crew decision. Then everything is under automation.
- Issue 14: Reduction of the human potential to adapt abnormal situations due to a loss of flexibility in automated system.

Specific procedures will be defined to help flight crew to manage non nominal or abnormal situations.

10 Human Performance and automation issues potentially not mitigated by design

- **Issue 6: Impact of task distribution on information sharing between pilots and ATCO**
  It is clearly stated that delegation from ATC to A/C of the responsibility of maintaining separation from a given target while ATC remains responsible of maintaining separation between the A/C pair and the surrounding traffic. ATCo is still responsible but he cannot be sure that the flight crew has selected the right aircraft, entered the right manoeuvre parameters or has well engaged the manoeuvre. Clear procedures will have to be established in collaboration with ground actors to make the use of the system acceptable.

<table>
<tr><td></td><td colspan="3">- Issue 26: The use of data-link communication will impact task sequencing and working methods
Use of Datalink implies a delay to receive and treat the message. It has to be confirmed with ground actors whether the use of datalink is acceptable.</td></tr>
<tr><td colspan="4">CONTEXT</td></tr>
<tr><td rowspan="2">11</td><td colspan="3">In which kind of organisation was the automation practice applied?</td></tr>
<tr><td colspan="3">This automation solution has been developed in the scope of an Airbus R&D project with means of cockpit mock-ups and simulators. Some flight tests and some coupled evaluations with ground actors will take place in the scope of SESAR.</td></tr>
<tr><td rowspan="2">12</td><td colspan="3">How often was the good practice applied in the past?</td></tr>
<tr><td colspan="3">The ASPA S&M application is not operational yet but some experimentations have been performed on the ground side and 5 evaluations campaigns have been performed on Airbus side.</td></tr>
<tr><td rowspan="2">13</td><td colspan="3">What were the required technical means and human resources to test/validate the practice?</td></tr>
<tr><td colspan="3">15 Airbus Flight test pilots and Airbus training instructors have been involved in the different evaluations campaigns on simulators.</td></tr>
<tr><td rowspan="2">14</td><td colspan="3">Integration of the concerned automation into a system or an ensemble of systems</td></tr>
<tr><td colspan="3">ASPA S&M application is fully integrated in existing cockpit (based on ATSAW function. Novelty is to provide an automation to acquire and maintain time spacing, with specific symbols /feedback on the Navigation Display and on PFD and specific pages on MCDU.</td></tr>
<tr><td rowspan="5">15</td><td colspan="3">On which phase of maturity of the concept/automation was the good practice applied?</td></tr>
<tr><td>☐ V1: Scope</td><td>☒. V2: Feasibility</td><td>☒. V3: Pre-industrial development and integration</td></tr>
<tr><td>☐ V4: Industrialisation</td><td>☐ V5: Deployment</td><td>☐ V6: Operations</td></tr>
<tr><td colspan="3">16.1 Rationale</td></tr>
<tr><td colspan="3">The project will start at phase V2 and objective is to reach V3 phase.

Initial baseline for this project is in the maturity phase V2. Indeed potential operational benefits are already identified. Development of functional requirements will be supported by the early validation in order to reach/progress V2 level for this platform. The validation of functional requirements for business aircraft will be performed through Human Factors assessment and System validation. They will be based on:
- Functional, performance and interoperability evaluation (maybe coupled with ANSP) in 2011. This first step will allow assessing an experimental design based on the initial requirements and implemented as a HMI mock-up. This model will be used for Pilot-in-the-loop evaluations and supported by small-scale modelling. (2011)
- Functional, performance and interoperability evaluation (maybe coupled with ANSP) in 2012. This second step will consist in experts' evaluation of technical validation results obtained for mainline aircraft (aircraft integration simulator, flight tests).
- The obtained validation results will be used to refine the initial functional requirements, and potentially to provide system, design, training and cockpit procedure recommendations.</td></tr>
</table>

FINAL CONSIDERATIONS	
16	What can be learnt from the proposed change in HP automation support?
	The automation mainly supports the action execution by automatically managing the acquisition (time to reach the time spacing) and the maintaining of a time spacing. However, the system keeps the crew in the loop, by providing him with information on the situation all along the manoeuvre. Moreover alerts are provided if the spacing cannot be maintained. The flight crew is informed by the system. Then, the flight crew is in charge of informing the controller who decides to instruct the interruption of the manoeuvre. The automation support respects the current responsibility sharing between ATCOs and flight crew.

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N°	TITLE	AUTHOR	ISSUE	DATE
1	Advanced Merging and Spacing Concept of Operations for the NextGen Mid-Term	FAA	1.4	09/18/2009
2	Package 1: Enhanced Sequencing and Merging Operations (ASPA S&M) – Application Description	RFG	2.3.0	01/20/2009
3	Project Initiation Report WP 9.05-Airborne Separation Assistance System - Spacing Sequencing & Merging	SJU	00.02.00	14/04/2010
4	Functional requirement definition – ASPA S&M	SJU	1.0	
5	Verification and Validation Plan – ASPA S&M Application for Mainline Aircraft	SJU	00.00.01	23/11/10

4.1.3 Air Traffic Situation Awareness in Trial Procedure in Oceanic Airspace (ATSAW – ITP)

1	Title of the automated solution
	ATSAW ITP – Air Traffic Situation Awareness In-Trail Procedure in Oceanic Airspace
2	Short description of the concerned automation
	ATSAW is an onboard application providing information about ADS-B traffic to improve situational awareness. ATSAW consists of 4 applications: AIRB (Airborne), ITP (In-trail procedure), VSA (Visual Separation on Approach), and SURF (Airport Surface). ATSAW is a step towards airborne traffic separation using Automatic Dependent Surveillance-Broadcast (ADS-B) position reporting. It is expected to enhance efficiency during conditions such as conditional taxi clearances (especially during night operations or at an airport unfamiliar to the flight crew). The application is also expected to decrease flight crew and controller workload by reducing requests for repeated information with respect to surrounding traffic.
	2.1 Description of the function

In cruise, **ATSAW ITP** enables the flight crew to change flight levels more frequently to reach optimum flight levels or to exit areas of turbulence. This enhancement can allow on board surveillance by flight crew to determine if optimum flight levels can be reached. Based on calculations the function indicates if and when a FL change is possible based on the ADS-B information from the aircraft around. With ITP the flight crew can calculate the feasibility of a request for a certain FL at a time. The algorithm of the function calculates the speed of rapprochement, the spacing and also considers the speed of the execution of the FL change manoeuvre. As can be seen in the picture below, the flight requested the calculation for the FL 370. The surrounding a/c pertinent for this manoeuvre are reported below. With this increased range capability, more flight level changes can be taken advantage of under a short period of reduced separation until the desired FL is reached. These flight level changes can give benefit towards favourable winds or decreased drag, thus saving fuel usage. The function increases flight safety by providing a more intuitive display of surrounding aircraft, while also allowing pilots to better plan for oceanic flight level changes to reduce fuel burn – resulting in significant cost savings.

Before beginning an ITP manoeuvre it is crucial to meet several criteria in order to ensure and maintain a 'reduced separation' between a/c.

An example: An a/c is flying at FL340 which will change its FL, therefore called ITP aircraft. The surrounding aircraft flying in the same direction but ahead is the reference aircraft. The ITP aircraft would like to request FL 370. Before starting the ITP climb the Pilot Flying (PF) must therefore check the following 2 criteria satisfied: that the requested FL is below RECMAX FL in order to make sure that the a/c is able to climb to a minimum of 300ft/min and to maintain aircraft speed, i.e. the cleared Mach number during the ITP manoeuvre.

[Pictures taken from Airbus Fast Magazine No. 47 Automatic Dependent Surveillance Broadcast (ADS-B)
https://w3.airbus.com/CRS/A233_GN60/Customer_Services/html/acrobat/fast47_ADS_B.pdf]

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

ATSAW ITP is a surveillance function and is supposed to enhance awareness and optimise usage of available FL. It facilitates normal situations when flying in oceanic airspace.

What is the linkage between the use of the function and traffic level?

Due to dense traffic, nowadays it is difficult to have the occasion to climb to the optimum FL. ATSAW ITP indicates the possibilities and with that information any chances of FL changes can be optimised.

2.3 Concerned domain

☒ Air ☐ Ground ☒ Air-Ground

Explanation:

Once the pilot has an indication of ITP possible and he issues the FL change request to ATC, ATC has to authorise. That means that the ATCO will verify if the ITP request is possible, e.g. if other TCAS only aircraft are in vicinity jeopardising the ITP possible. ATC authorises the request and the crew can effect the FL change.

2.4 Operational environment

Via 'ADS-B out' (capability to emit ADS-data) automated aircraft parameter can be transmitted between an aircraft and ATC. The technical enabler of ATSAW is **ADS-B in** (Automatic Dependent Surveillance Broadcast). 'ADS-B in' (capability to receive ADS-B data) provides automated aircraft parameter transmission between aircraft themselves. Hence, information of other ADS-B aircraft can be displayed in the cockpit.

ATSAW vs. TCAS are complementary and work together. Both systems ATSAW and TCAS operate independently of each other; however both systems are hosted by the same TCAS computer. To differentiate, ATSAW provides information on surrounding traffic and TCAS enables an immediate reaction on surrounding threats.

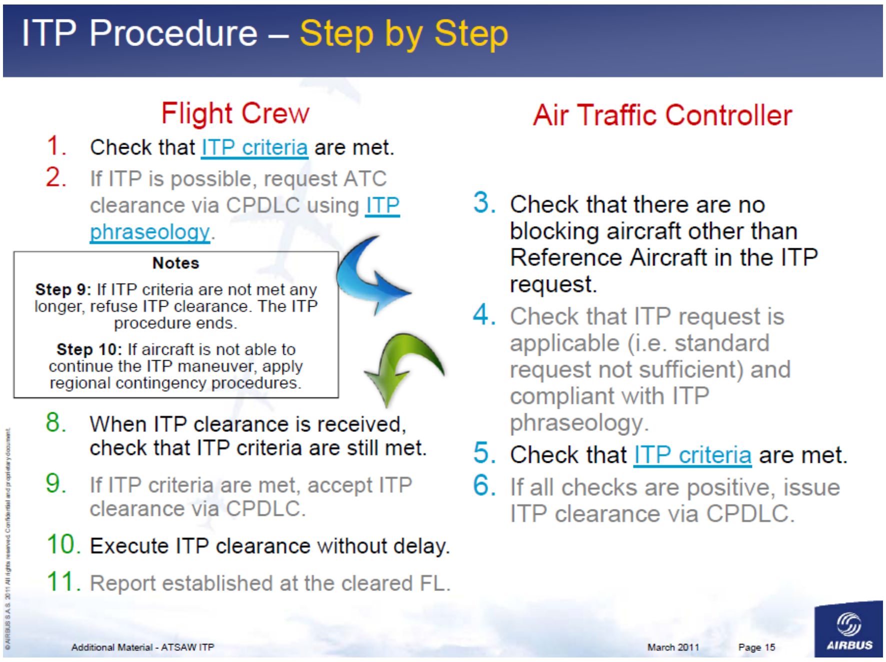
2.5 Reason for the change/ Problem to be handled

The reason for the change is motivated by using optimum FL in oceanic areas more efficiently. Besides operational efficiency this can bring environmental and economic benefits (fuel savings).

2.6 Applied solution/intervention

ATSAW indicates that an ITP manoeuvre is possible but it cannot take into account aircraft without ADS-B, since information between aircraft is transmitted via ADS-B. As described in the picture below (cf. step 3) this could be a ‘blocking aircraft’ for the maneuver. Depending on the equipment of these aircraft, ATSAW may detect some of them and display a message in the scratchpad. Since ATC has visibility of all aircraft, ATC remains responsible for ensuring a/c separation during ITP manoeuvre.

As depicted below the procedure on ITP between flight crew and ATC.



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2. Airbus Fast Magazine No. 47 Automatic Dependent Surveillance Broadcast (ADS-B) https://w3.airbus.com/CRS/A233_GN60/Customer_Services/html/acrobat/fast47_ADS_B.pdf
3. Getting to grips with Surveillance: http://www.cockpitseeker.com/wp-content/uploads/A320/pdf/data/gettingToGripsSurveillanceIssue1.pdf

CONTEXT

4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*				
	This automation solution has been developed at Airbus with simulation means through several stages of cockpit mock-ups and simulators.				
5	What were the required technical means and human resources?				
	Development of the function involves several stages of a multi-disciplinary team of engineers, pilots, operational experts and human factors experts.				
6	If applicable: How often was the good practice applied in the past?				
	N/A				
7	Integration of the concerned automation into a system or an ensemble of systems				
	Well integrated into current onboard systems. The request for ITP can be sent via CPDLC. This can save time compared to voice communications which due to transmission via an operational radio can take up to 11 min or longer over oceanic airspace.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☐ V2: Feasibility	☐ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☒ V5: Deployment	☒ V6: Operations		
	8.1 Rationale				
	ATSAW ITP has been certified and is between V5 and V6 in pre-operations.				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☒ En Route	☐ Descent	☐ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	ATSAW ITP is only applicable during en-route flight phase to support manoeuvres for reaching the optimal FL.				
10	Actor(s)				
	Air: Pilot ☒ PNF ☒ PF	Ground: ATCO ☐ EC ☐ PC ☐ Supervisor ☐…			
	10.1 Rationale				

	Both pilots have the information about surrounding traffic available on the crew interfaces. Both can verify if a FL change manoeuvre is possible. In terms of task sharing the decision to request a FL change is taken conjointly. As according to usual procedures, the PF executes the FL change, the PNF remains with the head down checking the spacing.

TASK		
11	Pilot tasks	ATCO tasks
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☒ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☒ Monitor system/ aircraft status and surroundings ☒ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	ATSAW ITP supports the pilot in identifying if a FL change is possible. If the FL change request is sent via CPDLC it supports also communication. On ground side, the ATCO remains responsible in detecting conflicts.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The responsibilities of the flight crew and the ATC remain unaltered. The ATCO remains responsible for the aircraft separation. Thus, the flight crew is not required to monitor the separation with the Reference Aircraft during the ITP manoeuvre. With ATSAW ITP the ATCO does not have any means to recover the situation during the manoeuvre.	

12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA	A0	A4	B0	B2	n.a.	n.a.	n.a.	n.a.
	12.1 Rationale								

	ATSAW ITP supports information acquisition and information analysis (distance to other a/c) proposing a decision (possibility) about FL change feasibility, precisely if an ITP is possible or not. The execution of the FL change remains up to the pilots. Before the change, pilots do not have any other means to verify the feasibility of FL changes other than asking directly to ATC. (A and B0) After the change the crew receives information on surrounding a/c via ADS-B which they did not have at disposal before. (A4) The pilots request ATSAW ITP and once the system announces if ITP is possible or not, the result of the query turns into another colour. (B2)
IMPACTS ON HUMAN PERFORMANCE	
13	13.1 Which changes do you see in the way the Human Performance is supported?
	With ATSAW ITP, pilots can evaluate if a request to ATC on a FL change could be possible. That optimises the usage of optimal FL and optimises ATC and pilots communication. The requests are by default more promising because in case a FL change is not possible the system would indicate until which time. During that known period, the pilot would save continuous (not promising) requests to ATC. As a result, the ratio between requested FL change by pilots and the ones authorised by ATC becomes more equal. ITP requires both flight crew and ATC training.
	13.2 Which benefits do you expect on SESAR KPAs?

☐ Capacity	
☒ Efficiency	Enhances operational efficiency; more flight level changes can be taken advantage of; reduces fuel burn through transoceanic flight routing using In-Trail procedures; in combination with CPDLC quicker exchange on (non) authorisation of FL change
☐ Flexibility	
☐ Predictability	
☒ Safety	Flight safety is improved.
☐ Access and Equity	
☒ Interoperability	optimizes pilot-ATC communications

	13.3 Human Performance and automation issues expected to be mitigated
	Workload is reduced because the pilot is saved from repetitive requests from ATC that are likely to be impossible. The flight crew can instead request ATSAW ITP to calculate the possibility of ITP. If the request is sent by CPDLC confusion for the reference aircraft (hearing its call-sign mentioned by the ITP aircraft crew not ATC) can be avoided. - <u>**Issue 5**</u>**: The automation of routine tasks may remove an important information source which may reduce situation awareness.** Situation awareness is enhanced by giving supporting information on the surrounding a/c and by indicating feasibility of FL changes. - <u>Issue 12</u>: Poorly designed automation may lead to simultaneous tasks competing for user attention or causing interruptions of high workload activities, reducing efficiency and increasing

	the risk of human error. - Issue 25: New communication systems that will change working methods may lead to new types of error. The issues 12 and 25 are prevented because the automation optimises communication between crew and ATC and therefore reduces an occurrence of simultaneous tasks. The pilots can choose when to launch a query of ATSAW ITP. - Issue 17: Information flooding due to poorly designed automation support may impact situation awareness and increase cognitive workload. Pilots receive the relevant information if the FL change manoeuvre is feasible in one statement on the display. They can check more information on surrounding a/c on associated displays if they want, but there is no information flood to be handled. - Issue 20: Automation intervention impacting on both air and ground operators but interacting with only one of the two actors may jeopardize air-ground interoperability, increasing the risk of unsafe acts by both ATCOs and pilots, caused by confusion regarding responsibility for authority. Since the ITP request can be transmitted directly via CPDLC, interoperability is enhanced. The transmission delay (as usual via operator radio over the ocean of 11 min +) is abolished. - Issue 21/22 on trust: The issues on trust are not critical since the system provides an analysis of feasibility based on which the pilots sends a request to ATC which only becomes valid after the ATCO authorises the manoeuvre. The ATSAW function must not be used for self-separation and collision avoidance. In distinction of TCAS, in case of TA or RA alerts conventional TCAS procedures will be applied.
	13.4 Human Performance and automation issues potentially not mitigated by design
	- Issue 15: Data fusion and filtering in automated support systems may reduce ATCO and pilots' accessibility to relevant information, with negative impact on decision making processes and situation awareness. If surrounding aircraft are not ADS-B out equipped they will not be visible via ATSAW. Thus the ATC authorises the FL change request since he has the full picture and sees TCAS equipped a/c. - Issue 18: New automation support that results in greater use in visual information may lead to visual channel overload, with decrease in situation awareness and performance efficiency. This issue is related to any new automated functions relying on the visual channel.
	13.5 Would you expect that procedures will change?
	☒ Yes ☐ Likely yes ☐ No Likely no Explanation: Procedures on FL change do not change but the In-Trail-Procedure as such brings a new procedure.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	ATSAW ITP provides information about the feasibility of a FL change manoeuvre based on surrounding a/c information. These a/c also transmit data via ADS-B. However, ATC authorises because there could be also non-ADS-B equipped a/c in vicinity on which ATSAW ITP does not have ADS-B information. With ATSAW ITP the pilots possess more information on FL change feasibility before issuing a request to ATC. They have more awareness if the request is possible or not (binary option). If the FL change is not possible the system also indicates until when ('ITP is not possible before xxx). With the feasibility information, pilots can anticipate and time when to make the next query to the

	system. Once the flight crew makes another 'ITP-feasibility check' and if the result indicates a possible FL change, the likelihood that this FL change request is authorised by ATC is increased.

4.1.4 Air Traffic Situation Awareness during Surface Operations (ATSAW SURF)

1	Title of the automated solution
	ATSAW SURF – Air Traffic Situation Awareness during surface operations
2	Short description of the concerned automation
	ATSAW is an onboard application providing information about ADS-B traffic to improve situational awareness. ATSAW consists of 4 applications: AIRB (Airborne), ITP (In-trail procedure), VSA (Visual Separation on Approach), and SURF (Airport Surface). ATSAW is a step towards airborne traffic separation using Automatic Dependent Surveillance-Broadcast (ADS-B) position reporting. It is expected to enhance efficiency during conditions such as conditional taxi clearances (especially during night operations or at an airport unfamiliar to the flight crew). The application is also expected to decrease flight crew and controller workload by reducing requests for repeated information with respect to surrounding traffic.
	2.1 Description of the function
	ATSAW SURF can improve safety and efficiency of surface operations thanks to a better anticipation of potential conflicting situations, a better understanding of the traffic situation on the surface and more efficient conditional taxi clearances. During final approach until parking and departure from gate to take-off, flight crews are provided with a display of surrounding traffic (aircraft on the airport surface, as well as aircraft flying in vicinity) together with own-ship position overlaid on a map of the airport. The information provided by the display is used to complement the normal out-the-window scan to enhance position and traffic situation awareness on the airport surface for both taxi and runway operations. During current operations at controlled airports, flight crews navigate on the airport surface via their ATC-assigned taxi route by use of a paper or electronic map and airport visual aids. At uncontrolled airports, flight crews plan and implement their own taxi routes, and broadcast their intentions, whilst maintaining out-of-the-window (OTW) vigilance for other traffic. At all airports, OTW visual aids and information include pavement lines, lights and signs, as well as other aircraft and ground vehicles. The ATSAW-SURF application may be used for runway and taxiway operations at controlled and uncontrolled airports, in all visibility conditions.
	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐ abnormal situations ATSAW is a surveillance function and can be used at pilot's discretion. There is no alert function incorporated and there is no obligation to consider the given information, so the function is not to handle abnormal situations.
	What is the linkage between the use of the function and traffic level? There is no special relation between ATSAW SURF performance and traffic level. It is useful under any traffic level. On complex airports and under high traffic conditions the application will be more of use. To avoid cluttering of the information ATSAW SURF follows a filtering logic displaying a maximum number of aircraft in proximity of the own aircraft.
	2.3 Concerned domain

☒ Air ☐ Ground ☒ Air-Ground

Explanation:

The ground perspective is implicitly concerned because ATSAW enhances the view beyond the single perspective of the own-ship. The pilot gains a better idea on the traffic view and can thus also better anticipate his requests to ATC.

2.4 Operational environment

Via ‘ADS-B out’ (capability to emit ADS-data) automated aircraft parameter can be transmitted between an aircraft and ATC. The technical enabler of ATSAW is **ADS-B in** (Automatic Dependent Surveillance Broadcast). ‘ADS-B in’ (capability to receive ADS-B data) provides automated aircraft parameter transmission between aircraft themselves. Hence, information of other ADS-B aircraft can be displayed in the cockpit.

ATSAW vs. TCAS are complementary and work together. Both systems ATSAW and TCAS operate independently of each other; however both systems are hosted by the same TCAS computer. To differentiate, ATSAW provides information on surrounding traffic and TCAS enables an immediate reaction on surrounding threats.

2.5 Reason for the change/ Problem to be handled

The initial problem was about awareness of pilots on complex airports. The NTSB has shown some years ago that runway incursions were one of the main problem causing accidents. Not knowing the own position on the airport surface was the problem. Consequently, first attempts on Airport NAV and Airport Moving Map have been launched also to facilitate airport operations during All Weather Conditions.

The primary goal of the ATSAW-SURF application is to reduce the potential for errors, runway and taxiway incursions, and collisions with an impact on efficiency and safety.

2.6 Applied solution/intervention

The problem mentioned was handled by providing enhanced situation awareness of all traffic, vehicles and aircraft to the flight crew on the manoeuvring area of an airport and all aircraft flying in the vicinity of an airport. The enhanced information given on the displays completes the normal out-of the window scan.

Example of Navigation Display. Position and trajectory of other aircraft on taxiways are

	indicated. [Picture taken from Airbus FAST magazine No. 47 Automatic Dependent Surveillance Broadcast (ADS-B) https://w3.airbus.com/CRS/A233_GN60/Customer_Services/html/acrobat/fast47_ADS_B.pdf] - The additional information on surrounding traffic consists of: aircraft orientation and the relative information from aircraft in vicinity which are displayed on the Navigation Displays. - Additional information on specific pages can be accessed on the Multi-purpose Control and Display Unit (MCDUs, such as a traffic list of aircraft with the following parameters: aircraft identification (callsign); bearing/distance; heading; Wake vortex category; Relative and absolute altitude; Ground speed. - With 2 traffic selector knobs the flight crew can interact with Navigation Display (ND) symbols.
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CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	This automation solution has been developed at Airbus with means of cockpit mock-ups and simulators.
5	What were the required technical means and human resources?
	Development of the function involves a multi-disciplinary team of engineers, pilots, operational experts and human factors experts.
6	If applicable: How often was the good practice applied in the past?
	ATSAW SURF is under developed for different aircraft programs.
7	Integration of the concerned automation into a system or an ensemble of systems
	ATSAW information is integrated in already existing crew interfaces.
8	On which phase of maturity of the concept/automation was the good practice applied?

<table>
<tr><td></td><td colspan="2">☐ V1: Scope</td><td colspan="2">☒ V2: Feasibility</td><td colspan="2">☒ V3: Pre-industrial development and integration</td></tr>
<tr><td></td><td colspan="2">☐ V4: Industrialisation</td><td colspan="2">☐ V5: Deployment</td><td colspan="2">☐ V6: Operations</td></tr>
<tr><td></td><td colspan="6">8.1 Rationale</td></tr>
<tr><td></td><td colspan="6">ATSAW SURF can be located between phase V2 and V3. Feasibility tests have been conducted and the development is ongoing.</td></tr>
<tr><td colspan="7">CONTEXT OF THE TASK</td></tr>
<tr><td>9</td><td colspan="6">What are the concerned flight phases?</td></tr>
<tr><td></td><td>☒ Turnaround</td><td>☒ Pushback</td><td colspan="2">☒ Taxi-out</td><td>☒ Take-off</td><td>☐ Climb</td></tr>
<tr><td></td><td>☐ En Route</td><td>☐ Descent</td><td colspan="2">☐ Approach</td><td>☒ Landing</td><td>☒ Taxi-in</td></tr>
<tr><td></td><td colspan="6">9.1 Rationale</td></tr>
<tr><td></td><td colspan="6">ATSAW SURF is activated during all flight phases when the aircraft is on ground. Once the aircraft takes off, another ATSAW application becomes more relevant: ATSAW Airborne. During descent ATSAW Visual Separation Approach (VSA) provides the relevant information and once the aircraft has landed ATSAW SURF is active again.</td></tr>
<tr><td>10</td><td colspan="6">Actor(s)</td></tr>
<tr><td></td><td colspan="3">Air: Pilot
☒ PNF ☒ PF</td><td colspan="3">Ground: ATCO
☐ EC ☐ PC ☐ Supervisor ☐…</td></tr>
<tr><td></td><td colspan="6">10.1 Rationale</td></tr>
<tr><td></td><td colspan="6">Both pilots have the information about surrounding traffic available on the crew interfaces.</td></tr>
<tr><td colspan="7">TASK</td></tr>
<tr><td>11</td><td colspan="4">Pilot tasks</td><td colspan="2">ATCO tasks</td></tr>
</table>

Operate:

☐ Control the aircraft
☐ Manage the autopilot
☐ Monitor the flight parameters

Navigate:

☐ Aircraft position management
☐ Flight planning/ trajectory management

Communicate:

☐ Communicate with ATC
☐ Communicate within the crew
☒ Communicate with other aircraft, airline, maintenance

Manage system status and surroundings:

☒ Monitor system/ aircraft status and surroundings
☒ Evaluate system/ aircraft status and surroundings
☐ Handle system/ aircraft status and surroundings

☐ Monitoring traffic
☐ Providing traffic information
☐ Issuing instructions/clearances
☐ Detecting conflicts
☐ Resolving conflicts
☐ Planning strategy
☐ Assuming and transferring traffic
☐ Ground-ground communication

11.1 Rationale

With the enhanced information, an information exchange between aircraft via ADS-B is enabled. ATSAW SURF supports pilot's monitoring of parameters of aircraft in surroundings.

11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

ATSAW is not expected to have an impact on task sharing of pilots supposed not to create additional training efforts. ATSAW enhances traffic awareness only. Therefore there are no role changes in the cockpit expected.

Even though ATC can be aware of ATSAW existing onboard and thus the pilots having a broader picture of traffic in vicinity, it has to be clear that SURF must not be used for self-separation or collision avoidance. Any kind of delegation can be excluded.

12 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA	A1	A5	B1	B4	n.a.	n.a.	n.a.	n.a.

12.1 Rationale

Before ATSAW SURF the pilots had to rely on the out-of –the window scan and information on surroundings by ATC. Also artefacts such as airport maps on paper, signs and indications on the runway were available to acquire and analyse information in order to follow the taxi route appropriately. (A1)

ATSAW SURF supports the information acquisition by providing airport information (maps, buildings, gates, etc.) and in addition the aircraft navigation on the surface. This corresponds to A5.

	At the same time the function supports an information analysis because algorithms filter which information to display (based on proximity rules) and integrate the parameters and positioning on surrounding aircraft. Pilots are able to select and highlight certain aircraft symbols. Please note that there are no alerts. Nevertheless the information analysis corresponds to B4.
IMPACTS ON HUMAN PERFORMANCE	
13	13.1 Which changes do you see in the way the Human Performance is supported?
	ATSAW Surf can enhance flight crew's situation awareness by providing more surveillance information. Increased situation awareness can reduce the potential for errors. To facilitate workload, data from both ATSAW and TCAS are illustrated in a single symbol. Moreover, more information is given since the symbol indicates the equipage status of the aircraft: only TCAS, only ATSAW or both TCAS and ATSAW. The pilots can interact with the function. By highlighting a traffic symbol on the ND, further information can be displayed and selection helps them to follow. With that, the pilot can choose several modes to adapt the information he wants to display: • Basic: location and track orientation • Extended: with Flight ID • Full: + relative altitude and vertical tendency The traffic selector enables the pilot to change also the range of the ND to adapt his view on the information he intends to display. Through the highlight and selection function, one pilot can share information on a selected aircraft with the other flight crew member. This enhances mutual awareness within the crew. In respect of the surface operation nothing changes in the way the pilots perform them.
	13.2 Which benefits do you expect on SESAR KPAs?
	☐ Capacity
	☒ Efficiency — Enhances operational efficiency
	☐ Flexibility
	☐ Predictability
	☒ Safety — Improve safety and situation awareness by displaying more aircraft and more information than TCAS-only systems. ATSAW SURF is expected to enhance airport safety. Furthermore reduce taxi time during low visibility conditions and by night.
	☐ Access and Equity
	☒ Interoperability — optimizes pilot-ATC communications
	13.3 Human Performance and automation issues expected to be mitigated
	Any issues related to insufficient situation awareness will be mitigated since the automated system provides reliable information that pilots would have to search for in a more time-consuming way. The information that the crew obtains is useful and reliable and supports their navigation on the airport.

	13.4 Human Performance and automation issues potentially not mitigated by the design
	• Visual scan (out-of-the window) remains, so with the system the pilot has two resources of information to match. If surrounding aircraft are not ADS-B out equipped they will not be visible via ATSAW. Since the information on other aircraft parameters provided by ATSAW SURF is reliable and rich, this could induce a belief about completeness of the information (provoking complacency). (related to **issue 22 Air example 2**) • **Issue 10:** The fact of having to match the information displayed with the look out of the window under consideration of a 'mixed-mode environment (ADS-B/TCAS only equipage status) could increase task demand. In case of ADS-B not available, ATSAW will use TCAS data to fill in blanks on the parameters, if possible. Otherwise dashes will appear. The title line indicates data source in use (so this is a reminder of availability of system). • In turn, the completing out-of-the window scan might be neglected with an increased head-down time focussing on the displays. **(Issue 13)** • With the advanced level of information it could happen that pilots navigate faster on airports than earlier when they had to search and analyse information at the same time. Since the task accomplishment is facilitated.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: Since ATSAW is a surveillance function and as such an 'aid' which provides additional information, there is no special procedure to interact with. There is no obligation to consult the information; the pilot can even switch off ADS-B (which also would disable ATSAW). The ATSAW function must not be used for self-separation and collision avoidance. In distinction of TCAS, in case of Traffic Alert (TA) or Resolution Advisory (RA) conventional TCAS procedures will be applied. This application is not intended to change the existing ICAO procedures or provisions. The SURF application is not considered as a substitute for current requirements in deploying new procedures at specific airports/ aerodromes.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	ATSAW SURF supports mainly the cognitive tasks of searching and analysing information which relieves the pilots; so they can rather focus on the task execution as such (following the taxi/runway clearance.) Pilots are not supposed to spend effort on finding the information anymore but rather checking and matching the information from different sources (out-of-the-window and displays). Under conditions of reduced or bad visibility, pilots have means to localise aircraft more easily and more reliable and can be more vigilant to do the correlation between visual scan and display information. The crew's decision-making and task execution is not concerned by ATSAW SURF and the decision if the crew wants to consider ATSAW SURF information is left to pilots' discretion. This flexibility makes that pilots would engage ATSAW SURF when they are expecting that the information helps them.

4.1.5 Brake to Vacate (BTV) – Autobrake

1	Title of the automated solution
	Enhanced automated braking system with BTV "Step 2" (Brake-To-Vacate). Note: "Step 2" here

<table>
<tr><td></td><td colspan="3">means the first step of BTV development and must not be confused with the SESAR Step 2 implementation phase</td></tr>
<tr><td>2</td><td colspan="3">Short description of the concerned automation</td></tr>
<tr><td></td><td colspan="3">BTV is an enhancement of the classical auto-brake system at landing. It allows pilots to select the runway exit they can reach, by visually indicating to the crew the minimum braking distance they need regarding the aircraft performance and runway conditions. The enhanced auto-brake system allows the aircraft to optimally reach the designated runway exit. The auto-brake activates roughly at the moment when the nose landing gear are down. The system guarantees the aircraft to vacate at the assigned exit with optimization of the brake energy regarding current operational constraints (weather, wet runway conditions ...), with minimization of the runway occupancy, and improvement of the passenger comfort. BTV allows pilots to select the runway exit they desire following these information and they can communicate to ATC

BTV is coupled to a Runway Overrun Protection System (ROPS) which allows preventing the runway excursion risk at landing. It consists in ROW (Runway End Overrun Warning) that triggers alerts during approach if the runway will be too short for landing, and ROP (Runway Overrun Protection) that triggers, after touch-down, messages for pilot actions and can automatically activate max pressure braking if needed.

BTV/ROPS step2 is applicable in the following operational environment:
- From dry to wet runways
- In all visibility conditions and landing configurations
- With autopilot engaged or not

BTV “Step 2” is supported by OANS environment (Onboard Airport Navigation System) as it uses airport data bases and the electronic charts to provide associated visual information to pilots needed to configure the system.

Several automated solutions are interested to consider for their impact on human performance:
- BTV: enhanced automated braking system
- BTV: exit selection
- ROPS: Runway Overrun Warning (in flight) and Runway Overrun Protection (on ground)

The automated solution described in the current template is the auto-brake system enhanced by BTV.</td></tr>
<tr><td></td><td colspan="3">2.1 Applicable domain</td></tr>
<tr><td></td><td>☐ Air</td><td>☐ Ground</td><td>☒ Air-Ground</td></tr>
<tr><td></td><td colspan="3">Explanation:

Despite BTV is an airborne system which is entirely dedicated to pilots’ use, the function may have impacts on ground domain, as it helps to better predict and ensure a runway exit. The ramp where the aircraft exits is the starting point of the taxi-in clearance given by the controller. Ground systems and actors would then be able to plan the aircraft movement if pilots can ensure to ATC the runway exit he is going to take after landing. Auto-brake of BTV may improve the whole surface routing and planning.</td></tr>
<tr><td>3</td><td colspan="3">Description of the specific function</td></tr>
</table>

Enhanced auto-brake system with BTV allows the aircraft to brake optimally and without pilot's action until a pre-selected runway exit.

The optimum braking application depends on the pre-selected exit, which depends itself on multiple criteria and constraints that can only be known in their full complexity by the pilot and the ATCO:

- Optimum braking energy (complex as function of taxi, of requested Turn Around Time (TAT), of noise abatement procedures preventing maximal reverse thrust usage out of safety needs),
- Minimum number of brake applications,
- Minimum runway occupancy time,
- Best exit for taxi duration.

3.1 Reason for the change

In order to keep the pilots free to perform other tasks (during high workload operations), the first auto-brake system was designed to control the aircraft longitudinal deceleration during rollout and down full stop. This one allows selecting a pre-defined braking energy (low-medium-high) but the aircraft stops often too far or too short from the desired exit. The current auto-brake is also not adapted to each landing situation and weather constraints, which has specific touchdown and braking characteristics.

To compensate the system shortcomings, the pilots have often to manually override the auto-brake at the right time and depending on their estimation to reach a runway exit. In low visibility conditions (crew blindness), the pilot cannot compensate the classic auto-brake system blindness, being 'blind' himself. In that operational case, auto-brake deceleration often brings the aircraft at low speed in the middle of nowhere. Then, the pilot taxies on the runway until he finds an exit. These shortcomings cannot answer to the problem of congestion issues on airports as the runway occupancy time is not reduced (and runway capacity is still more reduced during low visibility conditions).

BTV is a compromise which guarantees to optimally brake until a pre-selected exit, removing the need of pilots' corrective actions to reach it, and reducing runway occupancy time. Thanks to this function the runway occupancy time in LVP may be the same as in good visibility operations, as the rolling on runway is reduced to its minimum.

3.2 Applied solution

Before the aircraft brakes automatically, the pilots have to configure BTV and select the desired exit with specific interfaces. This preparation is done during the approach.

The auto-brake activates at the aircraft touch-down and brakes automatically with the optimum energy until 10 knots. At 10 knots BTV is disengaged and pilots take back the aircraft control. At this moment they have reached the desired exit.

If the aircraft lands more or less far from the expected touch-down point, or if the runway is in bad weather condition, the auto-brake adjusts dynamically the braking energy to reach the desired exit. If the system estimates the exit reaching not possible, the auto-brake increases deceleration order.

3.3 Which benefits on SESAR KPAs are expected?

☒ Capacity	The runway capacity is improved with BTV, as it allows reducing the Runway Occupancy Times (ROT). Studies have shown that depending on the traffic mix (various aircraft types), runway capacity can be increased between 5% (in the case of single-runway airports) and 15% multiple-runway airports) by reducing

		ROTs. A remarkable example is the 19% capacity increase achieved over a period of three years on the single runway at Manchester, U.K.
	☒ Efficiency	BTV optimizes the braking energy needed at landing and regarding current operational constraints, while improving passenger comfort.
	☒ Flexibility	BTV allows the crew to evaluate and reconfigure and new runway exit and braking performances in case of unexpected event (e.g.: runway change, weather change...).
	☒ Predictability	The predictability of the aircraft movement is improved with BTV, because the crew is able to robustly predict and reach the runway exit they will use at landing.
	☐ Safety	
	☐ Access and Equity	
	☒ Interoperability	Air/ground interoperability is improved thanks to the guaranteed runway occupancy time and runway exit communicated to the controller (by voice or by systems). It allows him to anticipate the taxi path of the aircraft and the overall surface management with more predictability.
4	Which kind of situation(s) does the function support?	
	☒ normal situations	☒ abnormal/ emergency situations BTV/ROPS is available in overweight situations.
CONTEXT OF THE TASK AND TASK		

5	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☐ Descent	☐ Approach	☒ Landing	☐ Taxi-in
	Explanation Please describe ‘border cases’ if applicable.				
6	Involved Actor(s)				
	Air: Pilot ☒ PNF ☒ PF	Ground: ATCO ☐ EC ☐ PC ☐ GND ☐ RWY ☒ TWR ☐ Apron Controller ☐ Supervisor			
	6.1 Rationale				
	Pilots are in charge of: - BTV configuration/reconfiguration, - Monitoring and announcing the progress of BTV procedure, - BTV disconnection.				

	Tower ATCO is concerned by the supervision of the aircraft approach and landing.	
7	Pilot tasks	ATCO tasks
	Operate: ☒ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☒ Evaluate system/ aircraft status and surroundings ☒Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	7.1 Rationale	
	The BTV function supports the control of the aircraft as it operates the automatic aircraft braking at landing. BTV also supports the evaluation and the handling of the aircraft abilities to brake with the optimum energy, comfort and distance according to the weather and runway conditions. The function is also able to evaluate if the braking distance (runway exit) will be achieved or not during the deceleration phase and can adapt the deceleration level of the aircraft to try to reach the exit.	
	7.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The BTV function is not expected to lead to changes in roles, responsibilities, authority sharing and delegation.	
	7.3 Would you expect that procedures change?	
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no	
8	Classification of supported cognitive functions and automation level	

	Associated cognitive function being supported by automation			
	A	B	C	D

	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
					C1	C6	D3	D6

8.1 Rationale

The current and enhanced auto-brake system supports mainly action implementation.

Before change, pilots used to activate the auto-brake during final approach and choose a desired energy (low/medium/high). Once the aircraft nose wheel on ground, the system had to apply the energy chosen during the procedure activation. The auto-brake used to require some pilots' manual adjustments regarding the situation and the braking progress. Nevertheless, before change, the system required from pilots' to manually control and to correct the braking progress (override), sustaining violent braking behaviours from the aircraft and without knowing where the aircraft will stop.

After change, pilots still have to activate BTV during approach in order for the auto-brake to also activate. But, during the operation, the system decides and adjusts itself the braking energy considering the braking progress, runway conditions, point of touch-down, etc, to optimally and progressively reach the pre-selected exit. That is why the decision and action selection on brakes are considered as fully automated because pilots are not aware of all the parameters and estimations made by the system when it brakes, they can monitor only the result of these calculation, represented by the braking itself.

The system does not require any pilots' action but they can override it. The overriding consists of the auto-brake stop and leads pilots to fully take over manually the braking operation.

IMPACTS ON HUMAN PERFORMANCE

9 Human Performance and automation issues expected to be prevented or mitigated

The HP issue 1 is expected to be mitigated by the enhanced auto-brake system.

"Lack of user involvement in automation assisted processes may lead to reduced vigilance and loss of situation awareness".

With the existing auto-brake system, the pilots select a fixed braking energy and the aircraft decelerates according to this entry, but the pilots are not aware of the braking distance it represents and don't know where the aircraft is going to stop on the runway. The auto-brake with BTV indicates visually (with virtual stop-bar on the runway, on airport moving map) the distance of deceleration left as soon as the aircraft starts its automatic braking at touch-down.

The HP issue 8 can also be applicable to the enhanced auto-brake solution.

"Automation support for decision making may be based on too simplistic algorithms and parameters to cope with the complexity of the operational environments inducing workarounds and higher workload in human operators."

The criteria on which the auto-brake system is based have been refined and improved in order to operate appropriately in complex operational environments.

10 Human Performance and automation issues potentially <u>not</u> mitigated <u>by design</u>

CONTEXT			
11	In which kind of organisation was the automation practice applied?		
	The automated solution was practiced in aircraft industry design and development (in cockpit simulators, mock-ups, flight tests) and a first step of the BTV function (including the enhanced auto-brake system) is operationally in service on A380.		
12	How often was the good practice applied in the past?		
	The auto-brake of BTV is operational on A380 for 3 years.		
13	What were the required technical means and human resources to test/validate the practice?		
	To test and validate the function, mock-ups, flight simulators, test benches and flight test aircraft are generally needed. In these cases technical support is needed to run and monitor the test means. Several human resources intervene in design and operational validations: cockpit designers, human factors specialists, pilots and simulator technical support. For air-ground validation, controllers are also required.		
14	Integration of the concerned automation into a system or an ensemble of systems		
	The BTV function is integrated into the existing aircraft systems and interfaces. The integration of this novelty respects the Airbus cockpit philosophy.		
15	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☒ V6: Operations
	16.1 Rationale		
	Please explain your rating, also in case you crossed more than one phase. BTV Step 2 is already implemented on A380 in-service aircraft.		
FINAL CONSIDERATIONS			
16	What can be learnt from the proposed change in HP automation support?		
	The practice has permitted to improve the automatic braking action. The braking is so optimal that it requires no action from pilots until 10 Knts, but at the same time, they have to monitor and to keep aware of the aircraft abilities and rolling progress until the target exit. In other words, even though the automation is increased and does not need any human action during the execution, flexibility is kept for pilots. Pilots can handle the aircraft by overriding the auto-brake if needed while being aware of the aircraft status and progress of the operation.		
REFERENCES			

Airbus FAST Magazine #44 / December 2009: http://www.airbus.com/support/publications/

4.1.6 Brake to Vacate (BTV) – Exit Selection

<table>
<tr><td rowspan="2">1</td><td colspan="3">Title of the automated solution</td></tr>
<tr><td colspan="3">Runway exit selection with BVT “Step 2” (Brake-To-Vacate). Note: “Step 2” here means the first step of BTV development and must not be confused with the SESAR Step 2 implementation phase</td></tr>
<tr><td rowspan="4">2</td><td colspan="3">Short description of the concerned automation</td></tr>
<tr><td colspan="3">BTV is an enhancement of the classical auto-brake system at landing. It allows pilots to select the runway exit they can reach, by visually indicating to the crew the minimum braking distance they need regarding the aircraft performance and runway conditions. The enhanced auto-brake system allows the aircraft to optimally reach the designated runway exit. The auto-brake activates roughly at the moment when the nose landing gear are down. The system guarantees the aircraft to vacate at the assigned exit with optimization of the brake energy regarding current operational constraints (weather, wet runway conditions ...), with minimization of the runway occupancy, and improvement of the passenger comfort. BTV allows pilots to select the runway exit they desire following these information and they can communicate to ATC

BTV is coupled to a Runway Overrun Protection System (ROPS) which allows preventing the runway excursion risk at landing. It consist in ROW (Runway End Overrun Warning) that triggers alerts during approach if the runway will be too short for landing, and ROP (Runway Overrun Protection) that triggers, after touch-down, messages for pilot actions and can automatically activate max pressure braking if needed.

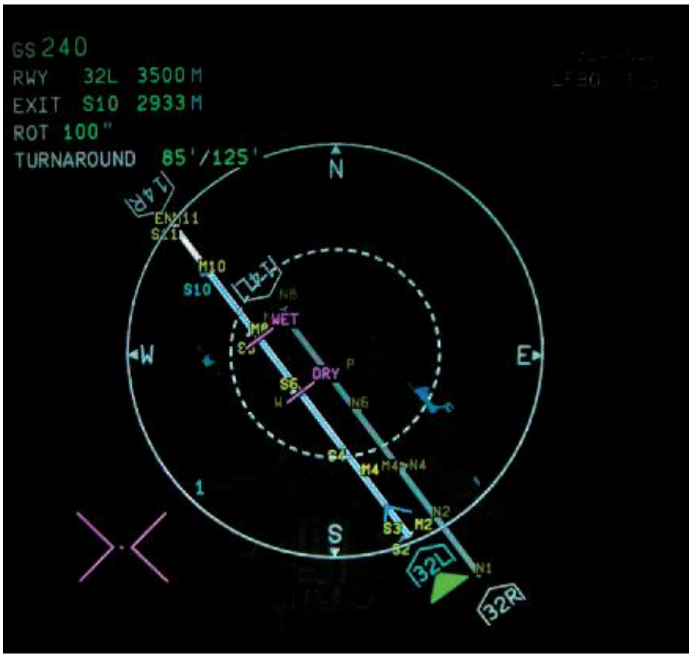
BTV/ROPS step2 is applicable in the following operational environment:
- From dry to wet runways
- In all visibility conditions and landing configurations
- With autopilot engaged or not

BTV “Step 2” is supported by OANS environment (Onboard Airport Navigation System) as it uses airport data bases and the electronic charts to provide associated visual information to pilots needed to configure the system.

Several automated solutions are interested to consider for their impact on human performance:
- BTV: enhanced automated braking system
- BTV: exit selection
- ROPS: Runway Overrun Warning (in flight) and Runway Overrun Protection (on ground)

The automation described in the current template concerns the runway exit selection of BTV.</td></tr>
<tr><td colspan="3">2.1 Applicable domain</td></tr>
<tr><td>☐ Air</td><td>☐ Ground</td><td>☒ Air-Ground</td></tr>
</table>

	Explanation: Despite BTV is an airborne system which is entirely dedicated to pilots' use, the function may have impacts on ground domain, as it helps to better predict and ensure a runway exit. The ramp where the aircraft exits is the starting point of the taxi-in clearance given by the controller. Ground systems and actors would then be able to plan the aircraft movement if he can ensure to ATC the runway exit he is going to take after landing. Knowing the runway exit *in advance* may improve the whole surface routing and planning for ground actors.
3	Description of the specific function
	BTV function allows pilot to select the appropriate runway exit during descent or approach preparation. In an operation, the optimum exit selection depends on multiple criteria and constraints that can only be known in their full complexity by the pilot and the air traffic controller: - Optimum braking energy (based on several parameters intrinsic to the aircraft (performances) and also external to the aircraft, e.g.: requested Turn Around Time (TAT), of noise abatement procedures etc.), - Minimum number of brake applications, - Minimum runway occupancy time, - Best exit for taxi duration.
	3.1 Reason for the change
	Without the use of BTV Step 2, the pilots are not able to know which runway exit they are able to reach at landing. It depends on several complex parameters that are different to apprehend including aircraft (braking) performances, runway and weather conditions, airport configuration (runway length, exits location), the point of touch-down of the aircraft and others... As OANS system is able to provide a part of these data, the runway exit selection is made possible and guaranteed to the aircraft, and allows pilots to use a visual interface to support this task.
	3.2 Applied solution
	To help the exit selection chosen by the pilot, the BTV system proposes a dedicated interface providing intuitive information to assist the selection of an optimum exit and to monitor BTV operation progress. This dedicated interface provides also a predicted and guaranteed ROT (Runway Occupancy Time) and an estimated TAT (Turn Around Time). Nevertheless, the selection of the 'optimum' exit remains the pilot's responsibility and is not a contractual information between flight crew and controllers. These indications help the crew on the optimal thrust reversers' usage strategy during the landing roll on dry runway.



Example of a BTV interface for a landing at CDG.

