

First ATC Support Tools Implementation (FASTI) – Cognitive Task Analysis

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Abstract					
<p>This document presents a Cognitive Task Analysis (CTA) for First Air Traffic Control Support Tools Implementation (FASTI). This CTA describes how ATC tasks will change following the implementation of FASTI tools (i.e., MTCD, MONA, and SYSCO) and identifies the mental demands associated with these tasks.</p>					
<p>Based on the CTA, the report identifies the Human Performance benefits and issues associated with FASTI, and makes recommendations to address these issues. These recommendations refer to training, the human machine interface, working methods, and allocation of tasks / functions.</p>					
<p>The CTA will be of value to project teams involved in the implementation of FASTI-like support tools, in particular to Human Factors experts and training experts.</p>					
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EXECUTIVE SUMMARY

The First ATC Support Tools Implementation (FASTI) Programme aims to support the co-ordinated implementation and rapid deployment of an initial set of controller support tools. The FASTI support tools include Medium Term Conflict Detection (MTCD), Monitoring Aids (MONA), and System-Supported Co-ordination (SYSCO).

This document reports the findings of this Cognitive Task Analysis (CTA) study that was carried out within the FASTI Programme. The aim of the CTA was to understand in more detail the impact of the FASTI tools on the controller's task and the mental demands associated with these tasks.

The study has produced a CTA that represents the controller's task when interacting with FASTI tools as implemented in EUROCONTROL's FASTI demonstrator. Although the results of the CTA are largely formulated on a level that is independent of a specific Human-Machine Interface (HMI), it cannot be avoided that they reflect the specific FASTI concept used in the demonstrator.

Based on the results of the CTA, the document identifies the human performance benefits as well as potential issues (in terms of task demands and error potential) associated with the implementation of FASTI tools. Recommendations pertaining to training, working methods, system or HMI design are made to address the identified issues.

The present document is structured as follows:

Section 1, 'Introduction', outlines the background, objectives, scope and outcome of the CTA study.

Section 2, 'Elements of the FASTI Concept', describes the three building blocks of the FASTI toolset, which are MTCD, MONA, and SYSCO.

Section 3, 'Method', provides an overview of the process taken for the construction of the CTA and lists the assumption made in the CTA.

Section 4, 'Cognitive Task Analysis: PC/TC staffing', describes the impact of FASTI tools on mental demands if the sector is controlled by a team of a Planning Controller (PC) and a Tactical Controller (TC).

Section 5, 'Cognitive Task Analysis: Variant Staffing Options', does the same for Single-Person Operation and the use of a Multi-Sector Planner for more than one Tactical Controller.

Section 6, 'Conclusions and Recommendations' provides a summary of the main findings of the CTA study, in terms of performance benefits and potential issues, and suggests how potential issues can be resolved.

Appendices A, B, and C contain models used and assumption made in the CTA. Appendix D provides the full CTA for the PC/TC staffing options. Appendix E includes the cognitive demand and error analysis that has been carried out on the basis of the CTA.

References and the list of acronyms and abbreviations are presented at the end of the document.

1. INTRODUCTION

1.1 Background

The FASTI programme is designed to co-ordinate the implementation and deployment of controller tools and system support across Europe in a harmonised way. The controller tools that are included in the concept are Medium Term Conflict Detection (MTCD), Monitoring Aids (MONA), and System-supported Co-ordination (SYSCO).

FASTI has the following aims:

- Increase sector capacity, improve flow rates, and reduce delays.
- Increase potential for flexibility, changes in operational practices and changes in conditions specified in Letters of Agreement (LOAs).
- Introduce the potential for cost savings through the automation of routine tasks, flexible staffing, system and airspace development, and controller training.
- Support an improved quality of service to airspace users in the form of optimum profiles and routes, and less ATC interventions in flight.

Human factors (HF) are central to the realisation of the objectives of the FASTI project. In particular, the FASTI concepts must be based on a sound understanding of the impact of the changes on controller cognitive and team behaviour. The aim of this Cognitive Task Analysis (CTA) is to support this requirement by providing a more detailed understanding of impact of FASTI tools on the controller. In turn, this will allow human performance benefits and potential issues associated with FASTI to be identified.

1.2 Study Objectives

CTA is a method for identifying the strategies and information processing demands associated with skilled behaviour. The purpose of this study is to develop a CTA that describes (a) how air traffic controllers' tasks will be performed following the implementation of FASTI, and (b) the mental demands associated with these tasks.

1.3 Study Scope

The study has produced a CTA that represents the controller's task when interacting with FASTI tools as implemented in EUROCONTROL's FASTI demonstrator. Although the results of the CTA are largely formulated on a level that is independent of a specific Human-Machine Interface (HMI), it cannot be avoided that they reflect a specific FASTI concept. One characteristic of this concept is that MTCD is used for planning purposes.

The study also considers variant staffing option for the use of FASTI tools in addition to a PC/TC staffing option. The changes caused by Single Person Operation and Multi-Sector Planner staffing options were assessed, and are presented in this report.

Throughout the document, the following terminology will be used: The term “FASTI” refers to a generic concept or set of tools that is independent of a specific implementation. “FASTI demonstrator” refers to a specific implementation of the FASTI tools, with one characteristic being the usage of MTCD primarily as a planning tool.

1.4 Study Outcomes

The CTA report identifies the human factors issues and benefits associated with the different implementations of FASTI tools, and makes recommendations to address these issues. These recommendations refer to training, the human machine interface, working methods, and allocation of tasks / functions.

2. ELEMENTS OF THE FASTI CONCEPT

2.1 Introduction

This study is based on the description of the FASTI tools and concept as provided in the FASTI Operational Concept document (version 1.3, May 2006). Below, the different elements of the FASTI toolset are described. Whenever specific illustrations of the tools are given (e.g., in screen-shots), they reflect the FASTI tools as implemented in the FASTI demonstrator.

2.2 FASTI Concept and Proposed Human-Machine Interfaces

The CTA aims at capturing changes in controller tasks that are generic over a wider set of implementations. However, in practice, this is difficult to achieve. Human behaviour (including cognition) is influenced by how a particular concept is implemented.

The CTA data collection was based on a concept in which MTCD is primarily used as a planning tool. The FASTI Demonstrator and the working methods described in the FASTI Operational Concept document were used for the CTA data collection. Therefore, it cannot be avoided that some of the comments made by participants - and consequently some of the CTA findings - reflect specific implementations of the FASTI tools. However, it is attempted to bring all findings – at least for the identification of benefits, issues and recommendation – to a conceptual level.

2.3 Medium Term Conflict Detection (MTCD)

MTCD is a collection of software data processing functions designed to assist controllers in the search for conflicts in a particular time frame. The specific time frame will depend on the local implementation; however, the look-ahead horizon may be up 20 minutes.

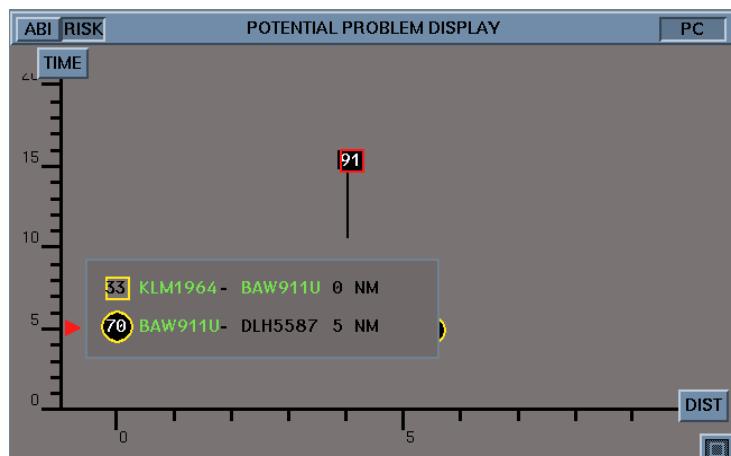


Figure 1 - Potential Problem Display

MTCD achieves conflict detection through continuous monitoring and prediction of aircraft trajectories. The FASTI demonstrator contains the following HMI elements:

A Potential Problem Display (PPD) that shows predicted potential conflicts on a graph of time (minutes until closest point of approach) and predicted minimum separation.

Functionally, the PPD is separation prediction display. In the CTA, the term '*separation prediction display*' (rather than PPD) will be used in order to keep the CTA independent from the specific implementation in the demonstrator.

A Vertical Aid Window (VAW) that presents the vertical profile of an aircraft through the sector, including any Flight Level (FL) changes. The VAW also shows potentially conflicting aircraft on different FLs within a range of 10,000 ft.

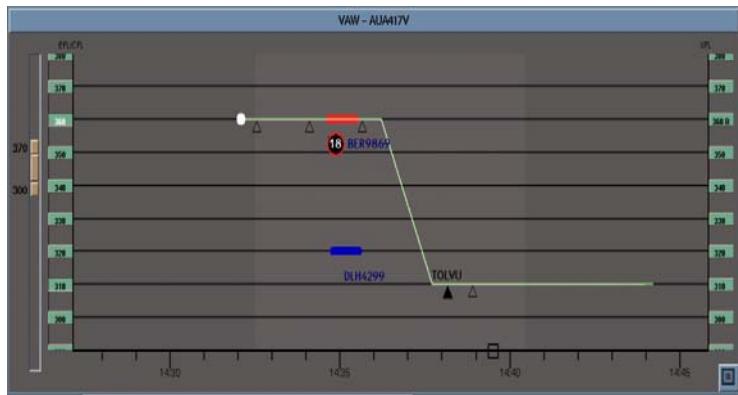


Figure 2 - Vertical Aid Window

A Problem-orientated Flight Leg (POF). The POF shows on the Plan View Display (PVD), for a pair of conflicting aircraft, their trajectories and predicted point of minimum separation.

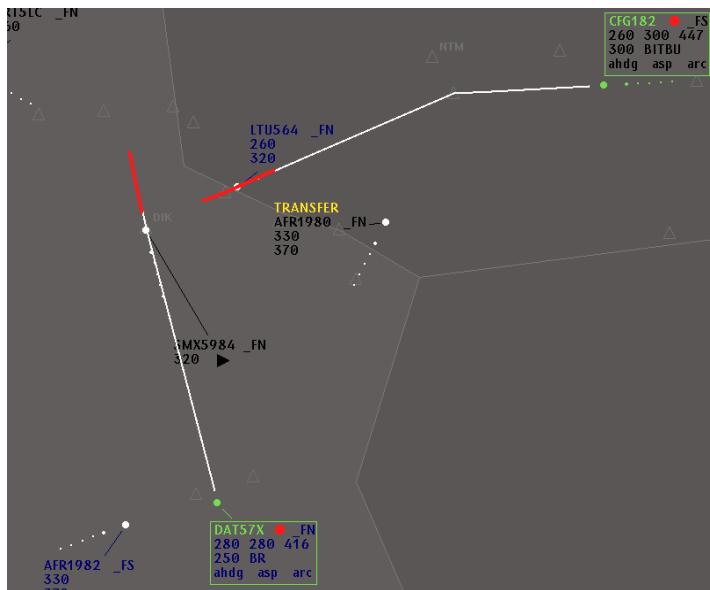


Figure 3 - Illustration of a Problem-orientated Flight Leg

The **Aircraft –orientated Flight Leg** (AOF) shows, for a single aircraft, its trajectory through the sector, and any conflicts or separation risks associated with that flight.

Manual MTCD is a feature that allows for the display of the predicted minimum distance for a pair of aircraft selected by the controller.

Note that MTCD implementations vary, and not all of the above described HMI elements may be found. For the purpose of this CTA, it is assumed that the MTCD HMI comprises at least: (a) visual presentation of all predicted conflicts in a specific time frame (i.e. the ‘separation prediction display’), and (b) the presentation of conflict information in the aircraft trajectory(ies).

2.4

Monitoring Aids (MONA)

MONA functions inform the controller of the progress of flights through the sector. The system can **remind** the controller regarding actions that need to be carried out (a turn or descent instruction or transfer of an aircraft, for example). **Warnings** provide alerts related to deviations of a flight from a clearance or a plan (lateral deviations, FL deviations, and FL busts).



Figure 4 - Example of MONA Warnings and Reminders

In the FASTI demonstrator, MONA messages are displayed in line 0 of the relevant aircraft label on the Plan View Display (PVD).

2.5

System-Supported Co-ordination (SYSCO)

SYSCO offers screen-to-screen dialogue in the coordination and transfer of control of a flight to/from a neighbouring unit or sector.

More details on the components of these tools can be found in the FASTI Operational Concept document. The OLDI messages that are utilised by SYSCO are further described in the appropriate standards (the EUROCONTROL Standard Document for On-Line Data Interchange (OLDI), edition 3.0, for example).

2.6

Human Tasks and Roles

The FASTI tools are both enabled by and dependent upon certain other changes to Air Traffic Management (ATM). Working Methods, task distribution and frequency, and cognitive strategies are all likely to be altered along with an implementation of FASTI.

The purpose of this study is to present and communicate a view of how these tools and changes will alter the cognitive work of air traffic controllers.

3. **METHOD**

3.1 **Introduction**

For the purpose of this study, Task Analysis (TA) is used to refer to the general family of HF methods that aim to represent human activities. Cognitive Task Analysis (CTA) is defined as a process and output that describes the tasks, cognitive strategies, and information processing demands that underlie goal-directed behaviour.

An information-processing perspective was applied to the CTA (see Appendix A for assumptions on the Cognitive Architecture). This means that the major focus of the CTA was on capturing the information-processing demands and strategies necessary to achieve the goals and tasks associated with the FASTI tools. Wider social and work environment factors were not a focus of this study. This approach is compatible with the aims of the study – in particular the requirement to identify potential for human error (human error identification methodologies such as TRACEr and HERA also utilise this information-processing approach).

