The CREDOS Project
WP4
D4-10 Human Factors Case Report

Abstract:
This document describes the Human Factors (HF) Case conducted for the Crosswind Reduced Separation for Departure Operations (CREDOS) project as part of WP4. The HF case provides a structural framework to identify, understand and manage Human Factors (HF) issues relating to the CREDOS concept within the context of the CREDOS project so that the required HF validation activities are performed at the appropriate time in the concept development process. The HF issues identified and the HF validation activities conducted to address and better understand these issues are described in this report together with the findings and concept design recommendations derived from these activities. Recommendations for future validation activities are also defined.

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EXECUTIVE SUMMARY

This report describes the Human Factors (HF) Case conducted for the Crosswind Reduced Separations for Departure Operations (CREDOS) project.

The aim of the CREDOS project is to investigate the feasibility of a departure operation whereby the ICAO wake turbulence separations between certain aircraft departure pairs (e.g. a Heavy followed by a Medium) can be temporarily suspended under certain crosswind conditions. The aim of the concept is to temporarily increase departure runway throughput in such a way that demand peaks are absorbed and departure delays are reduced.

ATM is a human centric system, thus the development of the CREDOS concept must be based on a solid understanding of the impact of CREDOS on controllers’ roles and tasks. It is important to identify and consider human performance issues in the design and development of the CREDOS concept to ensure that it both achieves the proposed system performance benefits and is acceptable to the end users.

The CREDOS project uses a case based validation approach to develop and demonstrate the feasibility of the CREDOS concept. The HF Case provides a framework to identify, understand and manage the Human Factors issues in the design and development of the CREDOS concept. This document describes the HF Case process applied to the CREDOS project. The HF Case consists of five stages, only the first four are of direct relevance to the CREDOS project and are reported in this document:

• **Stage 1 – Fact Finding.** This initial assessment indicated that the implementation of CREDOS would mainly impact three HF work categories: 1. Procedures, Roles and Responsibilities; 2. the Human in the System relating to HMI design etc., and; 3. Teams and Communications.

• **Stage 2 – Human Factors Issue Analysis (HFIA).** A total of 29 HF related issues were identified in the Human Factors issue analysis. Of these 29 issues, 20 were considered of direct relevance and needed to be addressed in the HF Case at this stage of the design and development process. As a result of the issues identified and the level of maturity of the CREDOS concept the main HF objectives for the CREDOS project were twofold:

  o to support the design of CREDOS procedures and HMI and;

  o to assess the impact of the CREDOS procedures and HMI on controller workload & cognitive processing demands; human error; acceptance and trust.

• **Stage 3 – Action Plan.** A plan of the HF validation activities required to further investigate and address the 20 issues identified in stage 2 was developed. Eight activities were identified as necessary, including: a task analysis / cognitive task analysis; stakeholder workshop; a field study of current working practice and equipment in tower control centres; prototyping & real time simulations.

• **Stage 4 – Action Implementation.** The activities defined in the HF action plan to address and further investigate the issues identified in the HFIA were conducted. The findings from each these activities gave rise to design recommendations to mitigate the potential negative impacts of CREDOS on controllers work. These design recommendations mainly related to the CREDOS procedures and HMI, and are described in this report.

Future validation activities required to further our understanding and address outstanding issues that were either not fully addressed or arose from the HF validation activities conducted to date are also defined.
THE INTRODUCTION

1.1. DOCUMENT PURPOSE
The purpose of this document is to report on the HF Case approach adopted for the CREDOS project including the HF issues identified relating to the CREDOS concept, the HF validation activities conducted, the findings from these activities and recommendations.

1.2. BACKGROUND
The aim of the Crosswind Reduced Separations for Departure Operations (CREDOS) project is to evaluate the feasibility of the use of conditional reduced separations for departure operations under specific crosswind conditions. The CREDOS project has three main objectives:

- Increase the body of knowledge relating to wake turbulence behaviour during the initial climb phase of flight, and in particular identifying the precise crosswind conditions required to blow wake turbulence laterally away from the runway thus allowing a follower aircraft to take off sooner than is currently permitted by ICAO standards;
- Develop, and then demonstrate the feasibility of, a concept of operations that allows reduced separations for single runway departures under certain crosswind conditions;
- Provide all stakeholders with the required information to facilitate the implementation of the CREDOS concept in the near term (pre-2012).

The HF case is part of work package 4 (WP4) of the CREDOS project. The objective of WP4 is to ‘develop and then demonstrate the feasibility of a concept of operations that allows reduced separations for single runway departures under certain crosswind conditions’.

The CREDOS project is co-funded by the European Commission DG-RTD Framework 6 and co-ordinated by EUROCONTROL. The project started on 1st June 2006 and will last a total of 42 months. The HF Case was performed within this timeframe starting in April 2007 and finishing end of August 2009. The work on the CREDOS project has been performed by eleven European Organisations (Airbus, Berlin Technical University, DFS, DLR, EUROCONTROL, INECO, M3Systems, NATS, NLR, ONERA, and Université Catholique de Louvain) and with close collaboration with the FAA.

1.3. THE CREDOS CONCEPT
Currently, depending on the national / local application of ICAO, airports use either procedural time separation or radar separation in order to mitigate the impact of wake turbulence encounters for departures (Ref. Tower Survey, Appendix D). ICAO defines a minimum radar separation of 5.0NM (which may be reduced to 3NM when radar capabilities permit). The current ICAO wake turbulence radar separation minima depends only on the aircraft weight class of the preceding and succeeding aircraft combination and does not take into account specific weather conditions that may advance wake vortex decay or transport (crosswind/sink). As such the present minimum separation may be considered over-conservative in certain cases, leading to a loss of potential capacity.

The CREDOS concept proposes that wake turbulence separations can be suspended between certain pairs of departures when the wind conditions are such that the wake turbulence of the first aircraft is blown out of the path of the second one. The aim of which is to temporarily increase departure runway throughput in such a way that demand peaks are absorbed and / or departure delays are reduced.
<table>
<thead>
<tr>
<th>Leading Aircraft</th>
<th>Following Aircraft</th>
<th>Radar separation</th>
<th>Runway Separation Time for Departures (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAVY</td>
<td>HEAVY</td>
<td>4 NM</td>
<td>-</td>
</tr>
<tr>
<td>HEAVY</td>
<td>MEDIUM</td>
<td>5 NM</td>
<td>2</td>
</tr>
<tr>
<td>HEAVY</td>
<td>LIGHT</td>
<td>6 NM</td>
<td>2*</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>LIGHT</td>
<td>5 NM</td>
<td>2</td>
</tr>
</tbody>
</table>

* 3 minutes if taking off from an intermediate position

Table 1: Current ICAO wake turbulence minimum separations for departures

1.4. OBJECTIVE OF THE HF CASE

The CREDOS concept validation process uses a case based approach, and includes a Human Factors (HF) Case, Safety Case, Environmental Case and Business Case. The objective of the HF Case is to provide a structural framework to identify, understand and manage the HF issues relating to the CREDOS concept within the context of the CREDOS project so that the required HF validation activities are performed at the appropriate time in the concept design and development process. This will help to ensure that the proposed performance benefits of the CREDOS concept are achieved and the CREDOS Concept of operations is acceptable to the end users.

1.5. SCOPE

The CREDOS project investigates the possibilities of safely reducing separation minima for departures, by suspending the wake turbulence separation under specific crosswind conditions (note: there is no reduction of the minimum radar separation).

In terms of level of maturity the CREDOS concept is currently in the feasibility phase, that is level V2 according to the E-OCVM. The purpose of the feasibility phase is to develop and explore the concept until it can be considered operationally feasible (E-OCVM maturity level V3). That means that by the end of level V2 the operational procedures and requirements should become stable. Aspects that are focused on at this level of maturity are operability and acceptability of the operational concept.

The CREDOS validation process has adopted a case based approach in which a safety case and business case are being performed concurrently with the HF case. Information identified from the HF case activities that is seen as relevant to the other cases will be exchanged. Likewise, information from the other cases that is relevant to the HF case will be used to support the HF case.

It should be noted that the validation process is iterative hence each HF validation activity conducted helps to further develop and refine the CREDOS concept of operations.

The HF Case will consider, to varying extents, those actors whose work is directly affected by the introduction CREDOS, namely the tower and TMA controllers, the tower supervisor and aircrew.

CREDOS is a research project. The focus of the CREDOS concept is at the generic conceptual level and is currently not for a specific local implementation.

1.6. APPROACH

HF is a broad discipline, which considers all the issues that influence human and system performance, such as roles and responsibilities, procedures and task design, team issues and Human-Machine Interface (HMI) design. Also incorporated is the impact on Human Resources (HR) practices such as selection, training, planning, staffing, competency checking and licensing. Figure 1 broadly illustrates the HF issues considered within the “HF Pie” that is used to categorise HF Issues in the HF Case approach.
The HF Case has been designed to facilitate managing HF within the Air Traffic Management (ATM) system. It is a five-stage process to systematically identify and mitigate HF Issues as early as possible in the project life-cycle.

The HF Case stages are:

• **Stage 1 – Fact Finding**: This stage records the factual information about a project, including its background, system and environment, key stakeholders and documentation. The objective is to scope the project from an HF perspective to identify what will change, who will be affected and how.

• **Stage 2 – Issues Analysis**: This stage is about the identification and prioritisation of the project-specific HF Issues and their potential impacts on the project.

• **Stage 3 – Action Plan**: During Stage 3 an Action Plan is developed which describes actions and mitigation strategies to address the HF Issues identified for the project.

• **Stage 4 – Actions Implementation**: This stage implements the Action Plan. The output is the HF Case Report which provides findings and conclusions from the actions taken to address the HF Issues from Stage 3.

• **Stage 5 – HF Case Review**: This stage provides an independent review of the HF Case. It suggests recommendations for improvements to the HF Case methodology.

It should be noted that only stage 1 to 4 will be reported in this document, as stage 5 is not specifically relevant to the CREDOS project.

The HF Case focus is on the HF impacts upon human performance, e.g. augmenting human strengths and
compensating for human limitations to improve total system performance (see Figure 3). It can answer questions such as:

- In which way will the operator’s task and task demands change?
- What is the likely impact of the task changes on human performance (i.e. human error)?
- Will the operators accept and trust the new/changed system or tool?
- Will they be motivated to use it?
- Will there be excessive training and re-training costs?
- Will a different type of profile be needed to select candidates?
- Will the system fit in with conventional job roles and, if not, have new roles been considered?
- Will the operators have the right skills, and has training been planned?
- Will the operators still be able to take over if/when the system fails or starts to generate bad data?
- Will there be sufficient operators available?

![Figure 3: HF Impact on Human Performance ‘wheel’](image)

1.7. DOCUMENT PURPOSE AND STRUCTURE

This document is structured as follows:

- Section 2 describes the HF Case approach for the CREDOS project, including a summary of outcomes of the HF issues analysis, a description of the action plan developed to address the issues identified as well as a description of the actions completed to date.
- Section 3 describes the findings and recommendations identified from the HF Case activities conducted.
2. THE CREDOS HF CASE PROCESS OVERVIEW

2.1. INTRODUCTION

This section provides an overview of each stage of the HF process conducted for the CREDOS project from stage 1 to stage 4 (see Figure 4 for overview). For each stage the objective/purpose, method employed and outcomes are highlighted.

The HF Case was completed over a 27 month period:

- Stage 1: Fact Finding: April 2007
- Stage 3: Action Plan: July-August 2007

![Figure 4: Flow diagram of the HF Process](image)

2.2. CREDOS ASSUMPTIONS

The CREDOS concept is based on the following assumptions:

- CREDOS is proposed to be used for single departure mode independent runways only.
- Departures from intersections will not be addressed.
- WT separation minima behind a Super Heavy will not be suspended.
• Departures are controlled in an environment equipped with a surveillance system (e.g. radar, ADS-B) both on ground and when airborne.

• The wind criteria has to be determined per airport (sometimes even per runway).

• There will be no sliding scale depending on actual wind transportation effect.

• The CREDOS concept is based on today’s technical environment and so does not rely on DMAN or electronic flight strips, etc..

• Transition to another type of separation (i.e. ICAO wake turbulence separation minima, or vertical or lateral separation) is considered.

• SIDs will be considered in concept if the split is early (i.e. before 4NM from the start of the runway).

• The WT separation suspension ‘box’ is dependant on the local capabilities to measure wind, aircraft deviation from track and aircraft performances (climb angle) and so has to be determined per runway.

2.3. STAGE 1 – FACT FINDING

2.3.1. Objective

The objective of stage 1 of the HF Case process was to scope and understand the CREDOS project from an HF perspective. The feasibility of applying the HF Case for the CREDOS project is addressed here.

2.3.2. Method

In April 2007, information was gathered on the CREDOS project from the concept developers and operational experts to understand what was changing with the introduction of CREDOS, who would be impacted and how they would be impacted. The factual information sheet was completed and can be found in Annex A of the Human Factors Action Plan, Ref. 2.

2.3.3. Outcome

This initial assessment indicated that the implementation of CREDOS would impact the following HF categories:

• Procedures roles and responsibilities: It was identified that CREDOS would impact to varying degrees the tasks and working methods of the runway controller, supervisor, ground controller and aircrew.

• Human and the system: It was identified that implementation of CREDOS would require additional CREDOS related information to be displayed to the Runway controller, supervisor and ground controller.

• Teams and communications: Teams and communication would also be impacted by CREDOS, for example CREDOS specific phraseology would need to be developed to inform the air crew that CREDOS is to be used.
2.4. STAGE 2 – ISSUES ANALYSIS

2.4.1. Objective
The objective of Stage 2 of the HF Case was to identify and prioritise the specific HF issues relating to CREDOS and consider their potential impact on human performance and the wider system.

2.4.2. Method
An initial Human Factors Issue Analysis (HFIA) workshop was performed in May 2007 with five participants, including four controllers and one pilot. The HF work areas identified from the fact finding exercise as being the areas that would be impacted by CREDOS were validated. The HF issues relating to the three HF work areas identified were then generated using the ‘what if?’ question.

These issues were then prioritised by evaluating the likely impacts or consequences of not addressing each issue identified appropriately.

The group then identified initiatives that could help address, (i.e. prevent, control or mitigate) the HF issues and impacts.

Those issues identified that had safety implications were forwarded on to the safety team so they could be addressed in the CREDOS safety case.

2.4.3. Outcome
The subject matter experts participating in the HF issue analysis (HFIA) agreed with the findings from Stage 1 that the three main HF work areas that would be affected by CREDOS and needed to be addressed at this stage of the development cycle were:

- Procedures, roles and responsibilities. However, it was thought that CREDOS would also affect the roles, tasks and responsibilities of the TMA controllers, in addition to the other users identified in stage 1.
- Human and the system. It was also believed that TMA controllers would be affected by CREDOS so a suitable HMI would need to be developed for the TMA controllers as well as the Runway controller, ground controller and supervisor.
- Teams and communications. Phraseology specific to CREDOS was identified as necessary.

The HFIA identified a total of 29 HF related issues. The most frequent likely impacts of the HF issues identified on human performance were found to be:

- Human error
- Lack of trust in the CREDOS procedures and tools
- Non acceptance of the CREDOS procedures and tools
- Additional workload
- Increasing in cognitive processing demands
- Change in required skill set

The main preventative / mitigation initiatives identified were:

- Intuitive and user-friendly HMI
- Definitive procedures / working methods
- Training issues for aircrew and controllers
Therefore, the HFIA identified that the Human Factors objectives with regards to the CREDOS project, given the current maturity of the concept, are two-fold:

1. To support the design of the CREDOS procedures and HMI (aircrew and controller training issues are dealt with at a later stage in the concept development life cycle)

2. To assess the CREDOS procedures and HMI in particular with regard to:
   - Controller workload
   - Human error
   - Acceptance and trust
   - Impact on controllers cognitive processing

It should be noted that several safety related issues were also identified during the HFIA. These safety issues were then fed into the CREDOS safety case that was being led by NLR. In addition three issues identified during the HFIA related to controller and aircrew training and two issues related to monitoring and evaluation of concept post-implementation. These issues were documented in the HFIA and will be considered later on in the concept development life cycle.