[*Picture taken from Airbus FAST magazine No. 44 Brake-to-Vacate system: The smart automatic braking system for enhanced surface operations http://www.airbus.com/support/publications/*]

When they select the runway for landing, BTV function estimates and shows the minimum braking distance in case the runway is dry and wet. This distance is symbolized with a bar meaning the point from where the aircraft will be able to stop. The pilots can then chose a runway exit located after the bar (according to dry or wet conditions).

BTV use in ATM context:

The main principle is to use efficiently the runway occupancy time reduction allowed by BTV fitted aircraft in the whole traffic converging on the considered airport; particularly, it takes benefit from the knowledge of the effective and guaranteed runway occupancy of the BTV-fitted aircraft using the 'runway resource'. Then, the followed dedicated arrival procedure is today imagined (still under study with the ATM community):

- Since the 'approach' controller manages the BTV-fitted aircraft, the pilot and the controller agree on the in-service landing runway and exit taxiway, which depends on several points as the airport layout configuration, aircraft landing performances, airline operational procedures and all other current landing conditions,
- The pilot (or in the future the aircraft itself) communicates the predictive runway occupancy time, which will be guaranteed,
- The 'approach' controller manages arrivals considering separations to be respected and the forecasted arrival time on the landing runway threshold.

3.3 Which benefits on SESAR KPAs are expected?	
☒ Capacity	The runway capacity is improved with BTV, as it allows to reduce the Runway Occupancy Times (ROT). Studies have shown that depending on the traffic mix (various aircraft types), runway capacity can be increased between 5% (in the case of single-runway airports) and 15% multiple-runway airports) by reducing ROTs. A remarkable example is the 19% capacity increase

		achieved over a period of three years on the single runway at Manchester, U.K.
	☐ Efficiency	
	☒ Flexibility	BTV allows the crew to evaluate and reconfigure and new runway exit and braking performances in case of unexpected event (e.g.: runway change, weather change...).
	☒ Predictability	The predictability of the aircraft movement is improved with BTV, because the crew is able to robustly predict and apply the runway exit he will use at landing.
	☒ Safety	With BTV, standard separation can be reached in LPV, as in good visibility (within a certain limit depending on other constraints).
	☐ Access and Equity	
	☒ Interoperability	Air/ground interoperability is improved thanks to the guaranteed runway occupancy time and runway exit communicated to the controller (by voice or by systems). It allows this one to anticipate the taxi path of the aircraft and the overall surface management with more predictability.
4	Which kind of situation(s) does the function support?	
	☒ normal situations	☒ abnormal/ emergency situations BTV/ROPS is available in overweight situations.

CONTEXT OF THE TASK AND TASK					
5	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☒ Descent	☒ Approach	☒ Landing	☐ Taxi-in
	Explanation BTV system is configured and armed during descent phase, monitored during approach and landing phases.				
6	Involved Actor(s)				
	Please choose using ☒				
	Air: Pilot ☒ PNF ☒ PF	Ground: ATCO ☐ EC ☐ PC ☐ GND ☒ RWY ☒ TWR ☐ Apron Controller ☐ Supervisor			
	6.1 Rationale				
	Pilots are in charge of: - BTV configuration/reconfiguration, - Monitoring and announcing the progress of BTV procedure,				

- BTV disconnection.

Tower ATCO is concerned by the supervision of the aircraft approach and landing. Pilots will also communicate to him their runway occupancy time and runway exit given by the aircraft system.

7	Pilot tasks	ATCO tasks
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☒ Evaluate system/ aircraft status and surroundings ☒Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	7.1 Rationale	
	The exit selection with BTV supports the crew in the selection of the first exit they can reach by presenting the aircraft possibilities based on the analysis of complex parameters. BTV also supports the crew in case of runway change by allowing an efficient reconfiguration and a new exit selection.	
	7.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The exit selection with BTV is not expected to lead to changes in roles, responsibilities, authority sharing and delegation.	
	7.3 Would you expect that procedures change?	
	☐ Yes ☒ Likely yes ☒ No ☐ Likely no Explanation: Except procedures directly associated to the function, the descent, and approach and landing procedures is not expected to change for pilots nor controller. In the future a procedure might be defined so that the pilots should systematically communicate the runway exit to ATC (currently it is not an obligation).	
8	Classification of supported cognitive functions and automation level	

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
	A1	(A5)	B1	B2				
	8.1 Rationale							
	Before change, the pilots had to gather relevant information using several tools, documentations and aircraft parameters to estimate the aircraft minimum braking distance. After change, pilots do not need to gather information as the system visually presents them the result of the estimation (magenta bars). The minimum braking distance representation will allow pilots to analyse if they can reach a certain exit or not (to arrive closer to the gate for example) and in a second step to decide which runway exit they want to use. The automated braking system of BTV depends on the runway selection, in order for the aircraft to optimally brake to reach the selected exit.							
IMPACTS ON HUMAN PERFORMANCE								
9	Human Performance and automation issues expected to be prevented or mitigated							
10	Human Performance and automation issues potentially <u>not</u> mitigated <u>by design</u>							
CONTEXT								
11	In which kind of organisation was the automation practice applied?							
	The automated solution was practiced in aircraft industry design and development (in cockpit simulators, mock-ups, flight tests) and a first step of the BTV function is operationally in service on A380.							
12	How often was the good practice applied in the past?							
	If the concerned practice is already operational, please specify since when or for how long it has been in operation. If the concerned practice is not operational, but was tested in some simulation exercise (e.g. RTS) please specify how often and how many times. The auto-brake of BTV is operational on A380 for 3 years.							

13	What were the required technical means and human resources to test/validate the practice?		
	To test and validate the function, mock-ups, flight simulators, test benches and flight test aircraft are generally needed. In these cases technical support is needed to run and monitor the test means. Several human resources intervene in design and operational validations: cockpit designers, human factors specialists, pilots and simulator technical support. For air/ground validation, controllers are also required.		
14	Integration of the concerned automation into a system or an ensemble of systems		
	The BTV function is integrated into the existing aircraft systems and interfaces. The integration of this novelty respects Airbus cockpit philosophy.		
15	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☒ V6: Operations
	16.1 Rationale		
	BTV Step 2 is already implemented on A380 in-service aircraft.		
FINAL CONSIDERATIONS			
16	What can be learnt from the proposed change in HP automation support?		
	Selecting a reachable runway exit alone has a value to support the taxi-in preparation (for pilots and controllers) whereas before it was predictable neither by pilots, nor by controllers. This may mean that an airborne automated solution can support also pilots and controllers in their work.		
REFERENCES			
Airbus FAST Magazine #44 / December 2009: http://www.airbus.com/support/publications/			

4.1.7 Brake to Vacate – Runway Overrun Warning and Protection (BTV-ROP/ROW)

1	Title of the automated solution
	ROW/ROP (Runway Overrun Warning and Protection) function of BTV “Step 2” (Brake-To-Vacate). Note: “Step 2” here means the second step of BTV development and must not be confused with the SESAR Step 2 implementation phase

2	Short description of the concerned automation
	BTV is an enhancement of the classical auto-brake system at landing. It allows pilots to select the runway exit they can reach, by visually indicating to the crew the minimum braking distance they need regarding the aircraft performance and runway conditions. The enhanced auto-brake system allows the aircraft to optimally reach the designated runway exit. The auto-brake activates roughly at the moment when the nose landing gear are down. The system guarantees the aircraft to vacate at the assigned exit with optimization of the brake energy regarding current operational constraints (weather, wet runway conditions ...), with minimization of the runway occupancy, and improvement of the passenger comfort. BTV allows pilots to select the runway exit they desire following these information and they can communicate to ATC BTV is coupled to a Runway Overrun Protection System (ROPS) which allows preventing the runway excursion risk at landing. It consist in ROW (Runway End Overrun Warning) that triggers alerts during approach if the runway will be too short for landing, and ROP (Runway Overrun Protection) that triggers, after touch-down, messages for pilot actions and can automatically activate max pressure braking if needed. BTV/ROPS step2 is applicable in the following operational environment: - From dry to wet runways - In all visibility conditions and landing configurations - With autopilot engaged or not BTV “Step 2” is supported by OANS environment (Onboard Airport Navigation System) as it uses airport data bases and the electronic charts to provide associated visual information to pilots needed to configure the system. Several automated solutions are interested to consider for their impact on human performance: - BTV: enhanced automated braking system - BTV: exit selection - ROPS: Runway Overrun Warning (in flight) and Runway Overrun Protection (on ground) The automated solution described in the current template is the ROPS function of BTV.
	2.1 Applicable domain
	☐ Air ☐ Ground ☒ Air-Ground
	Explanation: If more than one domain is concerned, please describe how the other domain might be affected by the change. Despite BTV is an airborne system which is entirely dedicated to pilots’ use, the ROPS function has impacts on ground domain. It helps pilots to detect during approach that the runway will be too short at landing and to handle the braking action if the runway is detected to be too short once the aircraft on ground. ROPS is a safety net which prevents runway excursions, which improve the overall surface management by reducing the risks on runway leading to runway closure or part of the airport closure.
3	Description of the specific function
	BTV coupled to the ROPS allows preventing the runway excursion risk at landing. The ROW function triggers an alert during approach in case the system detects that the aircraft

will be unable to stop before the runway limit and risks to overrun it.

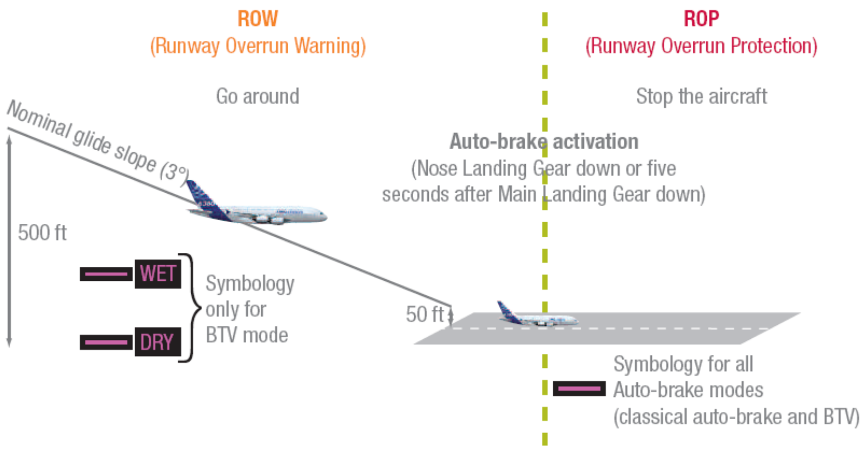
The ROP function triggers an alert once the aircraft is on ground, in case the aircraft is unable to stop before the end of the runway. Generally, the ROP function should never trigger if pilots make a corrective action when the ROW triggers (the corrective action in flight is the landing avoidance with the go around). But, it may happen that the ROP triggers but not the ROW, in case, for example, the runway conditions have changed before touch-down. In this case, the maximum automatic braking activates automatically at the aircraft touch-down in the same time as the alert.

3.1 Reason for the change

Before ROPS function of BTV, the pilots cannot precisely predict that the runway will be too short for landing during approach. They generally calculate the landing distance needed for the aircraft according to several parameters (e.g. aircraft performances, weight) but this can not be done in realtime up to touch-down and while accounting for wind gusts, aircraft position on runway, current ground speed, etc.. The ROPS based on BTV is able to give this precise information thanks to the considerations of the airborne progress and the airport databases.

3.2 Applied solution

ROPS function is available in all braking means, with BTV engaged or not.



Triggering conditions of BTV ROW/ROP function

ROW is an alert which triggers when the aircraft is in flight, indicating visually (on Airport Moving Map, and PFD) and aurally (audio message) that the aircraft braking distance will overrun the runway. In general, when this alert triggers, it is impossible for pilots to appropriately adjust approach parameters to recover the situation, then, the procedure applied is a go around.

ROP is an alert which triggers when the aircraft touches down, indicating visually (on Airport Moving Map, and PFD) and aurally (audio message) that the aircraft braking distance will overrun the runway. The ROP may generally not trigger because the ROW should trigger before, but it may happen that the runway conditions are misestimate and the ROP trigger the same alarm. Moreover, the ROP function associates also the auto-brake system to the alarm. This one activates automatically the maximum braking at the aircraft touch-down.

3.3 Which benefits on SESAR KPAs are expected?

☒ Capacity	BTV has a beneficial effect on runway throughput thanks to runway exit guarantee and runway occupancy time prediction.

	☒ Efficiency	BTV/ROPSoptimizes the pilots' efficiency to prepare and operate landing as it make them aware of the aircraft capabilities with dynamic information.
	☐ Flexibility	
	☒ Predictability	BTV has a beneficial effect on runway throughput thanks to runway exit guarantee and runway occupancy time prediction.
	☒ Safety	ROPS improves safety with the implementation of a runway overrun prevention system coupled to auto-brake system.
	☐ Access and Equity	
	☐ Interoperability	

4	Which kind of situation(s) does the function support?	
	☒ normal situations	☒ abnormal/ emergency situations BTV/ROPS is available in overweight situations.

CONTEXT OF THE TASK AND TASK

5	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☐ Descent	☒ Approach	☒ Landing	☐ Taxi-in
	Explanation Please describe 'border cases' if applicable. BTV/ROPS system is configured and armed during descent phase, monitored during approach and landing phases.				

6	Involved Actor(s)	
	Air: Pilot ☒ PNF ☒ PF	Ground: ATCO ☐ EC ☐ PC ☐ GND ☐ RWY ☒ TWR ☐ Apron Controller ☐ Supervisor
	6.1 Rationale	
	Pilots are in charge of: - BTV configuration/reconfiguration, - Monitoring and announcing the progress of BTV procedure, - BTV disconnection. Tower ATCO is concerned by the supervision of the aircraft approach and landing.	

7	Pilot tasks	ATCO tasks

	Operate: ☒ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☒ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	7.1 Rationale	
	The function is able to evaluate if the aircraft is going to overrun the runway end at landing: - During approach, the system calculates the aircraft performances and status and triggers an alert so that pilots make corrective actions or go around before landing - At touch-down, the system calculates the aircraft performances and status according to runway conditions (dynamically), triggers an alert and makes the aircraft automatically maximum braking (note: the pilots can override this automation if needed).	
	7.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The BTV/ROPS function is not expected to lead to changes in roles, responsibilities, authority sharing and delegation.	
	7.3 Would you expect that procedures change?	
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: Except procedures directly associated to the function, the descent, and approach and landing procedures is not expected to change for pilots nor controller.	
8	Classification of supported cognitive functions and automation level	

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change

ROW			B1	B5				
ROP					C1	C4	D2	D6

8.1 Rationale

ROW

Information analysis:

Before change, the information analysis for the runway overrun risk is generally made during departure preparation and landing preparation. Some parameters taken into account by the pilots are given by the system, some are given by papers (e.g. runway length from paper airport charts), and some are dynamic and evolve during the operation, and not always predictable by the pilots. The evaluation is theoretical and limited by the data available and pilots' situation estimation. After change the system is able to alert pilots about the risk to overrun the runway, by taking into account pre-defined and dynamic parameters in flight and at touch-down (weather conditions for example). The system does not content with making data available for pilots (in order for them to analyse the situation) but analyses data and present the results to the pilot (warning alert). Nevertheless, the system only gives information but does not generate options or action possibilities, pilots have to select the appropriate action to do following the alert and then remain the decision-maker.

ROP

Reminder: ROP triggers only at the aircraft touch-down. There are few chances it triggers without a ROW alert before, but the situation may happen in particular contexts (e.g.: weather changes).

Decision and action selection:

Before change: once on ground, pilots used to estimate the runway overrun by using parameters in the aircraft and information given by external environment (outside view: aircraft progress on the runway, runway conditions). The decision and action selection is dependent on this information and is operated by the pilot.

After change, the system is able to assess the situation and decide to brake with maximum energy if the aircraft risks to overrun the runway end.

Action implementation:

Before change, following the pilots' situation assessment, the aircraft braking action was either manually, or controlled by the auto-brake previously activated by the pilots.

After change, the ROP is systematically accompanied with the maximum braking action of the aircraft. The system decides and initiates the action of braking. Pilots can override this automation only by interrupting the operation and take the aircraft control manually.

IMPACTS ON HUMAN PERFORMANCE

9 Human Performance and automation issues expected to be prevented or mitigated

The HP issue 14 is expected to be mitigated by the enhanced auto-brake system.

"Loss of flexibility in automated systems will reduce the human potential to adapt to normal and abnormal situations".

Thanks to the possibility for pilots to keep the control of the aircraft braking when ROP activates on ground, the automated solution allows some flexibility to the human in the decision making and action implementation if he judges the situation does not require the maximum braking until the end of the procedure for example.

10 Human Performance and automation issues potentially <u>not</u> mitigated <u>by design</u>

CONTEXT			
11	In which kind of organisation was the automation practice applied?		
	The automated solution was practiced in aircraft industry design and development (in cockpit simulators, mock-ups, flight tests) and a first step of the BTV function (including the enhanced auto-brake system) is operationally in service on A380.		
12	How often was the good practice applied in the past?		
	BTV ROW/ROP has been operational on A380 for 3 years.		
13	What were the required technical means and human resources to test/validate the practice?		
	To test and validate the function, mock-ups, flight simulators, test benches and flight test aircraft are generally needed. In these cases technical support is needed to run and monitor the test means. Several human resources intervene in design and operational validations: cockpit designers, human factors specialists, pilots and simulator technical support. For air/ground validation, controllers are also required.		
14	Integration of the concerned automation into a system or an ensemble of systems		
	The BTV function is integrated into the existing aircraft systems and interfaces. The integration of this novelty respects Airbus cockpit philosophy.		
15	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☒ V6: Operations
	16.1 Rationale		
	BTV Step 2 is already implemented on A380 in-service aircraft.		
FINAL CONSIDERATIONS			
16	What can be learnt from the proposed change in HP automation support?		
	A safety net can be designed by combining the results of information analysis and a direct action implementation to avoid the risk.		

REFERENCES
Airbus FAST Magazine #44 / December 2009: http://www.airbus.com/support/publications/

4.1.8 Graphical Route Display on Airport Moving Map (D-TAXI)

1	Title of the automated solution
	D-TAXI function, specifically graphical route display on Airport Moving Map
2	Short description of the concerned automation
	D-TAXI function is an onboard function that allows: - CPDLC communication between pilots and controller during airport surface operations (sending and reception of messages) - The automatic graphical depiction of the datalink taxi route sent by the controller on the airport moving map (electronic charts) - The manual construction of graphical route on the airport moving map.
	2.1 Description of the function
	The specific automation (graphical route display) is designed as a situation awareness tool. It consists of the computation of the datalink message content to display the graphical route on airport moving map. The computation process is the same in the case the route elements are entered manually by the flight crew. The graphical route display allows a better situation awareness (own aircraft position) and assistance to the navigation, and allows the immediate route representation preventing the crew from searching on paper charts. In addition, the graphical route display is considered as particularly helpful under low visibility conditions on an airport.
	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐abnormal situations The graphical depiction of the taxi route can be used by pilots whenever they need to ensure a good level of situation awareness during airport navigation. There is no alert function incorporated and there is no obligation to consider the given information, so the function is not to handle abnormal situations.
	What is the linkage between the use of the function and traffic level? There is no specific linkage between the performance of the function and the traffic level. In any case the function is helpful for pilots to navigate on complex airports.
	2.3 Concerned domain
	☒Air ☐ Ground ☒ Air-Ground Explanation: D-TAXI function is a new controller/pilot communication tool including the optional possibility to display the taxi route clearance on the navigation display. That could bring benefits to all airports

in Europe, but most particularly to those that:

- Experience dense traffic at least during part of the day
- Have a complex taxiway and runway configuration
- Experience regularly degraded weather conditions

Please note that, a comparable system of traffic and clearance management exists on ground which is A-SMGCS (Advanced - Surface Movement Guidance and Control System) and is already implemented in some airports (e.g. Roissy - Charles de Gaulle, Prague).

2.4 Operational environment

Globally, the D-TAXI function is applicable in an operational context allowing CPDLC communication between controllers and pilots. But in case airports are not CPDLC equipped, the flight crew has the possibility to build the graphical route manually by entering the airport taxi element in the aircraft system. This function of manual building is optional.

Onboard, the function is supported by two systems:

- OANS (On-board Airport Navigation System), that allows the electronic map display including the ownship position display on the airport and the graphical taxi route.
- ATIMS (Air Traffic and Information Management System), which allows the datalink communication between pilots and controller and the display of taxi clearances, in a textual way.

The two systems are complementary to support the graphical display of the taxi route, as OANS needs ATIMS information.

To benefit from the graphical display of the taxi route, the aircraft have to be equipped with OANS system.

Note: OANS is an optional system for D-TAXI function

2.5 Reason for the change/ Problem to be handled

The main problem that the function addresses is the crew navigation errors and misunderstandings on complex airports. Pilots have difficulties to identify their own position on complex airports. Consequently, first attempts on OANS (Airport NAV) and Airport Moving Map have been launched also to facilitate airport operations during All Weather Conditions.

The pilots have also difficulties to navigate through their taxi path because of the high number of taxiways and intersections, and signs, especially in low visibility conditions.

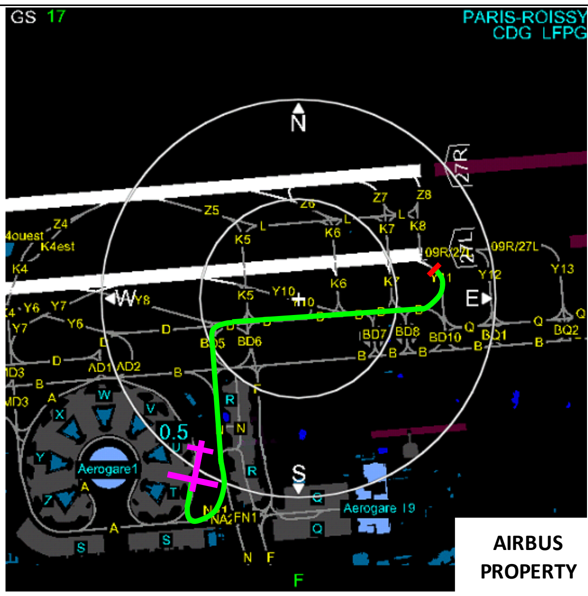
The primary goal of the D-TAXI graphical display functionality is to reduce the potential for errors, runway and taxiway incursions by increasing the situation awareness, with an impact on efficiency and safety.

2.6 Applied solution/intervention

The graphical display of the taxi route provides the flight crew an enhanced situation awareness of their own aircraft location, and an assistance for guiding the aircraft during taxi on expected/cleared taxi route (both Taxi Out & Taxi In phases).

It also supports the interpretation of the taxi path by reducing misunderstandings thanks to an immediate graphical translation of the textual information/clearances into graphic on airport moving map.

The enhanced information given on the displays completes the normal out-of the window scan.



Example of a graphical taxi route display for taxi-out operation on CDG.

Note: the picture shows the principle of the function, but does not necessarily reflects the exact current HMIs (definition still in progress and continuously changing)

3	REFERENCES
	SESAR WP9.13 PIR-Part 1-00.02.00 SESAR WP 9.13 D02 - Airport Surface Taxi Clearance Functional Requirement Document for initial package
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	The function is for the moment studied in the frame of R&D SESAR for which Airbus is in charge to define and develop onboard systems. At this step, the good practice was applied on cockpit mock-ups and cockpit simulators. The function definition requires several steps of validation according to the level of maturity of the concept: first validations occurred on mock-ups, then on simulators. Systems validations occur on system integration bench. For last definition steps, the validations are planned on integration simulators and finally on a flight test. In the meantime, several validation exercises are planned jointly with ground SESAR projects (WP6.7.2 & 6.7.3) in order to assess interoperability between air and ground.
5	What were the required technical means and human resources?
	Technical support is needed when validations stand on simulators or test benches to run the test means. In design and operational validations several human resources intervene: cockpit designers, human factors specialists, pilots and simulator technical support. For air/ground validation, controllers are also required. Technical means are described in part 4.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	Preliminary to SESAR, the function was studied and defined in the context of EMMA 2 project (Air/Ground European programme for surface routing and guidance function). The IHM concepts for D-TAXI were based on these studies, which involved onboard, ground and air/ground validations, including several partners and several competencies and experts.

7	Integration of the concerned automation into a system or an ensemble of systems				
	D-TAXI graphical route information is integrated in already existing crew interfaces.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☒ V2: Feasibility	☒ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations		
	8.1 Rationale				
	D-TAXI concept can be located between phase V2 and V3. Feasibility tests have been conducted and the development is ongoing.				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☒ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☐ Descent	☐ Approach	☐ Landing	☒Taxi-in
	9.1 Rationale				
	The graphical taxi route is displayed to support taxi-in and taxi-out operations as it provide taxi clearances and surface routing information on navigation display: - From runway exit to the gate in taxi-in operations - From the gate to the departure runway for taxi-out operations.				
10	Actor(s)				
	Air: Pilot ☒ PNF ☒ PF	Ground: ATCO ☐ EC ☐ PC ☐ Supervisor ☐…			
	10.1 Rationale				
	Generally, PF perform the taxi and the PNF assist him in the navigation task. Both pilots can see the taxi route on the moving map, using different ranges, according to their need and current task.				
TASK					
11	Pilot tasks	ATCO task			

Operate:

☐ Control the aircraft
☐ Manage the autopilot
☐ Monitor the flight parameters

Navigate:

☐ Aircraft position management
☐ Flight planning/ trajectory management

Communicate:

☒ Communicate with ATC
☐ Communicate within the crew
☐ Communicate with other aircraft, airline, maintenance

Manage system status and surroundings:

☒ Monitor system/ aircraft status and surroundings
☒ Evaluate system/ aircraft status and surroundings
☒ Handle system/ aircraft status and surroundings

☐ Monitoring traffic

☐ Providing traffic information

☐ Issuing instructions/clearances

☐ Detecting conflicts

☐ Resolving conflicts

☐ Planning strategy

☐ Assuming and transferring traffic

☐ Ground-ground communication

11.1 Rationale

Communication task with ATC is a prerequisite to the taxi route display as it is based on the extraction of the taxi elements coming from the CPDLC taxi clearances sent by ATC, or given by voice and entered manually by the pilot.

The graphical route display supports pilot's monitoring of their position on the airport during taxi phase. It allows them to evaluate if the ownship is navigating in compliance with the taxi clearance delivered by ATC and assist them to manage route revision by providing the graphical representation of the new path, or by allowing the crew to build a graphical path manually (in case the clearance is provided by the controller through R/T).

11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

D-TAXI function will not have an impact on pilots' task sharing. As the function is a new communication media no role changes is expected in the cockpit.

The graphical route display on airport moving map enhances the situation awareness of pilots only, and has not to be used as the clearance or as a substitute to ATC. The only clearance that is guaranteed is the datalink textual clearance (or vocal clearance); the graphic is considered only as assistance to the crew.

12 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA	A1	A3/ A4	n.a	n.a.	n.a.	n.a.	D0	D2

12.1 Rationale

Information acquisition and action implementation are the main subjects of change caused by the graphical display of the taxi route on navigation display.

Before the change, pilots had to search and note their taxi route on airport paper maps, and to navigate by looking down on it from time to time. Without the airport map they also had to locate their own aircraft by analysing the link between the out-of-the window and the route they noted on the paper maps. The automatic graphical route display will reduce the time to proceed and analyse the taxi route by displaying the path immediately. It will also allow the crew to immediately locate their aircraft on the airport and on the path, as the graphic is dynamic and progresses according to the aircraft taxi progress on airport surface. (This concerns A1 and A4).

In case the taxi elements are entered manually by the pilot, the change corresponds to the A3 level, as the system built the taxi route based on the user's settings.

In case the graphic is based on the CPDLC clearance, A4 level is concerned because the pilot has no additional action to do to display the taxi clearance, and he is aware of what compose the graphical route (it represents the taxi elements given in the clearance).

Despite the immediate and automated positioning of the aircraft along the taxi route, the pilots will always have to analyse and merge what they see out-of-the-window (taxiway and runway signs, ground marks) with what they see depicted in the cockpit to perform the airport surface navigation.

With the graphical route display and the ownship position, D-TAXI provides guidance in the execution of the taxi clearance according to automation level D2. The graphical route display provides the flight crew with feedback of the action they are performing, as they see the ownship moving on the airport surface.

IMPACTS ON HUMAN PERFORMANCE

13 13.1 Which changes do you see in the way the Human Performance is supported?

The graphical display of the taxi route clearance coupled with the own aircraft position along the path can reduce the navigation errors during airport surface operations. It also contributes to the movement fluidity as it is expected to reduce crew hesitations on their position.

The automated route display will change pilots task of taxi preparation; at a datalink clearance reception, the pilots will not have to search and note the path on paper, but are supposed to perform a cross-check between the message and the graphic and to analyse the path.

13.2 Which benefits do you expect on SESAR KPAs?

☒ Capacity	As the situation awareness of pilots is enhanced during surface operations, the occupancy time of taxiways is expected to be reduced. (This is also applicable for efficiency.)
☒ Efficiency	As the situation awareness of pilots is enhanced during surface operations, the taxi times, taxi obstructions, taxi errors, fuel consumption and punctuality are expected to be reduced.
☒ Flexibility	The display of the route will facilitate the taxi route revisions on airport, as it will provide assistance to locate and analyse the new path given to the crew.
☒ Predictability	The immediate consequence of a better efficiency will lead to better predictability of the aircraft for departure and arrival.
☒ Safety	The display of the route will contribute to a reduction of taxing errors and runway incursions.

	☐ Access and Equity	
	☒ Interoperability	The graphical route extracted from datalink clearance will allow pilots to represent the route easily and to remove misunderstandings about the clearance content when only given by voice.
	13.3 Human Performance and automation issues expected to be mitigated by design	
	The issue 13 can be applicable to the graphical display of the taxi route: Issue 13: "Specific automation supporting monitoring activities may lead to excessive 'head down' time at the expense of 'out of the window' checks by both pilots and tower ATCOs, with potential negative impact on human performance." Performing taxi requires necessarily to look out-of-the-window by the pilots as they still need to control the aircraft along the path, then, they still need to understand and analyse they progress and position on airport surface. As a matter of fact, this issue is supposed to be mitigated by itself.	
	13.4 Human Performance and automation issues potentially not mitigated by design	
	The following issues cannot be mitigated by the design. The issue 22 can be applicable to the graphical display of the taxi route: Issue 22: "Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness." Today, the graphical display is meant to be used as a situational awareness tool. The textual datalink clearance is meant to be the element on which the pilots had to rely first. Pilots must not use the graphical display as a primary means of navigation. The risk linked to the use of this tool like a "GPS" is that the pilot may finally end up taxiing without knowing where the aircraft is and where it goes, and then, lose its situation awareness. It is the essential counter effect to this system (and more generally to the GPS). To limit this counter effect, the right balance should be found by pilots between looking out of the window and monitoring their displays (Head-up versus Head-down). Only training or new procedures (cross-check) could mitigate this issue, but there is still a risk for pilots to be unconsciously tempted to rely on the graphic as a primary means. Moreover, new young pilots used to GPS and new technologies might be more prone to this issue.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: Procedures are not expected to change for pilots, as the graphical function is only complementary information to the datalink textual clearance. Nevertheless, during the development process procedures could be needed to be defined for the function.	
FINAL CONSIDERATIONS		
14	What can be learnt from the proposed change in HP automation support?	
	The taxi route display supports pilots' cognitive tasks of searching and analysing information which allows them rather focusing on the flight execution. Pilots are not supposed to spend effort on analysing and interpreting taxi clearance on maps but rather to prepare strategic tasks for the flight phase. Navigation on airport surface is made easier, which allows pilots preparing the take-off and flight phase 'mentally' during airport movements. The function supports particularly the low visibility operations on airport surface, as it compensates considerably the lack of information from outside and requires from pilots only to	

	check and match the information from different sources (out-of-the-window and displays). This automation will relief more cognitive resources to the pilots during airport surface operations in case of decision making or/and events management.

4.2 Ground functions

Sampling of ground functions gathered sixteen automated solutions, as follows:

[1] A-SMGCS - SCA (Advanced Surface Movement Guidance and Control Systems – Surface Conflict Alerting)
[2] A-STCA (Advanced – Short Term Conflict Alert)
[3] CATO (Controller Assistance Tools) - What-if-probing Function
[4] CATO (Controller Assistance Tools) - ECS (Executive Conflict Search) Function
[5] CATO (Controller Assistance Tools) – flight path monitoring Function
[6] CLOU (Cooperative Local Resource Planner)/ FMAN (Flow Manager)
[7] Combined use of AMAN (Arrival Manager) and Point Merge System (PMS) Procedure
[8] DFS AMAN
[9] DSAM (Down-linked Selected Altitude Monitoring)
[10] ERATO (En-Route Air Traffic Organizer) Filtering Function
[11] ERATO (En-Route Air Traffic Organizer) Monitoring Function
[12] ERATO (En-Route Air Traffic Organizer) Task Scheduler Function
[13] ERATO (En-Route Air Traffic Organizer) What-If Function
[14] E-TLM (Enhanced Task Load Monitoring)
[15] FAGI (Future Air-Ground integration) concept: AMAN timeline, turn-to-base advisories and air-ground negotiation
[16] PERSEO (Operational Sectorizations Network Effect Analysis Platform)
[17] SARA (Speed and Route Advisor)
[18] Tower HMI - ARR and DEP Integrated Planning Information Display

Hereafter each automated function is presented in the template.

It is worth clarifying that ERATO Filtering and What-if functions are presented in the same template, even if they address different types of HP automation support (this is the reason why until now they were presented separately).

4.2.1 A-SMGCS - SCA (Advanced Surface Movement Guidance and Control Systems – Surface Conflict Alerting)

1	Title of the automated solution
	‘Advanced Surface Movement Guidance and Control Systems’ (A-SMGCS) **Surface Conflict Alerting System (SCA)**
2	Short description of the concerned automation
	Advanced Surface Movement Guidance and Control Systems (A-SMGCS) [ICAO-A-SMGCS], “A system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety.” AVOL is defined as, “The minimum visibility at or above which the declared movement rate can be sustained.” [ICAO-A-SMGCS]. The concept A-SMGCS has been developed to help improve upon current systems, procedures and practices in the face of increasing traffic levels, airport complexity and the need to maintain the highest level of service at all times.

The main functions of A-SMGCS as they are defined in the ICAO A-SMGCS Manual are:

- Surveillance, which provides controllers (eventually pilots and vehicle drivers) with situational awareness on the movement area (i.e. a surveillance display showing the position & identification of all aircraft & vehicles);
- Control, providing conflict detection & alerting on runways (& eventually the whole movement area);
- Routing, through which manually (eventually automatically) the most efficient route is designated for each aircraft or vehicle;
- Guidance, giving pilots and drivers indications enabling them to follow an assigned route.

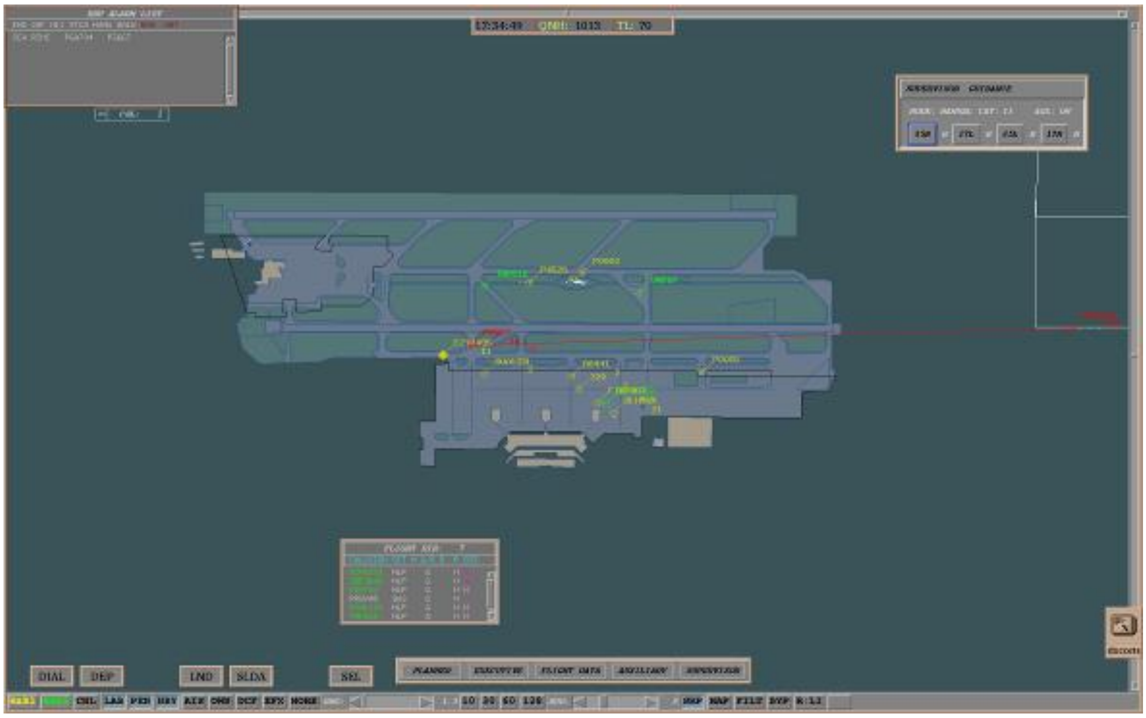
2.1 Description of the function

The Surface Conflict Alert (SCA) is responsible for automatic conflict detection and alerting within the A-SMGCS. SCA analyses the track data provided by the Multi Sensor Function (MSF) or by the Surface Movement Tracker (SMT) with respect to conflict situations on the manoeuvring area of the airport.

SCA is able to detect an alert situation: around each object (aircraft or vehicle), SCA defines a security area called Safety Bubble. A superposition between two or more safety bubbles is identified as a conflict situation. A superposition between a safety bubble and an airport obstacle (stop-bar, OFZ, ILS critical zone and so on) is also identified as a conflict situation.

The SCA is configurable in terms of acoustic signalling with independent settings (enabling/disabling) for warnings and alarms (e.g. beep on/off for all alarms, beep on/off for all warnings).

The runway and surface conflict alerting was integrated into the airport surveillance radar (ASR) and surface movement radar (SMR) displays as show in the figure below together with the depiction of a conflict alert for two involved aircraft:



Controller Working Position with integrated SCA

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

SCA analyses the track data provided by the "Multi Sensor Function (MSF)" or by the "Surface Movement Tracker (SMT)" with respect to conflict situations on the manoeuvring area of the airport. SCA is able to detect an "alert situation" and to automatically alert controllers.

The term "alert situation" is defined as: any situation relating to aerodrome operations, which has been defined as requiring particular attention or action. It is a generic term used to cover all situations, which, according to the operational requirements, should be brought to the attention of the user of the A-SMGCS.

What is the linkage between the use of the function and traffic level?

Surface Conflict Alert as a part of the safety net provided by A-SMGCS equipment is not linked to the traffic level as such, but to the increment of the safety level under normal operational conditions.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

Explanation:

Whenever a conflict is detected, SCA sends a conflict alert message to the controller.

2.4 Operational environment

SCA operates in all the airport operational conditions:

- Visual Approach Operation
- CAT1 Operation
- CAT2/3 Operation

2.5 Reason for the change/ Problem to be handled

As a part of the safety net of alerts and alarms provided by A-SMGCS, the issue addressed by SCA is the detection of potentially dangerous conflicts in order to improve safety on runways and manoeuvring areas.

SCA is an automated service capable of detecting conflicts and infringements of some ATC rules involving aircraft or vehicles on runways and restricted areas. It assists the controller in preventing collisions between aircraft, and between aircraft and vehicles and therefore contributes to the increment of safety level with normal traffic under reduced and normal visibility conditions.

2.6 Applied solution/intervention

Whenever a conflict is detected, SCA sends a conflict alert message to the controller with the following contents:

- Conflict status
- Conflict Type/Sub-Type
- Conflict Attribute
- Conflict Priority
- Time of detection
- First time of detection
- Mobile Identity
- Partner Identity
- Predicted Time of Collision
- Predicted Position of Collision
- List of activated/inactivated Conflicts Type

	If a conflict is detected for the first time the conflict status is set to “New”. If a conflict is detected for a second time or more, the conflict status gets the value “Active”. If a conflict with conflict status “New” or “Active” is no longer detected the conflict status is set to “Cleared”.
3	REFERENCES
	ICAO European Manual on Advanced Surface Movement Control and Guidance Systems (A-SMGCS) AOPG, Final Draft, Nov 2001 European Airport Movement Management by A-SMGCS (EMMA), Malpensa A-SMGCS Verification and Validation Results (D6.5.1), Version 1.0, EMMA Consortium, Naples, April 2007 European Airport Movement Management by A-SMGCS Part 2 (EMMA2), Validation Comparative Analysis Report (2-D6.7.1), V1.0, 2009, www.dlr.de/emma2 European Airport Movement Management by A-SMGCS Part 2 (EMMA2), EMMA2 A-SMGCS Services, Procedures and Operational Requirements (D1.1.1), Version 0.12, EMMA2 Consortium, Braunschweig, April 2008 European Airport Movement Management by A-SMGCS Part 2 (EMMA2), Milan Malpensa Validation Test Plan (2-D6.1.5), Version 0.62, EMMA Consortium, Naples, January 2009 European Airport Movement Management by A-SMGCS Part 2 (EMMA2), Milan Malpensa A-SMGCS Test Report (2-D6.5.1), Version 0.9, EMMA Consortium, Rome, January 2009 European Airport Movement Management by A-SMGCS Part 2 (EMMA2), Milan Malpensa A-SMGCS Safety Assessment Report (2-D6.5.2), Version 0.6, EMMA Consortium, Amsterdam, January 2009 European Airport Movement Management by A-SMGCS Part 2 (EMMA2), Milan Malpensa A-SMGCS Safety RTS Test Report (2-D6.5.3), Version 0.8, EMMA Consortium, Amsterdam, January 2009
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	A-SMGCS was among the new concepts for a structural revision of the ATM processes. The ‘European Airport Movement Management by A-SMGCS’ (EMMA) integrated project was set within the Sixth Framework Program of the European Commission (Directorate General for Energy and Transport) and looked at A-SMGCS as a holistic approach for changes in airport operations. It builds on the experiences of earlier projects such as ‘Operational Benefit Evaluation by Testing A-SMGCS’ (BETA). Although A-SMGCS progressed from a demonstration status to a full operational system, the complete proof of benefit of A-SMGCS was missing. Therefore, EMMA was supposed to set the standards for A-SMGCS systems and their operational usage, safety and interoperability while also focussing at the benefit expectation in Europe. EMMA was subdivided into two project phases: the first phase of EMMA, which ran from 2003 until 2006, mainly looked at different implementations of lower level A-SMGCS at a number of European airports as an initial step for enhancing safety and efficiency on the ground. In particular, additional surveillance services (Level I) and an automated control service for detecting potentially dangerous conflicts on runways and in restricted areas (Level II) were investigated. The second phase of the EMMA project- from 2006 to 2009, focused on the development and validation of a higher-level A-SMGCS operational concept. This means that in addition to the services investigated in the first phase of EMMA, higher-level functions and services were developed and validated. The higher-level services allow for the sharing of traffic situation awareness among pilots and drivers on the airport, the introduction of an automated routing

	function and the up-link of a validated route planning to pilots and drivers. Validation exercises of the EMMA2 functionality were performed on three ground sites (Prague-Ruzyně, Toulouse-Blagnac and Milan Malpensa airports) and different airborne platforms which are collectively referred to as the airborne site. Additional validation exercises were carried out in research simulators. In order to provide different possibilities of testing (i.e. different methodologies and different validation objectives), three different validation techniques were applied: • Real-time simulations, to reproduce safety-critical events and validate A-SMGCS provided functions, in a realistic environment under different operational conditions. • Shadow-mode trials, to verify the system, to test the general acceptance of new equipments/ provided information and procedures by operational controllers, and to support the definition of new standards and procedures for A-SMGCS. • Operational trials, to validate in the real operational environment some of the standards and procedures that have been defined.
5	What were the required technical means and human resources?
	Comparing to the RTS environment, with the passive shadow mode trials human performance is hard to be measured because the human is not working but only monitoring. But performance can be measured referring to tasks that results from an interaction with the system without direct influence to the regular traffic. The overall real environment cannot be copied by simulation (e.g. real tower light conditions) or there are circumstances that cannot be predicted without operational trials (e.g. behavior of the controller with pseudo pilots vs. real pilots). However, a lot of restrictions have to be taken into account here. Environmental conditions (e.g. traffic amount, system running or not) cannot be influenced by validation test team. In most cases, only parts of the system can be tested. Additionally, it is not permitted to induce safety-critical situations to test the human reaction. All together, the variables cannot be assessed over the complete spectrum, only prevailing test conditions can be used, and the human performance can only be assessed with non-intrusive methods. The non-intrusive methods mainly comprise by post-run questionnaires and debriefings. The following team roles were identified to conduct Validation testing activities: • Validation Supervisor: defines, organises and supervises the validation tests; • Experiment Leader for Validation Tests: coordinates the Validation on-site activity, ensures the correct execution of the Validation tests; ensures that all non-electronic results are recorded; gives instructions to controllers; collects subjective feedback from controllers; collects the controller answers of the different questionnaires; • System Architect and Configuration Manager: ensures the good operation of the A-SMGCS equipment during the tests; ensures that the A-SMGCS equipment is adequately configured for each test; provides technical support; is responsible for repairing all deficiencies and/or defects identified during testing; ensures that all electronic results are recorded; • Observer: experienced in air traffic control operations, observes and notes down the controller's behaviour in special situation and all the events that are retained significant for the Validation analysis; • Controller: user of the CWP; provides subjective feedback; TWR and GND controllers participated to the experiments.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	Several programmes/implementations were conducted in Europe to investigate into A-SMGCS concepts and installations prior to EMMA project (e.g. BETA- 'operational Benefit Evaluation by Testing A-SMGCS', ATOPS – 'A-SMGCS Testing of Operational Procedures by Simulation',

<table>
<tr><td></td><td colspan="5">LEONARDO-'Linking Existing ON ground, ARrival and Departure Operations'). The majority of them were taken into account to support the development of EMMA's concepts of operations, equipment and V&V activities. The EMMA project was conducted on 4 European test sites – Paris CDG, Prague Ruzyne, Toulouse-Blagnac and Milan-Malpensa.

Following the conduct of EMMA project, some functions and aspects of A-SMGCS were further taken into consideration for the operational implementation.

Based on the currently available information we cannot state with certainty if SCA function is fully implemented and operational on these airports. A full RIMCAS (Runway Incursion Monitoring and Collision Avoidance System) is operationally used at the Prague Ruzyne airport. However it is still unclear whether this implementation was done in accordance with the EMMA SCA specifications.</td></tr>
<tr><td>7</td><td colspan="5">Integration of the concerned automation into a system or an ensemble of systems</td></tr>
<tr><td></td><td colspan="5">In EMMA2, two different kinds of Surface Conflict Alerting systems were tested. At the DSNA Athis-Mons site for Charles-de-Gaulle Airport (CDG), an Advanced Runway Safety Net (A-RSN) was developed and integrated, taking into account control instructions that were entered into the system through electronic flight strips. In the NARSIM-Tower validation environment for Milan-Malpensa (MXP), a taxiway conflict alerting tool based on a separation bubble algorithm (warnings and alerts are issued when the virtual safety bubbles around two aircraft touch) was implemented on top of the existing runway incursion safety net.</td></tr>
<tr><td>8</td><td colspan="5">On which phase of maturity of the concept/automation was the good practice applied?</td></tr>
<tr><td></td><td>☐ V1: Scope</td><td colspan="2">☐ V2: Feasibility</td><td colspan="2">☒ V3: Pre-industrial development and integration</td></tr>
<tr><td></td><td>☐ V4: Industrialisation</td><td colspan="2">☐ V5: Deployment</td><td colspan="2">☐ V6: Operations</td></tr>
<tr><td></td><td colspan="5">8.1 Rationale</td></tr>
<tr><td></td><td colspan="5">The Milan Malpensa SCA (E-SCA) that was tested in the NARSIM-Tower environment was studied as part of a safety assessment. Its basic functionality was already assessed during verification activities in EMMA1.</td></tr>
<tr><td colspan="6">CONTEXT OF THE TASK</td></tr>
<tr><td>9</td><td colspan="5">What are the concerned flight phases?</td></tr>
<tr><td></td><td>☐ Turnaround</td><td>☐ Pushback</td><td>☒ Taxi-out</td><td>☒ Take-off</td><td>☐ Climb</td></tr>
<tr><td></td><td>☐ En Route</td><td>☐ Descent</td><td>☐ Approach</td><td>☒ Landing</td><td>☒ Taxi-in</td></tr>
<tr><td></td><td colspan="5">9.1 Rationale</td></tr>
<tr><td></td><td colspan="5">SCA function is applicable for the conflicts on the runways and taxiways of the airport and therefore is supporting the phases of flights that are taking place on those surfaces.</td></tr>
<tr><td>10</td><td colspan="5">Actor(s)</td></tr>
<tr><td></td><td colspan="2">Air: Pilot
☐ PNF ☐ PF</td><td colspan="3">Ground: ATCO
☐ EC ☐ PC ☐ Supervisor ☒ GND ☒TWR</td></tr>
<tr><td></td><td colspan="5">9.1 Rationale</td></tr>
</table>

	SCA is an automated tool for conflict detection on the manoeuvring area of the airport –runways and taxiways. Therefore, it assists TWR (Tower Controller) in detection of runway incursions and on the other hand to the GND (Ground Controller) as taxiway conflict alerting tool.	
TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☒ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	SCA analyses the track data provided by the "Multi Sensor Function (MSF)" or by the "Surface Movement Tracker (SMT)" with respect to conflict situations on the manoeuvring area of the airport and when detects an "alert situation" SCA automatically alerts controllers.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	With SCA function the work of the controller should be facilitated as it would assist him in the detection of the conflicts on the airport surfaces However, there are no impacts related to the changes of roles, responsibilities, authority sharing and delegation.	