This section presents the method that was followed by the study.

3.2 **Overview of the Method**

In summary, the method contained the following steps:

1. Establish CTA approach
2. Review FASTI system descriptions and relevant literature
3. Construct initial Hierarchical Task Analysis of observable tasks
4. Use cognitive walkthrough interviews and observations at FASTI demonstrator to identify cognitive strategies
5. Identify information processing demands and performance shaping factors
6. Identify potential human error modes
7. Collate human factors issues and benefits

3.3 **Initial FASTI Task Analysis**

The development of a pre-FASTI task analysis (TA) was intended as a ‘baseline’ exercise only. The aim for the pre-FASTI task analysis is to provide a context and baseline against which the post-FASTI changes can be compared. This is especially important with regard to any changes in cognitive strategy.

The baseline was developed using previous TAs of en-route air traffic control (e.g., Rantanen and Nunes (2005), Eyferth et al. (2003), Bressolle et al

(2000), Seamster et al. (1993)), and the EUROCONTROL Integrated Task and Job Analysis of Air Traffic Controllers (EUROCONTROL, 1999).

Based on the baseline TA, a draft FASTI task analysis was developed through reference to the associated literature. The initial FASTI TA was effectively a functional hierarchical decomposition that contained observable behaviours, as well as some cognitive processing activities. This TA was linked to the barrier model (see Appendix B).

3.4 Cognitive Walkthrough Data Collection

To build the FASTI demonstrator CTA, cognitive walkthroughs were used in order to elicit the strategies and task steps associated with the use of the controller tools.

The protocol for the cognitive walkthroughs was loosely based on the Applied Cognitive Task Analysis (ACTA, Militello and Hutton (1998)) method. This method uses a grounded interview technique in order to extract CTA information from Subject Matter Experts (SMEs).

Some aspects of expertise can be difficult to articulate or to consider subjectively. To support the cognitive walkthroughs, observations were conducted using the FASTI demonstrator platform in order to observe some aspects of usage of the tools (frequency and series of use, and use of the manual MTCD, for example).

To qualify the interview and observational data further, previous simulation reports (including the Shadow Mode and Advanced Shadow Mode trials reports) and other relevant literature were used to verify the data.

3.4.1 Locations and Participants

The data collection session was conducted at the FASTI demonstrator at EUROCONTROL Headquarters, Brussels. Four participants (in pairs of two) took part in the FASTI data collection. All participants were former or current air traffic controllers.

In addition, a meeting was held at DFS in Langen to discuss the experiences of DFS in recent simulations involving MTCD tool support and the Multi-Sector Planner (MSP) role.

All contributors to the CTA are thanked for their input to this project.

3.4.2 Process

Participants received a briefing pack ahead of time that provided an agenda, a background to the study, and details and definitions of some of the human factors concepts that may be discussed during the sessions.

All of the participants had experience of using the FASTI demonstrator. In this way, it was ensured that the data collected is representative of expert performance.

The data collection sessions had the following format:

1. Briefing
2. Familiarisation with the relevant demonstrator and task observation
3. Initial discussion and review of the task diagram
4. Detailed interviews on each major goal and task associated with the FASTI demonstrator. These interviews were conducted in the room in which the demonstrator was located. Situations from the observation session were used as context for the walkthrough. The facilitators used the following prompts during the walkthroughs:
 - i. Who performs the task.
 - ii. What cues, strategies and information sources (knowledge objects) the controller will refer to in order to achieve the task.
 - iii. The decisions, evaluations and judgments required, and how these are made.
 - iv. Credible errors, based on a limited set of HERA-PREDICT keyword prompts.
5. If time was available, other factors (i.e., traffic load or airspace type differences) were considered.

Following the data collection sessions, the baseline CTA was modified to produce a 'FASTI demonstrator CTA'. This CTA represented the controller's task if MTCD is primarily used as a planning tool, and the sector is staffed with a team of Planning Controller (PC) and Tactical Controller (TC). The CTA was then modified to account for the variant staffing options (Single Person Operation and Multi-Sector Planner¹).

A summary of the CTA can be found in Section 3 and Section 4. The full CTA can be found in Appendix D.

3.5

Cognitive Demands and Human Error Identification

Based on the CTAs, a limited analysis of cognitive demands and human error was conducted. The purpose of this analysis was to answer the following questions:

- Do the FASTI tools (as implemented in the FASTI demonstrator) cause any notable changes in information processing (IP) demands or functioning? (for example, do the tools change the information modality or the information processing function of an existing task)

¹ The MSP CTA is based on information provided by DFS, rather than on a cognitive walkthrough. This information reflects the experiences and results from a real-time simulation in which FASTI tools were used in an MSP configuration.

- What are the potential error modes (that is, observable task failings) associated with the changed or new tasks?
- What are the IP functions and Performance Shaping Factors (PSFs) associated with the potential error modes?

The basic approach to this analysis was compatible with the TRACER-Lite and HERA-PREDICT human error identification methodologies (EUROCONTROL, 2004). The results of this analysis can be found in Appendix E.

3.6

Collection of Human Factors Issues and Benefits

Human factors issues and benefits were captured as the study progressed. These issues and benefits are traceable either to the data collection interviews, the subsequent revision of the CTAs, or the cognitive demand and human error identification exercise. The issues and benefits relate to new or changed tasks only, relative to the baseline situation.

The issues and benefits associated with the changes are presented in context in Section 3, in relation to the relevant goals. A summary by human factors topic area, and further analysis, is provided in Section 6.

3.7

Assumptions

The assumptions that were used in the study can be found in Appendix C. The main assumptions are listed below.

3.7.1

Controller tools and working environment

It is assumed that controllers work with a predominantly graphical HMI (i.e., the HMI may have electronic flight strips but flight information can be displayed / recorded through the aircraft label on the PVD).

3.7.2

Controller tasks and characteristics

The CTA is designed to reflect the way that controllers who are experienced using the FASTI demonstrator will perform tasks. The CTA is based on the assumption that the user of the tools is also experienced at controlling the type of airspace under consideration.

In order to keep the data to a manageable amount, the CTAs focus on those tasks that are expected to be influenced by the introduction of the FASTI. This might mean changes to the task in terms of how it is performed, the duration/frequency of the task, or the importance of the task. New tasks were also identified.

Although the implementation of FASTI tools often coincides with the introduction of a (paper) stripless environment, changes in controller tasks that result from the replacement of paper strips are beyond the scope of this study.

4.

COGNITIVE TASK ANALYSIS: PC/TC STAFFING

4.1

Introduction

The purpose of this section is to summarise the CTAs for each goal affected by the FASTI demonstrator. Sector Team Operation (i.e. one PC and one TC) is assumed for this CTA, as are the assumptions contained in Section 3.7.

The full CTA for this staffing option can be found in Appendix C.

This section contains several CTA diagrams. In these diagrams, the following conventions are used:

- *Italic text* refers to tasks that are changed or made redundant by the implementation of FASTI tools.
- **Bold text** refers to tasks that are new as a result of the implementation of FASTI tools.

4.2

Overview of ATC Goals

For the CTA, the following structure of ATC goals is assumed. The overall goal “Provide the Air Management Services” includes the following high-level goals (see also Figure 6):

1. Confirm & Update Mental Model – Maintain SA
2. Workload Monitoring
3. Control Process: Make Action Plan /Hierarchy
4. Conflict Avoidance
5. Tactical De-confliction
6. Flight Progress Monitoring
7. Co-ordination & Transfer

In the following chapters, the focus will be on Goals 4 – 7. The reason is that these are the tasks that are directly impacted by FASTI tools. The full CTA – covering all seven goals –can be found in Annex A.

4.3 Conflict Avoidance

4.3.1 General Description

The goal of conflict avoidance is to identify, assess and potentially solve potential conflicts before the a/c enters the sector under control (i.e., within the Planning timeframe).

The Conflict Avoidance goal is mainly associated with the MTCD element of the FASTI concept (and the associated TP enabler). SYSCO is also utilised in support of the Conflict Avoidance goal (for co-ordinations during the implementation of a solution). However, it is typically associated with another task – this is covered under ‘Co-ordination and Transfer’).

Supporting the Conflict Avoidance goal is seen as central to the success of the FASTI concept. The FASTI Change Assessment Workshop Report (Edition 0.1, 2006) concludes that Conflict Avoidance is the most important focus area for subsequent safety assessment. The rationale behind this finding is based on the premise that improving Conflict Avoidance will reduce the ‘workload’ on the goals performed by the TC, such as Tactical De-confliction. In this way, the FASTI tools also support the ‘workload management’ in the team.

For the purpose of this study, given the importance of Conflict Avoidance to the FASTI project as a whole, a fairly detailed CTA was produced for the Conflict Avoidance goal.

It is assumed that only the PC role has tasks associated with the Conflict Avoidance goal.

4.3.2 Planning Controller Goals

Figure 5 shows the context and overall structure for the goal ‘Conflict Avoidance’ for the PC.

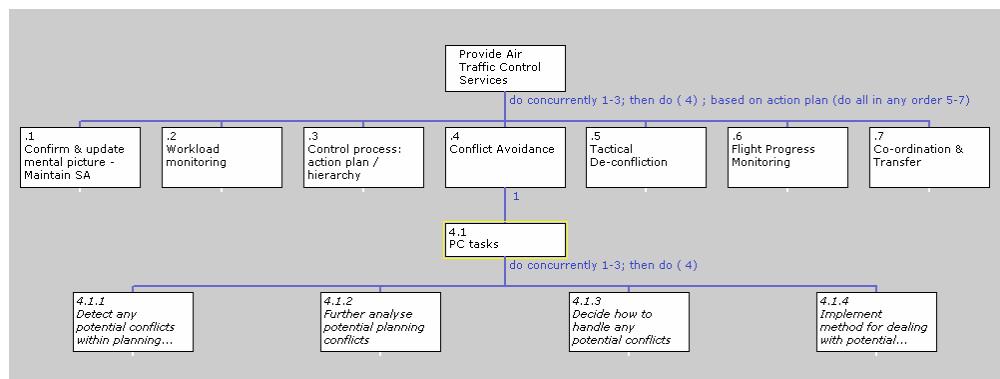


Figure 5 - Context for Planning Controller Conflict Avoidance Tasks

It can be seen from Figure 5 that, at this high-level, there are no differences between the pre- and the post- FASTI situations with regard to overall plan and strategy associated with conflict avoidance. For both situations, all sub-

goals still have to be achieved, and they have to be achieved in the same order (as indicated by the blue text indicating the sequence of sub-goals). The difference between the pre- and the post- FASTI situation concerns the way in which the sub-goal “Detect any potential conflicts within the planning timeframe” is carried out (as indicated by the fact that the sub-goal is displayed in italics).

This section discusses some of the notable cognitive behaviours associated with the FASTI changes in the Conflict Avoidance goal. Not every task in the CTA associated with Conflict Avoidance is presented or discussed in this section (the full analysis of this task can be found in Appendix C).

4.3.2.1 ***Detect any potential conflicts within planning timeframe***

Figure 6 shows the sub-goals for the goal ‘Detect any potential conflicts within the planning timeframe’:

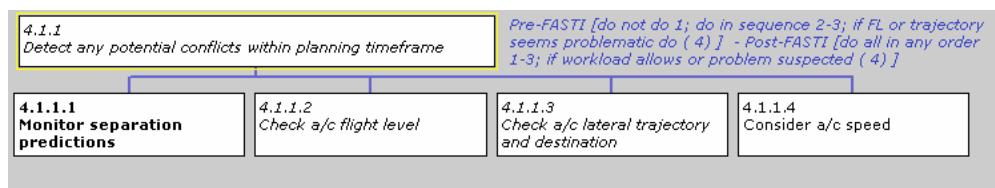


Figure 6 - Determine any potential conflicts within planning timeframe

The main difference in this task concerns the fact that there is a new source of information that supports the detection of conflicts in the post-FASTI situation. This new source of information is the MTCD HMI elements, in particular, the separation prediction display (or: PPD in the FASTI demonstrator).

Post-FASTI, there is evidence from the data collection session that the PC will not solely rely on the separation prediction display for the detection of conflicts. In Figure 7, this observation is reflected by the fact that flight level, trajectory and destination, and - if required – speed are still checked in order to identify potential planning conflicts. Given the limited extent of data collection, it was not possible to fully explore the reasons for this observation. It may be partly associated with an element of ‘habit intrusion’ from the classical ways of working. This would be consistent with training theory.

The strategy may also be associated with the degree of trust that controllers place in the sensitivity of MTCD (the extent of the accuracy of the tool in certain situations). The strategy for the execution of this task will depend on the understanding and experience that the PC has of the functioning and accuracy of MTCD (the ‘reliability level’ of the automation). MTCD can be classified as a form of ‘imperfect diagnostic automation’ (Parasuraman, Sheridan, & Wickens, 2000). Therefore the PC will have a PPD monitoring and investigation strategy that is based on trying to balance the degree of ‘reliance’ they should have in MTCD (i.e., the extent to which they can and should monitor using the PPD only, and not the underlying PVD radar).

Whatever the reason the evidence available to this study seems to suggest the following conflict detection strategy:

1. Monitor separation prediction display

2. For aircraft not in the PPD, and if workload allows, check aircraft FL and trajectory/destination
3. Consider aircraft ground or vertical speed if analysis in Step 2 identified a problem

This strategy may be different from the recommended working method, but, for the purposes of addressing anticipated control behaviours in a realistic way (during safety assessment for example), it is recommended that this strategy is taken as the basis for any understanding of the PC Post-FASTI conflict detection goal.