The CREDOS HF Action plan, deliverable 4.3, Ref. 2 provides the details of the HF Issues analysis described above. The issues identified from the HFIA are described in Appendix D. However, the table below presents a summary of the initial HF issues / questions identified from the HFIA for the three HF work areas that would be impacted by CREDOS. The list in the table below should not be considered exhaustive or complete but as a starting point to facilitate directing the scope of the HF activities within the CREDOS project.
<table>
<thead>
<tr>
<th>Procedures, Roles and Responsibilities</th>
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<tr>
<td><strong>Acceptance &amp; trust</strong></td>
</tr>
<tr>
<td><strong>Workload &amp; Cognitive processing demands</strong></td>
</tr>
<tr>
<td><strong>Roles &amp; responsibilities</strong></td>
</tr>
<tr>
<td><strong>Working methods</strong></td>
</tr>
<tr>
<td><strong>Procedure format &amp; structure</strong></td>
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<tr>
<td><strong>Skill change</strong></td>
</tr>
<tr>
<td><strong>Situation awareness</strong></td>
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**Human in the System**

| Information requirements | Controller needs an indication of CREDOS availability – should this be case by case or periodic? What information to display regarding CREDOS status (active vs not active and GO / NOGO per aircraft pair)? Is support for ATCO to know what SID to use under which wind conditions required? Need 2 define wind info requirements for controllers? What info. does aircrew need a wind sock? What information does RWY need to ensure heavy has taken correct SID before giving a CREDOS clearance? Need to determine aircrew information requirements – to help build trust & confidence |
| User requirements | What support is required to help achieve 3NM separation consistently? What if contradictory wind information is displayed? Need to ensure HMI is clear and easy to interpret? Need to ensure HMI minimises WL & human errors. Does departure of Heavy/a/c need to be recorded & tracked to ensure clearance to a/c #2 is given at correct time & ensure situation awareness maintained? Need to ensure controller cannot apply CREDOS on wrong SID |
| Visual displays | What if x-wind lingers around threshold? Need to ensure CREDOS HMI does not provide continuously variable data – this could lead to human error, loss of trust or bending of rules. |
| HMI usability | What if wrong wind meter / wind info display is selected and CREDOS spacing is applied? What if CREDOS status indication is not clear and intuitive? Need to ensure design of CREDOS HMI maintains controller SA & minimises error? |

**Team and communication**

| Communication methods | How to inform DEP CREDOS is being applied? How to inform aircrew CREDOS being applied? Need to ensure TMA controller is informed CREDOS is being applied. |

**Table 2: Summary of outcome of Stage 2: HF work areas and issues identified for CREDOS**
2.5. STAGE 3 – ACTION PLAN

2.5.1. Objective

The objective of stage 3 was to select and describe the HF validation activities required to address the prioritised HF issues identified in Stage 2. Risks and constraints that may affect the validation activities required were also identified.

2.5.2. Method

For each (priority) HF issue, the tasks and activities required in order to develop HF specifications and assess the impact of the concept on human performance were identified. The sequence and relationships between the different activities were then determined. Each activity was described in terms of its objective, inputs required, expected outcome, benefits of performing such an activity, planning and approach and timeline, resources required. The issues addressed by each activity were also defined. (see the HF action plan in D 4-3, Ref. 2 for details).

2.5.3. Outcome

Eight different HF validation activities were identified as necessary to deal with the issues identified in the HFIA. The HF validation activities required and their objective are described below.

2.5.3.1. Activity 1 – Task analysis

The objective of the CREDOS task analysis was to identify the changes to tower controllers' tasks (including the clearance delivery controller runway controller, and ground controller) under CREDOS operations compared to current day operations and to assess the impact of CREDOS on the controllers' work using a structured approach.

2.5.3.2. Activity 2 – Cognitive Task analysis (CTA)

The cognitive task analysis built on the task analysis developed in Activity 1. The aim of the cognitive task analysis was to better understand whether or not the introduction of CREDOS would result in any significant cognitive changes to controllers work, for example in terms of the way controllers make decisions, plan their work etc.. From the CTA the impact of CREDOS on human error potential, workload and team interaction can be better understood and specific CREDOS-related issues can be identified. The CTA is also used to support the identification of CREDOS HMI information and procedural requirements.

2.5.3.3. Activity 3 – Stakeholder workshop

The aim of the workshop was to support the development of the CREDOS procedures and HMI design by consulting the potential users e.g. controllers, aircrew, that would be directly affected by the introduction of CREDOS. The objective was to consider and discuss HF issues and requirements identified in previous validation activities with the potential end users. The involvement of the potential end users relatively early in the concept development process should not only lead to a better design but also helps to ensure acceptance of the concept.

2.5.3.4. Activity 4 – Field studies

A study of current tower control working practices was planned to gain a good understanding of the current equipment available in European tower control centres and also current working practice. This was seen as necessary as CREDOS is a short term project with implementation proposed in the near terms (around 2012) The survey would help to ensure that the HMI developed and the proposed support tools for CREDOS are feasible in today's current systems. In addition, the survey would also enable a better understanding of how certain procedures are undertaken in towers and TMAs across Europe today in order to provide a better basis for design of the CREDOS separation procedures.

2.5.3.5. Activity 5 – HF input into HMI Development

HMI requirements identified from the cognitive task analysis, stakeholder workshop were used together with HF design standards and guidelines to develop and refine initial HMI solutions for CREDOS. The utility and usability of selected CREDOS HMI prototypes would be later assessed in both a part- task and full real time simulation (see activity 8).
2.5.3.6. **Activity 6 – Human Factors input into Procedural Development**

Findings from the CREDOS task analysis / cognitive task analysis and feedback from the stakeholder workshop were used to inform the development of the CREDOS operational procedures for the tower and TMA controllers. A Human Error Analysis was recommended to identify potential human errors that may result due to the CREDOS procedures. A part task and full real time simulation would assess the proposed CREDOS procedures (see activity 8).

2.5.3.7. **Activity 7 – Phraseology development**

Phraseology is a sub-set of activity 6 (Procedure Development). The aim of this activity was to develop clear and concise phraseology for CREDOS operations.

2.5.3.8. **Activity 8 – Simulations**

The objective of the real time simulations was to present the CREDOS concept to controllers in a realistic setting and evaluate whether or not the CREDOS concept impacts controller performance with regards to workload, human error, trust, acceptance and cognitive processing. The simulations would also be used to assess the utility and usability of the CREDOS HMI and procedures, and hence further identify CREDOS related HMI and procedural requirements. A part task simulation followed by a full task simulation was planned.

Two additional activities were defined as a result of issues identified during the HFIA, namely: 1) controller and aircrew related training and; 2) post implementation monitoring and benefit study. However, given the level of maturity of the concept these activities were out of the scope of the current CREDOS project, but would need to be considered and defined in more detail later on in concept development life cycle.
The diagram below defines the activities and illustrates the relationships between the different activities.

Figure 5 illustrates the relationships between the eight HF validation activities identified as necessary to address the issues identified from the HFIA in Stage 2. Thus these activities would be used to assess the feasibility and acceptability of the CREDOS concept and inform the development of the CREDOS ConOps. The task analysis is used as a basis for the field studies and both task analysis and field studies will be used as inputs to the cognitive task analysis. The cognitive task analysis will be used to inform CREDOS procedure and HMI development together with the outcome of the stakeholder workshop. The HMI and procedures developed plus phraseology will be assessed in both a small scale and large scale simulation.
2.6. STAGE 4 – ACTION IMPLEMENTATION

2.6.1. Objective

The objective of Stage 4 of the HF Case process was to conduct the activities outlined in the Action Plan. The output of each HF validation activity outlined in the HF action plan will inform the design and scope of the CREDOS concept of operations.

It must be remembered that the validation process is an iterative process and each activity informs the development of the concept such that the concept changes and evolves as the validation process progresses. The HFIA conducted in Stage 2 was based on an initial version of the concept of operations (version A). However, each activity conducted enables a better understanding of the issues relating to the CREDOS concept and helps to develop and evolve the CREDOS concept of operations. Hence, the final version of the CREDOS Concept of operations (version E) has incorporated the findings and recommendations from the HF validation activities as described in the HF action plan as well as other activities conducted as part of the concept of operations validation process.

2.6.2. Activity 1 – Preliminary Task Analysis

2.6.2.1. Purpose and method

A Task Analysis is an informal assessment technique in which a task is broken into its essential components or subtasks. A pre-developed generic task analysis of current day European tower operations was used as a baseline to identify task changes that would occur under CREDOS operations. The generic task analysis described the tasks of three tower positions, namely: Clearance Delivery Controller; Ground Controller, and Runway Controller. The generic baseline task analysis was developed based on visits to four control towers (Stockholm Arlanda, London Gatwick, Rome Fiumicino, and Naples Capodichino). Walkthrough analysis involving tower controllers from several different European ANSPs were then conducted and once completed the task analysis was sent out for validation by the control towers that had participated in the development of the generic task analysis.

The changes that would occur to current operations as a result of CREDOS were identified through talk-through analysis with operational subject matter experts and CREDOS concept developers. (It should be noted that the version of the CREDOS ConOps used in this activity was version A, which considered implementing CREDOS into an advanced environment with electronic flight strips and A-SMGCS, and CREDOS operations supported by a CREDOS availability indicator with an integrated automated countdown timer)

2.6.2.2. Outcome

A preliminary CREDOS task analysis was conducted in September 2007. The task analysis compared the generic tasks of current operations with tasks under CREDOS operations for the clearance delivery controller, ground controller, runway controller and flight data assistant showed that the main role that would be affected by the introduction of CREDOS was that of the Runway controller. Little or no change to the other positions was identified. Therefore the scope of subsequent CREDOS HF activities would focus mainly on the role of the runway controller.

2.6.3. Activity 2 – Cognitive Task Analysis

2.6.3.1. Purpose & method

The Cognitive task analysis (CTA) built on the preliminary task analysis developed in Activity 1 in order to gain a more in-depth understanding of how CREDOS would affect the controller’s tasks at the cognitive level. Thus, the aim of the CTA was to understand what changes would occur to the controllers tasks in terms of perception / detection of visual and auditory stimuli; decision making and problem solving, planning and; response execution. This helps us to better understand the impact of CREDOS on controller performance and workload / mental demand and human error potential which in turn helps to identify whether additional support tools are necessary and what, if any, CREDOS related information is required to support controllers in their work. The CTA is also used to support the development of operational procedures.
As the preliminary tower task analysis showed that the runway controller position would be most affected by the introduction of CREDOS, the CTA only focused on the runway position. As the preliminary task analysis was relatively high level, the first step was to conduct a cognitive talk through interview with an operational expert on current day operations to establish a more in-depth baseline. To aid data collection, simplifying assumptions were made to facilitate discussion, the assumptions were developed based on CREDOS ConOps version A. The operational expert used in this exercise was also involved in the development of the CREDOS concept. Once the baseline task analysis of current operations had been completed and agreed, a cognitive talk-through interview of future operations with CREDOS was conducted with the concept / operational expert. The cognitive talk through of CREDOS operations involved stepping through each of the tasks with particular focus on the new / changed tasks. The subject matter expert was probed about information requirements, decision making and strategy / goal aspects of each task. The changes that would occur with CREDOS operations compared to current day operations were identified and the potential impact of these changes on human performance determined.

2.6.3.2. Outcome
The CTA was completed in February 2008. It identified eight new tasks under CREDOS and another eighteen tasks that would change as a result of CREDOS operations. The impact of the potential additional tasks and task changes identified were determined and recommendations to mitigate any potential negative impact of the task changes were identified. The recommendations refer mainly to HMI information requirements, additional support tools required to help the controller in his work, and procedural requirements. Scenarios that need to be considered in the concept development process (i.e. future validation activities) were also identified, as were additional issues relating to CREDOS operations that need to be investigated in future HP validation activities, i.e. the real time simulations. The findings from the CTA are summarised in Appendix A.

2.6.4. Activity 3 – Stakeholder workshop
2.6.4.1. Purpose & method
This aim of the workshop was to present the Concept of Operations to operational stakeholders (controllers and aircrew) and encourage their active participation in the validation process. In particular they were asked to validate the list of outstanding research issues identified by the project, and highlight any issues not considered. The initial CREDOS prototype HMI for an advanced system that had been developed based on the CREDOS ConOps A and the output of the HFIA was also presented to the controllers for preliminary feedback (see Ref. 5, D4-5 Initial Human Machine Interface design for a description and demonstration of the advanced CREDOS HMI presented to the stakeholders in the workshop).

2.6.4.2. Outcome
The first CREDOS stakeholder workshop was held in November 2008. Fourteen controllers and six aircrew from both Europe and America participated in the workshop. The outstanding research issues were validated and discussed together with questions regarding the concept raised by the stakeholders. The main issues discussed relating specifically to the HF case during the workshop included: trust and stakeholder acceptance, roles and responsibilities, operational procedures, the use of CREDOS with SIDs, plus HMI and support tools.

Feedback from controllers at the stakeholder workshop regarding the CREDOS prototype HMI for an advanced system was basically to go back to basics, and start simple this included: 1) developing the CREDOS concept so it could be implemented in airports environments that did not have advanced technology such as electronic flight strips and A-SMGCS and; 2) keeping the HMI as simple as possible. (A summary of the output of the stakeholder workshop can be found in Appendix B).

2.6.5. Activity 4 – Field study
2.6.5.1. Purpose & method
The aim of the field study was twofold, 1) to understand the ‘state of the art’ in terms of equipment available in European tower control centres today and; 2) to gain a better understanding of how operational procedures relating to aircraft separation are currently implemented by European controllers. This activity was deemed necessary as the aim of the CREDOS project is to develop a CREDOS concept that can be easily adapted to
A survey was used to collect this information as it was felt more tower control centres could be involved in a survey than interviews. The survey was developed with the help of the CREDOS concept developer, a tower control operational expert and a HF specialist. The survey covered areas of interest that had been identified through the Human Factors Issue Analysis (HFIA) and preliminary stakeholder workshop. Twenty European airport / tower control centres were contacted via email and asked to participate in the survey.

2.6.5.2. Outcome

The survey was conducted between March and July 2008. Nine airports responded to the survey. The findings showed that there was great variability between the airports surveyed in terms of the equipment available. Due to the variability between the airport equipments, no one definitive solution for the CREDOS HMI can be developed, as the HMI must be tailored to integrate well into the existing system. However, HMI recommendations for implementing CREDOS into different environments with different equipment and levels automation / technology can be proposed.

The survey also showed that there was great variation between airports in how they apply the ICAO wake turbulence rules, for example some airports use only radar minima, and others sometimes delegate separation responsibility to aircrew. Therefore the benefits of CREDOS will depend on the way in which ICAO wake turbulence rules are currently implemented. Therefore, it is recommended that a separate benefit study for each airport would need to be done before CREDOS is implemented. (The Tower control survey results can be found in Appendix C).

2.6.6. Activity 5 – HF input into HMI development

2.6.6.1. Purpose & method

The aim of activity 5 was to support the development of a HMI for CREDOS operations in order to ensure that the HMI developed is usable and that the necessary information / support is available to the controller(s) at the right time. The development of the HMI was an iterative process. The HMI was continuously developed, assessed and refined/modified based on the findings of several HF validation activities conducted as described.

The HFIA based on the CREDOS ConOps version A, identified possible mitigation actions / recommendations for those identified issues (see Ref. 2 for details). Several of the mitigation actions identified related to the design of the CREDOS HMI and support tools that could perhaps assist the controllers in their work. Based on recommendations identified in the HFIA a HMI design expert developed an initial HMI to support CREDOS operations. The CREDOS HMI was designed to be in conformance with ECHOES (EUROCONTROL Consolidation of HMI for Operations, Evaluations and Simulations) requirements. This preliminary CREDOS HMI developed was based on an advanced system that had A-SMGCS and electronic flight strips.

The preliminary CREDOS HMI for an advanced system was presented at the stakeholder workshop. The feedback from controllers at the workshop was that a simpler HMI for a less advanced system needed to be developed. Therefore based on the feedback from the stakeholder workshop and findings from the cognitive task analysis and survey of current European tower operations, a simpler HMI for CREDOS was developed. Findings from the Functional Hazard Assessment (FHA) and Human Error Analysis (HEA) conducted as part of the safety and business cases respectively were also used to inform the design and development of a HMI for CREDOS. Therefore, two possible HMIs were developed; one for an advanced system and; another for simpler systems which did not have advanced technology such as A-SMGCS and electronic flight strips. (A couple of additional information and support tool options were also proposed as a result of the findings from the validation activities conducted). Prototypes of the simple and advanced HMI solutions were developed and implemented on the integrated tower working position (ITWP) simulator. It should be noted that the development of the HMI prototypes was continuously supported with input and feedback from EUROCONTROL operational experts. (For a description of the prototypes developed for ITWP see Ref. 5. D4-5 Initial Human Machine Interface design)

Two potential CREDOS HMI solutions based on the simple HMI and tailored for the Schiphol / NARSIM environment were presented to controllers in a part-task real time simulation and the utility and usability of the
2.6.6.2. Outcome

The activities described above enabled the minimum HMI information requirements for CREDOS and support tools necessary to help controllers apply CREDOS separations to be identified. The minimum HMI information requirements and support tools are dependent not only on the tools and technology available in the tower centre but also on the airport configuration i.e. the SID structure. (A summary of the recommendations for the HMI information requirements and support tools can be found in chapter 3 or in Ref. 6, D4-15 CREDOS Real Time Simulation conduct report).