12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA			B0	B5				
	12.1 Rationale								

Without SCA, the controller analyses by way of mental elaboration based only on the available information to detect possible conflicts on the manoeuvring surfaces.
SCA helps the controller in detecting conflicts by analysing data obtained from MSF and SMT based on predefined parameters.

These parameters can be modified:

The enabling/disabling operation of each of the single conflict type/subtype/attribute/area is available by means of an off-line modifiable ASCII configuration file. SCA will load the configuration file (after any modification), by means of an on-line order (I/O console), available only at setting-up time.

The conflict type/subtype/attribute/area status can be displayed on the I/O console by means of an on-line dedicated order.

It is possible at system configuration time to enable/disable the detection of each of the single conflict type/subtype/attribute; selectively for each airport zone (i.e. it is possible to configure the available conflicts type/subtype/attribute detection for each RWY, for each taxiway and so on).

It is possible at system configuration time to switch on/off the detection of the RWY Incursion Conflict type/subtype/attribute for each single runway, maintaining the conflict detection for the other runways.

It is possible at system configuration time to switch on/off the detection of the taxiway conflict type/subtype/attribute detection for each single taxiway, maintaining the conflict detection for the other ones.

IMPACTS ON HUMAN PERFORMANCE

13 13.1 Which changes do you see in the way the Human Performance is supported?

SCA helps controllers in the detection of conflicts by analysing data obtained from MSF and SMT based on the predefined parameters.

Hence, with the use of SCA runway and other restricted areas incursions will be detected faster and more reliably than without SCA when controllers detect possible conflicts by analysing available information by way of mental elaboration and without support of alerting tools.

13.2 Which benefits do you expect on SESAR KPAs?

☐ Capacity	
☐ Efficiency	
☐ Flexibility	
☐ Predictability	
☒ Safety	As a part of safety net, SCA contributes to the increment of safety level.
☐ Access and Equity	
☐ Interoperability	

13.3 Human Performance and automation issues expected to be mitigated

Issue 23: Inadequate trade-off between nuisance/false alerts and warning time may cause mistrust in automation and increase workload.

The nuisance alerts that may occur appear to be exclusively dependant on the quality of the available surveillance system. Namely, if the surveillance system is adequate and updates are

	reliable, then the nuisance is avoided and mistrust of the controller in the system and increase of the workload are avoided. Additionally, as SCA provides both warnings and alerts, the possibility of having nuisance alert is decreased. There is a possibility of having the warning, but as new updates are received in case of nuisance it will not develop into an alert.
	13.4 Human Performance and automation issues potentially not mitigated
	Issue 13: Specific automation supporting monitoring activities may lead to excessive 'head down' time at the expense of 'out of the window' checks by both pilots and tower ATCOs, with potential negative impact on human performance. Even though this issue might be a typical side effect of applying A-SMGCS-like systems (including SCA function), there is no reference to it in the available documentation, nor evidence of how it is mitigated. Therefore, this issue is stated as possibly not mitigated.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: SCA function is intended to facilitate detection of conflicts by the controller. However, there is no anticipated consequent change of procedures that controller applies.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	The main advantage of the implementation of A-SMGCS functions (including SCA) was that a small number of specific rules and functions were assessed at a time with the involvement of the end-user, i.e. incrementally and with testing the limited set for several months, rather than trying to validate the whole set at the same time. Therefore, for each step of the development technical feasibility of the implemented functions was tested and at the same time the feedback and user acceptance was collected to increase future usability of the functions. In this way dependencies and correlations of the implemented functions were validated and the more efficient way for their integration was proposed both from technical and operational side.

4.2.2 A-STCA (Advanced – Short Term Conflict Alert)

1	Title of the automated solution
	Advanced Short Term Conflict Alert (A-STCA)
2	Short description of the concerned automation
	Advanced STCA includes new algorithms in order to better predict loss of separation between aircrafts and best fit to the ATCOs assessment of loss of separation, i.e. reduce false alerts estimated by ATCOs.
	2.1 Description of the function
	Advanced STCA aims to anticipate positional conflicts and to generate alerts for all eligible system track pairs whose separation distance is expected to be lower than the minimum separation requirement within a given time, usually called "look ahead time". Based on surveillance data enriched by trajectory prediction and ADD[1], the advanced STCA use multi-

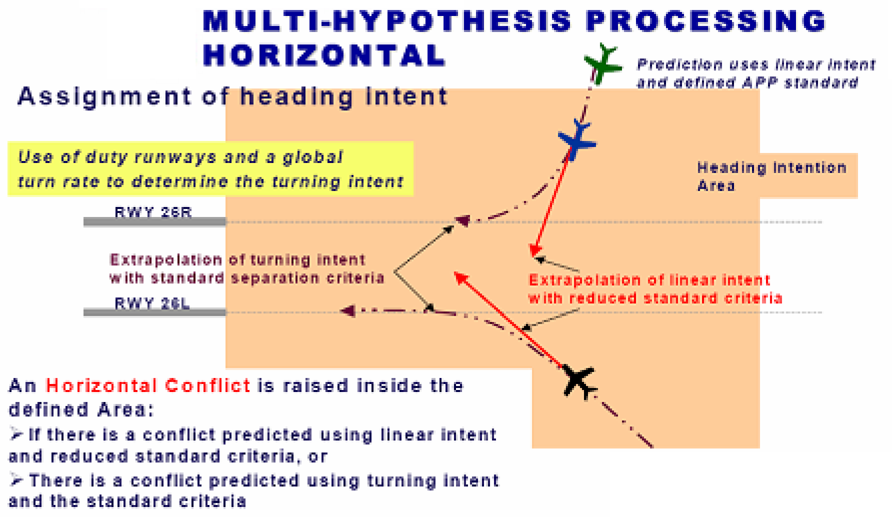
[1] Aircraft Derived Data provided from surveillance to advanced STCA through ASTERIX item 062/380.

hypothesis processing in an attempt to reduce the nuisance alerts in areas of predictable manoeuvres such as for example, but not limited to, aircrafts being sequenced for final approach. The ADD data used to better fit the trajectory are: selected altitude, vertical rate, track angle, true track angle, track angle rate and roll-angle.

Thus, the goals of advanced STCA is to improve the performance and accuracy of the STCA both in approach areas, by:

- Decrease STCA nuisance alerts using multi-hypothesis algorithms and
- Provide adequate Warning Time.

The standard STCA functions use a mono-hypothesis algorithm applying standard extrapolation using a straight-line model whereby radar surveillance information is used to predict typically the next 90 seconds of the flight trajectories and to predict potential separation violations. This kind of processing assumes that the current state vector of the aircraft represents the best knowledge of likely behaviour in the timescale under consideration. It can result in a significant increase of nuisance alerts and hence losses of operator trust in the functions. Some recent advances in STCA use multi-hypothesis processing in an attempt to reduce the nuisance alerts in areas of predictable manoeuvres such as for example aircraft being sequenced for final approach.



The intent of Advanced STCA is to extend the standard STCA to:

- Improve performances and accuracies of the STCA
- Reduce the nuisance alerts,
- Optimize the air traffic flow.

	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐ abnormal situations The basic skill of the ATCO is to maintain the separation between aircrafts. STCA is a safety net that supports this task.
	What is the linkage between the use of the function and traffic level? Mainly for high level of traffic, as the risk of loss of separation is lower in a low level of traffic.
	2.3 Concerned domain

	☐ Air ☒ Ground ☐ Air-Ground Explanation:
	2.4 Operational environment
	Advanced STCA is currently deployed in real operational environment in Switzerland (Skyguide ANSP). It will be deployed in other European & Asian ANSPs in the near future.
	2.5 Reason for the change/ Problem to be handled
	The major reason for change is that STCA has to provide a substantive safety benefit in ATM operations. The proportion of conflicts detected by the ATCO in time for controller resolution has to be enhanced by the use of STCA, meaning that STCA has to provide a significant contribution to operational safety. Therefore, the improvement of STCA has demonstrated safety benefits in terms of detection of real conflict alerts and significantly outweighs the negative effects in term of the number of nuisance alerts. This behaviour increases ATCO trust in the capability and can allow the evolution of operational procedures such as development of parallel approaches.
	2.6 Applied solution/intervention
	The multi-hypothesis algorithms, conceived by supplier system engineer's specialists, have been refined and tuned by using fast time simulations with real traffic on existing automation (standard STCA) to detect false alerts and issues that needed to be solved. Modification of the automation to solve part of those issues has been implemented, while remaining ones have been discussed with operators during working group sessions to see the characteristics that could be used to not trigger the alert. Mainly system engineer's specialists of both supplier and ANSP, and ATCOs composed the working team. Iterative approach and process has been applied for refining and tuning algorithms. At each automation evolution, several weeks of fast time simulation of real traffic data has been played in order to validate the new algorithms.
3	REFERENCES
	Many documents are available on the EUROCONTROL web site: **http://www.eurocontrol.int/safety-nets/public/standard_page/stca_02.html** Relevant ones are listed below: EUROCONTROL Specification for Short Term Conflict Alert Ed 1.1 EUROCONTROL Guidance Material for Short Term Conflict Alert Appendix A: Reference STCA System Ed 2.0 Skyguide Safety Bulletin 26 March 2009 http://www.skyguide.ch/en/Dossiers/Dossier_Safety/Downloadables_dossier_safety/Safety_bulletin_25_march2009.pdf
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*

	ANSP: ACC, APP/TMA ATCO and system engineer's specialists, operational safety experts. Supplier: System engineer's specialists, operational ATC experts, operational/equipment safety experts.		
5	What were the required technical means and human resources?		
	Working group composed by Operational experts, HF experts, System engineer specialists, and safety experts. Fast time simulations to play real traffic data recording. Specific tool (DART, Display, Analysis & Replay Tool) to analyse real traffic data results.		
6	If applicable: How often was the good practice applied in the past? Please estimate.		
	Advanced STCA is currently deployed in real operation in Switzerland (skyguide ANSP). It will be deployed in other European & Asian ANSPs in the near future.		
7	Integration of the concerned automation into a system or an ensemble of systems		
	The STCA concept and philosophy remains unchanged. The new automation aims at improving the existing one to increases ATCO trust in the capability.		
8	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☒ V6: Operations
	8.1 Rationale		
	Deployed in live operation in Switzerland (skyguide ANSP).		

CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☒ Climb
	☒ En Route	☒ Descent	☒ Approach	☒ Landing	☐ Taxi-in
	9.1 Rationale				
	Advanced STCA alerts are used by ACC and APP/TMA ATCO				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☐ PC ☐ Supervisor ☐…			
	10.1 Rationale				
	The EC ATCO is using the automation to issue speed/level instructions.				
TASK					

11	Pilot tasks	ATCO tasks
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☒ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	Advanced STCA is a safety net that allows anticipating a potential loss of separation between aircrafts. The automation provides conflicts detection allowing ATCO to solve conflicts. It is mainly used by EC ATCO.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	No change in roles by the evolution introduced in this new version of the automation.	

12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA	A5	A5	B5	B5	C0	C0	D0	D0
	12.1 Rationale								

<table>
<tr><td></td><td colspan="2">As mentioned before, the advanced STCA does not bring significant change in the automation. The STCA capability is always the same. For this reason the LA taxonomy "before and after change" match. However, more accurate and reliable algorithms have brought in the ATCO greater confidence in their use.

This goal was achieved thanks to the methodology used for developing and adjusting the algorithms. This methodology is based on an iterative process of algorithms tuning, driven by a multidisciplinary team. Any product change is tested with various fast time simulations playing real traffic scenarios. This allowed conceiving a reliable product adaptable to any operational environment in compliance with the operational needs of different ANSPs.

Moreover, in each phase of product development lifecycle the multi-disciplinary team ensured the trade-off of all aspects (operational, safety, HF, system engineering).

Thus, the good practice lies in the development process and methodology.</td></tr>
<tr><td colspan="3">IMPACTS ON HUMAN PERFORMANCE</td></tr>
<tr><td>13</td><td colspan="2">13.1 Which changes do you see in the way the Human Performance is supported?</td></tr>
<tr><td></td><td colspan="2">More accurate and reliable algorithms have brought the ATCO greater confidence in their use.</td></tr>
<tr><td></td><td colspan="2">13.2 Which benefits do you expect on SESAR KPAs?</td></tr>
<tr><td></td><td>☐ Capacity</td><td></td></tr>
<tr><td></td><td>☐ Efficiency</td><td></td></tr>
<tr><td></td><td>☐ Flexibility</td><td></td></tr>
<tr><td></td><td>☐ Predictability</td><td></td></tr>
<tr><td></td><td>☒ Safety</td><td>Safety benefits have been demonstrated in terms of detection of real conflict alerts and significantly outweigh the negative effects in term of the number of nuisance alerts.</td></tr>
<tr><td></td><td>☐ Access and Equity</td><td></td></tr>
<tr><td></td><td>☐ Interoperability</td><td></td></tr>
<tr><td></td><td colspan="2">13.3 Human Performance and automation issues expected to be mitigated</td></tr>
<tr><td></td><td colspan="2"><u>Issue 21</u>: Lack of trust in automation may induce misuse, disuse or abuse of automation
The new automation aims at improving the existing one to increases ATCO trust in the automation

<u>Issue 23</u>: Inadequate trade-off between nuisance/false alerts and warning time may cause mistrust in automation and increase workload
The advanced STCA improves the performance and accuracy of the STCA, by decreasing the nuisance alerts using multi-hypothesis algorithms and providing adequate warning time</td></tr>
<tr><td></td><td colspan="2">13.4 Human Performance and automation issues potentially <u>not</u> mitigated</td></tr>
</table>

	<u>Issue 22</u>: Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness. The trust increase in automation may lead the operators in deviating the intended use of the A-STCA, i.e. they may start using the A-STCA as a tool to ensure separation instead of using it as a safety net to detect and recover an error of the operator.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: Even enhanced, the A-STCA remains a safety nets function.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	The good practice that can be generated from the advanced STCA lies in the development process and methodology applied for developing and tuning the advanced automation. This methodology is based on an iterative process of algorithms tuning, driven by a multidisciplinary team that has ensured the trade-off of all aspects (operational, safety, HF, system engineering). Moreover, each change injected in the advanced automation has been tested with various fast time simulations playing real traffic scenarios.

4.2.3 CATO (Controller Assistance Tools) - What-if-probing Function

1	Title of the automated solution
	CATO (Controller Assistance Tools) – Controller Tools in lower airspace **What-if-probing** The project is linked to the DFS activity for the SESAR Joint Undertaking WP 04.07.02 “Separation Management En-Route”.
2	Short description of the concerned automation
	CATO is a DFS internal innovation project carried out by the business unit control centre, the DFS Bremen and Munich ATC centres and the research & development department. The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. While several automated support tools for air traffic controller are established in the upper airspace (UAC), their applicability for the lower airspace requires adaptation of algorithms and parameters as procedures, traffic, sector layout and routing differ considerably between UAC and ACC. Within the CATO project different automated support tools are developed for ACC: • Executive Conflict Search (ECS), • “What- if- probing” and • Flight Path Monitoring. These tools support controller’s communication, monitoring of flight paths, conflict detection and conflict resolution. The use of these tools is not mandatory and the controller can still base his

decisions on its own judgements. However, all functions are displayed to the controller and he can decide if he uses their functions.

These tools shall be used in an operational environment which is data link enabled (CPDLC = Controller/ Pilot Data Link Communications) and clearances (climb/descent, directs and transfer) can be issued.

This will be achieved using the PSS (paperless strip system), which is already in operation in parts of the German airspace and is expected to be used in all German lower airspace centres.

During development these tools are validated on the basis of Real Time Simulations (RTS).

2.1 Description of the function

The what-if-probing functionality can be used to check if cleared flight levels or direct inputs would be conflict free for a certain time horizon. The what–if probing computes potential conflicts for a configurable time horizon, (the next 6 minutes for lower sectors or 8 minutes for upper sectors) for aircraft that violate either the 6NM lateral or 700 ft vertical separation criteria. Hence, the what–if probe has a time buffer of 2 minutes before an ECS conflict is displayed.

For any given aircraft more than 500 conflict probes are computed, which represents 50 flight levels with 10 rates each. The what-if probe display update rate is the same as the radar update rate.

The figure below shows the aircraft RYR4SX with an ECS warning. The what-if probing window is open and shows the results of the what-if probe calculation. Green flight levels are free of conflicts, blue flight levels need to be combined with a cleared (green) rate to be free of conflicts, and orange flight levels are not free of conflicts regardless of specifying a rate.

The concept behind the displayed options is to provide a controller with flight levels that will not cause further conflicts if selected.

What-if probing for flight levels displayed in the CFL menu

The what-if probing functionality for direct inputs in the figure below. It shows conflict free direct input possibilities in green. Waypoints displayed in red may also be selected but will cause a potential conflict according to the trajectory prediction.

What-if probing for directs

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

What is the linkage between the use of the function and traffic level?

Generally the tool is of use in any traffic level. However, with increasing traffic volume or complexity the available time for creating and checking decision alternatives and to select the appropriate one is reduced. Thus, this tool is of increasing value with higher traffic, and offers a possibility to reduce mental workload.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

Explanation:

2.4 Operational environment

The CATO functions are designed for lower airspace and specifically for the ACC Munich and ACC Bremen. They are intended for being mainly used by EC and if applicable by PC.

A pre-requisite for controller use is that the tools must support clearance inputs and be able to display the results of such inputs and any co-ordination results. The clearance and coordination inputs will be supported using the Paperless Strip System (PSS) which is already in operation in the ATC centres being used to perform the CATO studies.

2.5 Reason for the change/ Problem to be handled

The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. The intention is, to transfer tools intended for upper air space into lower air space. Applicability for the lower airspace requires adaptation of algorithms and parameters as procedures, traffic, sector layout and routing differ considerably between UAC and ACC.

2.6 Applied solution/intervention

The executive and planner controller monitor that aircraft behave as expected based on flight plan and tactical instructions. Shortly after input of a tactical instruction (one radar update) the ECS recalculates the overall traffic situation and the conflict alert in the aircraft labels will be removed if the conflict is resolved.

Alternatively, an executive controller may delegate conflict resolution to another sector (e.g. if

	one of the involved aircraft is not yet handed over). Conflict resolution delegation for an executive controller will be carried out by the associated planner controller. The executive controller of the most upstream sector having flight information for both aircraft involved in a conflict is responsible for the initiation of conflict solutions. This executive controller identifies the conflicting aircraft pair(s) and assesses the traffic situation. In airspace with a low proportion of vertically manoeuvring traffic most conflicts can be detected and solutions planned by the planner controller. With an increasing proportion of vertically manoeuvring traffic the executive controller may also receive conflict warnings and plan conflict solutions on a shorter time horizon. For solution planning, the controller selects one of the involved aircraft and has the following options: - Open the Flight Level menu, the flight levels will be shown in different colours for conflict free levels, levels that require a specific vertical rate to be conflict free and levels which are not conflict free; - Open the Direct menu, the waypoints will be shown in different colours for conflict free and non conflict free direct inputs; Once a solution has been determined the executive controller selects the preferred solution and issues the tactical clearance to the aircraft **either by voice or data-link**. The executive and planner controller monitor that aircraft behave as expected based on flight plan and tactical instructions. Shortly after input of a tactical instruction (one radar update) the ECS recalculates the overall traffic situation and the conflict alert in the aircraft labels will be removed if the conflict is resolved. Alternatively, the executive controller may delegate conflict resolution to another sector (e.g. if one of the involved aircraft is not yet handed over). Conflict resolution delegation for an executive controller will be carried out by the associated planner controller.
3	REFERENCES
	- TE im Fokus, Ausgabe 2/2010 - *Vorhaben CATO – Betriebliche Nutzbarkeit von Controller- Tools für den unteren Luftraum.* [public version: www.dfs.de] - http://www.dfs.de/dfs/internet_2008/module/forschung_und_entwicklung/deutsch/forschung_und_entwicklung/forschungszeitschrift/2010/fokus1002.pdf - DFS (2011): Project CATO Controller Assistance Tools. Concept of Use, Phase 1, Release 1.
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	CATO is a DFS internal innovation project carried out by the business unit control centre, the DFS Bremen and Munich ATC centres and the research & development department. The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. The CATO tools were first tested within real time simulations at the AFS (advanced function simulator) with a very advanced system environment. Subsequently, the real time simulations with an operational system environment (P1/ ATCAS with PSS) followed. The focus is on the functionality and the underlying algorithms, not on implementation options such as HMI design.
5	What were the required technical means and human resources?

	The CATO- tools are validated in form of real time simulations (RTS) with ATCO participation. Therefore a simulator facility with necessary personnel (pilots, technicians, etc.) is required. There should be a sufficient number of CWP available to simulate multiple sectors and interdependencies between them. Furthermore different sectors need to be simulated to derive sector specific parameters relevant for the automated tool, e.g. depending on the sector size and layout, route structure, etc. the lateral and vertical separation criteria as well as look-ahead time need to be adjusted. In a high fidelity RTS the P1/ATCAS operational system environment was integrated, increasing the required expertise of the staff involved.		
6	If applicable: How often was the good practice applied in the past? Please estimate.		
	It wasn't applied until now; it is still in the pre- industrial development. Several real time simulations with ATCOs have been conducted to evaluate functionality and algorithms. The simulations were conducted in the DFS system test bed. Typically, 4 sectors were simulated, i.e. 4 CWP, and 4 simulation pilots were involved. A medium traffic load scenario was used with approximately 30 to 40 a/c per hour in a sector.		
7	Integration of the concerned automation into a system or an ensemble of systems		
	Though not yet in operational state the CATO tools are planned to be integrated into the existing P1/ATCAS system environment. A pre-requisite for controller use is that the tools must support clearance inputs and be able to display the results of such inputs and any co-ordination results. The clearance and coordination inputs will be supported using the Paperless Strip System (PSS) which is already in operation in the ATC centres being used to perform the CATO studies.		
8	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☒ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations
	8.1 Rationale		
	CATO is in a conceptual state. Automated support tools already used in upper airspace (UAC) are adapted to the needs in lower airspace (ACC). The aim is to prove that the tools are beneficial for ACC purposes. This corresponds to V1 and V2. Furthermore a coupling of the tools with PSS (Paperless Strip System, already operational) is realised to achieve the look and feel of the target operational system, as it is foreseen to implement those tools in the near future (V3).		

CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☒ Climb
	☒ En Route	☒ Descent	☐ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	CATO is designed for the lower airspace (ACC) with climb, en route and descent flight phases.				

10	Actor(s)	
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☐ PC ☐ … ☐…
	10.1 Rationale	
	The what-if probing tool is used by executive controllers only to check if tactical clearances like flight level or a direct would be conflict free for a certain time horizon (6 or 8 min depending on sector).	
TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☒ Issuing instructions/clearances ☒ Detecting conflicts ☒ Resolving conflicts ☒Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	With the introduction of the what-if-probing tool described above tasks and operating methods will change mainly related to conflict search, solution planning and implementation of clearances.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The executive controller is primarily responsible for assuring and maintaining separation between flights under his control (and against flights which are known to him, but may be under the control of another sector) whilst ensuring that flights achieve their co-ordinated sector exit conditions. The maintenance of separation against prohibited and restricted airspace, from danger areas and from terrain is also the responsibility of the executive controller. With the introduction of the what-if-probing tool described above the fundamental responsibilities of the executive controller will not change. However, tasks and operating methods will change. These changes are mainly related to the tasks of conflict search, solution planning and implementation. In order to resolve conflicts, the executive controller uses his own “mental solution library” but also looks for novel solutions. The solution must be verified to see if it solves a conflict and if it creates other problems. Today the MinSep (Minimum Separation) tool is frequently used which forecasts the minimum separation distance if both aircraft maintain their current heading and speed. In the future, planning of solutions will be supported by what-if probing.	

12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA	A3	A3	B2	B3	C1	C2	D0	D0 (D3)

12.1 Rationale

Information acquisition:

Before: (A3) The typical radar and tracking system for surveillance is used for acquiring information. Surveillance data is automatically integrated and displayed to the controller. Colour coding is used to highlight concerned and unconcerned traffic. The controller can use flight level filter to select traffic relevant to his sector.

After: (A3) No change.

Information analysis:

Before: (B2) The controller has only limited tool support to analyse the traffic situation, e.g. speed vectors or the MinSep (Minimum Separation) tool that forecasts the minimum separation distance if both aircraft maintain their current heading and speed, and has to analyse the traffic situation and consequences of clearances to be issued mentally.

After: (B3) The what-if-probing supports the human in analysing the traffic situation providing automatically conflict free options for clearances to be issued. The parameters (lateral and vertical separation criteria as well as look-ahead time) for detecting conflicts are defined at design level and cannot be modified during operations.

Decision and action selection:

Before: (C1) The controller has to generate decision options by his own.

After: (C2) The planning of solutions is supported by the colour coding of the window presenting the results of the what-if-probe calculation. For example the colour coding helps to distinguish the flight levels which are free of conflicts (green), from those which are occupied (orange) and from those that need to be combined with a cleared (green) rate to be free of conflicts. Therefore a set of decision alternatives is generated which assists the cognitive function of decision and action selection, The human can select one of the alternatives proposed by the system or his/her own one.

Action implementation:

Before: (D0) Currently the controller transmits clearances using ratio telephony (r/t)

After: (D0) Once a solution has been determined the executive controller selects the preferred solution and issues the tactical clearance to the aircraft. If clearances are time critical, the controller will most likely transmit it using r/t. **(D3)** If the system will be implemented in an operational data link enabled environment, the controller could implement the chosen option and transmit it via data link to the a/c if not time critical.

IMPACTS ON HUMAN PERFORMANCE

13	13.1 Which changes do you see in the way the Human Performance is supported?

The main benefits of the what-if probing tool for the executive controller are related to safety, especially in periods of high traffic. Conflict free solutions for clearances and related information are displayed in a comprehensive manner and can be used to resolve conflicts or when issuing routine clearances.

The tool supports the executive controller with the provision of conflict-free alternatives. The released cognitive resources can possibly be used to handle more traffic and increase sector capacity.

The calculations executed by the what-if probing tool are based on tactical clearances input to the system by controllers. The usability of the tool is therefore constrained by the fact that all clearances and co-ordination results need to be entered into the ground system. This may cause additional workload and may change controller workflows. Additionally, all aircraft need to comply with these clearances in order to ensure that the trajectories calculated in the ground system can be reliably used as a basis for data input to the tools.

Incorrect suggestions by the what-if probing tool (not conflict free) must be kept to a minimum. However, in the real world it is not possible to completely avoid tool errors or failures, thus it is most important that controllers keep monitoring the radar display and checking suggested solutions and do not only rely on tool support. Controllers need to retain the ability to search, monitor, and find solutions to conflicts on their own. In case of tool failure the controller will revert to current methods of conflict search and conflict resolution.

13.2 Which benefits do you expect on SESAR KPAs?

☒Capacity	The capacity can be partially increased, because the controller's efficiency increases, too. With a better efficiency more traffic can be handled.
☒ Efficiency	The clear arrangement of displaying potential conflicts facilitates resolving these situations. This enhances ATCO's efficiency in organizing and controlling traffic.
☐ Flexibility	
☒ Predictability	The CATO- tool ECS generates very accurate predictions, because it considers actual clearances and up to date traffic information.
☒ Safety	CATO ECS enhances the detection of conflicts and supports their resolution.
☐ Access and Equity	
☐ Interoperability	

13.3 Human Performance and automation issues expected to be mitigated

- **Issue n. 2**: Lack of user involvement in automation assisted processes may lead to loss of skills and proficiency

Within the conflict resolution tool the ATCO's vigilance is still essential, because it is his responsibility to decide, which solution should be executed. The automated tools are generating lists of decision options that the human can select from or the operator may generate his own options. Additionally the ATCO has to implement the solution by himself.

- **Issue n. 10:** Automation may increase task demand and cognitive workload

The what-of-probing provides the ATCO with conflict free solutions for tactical clearances. Thus the planning of solutions and decision selection will be supported and mental workload is reduced.

- **Issue n. 16:** Poor usability of HMI may reduce the human performance benefits

	expected from the automation support To counteract this effect of "poor usability of HMI" in the CATO project iterative prototyping has been accomplished. Right from the start users (ATCO) had been integrated in the development with giving suggestions for improvement. This leads to a better usability under operational considerations and finally to a higher acceptance of the new tools. - **Issue n. 23:** Inadequate trade- off between nuisance/ false alerts and warning time may cause mistrust in automation and increase workload In the CATO project the number of false alerts is reduced by optimization of all parameters and algorithms via iterative prototyping and feedback from controllers.
	13.4 Human Performance and automation issues potentially <u>not</u> mitigated
	- **Issue n. 11:** Automation could require additional system inputs, which may lead to increased task load and reduced acceptance A pre-requisite to be supported by the what-if-probing is that all clearances have to be input into the system as these are used to update the tactical trajectory, which is the base for calculating conflict free solutions. If CPDLC is used, routine communication is no longer a verbal operation, but data transfer occurs per data input. The ATCO has to monitor this display for answers or new data in addition. - **Issue n. 22:** Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness Excessive trust in "conflict detection and resolution"- tools may lead to reduced situation awareness. Furthermore it is possible, that the ATCO trusts too much in the given proposals for solution of conflicts.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: The CATO- tools may imply minor changes in controller's working methods. But these tools were not tested with real traffic volume up to now.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	First, the development process how the good practice was accomplished has to be mentioned. Basically, a stepwise, iterative approach driven by a multidisciplinary team with participation of users (ATCO) is essential to develop automated tools. The concept and first prototypes are then evaluated and validated in RTS to improve and fine tune parameters and algorithms for all CATO tools ECS, Flight Path Monitoring and what-if-probing. Additionally this enables to optimise the HMI. From the RTS conducted so far the controllers' response was throughout positive concerning the basic functionality and its support was highly appreciated. The clear and comprehensive provision of conflict-free alternatives significantly reduced the necessary mental workload to develop conflict resolution decisions or when issuing routine clearances. It is expected that cognitive resources can possibly be used to handle more traffic and increase sector capacity. Therefore a strong wish was expressed by the participating controllers to implement this CATO solution in an operational system as soon as possible. Nevertheless, the RTS revealed that certain parameters and algorithms have to be fine tuned, especially to account for different sector configurations and their prevailing traffic mix. But to provide such feedback is just one reason to conduct RTS.

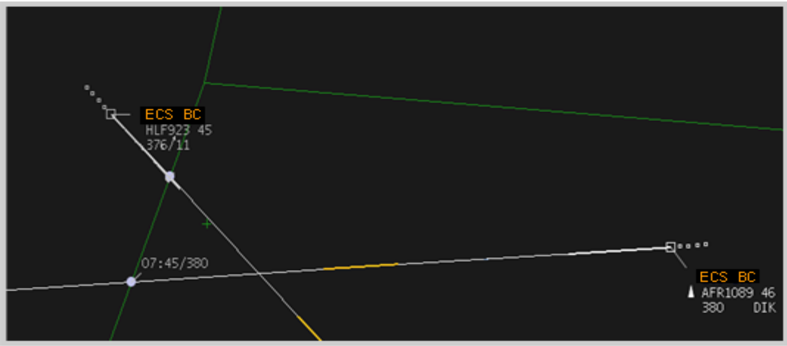
4.2.4 CATO - ECS (Controller Assistance Tools - Executive Conflict Search Function)

1	Title of the automated solution
	CATO (Controller Assistance Tools) – Controller Tools in lower airspace **ECS (Executive Conflict Search)** The project is linked to the DFS activity for the SESAR Joint Undertaking WP 04.07.02 “Separation Management En-Route”.
2	Short description of the concerned automation
	CATO is a DFS internal innovation project carried out by the business unit control centre, the DFS Bremen and Munich ATC centres and the research & development department. The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. While several automated support tools for air traffic controllers are established in the upper airspace (UAC), their applicability for the lower airspace requires adaptation of algorithms and parameters as procedures, traffic, sector layout and routing differ considerably between UAC and ACC. Within the CATO project different automated support tools are developed for ACC: • Executive Conflict Search (ECS), • “What- if- probing” and • Flight Path Monitoring. These tools support controller’s communication, monitoring of flight paths, conflict detection and conflict resolution. The use of these tools is not mandatory and the controller can still base his decisions on its own judgements. However, all functions are displayed to the controller and he can decide if he uses their functions. These tools shall be used in an operational environment which is data link enabled (CPDLC = Controller/ Pilot Data Link Communications) and clearances (climb/descent, directs and transfer) can be issued. This will be achieved using the PSS (paperless strip system), which is already in operation in parts of the German airspace and is expected to be used in all German lower airspace centers. During development these tools are validated on the basis of Real Time Simulations (RTS).
	2.1 Description of the function
	The ECS assists the executive controller in conflict detection. This is especially useful in airspace with an increasing proportion of traffic involving vertical manoeuvring. The tool computes potential conflicts based on the tactical trajectory. This trajectory is working with clearance data input by a controller and starts at the current track position. Clearance data is applied to the flight plan data which in turn updates the trajectory represented by the flight plan data. The ECS tool warns a controller if aircraft are predicted to violate either the lateral (6 NM) or vertical (700 ft) separation criteria within a pre-defined look ahead time horizon. Based on preliminary studies, the look-ahead horizon is set to 4 minutes in lower and 6 minutes in the upper sectors. The look-ahead time horizon and separation criteria parameters are configurable and variable due to sector size and complexity. If a cleared vertical rate is assigned by a controller, the cleared vertical rate is taken into account by the ECS (with a configurable vertical rate tolerance) when assessing compliance of a track to the cleared vertical rate input. If no rate is assigned the conflict detection will use a default minimum and maximum vertical rate (both are configurable, max rate e.g. 4000 fpm, min

rate e.g. 200 fpm).

A conflict is displayed at both planning and executive positions responsible for control of the traffic where a conflict is detected. The sector of the conflict's origin is defined as follows: The conflict is displayed in the next upstream sector that has got flight information on both flights (middle point of the closest proximity line, if there is no overlap). The warning will be shown together with a conflict ID. If there are more than two aircraft involved in a conflict, the ECS warning will always be shown for aircraft pairs with different conflict IDs.

The following figure shows an example of an ECS warning as displayed at a controller position. The trajectories of aircraft HLF923 and AFR1089 will cross at the same level. An ECS warning is displayed in both labels together with a conflict ID, which can be letters or numbers. Additionally the conflict is displayed with the same conflict ID in a "problem display window" on the radar screen, indicating the criticality and urgency of the conflict.



ECS Warning in Aircraft Label (conflict ID "BC")

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

What is the linkage between the use of the function and traffic level?

Generally the tool is of use in any traffic level. Having in mind that with increasing traffic volume or complexity the demand for monitoring the radar and checking the anticipated traffic situation also increases. Then it becomes clear that this tool is of growing value with higher traffic and especially useful in airspace with a high proportion of climbing/descending traffic.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

2.4 Operational environment

The CATO functions are designed for lower airspace and specifically for the ACC Munich and ACC Bremen. They are intended for being mainly used by EC and if applicable by PC.

A pre-requisite for controller use is that the tools must support clearance inputs and be able to display the results of such inputs and any co-ordination results. The clearance and coordination inputs will be supported using the Paperless Strip System (PSS) which is already in operation in the ATC centres being used to perform the CATO studies.

2.5 Reason for the change/ Problem to be handled

The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. The intention is, to transfer tools intended for upper air space into

	lower air space. Applicability for the lower airspace requires adaptation of algorithms and parameters as procedures, traffic, sector layout and routing differ considerably between UAC and ACC.
	2.6 Applied solution/intervention
	Upon display of an ECS conflict, a controller obtains information on the conflicting aircraft and trajectories. A controller has the following options: - A manual solution is planned with or without applying the what-if probing tool to one of the aircraft. The system flight plan data is updated and a tactical clearance instruction issued to the aircraft, usually via R/T. As soon as the aircraft has executed the clearance and the ECS has recalculated the overall traffic situation the ECS warning will be removed. - If a controller concludes that the ECS is not relevant, (e.g. the problem will be solved in another sector or false alarm) the ECS warning can be suppressed, i.e. the conflict is acknowledged by the controller with a mouse click either in the label or in the problem display window.
3	REFERENCES
	- TE im Fokus, Ausgabe 2/2010 - *Vorhaben CATO – Betriebliche Nutzbarkeit von Controller- Tools für den unteren Luftraum.* [public version: www.dfs.de] - http://www.dfs.de/dfs/internet_2008/module/forschung_und_entwicklung/deutsch/forschung_und_entwicklung/forschungszeitschrift/2010/fokus1002.pdf - DFS (2011): Project CATO Controller Assistance Tools. Concept of Use, Phase 1, Release 1.
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	ATO is a DFS internal innovation project carried out by the business unit control centre, the DFS Bremen and Munich ATC centres and the research & development department. The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. The CATO tools were first tested within real time simulations at the AFS (advanced function simulator) with a very advanced system environment. Subsequently, the real time simulations with an operational system environment (P1/ ATCAS with PSS) followed. The focus is on the functionality and the underlying algorithms, not on implementation options such as HMI design.
5	What were the required technical means and human resources?
	The CATO- tools are validated in form of real time simulations (RTS) with ATCO participation. Therefore a simulator facility with necessary personnel (pilots, technicians, etc.) is required. There should be a sufficient number of CWP available to simulate multiple sectors and interdependencies between them. Furthermore different sectors need to be simulated to derive sector specific parameters relevant for the automated tool, e.g. depending on the sector size and layout, route structure, etc. the lateral and vertical separation criteria as well as look-ahead time need to be adjusted. In a high fidelity RTS the P1/ATCAS operational system environment was integrated, increasing the required expertise of the staff involved.

6	If applicable: How often was the good practice applied in the past? Please estimate.				
	It wasn't applied until now; it is still in the pre- industrial development. Several real time simulations with ATCOs have been conducted to evaluate functionality and algorithms. The simulations were conducted in the DFS system test bed. Typically, 4 sectors were simulated, i.e. 4 CWP, and 4 simulation pilots were involved. A medium traffic load scenario was used with approximately 30 to 40 a/c per hour in a sector.				
7	Integration of the concerned automation into a system or an ensemble of systems				
	Though not yet in operational state the CATO tools are planned to be integrated into the existing P1/ATCAS system environment. A pre-requisite for controller use is that the tools must support clearance inputs and be able to display the results of such inputs and any co-ordination results. The clearance and coordination inputs will be supported using the Paperless Strip System (PSS) which is already in operation in the ATC centres being used to perform the CATO studies.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☐ V2: Feasibility	☒ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations		
	8.1 Rationale				
	CATO is in a conceptual state. Automated support tools already used in upper airspace (UAC) are adapted to the needs in lower airspace (ACC). The aim is to prove that the tools are beneficial for ACC purposes. This corresponds to V1 and V2. Furthermore a coupling of the tools with PSS (Paperless Strip System, already operational) is realised to achieve the look and feel of the target operational system, as it is foreseen to implement those tools in the near future (V3).				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☒ Climb
	☒ En Route	☒ Descent	☐ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	CATO is designed for the lower airspace (ACC) with climb, en route and descent flight phases.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☒ PC ☐ … ☐…			
	10.1 Rationale				

	The ECS tool is mainly used by executive controllers (EC) and assists him in conflict detection. It is of limited use to the planning controller (PC) as the look-ahead horizon of 4 or 6 min, depending on sector configuration, is too short to resolve conflicts through coordination activities with adjacent sectors. Nevertheless the conflict detected by ECS is displayed at both planning and executive positions responsible for control of the traffic.	
TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☒ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☒ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	CATO ECS provides support to monitoring traffic, detecting and resolving conflicts.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The executive controller is primarily responsible for assuring and maintaining separation between flights under his control (and against flights which are known to him, but may be under the control of another sector) whilst ensuring that flights achieve their co-ordinated sector exit conditions. The maintenance of separation against prohibited and restricted airspace, from danger areas and from terrain is also the responsibility of the executive controller. With the introduction of the ECS tool described above the fundamental responsibilities of the executive controller will not change. However, tasks and operating methods will change. These changes are mainly related to the tasks of conflict search, solution planning and implementation. Today, the executive controller searches conflicts by continuously scanning the traffic or checking special aircraft pairs or special routes where potential conflicts can occur. Another possibility is that the planner controller has already marked aircraft which might have a conflict. In the future, the executive controller will be supported by the ECS which automatically indicates potential conflicts within a given sector.	

12	Classification of supported cognitive functions and automation level				
		Associated cognitive function being supported by automation			
		Information acquisition	Information analysis	Decision and action selection	Action implementation

	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA	A3	A3	B2	B5	C0	C0 (C2)	D0	D0 (D3)

12.1 Rationale

Information acquisition:

Before: (A3) The typical radar and tracking system for surveillance is used for acquiring information. Surveillance data is automatically integrated and displayed to the controller. Colour coding is used to highlight concerned and unconcerned traffic. The controller can use flight level filter to select traffic relevant to his sector.

After: (A3) No change.

Information analysis:

Before: (B2) The controller has only limited tool support to analyse the traffic situation, e.g. speed vectors or the MinSep (Minimum Separation) tool that forecasts the minimum separation distance if both aircraft maintain their current heading and speed, and has to analyse the traffic situation and consequences of clearances to be issued mentally.

After: (B5) The ECS assist the information analysis and supports the human by automatically performing conflict detection and providing visual alerts. The parameters (lateral and vertical separation criteria as well as look-ahead time) for detecting conflicts are defined at design level and cannot be modified during operations.

Decision and action selection:

Before: (C0) The controller has to generate decision options by his own.

After: (C0) Though informed about a potential conflict the controller still has to generate decisions how to solve a conflict on his own. However, **(C2)** conflict resolution may be supported by another CATO tool, the what-if-probing. Based on previous information analysis, it assists the cognitive function of decision and action selection by generating options how to solve or avoid a potential conflict, thus providing decision alternatives. The human has to decide which alternative to choose.

Action implementation:

Before: (D0) Currently the controller transmits clearances using ratio telephony (r/t)

After: (D0) Once a solution has been determined the executive controller issues the tactical clearance to the aircraft. If clearances are time critical, the controller will most likely transmit it using r/t. **(D3)** If the system will be implemented in an operational data link enabled environment, the controller could implement the chosen option and transmit it via data link to the a/c if not time critical.

IMPACTS ON HUMAN PERFORMANCE

13 13.1 Which changes do you see in the way the Human Performance is supported?

The main benefits of the ECS for the executive controller are related to safety. The ECS is expected to improve situational awareness, especially in periods of high traffic. Conflicts and related information are displayed in a comprehensive manner and can be used to build a mental picture of the current traffic situation and its further evolution.

The tool may partly detect potential conflicts earlier than a controller and therefore allow more time to react to a conflict. The reaction to a conflict is in turn supported by the what-if probing tool with the provision of conflict-free alternatives. Even though the ECS is not a safety net, it acts as a second pair of eyes and in this way helps to ensure safety. The released cognitive resources can possibly be used to handle more traffic and increase sector capacity.

The calculations executed by the ECS and what-if probing tools, are based on tactical clearances input to the system by controllers. The usability of the tools is therefore constrained by the fact that all clearances and co-ordination results need to be entered into the ground system. This may cause additional workload and may change controller workflows. Additionally, all aircraft need to comply with these clearances in order to ensure that the trajectories calculated in the ground system can be reliably used as a basis for data input to the tools. It is essential for controllers to know whether an aircraft is adhering to the clearances or not, FPM is provided to ensure any deviations are brought to the attention of controllers.

False alarms (false positive) or not detected alarms must be kept to a minimum. However, in the real world it is not possible to completely avoid tool errors or failures, thus it is most important that controllers keep monitoring the radar display and checking suggested solutions and do not rely solely on tool support. Controllers need to retain the ability to search, monitor, and find solutions to conflicts on their own. In case of tool failure the controller will revert to current methods of conflict search and conflict resolution.

13.2 Which benefits do you expect on SESAR KPAs?

☒Capacity	The capacity can be partially increased, because the controller's efficiency increases, too. With a better efficiency more traffic can be handled.
☒ Efficiency	The clear arrangement of displaying potential conflicts facilitates resolving these situations. This enhances ATCO's efficiency in organizing and controlling traffic.
☐ Flexibility	
☒ Predictability	The CATO- tool ECS generates very accurate predictions, because it considers actual clearances and up to date traffic information.
☒ Safety	CATO enhances the detection of conflicts and supports their resolution.
☐ Access and Equity	
☐ Interoperability	

13.3 Human Performance and automation issues expected to be mitigated

- **Issue n. 10:** Automation may increase task demand and cognitive workload

The ECS relieves the controller monitoring the radar and checking for conflicts. Potential conflicts are automatically displayed with a special conflict code and an identification mark in the aircraft label. Via mouse click the ATCO gets further information, like trajectory of the aircraft. The ECS is expected to improve situational awareness, especially in periods of high traffic. Conflicts and related information are displayed in a comprehensive manner and can be used to build a mental picture of the current traffic situation and its further evolution.

- **Issue n. 16:** Poor usability of HMI may reduce the human performance benefits expected from the automation support

To counteract this effect of "poor usability of HMI" in the CATO project iterative prototyping has been accomplished. Right from the start users (ATCO) had been integrated in the development with giving suggestions for improvement. This leads to a better usability under operational considerations and finally to a higher acceptance of the new tools.

- **Issue n. 23:** Inadequate trade- off between nuisance/ false alerts and warning time may cause mistrust in automation and increase workload

In the CATO project the number of false alerts is reduced by optimization of all parameters and algorithms via iterative prototyping and feedback from controllers.

	13.4 Human Performance and automation issues potentially not mitigated
	- **Issue n. 11:** Automation could require additional system inputs, which may lead to increased task load and reduced acceptance A pre-requisite to be supported by the ECS is that all clearances have to be input into the system as these are used to update the tactical trajectory which is base for calculating potential conflicts. If CPDLC is used, routine communication is no longer a verbal operation, but data transfer occurs per data input. The ATCO has to monitor this display for answers or new data in addition. - **Issue n. 18:** New automation support that results in greater use in visual information may lead to visual channel overload, with decrease in situation awareness and performance efficiency Visual information is increasingly predominant by introducing an extensive use of CPDLC. This may lead to a visual channel overload and decrease the concentration and attention of the ATCO. - **Issue n. 22:** Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness Excessive trust in "conflict detection and resolution"- tools may lead to reduced situation awareness. Furthermore it is possible, that the ATCO trusts too much in the given proposals for solution of conflicts.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: The CATO- tools may imply minor changes in controller's working methods. But these tools were not tested with real traffic volume up to now.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	First, the development process how the good practice was accomplished has to be mentioned. Basically, a stepwise, iterative approach driven by a multidisciplinary team with participation of users (ATCO) is essential to develop automated tools. The concept and first prototypes are then evaluated and validated in RTS to improve and fine tune parameters and algorithms for all CATO tools ECS, Flight Path Monitoring and what-if-probing. Additionally this enables to optimise the HMI. From the RTS conducted so far the controllers' response was throughout positive concerning the basic functionality and its support was highly appreciated. The ECS is expected to improve situational awareness, especially in periods of high traffic. Conflicts and related information are displayed in a comprehensive manner and can be used to build a mental picture of the current traffic situation and its further evolution. With the tool potential conflicts may be detect earlier and therefore allow more time to react to a conflict, improving safety. The conflict resolution is further supported by the what-if probing tool with the provision of conflict-free alternatives for clearances. Nevertheless, the RTS revealed that certain parameters and algorithms have to be fine tuned, especially to account for different sector configurations and their prevailing traffic mix. Thus parameters for conflict calculation (look-ahead time) and safety buffers have to be adapted individually. In consequence, to provide such feedback is just one reason to conduct RTS.

4.2.5 CATO (Controller Assistance Tools) – Flight path monitoring Function

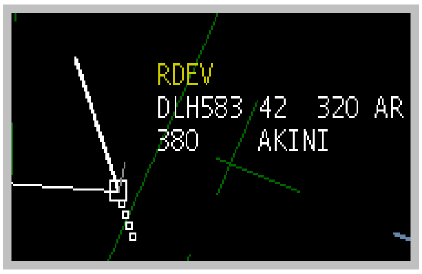
1	Title of the automated solution
	CATO (Controller Assistance Tools) – Controller Tools in lower airspace **Flight Path Monitoring** The project is linked to the DFS activity for the SESAR Joint Undertaking WP 04.07.02 “Separation Management En-Route”.
2	Short description of the concerned automation
	CATO is a DFS internal innovation project carried out by the business unit control centre, the DFS Bremen and Munich ATC centres and the research & development department. The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. While several automated support tools for air traffic controller are established in the upper airspace (UAC), their applicability for the lower airspace requires adaptation of algorithms and parameters as procedures, traffic, sector layout and routing differ considerably between UAC and ACC. Within the CATO project different automated support tools are developed for ACC: • Executive Conflict Search (ECS), • “What- if- probing” and • Flight Path Monitoring. These tools support controller’s communication, monitoring of flight paths, conflict detection and conflict resolution. The use of these tools is not mandatory and the controller can still base his decisions on its own judgements. However, all functions are displayed to the controller and he can decide if he uses their functions. These tools shall be used in an operational environment which is data link enabled (CPDLC = Controller/ Pilot Data Link Communications) and clearances (climb/descent, directs and transfer) can be issued. This will be achieved using the PSS (paperless strip system), which is already in operation in parts of the German airspace and is expected to be used in all German lower airspace centers. During development these tools are validated on the basis of Real Time Simulations (RTS).
	2.1 Description of the function
	The calculation of the conflict detection and resolution advisory tools is based on controller clearances and the compliance of aircraft to these clearances. If an aircraft does not adhere to its trajectory (i.e. it is not following the tactical clearance instructions) then a correct calculation is no longer possible, as conflict tools use the tactical trajectory and assume that the tactical trajectory is followed. For these cases an FPM tool needs to warn a controller of the situation. FPM compares the track positions as received in radar data from RDPS (e.g. position, speed) to tactical clearance data in the PSS and FDPS systems (e.g. level, waypoint, speed). If a deviation is detected a FPM warning is shown to the controller. The warning text is an abbreviation which indicates the type of deviation which may be one or more of the following: - Route deviation - Vertical rate deviation - Cleared flight level deviation - Imminent level bust When FPM detects no compliance to a trajectory, the tactical trajectory cannot be used for

conflict detection and what-if probing because it is not reliable. Instead a deviation trajectory will be calculated and used for conflict detection and what-if probing purposes.