4.3.2.2 **Analyse potential planning conflicts**

After an initial identification of potential conflicts, the potential conflict is analysed in more detail. The CTA for this activity is shown in Figure 7:

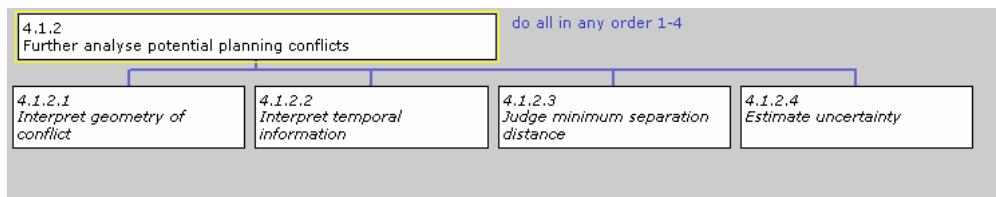


Figure 7 - Analyse potential planning conflicts

Figure 7 shows that the sub-goals within the ‘analysis’ stage of conflict avoidance are greatly changed by the FASTI tools, but the overall plan is consistent. This suggests that the major post- FASTI changes for this sub-goal support the contributing tasks rather than the plan of activities at this level of description in the task analysis. During the data collection session this was a common theme in relation to the interpretation of conflicts. For example, a strategy described by a participant involved using the length of the colour-coded conflicting trajectories in order to come to an initial characterisation of the nature of the conflict (*“If I can see a long red trail in the Vertical Aid Window then this means that a flight level change is the likely solution”*). As the example shows, there is a close link between the analysis of a potential conflict and the identification of a potential solution.

The example above shows how the FASTI tools change the information processing characteristics of this goal. A greater degree of visual support is provided through the various HMI elements for the display of MTCD information (which are, in the case of the FASTI demonstrator, the VAW, the POF and the AOF). Previously this group of sub-goals would have required the controller to project mentally the trajectories of the aircraft into the future. While, post-FASTI, it is still possible to perform this check, the controller can now use the visual information to support this goal.

In addition, information concerning conflict type and predicted minimum distance is now calculated and presented to the PC. Previously the minimum distance would have to be assessed by the controller.

Based on the literature review and data collection session, a new task was added under the sub-goal ‘estimate uncertainty’ (Figure 8) to account for the consideration that the PC must now give to their understanding of the MTCD output.

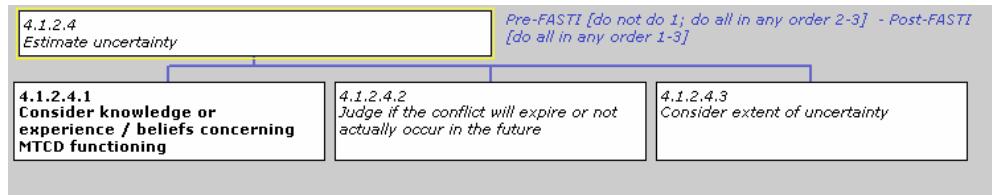


Figure 8 - Estimate uncertainty

Estimating the uncertainty associated with MTCD predictions is an important extra task. Controllers already make judgments regarding the probability or uncertainty associated with a potential conflict in the pre-FASTI situation. It is reasonable to assume that the behaviour of the TP and MTCD will be a factor that they will have to consider in the future.

Therefore, it follows that a basic understanding of the algorithms underlying both TP and MTCD are required to be able to interpret the information presented via the MTCD HMI. This should be part of the training for controllers that use MTCD.

4.3.2.3 **Decide how to handle any potential conflicts**

The analysis of information on a potential conflict serves to determine whether the potential conflict is likely to occur, and thus an ATC (PC or TC) action is required. If so, the next step is to decide how to handle the conflict. This process is illustrated in Figure 9:

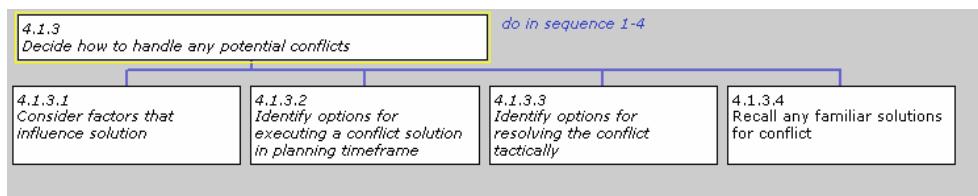


Figure 9 - Decide how to handle any potential conflicts

The main aim of this sub-goal is to make a decision on how to best handle a potential conflict: the PC can either decide to solve the conflict by co-ordination, or leave the conflict to be solved by the TC (i.e., transfer it to the TC). The FASTI tools provide a significant support to this goal through the provision of new information sources. This can be seen in Figure 10:

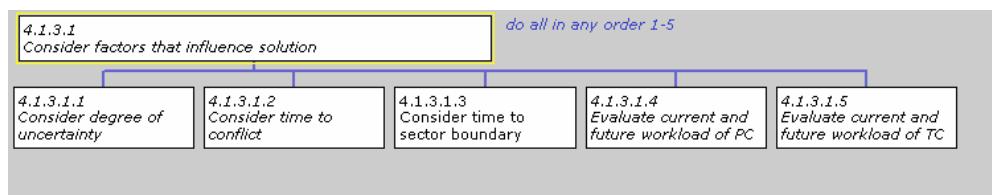


Figure 10 - Consider factors that influence solution

Figure 10 presents the sub-goals for the judgement of the factors that influence the selection of a solution. Other factors that may need to be considered include: the sector environment, military zones, and configuration of other traffic (in the sector and adjacent sectors).

By looking at the italic text in the figure, it can be seen that the FASTI tools change all tasks that influence this judgment, apart from some aspects of the position of the aircraft relative to sector boundaries.

The data collection activities found that the display of the vertical context of the potential conflict (through the VAW in the EUROCONTROL HMI) assists the controller in finding free levels that can be used to solve any potential conflict.

4.3.2.4 *Implement method for dealing with potential conflict*

The FASTI demonstrator includes a function by which a user can ‘flag’ a conflict by putting a warning on this conflict. This function is equivalent to marking or cocking strips in a paper strip environment. During the data collection session, though, the ‘warning’ function of MTCD was seldom used by the PC.

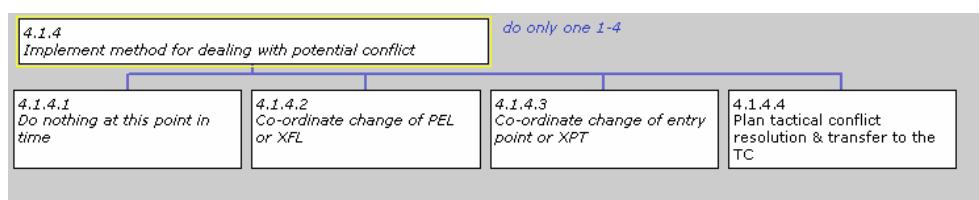


Figure 11 - Implement method for dealing with potential conflict

It was not possible during the data collection to reach a firm conclusion on some of the communication aspects of transferring a conflict to the TC. One pair of controllers stated that verbal communication across the team would be required when transferring a conflict. The other pair stated that verbal communication would be infrequent when transferring a conflict. It appears that the PC would need additional verbal communication if circumstances require a richer appreciation of the context, or if discussion is required.

However, there was some agreement that there was a strategy associated with the choice to transfer a conflict. Conflicts where the solution was ‘known’ or inherent in the nature of the conflict (crossing conflicts for example) were mentioned as being conflicts that would be transferred to the TC.

Details concerning the co-ordination with the adjacent sector to solve a conflict will be captured within the goal “Co-ordination & Transfer”.

4.3.3 *Issues and Benefits*

The following list presents the issues and benefits associated with the CTA of FASTI Conflict Avoidance tasks:

4.3.3.1 *Issues*

I1 The data collection supported the known issue that the MTCD is very dependent on the accuracy and behaviour of the TP function. Imperfection in the automation does affect the monitoring strategy adopted by the controller. There is evidence to suggest that the PC will, under some conditions, scan for conflicts using the Plan View

Display rather than obtain full assistance from the separation prediction display (PPD) for conflict detection.

- I2 Controllers need to understand the basic algorithms behind MTCD so that they are able to assess whether an MTCD predicted conflict is likely to occur in the future. This includes the use of TP for conflict detection, assumptions made in TP, and the use of uncertainty.
- I3 The data collection was inconclusive regarding the conditions under which the PC would verbally provide extra information when transferring a conflict by electronic means to the TC.
- I4 The FASTI demonstrator provides the possibility to highlight an MTCD predicted conflict. There is some evidence to suggest that such a 'warning' function would be seldom used by the PC.
- I5 If the PC adopts a strategy by which he or she immediately responds to every problem displayed, workload can increase. Such a reactive control strategy can also increase errors associated to losing the 'place' in an action sequence (i.e. omission or repetition of action steps).

4.3.3.2 Benefits

- B1 The graphical presentation of MTCD information in a conflict display and on flight legs reduces the information processing and working memory demands associated with mental projection of future a/c positions. Conflict detection and analysis change from tasks that are based on mental projection and computation to tasks based to a larger extent on visual perception.
- B2 The different trajectory displays, due to their spatial and graphical representation of the conflict, aid the controllers' understanding of the location, geometry and severity of the conflict.
- B3 The separation prediction display (PPD) reduces the requirement for the controller to remember conflicts and conflict details (such as severity of the conflict and context a/c) concerning conflicts after detection.
- B4 The tools allow for a less reactive approach to dealing with conflicts and a more effective time management. This results from the fact that MTCD facilitates the early detection of conflicts.
- B5 Certain types of conflicts (occurring after turns or with complex geometry) should be detected earlier and more accurately by MTCD than human mental projection. This, however, presupposes an adequate performance of the TP.
- B6 Some MTCD HMI elements (e.g. VAW, what-if probe, trajectory displays) can support the decision on how to handle a potential conflict, by facilitating the identification of conflict resolutions.

4.4 Tactical De-confliction

4.4.1 General Description

This goal is associated with the detection and resolution of conflicts within the near term (i.e., tactical) timeframe. Tactical de-confliction relates to detection and resolution of conflicts between aircraft already under the control of the TC.

4.4.2 Planning Controller Goals

Figure 5 shows the context and overall structure for the goal 'Tactical De-confliction' for the PC.

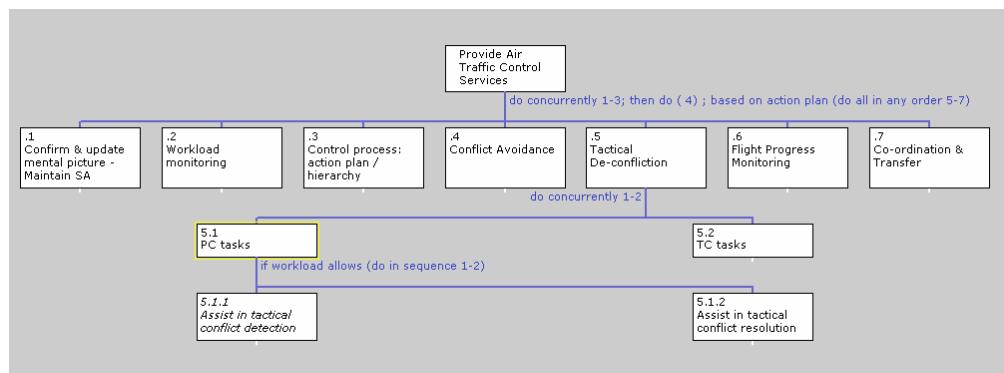


Figure 12 - Overview of the Context for the PC Goal 'Tactical De-confliction'

As can be seen in Figure 12, it is assumed in the CTA that the PC has a supporting role only for Tactical de-confliction. Depending on local airspace and traffic characteristics, though, there may be exceptions from this assumption.

4.4.2.1 Assist in Tactical Conflict Detection

The first goal for the PC to be considered is that of assisting with tactical conflict detection. The CTA for this goal can be seen in Figure 13.

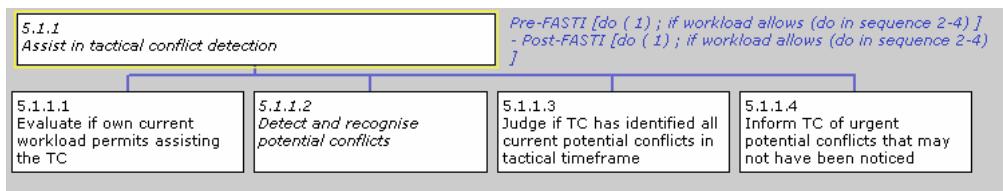


Figure 13 - Assist the TC with Tactical De-confliction

It should be noted that the successful performance of this goal is probably dependent on the result of task 5.1.2.1 (evaluate own current workload). The PC will focus on the planning timeframe and assist in the tactical timeframe when workload allows. This decision is not different from the current situation.

The cognitive walkthroughs did reveal some strategic elements as to the performance of this task. Participants taking the PC role in the walkthroughs

would describe situations where the assistance to tactical conflict detection would be seen as a 'secondary task' and only performed where possible.

Generally speaking, though, the detection of conflicts in the tactical time frame is supported by MTCD information in a similar way to conflict detection in the planning time frame. The separation prediction display enables the PC to display conflicts in the tactical time frame; other MTCD HMI elements such as a/c trajectories aid the understanding of the conflict geometry and location.