2.6.7. Activity 6 & 7 – HF input into Procedure & phraseology development

2.6.7.1. Purpose & method

The aim of activity 6 of the HF case is to help ensure that the CREDOS procedures developed are easy to use and integrate well into existing procedures / working methods and also help to ensure that potential human errors do not arise as a result of the new procedures. The aim of activity 7 was to develop the required CREDOS related phraseology that was consistent with current phraseology used as well as being easy to remember and interpret.

As with the development of the CREDOS HMI, the development of the CREDOS procedures and phraseology was an iterative process. The procedures were developed by operational experts and were refined and modified based on the findings from activities 1-4, defined above, i.e. the task analysis, cognitive task analysis, stakeholder workshop and survey of current European tower operations. The findings from the HF activities were supported by findings from the Functional Hazard Assessment (FHA) conducted as part of the safety case and Human Error Analysis (HEA) conducted as part of the business cases for Madrid-Barajas airport.

The CREDOS procedures as described in ConOps version C were presented and assessed by recently retired controllers in the part-task real time simulation conducted in November 2008 at NLR in Amsterdam using the NARSIM simulator. The findings from the part task simulation were used to inform the development of procedures and phraseology for nominal CREDOS situations (for details of the part task simulation see Ref. 6). The updated procedures resulting from the part task simulation are described in CREDOS ConOps version D.

A full task real time simulation was then conducted in March 2009 to evaluate the CREDOS ConOps D. One of the aims of the simulation was to present and allow current controllers to work with the modified procedures and phraseology in a realistic operational setting in order to assess the feasibility and acceptability of the concept. Findings from simulation were used to further inform the development of the CREDOS procedures. The updated procedures for nominal CREDOS events are described in the CREDOS ConOps version E.

A second aim of the simulation was to evaluate the procedures and phraseology developed by operational experts for non-nominal CREDOS related events. The non-nominal events had been previously identified by the HFIA, CTA, stakeholder workshop as well as the FHA conducted as part of the safety case. Only those selected events that were considered most feasible were simulated during a real time simulation. The procedures and phraseology for the non-nominal events were assessed in the full task real time simulation. Recommendations for procedures and phraseology for the identified non-nominal events are summarised in chapter 3. Details of the part and full task real time simulations conducted for CREDOS can be found in Ref. 6.

2.6.7.2. Outcome

Recommendations for CREDOS related procedures & phraseology for nominal and non-nominal events were identified and documented for each of the relevant activities conducted (see the following chapter for a summary of procedural recommendations). Where possible the recommendations were used to refine the CREDOS procedures and phraseology for both nominal and non-nominal events. The final version of the CREDOS ConOps is version E.

Additional activities required to further develop and assess the recommended modifications to the concept
procedures and phraseology were also identified. These recommendations are summarised in Chapter 3 and detailed in the Ref. 6, D4-15 The CREDOS Real Time Simulation conduct report.

2.6.8. Activity 8 – Real Time Simulations

2.6.8.1. Purpose & method

The aim of the simulations was to present the latest version of the CREDOS concept to controllers and allow them to work with the concept in a realistic tower setting to gain both feedback and performance data to assess the acceptability and feasibility of the concept. The feedback and performance data obtained would also be used to inform the development of the CREDOS concept including the CREDOS HMI and proposed support tools plus the procedures and phraseology.

Two real time simulations were conducted using the NARSIM tower simulator at NLR in Amsterdam:

2.6.8.1.1. Real Time simulation 1

The first real time simulation (RTS1) was a part task simulation that focused on the transition of flight from reduced CREDOS separations to standard separation before en-route. The aim of this simulation was to:

- Assess the different options in terms of CREDOS procedures and HMI and identify the design option most feasible in terms of their impact on aircraft separation assurance and human actors including subjective workload and acceptability. The various CREDOS options were compared to standard current day ICAO operations.
- Assess the utility and usability of two CREDOS HMI options proposed to support the controller in applying reduced CREDOS separations.

2.6.8.1.2. Real Time Simulation 2

The second real time simulation (RTS2) focused on the roles of the runway and departure controllers. The main HF aims of the simulation were to:

- Evaluate the impact of the CREDOS concept of operations as described in ConOps D on controller workload;
- Evaluate the impact of CREDOS on the controller roles and tasks;
- Assess the acceptability of the CREDOS ConOps D;
- Assess the utility and usability of the CREDOS HMI and proposed support tools.

RTS2 also had additional safety objectives which were also related to the HF objectives: The safety related objectives were twofold:

- To assess the impact of CREDOS on aircraft spacing;
- To assess the impact of hazard occurrences on the operational environment, and to gain insight into the controllers’ role in mitigating the effects of those hazard occurrences.

Therefore the HF team worked in close collaboration with the safety team to ensure the experimental design met both the HF and safety objectives. As with all the HF activities conducted as part of the CREDOS project, there was also close collaboration with tower control experts and the concept developers. For details of RTS1 and RTS2 objectives and methods see Ref. 6, D4-15, The CREDOS Real Time Simulation conduct report.
2.6.8.2. Outcome

2.6.8.2.1. Real Time Simulation 1

Four retired controllers participated in the simulation RTS1 conducted in November 2008. The simulation was conducted at NLR using the NARSIM tower simulator with the Schiphol airport environment. The findings from RTS1 showed that the CREDOS operational procedures described in ConOps C needed to be amended to ensure the required ICAO separations were met for en-route. The controllers generally perceived the concept to have potential benefits although more support was needed to help them in their work. Recommendations for improvements to CREDOS separation support tools were presented and ideas for alternative solutions were generated as a result. Improvements to the CREDOS HMI presented on the runway controller working position were also identified and HMI requirements for the departure controller were identified. Details of the RTS1 including the results and conclusions plus recommendations for the following simulation RTS2 can be found in Ref. 6 D4-15.

2.6.8.2.2. Real Time Simulation 2

RTS2 was conducted in April 2009 at NLR using an updated version of the NARSIM simulator based on recommendations from RTS1. Nine controllers participated in the study; six of whom were current controllers and three who had recently taken up other non-operational positions or were retired. From the simulation changes to controllers current roles and tasks were identified and potential human performance and safety issues were highlighted. Recommendations on how to mitigate the identified issues were proposed. The recommendations referred to improvements to the CREDOS HMI and proposed working methods/procedures plus phraseology. The need for additional support tools / automation under certain operational conditions was also identified and recommendations regarding these tools proposed.

In addition future validation activities to address or further investigate certain human performance and safety issues were identified. Details of RTS2 including the results and conclusions plus recommendations for the following simulation can be found in Ref. 6 D4-15.
3. HF CASE FINDINGS AND CONCLUSIONS

3.1. INTRODUCTION

This section provides a summary of the main findings and conclusions from applying the HF case process to the CREDOS concept. The main findings focus on the HF issues impacting human performance and the findings from the HF validation activities conducted to date. Conclusions and recommendations for further work are provided.

3.2. MAIN FINDINGS

To identify the main findings, the issues identified in stage 2 were revisited to see what had been learnt from the activities conducted in Stage 4 to better understand and address the issues identified.

The CREDOS Human Factors log in Appendix D shows a mapping of the issues identified in stage 2 of the HF case to the different activities that were both recommended and performed to address those issues, to recommendations that have come out of the HF activities conducted to date.

It should be noted that:

- The list of issues identified in Stage 2 are not exhaustive or complete but acted as a starting point to facilitate directing the scope of HF activities within the CREDOS project.
- The HF log in Appendix E of issues is a means to check and track what issues have or have not been addressed by the HF validation activities conducted. The current status of the issue was either said to be:
  - Closed. An issue was considered ‘closed’ when the issue had been sufficiently answered and no additional activities relating to that issue were foreseen as necessary.
  - Ongoing. An issue was considered as being ‘ongoing’ when the issue had been either: partially addressed and more studies were needed or; the issue had been addressed by certain activities but as a result other related issues had arisen that needed to be further investigated.
  - Not addressed. An issue that was ‘not addressed’ was considered to be either: outside the scope of the current activities conducted and needed to be addressed later on in the design process or; was out of the scope of the project.
- The CREDOS project is a research project and the CREDOS concept of operations is at a conceptual (generic) level hence the HF issues and findings are also generic in nature. Thus they act as a check list or guide for local ANSPs when implementing the CREDOS concept in a local environment. Therefore they will help to ensure that specific HF issues are considered and addressed when CREDOS is implemented locally.

The HFIA conducted in Stage 2 was based on an initial version of the concept of operations (version A). As the validation process progressed the findings from the various HF and other validation activities conducted were used to better understand the issues relating to the CREDOS concept and develop and evolve the CREDOS concept of operations. Therefore, the final version of the CREDOS Concept of operations (version E) has incorporated the findings and recommendations from the HF validation activities as described in the HF action plan as well as other activities conducted as part of the concept of operations validation process.

Table 2 summarises the main findings and recommendations identified to date from the HF activities conducted to address the issues that would impact human performance. Recommendations for future activities are also presented.
<table>
<thead>
<tr>
<th>HF issues impacting human performance</th>
<th>HF Activities conducted to date to address issue</th>
<th>Summary of main findings /recommendations from HF activities conducted</th>
<th>Future activities recommended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance &amp; Trust</td>
<td>Stakeholder workshop</td>
<td>Controllers: To aid acceptance and controller trust in the CREDOS concept:</td>
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<tr>
<td></td>
<td>RTS1 &amp; RTS2</td>
<td>• The CREDOS concept must have a strong safety case to re-assure controllers the concept is safe and does not increase potential risk of safety occurrences compared to current operations.</td>
<td>1. Evaluate CREDOS in real operational setting (Shadow trials).</td>
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<td></td>
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<td>• The CREDOS concept must be validated in a real operational environment for controllers to accept the concept.</td>
<td>2. Determine aircrew information / training requirements for CREDOS and develop a PR strategy / information campaign for CREDOS (this activity is to be carried out later on in the concept development process).</td>
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<td>• Transparency in HMI design is necessary: controllers must understand algorithms that underlie the different CREDOS status indications &amp; other support tools presented in the CWP.</td>
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<td></td>
<td></td>
<td>• Crosswind information should be present on CWP near CREDOS status indication so controllers can easily crosscheck CREDOS status.</td>
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<td></td>
<td>• Clear procedures &amp; phraseology for non-nominal events e.g. WV encounter, must be developed so controllers know and are trained to deal with such situations</td>
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<td></td>
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<td>• Sufficient training on CREDOS must be given before concept is introduced and at regular intervals (e.g. on an annual basis) to ensure controllers are familiar with CREDOS procedures for both nominal and non-nominal CREDOS related situations.</td>
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<td>• If possible the application of CREDOS and spacing achieved between a/c should be recorded. In an advanced technology environment equipped with electronic flight strip (EFS) and A-SMGCS controllers could be required to input into the EFS whether a CREDOS clearance was given or not and the commence of roll could be automatically recorded. This will also help in case there is a WV encounter &amp; subsequent investigation. In a simpler environment that uses paper strips controllers should be required to note whether CREDOS applied &amp; time of commence of roll on paper strip.</td>
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<tr>
<td>Flightcrew:</td>
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<td>To help ensure aircrew accept the CREDOS concept:</td>
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<td>• An information campaign is required to inform aircrew &amp; airlines of CREDOS and potential benefits to be gained. Ideally airlines would lead the campaign, as if airlines are behind the CREDOS campaign aircrew are more likely to accept CREDOS.</td>
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<td>• Presence of wind sock on runway may help so aircrew can crosscheck crosswind / CREDOS instruction.</td>
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<td>• Attention All Users notices (AAUs) have been used at airports in the USA to inform aircrew of the new procedures operational at an airport. The AAU notice informs aircrew what to expect regarding the new procedures and what to do. The AAUs notices issued by the FAA have been found to be very effective in</td>
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<tr>
<td>HF issues impacting human performance</td>
<td>HF Activities conducted to date to address issue</td>
<td>Summary of main findings / recommendations from HF activities conducted</td>
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</tbody>
</table>
| Workload / Cognitive processing demands | Cognitive task analysis | Runway controller: Subjective workload was found to increase under CREDOS compared to non-CREDOS operations (see RTS report Ref.6). Although the throughput of departure aircraft was found to increase with CREDOS compared to non-CREDOS operations, this increase in workload was also reportedly said to be due to:  
  - the need to plan more in advance with CREDOS, as controllers had to consider the assigned SIDs of the leading and following aircraft plus crosswind direction in addition to the status of the CREDOS GO / NO GO indicator in order to determine whether CREDOS could be applied or not. Therefore additional support is required when SIDs diverge near the runway (<4NM) to help controllers determine whether CREDOS can be applied or not depending on SIDs assigned to the leading and following aircraft & crosswind direction. (see information requirements section for more information)  
  - Increase in monitoring a/c in climb phase and responsibility for ensuring required ICAO a/c separation achieved before handover to DEP. A support tool to help the RWY achieve the required spacing in climb phase such as a timer or takeoff trigger advisory line as used in RTS1 and RTS2 respectively will help.  

Departure controller: No increase in workload or cognitive processing demands identified in RTS2 for the departure controller. | 3. Assess more advanced HMI options which integrates SIDs assigned with CREDOS status information (active / not active) & crosswind component & direction information. |
| Tasks, roles & responsibilities | Task analysis  
  Stakeholder workshop  
  Cognitive task analysis  
  RTS1 & RTS2 | Runway controller: In addition to current tasks, under CREDOS the RWY is responsible for deciding and applying CREDOS to departing aircraft. The RWY is also required to monitor aircraft in climb phase and ensure required ICAO aircraft separation is achieved at handover, this is an extra responsibility for some RWY controllers compared to existing practice but not for all. Therefore, the extent of the change in tasks, role & responsibilities depends on current working method: Therefore to support the controller perform the additional tasks related to CREDOS, the RWY requires:  
  - A CREDOS status indicator to help controllers determine whether or not CREDOS can be applied for the next departing aircraft. The type of information that needs to be incorporated in the CREDOS status indicator depends on the airport environment (see information requirements section).  
  - A spacing support to help ensure required ICAO separation is achieved at handover. (See user requirements section for details) |
### HF issues impacting human performance

<table>
<thead>
<tr>
<th>HF Activities conducted to date to address issue</th>
<th>Summary of main findings /recommendations from HF activities conducted</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Radar screen to monitor aircraft in climb phase is required in tower. Under CREDOS controllers need to have a radar licence and be radar trained therefore needs radar to monitor a/c during this phase.</td>
<td><strong>Departure controller:</strong> No real change in role and responsibilities identified.</td>
<td></td>
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<tr>
<td><strong>Supervisor:</strong> SUP responsible for activating and deactivating CREDOS operations – the wind forecast plus other factors such as traffic demands, runway in use must be considered in the decision. The supervisor must consult the departure supervisor before applying CREDOS to check there is no reason in departure control why CREDOS cannot be applied. The tower supervisor must also inform the tower controllers verbally just before CREDOS is activated or deactivated. (the departure controller should do the same in TMA). In order to support the SUP make the decision to activate or deactivate CREDOS:</td>
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<td>• The supervisor may require additional crosswind forecast information.</td>
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<tr>
<td>• The criteria for activating CREDOS need to be clearly defined for example, the threshold crosswind component value for CREDOS activation, and minimum duration of the forecasted crosswind.</td>
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</tr>
<tr>
<td>• Procedures for activation &amp; deactivation to be clearly defined (see procedure format &amp; structure section)</td>
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<tr>
<td><strong>Aircrew:</strong> No real change although aircrew must accept CREDOS clearance given by RWY.</td>
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</table>

<table>
<thead>
<tr>
<th>Working methods</th>
<th>Stakeholder workshop</th>
<th>Cognitive task analysis</th>
<th>Tower survey</th>
<th>RTS1 &amp; RTS2</th>
</tr>
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<tbody>
<tr>
<td><strong>Runway controller</strong></td>
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<tr>
<td>• RWY working methods found to change slightly because controllers had to consider additional factors (e.g. CREDOS status, SIDs assigned for leading and following a/c, crosswind direction) to determine whether or not CREDOS could be applied and plan departures more in advance.</td>
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<tr>
<td>• Controllers have to work in both CREDOS and non-CREDOS modes of operation. Therefore need to be able to switch easily from one working method to another. In addition as CREDOS is conditional on the crosswind strength &amp; determined on a case by case basis they will need to be able to change their working method within short notice. Feedback from controllers in RTS2 show that the conditional application of CREDOS and switching from one working method to another depending on the crosswind conditions is not considered a problem for controllers as long as there is not a continuous fluctuation between CREDOS and non-CREDOS operations.</td>
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<tr>
<td>• Therefore, the aircraft departure time must be noted on the strip to enable controllers to calculate required spacing for following aircraft in both CREDOS..</td>
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</table>
### HF issues impacting human performance

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</thead>
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<tr>
<td>... and non-CREDOS modes of operation (see user requirements... section). In addition a buffer must be introduced into the CREDOS status indicator to prevent continuous fluctuations between CREDOS and non-CREDOS modes of operations.</td>
<td>• Controllers also reported to monitor a/c for longer during climb phase under CREDOS compared to non-CREDOS operations. This was a change in working method for some controllers but not all. (see tower survey results in Appendix C) However, although this increase in monitoring was said to contribute to the increase in workload experienced under CREDOS, it was not considered problematic in that particular context.</td>
<td></td>
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<tr>
<td>• See Workload and Roles &amp; responsibilities sections for additional recommendations relating to working methods</td>
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</table>

### Departure controller:

- DEP working methods found to change slightly with regards to conflict resolution as they had to consider crosswind & WV behaviour when resolving. Therefore the runway controller must be given training on WV behaviour.