So this tool is a necessary enhancement for the conflict detection functionality. As conflict detection relies on the clearances data it is crucial for the controller to know when an aircraft is not complying with its clearances.

In the pictures below there are two examples of flight path monitoring alerts displayed to the controller depicted. Flight KYV953 is deviating from it's cleared flight level, whereas flight DLH583 is diverting from the route.

Flight path monitoring alert for deviation from cleared flight level



Flight path monitoring alert for deviation from cleared route

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

What is the linkage between the use of the function and traffic level?

Generally the tool is of use in any traffic level. Having in mind that monitoring is a process of continuous or discrete, intermittent comparisons between the anticipated traffic situation and the actual system state, it becomes clear that with increasing traffic volume the available time for monitoring reduces and deviations may go unnoticed. Thus, this tool is of increasing value with higher traffic.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

2.4 Operational environment

The CATO functions are designed for lower airspace and specifically for the ACC Munich and ACC Bremen. They are intended for being mainly used by EC and if applicable by PC.

A pre-requisite for controller use is that the tools must support clearance inputs and be able to display the results of such inputs and any co-ordination results. The clearance and coordination

	inputs will be supported using the Paperless Strip System (PSS) which is already in operation in the ATC centres being used to perform the CATO studies.
	2.5 Reason for the change/ Problem to be handled
	The objective of the project is to study the operational usability of new controller assistance tools in lower airspace thereby focusing on the possibility to gain quick wins from early implementation of the tools. The intention is, to transfer tools intended for upper air space into lower air space. Applicability for the lower airspace requires adaptation of algorithms and parameters as procedures, traffic, sector layout and routing differ considerably between UAC and ACC.
	2.6 Applied solution/intervention
	If an aircraft does not adhere to its trajectory (e.g. due to misunderstanding, incorrect input in FMS, technical failure etc.) a FPM warning is displayed. FPM warnings should generally be resolved before handing an aircraft over to the next sector. In cases where an aircraft is very close to a sector boundary resolution may not be possible, so that an aircraft with its deviation has to be handed over to the next sector. If a FPM warning is displayed, a controller immediately contacts the aircraft. If the pilot can correct the deviation he inputs the correct clearance in the FMS, otherwise the controller issues a new clearance which can be achieved by the aircraft. Both controller and pilot enter the new clearance in their systems and the pilot resumes navigation. If a pilot is not able to return to a cleared trajectory (e.g. due to technical failure) a controller clears an aircraft's route of other traffic, if necessary emergency procedures may apply. If a controller concludes that a FPM warning is not relevant (e.g. route deviation when heavy aircraft fly curved flight segments) the warning can be suppressed if required.
3	REFERENCES
	- TE im Fokus, Ausgabe 2/2010 - *Vorhaben CATO – Betriebliche Nutzbarkeit von Controller- Tools für den unteren Luftraum.* [public version: www.dfs.de] - http://www.dfs.de/dfs/internet_2008/module/forschung_und_entwicklung/deutsch/forschung_und_entwicklung/forschungszeitschrift/2010/fokus1002.pdf - DFS (2011): Project CATO Controller Assistance Tools. Concept of Use, Phase 1, Release 1.
CONTEXT	
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5	What were the required technical means and human resources?

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In a high fidelity RTS the P1/ATCAS operational system environment was integrated, increasing the required expertise of the staff involved.</td></tr>
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Typically, 4 sectors were simulated, i.e. 4 CWP, and 4 simulation pilots were involved. A medium traffic load scenario was used with approximately 30 to 40 a/c per hour in a sector.</td></tr>
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Furthermore a coupling of the tools with PSS (Paperless Strip System, already operational) is realised to achieve the look and feel of the target operational system, as it is foreseen to implement those tools in the near future (V3).</td></tr>
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10	Actor(s)	
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☐ PC ☐ … ☐…
	10.1 Rationale	
	The FPM tool is mainly used by executive controllers to detect deviations from the cleared trajectory.	
TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☒ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☒ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	The Flight Path Monitoring aids the controller in monitoring traffic and notifies if an aircraft leaves its trajectory. Additionally it facilitates the detection of possible conflicts which might be caused through route or altitude deviations.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The executive controller is primarily responsible for assuring and maintaining separation between flights under his control (and against flights which are known to him, but may be under the control of another sector) whilst ensuring that flights achieve their co-ordinated sector exit conditions. The maintenance of separation against prohibited and restricted airspace, from danger areas and from terrain is also the responsibility of the executive controller. With the introduction of FPM tool described above the fundamental responsibilities of the executive controller will not change.	

12	Classification of supported cognitive functions and automation level				
		Associated cognitive function being supported by automation			
		Information acquisition	Information analysis	Decision and action selection	Action implementation

	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA	A3	A3	B2	B5	C0	C0	D0	D0

12.1 Rationale

The flight path monitoring function assists the information acquisition as the controller does not have to permanently monitor the traffic for deviations from the cleared trajectory.

Information acquisition:

Before: (A3) The typical radar and tracking system for surveillance is used for acquiring information. Surveillance data is automatically integrated and displayed to the controller. Colour coding is used to highlight concerned and unconcerned traffic. The controller can use flight level filter to select traffic relevant to his sector.

After: (A3) No change.

Information analysis:

Before: (B2) The controller has only limited tool support to analyse the traffic situation, e.g. speed vectors and history dots, to detect deviations from cleared trajectory. Altitude deviations can only be detected by checking the actual flight level with the cleared one either in memory and/or documented on the paper flight strip.

After: (B5) The flight path monitoring function assists the information analysis as the controller does not have to permanently monitor the traffic for deviations from the cleared trajectory. The parameters for detecting a deviation are defined at design level and cannot be modified during operations.

Decision and action selection:

Before: (C0) If a trajectory deviation is detected by the controller, he immediately contacts the aircraft.

After: (C0) If a FPM warning is displayed, a controller immediately contacts the aircraft.

Action implementation:

Before: (D0) The controller will contact the pilot using ratio telephony (r/t).

After: (D0) Though it is CPDLC enabled environment, a trajectory deviation is a time critical event, requiring immediate response, the controller will contact the pilot using r/t.

IMPACTS ON HUMAN PERFORMANCE

13 13.1 Which changes do you see in the way the Human Performance is supported?

The main benefits of the FPM tool for the executive controller are related to safety, especially in periods of high traffic. It is essential for controllers to know whether an aircraft is adhering to the clearances or not, FPM is provided to ensure any deviations are brought to the attention of controllers.

False alarms (false positive) or not detected alarms must be kept to a minimum. However, in the real world it is not possible to completely avoid tool errors or failures, thus it is most important that controllers keep monitoring the radar display and checking suggested solutions and do not rely solely on tool support. Controllers need to retain the ability to search, monitor, and find solutions to conflicts on their own. In case of tool failure the controller will revert to current methods of conflict search and conflict resolution.

13.2 Which benefits do you expect on SESAR KPAs?

☒Capacity	The capacity can be partially increased, because the controller's

		efficiency increases, too. With a better efficiency more traffic can be handled.
	☒ Efficiency	The early display of deviations facilitates resolving potentially unsafe situations in a timely manner. This enhances ATCO's efficiency in controlling traffic.
	☐ Flexibility	
	☐ Predictability	
	☒ Safety	CATO enhances the detection of situations, which might become conflicts.
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	- **Issue n. 10:** Automation may increase task demand and cognitive workload The FPM tool supports the monitoring task of the ATCO who does not have to permanently check the traffic for deviations from the cleared trajectory. - **Issue n. 16:** Poor usability of HMI may reduce the human performance benefits expected from the automation support To counteract this effect of "poor usability of HMI" in the CATO project iterative prototyping has been accomplished. Right from the start users (ATCO) had been integrated in the development with giving suggestions for improvement. This leads to a better usability under operational considerations and finally to a higher acceptance of the new tools.	
	13.4 Human Performance and automation issues potentially not mitigated	
	- **Issue n. 11:** Automation could require additional system inputs, which may lead to increased task load and reduced acceptance A pre-requisite to be supported by the FPM is that all clearances have to be input into the system as FPM compares the track positions as received in radar data with tactical clearance data. - **Issue n. 22:** Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness Excessive trust in tools for flight path monitoring may lead to reduced situation awareness as the controller is not actively scanning and monitoring the radar.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: The CATO tool FPM may imply only minor changes in controller's working methods.	
FINAL CONSIDERATIONS		
14	What can be learnt from the proposed change in HP automation support?	
	First, the development process how the good practice was accomplished has to be mentioned. Basically, a stepwise, iterative approach driven by a multidisciplinary team with participation of	

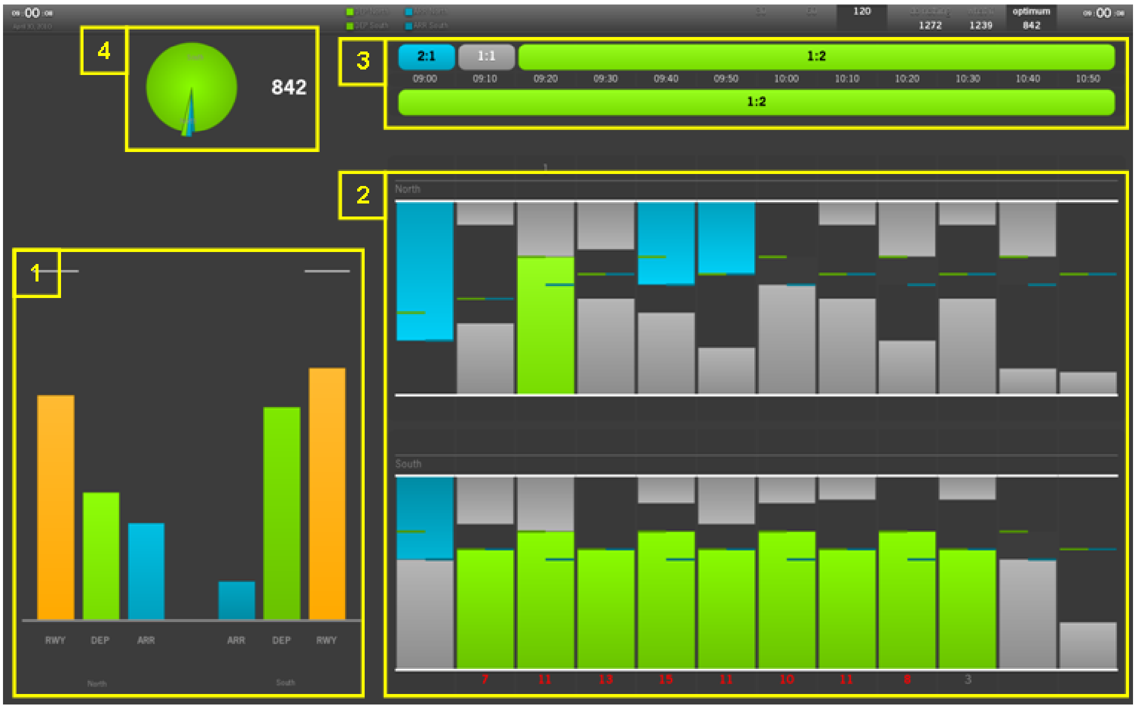
	users (ATCO) is essential to develop automated tools. The concept and first prototypes are then evaluated and validated in RTS to improve and fine tune parameters and algorithms for all CATO tools ECS, Flight Path Monitoring and what-if-probing. Additionally this enables to optimise the HMI. The activity of monitoring and keeping vigilance, i.e. the ability to maintain attention and alertness over prolonged periods of time, are not considered as human strengths. Thus automation should serve as tools which support the weak parts of the human information processing system. The Flight Path Monitoring offers such support tool. Controllers are relieved from constantly monitoring the radar and checking for deviations from cleared trajectories. Instead this is performed by an automation tool which brings such deviations to the attention of controllers in a timely manner. This enhances the safety and reduces mental workload, especially in periods of high traffic. From the RTS conducted so far the controllers' response was throughout positive concerning the basic functionality and its support was highly appreciated. While a similar tool (MONA) exists in the new operational ATC system VAFORIT for the UAC Karlsruhe of DFS, something similar is missing for the ACC domain. After the simulations the strong wish was expressed to implement the CATO solution in an operational system as soon as possible. However, it became clear, that certain features and parameters have to be fine tuned, so certain kinds of deviations are displayed while others are not. In consequence, to provide such feedback is just one reason to conduct RTS.

4.2.6 CLOU (Cooperative Local Resource Planner)/ FMAN (Flow Manager)

1	Title of the automated solution
	CLOU/ FMAN (Cooperative Local Resource Planner/ Flow Manager)
2	Short description of the concerned automation
	CLOU, with its optimization core FMAN, is a pre-tactical planning tool intended for TWR and APP. The system informs supervisors about capacity and demand predictions and proposes a strategy for capacity balancing. The prediction horizon ranges from 30min up to 6 hours but in operations predictability up to 2 hours is reasonable. With this planning support it is feasible to reduce number of delays significantly and to improve planning strategies, so that the capacity utilization of existing infrastructure is optimized. The aim is to avoid phases where the demand exceeds capacity by optimising the ratio of arrivals and departures served on a mixed mode RWY (RWY usage strategy). Thus enhanced predictability of traffic, better use of available capacity and reduced delays can be achieved.
	2.1 Description of the function

To enable a capacity- and demand- prediction CLOU receives data for demand from given flight plan data and calculates potential capacity from meteorological data and expected traffic mix (wake vortex categories). With these data optimisation of the strategy for utilization of the runway (respective ratio of arrivals and departures) is possible. CLOU/FMAN is intended for hub-airports and can be adapted to their specific requirements, i.e. number of runways, layout and dependencies between them.

To optimize capacity utilization of existing infrastructure CLOU increases traffic throughput by adjusting the preference between arrivals and departures for one or more RWY used in mixed mode.



The figure depicts the CLOU HMI for Munich airport with two parallel runways. Yellow frames with numbers serve the purpose of description: [1] Movements for each runway with orange= total number of movements, green= departures, blue= arrivals. [2] Main display, for each runway number of ARR and DEP are depicted in 10 min intervals. RWY North is on top, RWY south is below. For each RWY the predicted number of arrivals are the 'hanging' bars and the departures the 'standing' bars. The small blue and green lines depict the capacity threshold and the bars turn coloured if this threshhold is reached. [3] Suggested strategy for runway usage over time for each runway, i.e. proposed ratio or prioritisation of arrivals to departures depending on the movement numbers in [2]. In this case for the RWY North the strategy is to have a proportion of 2:1 arrivals to departures (blue box), then a ratio of 1:1 (grey box) and later a ratio of 1:2 arrivals to departures (green box). For RWY South a constant rate of 1:2 DEP:ARR is suggested. [4] Calculated delay and contribution related to arrivals (blue) or departures (green). In this example a total delay of 842 minutes is predicted for the displayed time horizon, most of it attributed to departures (green area in the pie chart).

For the displayed planning time horizon, the supervisor can make several inputs to let the system calculate strategies for runway usage: change direction of runway in use, propose own strategy, change the total capacity of all runways, change of capacity of a single runway.

2.2 Which kind of situation(s) does the concerned automation support?

	☒ normal situations ☐ abnormal situations CLOU/FMAN is a pre-tactical planning tool intended for TWR and APP, it informs supervisors about capacity- and demand- predictions and proposes a strategy for capacity balancing. Hence it is used for normal situations like monitoring incoming and outgoing traffic and making planning strategies.
	What is the linkage between the use of the function and traffic level? CLOU/FMAN is intended for major hub airports with traffic levels at the capacity limits. If there is low traffic, this pre-tactical planning tool isn't much support for supervisors (TWR or APP).
	2.3 Concerned domain
	☐ Air ☒ Ground ☐ Air-Ground
	2.4 Operational environment
	Currently, a strategy for the usage of runways for inbound and outbound traffic is relying on the human mental ability to make predictions on available data of estimated and planned times of arrivals and departures, analysing weather forecasts, the traffic mix of wake vortex categories, etc. All this is quite complex and the solution for a strategy might be non-optimal. Then, the interests of TWR and APP are potentially opposing, one trying to maximise the number of departures while the other the number of arrivals, but strategies have to be agreed upon. CLOU, a pre-tactical planning tool, is intended for supervisors in both tower and approach domain. Its purpose is to inform about capacity and demand predictions and to propose strategies for runway usage to optimise the ratio of arrivals and departures so that demand and capacity are balanced. Tower and approach supervisors have identical displays and share the same data. This is a major improvement for the ground- ground communication. Though coordination is still performed with telephone, they now have a support tool, which objectively proposes strategies and visualises the underlying data comprehensively. This facilitates to achieve an agreement on the near future operational strategy.
	2.5 Reason for the change/ Problem to be handled
	While major hub airports in Germany are working at their capacity limits, it is necessary to make optimal use of this capacity. Currently controllers (supervisors) in tower and approach have no automated systems for supporting pre-tactical planning, i.e. on a time horizon exceeding that of AMAN or DMAN. The human operator performs all cognitive functions, like analyzing information and making decisions in a demanding complex and dynamic environment. With the planning support of CLOU/FMAN it is feasible to reduce number of delays significantly and to improve planning strategies, so that the capacity utilization of existing infrastructure is optimised. Additionally the coordination between tower and approach is enhanced, as data is shared and the different strategies (focus on inbound or outbound traffic) can be agreed upon. Both TWR and APP supervisors have the same displays available and share identical data.
	2.6 Applied solution/intervention
	As a pre-tactical planning tool CLOU/FMAN supports supervisors of TWR and APP in the preparation and implementation of strategies for balancing capacity and demand of inbound and outbound traffic. The demand is derived from given flight plan data and the potential capacity

	calculated from meteorological data and the expected traffic mix. The system provides a unique display to inform supervisors about capacity and demand predictions and proposes a strategy for capacity balancing. The prediction horizon ranges from 30min up to 6 hours but in operations predictability up to 2 hours is reasonable.
3	REFERENCES
	TE im Fokus, Ausgabe 2/2010 – Validierung des prätaktischen Systemverbundes CAPMAN/ CLOU am Flughafen Frankfurt. [public version: http://www.dfs.de/dfs/internet_2008/module/forschung_und_entwicklung/deutsch/forschung_und_entwicklung/forschungszeitschrift/2010/fokus1002.pdf]
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	Please qualify the organisation and extend the list if necessary. CLOU is a research project (R/D project), which will provide a prototype intended for TWR and for APP. It was initiated within the government-funded LUFO III & IV (Luftfahrtforschungsprogramm) - K- ATM (Kooperatives Air Traffic Management, 2003 – 2007) - WFF (Wettbewerbsfähiger Flughafen, 2007 – 2010) - iPort (innovativer Airport, 2010 – 2012)
5	What were the required technical means and human resources?
	The pre-tactical planning tool CLOU/FMAN is in the development phase. At first, to provide a basis, laboratory tests with live data were made. Based on the findings CLOU/FMAN was further developed. As CLOU/FMAN was tested in a mock- up simulator, the necessary laboratory and personnel, like technicians and end-users, were needed. After laboratory tests the next phase followed which was conducted as a shadow mode in an operational TWR environment. The obtained data of the planning algorithms of CLOU were compared with actual conventional planning strategies of the controllers. The evaluation of the new system by operational personnel is a great advantage of this procedure. Furthermore controllers' suggestions for improvement of algorithms and HMI were obtained which are used for further development. This way the system is incrementally optimised via an iterative process, i.e. the system is modulated after every test run.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	So far it was tested in Frankfurt tower and Munich tower.
7	Integration of the concerned automation into a system or an ensemble of systems
	CLOU/FMAN is a new automation support system. It is not replacing an existing system nor is it integrated into an existing one. It is still under development but shows promising benefits to become operational. If operational, interfaces to other planning support systems like AMAN and DMAN are necessary.
8	On which phase of maturity of the concept/automation was the good practice applied?

	☐ V1: Scope	☒ V2: Feasibility	☒ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations
	8.1 Rationale		
	Primarily CLOU was tested in a feasibility study and is accomplished as a prototype. At the moment CLOU is in a pre- industrial development state, where improvements, via iterative prototyping, are made.		

CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☒ Take-off	☐ Climb
	☐ En Route	☐ Descent	☒Approach	☒Landing	☐ Taxi-in
	9.1 Rationale				
	CLOU is a pre-tactical planning tool for approaches and departures at large airports. It supports supervisors in creating planning strategies for approach/ landing and take- off within the next two hours.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☐ EC ☐ PC ☒ Supervisor ☐…			
	10.1 Rationale				
	This planning tool supports supervisors of TWR and APP by determining capacity and demand predictions and proposing a planning strategy for runway usage (ratio of arrivals to departures). Additionally it enhances the communication and coordination between TWR and APP by providing consistent data on identical displays, so misunderstandings can be avoided and a mutual strategy developed.				
TASK					
11	Pilot tasks	ATCO task			

Operate:

☐ Control the aircraft
☐ Manage the autopilot
☐ Monitor the flight parameters

Navigate:

☐ Aircraft position management
☐ Flight planning/ trajectory management

Communicate:

☐ Communicate with ATC
☐ Communicate within the crew
☐ Communicate with other aircraft, airline, maintenance

Manage system status and surroundings:

☐ Monitor system/ aircraft status and surroundings
☐ Evaluate system/ aircraft status and surroundings
☐ Handle system/ aircraft status and surroundings

☐ Monitoring traffic

☐ Providing traffic information

☐ Issuing instructions/clearances

☐ Detecting conflicts

☐ Resolving conflicts

☒ Planning strategy

☐ Assuming and transferring traffic

☒Ground-ground communication

11.1 Rationale

Tower and approach supervisors are supported with the aid of CLOU by assigning capacity and demand predictions and proposing planning strategies for ideal utilization of existing infrastructure. Furthermore it improves the ground-ground communication and coordination by providing consistent data for TWR and APP supervisors.

11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

This new pre-tactical planning tool doesn't change roles or responsibilities, because it just informs supervisors about capacity and demand predictions and proposes a strategy for capacity balancing of inbound and outbound traffic. The human has still to decide which planning strategy has to be implemented.

12 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA	A2	A3	B1	B4	C0	C2	n.a.	n.a.

12.1 Rationale

Currently controllers (supervisors) in tower and approach have no automated systems for supporting pre-tactical planning, i.e. on a time horizon exceeding that of AMAN or DMAN. The human operator performs all cognitive functions, like analyzing information and making decisions. The new CLOU/ FMAN automated system supports them in analyzing information (like giving a prediction of incoming traffic) and proposes strategies for runway usage making, thus offering decisions the supervisor can select from. The chosen action has to be implemented manually.

Information acquisition:

Before: (A2) Different sources of information are provided (flight plan data, weather, a/c

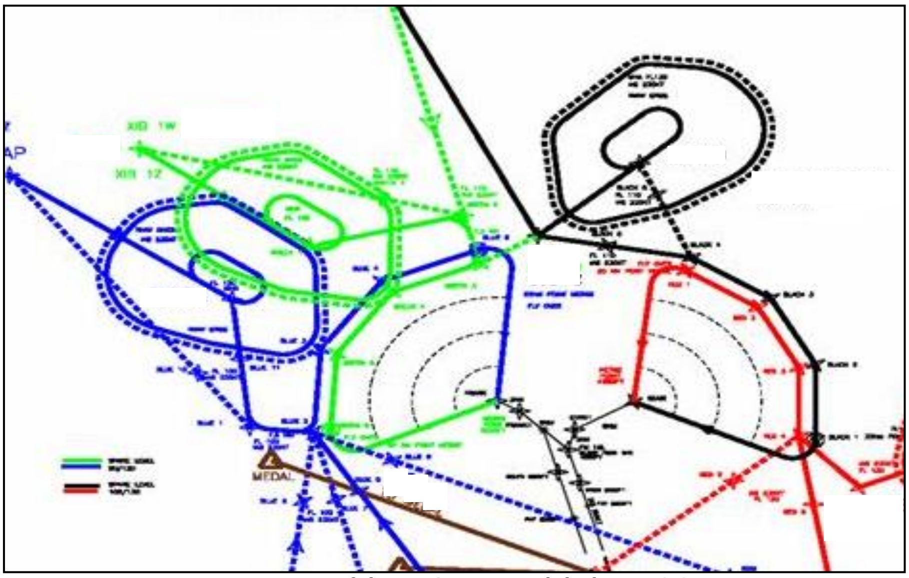
	performance data, airspace data). Though the provision of data is achieved automatically, the operator has to manually select from different data bases. **After: (A3)** Different sources of information are aggregated and displayed. Information analysis: **Before: (B1)** The different sources of information are displayed on separate screens/displays. The operator has to aggregate the information himself to build a mental picture of the current and future traffic demand and aligning it with the available capacity. **After: (B4)** Integration of several input variables, which are combined and displayed on one screen. The different input data is aggregated and algorithms calculate the optimal runway usage strategy. Decision and action selection: **Before: (C0)** No automation support, the supervisor has to mentally deduce a planning strategy from the information available. **After: (C2)** The system generates possible decision options, varying over time, i.e. runway usage strategies are constantly updated and displayed. The human chooses whether to implement an option or not. Action implementation: not applicable There is no interaction. The system supports decision making for strategically planning of runway usage in the near future. The strategy is not implemented by the supervisor, but the basic conditions are established, which determine the work of other actors (APP and TWR controllers).
IMPACTS ON HUMAN PERFORMANCE	
13	13.1 Which changes do you see in the way the Human Performance is supported?
	CLOU is a pro-active decision support for the controller. With its foresighted traffic predictions, it supports the controller in creating strategies for optimal runway utilization and helps to reach decisions. Furthermore, the system is a major improvement for the ground- ground communication and cooperation. Tower and approach supervisors have identical displays and share the same data. Though coordination is still performed with telephone, they now have a support tool, which objectively proposes strategies and visualises the underlying data comprehensively. This facilitates to achieve an agreement on the near future operational strategy.
	13.2 Which benefits do you expect on SESAR KPAs?

	☒ Capacity	With CLOU the existing infrastructure can be used to reach full capacity.
	☒Efficiency	Efficiency is increased by optimisation of the runway usage strategy. Ratio of arrivals and departures on a runway in mixed mode is adapted to the demand forecast.
	☐ Flexibility	
	☒ Predictability	CLOU can predict possible traffic bottlenecks, and by providing planning strategies for runway usage, overloads can be avoided.
	☐ Safety	
	☐ Access and Equity	

	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	- **Issue n. 1:** Lack of user involvement in automation assisted processes may lead to reduced vigilance and loss of situation awareness. Within the pre- tactical planning tools CLOU/ FMAN supervisors vigilance is still essential, because it is his responsibility to decide, which planning strategy should be executed. This planning tool generates a planning strategy, but the human can decide if he wants to implement this strategy or to create his own. Finally the decision and the execution depend on supervisors involvement. - **Issue n. 8:** Automation support for decision making may be based on too simplistic algorithms and parameters to cope with the complexity of the operational environments inducing workarounds and higher workload in human operators. This pre- tactical planning tool supports supervisors in creating a planning strategy and making decisions. Without this tool, there is no human support and therefore a prediction of traffic and a potential overload is more complicated. - **Issue n. 15:** Data fusion and filtering in automated support systems may reduce ATCO and pilots' accessibility to relevant information, with negative impact on decision making processes and situation awareness. The interlinking and preparing of data supports supervisors in creating planning strategies. But human has to make decisions and to accomplish the final execution. - **Issue n. 16:** Poor usability of HMI may reduce the human performance benefits expected from the automation support. To counteract this effect of "poor usability of HMI" in the CLOU/ FMAN project iterative prototyping has been accomplished. Right from the start users (supervisors) had been integrated in the development with giving suggestions for improvement. This leads to a better usability under operational considerations and finally to a higher acceptance of the new tool.	
	13.4 Human Performance and automation issues potentially <u>not</u> mitigated	
	Not relevant.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: The existing procedures will not be changed. The aim of this new system is to support supervisors in tower and approach to optimize the traffic flow with existing infrastructure. Procedures and processes will still stay the same.	
FINAL CONSIDERATIONS		
14	What can be learnt from the proposed change in HP automation support?	
	Laboratory tests with live data are providing an excellent basis for system development including algorithms and HMI. For further enhancements it is advantageous to conduct shadow mode tests for the system under development. These shadow mode tests are representing a realistic environment. The obtained data of the planning algorithms of CLOU can be compared with actual conventional planning strategies. The evaluation of the new system by operational personnel is a great advantage of this procedure and a means to gather feedbacks from users. With these feedbacks and suggestions the algorithms and HMI can be improved. The process of iterative prototyping with user participation optimises the system in a stepwise approach. In	

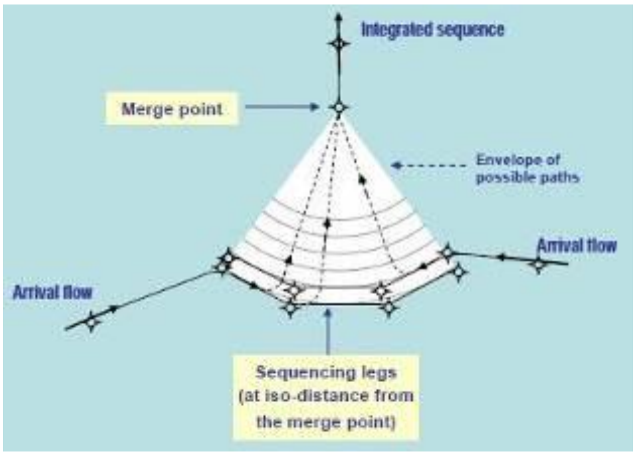
	the end, this increases acceptance and usability of the new system.

4.2.7 Combined use of AMAN (Arrival Manager) and Point Merge System (PMS) Procedure

1	Title of the automated solution
	4.2.7.1.1.1 AMAN (Arrival Manager) - PMS (Point Merge System) Interoperability
2	Short description of the concerned automation
	One of the objectives of the Project TMA2010+ Project South was to test the interoperability between the use of the tool AMAN (Arrival Manager) and of the arrival procedure called PMS (Point Merge System). AMAN is a sequence planning and support tool for arriving traffic with the aim of maximising the efficiency of the arrival traffic management, minimising airborne congestion and delays. While the PMS procedure aims at integrating arrival flows of traffic into a safe and efficient landing sequence without using the baseline method of radar vectoring. It facilitates the merging of traffic from a number arrival routes taking advantage of the P-RNAV (Precision Area Navigation) equipment on-board aircraft. The combination of AMAN and PMS is designed to assist controllers in upstream ACC sectors in arranging approaching flights in a manner that ensures a smooth flow of traffic entering the TMA. In the specific configuration tested during the second Real Time Simulation (RTS2) of the project, AMAN was set in a way to ensure a smooth flow of traffic when entering the 4 sequence legs (entry points) of 2 PMS triangles, also said ‘trombons’ (see picture below).  **An excerpt of the PMS map used during RTS 2** Once the a/c entered the PMS triangle AMAN ceased to be used and a/c were guide towards 2 different merging points (corresponding to 2 different runways) according to specific PMS rules. The PMS rules is based on an aircraft flying a quasi-arc, up to 30 NM long (Sequencing Leg), with a radius of 20+NM from the designated merge point. The controller clears the aircraft off the arc direct to the merge point when separation from the preceding aircraft is assured. Clearance to descend is not given until the aircraft is clear of all other traffic and is usually the

responsibility of the final approach director.

Each arc has a published altitude that the aircraft must have reached before establishing on the arc. In general the arc nearest to the merge point has the highest altitude and that furthest away has the lowest altitude. If the aircraft reaches the end of the arc without receiving a "direct to" clearance, it automatically turns towards the merge point (see the picture below).



Graphical representation of a typical PMS procedure

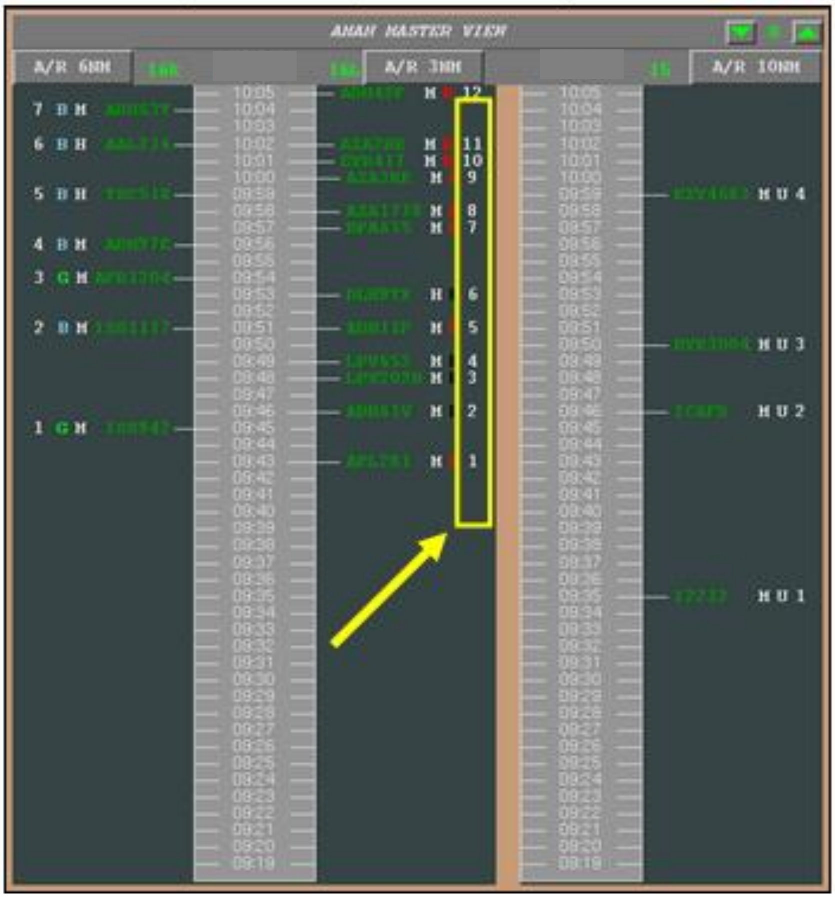
In practice AMAN is used by controllers in upstream sectors (in the so-called E-TMA, i.e. Extended TMA) to organize a smooth sequence of traffic at the entry points of the PMS triangles and reduce the risk that the same triangles become excessively full of traffic, making impossible for controllers of downstream sectors to apply the PMS procedure in a correct manner. When this happens, controllers are obliged to revert to other working methods (such as radar vectoring) and to ask for help to controllers of upstream sector. Typically they will ask to slow down the traffic entering into the PMS triangles with a variety of methods, such as holding patterns or 360° turns over a waypoint. Such methods are of course necessary to ensure a safe flow of traffic and minimize the risk of causing separation minima infringements, but they typically produce less orderly and efficient traffic flows, causing delays and inconveniences with negative impact on both en-route sectors and airport surface management.

The combined used of AMAN and PMS is therefore intended to facilitate a more anticipated management of such situation, with an improved cooperation between upstream controllers (in E-TMA sectors) and downstream controllers (in Approach sectors). In the specific setting tested during the project an additional role, i.e the *Sequence Manager*, was also introduced to take care of the arrival sequences with the support of AMAN, to ensure a correct balancing of the traffic load between the two PMS triangles (and therefore between the two runways) and to organize the work by mediating between E-TMA controllers and Approach controllers.

2.1 Description of the function

The automated function described here (i.e. AMAN) consist of two main components used by two different roles, but connected between them.

The first component is the "AMAN Master View", a side window, separate from the main radar screen, showing in a timeline format the sequences of a/c arriving to the 4 different entry points of the PMS triangles and directed to the 2 different runways associated to each triangle. This component is used by the Sequence Manager to visualize the sequence and instruct the other controllers accordingly. Each aircraft is visualized with its call-sign, with the specific entry point into the PMS triangle, with the runway in which it is expected to land and with a progressive number indicating its position in the sequence (see figure below).



The AMAN Master View Window

The Sequence Manager is free to manipulate the sequence and modify the order established by the system.

The second HMI component of AMAN are the "Time to Lose – Time to Gain" advisories which are displayed at the CWP of both the PC and EC of each E-TMA sector. It provides these controllers with time indications concerning the delay measures needed to comply with the optimised sequence.

The advisories are included in the track label of each aircraft and correspond to a determined time to gain or lose, thus becoming part of a well-defined ATCO's working method.

G (Gain)	2 minutes or more
L0 (Lose 0)	from 0 to 2 minutes
L (Lose)	from 3 to 5 minutes
LL (Lose/Lose)	6 minutes or more

In practice the two HMI components interact between each other, since the TTL-TTG advisories are based on calculations by the system of how to reach the optimized sequence displayed onto the "AMAN Master View". So every time there is an automatic update of the sequence or a manipulation of it by the Sequence Manager (e.g. it is decided that one a/c should precede another a/c which was previously before it in the sequence) there is an impact on the advisories. For example it is likely that the preceding a/c will receive a "G" on its track label and the following a/c an "L" or "LL".

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

Which level of traffic does the function support?

PMS and basic AMAN interoperability is intended to support ATCOs in high level traffic situations in a TMA operational environment.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

Explanation:

2.4 Operational environment

PMS and basic AMAN interoperability is intended for use in TMA and E-TMA sectors. It is designed to assist controllers in upstream ACC sectors in arranging approaching flights in a manner that ensures a smooth flow of traffic entering the TMA, which will in turn help to optimise the airport's capacity in the most efficient way.

2.5 Reason for the change/ Problem to be handled

TMA airspace is still generally regarded as being busy and it is certainly becoming more complex, since the demand of traffic is increasing. Some initiatives, such as P-RNAV and CDAs (Continuous Descent Approach) are bringing benefits today. However it is felt that more is needed in the transition towards SESAR. Particularly the need to contribute at the same time to more efficiency in the management of traffic (to achieve an higher level of capacity) and to safety (an increased number of accidents in the face of increased traffic will be considered unacceptable at social level!) have encouraged to look for new solutions aiming to increase the degree of standardisation of controllers working methods, whilst ensuring an adequate degree of flexibility and robustness to cope with variable traffic conditions and to face with possible unexpected events.

2.6 Applied solution/intervention

The combination of AMAN and PMS was the solution proposed in TMA2010+ Project South to handle the problems described above.

AMAN can help in optimising the flow of traffic by increasing the possibility that efficiency will not be reached only at the level of each specific sector (with the controller aiming at getting rid of its own traffic as soon as possible), but also at the level of all the concerned E-TMA sectors globally intended. As a matter of fact the calculation of the sequence of a/c is made by taking into account globally the different sectors included in the AMAN eligibility horizon. Therefore it may happen that an aircraft which will normally leave an E-TMA sector earlier will be asked to slow-down and land slightly later, because it is more efficient to give precedence to another a/c flying on a neighbouring sector. These estimations cannot obviously be done individually by controllers at the level of each specific sector, but can be duly guided by the automatic calculations of AMAN, under the supervision of the Sequence Manager.

On the other hand PMS can help to establish an highly standardized procedure with all controllers applying the same working method, i.e. asking a/c to fly a quasi-arc in the PMS and then clear them off the arc direct to the merge point, as soon as the separation from the preceding aircraft is assured (note that the final waypoint of each arc is recommended to be a "fly-over", thereby providing the controller with an unambiguous turning point for lost communications aircraft – e.g. in case of radio failure – while ensuring the maximum time to manage the traffic).

Therefore in this new combination the AMAN's role is changed from that of a *sequencing tool* - intended to optimise the traffic management - to a *pre-sequencing tool*, expected to also support the application of the PMS rules in the TMA.

It is also worth noting that in the specific setting of the second RTS of the project two different kinds of HMI were tested.

	The first kind of PMS&AMAN interoperability that had been tested was the PMS&AMAN with TTL/TTG advisories, already described above. The main advantage of AMAN, with TTL and TTG advisories, is that the sequence can be adapted manually to better reflect the current operational situation, as well as to reflect controller input on the arrival sequence. As a matter of facts, it permits freedom in selecting the more correct and easy action (i.e. speed reduction, trajectory variation, anticipated descent), according to the traffic conditions and according to the PMS criteria (that must be guaranteed at the entrance of the triangles). The second configuration of PMS&AMAN interoperability, that has not been described until now, was the PMS&AMAN with speed advisories and TOD. In this type of AMAN, the system is more advanced, since it directly provides ATCO with tactical control advisories (speed advisories and Top of Descent) to help achieving the sequence. ATCOs are expected to directly apply the speed and ToD displayed on the label of the concerned A/C. It is important to underline that these two different configurations of AMAN achieved different level of user acceptability. AMAN with TTL/TTG advisories resulted more acceptable than the enhanced AMAN (with speed and ToD advisories). The reason for that difference is that, with the latter, ATCOs had difficulties in applying AMAN resolutions in a context based on the sequence building and the inbound traffic management. The speed and ToD resolutions, in fact, implied a more rigid management of operations, due to the fact that the indications displayed by the system (Speed and ToD) were expected to be applied in a strict manner, in order to ensure a correct behaviour of the whole system. Nevertheless the complexity of the inbound traffic and the characteristics of the ATS geography often do not allow a strict compliance to the resolutions. On the other hand, as already said above, AMAN with TTL/TTG advisories was demonstrated to be more flexible to cope with the complexity of TMA traffic.
3	REFERENCES
	– SICTA, Deep Blue, ENAV (2011), TMA2010+V&S WP2: Conduct of RTS2 Simulation and delivery of Simulation Report, EUROCONTROL CFT A07/11028CG – SICTA, Deep Blue, ENAV (2011), TMA2010+V&S WP3: Final, consolidated simulation and validation activities report, EUROCONTROL CFT A07/11028CG
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	PMS & AMAN with TTL/TTG advisories interoperability was tested in R&D Project. In this Project, mentioned above, this organisation was simulated in two different RTS that recreated an APP and ACC control room in a TMA operational environment with high level of traffic.
5	What were the required technical means and human resources?
	PMS & AMAN with TTL/TTG advisories interoperability was tested in an R&D scenario with 2 Real Time Simulations. Both the exercises lasted 3 weeks, structured in one week of training and two weeks of simulation. The team in charge of conducting simulation activities was composed of HF experts and technical experts. Regarding the simulated airspace, it was made up of 7 measured sectors and 3 feed sectors, where the measured sectors were distinguished in 2 classes, namely en-route and TMA sectors. It is important to highlight that the en-route were actually the E-TMA sectors and they were all managed by 2 ATCOs each, namely one PC and one EC. The TMA sectors, instead, were managed by one controller each.

	In total, a team of 13 air traffic controllers and 10 pseudo-pilots was involved.				
6	If applicable: How often was the good practice applied in the past? Please estimate.				
	The PMS & AMAN with TTL/TTG advisories interoperability was applied in the two RTS mentioned above of TMA2010+ Project South.				
7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?				
	One could state that the usage of AMAN combined with PMS requires a cultural change affecting current ATCOs' working practices: the approach to the work of individual controllers should evolve in the direction of considering themselves not only as actors in a single sector but also as actors in a wider system. Nowadays controllers tend to handle and transfer the traffic in their own sector as soon as possible. While, according to this new philosophy, they are encouraged to either delay or speed up their own traffic also according to the needs of the neighbouring sectors. The coordination with neighbouring sectors is mediated either directly by the AMAN advisories or by the Sequence Manager also using the indications provided by this tool.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☒ V2: Feasibility	☐ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations		
	8.1 Rationale				
	Despite the AMAN used in the project is an off-the-shelf industrial product, the validation of the combined use of PMS & AMAN tested during TMA2010+ Project South can be considered as part of the V2 phase of E-OCVM methodology. Actually the concerned RTS activities mainly aimed at evaluating the potential fitness for purpose in European ATM operational environment and provided initial elements for technical feasibility. In this phase, in fact, the definition of the concept and supporting enablers are assessed, in order to evaluate if they can be considered operationally feasible or not.				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☒ En Route	☒ Descent	☒ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	The PMS & AMAN combination tested in the project especially covered traffic management in TMA sectors (Approach e Descent flight phases). Nevertheless, pre-sequencing of the traffic also at the level of E-TMA sectors was needed, in order to arrange approaching flights in a way to ensure smooth flow of traffic entering the TMA. In this perspective, en-route sectors (covering E-TMA airspace) were also involved in the use of this automation.				
10	Actor(s)				

	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☒ PC ☐ Supervisor ☒ Sequence Manager

10.1 Rationale

The actors involved in the usage of interoperable PMS & AMAN with TTL/TTG advisories are the Sequence Manager and the EC and PC of E-TMA sectors.

The Sequence Manager plays an essential role in the AMAN operational environment, since he is responsible for the whole arrival traffic management in the E-TMA. SM monitors the approach sequence defined by AMAN Master View and eventually confirms it when compliant with the overall strategy.

Otherwise, s/he can make adjustments (either modifying the approach sequence or providing planner controllers with precise instructions of delay-absorption or gain) aimed at smoothing the arrival traffic management and at reducing the overall delay. When a significant delay is detected, SM can:

- Swap the sequence position of the a/c causing delay by using the “Insert After” function;
- Change the CTA of the aircraft causing delay by updating manually the CTA by using the “Change CTA” function;
- Remove temporarily a flight from the sequence and manually re-insert it by using “Remove” and Re-insert” functions.

The above mentioned functions are all available on the AMAN Master View.

The EC and PC, instead, shall use TTL/TTG AMAN advisories for the purpose of pre-sequencing the inbound traffic in the E-TMA and APP sectors. They are expected to apply the speed adjustment actions indicated by the system with the supervision of the SM.

TASK

11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☒ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication

11.1 Rationale

AMAN Master View is used by the SM for *planning strategy* purposes, both acting directly on the sequence (so producing an effect on the TTL/TTG advisories) and using information about the sequence in order to coordinate with E-TMA and APP EC and PC.

AMAN TTL/TTG advisories are instead used by EC and PC of TMA sectors in order to *issue instructions and clearances* with the aim of sequencing aircraft in compliance with the instructions given by the SM.

11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

Using AMAN & PMS interoperability implies a change in working methods of ATCOs in the sense of a more proactive attitude in the relation between upstream sector and downstream sector controllers. As a matter of fact the sequence order provided by the AMAN Sequence List, allows E-TMA controllers to have clearer expectations regarding the sequence order of the flow of traffic entering the TMA, thus reducing the need for explicit communication exchanges with the Sequence Manager and with controllers of downstream sectors or making such communication easier thanks to common background information.

12 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA					C0	C2		

12.1 Rationale

The AMAN Master View offers a C2 level of automation support. The “C” level of supported cognitive function indicates that the system provides the ATCOs with support in decision making. In fact it represents on the screen a sequence of arrival aircraft that can be considered the “best” solution at a certain moment and with certain constraints. So, the sequence is built by the system itself and provided to ATCOs that can evaluate it.

ATCOs can rely on it or even change it: this is the reason why the LOA is at level 2: this means that ATCOs can change the sequence in compliance with complex or unexpected situations and that the system accepts these changes, updating the sequence according to them.

Also the AMAN TTL/TTG advisories, which resulted to be more fit-for-purpose during the project validation, can be classified as an automation at level C2. “C” because the tool provides ATCOs support for decision making; “2” because the system proposes one or more decision alternatives to the human, leaving freedom to the human to generate alternative options (e.g. by reducing or increasing the indications received by the tool to better accommodate with local separation needs and with specific constraints related to the PMS).

It is worth noting that the alternative AMAN HMI with speed and ToD advisories would have been classified as a C4 level. This indicates a more automated level of supporting function of the system (4). In this AMAN configuration, in fact, for the human operator is not possible to evaluate between two or more alternatives but it is only possible to execute (or not execute) the decision proposed by the tool (e.g. to instruct only a precise speed to the a/c, without room for any adjustment to accommodate for other constraints).

IMPACTS ON HUMAN PERFORMANCE

13	13.1 Which changes do you see in the way the Human Performance is supported?	
	See explanation in field 11.2 above (Consequences on changes in roles, responsibilities, authority sharing and delegation).	
	13.2 Which benefits do you expect on SESAR KPAs?	
	☒Capacity	The usage of PMS & AMAN would increase the capacity of TMA airspace because it improves standardisation of TMA operations. In this way, ATCOs can rely on more standardised procedures for managing approaching aircraft, thus reducing the number of re-routing and other tactical interventions. Pre-sequencing approaching aircraft in advance can also avoid time in holding, thus increasing the capacity of TMA airspace.
	☒Efficiency	PMS is a procedure that can improve efficiency of TMA airspace because it integrates arrival flows of traffic into a safe and efficient landing sequence without using traditional radar vectoring. The combination with AMAN permits the pre-sequencing of arrival aircraft in the E-TMA in order to meet the requirements of PMS (merging of traffic from a number arrival routes) when they have arrived in TMA.
	☐ Flexibility	
	☒Predictability	AMAN & PMS interoperability facilitates predictability of operations because it provides a sequence of arrival aircraft that helps ATCOs to know the traffic situation in advance. In particular, TTL and TTG advisories provide in advance the ATCOs of upstream sectors with a mental picture of the ongoing situation, before they would call by phone the downstream sectors.
	☐ Safety	
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	– **Issue n.1**: Lack of user involvement in automation assisted processes may lead to reduced vigilance and loss of situation awareness. – **Issue n.4**: Lack of user involvement in automation assisted processes may decrease motivation and job satisfaction This first grouping of issues concerns the task allocation between human and automation. The basic AMAN & PMS solution can mitigate the issues related to lack of user involvement in automation. As a matter of fact, AMAN is a decision-making support tool that let the controller retrieve the information used to build up the sequence. In this way, it enhances vigilance and SA. Therefore, it is a supporting system that leaves the ATCO the flexibility to change the list. In this way, s/he is taking control of the situation and s/he is not left out-of the loop. This may increase job-motivation and satisfaction. – **Issue n.8:** Automation support for decision making may be based on too simplistic algorithms and parameters to cope with the complexity of the operational environments inducing workarounds and higher workload in human operators. – **Issue n.14:** Loss of flexibility in automated systems will reduce the human potential to adapt to normal and abnormal situations This second grouping of issues is dealing with the impact that automation can have on the	

cognitive tasks to be performed by the human operators. TTL and TTG advisory function of basic AMAN provides the ATCO with a list of arrival aircraft that can be updated by the controller if needed. So, the sequence is not strictly fixed: this is fit to cope with the complexity of the TMA operational environment because controller can change the sequence in case of abnormal situations. This characteristic helps to avoid workarounds and high level workload to manage the changing of the sequence.