Furthermore, the MTCD conflict display supports the PC in evaluating his/her own workload as well as the workload of the TC when making the decision of whether support to tactical de-confliction is possible and needed. The number of conflicts displayed provides an indication of traffic complexity in the sector. The effect of MTCD on workload monitoring is also reflected in changes to the high-level goal "workload monitoring" (as displayed in Annex 8.6).

4.4.2.2

Assist in Tactical Conflict Resolution

Figure 14 contains the CTA for the PC goal of assisting the TC with tactical conflict resolution.

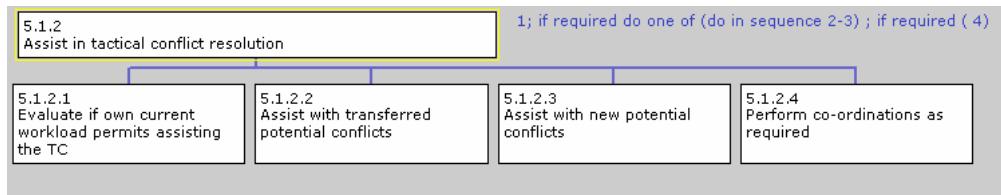


Figure 14 - Assist the TC with Tactical Conflict Resolution

As can be seen, there are no notable task changes or new tasks associated with FASTI for 'assist in tactical conflict resolution'. Minor changes may arise as a consequence of improved information for conflict analysis (e.g. vertical aid window, conflict display in aircraft trajectories) that can facilitate identification of a conflict resolution. Furthermore, the MTCD conflict display can facilitate the decision of whether workload permits to assist the TC.

4.4.3

Tactical Controller Goals

The sub-goals of the TC for Tactical De-confliction can be seen in Figure 15:

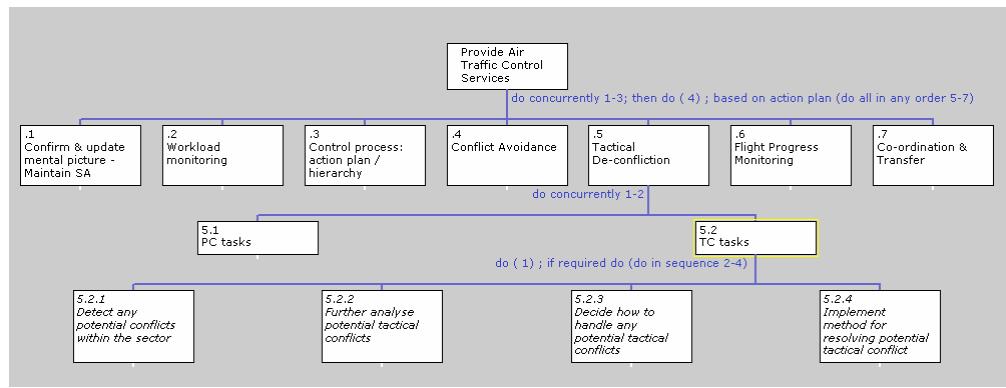


Figure 15 - Context for the TC Goal 'Tactical De-confliction'

Sub-goals 5.2.1 – 5.2.4 show the impact of FASTI tools on this set of tasks. All of the sub-goals of the TC associated with tactical de-confliction are affected by the implementation of FASTI tools.

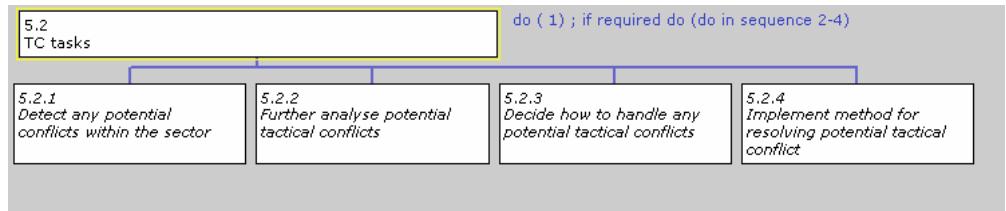


Figure 16 - TC Conflict Detection and Resolution Cycle

Participants at the data collection session stated that the basic process of detecting and resolving conflicts is similar to that used by the PC. Therefore, the basic process of detecting and resolving conflicts in the sector, as illustrated in Figure 16, is similar to that previously described for the PC.

4.4.3.1

Detect any Potential Conflicts in the Sector

Decomposing Figure 16 further, for the sub-goal 'detect any potential conflicts within the sector', the TC has one additional source of information (the separation prediction display) to consider. During the data collection, it became apparent that the TC would use the separation prediction display to recall and prioritise potential conflicts, rather than using the display as the only source for conflict detection. In this way, the display of potential conflicts can be used by the TC to reduce the requirement to hold in memory identified potential conflicts.

In common with the PC tasks, it was found that the flight legs with MTCD information and the VAW provide good means of supporting conflict detection and analysis through the PVD (see Figure 17).

The 'red dot' visual assistance (i.e., an indication of an MTCD predicted conflict in the aircraft label) was also described as supporting the allocation of visual attention during the task sequence.

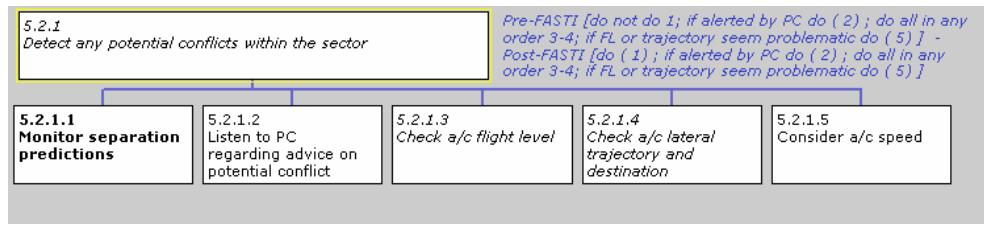


Figure 17 - TC Conflict Detection

Figure 17 shows the conflict detection routine for the TC. ‘Monitor separation prediction display’ is a new task for the TC, which will supplement the ‘conventional’ conflict detection (on the basis of monitoring aircraft FL, trajectory, and aircraft speed). As can be seen from this figure, the availability of FASTI tools changes most goals associated with conflict detection in the sector.

A totally new task is that associated with ‘monitoring of separation predictions’ (Figure 18):

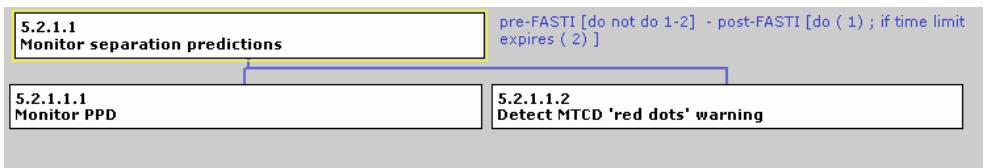


Figure 18 - Monitor Separation Predictions

The display of MTCD predicted conflicts in the aircraft labels (i.e. ‘red dots’ in the FASTI demonstrator) at a certain time-to-conflict introduces a means of recovery in cases where the TC may have mis-judged the time available to solve the conflict.

The sub-goal “Check a/c flight level” changes due to the availability of a ‘vertical conflict display’ (VAW) as can be seen in Figure 19:

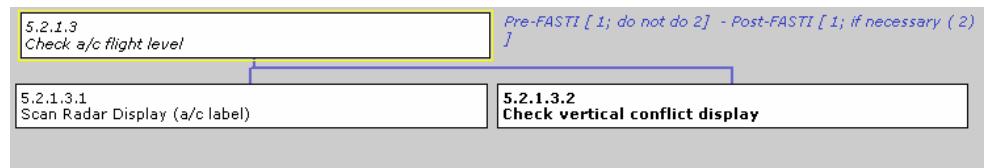


Figure 19 - Check Flight Level

Figure 20 shows the differences (pre and post FASTI) for the sub-goal ‘check aircraft lateral trajectory and destination’.

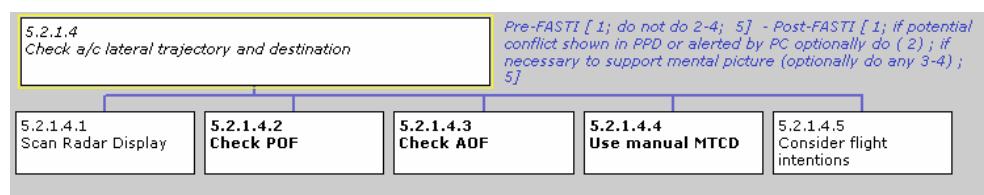


Figure 20 - Check lateral trajectory and destination

4.4.3.2

Further Analyse any Potential Tactical Conflicts

Figure 21 presents the CTA for the TC sub-goals associated with ‘further analysing potential tactical conflicts’.

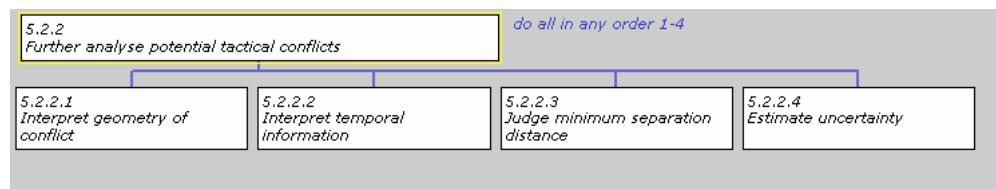


Figure 21 - Further analyse potential tactical conflicts

FASTI alters all of the tasks associated with this sub-goal. For example, information concerning the geometry of the potential conflict and the minimum separation distance can now be inspected using the problem flight leg and the vertical conflict display (VAW). The Separation Prediction Display (PPD) also provides information concerning the point of minimum time and distance.

The estimation of uncertainty is changed by the information provided by the tools, and also the beliefs, knowledge and experience that the TC has concerning the performance of the TP system functionality.

4.4.3.3

Decide how to Handle any Potential Tactical Conflicts

The next step in the CTA concerns the TC sub-goal of ‘deciding how to handle any potential tactical conflicts’ (Figure 22).

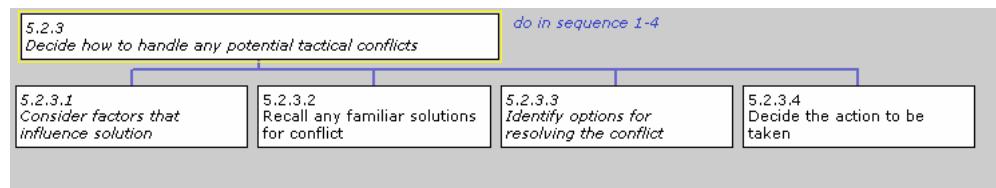


Figure 22 - Decide how to handle any potential tactical conflicts

The sub-goals that change in Figure 22 (‘Consider factors that influence solution’) are described in more detail below (see Figure 23):

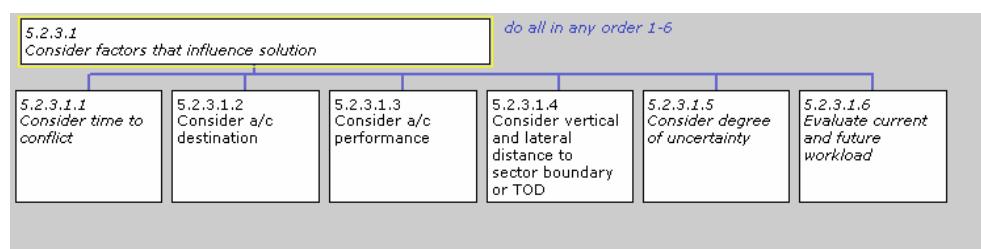


Figure 23 - Consider factors that influence solution

The TC is supported in the identification of options to resolve the conflict by the vertical aid window. The vertical aid window is used to identify FLs that may be available to solve the potential conflict.

4.4.3.4 **Implement Method for Resolving Potential Tactical Conflict**

The next step in the tactical de-confliction goal sequence is associated with implementing the method for resolving the conflict (Figure 24).

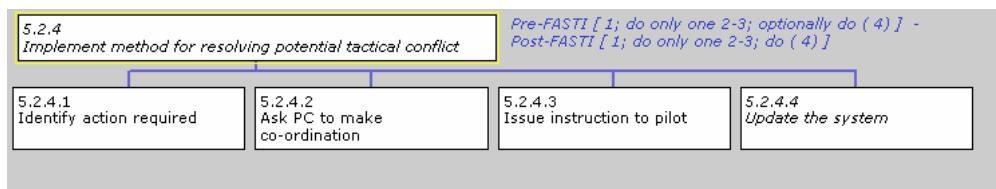


Figure 24 - Implement Method for Resolving the Conflict

The sub-goal 'Update the System' is a significantly changed in the post-EATM FASTI situation. Updating the system with the issued clearances becomes an important task post-FASTI, because the TP and hence, MTCD, relies on this information. Failure to update the system is likely to result in MONA warnings, MTCD nuisance alerts or missed conflict situations. For this reason, controllers need to understand the importance of updating the system.

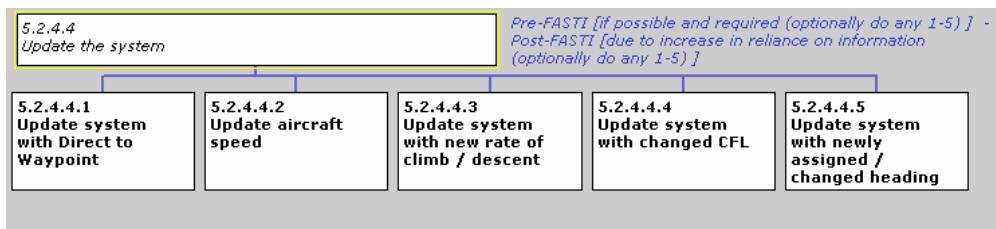


Figure 25 - Update the system

The human error analysis found that this goal may be especially susceptible to post-completion errors (PCEs). PCEs are a type of error where tasks occurring after the completion of the major goal (in this case, issuing a clearance to an aircraft) are not performed. The propensity for this type of error may change if the value of updating the system is incorrectly understood by controllers, or if the task is shed under periods of high workload.