### Runway controller:

- CREDOS procedures for RWY must be clearly defined for both nominal & non nominal situations. Procedures at the generic level were developed for nominal & certain non-nominal events identified during the validation process and evaluated in the RTS2. See CREDOS ConOps Ref. 3 for examples.
- The CREDOS procedures must be consistent and integrate well into existing operational procedures & working methods both for nominal and non-nominal events. Hence when CREDOS is implemented at a local level existing operational procedures must be considered. Thus, for local implementation the CREDOS procedures would depend to an extent on existing operational procedures.
- As the RWY need to provide at least 3NM consistently under CREDOS to ensure safety, the CREDOS procedures for ensuring that the required spacing is achieved must be clearly defined and adhered to.
- Regulation for CREDOS separation procedures could be a means to ensure CREDOS procedures are adhered to and applied consistently.
- It is recommended that controllers give wind information to aircrew when giving a departure clearance, this helps to ensure that the RWY checks the CREDOS status before giving the CREDOS clearance, (in order for this to be the case the crosswind information should be situated next to the CREDOS status indication).
- The procedures evaluated in RTS2 recommended that following a WV encounter report CREDOS separations should be suspended immediately...

### Procedures structure & format

- Cognitive task analysis
- Tower survey
- RTS1 & RTS2

- 4. The tower survey identified different working methods used in different tower control centres to achieve required spacing. However, no real world performance data has been obtained to determine the accuracy & consistency of spacings achieved using these different working methods. Therefore a study should be conducted to identify best practice for achieving required separation consistently.

- 5. Procedures for certain non-nominal events need to be refined, and alternative procedures evaluated. A study to investigate whether or not CREDOS separations should be suspended after a WV encounter report
<table>
<thead>
<tr>
<th>HF issues impacting human performance</th>
<th>HF Activities conducted to date to address issue</th>
<th>Summary of main findings /recommendations from HF activities conducted</th>
<th>Future activities recommended</th>
</tr>
</thead>
</table>

...However, some controllers questioned this procedure as a single report might not be enough to stop the procedure. Further study required to determine whether CREDOS should be suspended following a WV encounter report.

**Departure controller:**

The feedback from RTS2 show that:

- The transfer of a/c from RWY to DEP must not be silent as this was found to cause confusion concerning responsibilities and co-ordination when aircraft deviated from expected route, i.e. non-nominal events. Therefore, verbal transfer of a/c required to ensure everyone knows who has responsibility for a/c.

- Procedures for non-nominal events which will affect DEP e.g. WV encounter, need to be clearly defined for DEP as well as RWY. Some non-nominal events that concern DEP have been identified through the validation process and were assessed with the procedures developed for each in the RTS2. See CREDOS CREDOS safety case Ref. 4 & CREDOS RTS conduct report Ref. 6 for details of non-nominal situations identified & procedures assessed.

**Supervisor**

- SUP is ultimately responsible for making the decision that CREDOS operations are activated or deactivated and hence whether CREDOS can be used or not. Clear procedures for SUP must be defined including criteria for CREDOS activation / deactivation.

- It is recommended that the tower supervisor checks with the departure supervisor before activating CREDOS. The tower supervisor must also inform the departure supervisor when s/he decides to deactivate CREDOS.

- The tower supervisor must inform the tower controllers verbally that CREDOS will be activated and/or deactivated. (The change in status will also be visible on each controller’s CWP). The departure supervisor will inform departure controllers that CREDOS will be activated or deactivated. Procedures developed at the generic level and assessed in RTS2 can be found in the CREDOS ConOps version E, Ref. 3.

**Aircrew:**

- Aircrew need to be informed asap that CREDOS is active and they may be given a CREDOS clearance when departing.

- Aircrew must also inform controllers if they are not willing to accept a CREDOS departure well in advance, to avoid situation where CREDOS clearance is refused when aircraft on runway as this may adversely affect efficiency and runway throughput.

- Aircrew must inform the controller that is on-frequency if WV is encountered.
<table>
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<tr>
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</tr>
</thead>
</table>
| Skill change                          | Cognitive task analysis                        | Runway controller:  
- To ensure safety (as margin for error is reduced under CREDOS) controllers will have to become more accurate and be able to consistently achieve the required minimum separation. A spacing support tool could help controllers achieve the required consistency and accuracy, (see user requirements section for more details).  
- As RWY is also responsible for monitoring a/c in climb phase, the RWY must be radar trained, as radar is required to enable RWY to monitor a/c during climb.  
- Controllers will need to know more about wake vortex behaviour. CREDOS training should include information about WV behaviour.  

Departure controller:  
No real change in skill. However, DEP needs to understand about crosswind and WV behaviour when resolving potential conflicts. Therefore, training on WV behaviour is required. | | |

| Situation awareness | Stakeholder workshop RTS1 & RTS2 | Runway controller:  
- RWY needs indication of CREDOS status.  
Four CREDOS states should be represented on the CREDOS HMI:  
  o CREDOS NOT ACTIVE (not activated by SUP);  
  o CREDOS ACTIVE and NO GO (i.e. CREDOS activated by SUP but CREDOS cannot be applied to following aircraft as CREDOS requirements not met e.g. crosswind below threshold);  
  o CREDOS ACTIVE and GO (i.e. CREDOS activated by SUP and CREDOS can be applied to next aircraft as requirements for applying CREDOS met);  
  o system failure relating to CREDOS.  
- Crosswind component and direction should also be displayed so controllers can crosscheck CREDOS status indicator  
- The CREDOS status indicator should inform controllers on a case by case basis whether or not CREDOS can be applied. Therefore, when active a GO / NOGO status for CREDOS is presented for each departing a/c.  

Departure controller:  
- DEP controllers need to have CREDOS status information available on their CWP, so they know when CREDOS separations may be applied. The minimum information requirement for the DEP regarding CREDOS status is the CREDOS GO / NO GO status indicator for each runway departure. The DEP needs to be alerted in some way (e.g. flashing visual indication or auditory signal) of change in CREDOS status. (see user requirements for more details). | | |
<table>
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</thead>
<tbody>
<tr>
<td>• In an advanced system the use of EFS could also help DEP situation awareness. A ‘Departure Status Information’ (DSI) window that displays the stage of a/c departure from pushback to take off as implemented in some DEP control centres could benefit the DEP controller. The DSI window is automatically updated for each flight each time a strip is moved from one bay to another by RWY in the feeder tower. Thus the DSI would keep the DEP immediately up to date and aware of the current situation for departing a/c. The DSI plus the CREDOS status indicator would enable the DEP to know immediately if CREDOS had been applied or not on a departing a/c.</td>
<td>• Crosswind component and direction should also be displayed so DEP knows how best to manoeuvre aircraft to minimise chances of a WV encounter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Aircrew must be informed as early as possible that CREDOS is active and that they may be given a CREDOS departure clearance. This will enable aircrew to inform the tower that they refuse to accept a CREDOS clearance. This will avoid aircrew refusing a CREDOS clearance when on the runway which could affect runway throughput.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Human in the system</td>
<td>Stakeholder workshop</td>
<td>Runway and Departure Controllers:</td>
<td>Runway and Departure Controllers:</td>
</tr>
<tr>
<td>Information requirements</td>
<td>Cognitive task analysis</td>
<td>• The RWY and DEP need to be informed of CREDOS status for each active departure runway. The information should be given on a case by case basis, i.e. for each departing a/c. It is recommended that four states be displayed to controllers:</td>
<td>6. Recommendation that a CREDOS status indicator that takes into consideration assigned SIDs for leading and following aircraft needs to be validated.</td>
</tr>
<tr>
<td></td>
<td>RTS1 &amp; RTS2</td>
<td>o CREDOS NOT ACTIVE (not activated by SUP);</td>
<td>7. Study to validate Ground controller information requirements regarding CREDOS.</td>
</tr>
<tr>
<td></td>
<td>Functional Hazard Assessment (FHA) (safety case)</td>
<td>o CREDOS ACTIVE and NO GO (i.e. CREDOS activated by SUP but CREDOS requirements not met e.g. crosswind component below threshold);</td>
<td>8. Study to better define Supervisor information requirements regarding CREDOS.</td>
</tr>
<tr>
<td></td>
<td>Human Error Analysis (HEA) (Business case)</td>
<td>o CREDOS ACTIVE and GO (i.e. CREDOS activated by SUP and requirements for CREDOS application met);</td>
<td>9. Study to determine the exact value of the buffer required in the CREDOS status indicator to ensure the CREDOS status does not continuously…</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o System error. Controllers should also be informed of any detected system errors relating to the CREDOS equipment.</td>
<td></td>
</tr>
<tr>
<td>HF issues impacting human performance</td>
<td>HF Activities conducted to date to address issue</td>
<td>Summary of main findings/recommendations from HF activities conducted</td>
<td>Future activities recommended</td>
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<tr>
<td></td>
<td></td>
<td>…&amp; sequence as they do currently as well as the CREDOS status</td>
<td>…&amp; sequence as they do currently as well as the CREDOS status indicator before giving a CREDOS departure clearance.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>indicator before giving a CREDOS departure clearance.</td>
<td>o If SIDs diverge near the runway (approx &lt;4NM) the CREDOS status indicator would have to take into consideration the assigned SIDs for the leading and following aircrafts. This would help to prevent CREDOS being applied when SID is not appropriate, and also help to ensure controller workload does not increase too much (see workload section). However, this more advanced CREDOS status indicator can only be implemented in an advanced system which has EFS or DMAN. Therefore CREDOS could not be implemented without EFS or DMAN if SIDs diverge near the runway.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A buffer is required in the CREDOS status indicator algorithm to ensure that the status does not continuously fluctuate from one mode to another.</td>
<td>• A buffer is required in the CREDOS status indicator algorithm to ensure that the status does not continuously fluctuate from one mode to another.</td>
</tr>
<tr>
<td>Runway controller</td>
<td></td>
<td>• RWY controller should have crosswind information for each runway displayed near the CREDOS status indicator so they can verify easily CREDOS status. This crosswind information presented should include the crosswind component and direction (Left or Right).</td>
<td>Runway controller</td>
</tr>
<tr>
<td>Departure controller</td>
<td></td>
<td>• Feedback from controllers in RTS2 regarding the CREDOS related information and tool requirements for the departure controller were mixed. As a result it is recommended that the DEP controller should have the option to select exactly what CREDOS related information is displayed, although as a minimum the CREDOS status indicator should be displayed.</td>
<td>Departure controller</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• From the findings of RTS2 it is also recommended that the DEP should be alerted to any changes in CREDOS status by some means e.g. flashing icon or auditory signal depending on HMI /alarm design principles adopted in the TMA centre, so that the DEP does not have to constantly monitor the CREDOS status indicator in order to be aware of CREDOS status. However, this can be an option the DEP can select to have or not.</td>
<td>• From the findings of RTS2 it is also recommended that the DEP should be alerted to any changes in CREDOS status by some means e.g. flashing icon or auditory signal depending on HMI /alarm design principles adopted in the TMA centre, so that the DEP does not have to constantly monitor the CREDOS status indicator in order to be aware of CREDOS status. However, this can be an option the DEP can select to have or not.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• The DEP controller also needs to have crosswind information for each runway displayed in case they have to resolve a potential conflict, as the direction of the crosswind will determine how best to manœuvre the aircraft to minimise risk of a WV encounter. This crosswind information presented should include the crosswind component and direction (Left or Right).</td>
<td>• The DEP controller also needs to have crosswind information for each runway displayed in case they have to resolve a potential conflict, as the direction of the crosswind will determine how best to manœuvre the aircraft to minimise risk of a WV encounter. This crosswind information presented should include the crosswind component and direction (Left or Right).</td>
</tr>
<tr>
<td>Supervisor</td>
<td></td>
<td>• The supervisor role was not investigated in detail in the HF validation activities hence more work is needed to define SUP information requirements regarding.</td>
<td>Supervisor</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>HF issues impacting human performance</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>...CREDOS.</td>
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<td></td>
<td></td>
<td>• However, at a minimum the supervisor will need to have, in addition to the usual information displayed on the supervisor CWP, an indication of CREDOS status plus additional crosswind forecast information to help determine when CREDOS should be activated and deactivated.</td>
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<td></td>
<td><strong>Aircrew:</strong></td>
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<td></td>
<td>• Aircrew need be informed that CREDOS is active at an airport and that they may be given a CREDOS clearance. It is suggested that this initial information regarding CREDOS active status is given via ATIS.</td>
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<tr>
<td></td>
<td></td>
<td>• Aircrew will be informed if they are subject to a CREDOS departure by the RWY. (If aircrew is unwilling to accept a CREDOS clearance they must inform the tower as early as possible)</td>
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</tr>
<tr>
<td>User requirements</td>
<td>Cognitive task analysis</td>
<td>Runway controller</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FHA (safety case)</td>
<td>• A spacing support tool to help ensure required ICAO separation achieved at handover. Three types of spacing support tool have been proposed and investigated during the HF validation activities (i.e. an automated timer, manual timer, a count down manual timer &amp; a static take off trigger advisory (TTA)).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RTS1 &amp; RTS2</td>
<td>o An automated timer for an advanced system that required EFS and A- SMGCS was developed and presented to controllers in the stakeholder workshop. Feedback varied — the automated timer was thought to be too complex by some controllers. Recommendation from workshop was to develop a simpler spacing support tool that could be used in an environment that did not have EFS &amp; A-SMGCS. However, it is recommended that the automated timer should be evaluated in a realistic operational environment to see whether it is a feasible solution or not.</td>
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<td></td>
<td></td>
<td>o In RTS 1 a manual timer was used to help controller achieved required spacing. The manual timer was found to increase workload as activation of timer was considered another action to perform. Further controllers often forgot to time or started timer too late.</td>
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<tr>
<td></td>
<td></td>
<td>o In RTS2 – a static takeoff trigger advisory (TTA) was used to support controllers achieve the required spacing. The takeoff trigger advisory was generally very well received and considered intuitive and easy to use by the majority of controllers. One concern was that controllers were not using it as an advisory and so were not taking into consideration a/c performance when using the static TTA as they should. It is suggested that a dynamic TTA that would move depending on aircraft performance and crosswind strength could be used – this solution needs to be assessed in a realistic environment.....</td>
<td>10. Feedback on the automated timer only gained from a demonstration. The automated timer needs to be properly assessed in a tower simulation where EFS and A-SMGCS are available.</td>
</tr>
<tr>
<td></td>
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<td>11. Assess the use of a dynamic TTA that takes into consideration to a/c performance and wind strength for each departure. This spacing support solution can only be implemented in an advanced environment that has EFS or DMAN.</td>
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<tr>
<td></td>
<td></td>
<td>12. Other possible spacing support tools also need to be developed and evaluated.</td>
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</tbody>
</table>
### HF issues impacting human performance

### HF Activities conducted to date to address issue

### Summary of main findings /recommendations from HF activities conducted

- It should be noted that exactly how a spacing support tool would be implemented locally would depend on the existing procedures, tools available & HMI.
- The RWY needs to be alerted to change in CREDOS status. The means to alert the RWY to a change in status will depend on the existing tower alarm philosophy / design principles; for example it could be an auditory alert or flashing icon. To minimise number of alerts it is more important that the RWY is signalled to a change in CREDOS status from GO to NOGO than NOGO to GO, as there will be safety implications if controller applies CREDOS when it can not be applied. The Tower Supervisor will verbally inform the tower controllers just before s/he decides to activate or deactivate CREDOS operations.

**Departure controller**

- The Departure supervisor will inform the departure controllers verbally that the tower supervisor will active or deactivate CREDOS. It is recommended that the DEP controller should have the option to select exactly what CREDOS related information is displayed, although as a minimum the CREDOS status indicator should be displayed.
- The DEP should have on their CWP the function to be able to inform other controllers that CREDOS reduced spacings should be stopped, this may be used if a non-nominal event occurs e.g. WVE report from aircrew. This function should be in addition to R/T or the telephone in case the lines are blocked. (One example of how such a function may be implemented was investigated in RTS2).