- **Issue n.6**: Changes and variability in task distribution may cause confusion, with negative impact on air-ground collaborative work efficiency and even lead to errors of omission or commission.

This issue can be mitigated by PMS & basic AMAN interoperability. In fact, this system improves mutual SA because ATCOs in the upstream sectors have some awareness of traffic situation in advance, i.e. also before communicating by phone with downstream sectors and SM. As a matter of fact, TTL and TTG advisories provide in advance the ATCOs with a mental picture of the ongoing situation.

13.4 Human Performance and automation issues potentially <u>not</u> mitigated

- **Issue n.11:** Automation could require additional system inputs, which may lead to increased task load and reduced acceptance

During the RTS conducted in the Project TMA2010+ Project South it was observed that, from times to time, AMAN system updated the sequence previously modified by the SM. Because of that, it was not possible to “freeze” the sequence planned by the SM. This kind of matter implied increased task load and acceptance-related issues, especially for SM. Hence, the possibility of freezing at least small portions of the sequence, as soon as it has been consolidated, has been proposed. Nevertheless, during the RTS exercises it was not possible to implement a technical solution to solve this problem.

13.5 Would you expect that procedures will change?

☐ Yes ☐ Likely yes ☐ No ☒ Likely no

Explanation:

The combined use of PMS and AMAN implies changes in controller’s working methods but is unlike to require modifications of standard ICAO procedures.

FINAL CONSIDERATIONS

14 What can be learnt from the proposed change in HP automation support?

The lesson that could be learnt from the identified practice is that high level of automation does not always match with high efficiency of the human-machine system. As a matter of fact in operational environments characterized by high level of complexity a too directive automated function could induce workarounds and additional task load in order to cope with the ongoing situation (for example if the operator needs to change current plans on the basis of unexpected situations).

In terms of automation support the AMAN with TTL/TTG advisories, which in this context has been combined with a PMS procedure, can be classified as a LoA “C2”. That is an high level in terms of the cognitive function being supported (C: Decision and Action Selection), but a relatively low level in the context of the specific function (C2: Automated Decision Support). This appears to be a suitable level for a crowded TMA environment and for the interoperability with PMS, since it leaves flexibility to the human in order to cope with the complexity of such an operational environment. While the alternative configuration tested during the second RTS in the project, (i.e. provision of specific speed advisories and of a specific indication of the time to start the descent) obliged ATCOs to take ‘as such’ the indications by AMAN and to transfer them into their instructions to pilots, without any possibility to really question their impact on surrounding traffic and on the correct performance of the following PMS procedure. In practice

	such level of automation, classifiable as LoA "C4", did not allow ATCOs to adapt the AMAN advisories to other constraints such as the need to ensure separation according to standard separation minima and the need to comply with speed requirements for a proper execution of the PMS procedure. This resulted in either unwanted perturbations of the flow of traffic exiting the E-TMA sectors or in totally ignoring the indications by AMAN, thus jeopardizing its intended support in establishing an orderly sequence of aircraft.

4.2.8 DFS AMAN

1	Title of the automated solution		
	DFS Arrival Manager at Frankfurt and Munich.		
2	Short description of the concerned automation		
	The AMAN is a support system for controllers, see [1], [2], [3] and [4] for details. It assists controllers in ensuring safe and efficient planning, coordination and guidance of traffic from different inbound directions into the TMA of an airport. The system helps to reduce delay and distributes it equally over all inbound directions and follows the principle of "first come - first served", all while reducing the controller workload.		
	2.1 Applicable domain		
	☐ Air	☒ Ground	☐ Air-Ground
3	Description of the specific function		
	From the time an aircraft enters the Flight Information Region (FIR) until it has safely landed, the AMAN generates a sequence of messages. These are displayed on a set of special displays in form of a timeline. Whereas the AMAN information is presented to the approach controller (APP) on a dedicated monitor (figure 1), the ACC controllers use an AMAN window overlay on their radar screen (figure 2). The AMAN uses adaptive planning, which takes the radar-track data and the flight plan data of each aircraft into account. Initially, an estimate is calculated of the time when an aircraft will be over or abeam the metering fix, which it has to pass when entering the TMA, and the time when it will reach the runway. Subsequently, the planning is checked against the continually received radar plots and is adjusted if necessary, see DFS [3]. All planning is generally carried out on the basis of standard procedures. In case the system detects a deviation from these procedures, the planning is adjusted to reflect the actual situation. Thus controllers do not have to input anything in the case off a missed approach or a swing over of an aircraft on final from one runway to the other. Additionally, manual interventions by controllers such as a sequence change, a move, the priority of an a/c, runway change etc., are possible if it is necessary to adjust or improve the planned sequence (Figs. 3, 4). The generation and updating of the sequence and the target times are done differently in ACC and APP. The aim of the planning for the controllers of the sectors adjacent to the TMA is to achieve the best possible planning stability, whereas the planning for the approach controllers first of all has to be highly adaptive to the actual guidance of the controllers.		

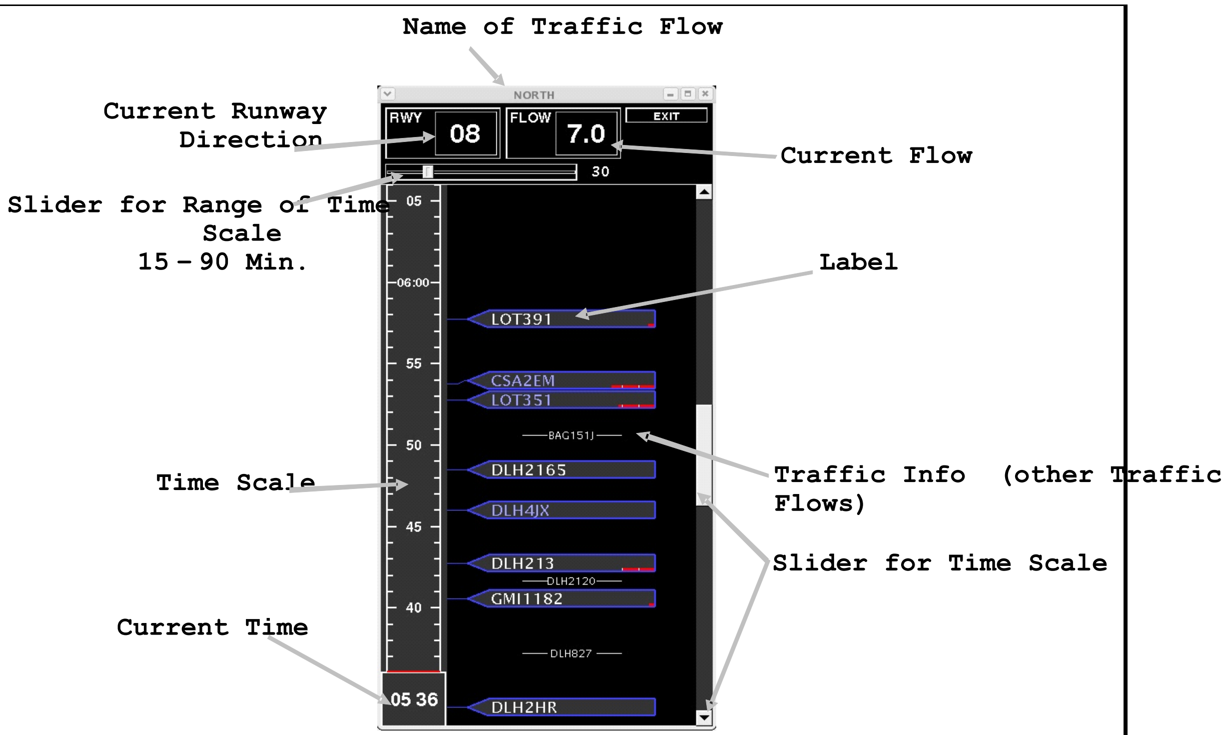


Figure 1: AMAN – Display ACC

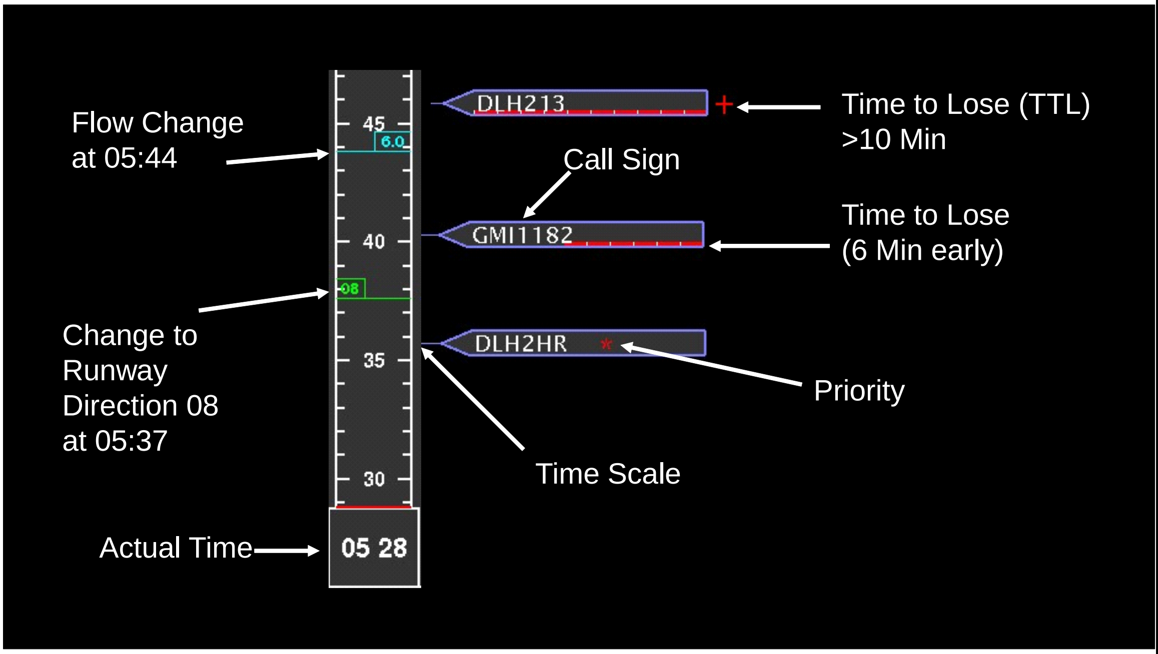


Figure 2: Details of the AMAN Display for ACC

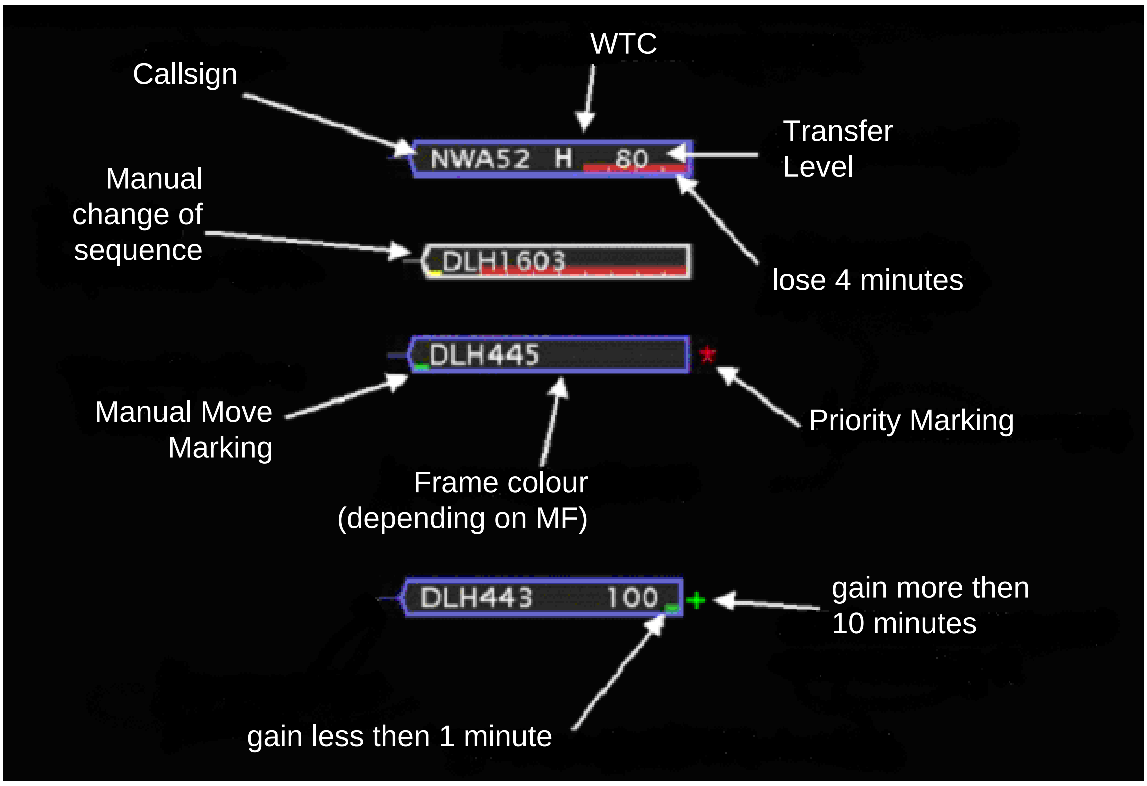


Figure 3: AMAN Label for ACC

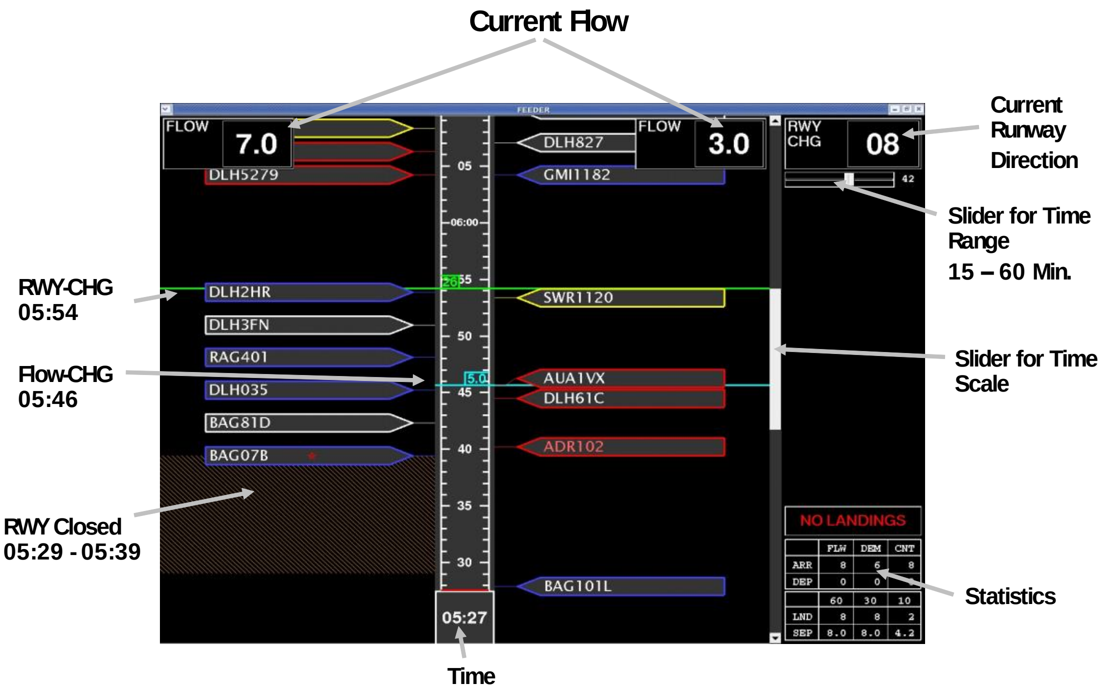


Figure 4: AMAN Display APP

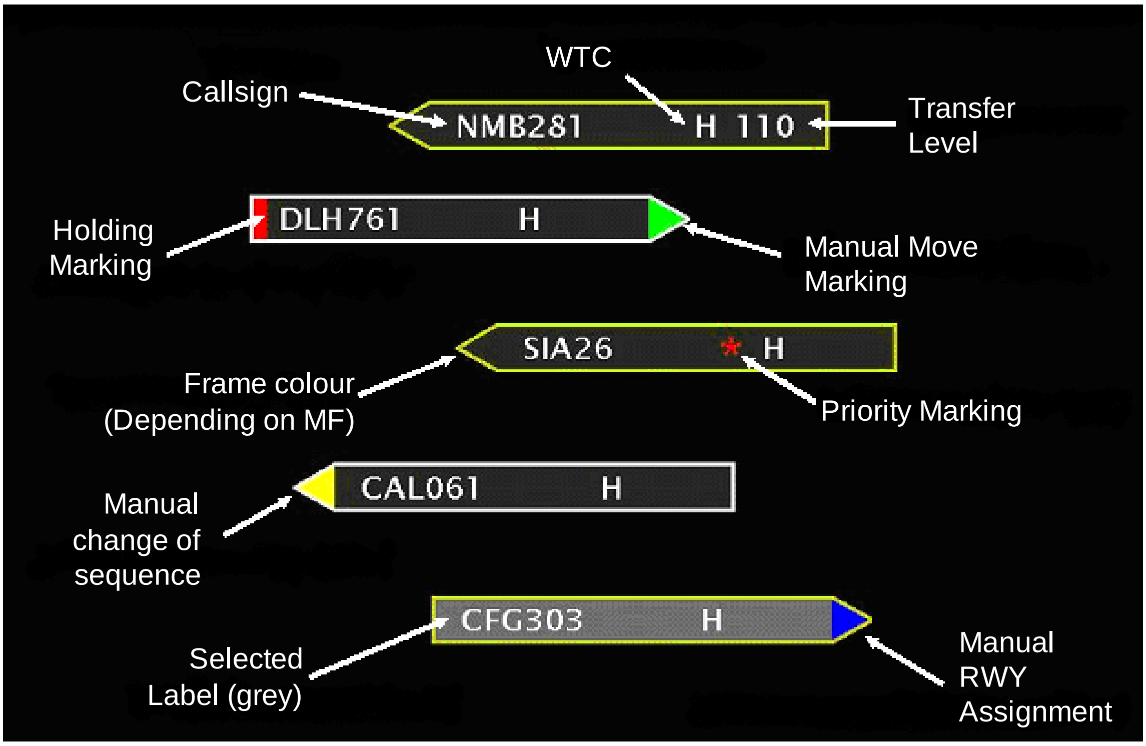


Figure 5: Details of the AMAN Display for APP

3.1 Reason for the change
This AMAN is a replacement of 1st generation AMAN at Frankfurt COMPAS (Computer Oriented Metering Planning and Advisory System), which applied static sequencing. Thus it is a planning system for optimising the arrival sequence, while reducing the coordination between ACC and APP controllers. The new AMAN can help in optimising the flow of traffic and efficiency as planning is involved with all the concerned E-TMA (Extended Terminal Manoeuvring Area) sectors, instead of local level of each specific sector, where controllers' are aiming at the throughput of the own traffic, handing it over as soon as possible. By this more global perception the AMAN could increase capacity and throughput at major hub airports.
3.2 Applied solution
The AMAN uses an adaptive planning process which takes the radar track data and the flight plan data of each aircraft into account. In the first step, initial planning is carried out with the target metering fix and runway threshold. In subsequent steps, this planning is checked against the received radar plots and adjusted as necessary (continual radar update). Planning is generally carried out on the basis of standard procedures, but deviations from these are detected and the planning is adjusted to match the actual situation. The system calculates estimated times for reaching the metering fixes and the runway threshold from the current settings for the FLOW value, the landing direction and the actual flight profile. This is based on the calculated Earliest Estimated Time of Arrival and the Latest Estimated Time of Arrival at the runway threshold which the aircraft can achieve on the basis of the abovementioned data. Missed approaches are detected automatically by the system and no intervention by the controller is necessary to place the related aircraft back in the sequence. The generation and updating of the sequence and target times is done differently in ACC and APP. The aim of planning in ACC is to achieve the best possible planning stability. This is done by freezing the metering fix times when an aircraft is closer than a defined limit to the metering fix. For the ACC controller, this means that the planning within this distance is absolutely stable

with respect to both the sequence and the times at metering fix. It should, however, be noted that only the target times at the metering fix are fixed, not the threshold times. This means that the planning in APP does not differ from the currently used approach. The adaptability of the planning in APP is fully maintained. The system will detect sequence changes automatically, except if the static mode is activated. The activation of static mode for a particular aircraft impacts all aircraft within that sector and corresponding sectors. The activation of the static mode and its impact to other aircraft is shown to the air traffic controller.

The incoming flow of traffic from the four arrival directions (e.g. at Frankfurt) into the TMA is controlled with the aid of the FLOW setting. Wherever possible the FLOW setting should be as close as possible to the processed flow of traffic. If the processing of the traffic by the APP controller differs from the actual FLOW setting, an underload or overload situation can result. If APP works faster than the FLOW setting, the AMAN can check whether there are aircraft in the ACC which can be shifted forward to fill the resulting gaps.

If APP works faster than the FLOW setting the ACC target times of any aircraft which are outside the defined area are shifted forward. If APP works slower than the FLOW setting, only the ACC target times of aircraft outside the defined area are shifted backward. These situations can occur whenever the FLOW setting is not adjusted in good time. Input of a new FLOW value always results in a recalculation of the times at the metering fixes for all aircraft in the sequence.

Wherever possible, the aircraft should be handed off at the metering fixe at the planned time. It is better to hand them off slightly earlier (one minute) than too late. The deliberate and continual early handoff to APP can lead to overload situations in the TMA. An aircraft which is handed over much too early will always block the position intended for an aircraft in another sector.

The aim of planning in APP is to achieve the necessary adaptability of the aircraft guidance by the controllers while maintaining a high level of planning stability.

Replanning should not be done too early because the situation might has been evaluated incorrectly, and this would make it necessary to change the planning back to the originally planned sequence.

In APP, the target times are continually adapted to match the actual changes in the approach profiles. The system also checks continually whether the proposed landing sequence is still plausible on the basis of the actual traffic situation. The sequence is modified automatically whenever the system detects changes from the radar situation. Changes could be caused by a controller who tries to set up a different sequence than originally planned by the AMAN system, which means that it is impossible to maintain the old sequence. The current positions, headings and speeds of the aircraft, and the ATC standards, are taken into account in this process. Within the TMA, the following procedures are taken into account:

- Detection of fan and transition
- Detection of short cuts
- Detection of various missed approach procedures and go-arounds

It is important to find a good compromise between planning on the basis of standards and separation criteria and the actual guidance by the controller. The aim of the system is to avoid re-planning as long as the current situation permits implementation of the currently planned sequence with the aid of normal guidance procedures. In most cases, it is not necessary to enter commands such as Sequence Change or Move, since these are detected automatically.

As an aircraft approaches the final, its variability with respect to the sequence becomes increasingly restricted. Aircraft which are already on final, or just before it, have thus assumed their positions and target times in the final approach sequence and are accepted as such by the planning system.

The adaptability is thus reduced as the aircraft approaches the threshold:

- Aircraft on final: Position and threshold fixed on the final
- Aircraft at final approach fix: Input of a sequence change, move or RWY left/right is overridden by the radar situation.

In general manual interventions such as Sequence Change, Move, Priority, RWY Change, etc.

	are possible if it is necessary to adjust or improve the sequences. The system automatically will detect a swing over from one runway to the other, as soon as the radar position indicates that the aircraft is crossing the midline between both runways.				
	3.3 Which benefits on SESAR KPAs are expected?				
	☐ Capacity				
	☐ Efficiency				
	☐ Flexibility				
	☒ Predictability	The AMAN increases the predictability of traffic flows because it provides a sequence of arrival aircraft and controllers can anticipate the future traffic situation. APP controllers are supported to build this sequence while ACC controllers get indications whether to decelerate or accelerate a/c to implement the sequence.			
	☐ Safety				
	☐ Access and Equity				
	☐ Interoperability				
4	Which kind of situation(s) does the function support?				
	☒ normal situations	☐ abnormal/ emergency situations			
CONTEXT OF THE TASK AND TASK					
5	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☒ Descent	☒ Approach	☒ Landing	☐ Taxi-in
	Explanation The AMAN covers the traffic management and planning in the E-TMA, which included the TMA and the adjacent ACC sectors. Only arrival traffic is concerned in the planning, thus the descent, approach and landing phases are affected.				
6	Involved Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☒ PC (ACC and APP) ☐ GND ☐ RWY ☐ Apron Controller ☐ Supervisor			
	6.1 Rationale				
	The same actors are involved as prior to implementing the AMAN, EC and PC in the ACC and APP controllers responsible for the TMA.				
7	Pilot tasks	ATCO tasks			

	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☒ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☒ Assuming and transferring traffic ☒ Ground-ground communication
	7.1 Rationale	
	The AMAN provides the ACC and APP controllers with a planning sequence of arrival traffic. In contrast to the former system at Frankfurt (COMPAS) the AMAN uses adaptive planning, taking radar-track data into account to reflect the actual situation and this way is continuously updating the sequence and time estimates. Furthermore, the AMAN provides indications whether to gain or lose time to meet target times at metering fix or runway threshold. By this the controller is supported give instructions to the pilot accordingly. Ground-ground communication between APP and ACC is greatly reduced as there is no need to negotiate the number of a/c which the TMA is able to accept. Instead this is made transparent to all actors by setting the FLOW value.	
	7.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	No changes are expected. The same ACC and APP controllers are involved as in the previous system, with the same tasks and responsibilities.	
	7.3 Would you expect that procedures change?	
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: Though working methods may be affected somehow, no modifications of standard procedures are expected or required.	

8	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before	After	Before	After	Before	After	Before	After

		change	change	change	change	change	change	change	change
						C0/C2	C2		

8.1 Rationale

Before change: The supported cognitive functions of the AMAN are related to the decision and action selection. Depending on the place of operation, the automation level before the change was either C0 or C2.

C0 applies for Munich APP as there was no arrival management system in use until implementation of the AMAN. The level of C2 applies to Frankfurt, where there was an arrival manager already in operations since 1989, called COMPAS (Computer Oriented Metering Planning and Advisory System) and it successor, the 4D Planner. The COMPAS system introduced the time line as controller interface to display the arrival sequence and the planned landing times. COMPAS, however, fixed the sequence at a very early stage. Since 2003 its successor, the AMAN, being developed in close cooperation of DLR and DFS, is in operation at Frankfurt Airport. It improves the sequence planning task by constantly considering the actual radar data. The AMAN is therefore able to adapt the schedule of arrivals to any ATC control action, even if this action deviates from the proposed plan.

The main difference between COMPAS and AMAN is that the former applied a static sequence, which was not updated by radar track data, while the AMAN is constantly updated.

After change: The AMAN offers a C2 support in decision and action selection. The system provides an arrival sequence calculated from the available data at a specific time. Controllers can evaluate it, accept this sequence and use the given indications for instructions (e.g. either to speed up or slow down an a/c to achieve the calculated estimate times at metering fix or runway threshold) or can choose to change this sequence manually. This represents the LOA 2 which means that ATCOs can change the proposals of the automated system, e.g. for reasons the system cannot anticipate and that the system accepts these changes, updating the sequence accordingly.

IMPACTS ON HUMAN PERFORMANCE

9 Human Performance and automation issues expected to be prevented or mitigated

Issue no 2: Lack of user involvement in automation assisted processes may lead to loss of skills and proficiency.

Issue no. 4: Lack of user involvement in automation assisted processes may decrease motivation and job satisfaction.

Issue no. 10: Automation may increase task demand and cognitive workload.

Planning of arrival sequences is a complex matter. Though this can be managed for each ACC sector adjacent to a TMA independently by human operators without automation support, things become complicated if several inbound streams are involved entering the TMA over different metering fixes. To identify and implement an arrival sequence which makes optimal usage of the available capacity is hardly achievable by cognitive abilities of humans. Computerized tools are much better suited for such sequence planning. Thus, no loss of skills or proficiency can be noticed, positive feedback of controllers indicates that they are relieved from certain tasks and finally their workload is significantly reduced.

Issue no. 7: Automation may impact the roles and tasks within a team and require changes to the working environment.

The implementation of the AMAN did not change any role, tasks or responsibility. The same controllers in ACC and APP are involved as before. The working environment did not change as the AMAN display is integrated on existing displays.

Issue no. 8: Automation support for decision making may be based on too simplistic algorithms and parameters to cope with the complexity of the operational environments inducing

	workarounds and higher workload in human operators. This relates to that “some operational environments may be too complex for the automation to support operator’s decision making, based on a pre-defined set of options. Such situations require a certain degree of interpretation by the operator based on the consideration of different constraints and opportunities which may exceed the set of parameters considered by the automation (e.g. amount of traffic, airport operational conditions, aircraft performances, weather conditions, needs for coordination with other actors, etc.).” However, in fact the situation of a TMA at a major hub airport is far more complex and dynamic for a human operator to plan an arrival sequence which makes optimal usage of given capacities. The AMAN was designed, developed and tested in several iterations with the aim to take all available data into account for establishing an optimal arrival sequence. **Issue no. 16:** Poor usability of HMI may reduce the human performance benefits expected from the automation support. Prior to implementing the AMAN, numerous real time simulations were performed with prototypes to optimise planning algorithms and the usability of the system. Controllers were involved and their criticism and suggestion were considered in the next iteration of system development. This user centred iterative approach was repeated until the system reached operational maturity.
10	Human Performance and automation issues potentially not mitigated by design
	Issues can be mitigated by means of design, procedures and training. These issues can either arise when introducing the concerned practice or continue to exist since they cannot be mitigated simply by design or because the design requires further improvements. Please refer to one or more issues from DEL02 and explain briefly why they are relevant.
CONTEXT	
11	In which kind of organisation was the automation practice applied?
	The DFS AMAN is operational at Frankfurt and Munich airports.
12	How often was the good practice applied in the past?
	The DFS AMAN is operational at Frankfurt since 2003 and in Munich since 2008.
13	What were the required technical means and human resources to test/validate the practice?
	Interfaces to the operational system are required, e.g. to the FDPS (flight data processing system), to the radar-tracking system, to meteorological data, etc.
14	Integration of the concerned automation into a system or an ensemble of systems
	If considered relevant, please elaborate on how the integration of the concerned automation into a system and in an ensemble of system went. How does the introduction of the concerned automation support or change the philosophy of the overall ensemble of functions or systems? N/A. The system is already operational and well implemented into the existing system infrastructure.
15	On which phase of maturity of the concept/automation was the good practice applied?
	☐ V1: Scope ☐ V2: Feasibility ☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation ☐ V5: Deployment ☒ V6: Operations

	16.1 Rationale
	The DFS AMAN is in operations at Frankfurt since 2003 and in Munich since 2008.
FINAL CONSIDERATIONS	
16	What can be learnt from the proposed change in HP automation support?
	Both, the AMAN at Frankfurt and at Munich have shown their operational benefit for several years now. The feedback is generally positive and the systems are constantly updated, e.g. to account for changing sectorization, route structures (transitions and STARs) or airport layout (new runway at Frankfurt). Besides the provision of a planning sequence of arrival traffic, one of the main benefits reported is the reduced coordination effort between APP and ACC and a reduction of instruction and clearances to pilots which altogether contributes to a considerable reduction of the workload of the controllers.
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[1] Bork, O., et al. (2010). ATM system guide lower airspace. Langen: DFS Deutsche Flugsicherung GmbH.

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[3] Deutsche Flugsicherung. (2010). System user manual Munich for AMAN release 3.1. Deutsche Flugsicherung GmbH Systemhaus/SoftwareEntwicklung Centresysteme, Langen.

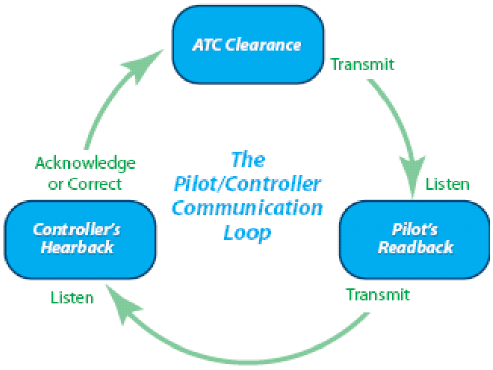
[4] Francke, S. (1997). 4D-Planer. DLR, Inst. für Flugführung, Braunschweig.

[5]U. Völckers, “The COMPAS system in the ATC environment,” Scientific Seminar of the Institute for Flight Guidance of DLR, 1990.

[6]U. Völckers, “Arrival panning and sequencing with COMPAS-OP at the Frankfurt ATC-Center,” The 1990 American Control Conference, San Diego, California, 1990.

4.2.9 DSAM (Down-linked Selected Altitude Monitoring)

1	Title of the automated solution
	4.2.9.1.1.1 Down-linked Selected Altitude Monitoring (DSAM)
2	Short description of the concerned automation
	DSAM is a monitoring aid introduced in the ground systems to allow early detection of discrepancy between Cleared Flight Level (CFL) and Selected Flight Level (SFL) on the flight deck. This practice has been introduced thanks to the MODE-S technology.
	2.1 Description of the function
	The ATCO issues a clearance for an aircraft to go to a given flight level via VHF voice communication. This clearance is the most frequent clearance given to aircrafts. Thus it is considered as a very frequent task. The pilot confirms the CFL to the controller. The Pilot/ATCO Communication Loop (see figure below) is supported by the read-back procedure. Read-back is defined as a procedure whereby the receiving station repeats a received message or an appropriate part thereof back to the transmitting station so as to obtain confirmation of correct reception (ICAO Annex 10 Vol. II).



The Pilot/Controller Communication loop (EUROCONTROL courtesy)

The action of reading back a clearance gives the controller the opportunity to confirm that the message has been correctly received by the pilot, and if necessary, to correct any errors.

An uncorrected erroneous read-back (known as a hear-back error) or a missed read-back may lead to a deviation from the intended clearance and may not be detected until the controller observes the deviation on his/her radar display (what is called level bust). This hazard is considered as severe as it can lead to the loss of the minimum separation between aircraft.

The Read-back procedure is not fail-safe; as for all the verbal orders, it presents more rooms for errors than written or electronics orders. By analysing the read-back procedure through the SHELL Model, we see that the critical focus of the model is the human participant, or Liveware, as well as the most flexible component in the system. Among of all the dimensions in the model, the Liveware is the one that is least predictable and most susceptible to the effects of internal (fatigue, motivation, hunger, etc.) and external (workload, noise, light, temperature, etc.) changes. Typical causal factors of failure between the Liveware-Liveware dimensions for the read-back procedure are: similar call sign, frequency change, radio interferences, non-standard phraseology, missed read-back or missed acknowledge. In this last case, most flight crews perceive the absence of an acknowledgement or a correction following a clearance read-back as an implicit confirmation of the read-back.

Thanks to the Mode-S technology, the Down-linked Aircraft Parameters (DAP) provided by the Mode-S transponder can be used to support the read-back function.

The ATCO issues a clearance for an aircraft to go to a given flight level via VHF voice communication and, at the same time, he selects it into the system through mouse/keyboard interaction. The pilot confirms the CFL to the controller. The pilot enters the selected altitude to autopilot control panel. The selected altitude (SFL) is down linked to the ATC centre through Mode-S. The enhanced Mode-S consists of the extraction of downlink aircraft parameters for use in ground-based air traffic management systems. The SFL is displayed in the selected track label.

In case of discrepancy between CFL and SFL, the DSAM alert is displayed on the track label.

The read-back procedure is kept; the DSAM support the read-back procedure by performing automatic crosschecking of climb/descent instructions and thus, help the early identification of potential level bust incidents.

This new alert is well appreciated by operators.

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

The flight level assignment is a basic ATCO procedure.

What is the linkage between the use of the function and traffic level?

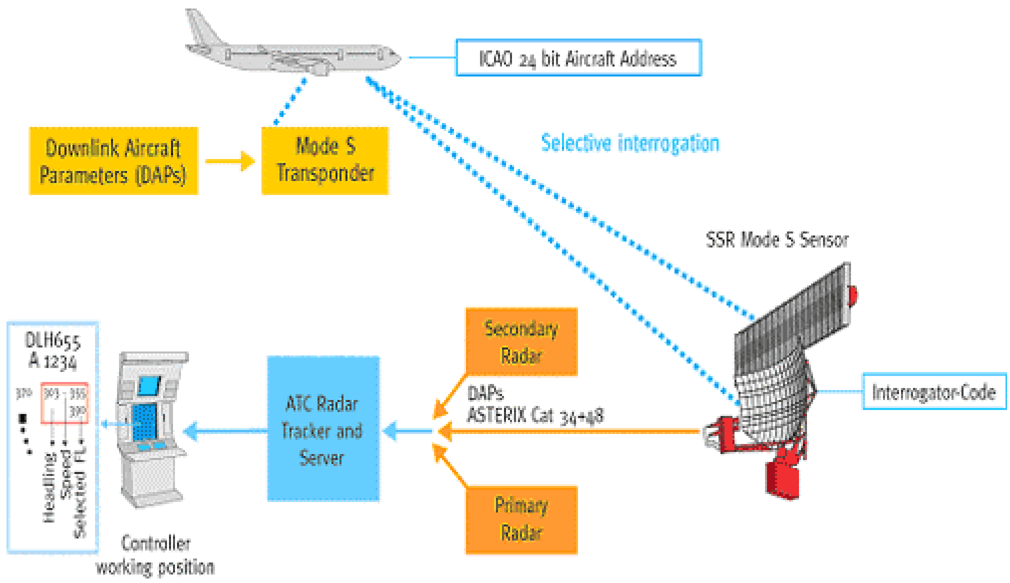
Either in low or high traffic level, as the risk of misunderstanding between pilot and controller can depend on the voice communication noise or erroneous selection in the autopilot control panel.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

2.4 Operational environment

Airspace covered by EHS Mode-S radar and aircraft are EHS Mode-S transponder equipped.



Mode-S operational overview (EUROCONTROL courtesy)

Enhanced Mode-S (EHS) is currently deployed in real live operation in Hungary, Belgium, United Kingdom, Germany and France.

Clearances need to be input into the ATC system by the ATCO.

2.5 Reason for the change/ Problem to be handled

The major reason for change is that DSAM allows ATCO to anticipate the detection of discrepancy between CFL and SFL.

In operational environment not equipped by Mode-S, the controller assigns the CFL to pilot via voice communication and waits the read-back to confirm that level. In case of misunderstanding between pilot and ATCO, due to for example noise in the voice communication or erroneous selection in the autopilot control panel (slips), the discrepancy between CFL and the aircraft altitude is detected by other monitor aids means, like CLAM (Clearance Level Adherence Monitor). CLAM compares the selected CFl by the ATCO (through the CFL menu using mouse interaction) and the actual flight level of the aircraft. Thus, the alert will be trigerred once the non-adherence to the cleared flight level is occuring or about to occur.

In this case, the ATCO has to solve the potential critical situation once the level bust is already

	occurring. Therefore, the DSAM enhances safety as it provides crosschecking of climb/descent instructions and help the early identification of potential level bust incidents.
	2.6 Applied solution/intervention
	The DSAM allows automatically detecting a discrepancy between CFL and SFL. This monitoring aid reports to the ATCO well in advance that a critical situation is faithfully identified. The DSAM helps in anticipating the possible effects of a misunderstood cleared level.
3	REFERENCES
	EUROCONTROL Preliminary System Safety Analysis for the Controller Access Parameter service delivered by Mode S Enhanced Surveillance V 1.1 - 07/04/2004 http://www.skybrary.aero/bookshelf/books/1306.pdf
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	It was tested in the context of R/D projects by different ANSPs. The tests included validations based on real time simulation. These tests were conducted by means of radar Mode-S track simulators. Enhanced Mode-S is already implemented in some European ATM systems
5	What were the required technical means and human resources?
	Working group composed by Operational experts, System engineer specialists, and safety experts. Real time simulations to play real traffic data recording. Shadow mode operations were also performed in order to validate the function. Specific tool to analyse real traffic data results.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	The DSAM is implemented in Belgium, since 2010.
7	Integration of the concerned automation into a system or an ensemble of systems
	The operational concept for the CFL monitoring remains unchanged. The new automation (DSAM) allows the automatic crosschecking of climb/descent instructions and supports the early identification of potential level bust incidents, without using the read-back pilot-ATCO for confirming SFL.
8	On which phase of maturity of the concept/automation was the good practice applied?
	☐ V1: Scope — ☐ V2: Feasibility — ☐ V3: Pre-industrial development and integration
	☐ V4: Industrialisation — ☒ V5: Deployment — ☒ V6: Operations
	8.1 Rationale
	Deployed in live operation in Belgium (Belgocontrol ANSP) since 2010. Moreover, it will be deployed for other ANSPs in the near future.

CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☒ Climb
	☒ En Route	☒ Descent	☒ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	DSAM alerts are used by ACC and APP ATCO.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☐ PC ☐ Supervisor ☐…			
	10.1 Rationale				
	Monitoring the altitude clearance provided to the pilot is part of the task of the executive controller.				

TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☒ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☐ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	The DSAM provides automatic crosschecking of climb/descent instructions and help the early identification of potential level bust incidents. In case of misunderstanding between pilot and ATCO, due to noise in the voice communication or erroneous selection in the autopilot control panel (slips), the discrepancy between CFL and SFL is detected by the system by comparing the CFL data available on the ground with the DAP-SFL (Down-linked Aircraft Parameters Selected Flight Level). One characteristic that should be underlined is that Giving a CFL (and making the associated read-back) is one of the most frequent tasks of the operators. This frequency implies that an	

	error has more chances to occur. Here, the automation comes to support a frequent task on which an error can have severe consequences (level bust with potential loss of separation).
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation
	No change in roles due to the automation.

12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA	A1	A5	B0	B5	C0	C0	D0	D0
	12.1 Rationale								

Information acquisition rationale:

(A1, A5) The system automatically integrates the Selected Altitude, down-linked from the aircraft. Before, ATCOs had to listen on the frequency the pilot to have the information.

Information analysis rationale:

(B0, B5) Thanks to the DSAM automation, the system performs comparisons and analyses of data available on the status of the process being followed based on parameters defined at design level.

The system triggers visual alerts if the analysis produces results requiring attention by the user.

Decision and action selection rationale:

(C0, C0) The human decides all actions to be performed. The system does not support the ATCO in the action selection, before and after automation implementation.

Action implementation rationale:

(D0, D0) The human executes and controls all actions manually. The system does not support the ATCO in the action implementation, before and after automation implementation.

IMPACTS ON HUMAN PERFORMANCE		
13	13.1 Which changes do you see in the way the Human Performance is supported?	
	Early detection of levels discrepancy allows ATCO to manage the separation more efficiently, with reduced stress.	
	13.2 Which benefits do you expect on SESAR KPAs?	
	☐ Capacity	
	☒ Efficiency	The DSAM provides automatic crosschecking of climb/descent instructions and supports the early identification of potential level bust incidents. Hence, it contributes to enhance ATCO's efficiency in maintaining separation.

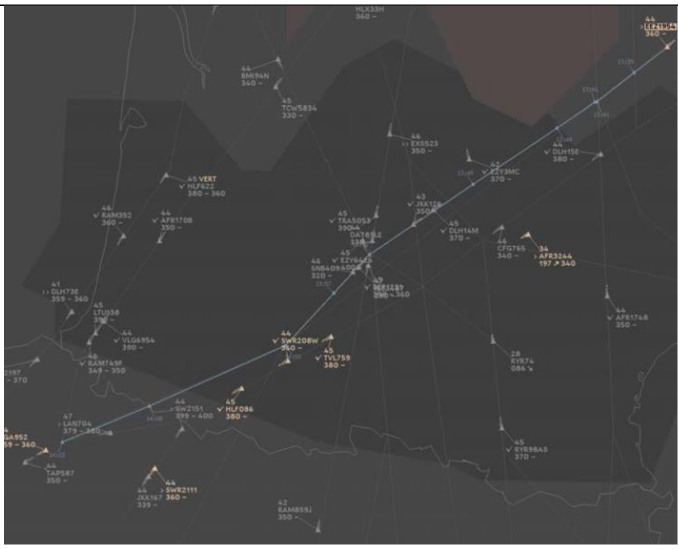
	☐ Flexibility	
	☐ Predictability	
	☒ Safety	Early detection of levels discrepancy gives the controller more reacting time to recover unsafe conditions. In the same way, it contributes to reduce the exposure time to unsafe situations.
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	No issue identified in the "Identification of Issues in Human Performance Automation Support" 16.5.1 – D2 document. DSAM has been designed to mitigate a human error (verbal slip of ATCO, erroneous entry of the clearance by the ATCO, or mishearing of the clearance by the pilot, or erroneous entry of the clearance by the pilot). It has not been designed to mitigate an existing automation issue.	
	13.4 Human Performance and automation issues potentially <u>not</u> mitigated	
	<u>Issue 22</u>: Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness. One potential drawback in DSAM is an excessive trust of the ATCO on this monitoring aid, which could lead to a decrease in the vigilance allocated on the read back (listening the acknowledgment of the clearance by the pilot). The read back is mandatory and is actually one safety mitigation mean to check that pilots have correctly understood the clearance. <u>Issue 23</u>: Inadequate trade-off between nuisance/false alerts and warning time may cause mistrust in automation and increase workload. DSMA is a new monitoring alert. Thus, it may generate new false alerts, which need to be estimated and investigated in order to avoid negative impacts on human performance. For example, special operational environments may require adaptations of the triggering logic of the alert: if ATCO use the clearance 'When ready, climb to FL 350', the alert should be triggered only when the aircraft starts climbing. If direct clearances are given (with an immediate application, and not a delayed one as in the 'when ready'), the alert should be triggered a few seconds after the clearance is given (taking into account the delay of the pilot to select the target altitude, and the time required for the aircraft to start changing level) in order to detect a delayed reaction of the pilot which could induce safety issues. So, to conclude, the logics may need to be adapted to operational environments, and they should be tested on a large sample of traffic in order to assess the expected amount of false alerts that will happen in operation.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: The DSAM automation is intended <u>to support</u> the ATCO in the read-back procedure by automatic crosschecking of climb/descent instructions. It does not replace the read back procedure; hence an operational procedure change is not expected.	
FINAL CONSIDERATIONS		
14	What can be learnt from the proposed change in HP automation support?	

	Operators' feedback is positive on DSAM. One lessons learnt could be on explaining the reasons of this feedback. First, the task of giving a CFL (and the associated readback) is a very frequent task. This frequency increases the number of possible occurrences of an error, which may lead to severe consequences. Thus, the first explanation could be that the characteristics of the task (frequent, safety critical) are well adapted for introducing a new automation which will support the operator. Second, monitoring data is not one of the human strength. Thus, adding an automatic check such as DSAM can be helpful from a human performance point of view. A third explanation could be on the design of the function. Indeed, DSAM is simple and does not involve complex algorithms. So it is easily understood by ATCOs and if false alerts may occur, they could be easily understood. Last, the new automation detects a potential level bust sooner than the current alerts, thus giving more time for the ATCO to react. This available reaction time may increase the ATCO self-level of trust in being capable of correcting the issue efficiently. In conclusion, the characteristic of the task, the obvious safety benefit, and the impact on human performance properties (trust) could be characteristics to be considered when deciding to implement an automation or not.