PCEs can be mitigated through active control strategies, and coupling of the primary goal with the supporting goal (maxims such as 'click/type as you speak' are a good example of strategies used to counter this type of error). Once the issuing of an instruction is sufficiently coupled with the data entry (i.e., the controller 'automatically' enters a clearance while issuing it), the probability of an error should be fairly low.

4.4.4 **Issues and Benefits**

The following list presents the issues and benefits associated with the CTA of FASTI Tactical De-confliction sub-goals. It should be noted that some of these issues and benefits also apply to Conflict Avoidance. In these cases, the numbering of the relevant issues and benefits is the same.

4.4.4.1 *Issues*

- I2 Controllers need to understand the basic algorithms behind MTCD so that they are able to assess whether an MTCD predicted conflict is likely to occur in the future. This includes the use of TP for conflict detection, assumptions made in TP, and the use of uncertainty.
- I6 Updates to the system are very important from a system perspective, but may be seen as secondary tasks by controllers in times of high workload.

4.4.4.2 *Benefits*

- B1 The graphical presentation of MTCD information in a conflict display and on flight legs reduces the information processing and working memory demands associated with mental projection of future a/c positions. However, this change is less prominent for tactical conflict detection than for conflict detection in a planning timeframe (the reason being that the TC will still continue to scan the PVD to identify conflicts).
- B2 The different trajectory displays, due to their spatial and graphical representation of the conflict, aid controllers' understanding of the location and nature of the conflict.
- B3 The separation prediction display (PPD) reduces the requirement for the controller to remember conflicts and conflict details (such as severity of conflict and the context a/c) after detection.
- B5 Certain types of conflicts (occurring after turns or with complex geometry) should be detected earlier and relatively more accurately by MTCD than human mental projection. This, however, presupposes an adequate performance of the TP.
- B6 Some MTCD HMI elements (e.g. VAW, what-if probe, trajectory displays) can support conflict resolution and responding to pilot requests.
- B7 The display of MTCD predicted conflicts in the aircraft labels (i.e. 'red dots') at a certain time-to-conflict introduces a means of recovery in cases where the TC may have mis-judged the time available to solve the conflict.
- B8 The MTCD separation prediction display supports the PC in evaluating his/her own workload as well as the TC's workload when deciding whether or not assistance in solving tactical conflicts is required.

4.5 Flight Progress Monitoring

4.5.1 General Description

The purpose of the Flight Progress Monitoring function is to ensure that an aircraft's passage through a sector is orderly, and in accordance with ATC clearances.

For the purpose of this CTA, a distinction is made between *conformance monitoring* (monitoring whether the flight adheres to the cleared trajectory) and *progress monitoring* (monitoring the flight progress against actions required for efficient flight handling). Whereas MONA warnings (e.g. Lat Dev, FL Dev, FL Bust) are related to conformance monitoring tasks, MONA reminders (e.g. transfer, turn, TOD) are linked to progress monitoring tasks. This distinction is described further in the following sections.

Within FASTI, conformance of the actual trajectory with the system trajectory is crucial for an accurate performance of the TP and, hence, the MTCD. It is the function of MONA to provide automatic conformance monitoring between the system trajectory and the actual aircraft behaviour) and to trigger trajectory re-calculation in case the aircraft gets out of conformance.

4.5.2 Planning Controller Goals

Figure 26 shows the context and overall structure for the goal 'Flight Progress Monitoring' for the PC.

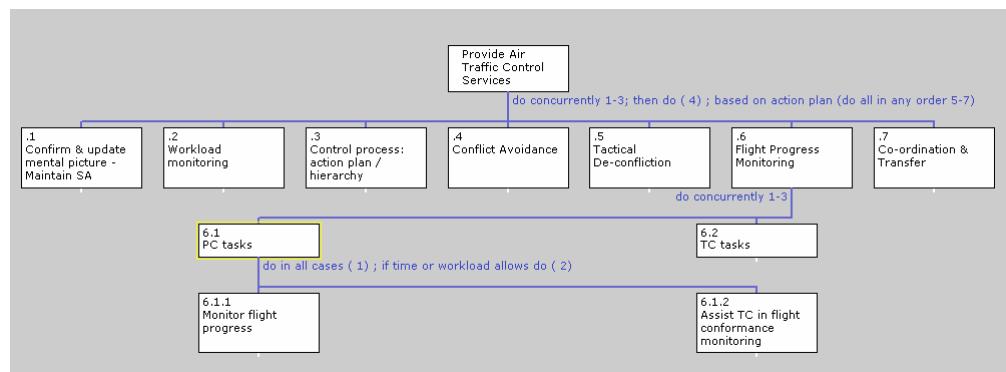


Figure 26 - Overview of the Context for the PC Goal 'Flight Progress Monitoring'

4.5.2.1 Monitor Flight Progress

The PCs sub-goals involve monitoring the progress of flights outside of the sector of responsibility, and assisting the TC with monitoring flight progress within the sector of responsibility. This task sequence can be seen in Figure 27:

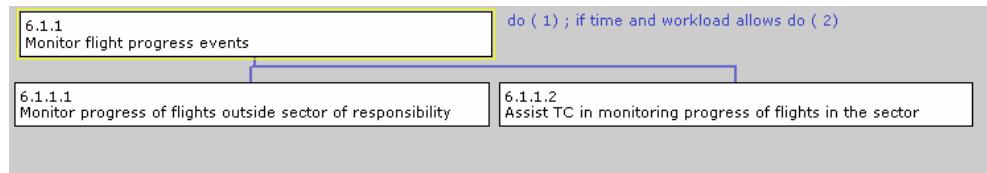


Figure 27 - Monitor progress of flights

FASTI was not found to alter the sub-goal 'Monitor progress of flights outside sector of responsibility', or any of the associated subtasks. MONA warnings are only available for aircraft under control.

Figure 28 shows the PC sub-goals associated with 'assisting the TC in monitoring the progress of flights within the sector'.

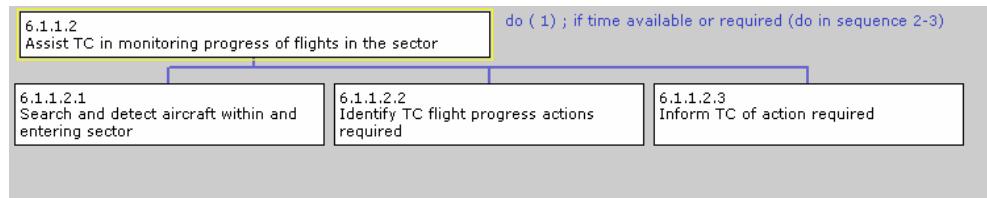


Figure 28 - Assist TC in monitoring progress of flights in the sector

FASTI is likely to change the PC's strategy for this task. If the PC monitors the PVD to a lesser extent (due to the availability of the separation prediction window), then they are less likely to support the TC in monitoring the progress of flights in the sector.

If the PC does support the TC in monitoring flights within the sector, there is a qualitative change in the task: The PC is supported in the same way by MONA alerts as the TC (see Figure 29).

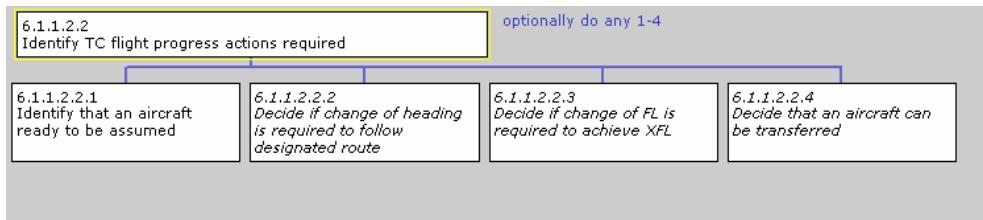


Figure 29 - Identify TC flight progress actions required

MONA also supports the PC in the identification of the actions that the TC needs to perform at a current point in time (e.g. transfer an a/c, turn aircraft back on planned route after HDG, issue descend clearance at TOD). This can be seen in Figure 29.

4.5.2.2 **Assist TC in Monitoring A/C Conformance with Clearance**

Figure 30 shows the sub-goals associated with the PC tasks of assisting the TC to monitor conformance with clearances:

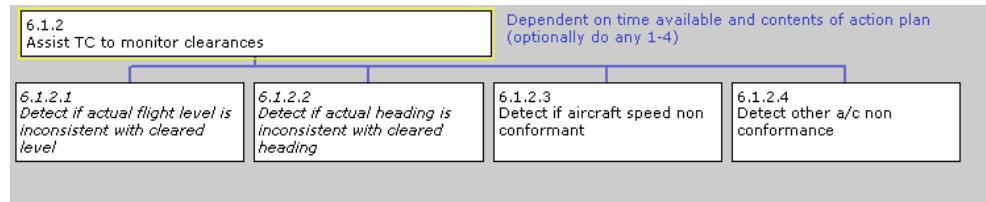


Figure 30 - Assist TC to monitor a/c conformance with clearances

With the FASTI tools, in particular, the separation prediction display, the PC is likely to spend less time scanning traffic on the PVD². For this reason, FASTI can be assumed to weaken the support function of the PC. If, however, the PC does assist the TC in flight conformance monitoring, he is supported by MONA warnings. MONA warnings (Lat Dev, FL Dev, FL Bust) are presented to both the PC and TC on the PVD.

The sub-goals from Figure 30 are further described below, in the context of the TC performing the tasks.

4.5.3 Tactical Controller Goals

The TC has the main responsibility for Flight Progress Monitoring (see Figure 31):

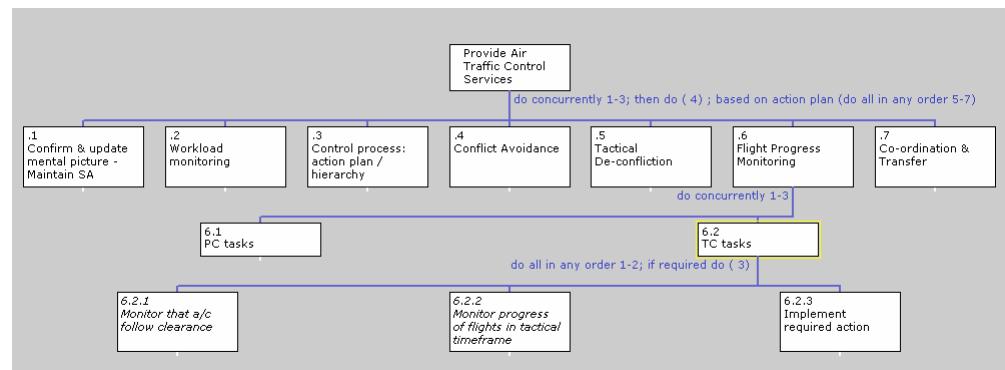


Figure 31 - Context for the TC Goal 'Flight Progress Monitoring'

In this CTA, the TC Flight Progress Monitoring goal has the following sub-goals: Monitor that aircraft follow clearance, monitor progress of flights in the tactical timeframe, and implement required action. These are described in detail below.

4.5.3.1 **Monitor that aircraft follows clearance (conformance monitoring)**

The TC sub-goal of 'monitor that aircraft follow clearance' is shown in Figure 32:

² The comparison refers solely to an environment in which no FASTI tools are available. All other aspects of the working environment, such as paper flight strips or the lack of a second radar screen for the PC (which can also influence the likelihood of the PC's scanning the screen) are beyond the present analysis.

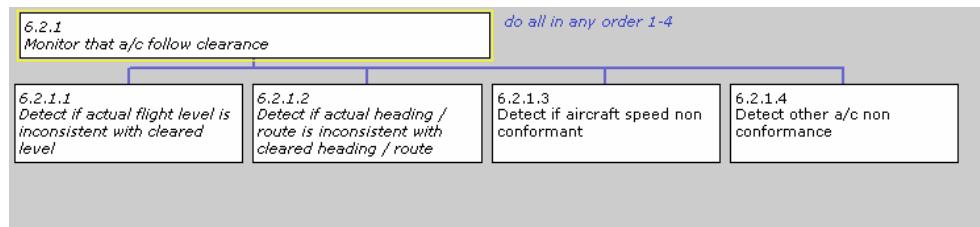


Figure 32 - Monitor that aircraft follows clearance

FASTI changes the sub-goals associated with monitoring the actual FL and heading / route against the clearance. Monitoring of aircraft speed or other aspects of conformance with a clearance (e.g., vertical rates) are not changed by FASTI.

FL deviation warnings, FL DEV and FL BUST (Figure 33), change the tasks associated with FL deviation monitoring.