### Visual displays

- **Tower survey**
- **RTS2**

### Controllers

- The CREDOS HMI must integrate well and be consistent with the existing system into which CREDOS is being implemented. Therefore, there is no 'One fits all' HMI solution for CREDOS.
- It essential that the colours used for the CREDOS HMI are consistent with the existing colour coding rules used in the tower in which CREDOS HMI is to be implemented. Therefore no specific colours are recommended - existing colour coding scheme must be adhered to avoid any confusion.

**Departure controller**

- The DEP controllers should have the facility to select what additional information relating to CREDOS they want to display e.g. takeoff trigger advisory so that each controller can tailor his CWP and display the information s/he requires.
- The CREDOS related HMI should be intuitive and easy to use. It should be fit for operational purpose, and should support controllers working method.
<table>
<thead>
<tr>
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</thead>
</table>
| HMI usability                         | Stakeholder workshop                          | • CREDOS HMI must be consistent with existing HMI. Therefore local working methods, available equipment & HMI design principles must be considered when implementing CREDOS and developing the HMI in a local airport environment.  
• The CREDOS status indicator must not continuously fluctuate from one status to another as this will reduce controller trust in system and controllers will no longer be willing to apply CREDOS. Therefore a buffer needs to be incorporated to ensure fluctuations of CREDOS status do not occur and CREDOS operations are active for a minimum period of time. The required buffer and active time for CREDOS have yet to be determined.  
• The information presented on the CWP must not be ambiguous. | |
| Teams & communication                 | RTS1 & RTS2                                    | **Controllers:**  
• The CREDOS status will be displayed on all concerned controller CWP.  
• All controllers should have on their CWP the function to be able to inform other controllers immediately that CREDOS reduced separations should be stopped, this may be used if an non-nominal event occurs e.g. WVE report from aircrew. This function would be in addition to R/T and telephone, in case the frequency and telephone lines are blocked. (One example of how such a function may be implemented was investigated and generally well received by the controllers in RTS2)  
• If CREDOS is implemented into an advanced system which has EFS, then information regarding CREDOS related actions could be input into the EFS. The EFS could be used to communicate to other controllers CREDOS current status and action performed per a/c. Certain information could be automatically input into EFS e.g. time of commence of roll, other information may have to be manually input e.g. whether CREDOS clearance given or not. (see section on situation awareness for DEP for description of departure status window used currently in some TMA centres)  
**Supervisor:**  
• The tower SUP will inform tower verbally that CREDOS will be active. Also by pressing the CREDOS ACTIVE button on the supervisor workstation the CREDOS ACTIVE status will be indicated on all controller CWP including the RWY, SUP, GND and DEP.  
• The tower and departure supervisors will communicate as currently, using telephones.  
**Aircrew:**  
• Aircrew should initially be informed CREDOS active and operational at an | |

13. The evaluation of CREDOS implemented into a more advanced system which includes EFS & A-SMGCS needs to be performed. (RTS 1 and 2 evaluated CREDOS in a relatively simple environment which did not include EFS).
### Summary of main findings /recommendations from HF activities conducted

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<tbody>
<tr>
<td>RWY will tell aircrew verbally using R/T whether or not the departure clearance given is a CREDOS clearance.</td>
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<tr>
<td>Phraseology</td>
<td>RTS2</td>
<td></td>
<td>14. Phraseology for non-nominal CREDOS related events needs to be refined.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• All phraseology relating to CREDOS for both nominal and non-nominal situations should be kept as simple and concise as possible as CREDOS may not be applied very often there it has to be short and easy to remember.</td>
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<tr>
<td></td>
<td></td>
<td>• CREDOS related phraseology should be consistent with existing phraseology used in the tower.</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>• For nominal situations wind reading should be given to aircrew with CREDOS clearance, this helps to ensure that the RWY looks at the crosswind component so they can crosscheck CREDOS status indicator.</td>
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</table>

**Table 3. Summary of main findings & recommendations relating to the impact of CREDOS on human performance**
3.3. CONCLUSIONS AND RECOMMENDATIONS

From the activities conducted as part of the HF case a number of recommendations have been identified to mitigate identified HF issues relating to CREDOS that may adversely impact human performance. However, it should be noted that CREDOS is a research project and although much progress has been made to better our understanding and further the development of a suitable concept of operations that can be implemented at airports in the near term there are still several issues that need to be further investigated and resolved. Where possible, future HF activities that should be conducted to address these issues have been identified. In total 14 future activities have been identified, these are defined in Table 3.
4. REFERENCES


## 5. ACRONYMS AND DEFINITIONS

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<tr>
<th>ACRONYM</th>
<th>DEFINITION</th>
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<tbody>
<tr>
<td>ACC</td>
<td>Area Control Centre</td>
</tr>
<tr>
<td>A-SMGCS</td>
<td>Advanced Surface Movement Guidance Control System</td>
</tr>
<tr>
<td>ATIS</td>
<td>Airport Terminal Information Service</td>
</tr>
<tr>
<td>Essential information for flight crews about a specific airport broadcasted on a designated frequency. Data provided is local weather conditions, runway in use, constraints and other useful information.</td>
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<tr>
<td>ATM</td>
<td>Air Traffic Management</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>ATCO</td>
<td>Air Traffic Controller</td>
</tr>
<tr>
<td>CREDOS</td>
<td>Crosswind-Reduced Separation for Departure Operations</td>
</tr>
<tr>
<td>CROSSWIND</td>
<td>The wind component acting at an angle relative to a specific runway direction.</td>
</tr>
<tr>
<td>DEP</td>
<td>Departure controller</td>
</tr>
<tr>
<td>DFS</td>
<td>Deutsche Flugsicherung, (German Air Navigation Services)</td>
</tr>
<tr>
<td>DLR</td>
<td>Deutsche Zentrum fur Luft und Raumfahrt (German aerospace centre)</td>
</tr>
<tr>
<td>DMAN</td>
<td>Departure Manager</td>
</tr>
<tr>
<td>An ATM system tool that assists controllers with sequencing, metering and advisory service for the traffic flow management of departing traffic.</td>
<td></td>
</tr>
<tr>
<td>DSI</td>
<td>Departure status indicator</td>
</tr>
<tr>
<td>A ‘Departure Status Information’ (DSI) window displays the stage of a/c departure from pushback to take off. The DSI window is automatically updated for each flight each time a strip is moved from one bay to another by RWY in the feeder tower.</td>
<td></td>
</tr>
<tr>
<td>EFS</td>
<td>Electronic Flight Strips</td>
</tr>
<tr>
<td>E-OCVM</td>
<td>European Operational Concept Validation Methodology</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration, USA</td>
</tr>
<tr>
<td>GND</td>
<td>Ground Controller</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument Flight Rules</td>
</tr>
<tr>
<td>ITWP</td>
<td>Integrated Tower Working Position</td>
</tr>
<tr>
<td>IMC</td>
<td>Instrument Meteorological Conditions</td>
</tr>
<tr>
<td>Meteorological conditions under which the outside view is restricted in such a way that aircraft control and navigation can only be done using special flight instruments</td>
<td></td>
</tr>
<tr>
<td>INECO</td>
<td>Ingenieria y Economia del Transporte SA (Spain)</td>
</tr>
<tr>
<td>NATS</td>
<td>National Air Traffic Services, UK.</td>
</tr>
<tr>
<td>NLR</td>
<td>Nationaal Lucht en Ruimtevaartlaboratorium</td>
</tr>
<tr>
<td>NM</td>
<td>Nautical Miles</td>
</tr>
<tr>
<td>A measure used in navigation. The unit is equal to 1852m.</td>
<td></td>
</tr>
<tr>
<td>D-DRTS</td>
<td>Real Time Simulation</td>
</tr>
<tr>
<td>RWY</td>
<td>Runway controller</td>
</tr>
<tr>
<td>SID</td>
<td>Standard Instrument Departure (Route)</td>
</tr>
<tr>
<td>SID standard ATS routes identified in an instrument departure procedure by which aircraft should proceed from take-off phase to the en-route phase.</td>
<td></td>
</tr>
<tr>
<td>SUP</td>
<td>Supervisor</td>
</tr>
</tbody>
</table>
### ACRONYM | DEFINITION
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**TMA** | **Terminal Manoeuvring Area**  
A control area normally established at the confluence of ATS routes in the vicinity of one or more major aerodromes.

**TTA** | **Target Trigger Advisory**  
A HMI ‘tool’ developed for CREDOS to help controllers achieve the required spacing for CREDOS departures.

**WV** | **Wake Vortex**  
Also known as wake turbulence (WT), the term preferred by ICAO. Wake turbulence is turbulence that forms behind an aircraft as it passes through the air. This turbulence includes various components, the most important of which are wingtip vortices and jetwash. Jetwash refers simply to the rapidly moving air expelled from a jet engine; it is extremely turbulent, but of short duration. Wingtip vortices, on the other hand, are much more stable and can remain in the air longer after the passage of an aircraft. Wingtip vortices make up the primary and most dangerous component of wake turbulence. Wake turbulence is especially hazardous during the landing and take-off phases of flight, for two reasons. The first is that during take-off and landing, aircraft operate at low speeds and high angle of attack. This flight attitude maximizes the formation of dangerous wingtip vortices. Secondly, takeoff and landing are the times when a plane is operating closest to its stall speed and to the ground - meaning there is little margin for recovery in the event of encountering a different aircraft’s wake turbulence.
6. GLOSSARY OF TERMS

For the purposes of this document the following definitions shall apply:

**Human Factors (HF):** Multidisciplinary effort to compile and generate knowledge about people at work and apply that knowledge to the functional relationships between people, tasks, technologies and environment in order to produce safe and efficient human performance.

**Human Performance:** The extent to which goals for speed, accuracy, quality, and other criteria are met by people functioning in working environments.

**Mental Picture:** The actual mental picture of a situation represents a moment-to-moment snapshot of the actual situation based on the mental model and the actually perceived external cues. A series of mental pictures represents the actual mental model including the actual parametrisation.

**Procedures:** Represent the organisation’s accepted working methods. Procedures are the particular courses of action intended to achieve a result. They are a set of activities that are performed by each person intervening in the process according to pre-established rules to enable a successful operation, e.g. abnormal and emergency procedures.

**Roles:** The position(s) or purpose(s) that someone has in an organisation. The typical or characteristic function performed by someone relating to the tasks that have been assigned to them.

**Responsibilities:** Things that are your job or duty to deal with. Having responsibilities means to have a duty to make certain that particular things are done.

**Situation Awareness:** The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future Endsley, 1988 - This also means the continuous extraction of environmental information, the integration of this information with previous knowledge to form a coherent mental picture and the use of that picture in directing further perception and anticipating future events.

**Working Method:** The way in which individuals perform their tasks.
APPENDIX A : SUMMARY OF FINDINGS FROM THE CREDOS CTA

CREDOS Cognitive Task analysis

CREDOS (Cross Wind Reduced Separation for Departure Operations) is a SESAR Operational improvement (OI) aimed at reducing separations for single runway departures under specific cross wind conditions. Under certain conditions the concept would allow for a conditional reduction of wake turbulence minima and corresponding decrease in lunch interval between departing aircraft.

To date, a concept of operation (version A) has been elaborated and a prototype HMI (advanced CREDOS HMI) has been proposed. A functional hazard analysis (FHA) has also been conducted, and this was made available to us after the CTA interview session.

Specification of the CREDOS operational concept

We worked from the following assumptions as laid out in the CREDOS concept of operations:

- That CREDOS would be operational;
- That a minimum crosswind component of 7 kts would be required for CREDOS operations;
- That normal 2 minute wake turbulence (WT) separation could be relaxed to 1 minute (for appropriate aircraft wake vortex class pairs);
- That dedicated departure runway (RWY), i.e. segregated operations, would be in place;
- That both upwind and downwind Standard Instrument Departures (SIDs) would be considered;
- That the HMI would be as proposed (advanced HMI solution); and
- That CREDOS would be applied only for medium (M) aircraft following heavy (H) aircraft.

Simplifying assumptions

Together with the SME a few additional simplifying assumptions were made to facilitate discussion. These were as follows:

- The aerodrome must be one of the busiest in Europe (to benefit from CREDOS), and must be at or above capacity;
- RWY controller is considered in isolation;
- Arrival aircraft is disregarded;
- Electronic Flight Strips are in use;
- Tower has access to TMA radar display;
- The aerodrome has CAT I ILS capability or better;
- The strategic planning level is specifically disregarded;
- Multilateration (a.k.a. hyperbolic positioning) capability is assumed, for tracking ground vehicle movements on the aerodrome surface.
**Procedure**

A set of familiarisation materials was sent to the SME in advance of our first meeting. This first meeting was held at EUROCONTROL Headquarters Brussels and lasted a single long day.

We first reviewed and agreed to a completed baseline HTA. In the process we were also able to:

- Make a preliminary assessment of new and changed tasks;
- Identify initial human factors issues; and
- Identify interesting “what-if” scenarios.

On the basis of this first session the baseline HTA was revised and a second set of familiarisation materials was distributed. The second (CTA) session lasted roughly ½ day and involved stepping through the tasks with particular focus on the new/changed tasks. The SME was probed for information, decision making and strategy / goals aspects of each task.

**Results**

This section presents details on the eight new, and eighteen changed, tasks identified in the CTA session.

**New tasks under CREDOS**

The following identifies the eight tasks that were identified as new under CREDOS operations, and provides a bit of surrounding background and detail on each. Reference is made to the task numbering used in the formal task analysis.³

**Confirm through strip that flight crew have been informed of CREDOS status** *(task 1.1.1.1.1.2)*

The flight crew must be aware when CREDOS is operational, and the RWY controller must be assured that they are aware. Flight crew acceptance of CREDOS, to the extent that it might be an issue, would be stated at this point. The RWY controller determines (with information from the strip) whether the flight crew is aware that CREDOS operations are active (or inactive). Based on that knowledge, the controller starts building up / revising a strategy for that aircraft. It is not yet decided whether flight crews will be made aware of CREDOS status at this stage of flight (i.e., prior to line up for takeoff). It might be sufficient for this information to be shared just prior to takeoff.

*Recommendation* – If electronic strip is being used, field for information that aircrew has been informed and is aware of CREDOS needs to be added to strip.

**Confirm through GND controller that the flight crew have been informed of CREDOS status** *(task 1.1.1.1.2.1, ref task 1.1.1.1.1.2)*

The RWY controller confirms via the strip that the flight crew have been informed of CREDOS status. This task can be done as a backup to confirm information on the strip, or

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³ The entire task analysis is available electronically in Task Architect™ format but in the interest of readability is not included in this report. Please contact Catherine Chalon, HF Specialist EUROCONTROL, EEC Bretigny sur Orge, FRANCE for a copy of the CREDOS CTA if required.
in case the strip lacks information on flight crew awareness of CREDOS operations. **Recommendation** (as above) – If electronic strip is being used field for information that aircrew has been informed and is aware of CREDOS needs to be added to strip.

**Consider whether CREDOS operation is applicable to A/C WV class**  
(task 1.1.3.4.1.1)  
It is assumed that the only A/C WV class that can benefit from CREDOS operations is Medium (M), and then only when taking off immediately after a Heavy (H) A/C. The controller has to identify WV class and select those eligible for CREDOS operations.

**Inform flight crew about CREDOS operation status**  
(task 1.1.6.3.3)  
The RWY controller transmits information to the flight crew regarding CREDOS status (either active or inactive). Flight crew will have to be informed that CREDOS operations are active, if not done previously. The controller determines this by referring to the current conditions and detecting a green CREDOS dial on the display panel. **Comment** – There will be some indication for the controller that CREDOS operations are active.

**Receive read-back acceptance of CREDOS operations**  
(task 1.1.6.3.5)  
The flight crew reads back information on CREDOS operation status. The RWY controller knows that the flight crew is aware and accept CREDOS operations. The controller can also assume that the flight crew knows reduced separation may be used.

**Inform flight crew about CREDOS operation status**  
(task 1.1.6.9.5)  
The RWY controller transmits information to the flight crew on CREDOS status. (either active or inactive). The flight crew will have to be informed that CREDOS operations are active, if not done previously. The controller determines this by referring to the current conditions and detecting a green CREDOS dial on the display panel.

**Note on strip that CREDOS operations have been used**  
(task 1.1.8.1.1)  
The RWY controller notes on the flight strip that A/C departed with CREDOS reduced separation. **Recommendation** – If electronic strips must be a field on the strip where controllers can input CREDOS reduced separation applied.

**Changed tasks under CREDOS**  
More common than entirely new tasks were tasks that appeared qualitatively changed under CREDOS. The same task description might have applied but the task was performed in an entirely new or novel way. There were eighteen such tasks identified, as described in the following.