4.2.10 ERATO (En-Route Air Traffic Organizer) Filtering and What-If Function

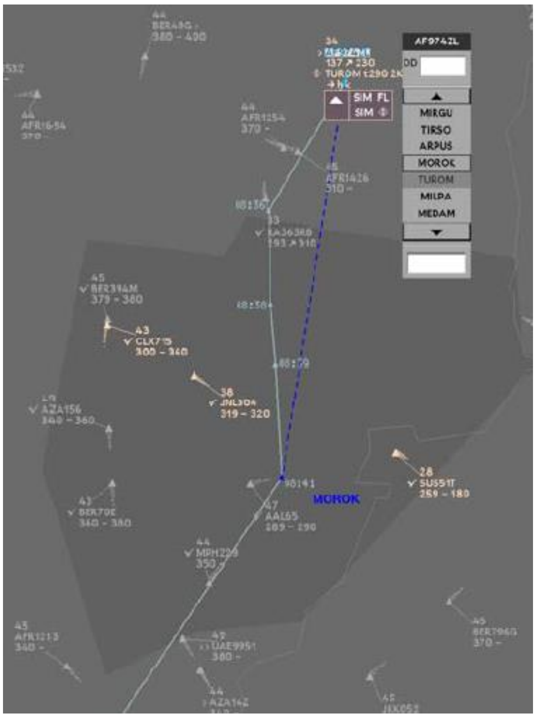
1	Title of the automated solution
	ERATO (En-Route Air Traffic Organizer) – Filtering Function and What-if Function
2	Short description of the concerned automation
	ERATO is a medium-term conflict detection tool integrated in the CWP and intended to increase controller's efficiency in conflict detection and resolution. It includes different functions, such as: A) Filtering and what if function, B) Monitoring function, C) Task Scheduler function. It is intended to be used by both PC and EC.
	2.1 Description of the function
	The ERATO Filtering and what-if functions are specific functions of the ERATO system offering to ATCOs the possibility to anticipate the identification of potential conflicts in the medium short-term (up to 20 minutes to the conflict). They are both activated on controller's request. The first function highlights potential intruders of a reference flight before any level or route change is applied. While the second function helps to spot potential conflicts before issuing a clearance implying some level or route change.
	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐ abnormal situations The ERATO toolset is designed to support normal working practices related to traffic separation assurance activities.
	Which level of traffic does the function support? The functions are intended to provide support to the ATCO with all levels of traffic. Nonetheless more added value is expected in case of medium-high traffic levels, due to the possibility to spot in advance potential conflicts and to prioritize them, with the associated support of the ERATO Task Scheduler function. If associated to appropriate working methods the functions are also expected to provide benefits in terms of a better balance of the workload between PC and EC,

	with a reduced cognitive load for the latter.
	2.3 Concerned domain
	☐ Air ☒ Ground ☐ Air-Ground Explanation:
	2.4 Operational environment
	ERATO filtering and what-if functions are mainly intended for use in en-route sectors. They are designed to identify conflicts in the medium-term, but can be used by both EC and PC (note that the sharing of the task between EC and PC is supported by another function, i.e. ERATO-Task Scheduler Function).
	2.5 Reason for the change/ Problem to be handled
	Preplanning of de-confliction strategies and anticipation of possible conflicts are essential elements of ATCO working activity. However the efficiency and safety of this activity may be reduced or degraded as much as the traffic density is increasing at each controlling sector, with a consequent increase of individual controllers' workload. An excessive workload is likely to reduce the ability to timely identify potential conflicts and take appropriate decision on the best de-confliction strategy sufficiently in advance. The automation solution here described is expected to support individual controllers in increasing ATC capacity and efficiency in each sector, whilst maintaining their ability to observe each flight into the wider picture and prevent potential infringements of separation minima.
	2.6 Applied solution/intervention
	The ERATO Filtering and what-if functions are intended to: (a)Support a quick analysis of flights in traffic context to timely detect possible conflicts and identify appropriate resolutions. (b) Help in anticipating the possible effects of a given clearance implying either a level evolution or a route evolution. (c)Support the identification of the appropriate moment to clear a flight to its exit level. The so called *basic filtering* enables to analyse more rapidly the context of the *reference flight* by highlighting all possible intruders of the flight itself and by dimming non interfering flights. Such filtering is made by using a forecast of the most liable behaviour for all the flights based on the most probable trajectories, according to the following data sources: (i) Flight plans data, (ii) Airspace definition (LOA / SID-STAR…), (ii) RDPS updates, (iv) Controllers updates.



Example of ERATO basic filtering highlighting potential intruders of a specific flight

While the what-if function provides a filtering of the possible conflicts corresponding to a simulation of level evolution or route evolution (in this case the function is also called *simulated filtering*). It applies the same logical value as a basic filtering but applied to simulated values. In this case a new flight level or a new routing. Furthermore the What-if function enables to identify the moment in which an ATCO can clear a flight to its exit level, by considering that the flight could occupy any level between its current level and its exit level (in this the function is also called *extended filtering*).



Example of ERATO What-if function used to plan a re-routing

3 REFERENCES

- En Route Air Traffic Organizer (ERATO) – Evaluation Session (Toulouse 2-4 July 2008 and 7-11 July 2008) – Version 4.0 – 29th July 2008 – ENAV [*Restricted*]
- Valutazione Operativa ERATO Demo – 16 Febbraio 2011 – ENAV [*Public*]

CONTEXT			
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*		
	The ERATO functions are not yet used operationally. They were tested in different Real Time Simulations performed in a French ACC , involving both French and Italian controllers.		
5	What were the required technical means and human resources?		
	As mentioned above, the ERATO functions were tested in different RTS sessions. The simulation setting involved at least 3 en-route sectors with planner and executive controller working positions and a corresponding number of pseudo-pilots.		
6	If applicable: How often was the good practice applied in the past? Please estimate.		
	The ERATO functions are not yet used operationally. They are available in the form of an advanced prototype and they have been considered in the development of the user requirements for the ATM system being developed in the context of the 4-Flight Programme, based on a collaboration between DSNA and ENAV.		
7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?		
	The use of the ERATO toolset is intended to assign a greater role to the PC in managing separation assurance activities, with respect to operational contexts not supported by any controlling tool. This may imply a considerable change in working methods and in the authority sharing particularly in ACC centres in which the PC's role is still considered ancillary with respect to the EC.		
8	On which phase of maturity of the concept/automation was the good practice applied?		
	☐ V1: Scope	☐ V2: Feasibility	☒ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations
	8.1 Rationale		
	The ERATO functions are currently in the form of advanced prototypes. Their industrialization has not started yet and their first adoption in a real operational environment is expected in 2015 as parte of the 4-Flight industrial platform.		

CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☒ En Route	☐ Descent	☐ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	The ERATO Filtering and What-if Function can be made available to controllers in both En route and TMA airspaces. Nonetheless ERATO is expected to perform much better in en-route, since the accuracy of trajectory prediction is favoured by sufficiently stable trajectories, with a limited number of vertical evolutions.				

10	Actor(s)	
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☒ PC ☐ Supervisor ☐…
	10.1 Rationale	
	Although the tool is designed for medium term-conflict detection (up to 20 minutes to the conflict) the ERATO Filtering and What-if Function are available to both EC and PC controllers. To prevent misunderstanding or overlaps in the use of the same function, another ERATO function (namely the Task Scheduler) helps to distinguish the conflict to be handled by one or the other actor, mainly based on a predefined threshold considering the time to the conflict.	
TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☒ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	The ERATO Filtering and What-if Function provides support to both *detection of conflict* and *planning strategies* thanks to the three different information items listed above: (a)possible conflicts of a reference flight along its current trajectory (b)anticipation of the possible conflicts of a reference flight in case a specific level or route evolution will be cleared. (c)Anticipation of the appropriate moment in which a reference flight can be cleared to its exit level with no risk of conflicts with other flights. While the function does not provide specific resolutions to prevent this conflict. The identification of the appropriate strategies and the decision of which to select is up to the controller.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	(as in field 7 above) The use of the ERATO toolset is intended to assign a greater role to the PC in managing separation assurance activities, with respect to operational contexts not supported by any controlling tool. This may imply a considerable change in working methods and in the authority	

sharing particularly in ACC centres in which the PC's role is still considered ancillary with respect to the EC.

12	Classification of supported cognitive functions and automation level

The ERATO Filtering and What-if functions only provide support to *information analysis*, since they help to predict possible conflicts according to current trajectories or in case of clearances implying a level/route evolution or evolution towards a certain exit level. Information acquisition is already possible without this function through the usual display of track position on the CWP. While, as anticipated above, both the *decision and action selection* and the *action implementation* are fully up to the controller.

A clear and definite comparison with the situation "Before the Change" cannot be made, since different implementations of MTCD-like tools exist around Europe, but there is no unique standard that can be acknowledged as actual state-of-the-art.

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA				B3				

12.1 Rationale

The ERATO Filtering and What-if functions only provide support to *information analysis*, since they help to predict possible conflicts according to current trajectories or in case of clearances implying a level/route evolution or evolution towards a certain exit level. The information analysis is always activate on controller's request (e.g. after click on a specific track label).

The Information acquisition is already possible without this function through the usual display of track position on the CWP. While, as anticipated above, both the *decision and action selection* and the *action implementation* are fully up to the controller.

A clear and definite comparison with the situation "Before the Change" cannot be made, since different implementations of MTCD-like tools exist around Europe, but there is no unique standard that can be acknowledged as actual state-of-the-art.

IMPACTS ON HUMAN PERFORMANCE

13	13.1 Which changes do you see in the way the Human Performance is supported?

There is an expectation that the number of conflict managed at strategic level will increase and that the PC will have more opportunities to support the EC in solving the conflicts for which a solution at strategic level was not possible.

13.2 Which benefits do you expect on SESAR KPAs?

☐ Capacity	
☒ Efficiency	The possibility to spot well in advance potential conflicts is expected to enhance ATCO's efficiency in organize an orderly and expeditious flow

		of traffic at each sector level, without degrading currently safety levels.
	☐ Flexibility	
	☐ Predictability	
	☒ Safety	The possibility to spot well in advance potential conflict is expected to at least maintain current ATCO's safety performance, whilst enhancing their efficiency in organize an orderly and expeditious flow of traffic at each sector level.
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	- **Issue n.8:** Automation support for decision making may be based on too simplistic algorithms and parameters to cope with the complexity of the operational environments inducing workarounds and higher workload in human operators. - **Issue n.10:** Automation may increase task demand and cognitive workload - **Issue n. 18:** New automation support that results in greater use in visual information may lead to visual channel overload, with decrease in situation awareness and performance efficiency - **Issue n. 22:** Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness - **Issue n. 23:** Inadequate trade-off between nuisance/false alerts and warning time may cause mistrust in automation and increase workload. The philosophy of ERATO Filtering and What-if functions is to leave to the ATCO complete control on the interaction with the automation. The functions are activated only on controller request and are generally intended to support existing working methods and skills, rather than replacing them. No automatic medium term conflict alerts are triggered and relevant conflicts are highlighted only in the context of specific checks made by the ATCO, referred to both current flight trajectories and clearances that the ATCO is going to issue. Such philosophy limit the number of nuisance alerts that may be triggered by the functions or at least prevent these from disrupting ATCO's actions or from significantly increasing their workload.	
	13.4 Human Performance and automation issues potentially <u>not</u> mitigated	
	- **Issue n.5**: The automation of routine tasks may remove an important information source which may reduce situation awareness. ERATO Filtering functions are based on highlighting potential intruders of a reference flight and de-colouring other non concerned flights. This may potentially degrade situation awareness and peripheral view which are very relevant skills in well-experienced controllers.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: The ERATO Filtering and What-if functions may imply minor changes in controller's working methods. However these are unlike to require changes in standard ICAO procedures.	
FINAL CONSIDERATIONS		

14	What can be learnt from the proposed change in HP automation support?
	The ERATO filtering and what-if functions appear as a good example of non-intrusive support to controller's performance in monitoring and conflict detection tasks. The functions are activated only on controller request and are generally intended to support existing working methods and skills, rather than replacing them. No automatic medium term conflict alerts are triggered and relevant conflicts are highlighted only in the context of specific checks made by the ATCO, referred to both current flight trajectories and clearances that the ATCO is going to issue. The choice of this level of automation (B3 – Medium Level Automation Support of Information Analysis) leaves more responsibility (and potentially more cognitive load) to ATCOs as opposed to similar function tools providing B4 or B5 automation support. Nonetheless the ATCO has more opportunities to adapt the use of the tool to its own working style and the risk of nuisance alerts caused by inaccurate trajectory predictions by the system is considerably limited. It is worth noting that such risk is high not only in case of operational contexts characterized by a low quality of surveillance data or inadequate algorithms to perform trajectory prediction. Rather, trajectory prediction may also be jeopardized by very complex operational conditions (e.g. complex ATS geography, contiguity between airspaces of different categories, etc.) with constraints and opportunities that can only be understood and managed by a human operator. In such cases the limitations of a B3 automation support appears largely compensate by the benefits in terms of reduced nuisance alerts and lower risk of causing interruptions and disturbances to the performance of the controller.

4.2.11 ERATO (En-Route Air Traffic Organizer) Monitoring Function

1	Title of the automated solution
	ERATO (En-Route Air Traffic Organizer) – Monitoring Function
2	Short description of the concerned automation
	ERATO is a medium-term conflict detection tool integrated in the CWP and intended to increase controller's efficiency in conflict detection and resolution. It includes different functions, such as: A) Filtering and what if function, B) Monitoring function, C) Task Scheduler function. It is intended to be used by both PC and EC.
	2.1 Description of the function
	The ERATO Monitoring function provides an alert to the ATCO in case of a/c deviating from the planned trajectory (as defined in the flight plan) on either the vertical and/or horizontal plane.
	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐ abnormal situations The ERATO toolset is designed to support normal working practices related to traffic separation assurance activities.
	Which level of traffic does the function support? It is intended to provide support to the ATCO with all levels of traffic. Even in low traffic situations it may be useful to spot an aircraft which is deviating from its trajectory due to misunderstandings with the concerned ATCO or to other problems that risk to go unnoticed since the overall traffic situation does not appear problematic to the ATCO. While in high traffic situations the function may obviously be supportive in helping the controller to distinguish a deviating traffic among other traffics that regularly follow their planned trajectory (provided that the alerting indication is not too intrusive and does not distract the ACTO from other more urgent alert situations). This is particularly useful since it can help to prevent a potential conflict before

identifying it with the Filtering or What-If function (at strategic level) or before a Short Term Conflict Alert is activated (at tactical level).

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

Explanation:

2.4 Operational environment

From a technical point of view the ERATO monitoring function can work on both En-route and TMA sectors. However a better performance (and therefore a better automation support) is envisaged in en-route sectors where the number of quick vertical evolutions and radar vectoring instructions by ATCOs is expected to be smaller, thus reducing the possibility to generate nuisance alerts caused by lack of timely updates of the planned trajectory into the system.

2.5 Reason for the change/ Problem to be handled

If identified too late a deviation from the planned trajectory (as defined in the flight plan) may generate conflicts which require extra-effort to be solved by the ATCO in a timely manner or even cause a degradation of safety margins (e.g. an infringement of aircraft separation minima). This may have a negative impact on either the efficiency of monitoring and conflict detection activities and on the overall safety of the system.

Furthermore problems may occur when changes to the planned trajectory (and to the associated flight plan) are instructed by ATCOs via R/T communication, but not timely updated in the CWP HMI. In such cases the system continues to assume a different planned trajectory with respect to then one which has been instructed. This may have a number of negative effects including wrong expectations and errors by the ATCO if s/he comes out with forgetting the change s/he has just instructed or inadequate functioning of other controlling tools whose performance depend on the information input by the controller (e.g. clearance adherence monitoring tools).

2.6 Applied solution/intervention

The ERATO Monitoring function continuously monitors that each flight stays inside a given volume along the planned trajectory (as defined in the flight plan). In case of deviation on the vertical plane or/and horizontal plane, the function alerts the ATCO by the addition of an alert on the label (i.e. HORIZ in case of horizontal deviation and VERT in case of the vertical one).

Example of 2 alerts generated by the monitoring function

The alert is activated also in case of inconsistency between the actual and the planned a/c trajectory, due to lack of update of the former by the ATCO. Actually every time a change in the planned trajectory – e.g. a direct routing to a certain waypoint – is either instructed by the ATCO or agreed between the ATCO and the flight crew, the controller is expected to edit the corresponding flight plan information by interacting with the specific track label. In case such updating is either omitted or forgotten an ERATO monitoring alert is activated as soon as the actual trajectory falls out of a predefined volume around the predicted trajectory.

3 REFERENCES

	– En Route Air Traffic Organizer (ERATO) – Evaluation Session (Toulouse 2-4 July 2008 and 7-11 July 2008) – Version 4.0 – 29th July 2008 – ENAV [*Restricted*] – Valutazione Operativa ERATO Demo – 16 Febbraio 2011 – ENAV [*Public*]
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	The ERATO functions are not yet used operationally. They were tested in different Real Time Simulations performed in a French ACC , involving both French and Italian controllers.
5	What were the required technical means and human resources?
	As mentioned above, the ERATO functions were tested in different RTS sessions. The simulation setting involved at least 3 en-route sectors with planner and executive controller working positions and a corresponding number of pseudo-pilots.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	The ERATO functions are not yet used operationally. They are available in the form of an advanced prototype and they have been considered in the development of the user requirements for the ATM system being developed in the context of the 4-Flight Programme, based on a collaboration between DSNA and ENAV.
7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?
	The philosophy of the overall system (intended as the CWP with the associated Multi Radar Tracking System) is not modified. However this function, as well as the other associated ERATO ones, goes in the direction of increasing the need for the controller to update the information used by the system by way of HMI inputs which are independent and work in parallel with R/T communications. On the one hand this allows the system to provide much more automation support to the user. On the other hand such automation support increasingly depends on the correctness and timeliness of controllers inputs and requires a considerable modification of older working practices exclusively based on R/T communications.
8	On which phase of maturity of the concept/automation was the good practice applied?
	☐ V1: Scope / ☐ V2: Feasibility / ☒ V3: Pre-industrial development and integration
	☐ V4: Industrialisation / ☐ V5: Deployment / ☐ V6: Operations
	8.1 Rationale
	The ERATO functions are currently in the form of advanced prototypes. Their industrialization has not started yet and their first adoption in a real operational environment is expected in 2015 as parte of the 4-Flight industrial platform.
CONTEXT OF THE TASK	
9	What are the concerned flight phases?
	☐ Turnaround / ☐ Pushback / ☐ Taxi-out / ☐ Take-off / ☐ Climb

<table>
<tr><td></td><td>☒ En Route</td><td>☐ Descent</td><td>☐ Approach</td><td>☐ Landing</td><td>☐ Taxi-in</td></tr>
<tr><td></td><td colspan="5">9.1 Rationale</td></tr>
<tr><td></td><td colspan="5">The ERATO Monitoring function can be made available to controllers in both En route and TMA airspaces. Nonetheless ERATO is expected to perform much better in en-route, since the accuracy of trajectory prediction is favoured by sufficiently stable trajectories, with a limited number of vertical evolutions. If the trajectory prediction is inaccurate or controllers do not have time to input updated information in the system every time an instruction is issued via R/T communication, the number of nuisance alerts may increase to al level which compromises the usability of the function.</td></tr>
<tr><td>10</td><td colspan="5">Actor(s)</td></tr>
<tr><td></td><td colspan="3">Air: Pilot
☐ PNF ☐ PF</td><td colspan="2">Ground: ATCO
☒ EC ☒ PC ☐ Supervisor ☐…</td></tr>
<tr><td></td><td colspan="5">10.1 Rationale</td></tr>
<tr><td></td><td colspan="5">Generally speaking the ERATO tool is better used by the PC to prevent conflicts in the long term and up to 20 minutes. However the specific ERATO monitoring functions can be very useful also for the EC to spot deviations from the planned trajectories and anticipate potential conflicts in the short term before they really occur or generate an STCA alert.</td></tr>
<tr><td colspan="6">TASK</td></tr>
<tr><td>11</td><td colspan="3">Pilot tasks</td><td colspan="2">ATCO task</td></tr>
<tr><td></td><td colspan="3">Operate:
☐ Control the aircraft
☐ Manage the autopilot
☐ Monitor the flight parameters
Navigate:
☐ Aircraft position management
☐ Flight planning/ trajectory management
Communicate:
☐ Communicate with ATC
☐ Communicate within the crew
☐ Communicate with other aircraft, airline, maintenance
Manage system status and surroundings:
☐ Monitor system/ aircraft status and surroundings
☐ Evaluate system/ aircraft status and surroundings
☐ Handle system/ aircraft status and surroundings</td><td colspan="2">☒ Monitoring traffic
☐ Providing traffic information
☐ Issuing instructions/clearances
☒ Detecting conflicts
☐ Resolving conflicts
☐ Planning strategy
☐ Assuming and transferring traffic
☐ Ground-ground communication</td></tr>
<tr><td></td><td colspan="5">11.1 Rationale</td></tr>
<tr><td></td><td colspan="5">The primary role of the ERATO monitoring function is to support the traffic monitoring activity, by helping EC and PC in spotting deviations of a/c from their planned trajectories. However the timely detection of these deviations can also help in detecting conflicts before or shortly after they occur.</td></tr>
<tr><td></td><td colspan="5">11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation</td></tr>
</table>

	No specific changes are expected in the roles of both EC and PC as a consequence of the introduction of the ERATO monitoring function.								
12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA			B0	B5				
	12.1 Rationale								
	The ERATO Monitoring function only provides support to *information analysis*, since it helps to spot possible deviations of a/c from currently planned trajectories on either the horizontal or vertical plane. Information acquisition on the deviation is already possible without this function through the usual display of track position on the CWP. The *decision and action selection* and the *action implementation* that may be necessary to correct the deviations are fully up to the controller.								

IMPACTS ON HUMAN PERFORMANCE		
13	13.1 Which changes do you see in the way the Human Performance is supported?	
	There is an expectation that the number of conflict managed at strategic level will increase and that the PC will have more opportunities to support the EC in solving the conflicts for which a solution at strategic level was not possible.	
	13.2 Which benefits do you expect on SESAR KPAs?	
	☒ Capacity	The function may potentially increase the capacity of the ATM system as indirect (but not guaranteed effect) of the increased efficiency (see below).
	☒ Efficiency	The function is expected to have a positive impact on the efficiency of separation assurance activity, since controllers (either EC and PC) have to possibility to spot possible deviations from the planned trajectories which – if unnoticed for too long time - may jeopardize their controlling activity either at strategic and tactical level with negative effects on efficiency.
	☐ Flexibility	
	☐ Predictability	
	☒ Safety	The possibility to spot deviations of a/c from planned trajectories can help controllers to prevent conflicts before they occur or foster their timely detection as soon as they occur. This may have at list a limited impact in improving the safety performance of the overall ATM system.

	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	– **Issue n.12:** Poorly designed automation may lead to simultaneous tasks competing for user attention or causing interruptions of high workload activities, reducing efficiency and increasing the risk of human error The HMI design chosen for the visual alerting of this function seems to prevent or at least minimize the risk of causing interruptions of other important monitoring tasks competing with the monitoring of a/c deviations from their planned trajectories. First of all the alert is only visual and not aural as in the case of some safety net implementations. Furthermore the indication “HORIZ” or “VERT” is displayed in a colour which can be clearly distinguished from an STCA (typically in sharp red, highlighting the entire label and also the connection with the other aircraft in conflict). Therefore, when competing for controller’s attention, there is very limited risk that an ERATO monitoring alert will be excessively intrusive and take priority over other more urgent alerts.	
	13.4 Human Performance and automation issues potentially not mitigated	
	– **Issue n.5:** Automation could require additional system inputs, which may lead to increased task load and reduced acceptance – **Issue n. 23:** Inadequate trade-off between nuisance/false alerts and warning time may cause mistrust in automation and increase workload. The ERATO monitoring function relies on timely and correct updates by the ATCO of the planned a/c trajectory by way of menu selection onto the CWP HMI. Such updates are required independently from the monitoring function and are necessary also for other purposes of the ATM system (e.g. as an aide-memoire for the controller regarding instructions s/he has previously issue or to ensure a correct performance of other tools, such ERATO Filtering and What-if function. Nonetheless the function should be appropriately tuned to prevent an excessive number of nuisance alerts caused by late controller’s updates and the use of the function in airspaces requiring an excessive number of trajectory modification and radar vectoring instructions (e.g. in crowded TMA areas) should be carefully considered, to prevent that a too high traffic load is required to update the system, thus jeopardizing the benefits achieved in terms of efficiency and safety.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☐ Likely yes ☐ No ☒ Likely no Explanation: The ERATO Monitoring function may imply minor changes in controller’s working methods. However these are unlike to require changes in standard ICAO procedures.	
FINAL CONSIDERATIONS		
14	What can be learnt from the proposed change in HP automation support?	
	The ERATO monitoring function appears as a good example of non-intrusive support to controller’s performance in monitoring and conflict detection tasks. The design of its HMI seems to be consistent with an holistic view to automation design, preventing automated alerts from being simply added with an incremental logic, not taking into account other existing alerts (e.g. those triggered by safety nets) and tools. Such design principle seem to positively contribute to the achievements of KPA targets such as efficiency, capacity and safety. On the other hand the introduction of this function, such as those of other supporting functions (e.g. ERATO Filtering and What-if) is expected to actually provide the expected benefits only if	

	controller's working methods include a systematic updates of trajectory related data into the CWP HMI even when controller-pilot communication is still entirely based on R/T communication. If the function is introduced in an operational context in which this is not practically feasible or not considered as a priority the expected benefits will be drastically reduced or counterbalanced by the negative impact caused by nuisance alerts.

4.2.12 ERATO (En-Route Air Traffic Organizer) Task Scheduler Function

1	Title of the automated solution
	ERATO (En-Route Air Traffic Organizer) – Task Scheduler function
2	Short description of the concerned automation
	ERATO is a medium-term conflict detection tool integrated in the CWP and intended to increase controller's efficiency in conflict detection and resolution. It includes different functions, such as: A) Filtering and what if function, B) Monitoring function, C) Task Scheduler function. It is intended to be used by both PC and EC.
	2.1 Description of the function
	The ERATO Task Scheduler function often referred to as Agenda, provides the ATCO with a service that helps him with scheduling (priority ordering) the potential conflicts that needs to be resolved. Such service is provided on a side display separate from the main radar screen to both PC and EC and is intended to support mutual awareness between the two roles on the conflicts to be resolved.
	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐ abnormal situations The ERATO toolset is designed to support normal working practices related to traffic separation assurance activities.
	Which level of traffic does the function support? It is intended to provide support to the ATCO with all levels of traffic. Nonetheless more added value is expected in case of medium-high traffic levels, due to the possibility to order and prioritize the traffic situations that need to be resolved. If associated to appropriate working methods the function is also expect to provide benefits in terms of mutual awareness between PC and EC fostering a better balance of the workload between the two.
	2.3 Concerned domain
	☐ Air ☒ Ground ☐ Air-Ground
	2.4 Operational environment
	From a technical point of view the function can work on both En-route and TMA sectors. However a better performance (and therefore a better automation support) is envisaged in en-route sectors where the number of quick vertical evolutions and radar vectoring instructions by ATCOs is expected to be smaller, thus reducing the possibility to generate unnecessary alerts caused by lack of timely updates of the planned trajectory into the system.

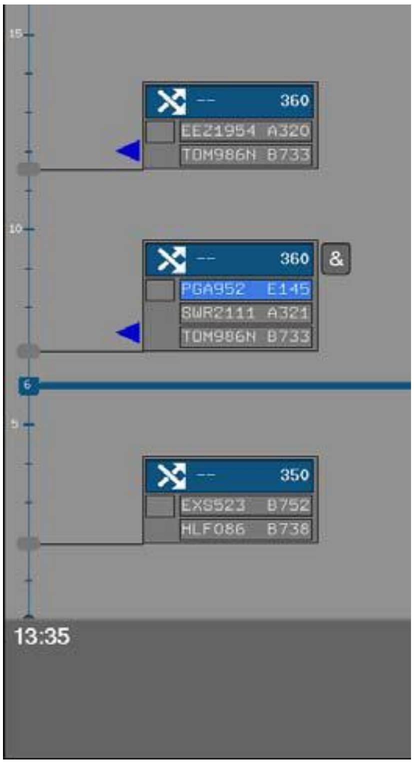
2.5 Reason for the change/ Problem to be handled

The traffic conflicts to be resolved do not have all the same urgency, therefore there is a need to prioritize them at both strategic and tactical level. The major benefits are of course achieved if conflict are prevented or solved at strategic level, thus reducing the need for late corrective instructions and fostering a safe, orderly and expeditious flow of traffic. However if less urgent conflict are solved before more urgent conflict, there is a risk that some of the more urgent ones will remain unsolved until they can only be managed by the EC with tactical corrections.

Furthermore the EC is the only one who can communicated with pilots, while the PC can only communicate directly with the EC and suggest her/him the best actions to be performed. In strip-less environment such voice communication is generally very rich but inherently ephemeral if not supported by some kind of tool, thus limiting the possibility to have mutual awareness of what is still to be solved and in which order of priority.

2.6 Applied solution/intervention

The ERATO Task Scheduler function provides ATCOs with a timeline representation of clusters of a/c that may be conflicting. The representation of each cluster include a number of information such as: the call signs and the type of a/c, the number of involved a/c, the geometry of the conflict, the separation level, the status of the problem (e.g. still to be analyzed, already analyzed, etc.).



ATCOs can click on such clusters to highlight the corresponding conflicts on the main radar screen.

As a matter of fact the clusters represent a list of conflict “proposed” by the system based on its own parameters. The ATCOs are allowed to check each of them, decide whether they are a real issue or not and modify the order of priority when necessary. The conflicts displayed by the system which are not considered a real issue by the ATCO can be eliminated with a sort of “trash can”.

Furthermore an adjustable “Problem Transfer Line” (the horizontal light blue line represented in the picture) helps to distinguish when the conflict needs to be managed by the PC or by the EC. The position of such line is based on a time parameter (e.g. from 20 up to 6 minutes to the conflict for PC issues and below 6 minutes to the conflict for EC issues) that can be adjusted by

	both roles depending on specific operational needs. In practice the task scheduler helps the PC to pre-plan the resolution of conflicts which he s/he is going to suggest to the EC. The EC, who is necessary more focussed on the main radar screen and with a narrower zoom level is unlike to interact with the task scheduler. However, looking at the task scheduler, s/he can have an idea of the amount of conflict still to be managed and of the level of workload of the PC. When a conflict passes the "Problem Transfer Line" threshold it is normally a sign that the PC was unable to manage it in advance and that s/he is probably experiencing an excessive workload.
3	REFERENCES
	– En Route Air Traffic Organizer (ERATO) – Evaluation Session (Toulouse 2-4 July 2008 and 7-11 July 2008) – Version 4.0 – 29th July 2008 – ENAV [*Restricted*] – Valutazione Operativa ERATO Demo – 16 Febbraio 2011 – ENAV [*Public*]
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	The ERATO functions are not yet used operationally. They were tested in different Real Time Simulations performed in a French ACC , involving both French and Italian controllers.
5	What were the required technical means and human resources?
	As mentioned above, the ERATO functions were tested in different RTS sessions. The simulation setting involved at least 3 en-route sectors with planner and executive controller working positions and a corresponding number of pseudo-pilots.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	The ERATO functions are not yet used operationally. They are available in the form of an advanced prototype and they have been considered in the development of the user requirements for the ATM system being developed in the context of the 4-Flight Programme, based on a collaboration between DSNA and ENAV.
7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?
	The development of the task scheduler function was intended as a smooth transition to a strip-less environment, whist maintaining some similarities in the working methods associated to the traditional physical strips. Therefore its implementation requires as a minimum the introduction in the context of a strip-less system or of a system including electronic strips only. Furthermore the use of the ERATO toolset is intended to assign a greater role to the PC in managing separation assurance activities, with respect to operational contexts not supported by any controlling tool. This may imply a considerable change in working methods and in the authority sharing particularly in ACC centres in which the PC's role is still considered ancillary with respect to the EC.
8	On which phase of maturity of the concept/automation was the good practice applied?
	☐ V1: Scope ☒ V2: Feasibility ☒ V3: Pre-industrial development and integration
	☐ V4: Industrialisation ☐ V5: Deployment ☐ V6: Operations
	8.1 Rationale

<table>
<tr><td></td><td colspan="5">The ERATO functions are currently in the form of advanced prototypes. Their industrialization has not started yet and their first adoption in a real operational environment is expected in 2015 as part of the 4-Flight industrial platform.</td></tr>
<tr><td colspan="6">CONTEXT OF THE TASK</td></tr>
<tr><td>9</td><td colspan="5">What are the concerned flight phases?</td></tr>
<tr><td></td><td>☐ Turnaround</td><td>☐ Pushback</td><td>☐ Taxi-out</td><td>☐ Take-off</td><td>☐ Climb</td></tr>
<tr><td></td><td>☒ En Route</td><td>☐ Descent</td><td>☐ Approach</td><td>☐ Landing</td><td>☐ Taxi-in</td></tr>
<tr><td></td><td colspan="5">9.1 Rationale</td></tr>
<tr><td></td><td colspan="5">The ERATO Monitoring function can be made available to controllers in both En route and TMA airspaces. Nonetheless ERATO is expected to perform much better in en-route, since the accuracy of trajectory prediction is favoured by sufficiently stable trajectories, with a limited number of vertical evolutions. If the trajectory prediction is inaccurate or controllers do not have time to input updated information in the system every time an instruction is issued via R/T communication, the number of nuisance alerts may increase to al level which compromises the usability of the function.</td></tr>
<tr><td>10</td><td colspan="5">Actor(s)</td></tr>
<tr><td></td><td colspan="3">Air: Pilot
☐ PNF ☐ PF</td><td colspan="2">Ground: ATCO
☒ EC ☒ PC ☐ Supervisor ☐…</td></tr>
<tr><td></td><td colspan="5">10.1 Rationale</td></tr>
<tr><td></td><td colspan="5">As anticipated the function is mainly supporting the activity of the PC who as more time to interact with it on a window separate from the main radar screen with respect to the EC. Nonetheless the function also support mutual awareness between the two roles keeping track of the conflict which have been already analyzed and prioritized by the PC and helping the EC to understand the level of workload experienced by the PC during their cooperation in conflict resolution activities.</td></tr>
<tr><td colspan="6">TASK</td></tr>
<tr><td>11</td><td colspan="3">Pilot tasks</td><td colspan="2">ATCO task</td></tr>
</table>

	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☒ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☒ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☒ Ground-ground communication
	11.1 Rationale	
	The primary role of the ERATO task scheduling function is to support the traffic *monitoring* activity as well as the detection of conflicts, thanks to the possibility to visualize them on a timeline representation. Nonetheless the possibility to manipulate the sequence, as well as to check and prioritize the conflict also supports the PC in its planning activity. Finally the shared representation between EC and PC and the possibility to visualize and tune up the “Problem Transfer Line” is a useful support to ground-ground communication between EC and PC.	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	The task scheduler function is expected to increase the cooperation between PC and EC. Associated with the ERATO Filtering and What-if function it is expected to move some of the workload from the EC to the PC fostering an earlier management of conflicts as opposed to situations without any support tools. This may also partially alter the authority sharing between the two roles, particularly in ACC centres in which the PC’s role is still considered ancillary with respect to the EC.	

12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA			B0	B4	C0	C2		
	12.1 Rationale								
	The function provides at the same time a support to *information analysis* (identifying which aircraft may be in conflict and how urgent are the conflicts to be resolved) and a support to *decision and action selection* (proposing an order to follow to get in touch with a/c and solve the								

	conflicts. The information analysis is based on parameters which may be also manipulated/tuned by the ATCO (B4), e.g. there is a possibility to inhibit some conflicts which are not considered operationally relevant. While the decision support is operated by proposing to the ATCO an order to follow for the resolution of conflicts, whilst leaving her/him complete freedom to consider conflicts different from those indicated by the system (also creating a representation of them on the timeline) and/or the possibility to propose a different order (C2). In both cases the situation before the change is assumed not to include any tool like the task scheduler. Therefore the automation level is supposed to be respectively B0 and C0.	
IMPACTS ON HUMAN PERFORMANCE		
13	13.1 Which changes do you see in the way the Human Performance is supported?	
	There is an expectation that the number of conflict managed at strategic level will increase and that the PC will have more opportunities to support the EC in solving the conflicts for which a solution at strategic level was not possible.	
	13.2 Which benefits do you expect on SESAR KPAs?	
	☐ Capacity	
	☒ Efficiency	The possibility to spot well in advance potential conflicts is expected to enhance ATCO's efficiency in organize an orderly and expeditious flow of traffic at each sector level, without degrading currently safety levels.
	☐ Flexibility	
	☐ Predictability	
	☒ Safety	The possibility to spot well in advance potential conflict is expected to at least maintain current ATCO's safety performance, whilst enhancing their efficiency in organize an orderly and expeditious flow of traffic at each sector level.
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	– **Issue n.8:** Automation support for decision making may be based on too simplistic algorithms and parameters to cope with the complexity of the operational environments inducing workarounds and higher workload in human operators. – **Issue n.23:** Inadequate trade-off between nuisance/false alerts and warning time may cause mistrust in automation and increase workload. As for the ERATO Filtering and What-if functions the ATCO maintains complete control on the interaction with the automation. The problems displayed on the agenda are only 'proposed' by the system as a mean to organize the work. The ATCO is free to accept them as relevant, to attribute them higher or lower relevance or to completely remove them. This reduce the risk for the automation of producing disturbance in case the trajectory prediction is insufficiently accurate and eliminates the need for workarounds when the indications provided by the automation do not take into account additional constraints emerged in the specific operational situation.	
	13.4 Human Performance and automation issues potentially not mitigated	

	The Agenda works as an assistant: it proposes some potential problems, but it does not constrain the ATCo's behaviour in any way. The ATCO maintains the complete responsibility and can delete any problem that s/he does not consider relevant, by using a dedicated waste basket. Once deleted, the problem remains inside the basket regardless of the results of ERATO new calculations, even if the prediction gets worse. Only a further controller's action could re-position the problem into the scheduler. During the RTS exercises such mechanism was sometimes questioned by the ATOCs and it was argued that some criteria should be introduced to trigger a re-insertion of the problem in the task scheduler if the automation perceive that the concerned problem is considerably worsening.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: The ERATO Task Scheduler function may imply minor changes in controller's working methods but no changes to standard ICAO procedures.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	The ERATO Task Scheduler function appears as a good example of non-intrusive support to controller's performance in monitoring and conflict detection tasks, with possibilities for the user to establish a sort of dialogue with the automation, whilst maintaining full control of the interaction. However, as for other automated functions including some kind of acknowledgment mechanism (in this case the possibility to delete from the schedule a problem which is not considered relevant by the user) it poses the problem of identifying a good mechanism for establishing which are the situations in which it is appropriate that automated interventions are again activated.

4.2.13 E-TLM (Enhanced Task Load Monitoring)

1	Title of the automated solution
	TMS (Task Monitoring System) – e-TML (enhanced TASK Monitoring Load)
2	Short description of the concerned automation
	Sectorisation is dynamically adapted to changing traffic patterns and flows to make best use of the available ANSP resources. Close co-operation with military authorities will assure the smooth transition to/from periods of airspace reservation with as much prior notice as possible so that any opportunities for efficiencies can fully exploited. The use of a TMS (together with the associated technologies described further on) will enable its implementation. TMS is a ground tool which can be used as a sector complexity tool manager by the complexity manager. The aim of the tool is to provide information about the expected workload in the controlled volume, taking into account traffic forecast two hours in advance. It also provides a proposal of the optimal sector configuration and a set of indicators. It includes different functions: A) e-TLM (enhanced Task Monitoring Load) it is composed by: A.1) WAC – provides a Workload matrix for each sector; A.2) Sector Optimizer – provides information about the optimal sector configuration based on the information about workload forecast and configuration parameters (available staff); B) Complex Workload Matrix – provides different complexity indicators than workload.
	2.1 Description of the function

The aim of the e- TLM function is to improve efficiency and capacity management by proposing sector configurations which fit better with the traffic complexity forecast in the next two hours.

The system calculates in real time the expected workload in the next two hours for the different airspace volumes. With this information and the available sector configurations (airspace volumes groups) the tool proposes the configuration which balances better the workload taking into account some user preferences as number of staff.

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

Which level of traffic does the function support?

The system is intended for high demand of ANSP resources, so it is supposed to provide useful information under high traffic load. The tool is based on a methodology of calculating workload which is not calibrated for very low traffic levels.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

2.4 Operational environment

It is mainly intended for use in en-route sectors, but it could be applied to TMA sectors

2.5 Reason for the change/ Problem to be handled

As flights will principally be filed and operated on 4D business trajectories, i.e. trajectories from SID exit till STAR entry, the airspace and the flow and capacity management will have evolved to a very responsive system that is mostly aimed at making resources (staffed sectors) available where and when necessary.

The TMS tries to enhance the capacity management and system efficiency in a volume composed by sectors, balancing the forecasted workload between them.

Besides, it improves the safety, because it allows decreasing the risk due to high workload or at least provides information about workload peaks.

Thus it improves controller efficiency by optimization of its work.

2.6 Applied solution/intervention

The objectives of the tool are to identify mental controller overloads in the sectors considered given the current sectorisation (also known as configuration), dynamic traffic density and overall traffic complexity.

Amongst the tool objectives it is possible to name the following:

- Assess the impact of different sectorisations in terms of controller team workload.
- Identify the optimum sectorisation (in terms of workload distribution) given a forecasted / expected traffic density and/or workload.

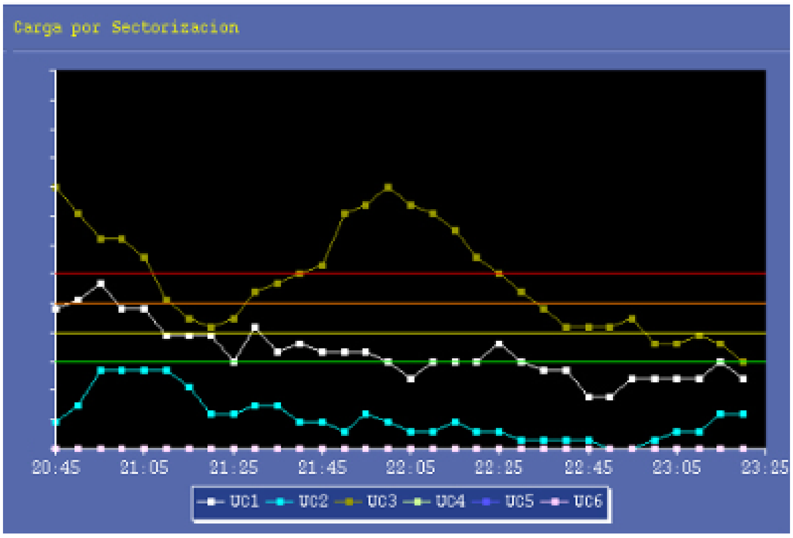
To meet these objectives, the tool implements the following functions (this is not a full functional set; the functions shown are only meant to be representative):

- Workload prediction for different controller working positions within a given sector configuration, and current and forecasted traffic loads.

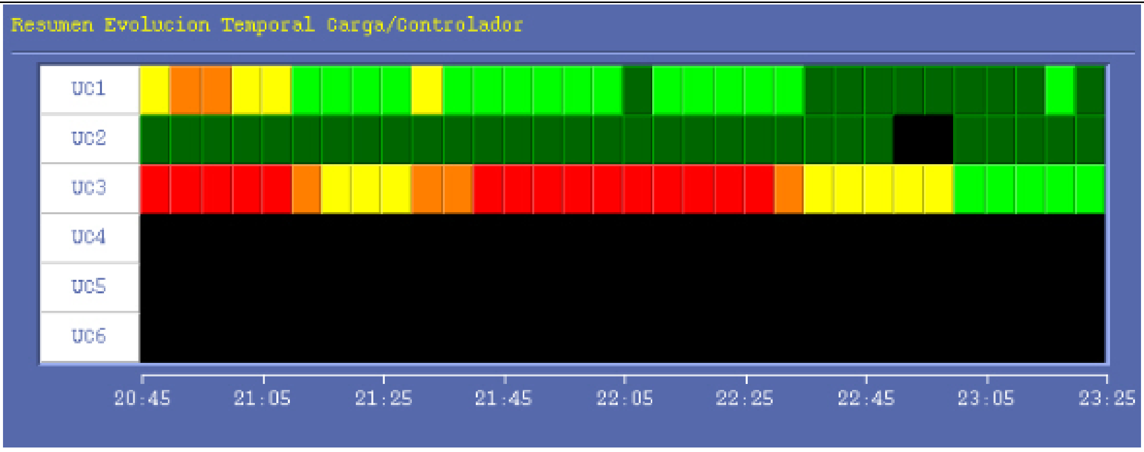
- What-if analysis based on the reconfiguration of the airspace.
- Decision making support function that presents the complexity manager a range of best options regarding sectorisation.

The table shown in the above figure indicates the controller and the sectors that he/she has to manage.

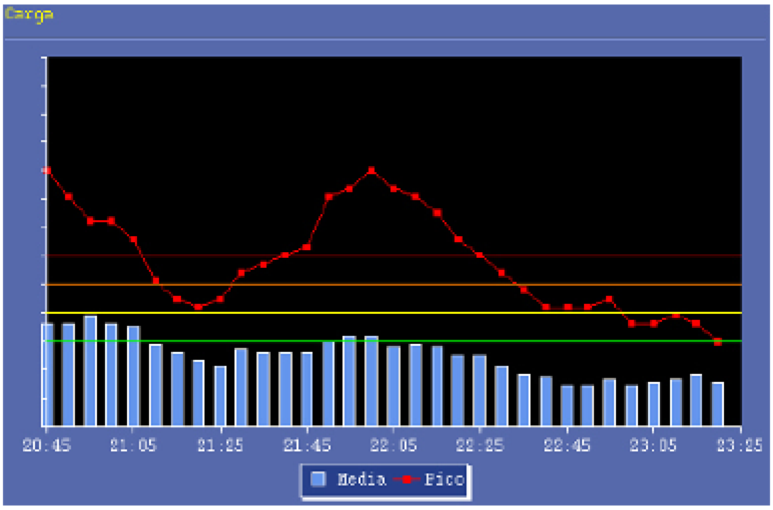
The following sub-window shows a graph with the workload of each controller in a defined period. Each curve corresponds to each controller .The horizontal colour lines are the levels of workload. Furthermore the size of period is configurable.



The following sub-window shows a graph with the workload of each controller in a defined period. The colour red indicates that the controller is overloaded. The horizontal axis is the time scale.



The following sub-window shows a graph of mean and peak global (all controllers). Furthermore, the four horizontal lines show the different levels of workload. The horizontal axis shows the time scale and the vertical axis indicates the controller's workload.



3 REFERENCES

[2007] Enhanced Traffic Load Monitoring, 26th Digital Avionics Systems Conference (DASC 2007), http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=4391890

All the following references have restricted access. Please contact Aena's project responsible in case you need to access them.

[2005] E-TLM Optimisation Module Presentation, 2005_03_07_G2G_eTLM_Optimisation.pps
[2005-1] E-TLM Workload Calculator Module Presentation, 2005_03_07_G2G_eTLM_WhatIf.pps
[2009] NORVASE report 2009, AENA DOSC-10-DTC-365-1.0 [2009-1] E-TLM Tool Description, eTLM_Tool_Description_v1.0.pdf

CONTEXT

4 In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*

	The e-TLM tool and its associated operational concept, named Dynamic Resectorisation (DR), were initially validated in the GATE TO GATE project sponsored by the European Commission in the V Framework Programme (see [2007]). Then e-TLM was integrated into the ACE Simulator (Avenue Compliant ESCAPE) for the Maastricht Upper Airspace Control Centre. It was first adapted to the TMS L0 (Traffic Management System Level 0) in MUAC to reach the robustness required for operational implementation and finally integrated in the TMS L0 as a future support tool for the Meta Sector Planner (new ATC role defined by MUAC). Currently an industrial version is been developed to be integrated into a SESAR IBP as part of project P4.07.01.
5	What were the required technical means and human resources?
	The means used were fast time simulation and shadow mode using controllers. The following enablers are considered necessary to implement the full operational concept (please take note that the implementation which is already in place does not have the full functionality): • Aircraft equipped with enhanced flight management and navigation capability; • Aircraft operator systems updated to interface with enhanced ATM systems and revised data formats; • Air-ground datalink communications services for controller-pilot datalink (CPDLC); • Airport ATC Operational Planning and Management Systems upgraded for collaborative working; • Airport operator systems upgraded for collaborative working; • ATCC airspace management system enhanced for collaboration and information sharing; • ATCC operational planning and management systems upgraded for collaborative working; • ATCC operational planning and management systems upgraded to enhance en-route and TMA operations; • ATFCM flight plan processing system enhanced with extended information; • ATFCM strategic and pre-tactical tools enhancements; • ATFCM tactical system enhanced with extended information; • ATFCM tactical system tools enhancements; • ATM Information based on common data models and data exchange standards; • Controller workstation equipped with tools for conflict management; • Controller workstation equipped with tools for processing and display of flight-related information; • En-route and TMA surveillance data processing systems enhanced to integrate new/improved data; • Flight data processing system enhancements to integrate new data sources; • Ground-ground data communications services for ATFCM; • Ground-ground data communications services for flight data; • Meteorological forecasting and nowcasting enhancements; Navigation infrastructure for RNAV.

6	If applicable: How often was the good practice applied in the past? Please estimate.				
	In the past the supervisor was the actor in charge to decide the optimal solution based on information provided by FMP (Flow management position). This information was related to the amount of flights forecast for each volume; however the innovation introduced by e-TML is the calculation of workload based on complexity. In conclusion this good practice has never been applied in the past outside the laboratory.				
7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?				
	Currently it is not integrated in an existing system.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☒V2: Feasibility	☒ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations		
	8.1 Rationale				
	The Concept of Operation behind Dynamic Sectorisation has been fully validated up from V2 to V3 maturity level (validation exercises performed in ACC Sevilla in 2006, in Maastricht in 2009, and future validations within the SESAR project P4.7.1 in Maastricht planned for end of 2011). Currently an industrial version is been developed to be integrated into a SESAR IBP as part of project P4.07.01.				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☒ En Route	☐ Descent	☐ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	Even though a system such as the one proposed concerns all flight phases because it has a strong impact on the planning, its main usage and focus will be in the en-route phase.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☐ EC ☐ PC ☒ Supervisor ☐…			
	10.1 Rationale				
	In the past the information was analyzed manually by the Flow management position (FMP) who analysed it consulting his information sources without any system support. Supervisor was the responsible to make all the possible sectors configurations options and choose one of them based on her/his experience and on the forecast received from the FMP without any system support. The complexity manager will have the role of a “strategic and pre-tactical planner” (using the existing nomenclature). From a SESAR standpoint, the complexity manager could be either the Network Manager or the Sub-network Manager (the specific role will be defined during the				

upcoming validation exercises). From this standpoint the role taken in this situation will always concern the planning and updating of the RBT.

TASK

11

Pilot tasks	ATCO task
Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication

11.1 Rationale

The aim of the tool is provide information about the expected workload and provide the optimal sectors configuration taking into account the foreseen traffic, so it provides higher precision regarding the strategic planning. Currently there is no system support to these specific activities, making it necessary to rely strictly on experience.

11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

There are no changes in responsibilities, authority sharing nor delegation. The only change is that a new role “the complexity manager” emerges, who integrates the functions of FMP and supervisor.