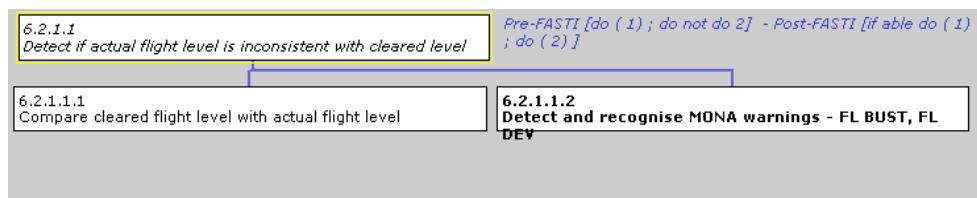


Figure 33 - Detect if actual flight level inconsistent with cleared level

FL deviations are difficult to detect pre-FASTI. These parameters are often only monitored after issuing an instruction. The cognitive walkthroughs also revealed that some time has to elapse in order to detect FL deviations, and this may have implications for working memory storage (i.e., remembering which aircraft to monitor when). Controllers did report a strategy where, in the pre-FASTI situation, detection processes would focus on finding conflicts rather than trajectory non-conformances. Trajectory non-conformances would be monitored in the period following the issuing of the instruction, as a general strategy. However, the specifics of this strategy depend on the particular flight and airspace characteristics.

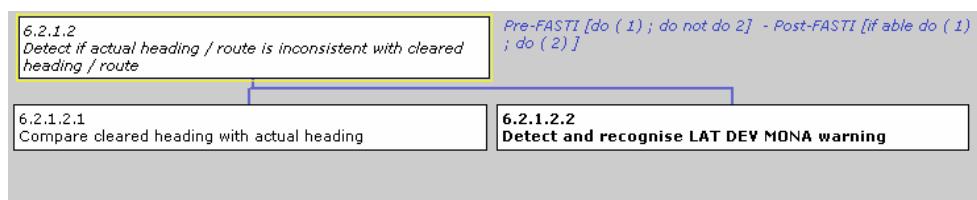


Figure 34 - Detect heading deviations

Figure 34 presents the task analysis for the sub-goal 'detect heading or route deviations'.

The MONA warnings relieve the controllers from visually searching for a flight parameter or position and identifying a possible mismatch with the clearance. In order to do so, the actual clearance will have to be recalled from memory by the TC, or visually located and read from the HMI or the paper strips.

In some cases, visual detection of deviations can be demanding and time-consuming, for instance, in case of judging whether there is a lateral deviation.

It should be noted that MONA does not include alerts for rate of climb or descent deviations. The FASTI demonstrator allows for an entering of Rate of Climb (ROC) or Rate of Descent (ROD) which mimics the working method for paper flight strips (where controllers would note issued ROC/ROD). Thus, the sub-goal of monitoring for conformance with the issued ROC/ROD is not changed by FASTI.

The data collected to support this CTA suggests that the TC will rely on MONA warnings for conformance monitoring in most cases. There are conditions, though, under which the TC should still monitor conformance conventionally. For example, if a clearance is issued to prevent a loss of separation, the controller needs to identify as soon as possible whether the pilots manoeuvre in the instructed direction. There is some evidence to suggest that controllers would generally monitor conformance after issuing an instruction to the aircraft. Further, the detection of some deviation (such as deviations from vertical rates) is not supported by MONA.

In order to be able to rely on MONA warnings, MONA should be consistent and bring - within its specification - all deviations to the attention of the TC. This can only be achieved with up-to-date flight information, and this in turn increases the reliance on the TC to enter correct and timely system updates (see Section 4.5.3.3 for a discussion of this issue). Furthermore, the TC needs to have an understanding in which situations he can rely on MONA for conformance monitoring, and in which situation conventional monitoring is still required.

4.5.3.2

Monitor progress of flights in tactical timeframe (progress monitoring)

The overall structure of the sub-goals associated with 'monitor progress of flights in tactical timeframe' can be seen in Figure 35:

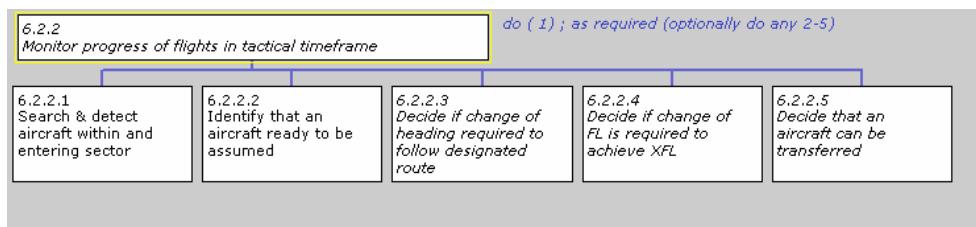


Figure 35 - Monitor progress of flights in tactical timeframe

Sub-goals significantly altered by FASTI are shown in italic lettering.

Figure 36 shows that no MONA functionality changes the tasks associated with 'identify that an aircraft is ready to be assumed'. The cues and tasks that the TC will have to perform are the same across the post-FASTI and pre-FASTI situations.

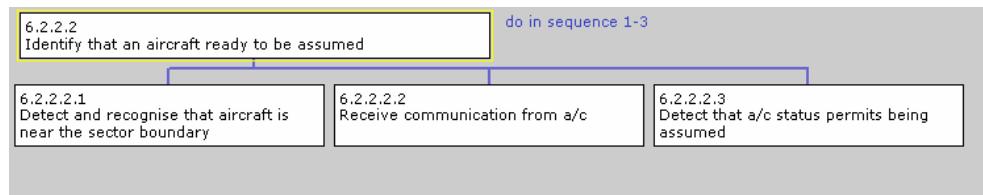


Figure 36 - Identify that an aircraft ready to be assumed

However, it is understood that future FASTI functionality may incorporate features to support these tasks.

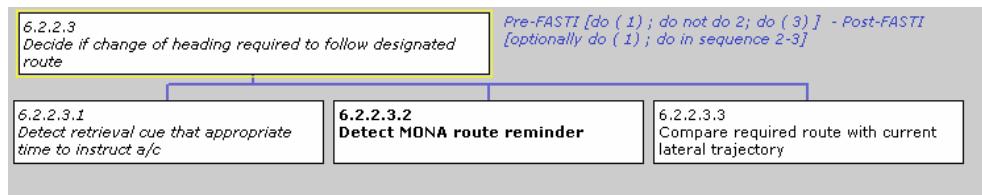


Figure 37 - Decide if change of heading required to follow designated route

With respect to the task 'decide if an aircraft needs to be turned back after an HDG instruction, MONA provides a route reminder function (Figure 37). There was evidence from the data collection sessions that the route reminder would be relied on to remember that the aircraft has to be turned at a certain point to follow the planned trajectory. As the route reminder reflects the TP assumptions on the lat/lon trajectory of the aircraft, the accuracy of the MTCD depends on whether the aircraft is turned back at a certain point.

Monitoring progress of a flight in relation to achieving its exit conditions (e.g. XFL) is shown in Figure 38:

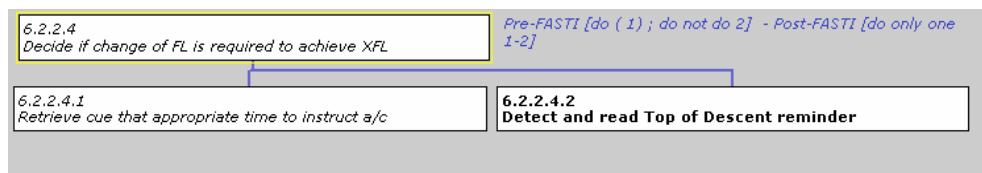


Figure 38 - Decide if change of FL required to achieve XFL

As can be seen, MONA provides a new source of information in the post-FASTI situation: a 'Top of Descent' (TOD) reminder. This reminder provides an indication to the controller that a descent clearance is required in order to ensure that the aircraft reaches the planned XFL.

However, the data collection did reveal some issues with the timing of this reminder. Participants tended to comment that the TOD reminder in the FASTI demonstrator often occurs later than when the controller would actually wish to provide the descend instruction to the aircraft.

Figure 39 presents the task analysis for the decision that an aircraft can be transferred:

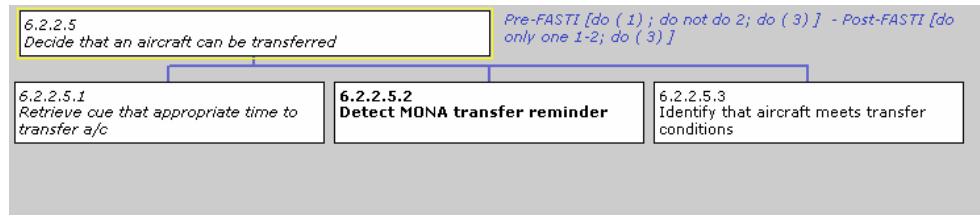


Figure 39 - Decide that an aircraft can be transferred

Figure 39 shows that FASTI introduces a MONA ‘transfer reminder’. This changes the need to rely on the memory in the post-FASTI situation. The extent, to which memory is supported, though, depends on the timing of reminders.

In summary, it appears that the timing of reminders (with respect to the optimal time to action implementation) is crucial in determining which strategy to adopt: A re-active strategy, in which the controller uses a reminder as trigger for an action, should only be adopted if reminders are issued before the optimal time for action implementation. If this strategy is used, MONA reminders support the identification of the *need* to perform an action, such as issuing an instruction to meet exit conditions or to hand-over an aircraft. In this way, MONA reminders support prospective memory (McDaniel & Einstein, 2000).

If MONA reminders are issued after the optimal time for action implementation, the controller should adopt a pro-active strategy – identifying the need for taking an action and performing it before the MONA reminder is issued. If the proactive strategy is taken, MONA reminders do not support prospective memory any longer. Rather, they become a source of recovery if the TC forgets to carry out the required action in time.

4.5.3.3 *Implement required action*

The required action depends on whether it is a result of conformance monitoring or progress monitoring. If the action is a result of a deviation between the cleared and the actual flight path, then the TC will contact the aircraft and reinforce the original clearance (or potentially issue an adapted clearance to achieve the original aim). If the action results from progress monitoring tasks, then the TC needs to contact the aircraft for a frequency change, a lateral or a vertical instruction.

The tactical tasks associated with ‘implementing the required action’ are changed by FASTI in a subtle way. In the post-FASTI situation, tasks associated with updating the system become important in order to ensure TP accuracy.

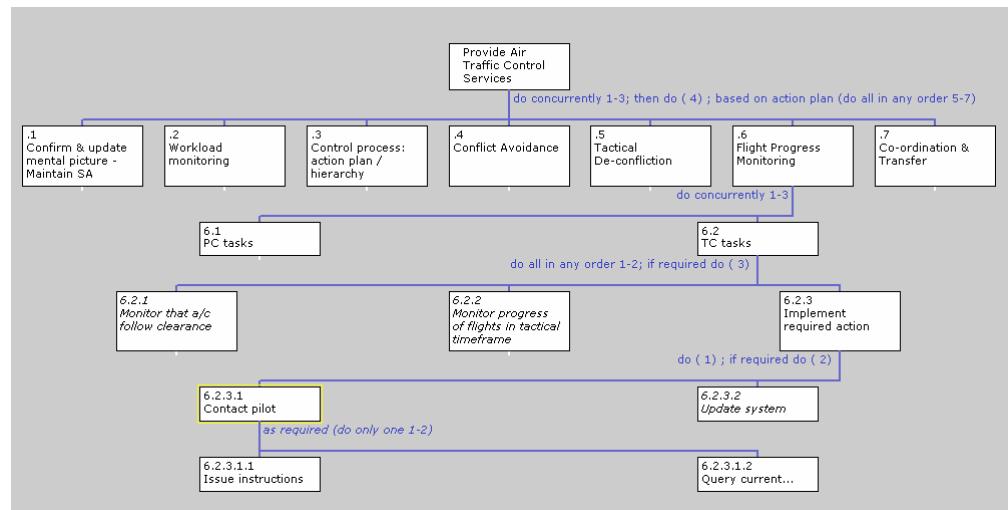


Figure 40 - Implement required action

In the case of the FASTI concept, some of these changes are discussed in more detail below in relation to SYSCO.

4.5.4 Issues and Benefits

4.5.4.1 Issues

- I7 If the TC relies on MONA warnings for ensuring pilot conformance with an ATC instruction, it is essential for MONA to detect all deviations in a timely way. There are situations in which MONA may not achieve this – either due to its specification or due to a failure to enter a clearance.
- I8 The TC may start to use MONA reminders as a trigger for actions to be carried out. Depending on the timing of reminders, actions should be preferably taken before the reminder. The reactive strategy to flight handling is in this situation undesirable.
- I9 With the separation prediction display, the PC is likely to spend less time scanning traffic on the PVD. For this reason, FASTI can be assumed to weaken the support function of the PC as compared to a pre-FASTI situation.

4.5.4.2 Benefits

- B9 MONA warnings support the TC in detecting aircraft deviations from a clearance. Pre-FASTI, this task involves: holding the cleared flight parameter in working memory, visually searching for the actual flight parameter, and comparing cleared and actual flight parameter. Post-FASTI, the task requires identification of MONA warnings, which poses less demands on memory and information processing.
- B10 MONA reminders help the TC to remember actions that need to be carried out to ensure a smooth flight progress. When reminders are issued before the optimal time for action implementation, they substantially reduce demand on prospective memory.

- B11 When reminders are issued after the optimal time for action implementation, MONA reminders can help the TC to recover from a failure to carry out an action in time.
- B12 MONA warnings and reminders have an indirect benefit for the PC. There is a reduced need for the PC to assist the TC in Flight Progress Monitoring within the sector.

4.6 Co-ordination & Transfer

4.6.1 General Description

Co-ordination and transfer refers to the process of obtaining agreement on the 'boundary conditions' for the transfer of control associated with an aircraft, and executing that transfer of control.

Many standard co-ordination processes are carried out automatically by the technical systems and do not require any controller involvement. This refers, in particular, to OLDI messages such as ABI, ACT, REV, MAC, for civil/mil BFD and CFD. The availability of these messages is assumed to be part of the pre-FASTI situation (i.e., the baseline). Thus, the following analysis is restricted to those types of co-ordination that are currently carried out by phone, for instance, change requests.