**Place strip in take-off sequence**  
(task 1.1.1.3.1)
The strip is placed in take-off sequencing according to a quick judgement of current conditions. The controller’s mental model is key to defining where that is. This only has to be done if the strip has not yet been placed, or is placed incorrectly. Constraints are not considered at this point-- it is more a task of recognising that the strip is received and registered in the traffic flow. This is the first task in which the RWY controller can evaluate where the A/C is in reference to other traffic, and whether it is in position to permit active CREDOS operations.

Consider SID
(task 1.1.3.1)
Where will the A/C fly after take-off? With CREDOS active, the controller will have to consider upwind/downwind SIDs to facilitate the reduced separation. Controllers are currently required to consider SID structure for converging flights, but not in conjunction with WV reduced separations. Under CREDOS, the controller will have to determine whether the SID is upwind or downwind. Further, the RWY controller would have to consider whether the designated SID for the A/C fits into the current sequencing. Wind, A/C type and constraints in preceding sectors will also have to be considered for the SID. The controller has to judge whether the SID can be applied in active CREDOS operations with reduced separation. If a H is taking off before a M, the controller has to take into account the H’s SID and flight path, and also wind directions / strength. The M has to fit into the departure and stay out of hostile areas.

Recommendation – Controllers may need some decision support tool to help them select appropriate SID for a/c pair when CREDOS applied

Consider existing A/C sequence
(task 1.1.3.2)
The RWY controller checks that the current sequencing, as reflected by the flight strips, is appropriate in regard to the current conditions. A decision is made on how to integrate A/C into the queue. The increased complexity the controller is likely to face in this task will most likely impact workload. During taxiing, and from the point the queue was first set, conditions may have changed (i.e. weather, runway in use, flight crew requests etc.) and rendered current sequencing impractical. Sequencing has to be considered since it limits the flow of departures. This normally does not have an effect on CREDOS operation since the decision on whether CREDOS operations will be used or not is decided and communicated to flight crew at an earlier stage.

Sequencing for take-off is carried out by previous controllers and the RWY controller will often just be required to double-check and verify that the sequencing is correct. RWY controller will have options to organise strips differently to better facilitate CREDOS operations. CREDOS may have been inactive when strips where first organised and during early A/C taxiing, but it is now available as the conditions have changed. This calls for an evaluation as to whether to re-organise the strips and the queue.

Comment – Support tool may be needed by RWY controller as task complexity and hence workload is potentially increased. Decision support could be integrated into DMAN.

Consider separation and/or spacing to be used between A/C pairs
(task 1.1.3.7)
For every A/C pair the RWY controller must ensure proper separation between departing
A/C. Separation requirements between departing A/C vary depending on whether visual conditions (e.g. visual, CAT II or III), and SIDs. A/C WV class and performance also matters. For example, runway separation (i.e. runway clear) may be sufficient for VFR flights departing; In this case, radar separation would not be necessary. Further, the RWY controller must ensure that adequate separation is provided between departing A/C. This determination might be (partly or wholly) dependent on the demands of the next sector. Runway separation still has to be provided. Further, the RWY controller tries to provide later airborne separation. To judge required spacing to achieve eventual airborne separation, the RWY controller relies on experience and monitoring of ongoing events to assess, for instance, typical wind behaviour in take-off direction and as altitude increases, behaviour of previous A/C departing, expected A/C performance, etc.

This task 1.1.3.7 is a significantly-changed one under CREDOS. CREDOS operations will have to conform to airborne separation requirements. RWY controllers use rules of thumb to create spacing equal to the correct separation, with a 2 min take-off separation roughly corresponding to approximately 6 NM radar of eventual airborne separation, and a 1 min take-off separation to roughly 3 NM of eventual separation. Thus CREDOS operations will naturally change airborne separation to less than 6NM and in some cases close to 3NM (which is currently normal in the TMA). It has to be decided locally what the minimum airborne separation shall be in the sectors following the runway sector. If this minimum separation varies depending on local procedures, or fluctuates depending on traffic load, this will have to be considered in CREDOS implementation.

**Comment** – Investigate different local operational procedures to see which one ensures ICAO separation requirements of 5NM not infringed but proposed benefits of CREDOS achieved.

**Consider other sectors’ constraints**
(task 1.1.3.8)
The RWY controller has to consider whether any possible constraints in following sectors might impact the take-off flow. The following TMA sector can, for example, request spacing for a certain minimum radar separation in either distance or time. Examples of such constraints include temporary restricted areas in TMA (which eliminate certain SIDs) or flow constraints. The following departure or TMA sector, or other sectors, can request CREDOS operations not to be used for certain reasons.

**Consider wind conditions**
(task 1.1.3.9.6)
Where does the wind come from, how strong is it and how does it fluctuate? The wind direction and strength govern which runway is to be used for take-off. The RWY controller needs to take into account more information about wind direction and wind strength when incorporating CREDOS. Certain wind levels need to be met in order for CREDOS operations to be available. The controller has to consider such values and whether the current weather conditions allow for safe CREDOS operations.

**Comment** – This information will be gauged by the system. Therefore a system indication could be used to indicate to the controller when wind conditions are such that CREDOS operations can be applied if so wanted. Therefore controllers would not need to monitor wind information / conditions as closely and/or become wind experts.
Select most appropriate departure sequence and holding point/runway entry  
(task 1.1.4)
Unlike task 1.1.3.2, where sequencing is only considered, sequencing is actually accomplished in this task 1.1.4. In this task, the RWY controller decides on the most appropriate departure sequencing after considering all the constraints. Normally, the previous GND controllers will have arranged a foundation for the sequencing and given A/C taxi clearances accordingly. Runway entry has to be decided and instructed to A/C, and this can vary depending on where A/C are and where they should be in the sequence. If CREDOS operations are in use, or become available due to conditional changes, the RWY controller can try to change, if needed, the existing sequencing. Otherwise, the gains of CREDOS operations may not be exploited fully until a group of A/C can be sequenced for the purpose of CREDOS operations. The controller’s options will to a great degree depend on airport infrastructure.

Comment – A decision aid / support e.g. DMAN which takes CREDOS operations into consideration, could help controllers with this task.

Decide when to give line-up clearance  
(task 1.1.6.2)
RWY controller makes decision when to issue a line-up clearance. This can be done more or less at the same time the clearance is issued, but also further in advance based on anticipation and expectations. If CREDOS operations are active, line-up clearance can be given earlier due to the reduced separation.

Ensure runway separation  
(task 1.1.6.7.1)
Runway separation refers to the minimum runway distance between two take-offs according to rules and regulations. The RWY controller is responsible for ensuring, at a minimum, runway separation. This has been considered in task 1.1.3 and is now ensured before the following A/C is cleared for take-off. If CREDOS operations are active, the controller is likely to work toward a goal of sustaining CREDOS reduced separation as long as possible in order to gain as much capacity and efficiency as possible. It can become an issue if the controller’s attention is focused on delivering CREDOS reduced separation and omitting the task of ensuring that minimum runway separation criteria are met.

Ensure Wake Turbulence separation  
(task 1.1.6.7.2)
The RWY controller has a responsibility to ensure that that minimum WT separation is maintained between take-offs. This varies, according to ICAO rules and regulations, between different A/C classes. This has been considered in task 1.1.3 and is now ensured before the following A/C is cleared for take-off. The controller takes time between departures to follow up on the procedural requirements. Today, ICAO states a minimum WT separation between H and M A/C of 2 min. More information can be found in task 1.1.3.4.1. If CREDOS operations are active, the minimum wake turbulence separation between H and M A/C changes from 2 min to 1 min. The RWY controller has to keep remember and recall these different times, and the conditions under which they apply. However, the task required greater awareness of upper level winds and A/C SIDs. As discussed elsewhere, this awareness might be lacking, either because the information is
not available, or because controllers are not accustomed to being / remaining aware of upper level winds and their interaction with some SIDs.

**Recommendation** – Decision support may be required to support controllers in this activity, perhaps DMAN could be adapted to support this task

Ensure spacing for airborne separation
(task 1.1.6.7.3)
Spacing is a task delegated to the RWY controller by the following sector (normally DEPARTURE). Due to constraints (e.g. capacity overload, routing of other departures or arrivals etc.) the following sector can request that the RWY controller create spacing for later separation in that sector. For example, en-route regulations require a minimum lateral separation of 5 NM. Whilst the RWY controller is not responsible for separation per se, he/she uses initial spacing (at time of takeoff) that will ensure adequate eventual separation. Controllers rely on experience and heuristics to accomplish this, and it is one of the aspects of the controller’s job that defies simple explanation. This task is considered in task 1.1.3 and is now ensured before the following A/C is cleared for take-off.

CREDOS availability can depend on constraints in other sectors. For example, if the DEPARTURE controller (for whatever reason) requests that the RWY controller deliver A/C with a 5 NM separation in all cases, potential CREDOS gains cannot be optimised. This is because an airborne 5 NM separation requires spacing in excess of 1 min between takeoffs. One minute corresponds to roughly 3NM of eventual separation, whilst 2 min between take-offs corresponds to approximately 6NM. A CREDOS reduced separation take-off can still be implemented as the controller will not have to wait for 2 min. But as the gain will be so little, roughly 20 sec, the usability can be questioned.

Spacing is assessed by controllers through the use of heuristics and a “feeling” depending on experience and current conditions. It would be interesting to dig into this mental calculation. For example: How is a later minimum airborne 5 NM or a 2 min separation provided between aircraft? What are the key inputs? What is the underlying knowledge? If timing is involved, when is it started/stopped?

**Comment** – a field study is being conducted to understand more how controllers do this and to answer the questions above.

Decide when to give take-off clearance
(task 1.1.6.8)
RWY controller makes a decision as to when to issue the take-off clearance. This can be done more or less at the same time that the clearance is issued, but also further in advance based on anticipation and expectations. If CREDOS is active, the take-off clearance will be given earlier due to reduced separation. In connection to this task, the controller will have to take a decision on whether to implement CREDOS or not.

**Comment** – A decision aid could help controllers make the decision on whether to apply CREDOS for each aircraft pair (i.e. a go / no go indicator per aircraft pair)
An aid e.g. a timer could help measure time between clearances to optimise application of CREDOS, and hence throughput

Check wind conditions
(task 1.1.6.9.3)
RWY controller checks what the current wind conditions are. The controller checks the wind conditions on the available equipment and displays. Information on wind speed and direction is needed by the flight crew for performance estimates and calculations. Further, it governs which runway is to be used for take-off. At this stage, the controller has already decided whether to use CREDOS or not. The task is simply a service to the flight crew, informing them of the current wind conditions. To determine CREDOS operation availability, more wind information is required. Not only does the wind direction / speed have to be above certain minimum values, but also stable enough that they will remain within limits during the 1 min takeoff interval.

**Recommendation** – Wind direction, speed and wind stability will be measured by the system hence the system could determine whether the cross wind conditions are such that CREDOS can be implemented.

Controllers should be able to access quite easily the necessary wind information as well as CREDOS availability indicator. If CREDOS operations are active cross-wind information should be accessible to RWY controllers so they provide this aircrew with cross wind information if necessary.

**Monitor A/C SID flight path visually**  
*(task 1.1.7.3.1)*

Monitor visually that the A/C follows the assigned SID by looking out the window. This is merely a task in which the RWY controller verifies that the A/C is airborne and is flying in the expected direction. It is not important for the RWY controller’s work to confirm that the A/C is flying within the acceptable boundaries of the cleared SID. The RWY controller may have to be able to more precisely monitor A/C conformance with SID if CREDOS operations are active. The controller has to know upwind and downwind SID and confirm that the preceding A/C is following the correct one. It may be possible to do so visually by looking out the window, but A/C distance and speed will likely make it very difficult. However, it can easily be determined whether the A/C is following an upwind or downwind SID.

**Comment** – Controllers will need the (TMA) radar display to track whether a/c following the right SID.

**Monitor A/C SID flight path on radar**  
*(task 1.1.7.3.2)*

The RWY controller monitors with radar (if equipped with TMA radar display) that the A/C follows the assigned SID. This is merely a task in which the RWY controller verifies that the A/C is airborne and is flying in the expected direction. It is not important for the RWY controllers work to confirm that the A/C is flying within the acceptable boundaries of the cleared SID. The RWY controller may have to be able to more precise monitor A/C conformance with SID if CREDOS operations are active. The controller has to know upwind and downwind SID and confirm that the preceding A/C is following the correct one. An airborne radar will be very helpful in monitoring this, and may be needed at all places where CREDOS operations will be used.

**Recommendation** – All RWY controllers should have an airborne radar. Perhaps there would need to be some indication on radar screen of up-wind / down-wind SIDs to support controller verify whether aircraft is flying within the boundaries of the cleared SID and confirm aircraft are following the correct SIDs.
Delegate task to departure control
(task 1.1.7.4.2)
If the A/C has left the RWY controller’s sector, or is about to, the task can be delegated to the DEPARTURE controller (next sector). This includes a handover of responsibility and a transfer change. SID deviations and non-normal occurrences in active CREDOS operations might necessitate an extended sector authority for the RWY controller. An increased knowledge requirement of wind behaviour with altitude, SID structure (upwind/downwind) and A/C conformance with SID may constitute such authority. Consequently, the RWY controller will have more time to try to solve the deviation or possible conflict. As current procedures for how, where and when the handover of control and associated frequency transfer shall occur, varies greatly with local procedures, the time when to delegate a task to the next / previous sector varies accordingly. Note that situation criticality will determine how important the time factor is in taking corrective measures.

Handover of control to DEPARTURE controller
(task 1.1.8.2)
This is where the DEPARTURE controller assumes control of the A/C. The procedure for assuming control is not universal; How the handover is performed varies with local procedures. CREDOS operations may require a more coherent procedure for how, where and when the handover shall occur. Reduced separation will, consequently, give a smaller opportunity window to take corrective actions in case of a non-normal or unforeseen deviation by the preceding A/C. The controller, who bears responsibility for the A/C, must be able to communicate with the A/C quickly in case of a deviation or non-normal situation. Current procedures do not always give the controller that possibility.

Recommendation - Coherent procedures for how, when and when handover shall take place must be defined.

R/T: Transfer of frequency
(task 1.1.9)
A/C is transferred from the RWY controller to the DEPARTURE controller’s frequency. Local procedures can vary greatly, but it is most common that the RWY controller issues a clearance to change frequency. Other procedures include directions to change frequency directly when airborne, or at a specific altitude. CREDOS operations may require a more coherent procedure for how, where and when the frequency change shall occur. The reduced separation will, consequently, give a smaller opportunity window to take corrective actions in case of a non-normal or unforeseen deviation by the preceding A/C. Though separated, this task is closely connected with the handover of control (task 1.1.8.2).

Recommendation - Coherent procedures for how, when and when frequency change shall take place must be defined.

What-if scenarios
Though it was not a primary focus of the interviews, over the course of the 1.5 days a few challenging scenarios emerged, such as:

- What if ground hands over A/C in a sequence not optimised for CREDOS?
- What if Departure control tells Runway control to stop CREDOS delivery?
- What if Departure control does not get indication of CREDOS operation, at handoff?
APPENDIX B : SUMMARY OF OUTPUT FROM
STAKEHOLDER WORKSHOP

This section presents human factors issues and feedback obtained from stakeholders during the stakeholder workshops taken from the ‘as it was heard’ reports.

1st CREDOS stakeholder workshop  27th-29th Nov. 2007

User trust / stakeholder acceptance

- How will you persuade the controllers and aircrew to trust CREDOS separation? Trust is an education issue. Training needed will be defined later. Stakeholder involvement through workshops like this can start addressing the point.

- How do you motivate aircrew to conform when benefits for them are small, e.g. a gain of 1 minute? For the first aircrew the benefits may be only 1 minute but if you are number 45 on the runway then the potential benefits could be that you could take of 45 minutes earlier. But again aircrew really need to trust and understand the system, therefore you need to educate aircrew on the concept and how it works. Aircrew acceptance of the concept is important because if aircrew do not trust CREDOS there is a risk of added workload for the controllers. Need to instil a different culture and move away from the notion that by accepting a reduced separation the aircrew is somehow accepting an increased risk. This is just another way of operating: no-one will be expected to accept a higher level of risk.