12

Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
LA	Before change	After change	Before change	After change	Before change	After change	Before change	After change
0	A0	A5	B0	B2	C0	C2	n.a.	n.a.

12.1 Rationale

<table>
<tr><td></td><td colspan="2">Information acquisition:

Before (A0): Human obtained the information without any tool support. He only had traffic dates and his/her own experience for choosing the best configuration.

After: (A5) Data collection is automatic. The system integrates dates coming from different sources but this information is not visible for the human. The system provides the controller's workload, the optimal configuration and other proposal but it does not show the information obtained by the resources.

Information analysis:

Before: (B0) Before the expected change the level of the "information analysis" was B0, because the information was analyzed manually by the user and all the analysis and decision making was made without system support.

After: (B2) Once the tool is available, it allows the user to access a detailed analysis of the forecasted traffic. The system does not do it automatically; the user has to press a button to obtain the desired result, hence e-TLM does not trigger any visual and/or aural alerts as this system is a planning tool.

Decision and action selection:

After: (C1) Before the expected change the user was solely responsible to make all the possible sectors configurations options and choose one of them based in her/his experience.

After: (C2) Once the tool is in operational use, the level of "decision and action selection" is C2.The system will provide options and their ranking, providing an effective tool to support the decision-making process. The controller can select one of the alternatives proposed by the tool or his/her own one (the system allows fix a specific configuration or modifying the time of this configuration).</td></tr>
<tr><td colspan="3">IMPACTS ON HUMAN PERFORMANCE</td></tr>
<tr><td>13</td><td colspan="2">13.1 Which changes do you see in the way the Human Performance is supported?</td></tr>
<tr><td></td><td colspan="2">The deployment of the e-TML will have a new associated role "the complexity manager". This new role will substitute the role of both the actual FMP and supervisor. Currently the role of the FMP is to analyze the traffic forecast in a manual way based in different sources of information, while the supervisor tries to choose the best configuration being supported by the FMP. Nonetheless the supervisor tries to choose the best sectors configuration without any automatic system support so his selection is only based on his experience.

e-TML will integrate the information and generate several options so it will facilitate the task of the "complexity manager". This system will achieve the optimal sectors configuration based on complexity so it will achieve to reduce workload peaks and balance the workload between sectors.</td></tr>
<tr><td></td><td colspan="2">13.2 Which benefits do you expect on SESAR KPAs?</td></tr>
<tr><td></td><td>☒ Capacity</td><td>The capacity can be increased not in a concrete sector but in an airspace volume, because the expected workload in the airspace has been balanced between the sectors, not changing the traffic but the sector configuration.</td></tr>
<tr><td></td><td>☐ Efficiency</td><td></td></tr>
<tr><td></td><td>☐ Flexibility</td><td></td></tr>
<tr><td></td><td>☐ Predictability</td><td></td></tr>
<tr><td></td><td>☒ Safety</td><td>e-TML will reduce the risk of overload, reducing workload peaks and</td></tr>
</table>

		providing information about them.
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	-Issue n 10: Automation may increase task demand and cognitive workload e-TML will achieve the optimal configuration which best balances the workload between controllers, hence the system will reduce workload peaks and thus avoid controller overload. Before implementation of e-TLM the supervisor cannot assure that the workload was balanced, so some controllers could be overloaded while other ones experienced low workload. Moreover the "complexity manager" will achieve the best configuration in a few seconds pressing a button, so e-TML will reduce the manager complexity's workload drastically.	
	13.4 Human Performance and automation issues potentially <u>not</u> mitigated	
	-Issue 5. The automation of routine tasks may remove an important information source which may reduce situation awareness**.** After the implementation of e-TLM, if this tool fails the complexity manager will not have enough information to decide the needed configuration because of e-TLM integrates the incoming information and shows him/her only its analysis, so complexity manager will not have any information resources. Moreover in the case that the complexity manager could obtain this information by other resources he/she will be used to use e-TLM so probably he/she will be not able to achieve the best configuration analysing the available information resources and his/her workload will increase notably.	
	13.5 Would you expect that procedures will change?	
	☐ Yes ☒ Likely yes ☐ No ☐ Likely no Explanation: The use of the e-TML will allow the introduction of a new role "the complexity manager". Furthermore the number of configuration changes will be increased so it will affect the situation awareness of the controller but will not modify their procedures.	
FINAL CONSIDERATIONS		
14	What can be learnt from the proposed change in HP automation support?	
	The use of the e-TLM showed that the use of support tools provides the background needed to start the full automation of a specific process. The stepwise approach followed during the R&D of the e-TLM has facilitated user buy-in and acceptance, thus making the transition to higher levels of automation easier. The development of the e-TLM also shows that automation cannot be restricted to just the technical aspects. It is quite important to always take into account human factor issues such as situational awareness in highly automated environments, and user trust.	

4.2.14 FAGI (Future Air-Ground integration)

1	Title of the automated solution

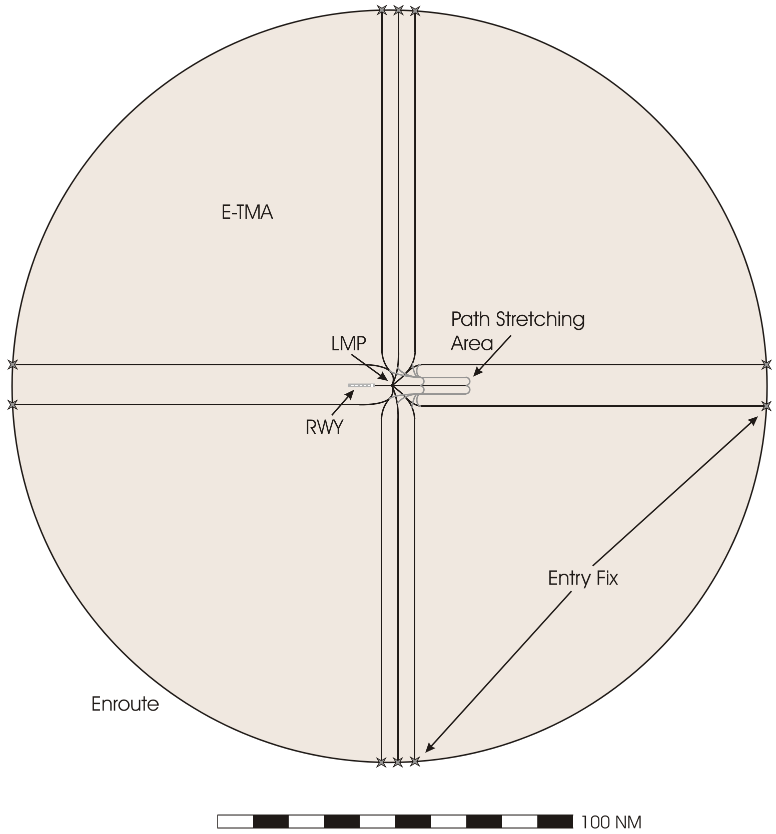
FAGI (Future Air Ground Integration)

2	Short description of the concerned automation

The main objective of the DLR-internal project FAGI was to enable approach controllers to integrate Continuous Descent Approaches (CDA) into a stream of conventionally guided traffic.

The basic concept relies on the following arrangements that are all together responsible for the success of managing mixed approach traffic:

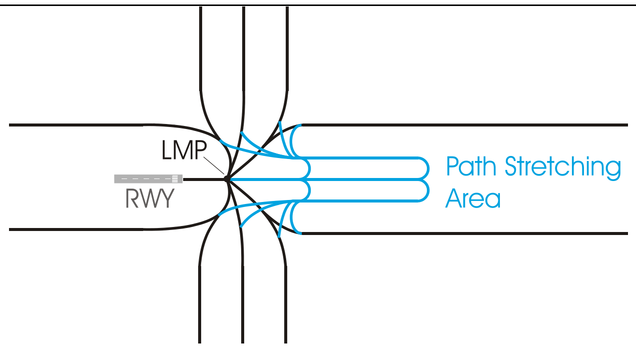
- A sophisticated decision and guidance support tool AMAN on ground for controllers
- An air-ground protocol for the negotiation of requested times of arrival (RTA)
- A new layout of the extended terminal manoeuvring area (E-TMA) with the concept of late merging and parallel Standard Arrival Routes (STARs) and Transitions



Schematic illustration of the FAGI airspace structure with Late Merging Point (LMP)

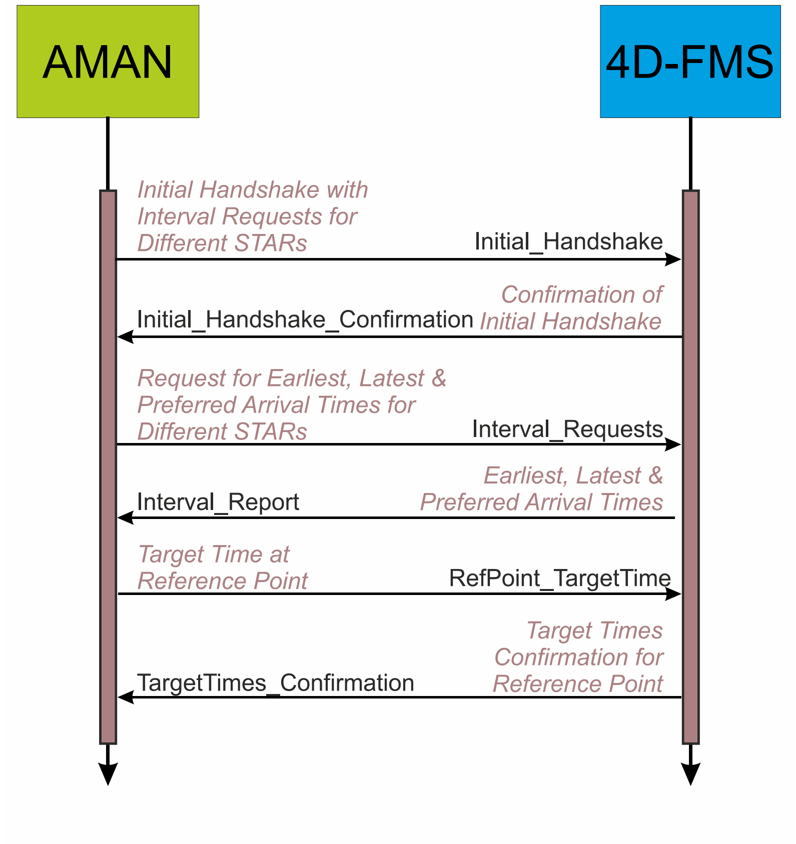
The suggestion is to have two or three entry fixes per approach direction with laterally separated parallel arrival routes. Thereby the ACC controller has the possibility to split up the traffic from one direction to several entry fixes, so that they will not violate separation minima until the a/c reach the inner circle of 10 nautical miles (NM) around the LMP. The position of the LMP is on the final just less than 6 NM before the threshold.

Negotiated CDA approaches are flying on predefined short ways to the LMP. The conventionally guided traffic, that means guided by radio telephony (R/T), is lead to the LMP by using trombone patterns as path stretching areas, depicted in blue colour on the figure below.



The inner circle around the Late Merging Point (LMP)

The FAGI concept takes advantage from the highly precise 4D-FMS equipment in parts of the modern a/c fleet. When these a/c are additionally equipped with data link functionality an air ground communication takes place before top of descent (TOD) where the time at LMP is negotiated between AMAN and 4D-FMS. This negotiation combined with separated arrival routes allows the a/c to fly CDA profiles, saving fuel burn and reducing noise emissions. It will produce benefit for the airlines to upgrade the a/c equipment, as those a/c are allowed to fly CDAs on short ways to the runway.



Air Ground Negotiation Procedure

The air ground negotiation results in a RTA for the LMP that is used by the AMAN for sequence building purposes. The figure above gives an impression of the negotiation process.

If the time interval sent by a fully equipped a/c cannot be used for sequence building by the ground system or the a/c deviates a lot from its planned trajectory there is always the fallback case of guiding this a/c like a conventional one. In FAGI this process is called “degradation”.

As the tasks of the approach controllers are highly influenced by the FAGI concept it can be stated that without specially tailored controller support the time-based integration of negotiated CDAs cannot be realised without a significant loss in capacity. So for the FAGI Real Time Simulations (RTS) the trajectory based DLR AMAN “4D-CARMA” was adapted to the approach controller needs.

The simulation working positions were those of the so-called pickup and feeder. The pickup welcomes the aircraft in the E-TMA and implements a pre-sequence by speed and descent advisories. The role of the feeder is to build the sequence on the centreline by a timely precise turn-to-base command and appropriate speed and descent commands for interception of centreline and grant the prescribed separation on the last miles before landing.

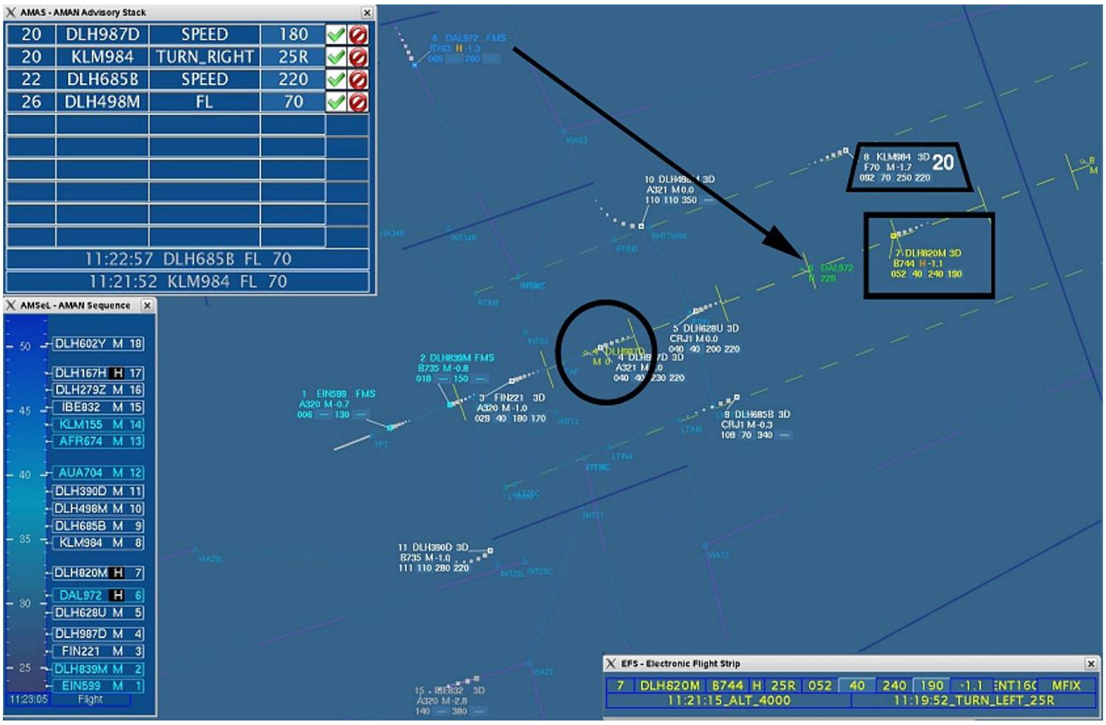
2.1 Description of the function

The automated function described here (i.e. AMAN) consists of five main functions connected each other and used by approach controllers.

This subsection provides an overview of all these main functions, as follows:

1. Dynamic Time Line

   To visualise the planned landing sequence and target times the controller is supported with a dynamic time line. The time is displayed top down to the actual scenario time. Right to this time line you see icons fixed to it from all aircraft planned by 4D-CARMA. The icons contain callsign, wake class, and position in the sequence. Furthermore the wake class “heavy” and the equipment status are highlighted by a colour code. Additional to the time line the system supplies the controller with an electronic flight strip as displayed in the figure below at the bottom right.



FAGI radar display with controller aids

2. Timely precise guidance advisories

The controller has the possibility to choose what kind of advisories consisting of reduce, descent and turn advisories should be displayed. These advisories are first shown 30 seconds before they should be executed. A second by second countdown shows how near the advisory is to its proposed execution point of time. Accepting the advisory moves the cleared commands to the a/c label in the radar display. As the controllers liked most the turn-to-base advisory display, they proposed to integrate it into the a/c label by showing the countdown next to it.

FAGI radar display with turn-to-base countdown integrated to label

3. Ghosting and Targeting

As FAGI is following the modern concept of time-based guidance the controllers feel uncomfortable not to be able to continue with their distance-based procedures they are used to. It is almost impossible to translate the scheduled time distances of the AMAN to comprehensible spatial distances for the controller. So we implemented in 4D-CARMA a target label function, which projects an additional aircraft "target" label of a conventional approach with its remaining (AMAN-planned) flight distance to the threshold on the centreline. The figure below shows flights "DLH996U" and "AFR990" on the northern and southern downwind with a remaining flight distance of more than 20 NM to the threshold. The target label (yellow labels with sequence position 3 and 4) are the projections of their planned remaining flight distance onto the centreline. The target label is moved with the AMAN-planned speed in the flight direction of the final and disappears when met by the turned a/c. Symbolising the ideal approach window the feeder has the task to meet the target label by giving the pilots timely precise turn-to-base commands.

FAGI radar display with a/c DLH996U and AFR990 on downwind segments and their

(yellow) targets on the centreline

The second kind of item called “ghost” is the item representing negotiated CDA approaches. That means we compute where the negotiated CDA aircraft would be located on the centreline if it was taking this way. In the figure below: The green label of flight “DAL972” on the bottom right of the screen shot represents the “ghost”, moving on the final. The label of the real aircraft is the light blue label on the top left, coming from the north and flying directly to the LMP without using the path stretching area.

FAGI radar display with equipped a/c DAL972 and its (green) ghost on the centreline

4. Reporting line

As the guidance of the aircraft flying negotiated CDAs is not requiring radio activities apart from transferring control to other controller working positions the controllers complained of losing situation awareness for them. They proposed to force the pilots to call in when crossing a “reporting line” that is near the position where the pickup would transfer the control to the feeder (Figure above, dark blue line). This report helps pickup and feeder controllers not to neglect an aircraft close to the LMP heading for it automatically. At this point they get the last chance to make use of the fallback procedure by giving a direct to, reduce or descent command to an equipped aircraft and thereby degrade and treat it like a conventional one.

5. Move and Freeze

To supply the controller with a powerful procedure to communicate his own planning intentions to the system the functionality of “freeze” and “move” was implemented in the dynamic time line window on the controller’s display. The freeze command makes it possible to fix a sequence from any position to the bottom of the timeline where you will always find the aircraft with position one in sequence. This means the system is not going to change the position of any aircraft in the frozen sequence but adapts the scheduled landing times. The functionality overrides all optimization criteria that are fundamental to sequence building in the sequencing algorithm. A comparable effect is achieved by a move command. If the controller decides to move aircraft A at position 8 to position 10 after aircraft B then it will remain there until landing or until the controller decides to release the moved aircraft again. The move command is implemented as drag and drop on the timeline. If move or freeze commands were given, you will have a colour coding of the concerning areas on the time line. Moving of aircraft with negotiated CDAs is not permitted as they are not allowed to change their target times.

2.2 Which kind of situation(s) does the concerned automation support?
☒ normal situations ☐ abnormal situations

	FAGI is intended to support ATCOs in traffic situations with high task load in an extended TMA operational environment, where CDAs and conventional approach procedures are implemented at the same time.
	2.3 Concerned domain
	☐ Air ☒Ground ☐ Air-Ground
	2.4 Operational environment
	FAGI is intended for use in TMA and E-TMA (in part todays ACC sectors). It is designed to assist controllers in guiding mixed traffic, so that CDAs can be managed in crowded TMAs.
	2.5 Reason for the change/ Problem to be handled
	TMA airspace is still generally regarded as being busy and it is certainly becoming more complex, since the demand of traffic is increasing. Some initiatives, such as P-RNAV and CDAs (Continuous Descent Approach) are bringing benefits today. However it is felt that more effort is needed in the transition towards SESAR. Particularly the need to contribute at the same time to fuel saving and noise abating procedures while capacity is not going down is a challenge that has special impact on approach controllers.
	2.6 Applied solution/intervention
	The combination of innovative airspace layout, air ground negotiations of target times and sophisticated controller aids in ground tools was chosen to handle the problem of mixed traffic. The application of FAGI ideas is based on the planned intensified deployment of 4D-FMS and data link installations. Air-ground negotiations will enable ground tools to get more precise estimations of the flown a/c speed and altitude profiles and thereby improve the overall ground based planning process. Although FAGI is implementing a rather high level of automation, many features intend to keep the controller in the loop and his situation awareness on an appropriate level. The FAGI concept was validated in extensive RTS at the DLR Braunschweig ATC Simulator ATMOS with several international controller teams from France, Germany, and Luxemburg. The evaluation of the FAGI trials showed that the workload of approach controllers must not be inevitably increased by integrating CDAs. The average flight time and flight path length was decreased in mixed traffic scenarios compared with baseline scenarios where the whole traffic was guided conventionally. The progress in developing innovative decision support tools and FMS functionalities will allow the implementation of air ground communication based concepts as are propagated by the SESAR programme. Nevertheless in case of absence of data link installation the air-ground negotiation of RTAs at the LMP could be realised by R/T.
3	REFERENCES
	http://www.atmseminar.org/seminarContent/seminar9/papers/142-Temme-Final-Paper-4-13-11.pdf
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*

	During the development phase of FAGI several controllers took part in consulting sessions and preliminary trials. The R&D project FAGI concept was validated in RTS with approach controllers from several European countries at the DLR APP simulator ATMOS in Braunschweig, using DLR research FMS and AMAN implementations for the air-ground negotiation and controller support functionalities.
5	What were the required technical means and human resources?
	The setup for the final validation trials in November 2009 was as follows: • All scenarios had a traffic mix of 30% equipped and 70% conventional aircraft • There was always a time line displayed by 4D-CARMA These setups of displayed controller aids were used in high and low traffic scenarios: • Base Line: without aids and all aircraft flying conventional profiles • Late Merging with two aids: timely turn-to-base advisories and ghost labels • Late Merging with three aids: timely turn-to-base advisories, ghost and target labels Several kinds of professionals contributed to every RTS run: 2 controllers, 6 pseudo-pilots, 3 HF experts and at least 3 technicians and 4D-CARMA as well as 4D-FMS engineers.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	The FAGI concept was applied at the simulation trials in Braunschweig.
7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?
	The concept generates challenges really new to approach controllers: • She/He has to estimate the automatically cleared flight level and speed profile of the equipped aircraft. The only detail that is known of this trajectory is the predicted time at the LMP. • The reduced communication with the equipped aircraft may lead to losing the situation awareness for this category. • The approach routes from equipped and conventional aircraft differ by default. • She/He has to cope with the late merging of conventional and equipped aircraft that appear on the centreline for a short time. In normal operation mode all aircraft are put into a row on the centreline before touchdown. Then the controller gets a good idea of how to produce the separation by speed commands. • The concept of time-based guidance produces new challenges differing from the traditional distance-based guidance. The radar position display and the controller aid of mileage icons nowadays lead to work intuitively distance-based. • The high level of automation produced by the negotiation with CDA flying a/c and integration of the target time results as input to the planning tool forces the controller to rely on the advisories of the system. She/He is instructed to use the facilities to communicate her/his own planning intention to the AMAN and the system recognizes those intentions in time. • The advisories of the planning system may narrow the creativity and flexibility of the controller and may influence his situation awareness.

	The implementation of the FAGI concept will have big impact on the role and procedures of approach controllers. They will have to rely on the proposed sequence and advisories and for the a/c with negotiated trajectories their job will intensify monitoring them instead of guiding. The general principle of fairness as is known in ATC, you can call it "first come first serve" is affected as equipped aircraft fly on shorter routes by default and thereby reach the threshold earlier than their conventional neighbours. That means that a/c with higher equipage level are by intention privileged as they are better adapted to new ATM concepts.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☒ V2: Feasibility	☐ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations		
	8.1 Rationale				
	The AMAN used in the project is a research prototype for testing innovative guidance procedures and HMIs in all kinds of ATM projects. The 4D-FMS used in the FAGI trials is also a research prototype, which is able to calculate trajectories and flying the route automatically meeting time constraints at waypoints in an interval of +3/-3 seconds.				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☒ Descent	☒ Approach	☒ Landing	☐ Taxi-in
	9.1 Rationale				
	The FAGI project concentrates on the role of approach controllers. The functionality reaching into the responsibility of En Route controllers is the route assignment by 4D-CARMA. That means the system proposes the Entry Fix to use for lateral separation purposes, as every direction has several available Entry Fixes.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☐ EC ☐ PC ☐ Supervisor ☒ Sequence Manager			
	10.1 Rationale				
	The actors involved in the usage of FAGI are the approach controllers, here called Sequence Manager (SM), to be comparable to the other implementations, e.g. TMA2010+, described in this document. The SM plays an essential role in the AMAN operational environment, since she/he is responsible for the whole arrival traffic management in the E-TMA down to the runway threshold. She/He can make adjustments by modifying the approach sequence aimed at smoothing the				

arrival traffic management and at reducing the overall delay. When the SM realises that the sequence proposed by the automation system deviates from her/his own plans she/he can swap the sequence position of the a/c by using the "Move" function.

If she/he is satisfied with the sequence in the part of the final approach on downwind and centreline sector she/he can force the AMAN not to change the sequence any more according to its own optimisation criteria by freezing this part of the sequence from position 1 to position x.

The above mentioned functions are all available on the time line.

TASK

11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☒ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☒ Monitoring traffic ☐ Providing traffic information ☒ Issuing instructions/clearances ☒ Detecting conflicts ☒ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☒ Ground-ground communication

11.1 Rationale

The FAGI concept supports the ATCO when planning the mixed traffic by showing the timeline with the equipped a/c easy to distinguish, as they are only allowed to be planned at a different target time when losing their air-ground contract. The crossing points of routes flown by equipped a/c with CDA procedure and by a/c using the trombone pattern are separated by concept. The late ones are entering the downwind segments at FL 70 or above, the others have already descended to FL between 30 or 40 as they are heading for the LMP on the shortest possible way.

The conventional a/c are guided by speed and altitude and turn-to-base commands over R/T. As the turn-to-base command is very time-critical in that environment the ATCO is supported by a countdown for this command at the a/c label in the situation data display.

Pilots of equipped a/c have to be aware of the air-ground negotiation and contract. She/He is responsible for executing the negotiated trajectory and calling in if she/he gets to know that the contract will not be fulfilled.

11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation

Using FAGI implies a change in working methods of ATCOs. For equipped a/c with contract they only have to monitor if the CDA is still possible and conflicts with conventional a/c are avoided. The responsibility for the layout of the CDA descent profile is completely going to the actors in the cockpits. The biggest challenge is the maintenance of the separation on the centreline and final, as a/c with contract only appear there on the last 6 NM before landing. So the support functions advisories, target and ghost projections on the centreline become an essential controller aids for the time based guidance and a change to the controller's view on the final approach phases.

12 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
LA	Before change	After change	Before change	After change	Before change	After change	Before change	After change
AMAN timeline					C0	C2		
Turn-to-base advisories							D0	D2
Air-ground negotiation							D0	D6

12.1 Rationale

As shown in the table above, the kind of HP automation support is analysed with reference to 3 main components of FAGI concept, i.e. AMAN timeline, turn-to-base advisories and air-ground negotiation.

Rationale is provided for each function analysed.

The AMAN timeline offers a C2 level of automation support. The "C" level of supported cognitive function indicates that the system provides the ATCOs with support in decision making. In fact it represents on the screen a sequence of arrival aircraft that can be considered the "best" solution at a certain moment and with certain constraints. So, the sequence is built by the system itself and provided to ATCOs who can evaluate it.

ATCOs can rely on it or even change it: this is the reason why the LOA (Level of Automation) is at level 2: this means that ATCOs can change the sequence in compliance with complex or unexpected situations and that the system accepts these changes, updating the sequence according to them.

Also the timely AMAN turn-to-base advisories and target or ghost labels can be classified as an automation at level D2. "D" because the tool provides ATCOs support for action; "2" because there is still the possibility to ignore:

1. The timely turn-to-base advisories
2. The planned approach procedure of CDA flying a/c by dismissing the air-ground contract.

The air-ground negotiation can be even declared as D6 level. This indicates a more automated level of supporting function of the system. The result of that negotiation, in fact, is executed without ATCO intervention.

IMPACTS ON HUMAN PERFORMANCE

1 13.1 Which changes do you see in the way the Human Performance is supported?

3	See explanation in field 11.2 above (Consequences on changes in roles, responsibilities, authority sharing and delegation).	
	13.2 Which benefits do you expect on SESAR KPAs?	
	☐Capacity	
	☒Efficiency	The FAGI concept implementation can improve efficiency of TMA airspace because it integrates arrival flows of traffic into a safe and efficient landing sequence based on STARs. The integration of CDAs without negative impact on the capacity offers benefit in fuel burn costs and reducing noise emissions. The human-in-the-loop simulations showed a reduced strain of controllers with respect to voice communication.
	☐ Flexibility	
	☒Predictability	The FAGI concept implementation facilitates predictability of operations because it provides a sequence of arrival aircraft that helps ATCOs and other stakeholders at the airport to know the traffic situation, especially the use of runway resources in advance. On the other hand it also provides the airlines of CDA flying a/c with their exact touchdown time at about 20 min. before landing. There will be no variations in time and way by using trombone legs, according to traffic density.
	☐ Safety	
	☐ Access and Equity	
	☒ Interoperability	The FAGI concept implementation is an example for the air-ground integration. Data about planned trajectories are exchanged between board and ATC.
	13.3 Human Performance and automation issues expected to be mitigated	
	– **Issue n.1**: Lack of user involvement in automation assisted processes may lead to reduced vigilance and loss of situation awareness. Especially a/c flying negotiated CDAs will not get commands by the ATCO so she/he might forget where the a/c is flying and in what altitude. Those a/c are supposed to be neglected during the approach phases that are not close to final. The issue is tackled by the concept of reporting lines for CDA flying pilots. – **Issue n.3:** Lack of user involvement in automation assisted processes may impact recovery from system failure. If the system is down it will be difficult to find out which a/c had a contract and for what RTA it was determined to reach the LMP. The whole planning process has to change to conventional guidance after recovery, causing high R/T communication activity. But high recovery workload is supposed to arise for all automated planning activities of ATCOs. – **Issue n.5**: The automation of routine tasks may remove an important information source which may reduce situation awareness. As the a/c with negotiated CDA contracts are flying their user preferred approach profile the ATCOs doesn't know at what altitude and speed the a/c will descend to the LMP. So the ATCO can gather information about CDA profile by monitoring the flight. Furthermore the CDA flying a/c and the conventional ones are laterally separated on the STAR legs and vertically at the crossing	

points at the beginning of the downwind segments.

- **Issue n.10:** Automation may increase task demand and cognitive workload

As CDA flying a/c and those conventionally guided are approaching on different route in the final approach the ATCO is no longer able to intuitively sequence them by estimating the length of the way they still have to fly to the LMP. The CDA a/c may be much further away but will get an earlier position in the sequence. The FAGI HMI with the planned sequence relieves her/him from the sequencing task under these complex conditions.

- **Issue n.14:** Loss of flexibility in automated systems will reduce the human potential to adapt to normal and abnormal situations

By training and often working with support functions like timely precise turn-to-base commands or ghosts and targets the ATCO may lose skills in estimating the effects of current speed and altitude on the distance and time an a/c needs to fly to any waypoint on the approach route, especially to those with crossing traffic. For that it is useful for the ground tool to have less support functionalities in times of lower task load for the retention of controllers' essential skills.

- **Issue n.18:** New automation support that results in greater use in visual information may lead to visual channel overload, with decrease in situation awareness and performance efficiency

As the ground tool is offering a bundle of visual aids for the controller to support her/his timely precise guidance the controller has the possibility to choose what kind of aids she/he would like to have displayed. When all possibilities were active the ATCOs stated that her/his picture was overloaded with moveable icons.

- **Issue n.21:** Lack of trust in automation may induce misuse, disuse or abuse of automation

If the ATCO is not satisfied with the shown plan when looking at the timeline he must get the possibility to change the sequence. Otherwise she/he will work against the system, that will process planning as before. To mitigate this kind of friction loss, 4D-CARMA offers the “Move” command in the timeline, to let the AMAN know, what the user wants, and to consider these wishes as hard constraints in all further planning cycles.

- **Issue n.25:** New communication systems that will change working methods may lead to new types of error.

As FAGI needs air-ground communication facilities different from standard R/T and CPDLC intrinsic communication errors of data link deployment will be new.

13.4 Human Performance and automation issues potentially not mitigated

- **Issue n.22:** Excessive trust in monitoring automation support may lead to complacency and reduced situation awareness

As all highly automated concepts FAGI with all its controller support functionalities may lead to complacency, reduced situation awareness and loss of skills. In the end these problems will have to be faced by well-directed tailoring of the monitoring aids and by reducing automation levels in times of low workload.

13.5 Would you expect that procedures will change?

☒ Yes ☐ Likely yes ☐ No ☐ Likely no

Explanation:

The combined use of FAGI implies changes the airspace layout and in controller’s working methods and her/his communication with the pilot. New phraseology will be needed to inform pilot or ATCO about abnormal situations caused by the negotiation and its result the contract.

FINAL CONSIDERATIONS

14	What can be learnt from the proposed change in HP automation support?
	The integration of negotiated CDAs into conventional approach traffic of big hub airports is highly affecting the working position of approach controllers. Their tasks of planning and decision making get more challenging as the complexity of the traffic situation perception and anticipation increases. The interpretation of the picture on her/his situation display is much more difficult as she/he has to distinguish between aircraft with two types of approach procedures, one of them not flying according to her/his own commands. Her/his mental picture, the base of her/his actions, has to be stated more precisely to fulfil his tasks of situation analysis, anticipation, and monitoring. To meet these requirements specific controller aids were implemented in the DLR AMAN. Amongst others these aids cover ghosting functionalities and timely precise advisories for turn-to-base commands. If the controller does not agree with the recommendations of the system he has the possibility to change them by his own input. So she/he will always feel in the loop and keep situation awareness. The further assistant part of the FAGI concept is the air ground negotiation of CDA approaches with aircraft equipped with data link and 4D-FMS. If you do not negotiate times at waypoints CDAs may not be integrated in a conventional sequence planning without a significant loss of capacity. There is no possibility to anticipate flight profiles and landing times for CDAs. So the airport will not get a stable sequence before about 20 min. before landing and thereby no trusted information for the ground handlers. The optimal use of runway capacity cannot be guaranteed. So if you install negotiated CDAs with the FAGI concept you can plan the whole approaching traffic in one time-based sequencing system. The evaluation of the FAGI trials showed that the workload of approach controllers must not be inevitably increased by integrating CDAs. The average flight time and flight path length was decreased in mixed traffic scenarios. The progress in developing innovative decision support tools and FMS functionalities will allow the implementation of air ground communication based concepts as are propagated by the SESAR programme.

4.2.15 PERSEO (Operational Sectorizations Network Effect Analysis Platform)

1	Title of the automated solution
	PERSEO (Operational Sectorisations Network Effect Analysis Platform)
2	Short description of the concerned automation
	PERSEO, acronym for “Plataforma de análisis de Efectos de Red de SEctorizaciones en Operación”(Operational Sectorisations Network Effect Analysis Platform), is a project developed by Aena to cover the local needs for a decision support tool used in ATC units about operational sectorisations in a local scope, taking into account the global effects of Aena´s sector network. PERSEO is a platform focused on providing a local/subregional tool to analyze sectorisations to be set, in each ATC, over the operation day. The main aim of this tool is to support decision making related to Aena´s Air Traffic Management. To achieve this aim, the platform works as a data mining process, collecting data of different sources of information, and delivering results through the combination and analysis of such data. These results are provided by air traffic manager system status indicators that are either calculated or extracted from the most reliable sources of information available. These indicators can provide general conclusions, allowing the user to increase the level of detail of the information displayed, in order to analyze the potential causes of any problems identified by the system, therefore providing assessment to locally solve any potential (or current) imbalance.
	2.1 Description of the function

Data Mining

The platform provides a unique data model that is able to store information coming from different data sources, ensuring the consistency and reliability of this data, and consequently allowing the possibility of its combination and analysis.

Data acquisition is performed automatically (no user actuation), providing mechanisms to configure the location of the source, transfer mode, frequency of capture, etc.

Data storage is performed automatically, as well, by different source-specific modules that adapt/transform the data from original source model to platform model, checking the reliability of the acquired data.

This process, apart from automatic, is also autonomous, recording the activity of the process, notifying errors or actions that require confirmation by the system administrator.

Analysis and indicators calculation

The calculation of the indicators will be made depending on the kind (source) of data involved in the information that will be displayed by the indicator. The platform decides, depending on the features that describe the indicator, if the analysis of data that each indicator uses is done either at applying the indicator, or at storing this data.

PERSEO provides different indicators that can be used by the final user at different time scopes: historical, meaning until the day of operation; and forecast, covering the period from the day after the operation day.

Below are some of the indicators mentioned which are currently provided by this platform:

- Capacity: Number of flights that can be controlled simultaneously in a particular sector of airspace over a period of time.
- Demand: Expected number of flights to be controlled simultaneously in a given sector of airspace over a period of time.
- Flow: Real number of flights controlled simultaneously in a given sector of airspace.

2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐abnormal situations

The tool is being developed to be used every day.

Which level of traffic does the function support?

The use of PERSEO is not limited or affected by the amount of traffic.

2.3 Concerned domain

☐ Air ☒ Ground ☐ Air-Ground

Explanation:

PERSEO is a ground system that will be used by the supervisor in an ATC center.

2.4 Operational environment

PERSEO has been developed to be used in both en-route and TMA sectors.

2.5 Reason for the change/ Problem to be handled

The PERSEO project aims to enhance controller efficiency by optimization of sector configurations. Without this tool supervisor has to obtain the sector configurations manually, consulting different sources hence PERSEO will automate and easy his/her work.

This tool will obtain the best planning of sector configurations, Each configuration requires a minimum number of controllers, for example the configuration 8A (8 sectors opened) will need 22 controllers, the configuration 7A 19 controllers, etc. If the best configuration on a specific day during a specific period of time is the configuration 8A but the controller does not know this data because he does not have this tool he could mistake and choose other number of controllers. If the number of foreseen controllers is lower than 22 the supervisor will be obliged to choose a configuration7 so the controller's workload could be increased appreciably and as a consequence this could lead to a reduction in safety.

If the number of foreseen controllers is superior to 22, there will be too much controllers and the supervisor will not be adjusting to the minimum needed resources.

2.6 Applied solution/intervention

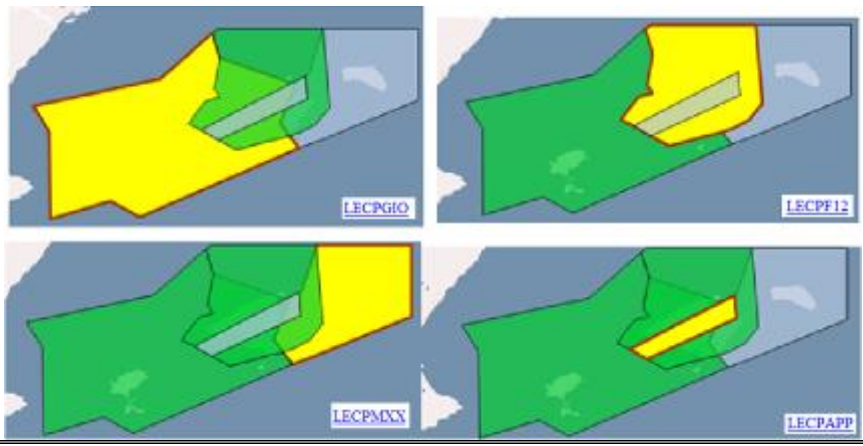
Currently PERSEO is mainly being used to make two kinds of planning:

- Long-term planning. It allows to achieve planning 30 days before the operation day. It is obtained from different sources such as historical dates.
- Short- term planning. This planning can be obtained 7 days before the operation day. It is obtained using the analyzed optimal configurations just 7 days before.

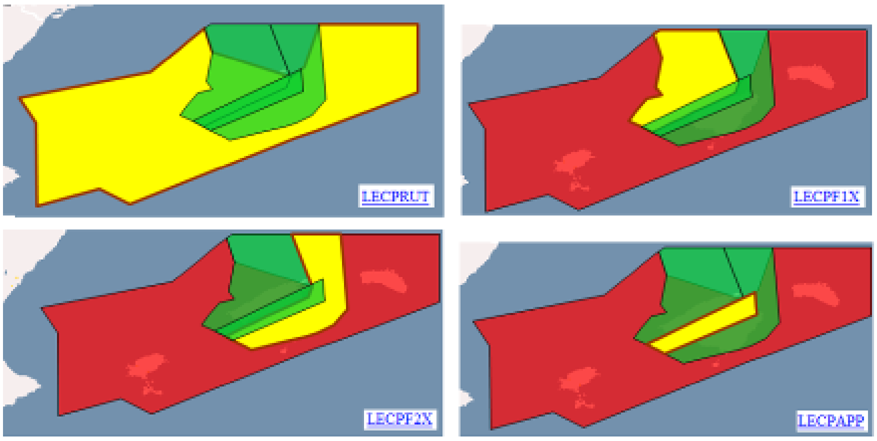
The above figure is a practical case where the controller tries to obtain long-term planning. This planning indicates that the best option will be to use Configuration 4A from 13:00 pm to 15.40 pm, Configuration 5F from 15.40 pm to 18.40 pm,…etc

A configuration is a set of opened sectors in a given period. For example, configuration 4A means that a specific airspace has been divided into 4 areas to control, so the number means the number of volumes into which the airspace has been divided and the letter is the way to divide this airspace. For example the difference between Configuration 4A and 4B are the following:

- Configuration 4A: This configuration is composed of the following 4 sectors: LECPGIO, LACPF12, LACPMXX and LECPF1X (observe yellow sectors in the figure below):

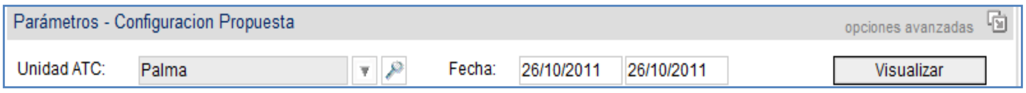


- Configuration 4B. This configuration is composed of the following 4 sectors: LECPRUT, LECPF1X, LECPF2X and LECPAPP (observe yellow sectors):

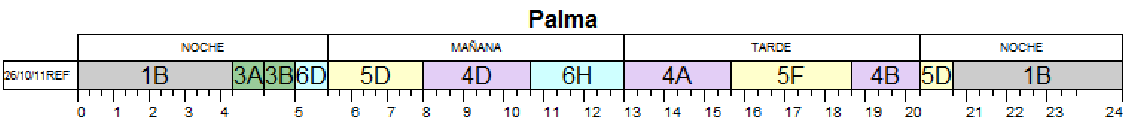


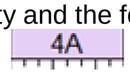
The following text describes the process carried out by the controller to obtain the planning:

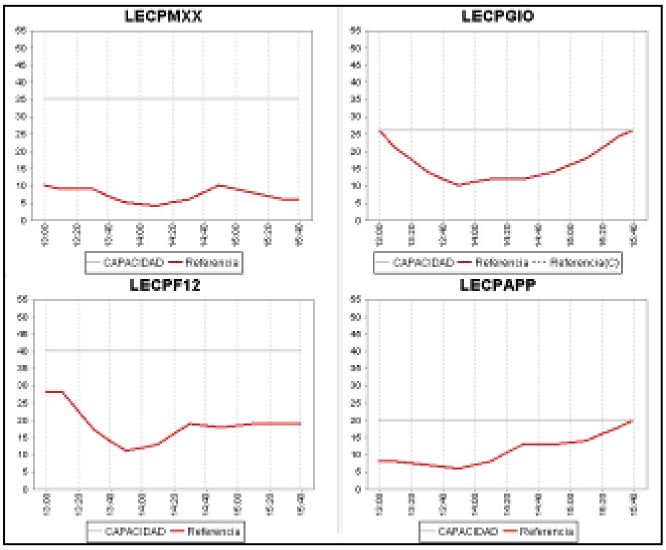
1- Controller will select the date and the ATC unit.



2- The system will provide the configurations that will be needed along this day (the best configurations)

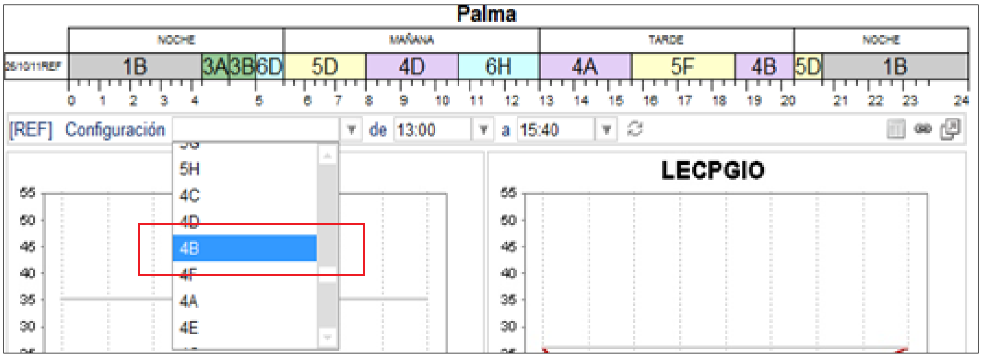


Moreover the supervisor can push with the mouse over any configurations in the below chart below to know the capacity and the foreseen demand in each sector. For example, if he/she pushes over  PERSEO will show the capacity and demand in these 4 sectors from 13:00h to 15:40h:

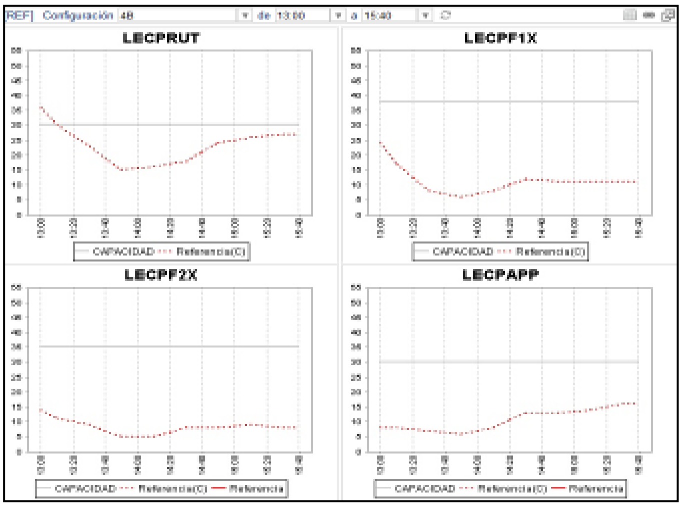


The red line indicates the sector's demand while the grey line shows the capacity of the sector.

3- The Supervisor has the possibility to know the demand and capacity if he/she finally decides to use a different configuration (even in another time period). For example if he/she decides use configuration 4B instead of configuration 4A:



Achieving the following values of capacity and demand:



The demand in the sector LACPRUT from 13:00 pm to 13:10 pm exceeds the capacity, so it shows that Configuration 4B is worse than Configuration 4A in this case.

3	REFERENCES
	• Perseo Overview in SJU Project P13.02.03
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	ACC, Headquarters
5	What were the required technical means and human resources?
	Usual servers architecture. Currently in prototype status, it will be integrated into the normal IT structure of AENA with no expected noticeable work overload.
6	If applicable: How often was the good practice applied in the past? Please estimate.
	This tool has been used by AENA since 2010 to plan the sectorization in each ATC. By means of PERSEO AENA can obtain a short-term planning 7 days in advance, allowing the estimation of the amount of necessary resources(number of controllers) on the operation day.

7	What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?				
	Best resources allocation and optimal use of airspace. What-if capabilities. Doesn't have special integration needs with other systems, accessing information by subscription mechanisms.				
8	On which phase of maturity of the concept/automation was the good practice applied?				
	☐ V1: Scope	☐ V2: Feasibility	☒ V3: Pre-industrial development and integration		
	☐ V4: Industrialisation	☐ V5: Deployment	☐V6: Operations		
	8.1 Rationale				
	Currently PERSEO is an active tool used to estimate the best configurations in each ATC, hence we could classify its level of maturity as" Pre-industrial". Although it is being used on a daily basis in operations environment, it is not fully integrated with ATC Systems and not in the IT structure inside the Center, so in terms of maturity level it is V3. Work in progress in P13.2.3 Step 1 is expected to raise status.				
CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐Climb
	☒ En Route	☐ Descent	☐ Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	The main usage of PERSEO is to focus on the en route phase				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☐ EC ☐ PC ☒ Supervisor ☐…			
	9.1 Rationale				
	PERSEO will be used by the supervisor in an ATC center who will be in charge to obtain possible configurations to use and a planning of the human resources needed.				
TASK					
11	Pilot tasks	ATCO task			

	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☐ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	The task carried out by the supervisor is "planning strategy"	
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation	
	No role change.	

12 Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	A		B		C		D	
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
LA	Before change	After change	Before change	After change	Before change	After change	Before change	After change
0	A0	A5	B0	B2	C1	C3	n.a.	n.a.

12.1 Rationale

Information acquisition:

Before (A0): Human obtained the information without any tool. Supervisor analysed the recent historical data traffic and foresaw the needed configuration.

After: (A5) Data collection is automatic. The system integrates data coming from different sources but the supervisor can´t consult this data. The system uses historical data for predicting the best configuration but in PERSEO it is not possible to consult this data, as this information is not visible to the human. Upon request by the operator the tool shows the set of configurations needed during that day.