4.6.2 Planning Controller Goals

Figure 41 shows the context and overall structure for the goal 'Co-ordination & Transfer' for the PC. The PC is responsible for the 'co-ordination' part of the overall ATM system goal.

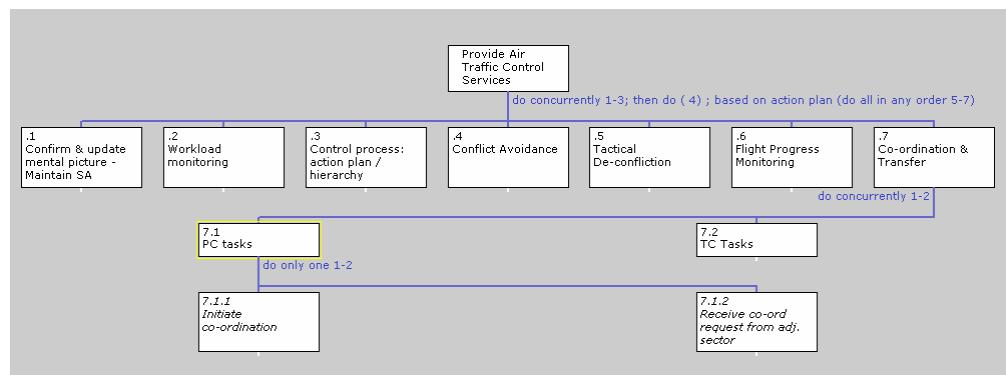


Figure 41 - Overview of the Context for the PC Goal 'Co-ordination & Transfer'

4.6.2.1 *Initiate co-ordination*

The sub-goal 'initiate co-ordination' for the PC is shown in Figure 42:

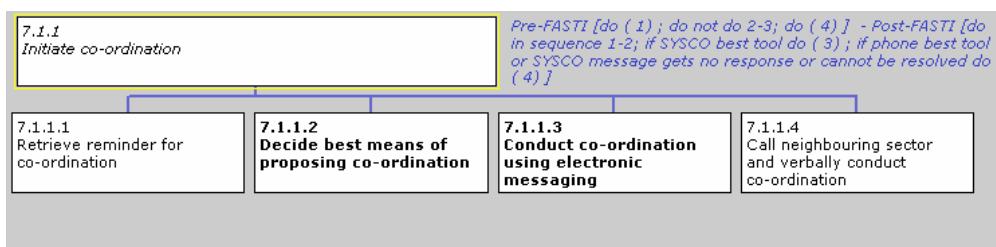


Figure 42 - Initiate co-ordination

The key tasks for the PC in relation to this goal under FASTI is to decide the best means of proposing a co-ordination (through SYSCO or via verbal communication) and to carry out this co-ordination. Note that the decision to co-ordinate has been made as part of the goal 'Conflict Avoidance'.

The participants at the data collection session indicated that SYSCO would not be used for complicated co-ordinations. The participants suggested that they would use it for routine co-ordinations such as FL changes and direct routings that are conflict-free. These are the reasons for the vast majority of co-ordination requests.

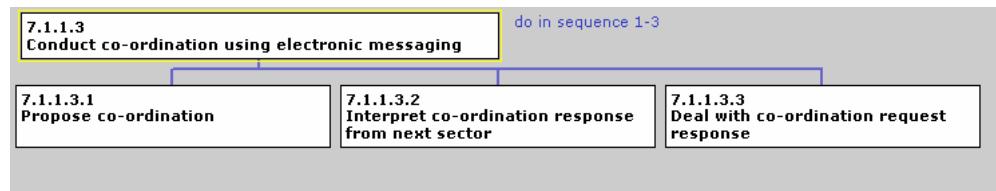


Figure 43 - Conduct co-ordination using electronic messaging

SYSCO would also be used if the controller was confident that the next sector would accept the co-ordination request. Verbal communication would be preferred for situations where a discussion is expected, or where multiple changes are necessary. It was also recognised that the phone is more attention-attracting for the receiving part of the co-ordination than a visually displayed message.

Cognitively, a major difference between phone co-ordination and SYSCO can be seen in the fact that phone co-ordinations are carried out sequentially, that is, one after the other. A phone co-ordination will usually yield an immediate response to the request (unless the other PC postpones the response by suggesting calling back). Only if one phone co-ordination is closed, the PC would initiate the next co-ordination. In contrast to this, SYSCO allows for parallel co-ordinations. This means that a number of co-ordination requests can be open at the same time, which has implications for the PC's working memory load. In this situation, the ability of the PC to keep track of the details of open co-ordination requests using SYSCO functionality (such as lists of open requests (MESSAGE OUT window)) will become important.

4.6.2.2

Receive co-ordination request from adjacent sector

Figure 44 and Figure 43 illustrate the sub-goals associated with receiving a co-ordination request from an adjacent sector:

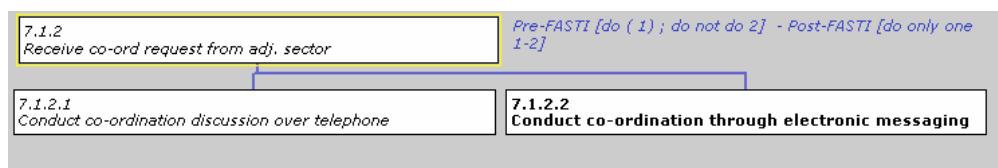


Figure 44 - Receive Co-ordination Request

Interacting with a flight (by changing the PEL or XFL for a flight, for example), will trigger a co-ordination request to the relevant sector. This reduces the

number of task steps associated with making a co-ordination request in comparison to a phone co-ordination.

Using SYSCO, the receiving PC does not have to respond to a request immediately, as they would if receiving a phone call. Potentially, this allows time to decide which co-ordination requests to deal with first and to decide when to answer a request.

Another benefit with respect to handling incoming co-ordination requests refers to the availability of MTCD HMI elements: On the basis of the vertical aid window or the what-if probe, the PC can decide more easily whether the request can be accepted.



Figure 45 - Manage Co-ordination Request

4.6.3 Tactical Controller Goals

The goals for the TC relate to receiving and handing off aircraft. The general structure is seen in Figure 46:

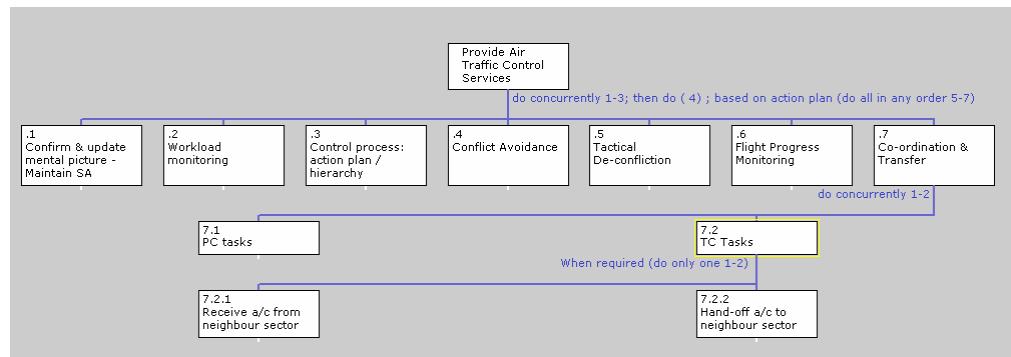


Figure 46 - Context for the TC Goal 'Co-ordination & Transfer'

4.6.3.1 Receive aircraft from neighbouring sector

As can be seen in Figure 47, the high-level sub-goals for 'receiving an aircraft from a neighbouring sector' are not altered by FASTI. Any HMI features that may facilitate this task in the FASTI demonstrator (e.g. colour coding of a/c labels) are considered as outside the scope of FASTI.

The analysis distinguishes between internal and external transfer of aircraft. The reason is that procedures may differ, for instance, with respect to the transfer conditions that need to be met. For FASTI, however, this distinction can be disregarded: FASTI support is the same regardless of whether an aircraft is received from / handed off to the same or a different center.

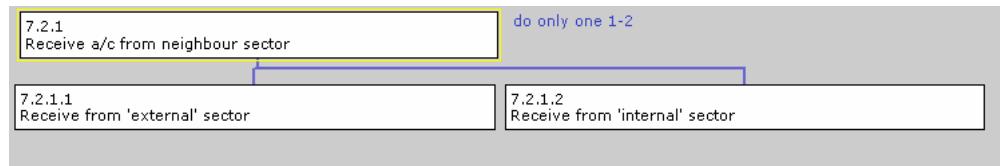


Figure 47 - Receive aircraft from neighbouring sector

4.6.3.2

Hand-off aircraft to neighbouring sector

Figure 48 shows the top-level sub-goals for handing off an aircraft to a neighbouring sector. The transfer of aircraft to the next sector is facilitated by the MONA transfer reminder.

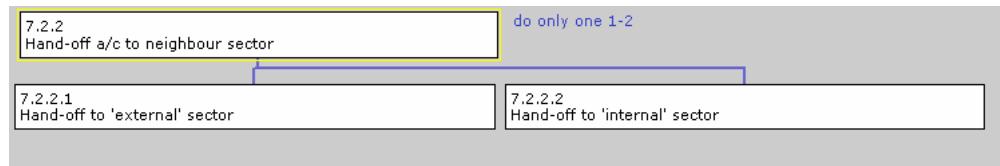


Figure 48 - Hand-off aircraft to neighbouring sector

4.6.4

Issues and Benefits

4.6.4.1

Issues

- I10 Co-ordination can involve more time and workload if the PC starts a co-ordination using SYSCO and then has to move to the phone.
- I11 For PCs initiating co-ordinations, there is a possibility of several requests being open at the same time. This adds to working memory load.
- I12 SYSCO change requests may not be answered in time. This may make the request redundant or delay other PC actions.

4.6.4.2

Benefits

- B13 SYSCO allows the PC to choose the order in which requests are dealt with, and to work at their own pace rather than being disturbed by phone calls.
- B14 Proposing simple change requests is more efficient (in terms of task steps) using SYSCO functionality than using phone.
- B15 Some MTCD elements (such as the vertical aid window or the what-if tool) support the PC in deciding whether an incoming co-ordination request can be accepted.

5. COGNITIVE TASK ANALYSIS: VARIANT STAFFING OPTIONS

5.1 Introduction

This chapter considers the potential role of the FASTI tools within different staffing options. Two staffing options were considered: Single Person Operation (SPO) and Multi-Sector Planner (MSP).

5.2 Single Person Operation

In SPO, one controller is responsible for planning and tactical ATC goals. It was not possible to collect sufficient data to understand the cognitive implications of the use of FASTI in Single Person Operation. Participants at the data collection session had not experienced this method of working with the FASTI tools and therefore did not feel comfortable conducting cognitive walkthroughs for this staffing option.

However, a tentative analysis of SPO (based on literature review) suggests that the controller will be supported by the FASTI tools in a similar way as in a PC/TC staffing option. Thus, the majority of findings (in terms of issues and benefits) identified for the PC/TC staffing option seem to apply to SPO as well.

In spite of this, the following differences between SPO and a PC/TC staffing option can be identified:

- Within the ‘Conflict Avoidance’ goal, the controller still has to make the decision whether to solve a conflict by planning means or tactically. When the decision is made to solve the conflict tactically, there is no transfer of the potential conflict to a different working position required.
- All sub-goals that refer to the PC’s assistance in primarily tactical tasks (i.e. tactical de-confliction and flight progress monitoring) become redundant in the SPO staffing option. Thus, there is no “second pair of eyes” supporting the TC in these tasks. As FASTI was identified to support tactical conflict detection and Flight Progress Monitoring, the benefits associated with these tasks should be particularly relevant for a controller in SPO.
- There is an issue of whether a controller in SPO is able to follow the suggested working methods (i.e., identification of planning conflict on the basis of MTCD information displays only, solving potential problems longer in advance) to the same extent as a controller who is only responsible for planning tasks.

As mentioned above, data are insufficient to carry out an exhaustive analysis on the impact of FASTI tools in SPO. For this reason, the above statements have to be interpreted with caution and should not be considered complete.

5.3 Multi-Sector Planner

5.3.1 Data collection

Data collection for information concerning the Multi-Sector Planner (MSP) staffing option in relation to FASTI-type tools included the following sources:

- Limited discussion using the FASTI demonstrator, during the sector team operations data collection
- Human factors literature review, including the results of relevant simulations
- Discussion with Deutsche Flugsicherung (DFS). This visit took the form of a round-table meeting where experiences and opinions relating to MTCD and use of a MSP were discussed. DFS experiences were based on a real-time simulation that was carried out in March 2006 in the DFS research simulator. The simulation used both a vertical and a lateral multi-sector area and investigated, among others, differences in working methods between a team consisting of PC and TC and a team of consisting of an MSP and two TCs (cf. Herr and Herber, 2006a, b).

5.3.2 Description of concept

The following assumptions are made with regard to the role of the MSP:

- The MSP role refers to the existing PC taking on responsibility for $n > 1$ sectors, rather than being a dedicated role that is used in addition to the TC&PC roles.
- The MSP may be a step towards complete trajectory-managed ATC, but only near-term (i.e., aspects supported directly by FASTI) changes were considered to be 'in-scope'.
- The MSP will focus on planning future traffic (i.e., aircraft in advanced state).
- The MSP should aim to de-complexity the whole traffic situation for the TC.
- The MSP will not be required to assist the TC in monitoring the progress of flights within the sector, or in the resolution of conflicts within the sector.
- The TC role is in accordance with the post-FASTI sector team operations staffing option.
- Any implementation of the MSP concept is likely to be associated with changes to airspace design, such as dynamic sectorisation and further standardisation of (direct) routes.