- As a aircrew I cross-check everything but how can I cross check the information the controllers give me regarding CREDOS? I could check wind profile history from the aircraft during the approach but I need to be able to cross check. I need to understand the system to build up trust. System integrity depends on system design. Trust will build up with experience. In other cases, for example when asked to reduce separation margins aircrew can see the benefit, as a aircrew the element missing is that margins are reduced and there is no tool to assess whether the controllers’ instruction is safe – I have to trust what the controller says. Aircrew need a tool to confirm. Data available in ATIS for Aircrew but not available to controllers. Need to consider and identify aircrew information requirements with regards to CREDOS. Today aircrew have a lot of confidence in the operations that they have acquired, based on their experience. Need to find a way to give them the confidence

- How will controllers be able to verify the wind at 3000ft? How can they confirm that the information given on the HMI with regards to CREDOS, is correct? If necessary this information can be displayed but it depends on what information is needed, you do not want to overload the controllers with too much information. Further the information must be presented to the controller in a form s/he can use directly and not have to digest. Perhaps there could be a transition phase to help controllers understand the system and how it works and hence build up their trust in the system

- But does CREDOS really change controllers’ current work? There is a change for the controller when something goes wrong as the controller will need to apply wake turbulence separation if wake turbulence does occur after takeoff when CREDOS separation is applied. The introduction of the notion of upwind and downwind SIDs would constitute a change in controller working. Although CREDOS is targeted at delay reduction and not capacity gain, if it is successful, it would ultimately be used to increase capacity and so augment Controller workload.

- Isn’t CREDOS just an extension of existing practice in some airports? Currently some airports have already reduced heavy aircraft behind a heavy to 60 seconds when they diverge 45 degrees off track, so you could say that CREDOS is going just one step further by wanting to do the same with a
medium. Perhaps this is the way to introduce CREDOS and gain stakeholder acceptance as it is easier to modify an existing practice than to introduce something completely new. CREDOS would not represent a significant change in working. By proving that it is safe to relax wake turbulence separations it would equate to today’s practises for M-M pairs. However, there would be a significant difference in the case of non-nominal situations. The reduced margins increases the difficulty for recovery in the event that something goes wrong. Recovery from non-nominal situations is part of the Safety Case. It must be emphasised that the development of the Safety Case would be done with the greatest transparency to ensure that all scenarios are considered. There is a challenge to move away from the mindset that CREDOS is somehow less safe. The whole purpose of the Safety Case is to prove that there is equivalent or improved safety.

Roles and responsibilities
- Who will be responsible for deciding when CREDOS will be applied? The CREDOS algorithm will propose the availability of CREDOS according to those conditions. It is currently proposed that the supervisor should be the one to decide when (and when not) to apply CREDOS separation. It is suggested that there will be a CREDOS Availability Indicator on the HMI to inform the supervisor when the CREDOS meteorological conditions are met and hence CREDOS can be applied. If the supervisor is responsible for deciding when CREDOS operations are in place then the mechanism by which the supervisor informs the other controllers that CREDOS procedures can be applied has to be determined. CREDOS should be available but used if necessary. Safety remains the number one priority of the controller, expedition of the traffic is secondary to this. The reduction of delays is not the primary task of controllers. The decision to apply CREDOS must be made by ATC. The information needed for the decision would be provided by the Meteorology service, either directly or via the support tool, but the decision itself must be made by ATC.

HMI
- Do the controllers also need this CREDOS availability information on their HMI? Whether this information should be available to all controllers has yet to be determined. Footnote: The go/no go indication per aircraft couple will be available instead

- Is this CREDOS availability information enough? Is more information required? Supervisors may be interested in having more wind information as they also need this information for runway configuration. Supervisors also have more time available to check the wind information. Controllers just need to know whether or not they can apply CREDOS. The controllers do not need additional information / detailed wind information and they do not have the time to check if all the elements are correct. The information requirements for both aircrew and controllers regarding CREDOS need to be determined.

- What would the HMI contain? There needs to be discussion on the suggestion of a green light and a timer function. This was not the appropriate forum to go into the details, Eurocontrol have specialised groups for designing procedures and HMI. No timer is necessary (in the same way as one is not used today for non-vortex pairs). In order for a system support function to manage the timing it would need to be informed of when an aircraft starting to roll. No problem with the use of a push-button when clearance was given, but note that there would be an imprecision of up to 20 seconds between clearance and roll. HMI must be kept as simple as possible. A clear indication of the availability of CREDOS operations only. Wind information could be displayed but it is hoped that this would only be a requirement of a transitional phase to instil confidence in the system. In the cockpit, the display of wind information to allow cross-check would be appreciated by aircrew
Operational Procedures

- How do you time the 2 minutes separation? The measurement of 2 minutes differs from airport to airport. There are a variety of ways of applying today’s rule. We need to know best practice. Field studies are planned as part of the HF case to identify current ‘best practice’. The potential benefit from simply standardising practises regarding the application of 2 minute spacing has probably a bigger gain than the benefit of the CREDOS concept itself. Because of the way it is applied sometimes the 2 minutes becomes effectively 3 minutes. The participants felt there were “Low hanging fruit” to be gleaned in this area.

- When do you start timing 2 minutes? This is important if we are going to use the 60 seconds. Again different controllers use different starting points. The understanding of this rule is not unified. SH - There is nothing in the training manuals to say how to do it - it is up to the service provider to decide how to do it. There is margin for interpretation and application of the “2 minutes” separation. In the context of CREDOS this should be more precise. For example, in the USA most controllers start timing 2 minutes from when they give clearance. In CDG they use a timer that is integrated on the controllers’ HMI. Most controllers in CDG start timing when the aircraft starts to roll – this is not a rule but what most controllers do as the controller can give a clearance but the aircrew may not start to roll immediately. Some controllers start the timer when the aircraft starts lifting. When its peak hour and you have high workload you need this timer because it means that you do not have to remember and keep monitoring the clock – you can just start the timer and then get on with something else. In Belgocontrol, as rule of thumb the controllers start to time 2 minutes from when the aircraft rotate so we are sure the aircraft passes V1. Different airlines roll at different rates. Different aircrew handle aircraft differently. Most runways are the equivalent of 2Nm in distance. It gives me a relative idea of time versus distance. I do not need a timer. This issue will also be addressed by the field studies outlined in the HF case. Further AENA have already collected lots of data relating to the ‘time of tasks’ –this information may be of use.

- Does CREDOS deliver spacing for radar? In the USA 2 minutes can be replaced by 5Nm. Footnote: In Europe it seems one cannot replace the other. Transition back to radar separation is not seen to be a show stopper. A medium aircraft can catch up with a heavy – it happens everyday when you have an Airbus 340 - 200, 300 series and then anything behind!

Project assumptions

- What is the impact of CREDOS on the arrival sequence on mixed mode runways? Implementing CREDOS on mixed mode runways may have additional implications compared to single mode runway implementation, for example, if a aircrew refuses a CREDOS separation on a single mode departure runway then there is no problem, however, if a aircrew refuses a CREDOS separation on a mixed mode (departure and arrival) runway then this will impact the arrival sequence.

- If CREDOS is to be used on mixed mode runways then this may have an affect the ‘look ahead time’, i.e. you may need to be able to ‘look ahead’ longer, e.g. 15-20 minutes to enable for planning. This will also have implications for the HMI.

CREDOS and SIDs

- What about the use of CREDOS with SIDs? If you have a complex SID system and then if for every medium aircraft behind a heavy you have to assess each SID you can use, then using CREDOS
becomes very complex. If it becomes too complex in an already complex system I would not use CREDOS.

- What about the use of CREDOS with SIDs? SIDs are part of noise abatement and so cannot be easily changed. If you use existing network it is too difficult for a controller to do without automation. Automation could back up controller by assigning the SID and sequence for aircraft. Having SIDs makes CREDOS more complicated. If you want to introduce CREDOS do it in airports without SIDs. If you want the controllers to take into account of upwind/downwind SID you need a DMAN.
Background
The aim of the CREDOS project is to investigate the feasibility of, under certain crosswind conditions, relaxing the ICAO wake turbulence separation minimum that is normally required when aircraft depart immediately behind Heavy or Medium aircraft. It is proposed that the suspension of the separation can take place when there are sufficient cross winds to move the wake vortices out of the path of the following aircraft trajectory.

One of the activities defined in the CREDOS Human Factors plan (Ref.1) is to investigate current practices at European airports. The purpose of this activity is to ensure that the CREDOS concept developers have a good understanding of ‘the current state of the art’ in terms of tower equipment, procedures and practice relating to wake vortex separation. As such, this activity will provide a better basis for the design of the CREDOS separation operational procedures and inform the development of the CREDOS concept as a whole.

This annex to the CREDOS project Human Factors case deliverable presents the findings from the survey sent to a selection of European airports requesting information about their current procedures, equipment and practices concerning wake vortex separation.

Methodology
The survey to investigate current tower equipment, procedures and practice relating to wake vortex separation was developed with the help of CREDOS concept developers, tower control operational experts and a Human Factors specialist. The survey included questions that covered areas of interest that had been identified through the Human factors issues analysis (Ref. 1) and the stakeholder workshop (Ref. 2) held in November 2007. Thus the survey has two main areas of interest: 1) to understand the ‘state of the art’ in terms of the equipment and information available in European tower control centres today and; 2) to gain a better understanding of current European operational procedures and practice relating to aircraft separation.

Twenty European airport / tower control centres were contacted via email and asked to participate in the survey. Eight of the twenty airports contacted responded positively and completed the survey. The survey responses have been collated and are reported in this document. The majority of airports that have participated in this survey have asked for their responses to remain anonymous. As a result, no specific airport names are mentioned in this document.

Summary of findings
Eight airports responded to the survey. The results clearly indicate that the CREDOS concept and HMI development is strongly affected by local differences in terms of equipment, operational procedures and practices concerning wake vortex separation. The main findings from the survey are described below.

Identified differences between airports in relation to crosswind departures concept

SID system
In CREDOS it is foreseen that if the airport has SID’s that often diverge close to the runway there are further benefits that could be exploited when in crosswind conditions. By relaxing wake turbulence radar separation requirements on favorable SID’s this benefit can be realized. For instance a MEDIUM aircraft following a HEAVY and that is turning upwind and away from the track of preceding very soon after departure could be exempt from wake turbulence separation requirements.

All larger airports use SID’s, in most cases for all traffic. With P-RNAV and SID’s the predictability of what departing aircraft will actually do and where they will be becomes larger. Precision in navigation
is also improved the more detailed the SID is.

The survey findings show that airports vary a lot in terms of diverging point in distance from threshold. Variations even occur locally depending on what runway direction is in use. One of the airports doesn’t have any published SID’s

Types of separation other than radar
Other separation solutions providing higher possible departure capacity/throughput are used but not applied in a coherent way across the airports. Some airports apply visual separation even for IFR flights when in good weather conditions but most airports do not.

Off-track climb out can be used in exceptional situations (i.e. go around, emergency, equipment failure, CB-activity or activation of military or restricted sectors situated close to the runway) but are very rarely allowed as a standard for jet-engine IFR traffic due to environmental constraints.

How to measure 2 minutes?
In ICAO Doc 4444 the runway wake vortex rule states that aircraft should be separated by 2 minutes or more. ICAO has not provided guidelines on how to obtain or measure 2 minutes. Depending on the airport we have found that the methods used to measure 2 minutes separation vary. The two principle measuring methods are to measure 2 minutes from start of roll until start of reading the take-off clearance or from lift-off to lift-off minus the estimated time it takes for number two to roll down the runway. Variations of the two methods exist where the aircrew reaction time from receiving the take-off clearance until the actual start of the take-off roll is estimated and subtracted from the 2 minutes. Rules of thumb are used in some towers, for example in one instance when tower controller sees on the radar that a certain distance out of the threshold has been past by aircraft number one, then aircraft number two can be released for take-off. In the CREDOS project it has to be recognized that the present methods vary and therefore might need to be changed in the local procedures if CREDOS is introduced.

Equipment differences
CREDOS can be applied even in less advanced environments in terms of equipage but some of the more complex decisions the Controller needs to make will be eased if more advanced equipment is installed.

Only two of the eight airports in the survey have full A-SMGCS including multilateration. Five of the eight airports reported to have electronic strips and another planned to introduce them this year.

For airports that have or plan to have electronic strips this will also enable integration of some CREDOS HMI related to SID’s, sequencing and timer functions.

For the time being none of the airports of the survey has a DMAN. In order to apply even an advanced CREDOS HMI solution a DMAN is not deemed necessary. Electronic Flight strips will be able to fulfill the CREDOS requirements.

Application of ICAO rules
One service provider applies 5 instead of 3 wake categories. In one of the countries in the survey, towers who use TMA air radar only apply the wake turbulence radar minima and not in combination with the wake turbulence runway separation minima as other European nations do. The latter method is similar to the way the rules are applied in USA.

The relaxation of the 2 minute rule for the runway gives in most cases benefits as 5 Nm radar separation is considered to be achievable earlier than 2 minutes. In CREDOS only the 3 present categories Heavy, Medium and Light are considered but more categories could easily be introduced. The application of radar separation and no runway separation is very interesting for the CREDOS project and further exploration of this interpretation of the ICAO rules could be very useful in order to improve throughput at saturated airports.

Commonalities related to crosswind departures
Tower Controller responsibilities for radar separation
Many of the airports in this survey take on responsibility for more than just the runway separations.
This is done in a limited or a larger extent and is interesting for the CREDOS concept for many reasons. The major drivers for relocating responsibility from TMA control to Tower control are:

- It is technically feasible nowadays because of daylight radar screens
- Tower controllers often already have radar rating for departures and arrivals
- In the tower a safety net exists by looking out the window that works in most weather conditions (to a certain extent even in degraded conditions),
- TMA radar equipment has delays in update rate that can be compensated by looking out the window if the control is done in a tower.
- TMA radar equipment doesn’t always capture radar returns close to ground, this can also be compensated by looking out the window when execution is done in the tower.
- There is an uncertainty in where and when departures will actually be available on the airborne radar radio frequency so by letting tower keep radio contact longer a critical phase of flight is not disturbed by the handover procedure
- Surface Movement Radar systems are able to capture airborne traffic closer to ground and with higher accuracy than TMA radar systems

From the results in the survey it seems as if the larger airports have moved towards delegating more and more of the departure separation responsibilities from radar Departure Control to the tower Runway controller. This fits well with what is intended for CREDOS just after departure in the initial climb phase of flight.

**Miscellaneous**

None of the airports reported to be collecting data of the actual resulting time distance separation obtained between consecutive departures when the two or three minute wake turbulence separation rule is applied. This implies that it might be difficult to state a baseline to measure against when a new separation is introduced, both in terms of efficiency and safety.

**Conclusions**

The survey clearly shows that some of the differences between airports and between rules depending of country make it difficult to develop one common concept. Therefore concept development for airports should remain high level in the earlier stages of validation because of the local differences in terms of needs, infrastructure, procedures and equipment. It can also be assumed from the survey results that quick wins by promoting best practise and harmonised methods could lead to improved runway throughput and safety even without the introduction of CREDOS. As an example the commonly applied suspension of runway wake turbulence separation in one of the countries when radar is used should be further discussed and investigated.

Based on the survey results it is now proposed that the CREDOS concept will describe the runway controller and not departure control in the TMA as responsible for airborne phase of flight immediately after departure. This approach also fit well to the already existing procedures at many of the major airports that are believed to have the greatest advantages from introducing CREDOS. As half of the airports indicate that they could profit from reduced 3 minute separation when using intersection for departure, this aspect should be further investigated in the crosswind concept development.
The objective of the Human Factors Log (see Table ? below) is to track the changes to the concept that may impact the HF issues. The HF log describes the Human Factors issues that were identified in the Human Factors Issues Analysis (Stage 2 of the HF case). For each HF issue, the HF dimension that it relates to and the potential impact such an issue could have on human performance is identified. In column 4 the recommended activities to either better understand the issue or to mitigate it are listed. Column 5 lists the actual activities conducted to date to address the issues. The final column describes the current status of the issue, (i.e. ‘closed’, ‘ongoing’ or ‘not addressed’), the recommendations based on the activities conducted and / or additional issues raised regarding the concept as a result of the activities conducted. Recommendations for future work that needs to be conducted to address the outstanding issues plus further issues identified during the HF validation process are also listed in the final column.