Information analysis:

Before: (B0) The controller had no tool support to analyse the traffic expected. He/she only had reference configurations on paper. He/she tried to choose the optimal configurations comparing

	these reference configurations and the expected traffic. **After: (B2)** The system allows the obtaining of the optimal configuration by pressing a button but it does not trigger visual and/or aural alerts. Decision and action selection: **After: (C1)** As mentioned before, the human generated decision options, selected the appropriate ones and decided all actions to be performed utilising paper. **After: (C2)** PERSEO calculates the optimal configurations but controller can ask the system to generate new options. Moreover it allows the supervisor to generate his/her own options, fixing a specific configuration or modifying the time of this configuration.(compare the example shown in section 2.6).

IMPACTS ON HUMAN PERFORMANCE		
13	13.1 Which changes do you see in the way the Human Performance is supported?	
	The use of this tool decreases the probability of establishing a bad planning reducing the risk of have a lower number of controllers in that session of work due to this bad planning, hence, it will avoid an excessive controller's workload.	
	13.2 Which benefits do you expect on SESAR KPAs?	
	☒ Capacity	PERSEO allows Demand Capacity Balance by suggesting the best possible use of airspace in terms of available human resources.
	☒ Efficiency	This tool will allow reduce cost by estimating the amount of optimal needed resources(or at less achieving an enhanced estimation)
	☐ Flexibility	
	☒ Predictability	PERSEO will increase the predictability
	☐ Safety	
	☐ Access and Equity	
	☐ Interoperability	
	13.3 Human Performance and automation issues expected to be mitigated	
	-Issue 10: Automation may increase task demand and cognitive workload As indicated before, the main aim of PERSEO is to achieve a planning that balances capacity and demand optimizing human resources. Moreover PERSEO achieves to balance the workload between all controllers, ensuring all controllers have a similar workload, avoiding workload peaks in any sector. Furthermore the supervisor can easily obtain the best sector configuration, so there is no time required to analyze historical dates and elaborate the optimal sectorisation, hence PERSEO will reduce his/her workload.	
	13.4 Human Performance and automation issues potentially <u>not</u> mitigated	
	-Issue 5. The automation of routine tasks may remove an important information source which may reduce situation awareness**.** Currently the supervisor chooses a set of configurations along the day basing on his/her own experience and the analysis of historical data, nevertheless after PERSEO implementation	

	supervisor will achieve the optimal configurations pushing a bottom. The automation of this task could lead to the removal of relevant information that helps to evaluate the situation. The supervisor will not have any traffic report or historical data hence if a failure occurs he/she will not have enough information to analyze the situation and probably he/she will not able to achieve the best planning.
	13.5 Would you expect that procedures will change?
	☐ Yes ☐ Likely yes ☒ No ☐ Likely no Explanation: The procedures will not change, however the way in which the human is supported by the automation will be different. The supervisor will receive automatically suggestions of optimal sector configuration to be implemented instead of current situation of manual analysis.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	The automation could improve the use of resources by combining forecast traffic information, operational experiences and staff restrictions in order to provide the optimal sector configuration for the expected traffic on the day of operation. The main advantage of PERSEO is to achieve a long-term planning that will be refined subsequently achieving a short-term planning a few days before to the operation day.

4.2.16 SARA (Speed and Route Advisor)

1	Title of the automated solution
	SARA (Speed and Route Advisor)
2	Short description of the concerned automation
	The aim of SARA (Speed and Route Advisor) is to deliver advanced system support tools that will contribute to the stability and prediction of inbound traffic streams giving advisories on speed and/or routing to (Upper) Area Controllers in order to achieve the planned arrival time(s) of the aircraft over fixes. Furthermore to meet the planned arrival time, the suggested trajectories by the system are probed for conflicts and resolved where necessary achieving a more accurate delivery of traffic at the metering fixes (IAFs). It will lead to a reduction of controllers' workload through reducing the number of tactical clearance. In the future, these SARA options could be made available for the flight through datalink, preferably before Top of Descent, so that on-board systems can maximise the efficiency for the flight in relation to its constraints/requirements. This will also help to provide increased predictability in profile and time adherence for the ATC systems and controllers. SARA project is being developed by the following partners: • KDC (Knowledge & Development Centre, Mainport Schiphol) • Boeing • MUAC (Maastrich Upper Area control) • EUROCONTROL • KLM • Transavia • NLR The results obtained after carrying out validation exercises are the following:

- Accuracy at IAF. The results showed that SARA supported to the controller increasing the accuracy over IAF.
- Situational awareness. Controller situational awareness was lower with SARA as compared to standard operation. Nevertheless the lower situational awareness was considered acceptable since the ATCOs worked with a new tool and a new way of handling traffic.
- Workload. The workload did not increase, but it shifted. Previously it was spent on RT and system inputs, but more time was spent on mental tasks such as development of situational awareness.
- Controller impression. The ATCOs who participed in the trial felt that the SARA concepts were viable concepts of operation.

2.1 Description of the function

The objective of the SARA function is to give advice on speed and/or routing to (Upper) Area Controllers in order to achieve the planned arrival time(s) of the aircraft over fixes.

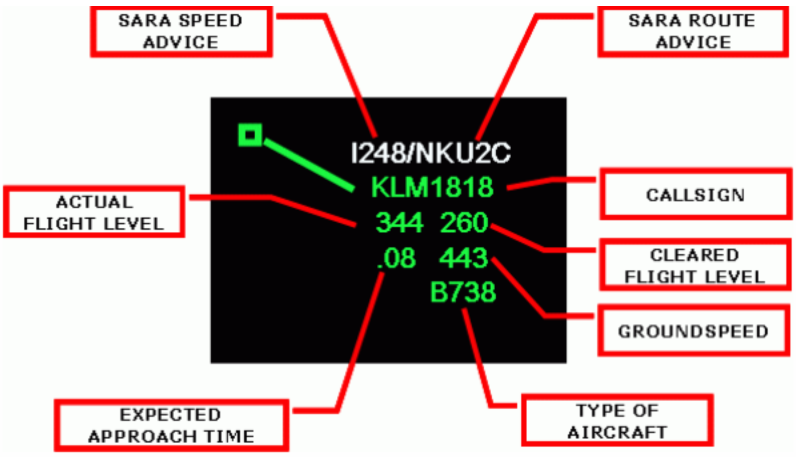
Furthermore SARA function will contribute to a more accurate delivery of traffic at the metering fixes (IAFs) causing less workload for the controllers involved. SARA function will overall reduce the number of tactical clearances (and thus the R/T load), because of its ability to generate a single, comprehensive, conflict-free solution to meet the time at the IAF.

From a systems perspective these benefits are needed to support an operational concept that is more stable and predictable.

SARA is used to achieve the following objectives:

- Traffic delivered with high accuracy at IAF
- Lower workload for controllers
- More predictability for airlines
- Lower fuel burn and emissions
- Use of defined procedures in TMA airspace
- Reduce planning deviations to enable Fixed P-RNAV routes in the TMA
- Shift executive workload to planning domain
- Implement the global Tailored Arrivals Concept in high-density airspace

HMI view ACC controller label:

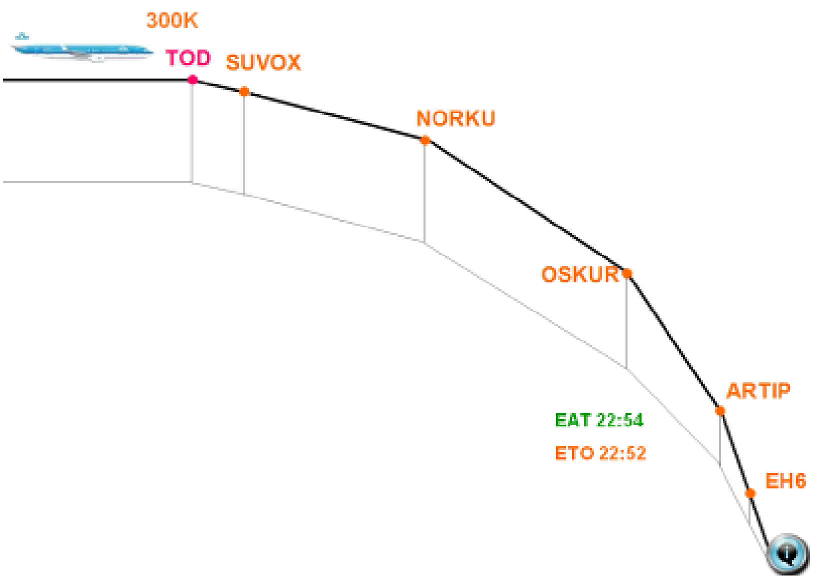
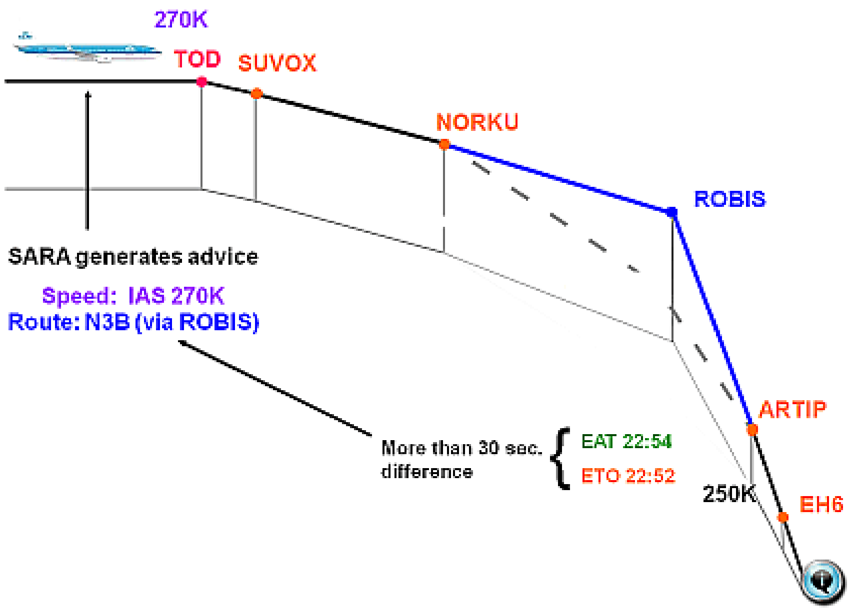


2.2 Which kind of situation(s) does the concerned automation support?

☒ normal situations ☐ abnormal situations

The use of SARA system is foreseen for handling arrival flows in normal situations in high-density airspace, like TMA serving Schiphol airport.

	Which level of traffic does the function support? SARA function will be used in airspace with high-density of traffic.
	2.3 Concerned domain
	☐ Air ☒Ground ☐ Air-Ground Explanation: SARA is a ground system support that will help controllers to manage arrival flows proposing speed and/or route options.
	2.4 Operational environment
	SARA tools will be used in TMA and E-TMA.
	2.5 Reason for the change/ Problem to be handled
	Taking into account the increase of traffic during the next years the capacity of the airports with high-density of traffic could be affected. During the approach phase the controller is continually giving instructions and clearance to the pilot so an increase of the traffic will cause a considerable rise of controller's workload. Therefore the use of SARA system would imply fewer interactions between pilot and controller and hence reduce the workload of the controller while increasing the capacity of management arrival flows to an airport. The result is improved flight efficiency due to improved flight profiles. This will contribute to a more accurate delivery of traffic at the metering fixes (IAFs) and causes less workload for the controllers involved. It is expected that the SARA system will overall reduce the number of tactical clearances and thus the workload because of its ability to generate a single, comprehensive, conflict-free solution to meet the time at the IAF. Furthermore this increase of the traffic will be associated with a rise of the noise and the emissions of contaminants in the vicinity of the airport. Early clearance using SARA system will reduce fuel burn and noise through achieving an efficient descent.
	2.6 Applied solution/intervention
	As mentioned before, SARA tool will start working with a flight before top of descent (TOD) and will calculate a descent speed and route that will put the aircraft at the IAF according to plan. The aim is that the accuracy over IAF will be high enough to allow for fixed route operation in the TMA. The following text describes the process: 1) The flight appears to the ATM system and is entered in the AMAN planning 2) Once the planning is considered stable, SARA starts working 3) SARA reads the Expected Approach Time (EAT) for the flight. 4) SARA contacts the Trajectory predictor (TP) and collects the current position of flights. It also uses the TP to calculate the flights Estimated Time Over (ETO) the IAF. 5) SARA compares the EAT and ETO. If the difference is outside a set bandwidth (+/- 30 seconds at IAF), it will initiate the process to generate advisories. 6) An iterative process is started where SARA uses the TP to calculate a speed and route combination that will bring the aircraft to the IAF such that the EAT and ETO is below the threshold value. 7) Once a solution is found, it is communicated to the controller. In the following example SARA shows that the flight will not achieve its planned time over IAF if it continues with the current speed and route. (This example has been extracted from the

	presentation “SARA_overview” elaborated by KLM)  Hence a new speed and route is calculated by SARA.  In the figure above the aircraft should arrive to the last waypoint at 22:54 (this is the expected approach time EAT, “the perfect time”) but taking into account the current speed and trajectory (TOD,SUVOX,NORKU,OSKUR,ARTIP,EH6) the system calculates that the aircraft will arrive at the last waypoint at 22.54h (ETO), so SARA has to calculate a new path since the aircraft is going to arrive 2 minutes in advance. SARA recalculates the path and includes a new waypoint in the trajectory (the waypoint ROBIS) in order to achieve a delay of the flight by two minutes.
3	REFERENCES
	Reference background information can be found in the KCD website, where apart from the official brochure and presentation there are links to relevant and specific press and technique articles about the project. • KCD website: http://www.kdc-mainport.nl/index.php Other references:

	• ***"Dutch ANSP embarks on time-based innovation"*** is a press article about SARA in the on-line specialised magazine 'Air Traffic Management Magazine': ▪ It describes the main lines of the project, going through the whole development phase of the project, as well as the implementation plan; ▪ Public document from March 2011; ▪ http://www.airtrafficmanagement.net/view_news.asp?ID=3024 • Paper: "Impact of future time-based operations on situation awareness of air traffic controllers" ▪ It analyses how controllers´ situational awareness is affected by the coming trajectory based operations and the tools to support them, including SARA tool. ▪ Public document from 2009; ▪ http://www.atmseminar.org/seminarContent/seminar8/papers/p_016_HF.pdf • EUROCONTROL TMA 2010+projects: SARA ▪ It is an introduction to the project by Eurocontrol. It is included a link to the SARA brochure and to all the partners involved. ▪ Public website, from January 2009; ▪ http://www.eurocontrol.int/tma2010/public/standard_page/sara.html • Conference presentation-Boeing Tailored arrivals symposium ***"LVNL perspective on Tailored arrivals"*** ▪ Overview of the process and steps to be followed to improve the ATM System, planning as the last the step the implementation of the SARA project; ▪ Public document. • Article about SARA in Jane´s Airport Review. Non-public article.
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*
	The developed SARA CONOPS first consisted of three variants: • Concept 1 – The system provides controllers with instructions to change speed only. The system changes the flight's speed to achieve the aircraft arrives to the last waypoint meeting the planned time over a fix. However the system does not change any waypoint in their flight plan, It will fly standard routes."This will be a time-based operation utilizing the current route structure" • Concept 2 - The system gives instructions regarding speed and route adaptations to meet the agreed times. It is similar to concept 1 but using multiples route options. The system can use different routes to increase the length and the time of the trajectory to meet the planned time over a fix (see the example shown in section 2.6 , the system adds the waypoint ROBIS to delay the flght 2 minutes) • Concept 3 - The system advises controllers to instruct a speed and change route dynamically. In addition it also provides support to solve conflicts. In addition to concept 2 the routes are probed for conflicts so all advice is conflict free. Concepts 1 and 2 were evaluated using Real Time Simulation (RTS) in NARSIM (NLR). Additionally concept 1 was evaluated in an Operational Trial at Schiphol LVNL (Air Traffic Control the Netherlands) in 2009. Trials were performed at ACC level, since the system starts advising aircrafts from the en-route

<table>
<tr><td></td><td colspan="3">phase, to support them to proceed with the appropriate descent rate to meet the arrival times.

The project has been linked to the Single European Sky SESAR programme in which the European ATM system is set to undergo a complete paradigm shift. SARA validation exercises during 2011 are part of SESAR's Release-1 package which will deliver the first benefits to airspace users.</td></tr>
<tr><td>5</td><td colspan="3">What were the required technical means and human resources?</td></tr>
<tr><td></td><td colspan="3">As it was mentioned in the previous point, Concepts 1 and 2 were evaluated with Real Time Simulation techniques, using NARSIM simulator in NLR facilities. NARSIM is an air traffic control simulator where new navigation procedures or tools can be adapted to real control positions and tested with real controllers.

To perform RTS trials apart from the simulator and SARA tool, it was needed a number of real controllers and pseudo-pilots to simulate real interactions between controllers and pilots. It was also required to build a traffic scenario with a significant level of operations.

Concept 3 was assessed with an operational trial in Schiphol (LNVL). However data about the exercise and its results has not been made public.

The objective of the simulation was to probe the impact of speed advice alone and the impact of speed and route advice combined. Furthermore the simulation wanted to test how the coordination between centres worked.

The results obtained that were made available are the followings:
• Situational awareness. Controller situational awareness was lower with SARA as compared to standard operation. Nevertheless the lower situational awareness was considered acceptable since the ATCOs worked with a new tool and a new way of handling traffic.
• Controller impression. The ATCOs who participated in the trial felt that the SARA concepts were viable concepts of operation.</td></tr>
<tr><td>6</td><td colspan="3">If applicable: How often was the good practice applied in the past? Please estimate.</td></tr>
<tr><td></td><td colspan="3">SARA is not operational until now. The concept was validated in a series of simulation and live trial exercises at Schiphol airport in 2009. These trials were part of Boeing's global programme to promote Tailored Arrivals.

The SARA system is not implemented yet, the Initial implementation is scheduled for 2012 at Schiphol airport and it will be co-ordinated with adjacent centres Maastricht UAC and UK air traffic services provider NATS.</td></tr>
<tr><td>7</td><td colspan="3">What are the consequences of the integration of the concerned automation into a system or an ensemble of systems?</td></tr>
<tr><td></td><td colspan="3">No major impact is expected.</td></tr>
<tr><td>8</td><td colspan="3">On which phase of maturity of the concept/automation was the good practice applied?</td></tr>
<tr><td></td><td>☐ V1: Scope</td><td>☐ V2: Feasibility</td><td>☒ V3: Pre-industrial development and integration</td></tr>
<tr><td></td><td>☐ V4: Industrialisation</td><td>☐ V5: Deployment</td><td>☐ V6: Operations</td></tr>
<tr><td></td><td colspan="3">8.1 Rationale</td></tr>
<tr><td></td><td colspan="3">As mentioned before, the SARA system is not implemented yet.

The initial implementation is scheduled for 2012 in the Schiphol airport and it will be co-ordinated with adjacent centres Maastricht UAC and UK air traffic services provider NATS.</td></tr>
</table>

CONTEXT OF THE TASK					
9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☐ Take-off	☐ Climb
	☐ En Route	☒ Descent	☒Approach	☐ Landing	☐ Taxi-in
	9.1 Rationale				
	SARA system concept has been developed to be used during Approach Phase.The SARA tool will allow the implementation of fixed arrival routes in the TMA and, at a later stage, continuous decent approaches. The system working timeframe starts during the en-route phase, generating a descent trajectory that enables the aircraft to meet the time at the IAF. The principal flight phase where SARA supports controllers´ actions is the Descent phase, being very important at the approach phase, since it will help to build the landing sequence.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☒ EC ☒ PC ☐ Supervisor ☐…			
	10.1 Rationale				
	The introduction of SARA will not imply any new role. This tool will be used by the executive and planning controller.				

TASK		
11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☒ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication
	11.1 Rationale	
	Controller will monitor the traffic and translate the instructions given by the system to pilot. The controller will not have to check whether these instructions are conflict free, as this will be	

	performed automatically by the system.								
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation								
	Use of SARA system does not imply a change of responsibilities of pilots and controllers, but it does change the way how controllers work.								
12	Classification of supported cognitive functions and automation level								
		Associated cognitive function being supported by automation							
		A		B		C		D	
		Information acquisition		Information analysis		Decision and action selection		Action implementation	
		Before change	After change	Before change	After change	Before change	After change	Before change	After change
	LA	n.a.	n.a.	B0	B5	C0	C4	D0	D0
	12.1 Rationale								
	Information analysis: **Before: (B2)** The controller monitors the flight and gives an instruction or clearance to the pilot based on the velocity and aircraft position displayed in the monitor. The system supports controllers by showing data like speed vector and possible conflicts. The conflicts are displayed by MTCD. MTCD tool shows the possible conflicts and the involved aircrafts (both trajectories are highlighted in colour green; the intersection of trajectories is the expected conflict) **After: (B5)** The system predicts the trajectory and evaluates if the difference between EAT and ATO is outside a set bandwidth (+/- 30 seconds).Before implementation the system only shows data like speed vector, possible conflicts,..etc but it does not calculate the time to achieve a waypoint nor gives clearance to arrives to this waypoint in a specific time. Decision and action selection: **Before: (C0)** After analysing the situation of the aircraft and the flight speed the controller makes a decision without any system support (instructions to change flight level or change the velocity) **After: (C3)** SARA works iteratively, so that it generates a speed / route advise (depending on the stage of development) that the controller transmit to the aircraft. If controllers or aircrafts does not meet such advice, the system will automatically recalculate a new speed / route advice to meet the arrival time to the IAF, if possible. When meeting the time is demonstrated not to be possible, ATC will be aware of the delay, so that to reorganise the approach sequence will be possible. This point highlights the possible benefits of having SARA working together with an AMAN tool. Action implementation: **Before: (D0)** The controller will contact the pilot using ratio telephony. **After: (D0)**. The controller will contact the pilot using ratio telephony.(Although It is expected that the communications between pilot and controller will be conducted by data link in a future)								
IMPACTS ON HUMAN PERFORMANCE									
13	13.1 Which changes do you see in the way the Human Performance is supported?								

The number of communications between controller and pilot will be reduced so the controller's workload will be decreased. Furthermore the controller will not have to analyze the situation and elaborate the best trajectory for arriving to IAF or the most appropriate velocity. These tasks are done by the tool so the controller only has to communicate to the pilot the instructions given by SARA system.

13.2 Which benefits do you expect on SESAR KPAs?

☒ Capacity	The capacity will be improved. The number of communications between controller and pilot will be reduced so the controller's workload will be reduced. This will imply that the controller will have the capacity to manage a higher amount of traffic.
☒ Efficiency	Flight efficiency is enhanced due to improved flight profiles.
☒ Flexibility	Flexibility of real time route allocation will be improved, that means that in real time aircrafts´ routes are updated according to flight constraints. This is in line with the concept of trajectory based operations, giving airlines the maximum flexibility as possible, allowing them to fly the most efficient trajectory, which is the desired trajectory by airspace users.
☒ Predictability	The predictability will be enhanced. SARA system will allow to achieve the planned arrival time(s) of the aircraft over fixes, increasing the flight time predictability, what is very important for airlines.
☐ Safety	
☐ Access and Equity	
☐ Interoperability	

13.3 Human Performance and automation issues expected to be mitigated

-Issue 10: Automation may increase task demand and cognitive workload

The implementation of SARA will reduce the workload of the controller, because of he/she will not have to think how manage the incoming traffic, SARA decides the route that the flight will follow, the specific aircraft's speed and the changes in aircraft´s speed, hence controller only has to transmit these clearances to pilots.

13.4 Human Performance and automation issues potentially not mitigated

-Issue 2: Lack of user involvement in automation assisted processes may lead to loss of skills and proficiency.

After implementation SARA the controller only has to monitor the traffic and transmit clearances. If a failure occurs the controller will have to manage incoming traffic, creating clearances like changes of speed and changes of altitude to meet with EAT. If the controller usually uses SARA he/she will probably lose skills to manage this traffic without any support system.

-Issue 3: Lack of user involvement in automation assisted processes may impact recovery from system failure

As indicated before, if the system fails controllers will lose situational awareness and the time to perform these tasks will increase (the controller will then need to do all the task mentally without any support system).

13.5 Would you expect that procedures will change?

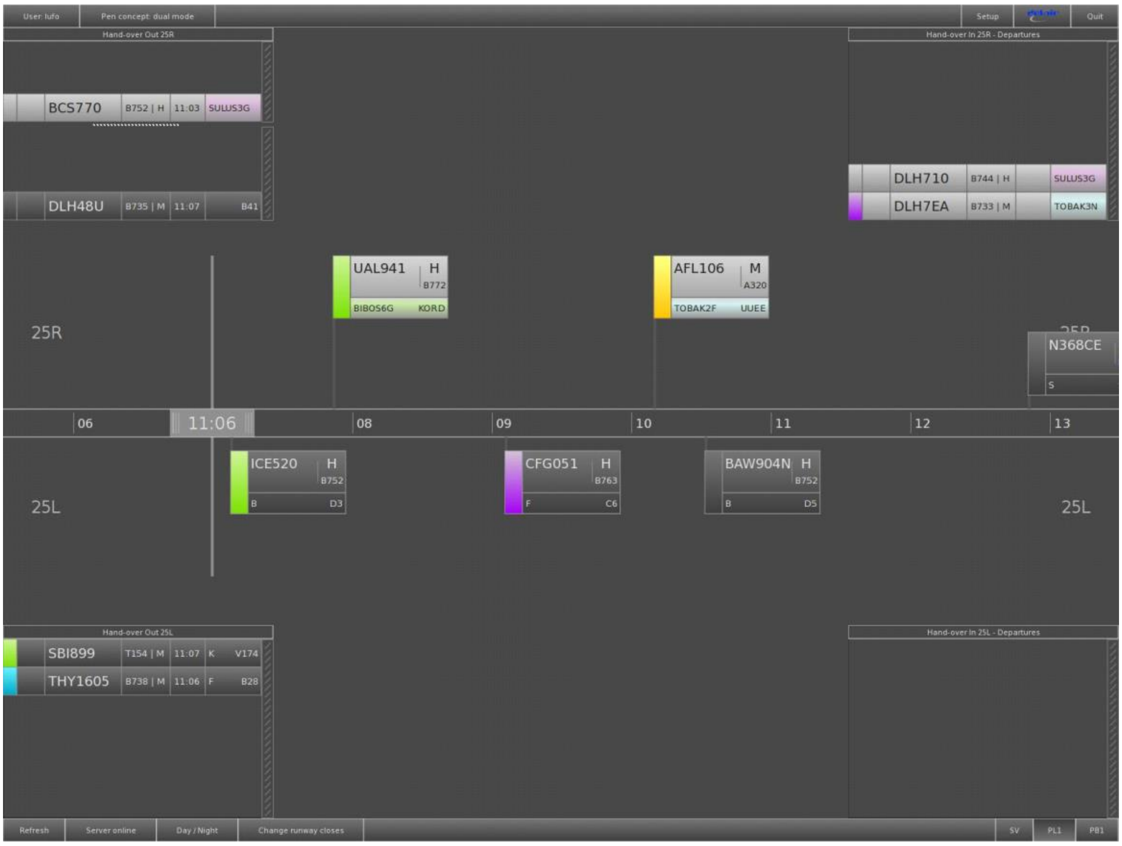
	☐ Yes ☒ Likely yes ☐ No ☐ Likely no Explanation: Before SARA system implementation controller was in charge of managing inbound traffic, monitoring the flights and resolving conflicts, but these flights did not follow fixed routes. After SARA system implementation the controller only has to translate the instructions given by the system and monitor the traffic, releasing him from the task of calculating speed and routes. One of the main expected results coming from the implementation of SARA is to minimize the holdings and to facilitate the provision of a landing sequence (something easy to achieve with the support of AMAN tools). This landing sequence will release directors´ controllers from defining it. The procedures will be affected since the arrival routes to the IAF are not fixed. It is not a route to arrive to the IAF, but a time when to do it. So that, the procedures are more based on times and not in routes. As said before, the implementation of SAR will facilitate to remove holdings before the IAF points.
FINAL CONSIDERATIONS	
14	What can be learnt from the proposed change in HP automation support?
	The simulations showed that the situational awareness of the controller was lower with SARA as compared to standard operation. Nevertheless the lower situational awareness was considered acceptable since the ATCOs worked with a new tool and a new way of handling traffic.. Other risk is that the users in not completely involved in the automation process (system calculates some data that are impossible to calculate by the controller like the precise speed to the flight arrives to a fix point) so if a failure occurs the controllers could have some difficulties to do their task.

4.2.17 Tower HMI - ARR and DEP Integrated Planning Information Display

1	Title of the automated solution
	Tower-HMI Arrival/ Departure Integrated Planning Information Display for Tower controllers (The prototype of a tower human machine interface has been honoured with the prestigious if communication design award as well as with the red dot design award and is nominated for the "Design Preis Deutschland 2011".)
2	Short description of the concerned automation
	The HMI integrates planning time information of different sources for arrival (4D- Planner) and departure (darts). The planning times for arrivals and departures for each runway are displayed in combination on one display using one timeline for the next 6 minutes. It supports local controllers on the tower by integrating necessary information for the actual traffic situation. It combines arrival and departure planning with the aim to optimize utilization of existing infrastructure and to provide all users with consistent planning information. Until now the information presentation and interaction with arrival and departure information systems were carried out at separated displays with discrete keyboards. Through presentation of flight plan information at only one display the controllers are more efficient in analysing the planning situation on the runway. Thus, the HMI enables the controllers to handle traffic efficiently.

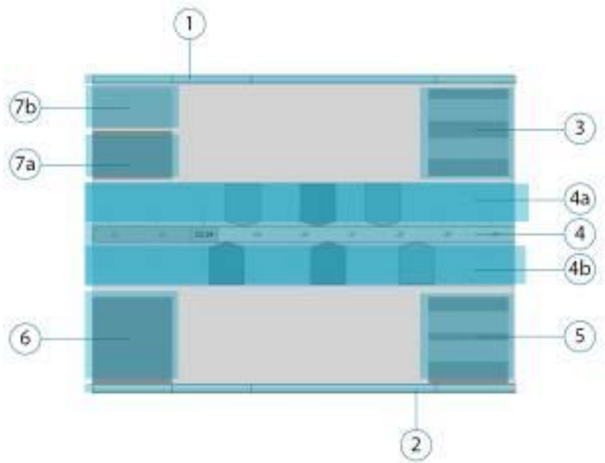
2.1 Description of the function

Because of the coupling of two systems, 4D- Planner (Arrival Manager) and darts (Departure Manager), it was necessary to create an interface, which combines these two information domains into one consistent HMI. It supports controllers in the tower by visualising the planning times of inbound and outbound traffic on one timeline (see figure below).



Layout of the TWR HMI

The schematic design of the HMI is described in the following:



Schematic design of the HMI

1) Status bar at the upper edge of the display (contains functionalities for user login or

display calibration)

2) Status bar at the lower edge of the display (contains functionalities for user login or display calibration)

3) Hand Over In 25R (contains the stack- list of arrival and departure for the RWY in northern direction)

4) Timeline (contains all flights within the last 3 minutes and next 6 minutes), separated in north (4a) and south (4b) RWY

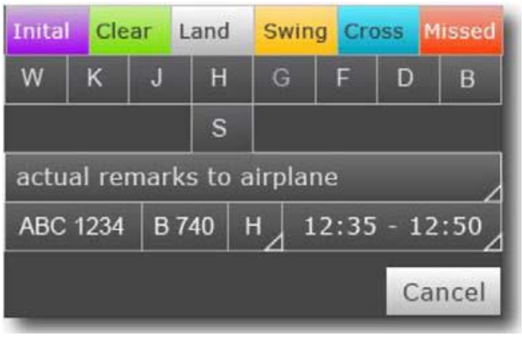
5) Hand Over In 25L (contains the stack- list of arrival and departure for the RWY in southern direction)

6) Hand Over Out 25L (contains the stack- list of arrival and departure for the RWY in southern direction)

7) Hand Over Out 25R (contains the stack- list of arrival and departure for the RWY in northern direction)

Further information is provided by the aircraft labels. Departures have a brighter, arrivals a darker background. Both labels contain the callsign, a/c type, wake category, remarks and status information. Arrival labels have taxi route or stand and arrival time displayed, whereas departure labels provide departure route and slot time.

Colours indicate the status of the concerned a/c. Below are the colours used, the examples show the context menu used for interacting with the system.



Colours for arrivals

Colours for departures

When implementing this HMI as an operational system at an airport, the level of automation support can be adapted. Depending on operational requirements the automation level can range from a full manual configuration, where planning information is displayed only but the sequence of departures and arrivals is set up by the controller, up to a level of automation, where the planning tool generates suggestions for sequence and times and the controller has either to accept them, or to implement his own planning strategy. Hence the level of automation can be adapted to requirements of each airport, without extensive changes of the HMI.

With this HMI the work of tower controllers shall be supported. The necessary information from arrival and departure manager are aggregated and displayed to the controller according to operational requirements. By this an optimal use of existing infrastructure is ensured by

	supporting controllers in adjusting the preference between arrivals and departures for one or more RWYs operated in mixed mode.
	2.2 Which kind of situation(s) does the concerned automation support?
	☒ normal situations ☐ abnormal situations This automated system is a tower human machine interface which integrates information for arrival and departure and displays the planning times on a timeline for the next 6 minutes.
	What is the linkage between the use of the function and traffic level? The main function of this system is combining data from two systems (4D- Planner and darts) and displaying them in one HMI. Providing this support is independent from level of traffic, but the more traffic occurs the higher is the profit of this tool.
	2.3 Concerned domain
	☐ Air ☒ Ground ☐ Air-Ground Explanation:
	2.4 Operational environment
	This HMI is used by tower controllers at major hubs to provide a combined display of both arrival and departure information.
	2.5 Reason for the change/ Problem to be handled
	Currently different systems for planning arrivals and departures (arrival manager and departure manager) are used at major hubs in Germany. The planning information is displayed on separate screens, with different HMIs. To make optimal use of existing runway resources, both planning systems need to be coupled. Likewise, if arrival and departure planning systems are combined, an integrated display is needed to merge both information sources and to display planning information (sequence and schedule) of arrival and departure traffic. With this HMI a faster perception of the planning situation is enabled, as interdependencies between arrivals and departures are visualised. Hence the utilization of runways is optimized and full capacity is reached. With this new interface a higher efficiency is given, because number of delays is significantly reduced. The graphical display and the interaction is standardised, all working positions have the same look and feel. By this it is avoided that controllers have to get accustomed to different displays or layouts if changing the working position during operations.
	2.6 Applied solution/intervention
	The need of a HMI, which interlinks planning tools for arrival and departure, launched the development of this planning tool and interface. After a first analysis of the existing procedures, the working situations and work place environment including current input devices, the target criteria for the interface were defined and a basic concept was developed.
3	REFERENCES
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	ung_und_entwicklung/forschungszeitschrift/2009/fokus0901.pdf] - The prototype of a tower human machine interface has been honored with the prestigious iF communication design award as well as with the red dot design award. http://en.red-dot.org/4278.html?&cHash=f1685a99c5d13a706788c2129f51f79b&detail=614 - Hofmann, T., König, C., Bergner, J. & Ebert, H. (2011): Tower HMI - Interface für Fluglotsen. In: Rat für Formgebung (Hrsg.): Designpreis der Bundesrepublik Deutschland 2011, Berlin.: Die Gestalten Verlag. - Hofmann, T., König, C., Bergner, J. & Ebert, H. (2011): Tower HMI - Interface für Fluglotsen. In: Peter Zec (Hrsg.): international yearbook communication design 2010/2011: hot & cool, Essen: Red Dot Edition. - König, C., Röbig, A., Hofmann, T., Bergner, J. & Bruder, R.. (2010). Fluglotsen-Arbeitsplätze der Zukunft. In: Neue Arbeits- und Lebenswelten gestalten, 56. Frühjahrskongress der GfA, 24. - 26. März 2010 in Darmstadt, Tagungsband. Dortmund: GfA-Press. - Hofmann, T., König, C., Bergner, J. & Ebert, H. (2009): Tower HMI - Interface für Fluglotsen. In: iF International Forum Design GmbH (Hrsg.): iF communication design award yearbook 2009. Basel: Birkhäuser. - König, C., Hofmann, T., Bergner, J., Bruder, R.: „Einsatz von Beobachtungsinterviews bei der Entwicklung von Interfaces für Tower-Fluglotsen“, In A. Lichtenstein, C. Stößel & C. Clemens (Hrsg.). Der Mensch im Mittelpunkt technischer Systeme, 8. Berliner Werkstatt, Mensch-Maschine-Systeme, 7.- 9. Oktober 2009, ZMMS Spektrum Band 22, Nr. 29, Düsseldorf: VDI Verlag, 2009, S. 173-174. „Tower HMI - Interface für Fluglotsen“. Beitrag im iF communication design award yearbook 2009. Basel: Birkhäuser. - Bergner, J.; König, C.; Hofmann, T.; Ebert, H.: „An Integrated Arrival and Departure Display for the Tower Controller“, 9th AIAA Aviation Technology, Integration and Operations Conference (ATIO), Hilton Head, South Carolina, USA, 21-23. Sept. 2009 - König, C., Hofmann, T., Bergner, J., Bruder, R.:„Inkrementelle nutzergerechte Etablierung eines Towerlotsen-HMI“, In: H. Wandke, S. Kain & D. Struve (Hrsg.) Mensch & Computer 2009. 9. Fachübergreifende Konferenz für interaktive und kooperative Medien. Grenzenlos frei? Proceedings of Mensch & Computer 2009, Berlin, Germany, 6. – 9. September 2009. - Bergner, J.:„Entwurf einer integrierten Planungsanzeige für den Tower-Controller“. In: Bereich Forschung und Entwicklung, DFS GmbH (Hrsg.) TE im Fokus - Informationen aus dem Bereich Forschung und Entwicklung der DFS GmbH. Ausgabe 01/2009, Langen, 2009. - König, C.; Hofmann, T.; Bruder, R.; Bergner, J.:„Arbeitsplatz Tower – Interessensrelevante Visualisierung komplexer Datenstrukturen“, In: USEWARE 2008 – Verfahrens- und Produktionstechnik, Engineering, Informationspräsentation und Interaktionskonzepte, VDI-Bericht 2041. Düsseldorf: VDI-Verlag, 2008. - Bergner, J.; König, C.; Hofmann, T.; Ebert, H.: „Entwurf einer integrierten Planungsanzeige für den Tower-Controller“, DGLR Deutscher Luft- und Raumfahrt Kongress 2008, Darmstadt, Germany, 23.-25. Sept. 2008. - König, C.; Hofmann, T.; Bergner, J.; Bruder, R.:„Evaluation eines Human-Machine Interfaces für Tower-Fluglotsen unter Einsatz eines Simulators“, In: H. Brau, S. Diefenbach, M. Hassenzahl, F. Koller, M. Peissner, K. Röse (Hrsg.). Usability Professionals 2008. Berichtband des sechsten Workshops des German Chapters der Usability Professionals Association e.V. Stuttgart: Fraunhofer IRB Verlag, S. 295-297.
CONTEXT	
4	In which kind of organisation was the good practice applied, either operationally or in an R&D

	project? *(such as ACC, APP, TWR, Cockpit simulator, Cockpit Mockup, etc.)*		
	Within the LUFO III (Luftfahrtforschungsprogramm) the devolpment of this HMI for cooperative planning of arrivals and departures, was achieved in collaboration of DFS, delair Air Traffic Systems GmbH, Institut für Arbeitswissenschaft (Institute for Ergonomics) of Technical University of Darmstadt, and university of applied sciences Osnabrück. Originally started as an R/D project, it is now under developed as an operational system for the tower of Frankfurt and later for Munich. The operational system is developed within DFS.		
5	What were the required technical means and human resources?		
	The HMI for tower controllers was developed in an interdisciplinary team, which participated from the beginning on, composed of controllers, ergonomists and HF specialists, software engineers, product and interface designers. Depending on the stage of development (see V-Phase below), especially concerning the HMI design, different technical means of increasing sophistication are required, ranging from gaming exercises, mock-ups of first prototypes to simulators and finally live trials in shadow-mode. The validity of the operational benefit is best tested in real time simulations with the participation of end-users. For arranging a real time simulation as realistic as possible to constitute a realistic tower environment and imitate the dependencies of arrivals, departures and the ground traffic, a 3D-Tower real time simulator, is needed, which ideally is coupled with an ACC simulator. The automation concept and HMI was iteratively tested in real time simulations with the participation of end-users. For the evaluation a realistic test environment is essential, therefore the DFS 3D-Tower simulator was chosen, which provides a realistic tower controller working environment with the complete 360°panorama view of the airport. The tower simulator was coupled with an ACC-Simulator to simulate in- and outbound traffic. During the simulation controllers were involved and interviewed in debriefings to gather their opinions and remarks about the new HMI, including their suggestions for improvements. Additionally working psychologist observed controllers and documented the user interactions for further analysis.		
6	If applicable: How often was the good practice applied in the past? Please estimate.		
	Until now it was only tested in simulations of Frankfurt tower as R/D project.		
7	Integration of the concerned automation into a system or an ensemble of systems		
	After development of a linkage between arrival and departure planning systems, an integrated display, which combines both information sources, was needed to display automated planning of arrival and departure sequences and times. This planning tool and corresponding HMI is replacing separated displays of arrival and departure information currently used.		
8	On which phase of maturity of the concept/automation was the good practice applied?		
	☒ V1: Scope	☒ V2: Feasibility	☒ V3: Pre-industrial development and integration
	☐ V4: Industrialisation	☐ V5: Deployment	☐ V6: Operations
	8.1 Rationale		

	The description of the good practice is related to the R&D project and therefore phases V1 to V3 apply. Currently the operational system is developed but cannot be regarded here.

CONTEXT OF THE TASK

9	What are the concerned flight phases?				
	☐ Turnaround	☐ Pushback	☐ Taxi-out	☒ Take-off	☐ Climb
	☐ En Route	☐ Descent	☐ Approach	☒ Landing	☐ Taxi-in
	9.1 Rationale				
	This HMI provides information about cooperative planning of departures and arrivals for tower local controllers at major hubs. It displays incoming and outgoing aircrafts on one time-line to improve the perception of the planning situation for controllers. They have the possibility to shift and reorganize departures on the runways, assigning new departures times or rearranging the sequence. Therefore mainly Take-off and Landing procedures are concerned.				
10	Actor(s)				
	Air: Pilot ☐ PNF ☐ PF	Ground: ATCO ☐ EC ☐ PC ☐ Supervisor ☒ TWR Local Controller responsible for RWY movements…			
	10.1 Rationale				
	Tower Local Controllers are responsible for landing and take-off procedures at the runways and the planning tools and HMI supports them.				

TASK

11	Pilot tasks	ATCO task
	Operate: ☐ Control the aircraft ☐ Manage the autopilot ☐ Monitor the flight parameters Navigate: ☐ Aircraft position management ☐ Flight planning/ trajectory management Communicate: ☐ Communicate with ATC ☐ Communicate within the crew ☐ Communicate with other aircraft, airline, maintenance Manage system status and surroundings: ☐ Monitor system/ aircraft status and surroundings ☐ Evaluate system/ aircraft status and surroundings ☐ Handle system/ aircraft status and surroundings	☐ Monitoring traffic ☐ Providing traffic information ☒ Issuing instructions/clearances ☐ Detecting conflicts ☐ Resolving conflicts ☒ Planning strategy ☐ Assuming and transferring traffic ☐ Ground-ground communication

	11.1 Rationale
	Through presentation of planning information for arrivals and departures at only one display the controllers are more efficient in analyzing the planning situation for several runways. Furthermore they can interact with the HMI to shift departures on the time line, assigning new departure times and rearranging the sequence. So delays can be avoided by organizing incoming and outgoing aircrafts more efficiently. Furthermore the HMI supports the controller by providing information about aircraft and displays if they already have received a certain clearance or if they still need one.
	11.2 Consequences on changes in roles, responsibilities, authority sharing and delegation
	With this new HMI all information is provided by one display with one input device, not by separate displays and input devices, as before. Interactions with the interface are realised via Grip-Pen without the aid of other equipment. The new HMI and interaction device simplify the work of controllers, but doesn't change any responsibilities or authorities.
12	Classification of supported cognitive functions and automation level

	Associated cognitive function being supported by automation							
	Information acquisition		Information analysis		Decision and action selection		Action implementation	
	Before change	After change	Before change	After change	Before change	After change	Before change	After change
LA	A2	A3	B0	B2	C0	C2	D0	D0

12.1 Rationale

	Information acquisition is improved by integrating two separate information sources into one interface which facilitates the controller's perception of planning information. Because of providing aircrafts flight plan information on a timeline the information analysis is facilitated. The level of automation in selecting decisions and actions (before implementing this HMI) is adjustable to the requirements of each airport. Information acquisition: **Before: (A2)** The provision of data is achieved automatically. Aircraft positions on the airport are provided by primary radar (ASR-Airport Surveillance Radar and SMR-Surface Movement Radar). Planning information is provided by arrival manager and departure manger systems. After: (A2) no change Information analysis: **Before: (B0)** Planning times of arrivals and departures are displayed on separate screens/displays. The data is usually displayed in tabular format. The operator has to aggregate the information himself to build a mental picture of the current and future traffic situation. **After: (B2)** Planning times of arrivals and departures are now combined and displayed on one screen in a graphical format. Decision and action selection: **Before: (C0)** no automation support, everything done manually. **After: (C2)** When implementing this planning tool, level of automation is adaptable. Depending on operational requirements the automation level can range from a full manual configuration, where planning information is displayed only but the sequence of departures and arrivals is set up by the controller, up to a level of automation, where the planning tool generates suggestions for sequence and times and the controller has either to accept them, or to implement his own planning strategy. Hence the level of automation can be adapted to requirements of each airport, without extensive changes of the HMI. In the highest level of automation the system generates possible decision options, the human chooses whether to implement an option or not which corresponds to level C2. Action implementation: **Before: (D0)** The human performs all tasks without automation support. **After: (D0)** Though the system generates possible decision options, the controller still has full control whether and which option to implement. Carrying out actions is done by the controller. There is no support concerning the action implementation, clearances are still issued via r/t.
IMPACTS ON HUMAN PERFORMANCE	
13	13.1 Which changes do you see in the way the Human Performance is supported?

Currently controllers get necessary information about meteorological data and flight plan information from separate displays with separate control panels and different input devices (keyboard and mouse).

With this new HMI all information is provided by one display with one input device. Interactions with the interface are realised via Grip-Pen without the aid of other equipment.

Controller in interaction with the interface by using the Grip-Pen

The new HMI and interaction device simplify the work of controllers, interaction is more intuitive resembling their operational procedures and working methods. Interaction is less time consuming, workload decreases are expected.

13.2 Which benefits do you expect on SESAR KPAs?

☒ Capacity	With this HMI a faster perception of the planning situation is enabled, hence the utilization of runways is optimized and full capacity is reached and number of delays is significantly reduced.
☒ Efficiency	With this new interface a higher efficiency is given, because information does not have to be integrated manually from different displays..
☐ Flexibility	
☒ Predictability	This HMI displays combined arrival and departure planning information on one timeline for the next 6 minutes.
☒ Safety	The graphical display and the interaction is standardised, all tower working positions have the same look and feel. By this it is a voided that controllers have to realign themselves to different displays or layouts if changing the working position during operations.
☐ Access and Equity	
☐ Interoperability	

13.3 Human Performance and automation issues expected to be mitigated

- **Issue n. 1:** Lack of user involvement in automation assisted processes may lead to reduced vigilance and loss of situation awareness.

The operator is directly involved with the planning process, staying "in-the- loop". Both the controller and the system generate possible decision options. The controller still has full control whether and which option to implement. Carrying out actions is done by the controller.

- **Issue n. 10:** Automation may increase task demand and cognitive workload.

Information analysis and building the mental picture of short-term traffic planning is facilitated, reducing the mental workload of controllers.

- **Issue n. 11:** Automation could require additional system inputs, which may lead to increased task load and reduced acceptance.

System inputs are made more easy as they are performed on one display only using a Grip-Pen. Previously inputs were required with different input devices (TID, keyboard or mouse) on different screens.

- **Issue n. 16:** Poor usability of HMI may reduce the human performance benefits expected from the automation support.

HMI usability is ensured through a multi disciplinary development process involving end-user, software engineers, product and interface designers and HF specialists/ ergonomists. The well-engineered graphical user interface has won two design awards.

- **Issue n. 17:** Information flooding due to poorly designed automation support may impact situation awareness and increase cognitive workload.

The new HMI reduces the number of existing displays and interfaces. All necessary information is integrated into one system. Scanning pattern is optimised, controllers attention focused on one single screen, decision making efficiency is improved as the data has not to be integrated manually.

13.4 Human Performance and automation issues potentially not mitigated

13.5 Would you expect that procedures will change?

☐ Yes ☐ Likely yes ☒No ☐ Likely no

Explanation:

ATC operations are not affected, no procedures will change. Only working methods of controllers might be changed.

FINAL CONSIDERATIONS

14 What can be learnt from the proposed change in HP automation support?

Basis for this good practice is the multi disciplinary approach right from the start of the project involving end-user, software engineers, product and interface designers and HF specialists/ ergonomists.

Then the development is conducted as an iterative, incremental process with user participation.

The benefits of this approach is that system development is assuring that the design meets the user's needs to accomplish their tasks as their feedbacks and suggestions can be used for further development of the system. This will ensure that a high degree of usability is achieved. As a result not only acceptance increases but also the commitment and identification with the developed system.

While this project had R&D status the mentioned multi disciplinary approach needs to be completed with adequate requirements engineering to develop an operational system (V-Phase

	4 to 6).

5 References

The following references are intended to be referred to chapters 1, 2 and 3 of the current document.

Regarding chapter 4 – List of REOAs, reference material has been included in the concerned template of each REOA, in order to make easier to find relevant information on a specific automated function when needed.

SESAR Joint Undertaking (2010). Identification and Integration of Automation Related Good Practices. WP 16.05.01 Project Initiation Report. Version 00.01.03.

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