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<tr>
<th>HF Issues</th>
<th>HF Dimension</th>
<th>Impact on human performance</th>
<th>Activities recommended</th>
<th>Activities conducted to date</th>
<th>Issues Status &amp; recommendations</th>
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<tbody>
<tr>
<td>1 – Aircrew and controller trust and acceptance of CREDOS could be impacted when/if an aircraft hits WV turbulence. What should be the expected reaction of aircrew and controller?</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>ATCO trust in CREDOS Could increase WL (depending on procedures)</td>
<td>Stakeholder Workshop Ground Simulation of CREDOS (event simulation) Live Trials of CREDOS Benefit study</td>
<td>Stakeholder workshop RTS2 (event simulated)</td>
<td>Ongoing - Procedures for such an event developed and tested in RTS2. In the procedures tested CREDOS was suspended after WV encounter reported by aircrew. However, mixed opinions obtained from controllers as to whether or not CREDOS should be suspended if WV encounter reported. Recommendation – The question ‘should CREDOS be suspended after wake vortex encounter reported?’ still needs to be further addressed and other procedures for such an event investigated</td>
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<td>2a – Understand how current practice of achieving 2 min departures consistently could affect CREDOS separations</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Acceptance of procedures by controllers (I,e. controllers more willing to accept tried and tested procedures)</td>
<td>Field study</td>
<td>Stakeholder workshop Tower survey of current operations</td>
<td>Ongoing – Tower survey collected information from 9 tower control centres about current working methods used to gain 2 minutes separation for departures. Working methods found to vary from tower to tower. However, unable to gain performance data relating to actual separation achieved for departures, so best practice to achieve 2 minutes consistently and accurately could not be identified. Recommendation – Field study to collect departure performance data from the different tower control centres surveyed required to identify best working practice for achieving 2 min separations for departures.</td>
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<td>2b. It is necessary to have a record of when a controller achieves a CREDOS separation, in the case of a WVE report &amp; subsequent investigation.</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Would help to improve safety and trust in the procedure.</td>
<td>Stakeholder Workshop Benefit Study Monitoring after implementation</td>
<td>Stakeholder workshop</td>
<td>Ongoing - Application of CREDOS should be marked on strip ((whether EFS or paper) by controllers. However, separation achieved can only be accurately recorded with EFS and A-SMGCS – therefore need the required equipment in order to record separation achieved. Controllers could use radar to see &amp; gain feedback of separation achieved. This could help to improve trust in CREDOS procedures but the separations would not be</td>
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<td>3. It is necessary for aircrew to know that CREDOS departures are available at that airport/at that time and/or that they are under CREDOS instruction for their departure. This could impact aircrew trust and confidence in CREDOS.</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Trust &amp; acceptability</td>
<td>Stakeholder workshop</td>
<td>Stakeholder workshop CTA RTS2 (aircrew participating in simulation questioned)</td>
<td>Out of current scope, focus to date is on tower controllers not pilots. However, aircrew should be informed that CREDOS departures are available at the airport as soon as possible. Further, if aircrew are unwilling to accept CREDOS departure they should inform the tower asap to avoid aircrew refusing a CREDOS takeoff when aircraft if on the runway as this would reduced efficiency. However, this may lead to gaming by some aircrew i.e. reporting to be willing to accept CREDOS before departure to gain departure place but not actually adhering to CREDOS departure instruction given when on runway. How can this issue be resolved? Aircrew can be informed that CREDOS is being used by ATIS to help reduce amount of R/T comms. by controllers. RWY must announce in departure clearance if CREDOS is applied. Phraseology developed for CREDOS clearance under nominal conditions can be found in RTS2 (see Ref.: .)</td>
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| 4 – Runway controllers will need to provide a minimum separation of 3nm consistently, for safety reasons. | Procedures, roles & responsibilities | Possible skill change | Field study Design support Stakeholder workshop | Workshop HMI Prototyping / Demonstrations RTS1 & RTS2 | Ongoing - Separation support tools to help controllers achieve minimum separations of 3nm consistently have been developed and evaluated. An automated timer for an advanced system that required EFS and A-SMGCS was developed and presented to controllers in the stakeholder workshop. Feedback varied – the automated timer was thought to be too complex by some controllers. Recommendation from workshop was to develop a simpler separation support tool that could be used in an environment that did not have EFS & A-SMGCS. Recommendation- Feedback on the automated timer only gained from a demonstration. The automated timer needs to be properly assessed in a tower simulation where EFS and A-SMGCS are available In RTS 1 a manual timer was used to help controller achieved required separation. The manual timer was found to increase workload as activation of timer was considered another action to perform. Further controllers often forgot to time or started timer too late. In RTS2 – a static takeoff trigger advisory (TTA) was used to support controllers achieve the required separation. The takeoff trigger advisory was generally very well received and considered intuitive and easy to use by the majority of controllers. One concern was that controllers were not using it as an advisory and so were not taking...
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<td>into consideration a/c performance when using the static TTA as they should.</td>
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<td><strong>Recommendation:</strong> Assess the use of a dynamic TTA that takes into consideration to a/c performance and wind strength for each departure. This separations support solution can only be implemented in an advanced environment that has EFS or DMAN.</td>
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<td>5 – Controllers will need an indication of the CREDOS status indicator (whether on a case-by-case or periodic basis). This needs to be designed to ensure that controller workload and errors are minimised, and that they trust the tool and that it is easy to use.</td>
<td>Human in the system</td>
<td>SA &amp; Human error Workload Trust</td>
<td>Stakeholder Workshop HMI design - discuss design requirements during workshop. Controller training</td>
<td>Stakeholder workshop CTA FHA (Safety case) HEA (Business case) RTS1 RTS2</td>
<td><strong>Ongoing</strong> - CREDOS status indication should be given on a case by case basis for each departing a/c. However, the HMI information requirements depend on the airport configuration:</td>
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<td>• If SIDs do NOT diverge near the runway (&gt;4NM) then CREDOS status indicator needs only to consider whether CRDDOS has been activated by the supervisor and if the crosswind component is above the threshold required for CREDOS.</td>
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<td>• If the SIDs diverge close to the runway (&lt;4NM) then the CREDOS status indicator must also take into consideration the SIDs assigned to the leading and following a/c. This requires a more advanced system that is equipped with EFS or DMAN. Therefore if SIDs diverge close to runway CREDOS can only be applied if the tower is equipped with EFS or DMAN. However, although recommended this solution needs to be evaluated in a RTS.</td>
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<td><strong>Recommendation:</strong> Solution recommended for diverging SIDs where CREDOS status indicator must also take into consideration the SIDs assigned to the leading and following a/c. has to be evaluated in a realistic setting. It is recommended that four CREDOS states should be displayed, i.e.:</td>
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<td>• CREDOS NOT ACTIVE (not activated by SUP),</td>
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<td>• CREDOS ACTIVE and NO GO (i.e. CREDOS activated by SUP but CREDOS cannot be applied to following aircraft as CREDOS requirements not met e.g. in simple system - crosswind below threshold; in advanced system –crosswind below threshold and / or SID not appropriate)</td>
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<td>• CREDOS ACTIVE and GO (i.e. CREDOS activated by SUP and CREDOS can be applied to next aircraft as all requirements for applying CREDOS met).</td>
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<td>• In addition controllers should be informed of any system failure relating to CREDOS and CREDOS status should be NOT ACTIVE.</td>
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<td>How exactly each CREDOS status is displayed on the CWP will depend on the</td>
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<td>5a – When landings and CREDOS departures are taking place on the same runway, need to take into consideration the uncertainty about when the #2 CREDOS-departing a/c will take off</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Procedure development Identify Best Practice</td>
<td>Stakeholder workshop RTS2</td>
<td>Not addressed. Out of project scope only single departure runways considered in CREDOS. ConOps.</td>
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<td>6 – Need to ensure (in a manual situation) that controllers record and track the departure time of the ‘heavy’ to ensure that 2nd a/c is given clearance at the correct time and so that controllers situation awareness is maintained.</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Could lead to lack of SA &amp; human error when CREDOS changes mode if time not recorded</td>
<td>Stakeholder workshop RTS1 RTS2</td>
<td>Closed - Controllers must record departure time of ‘Heavy’ on strip. This is the recommended procedure and was as evaluated in RTS2 i.e. controller had to write down time of commence of roll. This was considered acceptable by all controllers and was in line with current working practice. This procedure is necessary in case CREDOS changes status immediately following a departure and CREDOS can no longer be applied on the next departing a/c. If no EFS controllers have to record departure time manually on strip. With EFS time of commence of roll can be automatically recorded.</td>
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<td>7 – Ensure that controllers are only provided with wind information necessary to do their job.</td>
<td>Human in the system</td>
<td>The wrong amount of information could lead to increased stress, cognitive workload and errors and loss of trust and acceptance of CREDOS</td>
<td>Stakeholder Workshop RTS1 RTS2</td>
<td>Ongoing- Controllers require crosswind component and direction so they can verify CREDOS status on indicator. The crosswind information should be displayed near the CREDOS status indicator so the crosswind information can easily be checked when controller looks at the CREDOS status indicator. The inputs to crosswind information displayed should be independent of the CREDOS status indicator input (as far as possible) so that the crosswind information displayed can be used as a cross reference. In RTS2 procedures stated that controllers had to give wind reading in departure clearance – this was seen as a mechanism to help ensure controllers crosschecked CREDOS status with crosswind information displayed. However, it should be noted that the SUP will require more detailed wind forecast information than the controllers on which to base decisions to activate / deactivate</td>
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<td>HF Dimension</td>
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<td>CREEOS</td>
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<td><strong>Recommendation:</strong> However, depending on the algorithm behind the CREDOS status indicator there may be a temporary discrepancy between the CREDOS status indicator and the crosswind component value. This issue needs to be further investigated.</td>
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<td>8 - The Runway controller may need to ensure that Heavy a/c has taken the correct SID procedures before giving a CREDOS clearance (dependent on local procedures)</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>SA Human error</td>
<td>Stakeholder Workshop HMI design</td>
<td>Tower survey RTS2</td>
<td>Closed - The runway controller does need to track a/c for longer to ensure a/c has taken correct SID before giving CREDOS clearance if the SIDs diverge close to the runway, i.e. &lt;4NM. In order for RWY to track a/c during climb phase and ensure correct SID is taken the RWY requires a radar screen and will need to have a radar licence. This will be a change in working method for some but not all controllers.</td>
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</table>
| 9 – Ensure that the design of the CREDOS status Indicator maintains controller situation awareness, and minimises human error. | Human in the system | SA Human error Workload | Stakeholder workshop & demonstration HMI design | Stakeholder workshop Prototyping RTS1 RTS2 | Ongoing - RTS2 showed that a simple CREDOS status indicator that only took into consideration the CREDOS active status and the crosswind component was **NOT** sufficient if the SIDs diverge near the runway i.e. 4NM. Controllers regarded this HMI as ambiguous as the CREDOS status indicator could signal GO when 2nd aircraft was downwind of the leading a/c and there was an increased risk of a WV encounter and hence CREDOS could not be applied. In addition, with the simple HMI described in the paragraph above controllers had to consider SIDs, wind direction and whether or not the crosswind was upwind / downwind before applying CREDOS. This was reported to increase controller workload significantly. Therefore, it is recommended from the findings of RTS2 that:  
  * if SIDs do NOT diverge near the runway (i.e. >4NM) then a simple CREDOS status HMI that only considers whether CREDOS is active and the crosswind component is above the threshold is sufficient.  
  * if SIDs diverge near the runway (i.e. <4NM) the CREDOS status indicator should also take into consider the assigned SIDs of the leading and following aircraft plus crosswind direction. This more advanced system requires EFS or DMAN. However, the above recommendations still need to be validated. |
<p>| 10 – Need to ensure | Human in | SA | Stakeholder | Stakeholder | Ongoing – as above see 9 |</p>
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<tr>
<th>HF Issues</th>
<th>HF Dimension</th>
<th>Impact on human performance</th>
<th>Activities recommended</th>
<th>Activities conducted to date</th>
<th>Issues Status &amp; recommendations</th>
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<tr>
<td>that controller cannot apply CREDOS on the wrong SID (related to the concept of using Up-wind SIDs, and prevent the use of Down-wind SIDs)</td>
<td>the system</td>
<td>Human error</td>
<td>Workshop</td>
<td>workshop</td>
<td>Ongoing - CREDOS would need a big PR campaign before implementation to persuade aircrew to accept CREDOS procedures. If possible the PR campaign should be supported and led by the airlines. If airlines accept CREDOS and can be convinced there are financial benefits from CREDOS (in terms of fuel consumption) then they can instruct their aircrew to accept CREDOS. Aircrew also need to be informed about CREDOS. Recommendations - A strategy for the CREDOS PR campaign need to be developed but this is not in the current scope of the project and would need to be dealt with later on in the concept design cycle. Aircrew training needs regarding CREDOS need to be identified and a briefing or training pack for aircrew needs to be developed. This again is something that needs to be dealt with later on in the concept development process.</td>
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<td>11 – Aircrew lack of acceptance and trust in the CREDOS clearances could lead to aircrew not following CREDOS clearance (i.e. aircrew may take their time)</td>
<td>Procedures &amp; responsibilities</td>
<td>Acceptance Trust</td>
<td>Education</td>
<td>Stakeholder workshop</td>
<td>RTS1</td>
</tr>
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<td>14 – Need to ensure that for a particular runway the wrong wind meter cannot be selected, to guard against human error</td>
<td>Trust</td>
<td>System design</td>
<td>Stakeholder workshop</td>
<td>Stakeholder workshop</td>
<td>RTS1</td>
</tr>
<tr>
<td>16 – Ensure radar (TMA) controller is informed that CREDOS is being applied. Otherwise this could lead to frustration on the part of the radar ATCO</td>
<td>Procedures &amp; responsibilities</td>
<td>SA</td>
<td>Stakeholder workshop</td>
<td>Stakeholder workshop</td>
<td>RTS1</td>
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|                                                                 |              |                             | HMI design Training     |                             | Closed – At the minimum radar/Departure controllers need to know when CREDOS is active, so they know that CREDOS may be applied. Therefore, it is recommended that the CREDOS status indicator is presented on the departure CWP. In addition the departure controllers also need to know about the crosswind strength and crosswind direction so that if they have to manoeuvre aircraft e.g. if there is a potential conflict situation then they know in which direction the aircraft must be manoeuvred to avoid a wake vortex encounter. A few controllers participating in RTS2 reported to want all the CREDOS related information and tools that were present on the tower CWP when working the departure position. Therefore it is suggested that the departure controllers should have the option to select what additional CREDOS related information & tools they require so they can tailor the CREDOS related information displayed according to
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<td>17 – Runway controller is responsible for applying CREDOS separation only on the runway but not in climb-out path. If runway controller responsible for both (ground and air), this could impact on their workload, cognitive processes and radar skills.</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Stakeholder Workshop Field study for procedure design</td>
<td>Stakeholder workshop Tower survey RTS1 RTS2</td>
<td>Closed – The runway controller is responsible for applying CREDOS separation both on the runway and in the climb out path. Findings from the tower survey showed that in some tower control centres the runway controllers are currently responsible for separation on both the runway and climb out phase of flight. In order to ensure separation on the climb out path the RWY must have a radar display so they can accurately monitor the aircraft as they climb, hence the RWY also need to have a radar licence. In RTS2 all controllers reported that they felt it was acceptable for them as runway controller to be responsible for aircraft during the climb phase and although some controllers reported that this increased the amount of monitoring that was required compared to non-CREDOS operations, the increase in workload that was experienced due to the extra monitoring was not reported to be significant.</td>
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<td>19 – Installation of wind-socks at airports could help aircrew to cross-check the wind conditions for trust and aircrew acceptance of CREDOS</td>
<td>Trust and aircrew acceptance of CREDOS</td>
<td>Field study Workshop</td>
<td>Stakeholder workshop RTS2 (aircrew feedback)</td>
<td>Closed - Even though a wind sock will not give aircrew an accurate crosswind measure it does give them some indication of crosswind direction &amp; strength. Therefore, the installation of wind socks at each runway is recommended so that aircrew can cross check wind conditions</td>
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<tr>
<td>HF Issues</td>
<td>HF Dimension</td>
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<td>CREDOS (to mitigate against human error).</td>
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<td>24 – Controller has the responsibility for providing CREDOS clearances, although supervisor can over-rule controller, to guard against human error</td>
<td>Procedures, roles &amp; responsibilities</td>
<td>Error</td>
<td>Define clear roles &amp; responsibilities</td>
<td>RTS2</td>
<td>Closed – Agreed. Supervisor should be able to over-rule controller if necessary.</td>
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<td>25 – Ensure that the CREDOS status indicator chosen does not provide continuously variable data (indications) when the wind is lingering around the threshold. Otherwise this could cause frustration and uncertainty. It may lead to human error, or to controllers bending the rules, and loss of trust in the CREDOS status indicator</td>
<td>Trust &amp; user acceptance</td>
<td>Stakeholder Workshop</td>
<td>Stakeholder workshop</td>
<td>RTS1 RTS2</td>
<td>Ongoing – Agreed, a buffer needs to be introduced into the algorithm that determine the CREDOS status to ensure variable data is not presented to the controller. However, the exact value of the buffer required to ensure fluctuations in CREDOS status do not occur but also ensure that CREDOS can be used as frequently as is possible that the needs to be defined.</td>
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<td>26 - Case-by-case situation should not increase controller workload – where they have to check CREDOS availability for each departure</td>
<td></td>
<td>Stakeholder Workshop</td>
<td></td>
<td></td>
<td>Ongoing - see HF issue 9</td>
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*It should be noted that six issues identified in the HFIA were specifically safety issues. These issues were number 15, 18, 21, 27, 28, and 29. They were transferred to the safety case. For details of these issues please refer to the CREDOS Human Factors Plan. Three issues were removed as they were considered low priority; these were issues 12, 13, & 22. Issue 23 was merged with issue 3 as they were the same issue.*