5.3.3 Major points of variation from Sector Team Operations

The following points can be made with regard to the differences between the use of FASTI tools in a PC/TC staffing option and in a staffing option involving an MSP for several TCs:

5.3.3.1 ***Conflict avoidance***

The cognitive process of the detection of future conflicts is unlikely to change qualitatively, just quantitatively. The MSP has more conflicts to detect in the separation predictions window when compared to a PC, owing to the larger area of responsibility.

5.3.3.2 ***Tactical De-confliction***

The MSP is not expected to, and (because of the large area of responsibility) not able to, assist the TC with detecting and resolving conflicts within a tactical time frame (i.e. involving aircraft under control of the TC). Thus, the MTCD is likely to play a more important part in supporting the TC in the detection of tactical conflicts than in a PC/TC staffing option.

From the TC perspective, fewer solutions to tactical conflicts are available, as the TC is unlikely to choose a solution that involves an effortful and complex interaction with the MSP.

With respect to the comparison between a baseline MSP concept (i.e., one that would not incorporate FASTI tools) and one using FASTI tools, the potential problem of losing a “second pair of eyes” is mitigated by the use of FASTI tools. In this sense FASTI may be an enabler of MSP in certain airspace and traffic situations.

5.3.3.3 ***Flight Progress Monitoring***

The MSP is not expected to and also not able to assist the TC with monitoring aircraft within the sector. Flight Progress Monitoring is a function supported by MONA, therefore, the lack of a “second pair of eyes”, which could be a problem in an MSP concept without FASTI, can be compensated for by MONA.

There is no change for the TC in the goal of Flight Progress Monitoring between a PC/TC staffing option and an MSP concept with FASTI. Therefore, all changes identified between a pre- and a post-FASTI situation apply to the MSP concept as well.

5.3.3.4 ***Co-ordination & Transfer***

The MSP has more co-ordinations to make compared to a PC³, but the amount is likely to be less than the combined co-ordinations for the separate sectors. Internal co-ordination between two sectors in the area of

³ Although this should analytically hold, the results from the simulation (which were analyzed only after the meeting with DFS) showed that the number of verbal co-ordinations did not substantially differ between a PC and an MSP (cf. Herr & Herber, 2006b).

responsibility becomes redundant.⁴ Furthermore, when implementing an MSP concept, routes are likely to be standardised further, which leaves less room for individual solutions (requiring extensive co-ordination). Strictly speaking, though, standardization of routes is not part of the MSP concept.

The nature of inter-sector co-ordinations does not change between a PC/TC staffing option and an MSP concept with FASTI. Therefore, all changes identified between a pre- and a post-FASTI situation refer to the MSP concept as well.

There is no change for the TC in assuming and transferring aircraft between a PC/TC staffing option and an MSP concept with FASTI. Therefore, all changes identified between a pre- and a post-FASTI situation refer to the MSP concept as well.

5.3.3.5 Workload Monitoring

The MSP cannot monitor the TC's workload to the same extent as a PC, assuming both work with FASTI. However, in case the MSP realises differences in TCs' workload, he can take actions to even out these differences.

The TC's own workload monitoring remains unchanged between a PC/TC staffing option and an MSP concept with FASTI. Therefore, all changes identified between a pre- and a post-FASTI situation refer to the MSP concept as well.

5.3.4

Specific Issues and Benefits in relation to FASTI

Some general issues and benefits were associated with the MSP concept, including:

- The MSP can identify solutions that are better for the overall system, based on his/her awareness of larger areas of airspace.
- The MSP can take into account the workload of both TCs when choosing a solution or transferring a conflict, thereby helping to even out the workload between the TCs of sectors in the MSP area.
- For the TC, the options for conflict resolution decreases, as the TC will be unlikely to choose resolutions that require extensive interaction/assistance with the MSP.

However, no unique FASTI-MSP issues were found. All uncovered issues had already been derived through the PC/TC CTA. The only difference concerns the issue of a PC not relying on MTCD information as the only basis for conflict detection. This issue is less relevant in an MSP concept: According to DFS' simulation results, the MSP is less likely to continue to scan the PVD for conflict detection than a PC.

⁴ Although this should analytically hold, the results from the simulation (which were analyzed only after the meeting with DFS) showed that the number of verbal co-ordinations did not substantially differ between a PC and an MSP (cf. Herr & Herber, 2006b).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Identified Benefits

Table 1 presents the human factors benefits associated with the FASTI toolset that have been identified on the basis of the CTA.

Table 1 - Summary of Benefits

Number	Goal	Tool	Benefit
B1	Conflict Avoidance, Tactical De-confliction	MTCD	The graphical presentation of MTCD information in a conflict display and on flight legs reduces the information processing and working memory demands associated with mental projection of future a/c positions. Conflict detection and analysis change from a task that is based on mental projection to a task that is based to a larger extent on visual perception.
B2	Conflict Avoidance, Tactical De-confliction	MTCD	The different trajectory displays, due to their spatial and graphical representation of the conflict, aid controllers understanding of the location, geometry and severity of the conflict.
B3	Conflict Avoidance, Tactical De-confliction	MTCD	The separation prediction display reduces the requirement for the controller to remember conflicts and conflict details (such as severity of the conflict and context a/c) after detection.
B4	Conflict Avoidance, Tactical De-confliction	MTCD	The tools allow for a less reactive approach to dealing with conflicts and a more effective time management. This results from the fact that MTCD facilitates the early detection of conflicts.
B5	Conflict Avoidance, Tactical De-confliction	MTCD	Certain types of conflicts (occurring after turns or with complex geometry) may be difficult to detect by (human) mental projection. In these cases, MTCD support to conflict detection is particularly valuable.
B6	Conflict Avoidance, Tactical De-confliction	MTCD	Some MTCD HMI elements (e.g. vertical display, what-if probe, trajectory displays) support the decision on how to handle a potential conflict, by facilitating the identification of conflict resolutions.
B7	Tactical De-confliction	MTCD	The display of MTCD predicted conflicts in the aircraft labels (i.e. 'red dots') at a certain time-to-conflict introduces a means of recovery in cases where the TC may have mis-judged the time available to solve the conflict.
B8	Tactical-de-confliction (sub-task 'Workload	MTCD	The MTCD conflict display supports the PC in evaluating his/her own workload as well as the workload of the TC. The number of conflicts displayed in the window provides an indication not only of traffic complexity in the sector.

Number	Goal	Tool	Benefit
	Monitoring")		
B9	Flight Progress Monitoring	MONA	MONA warnings support the TC in detecting aircraft deviations from a clearance. Pre-FASTI, this task involves: holding the cleared flight parameter in working memory, visually searching for the actual flight parameter, and comparing cleared and actual flight parameter.. Post-FASTI, the task requires the visual identification of MONA warnings, which poses less demands on memory and information processing.
B10	Flight Progress Monitoring	MONA	MONA reminders help the controller to remember actions that are required to ensure a smooth flight progress through the sector. When reminders are issued before the optimal time for action implementation, they substantially reduce demand on prospective memory (i.e., remembering future actions to be carried out).
B11	Flight Progress Monitoring	MONA	When MONA reminders are issued after the optimal time for action implementation, they can help the controller to recover from a failure to carry out an ATC action in time (such as transfer an aircraft or issue a descend clearance at TOD).
B12	Flight Progress Monitoring	MONA	In case tactical and planning functions are split, MONA warnings and reminders have an indirect benefit for the PC. There is a reduced need for the PC to assist the TC in Flight Progress Monitoring within the sector.
B13	Co-ordination and Transfer	SYSCO	SYSCO allows the controller to choose the order in which requests are dealt with, and to work at their own pace rather than being disturbed by phone calls.
B14	Co-ordination and Transfer	SYSCO	Proposing simple change requests is more efficient (in terms of task steps) using SYSCO functionality than using a phone.
B15	Co-ordination and Transfer	MTCD	Some MTCD HMI elements (such as vertical window or what-if probe) support the controller in assessing whether an incoming co-ordination request can be accepted.

6.2 Summary of Identified Issues and Recommendations

Table 2 presents the issues associated with the FASTI toolset that have been identified on the basis of the CTA. The table also gives recommendations on how to address the identified issues.

Table 2 - Summary of Issues and Recommendations

Number	Goal	Tool	Issue	Justification	Recommendation	Recommendation category	Priority
I1	Conflict Avoidance , Tactical De-confliction	MTCD	Imperfection in the automation does affect the monitoring strategy adopted by the controller. There is evidence to suggest that the controller will, under some conditions, scan for planning conflicts using the Plan View Display rather than obtain full assistance from the separation prediction display for	The data collection supported the known issue that the MTCD is very dependent on the accuracy and behaviour of the TP function. The strategy for the execution of conflict detection by the PC will depend on the experience that the PC has of	<ol style="list-style-type: none"> Conflict situations that are undetected by MTCD should be extremely rare. The proposed working method should take into account imperfections in the MTCD (TP) behaviour. 	System design, training, working method	High

Number	Goal	Tool	Issue	Justification	Recommendation	Recommendation category	Priority
			conflict detection.	the functioning and accuracy of MTCD, in particular the number of missed conflict situations.	3. A specific training goal should be to allow controllers to develop a 'calibration' of their own understanding and response to any imperfections in the MTCD (TP) behaviour.		
I2	Conflict Avoidance	MTCD	Controllers need to understand the basic algorithms behind MTCD so that they are able to assess whether an MTCD detected conflict is likely to occur in the future. This includes the use of TP for conflict detection, assumptions made in TP, and the use of uncertainty.	There is a new cognitive task "estimate uncertainty" in case of an MTCD predicted conflict. In order to make best use of the MTCD, the controller needs to have an understanding of which MTVD alerts are likely to be nuisance.	A specific training goal should be to allow controllers to develop an understanding of any imperfections in the MTCD (TP) behaviour. This requires a basic understanding of the algorithms underlying MTCD (TP).	Training	High
I3	Conflict Avoidance	MTCD	The data collection was inconclusive regarding the strategies that the PC would use to transfer a conflict to the TC and communicate their intention.	It was not possible to extract this information using the proposed data collection procedure.	This issue should be investigated further.	Issues for further investigation	Low
I4	Conflict Avoidance	MTCD	The FASTI demonstrator provides the possibility to highlight an MTCD predicted conflict. There is some evidence to suggest that this 'warning' function would be seldom used by the PC.	The 'warning' function was intended to replace 'strip cocking' in a paper strip environment. Nevertheless, in the context of a separation prediction display (in which potential conflicts are already visually displayed), the concept of 'marking' a conflict may be superfluous.	The purpose and utility of the concept of 'warnings' in the context of a separation prediction display is to be reviewed.	System design, HMI	Low

Number	Goal	Tool	Issue	Justification	Recommendation	Recommendation category	Priority
I5	Conflict Avoidance	MTCD	Workload and errors associated to losing the 'place' in an action sequence (i.e. omission or repetition of action steps) can increase if the PC adopts a strategy according to which he responds immediately to a displayed conflict.	Controllers should complete tasks at their own pace, rather than immediately responding to every interruption by the system (i.e., a new potential problem being displayed). Fortunately, evidence suggests that controllers only adopt this strategy with MTCD under high workload or poor TP performance.	Train controllers to develop appropriate work and time management strategies so that they can deal appropriately with the requirement to 'comply' with the system and to investigate or resolve predicted MTCD conflicts.	Training, working methods	High
I6	Tactical De-confliction, Co-ordination & Transfer	MTCD, MONA	Updates to the system are very important from a system perspective, but may be seen as secondary tasks by controllers in times of high workload.	There is evidence that secondary tasks may be shed under high workload (as a result of prioritization or because of post-completion errors). In the case of MTCD, this would mean that the automation is inaccurate at precisely the time that the controller needs its support. Updating the system may also affect the subjective experience of workload if it is viewed as a secondary task. This is may be relevant for subjective workload measurement in simulation (i.e., experienced workload may be driven by perception of these overhead tasks, rather than the inherent demands of the primary task).	<ol style="list-style-type: none"> 1. Make controllers aware of the dependencies between system updates and TP/MTCD/MONA performance. 2. The likelihood of a failure to update the system can be decreased through active control strategies, and coupling of the primary goal with the supporting goal (maxims such as 'speak as you type' are a good example of strategies used to counter this type of error). 3. Look for opportunities to automate system updates where sensible to do so. 	Training, HMI, system design	High
I7	Flight Progress Monitoring	MONA	If the controller relies on MONA warnings for ensuring pilot conformance with an ATC instruction, it is essential for MONA to detect all deviations in a timely way. There are situations in which MONA may not achieve this – either due to its specification or to a failure to enter a clearance.	A failure to detect in time that an aircraft does not conform to a clearance may compromise safety. Relying on MONA warnings may not be sufficient in some situations.	<ol style="list-style-type: none"> 1. Make controllers aware of the dependencies between system updates and MONA performance. 2. Develop and train controllers on a working method describing in which situations conventional monitoring is still required (e.g. ROC/ROD instructions, imminent loss of separation) 	Training, working method	High

Number	Goal	Tool	Issue	Justification	Recommendation	Recommendation category	Priority
I8	Flight Progress Monitoring	MONA	The controller may start to use MONA reminders as a trigger for actions to be carried out. Depending on the timing of reminders, the optimal time for action implementation may be before the reminder. A re-active strategy to flight handling is in this situation undesirable.	There is a potential for the controller to "get behind", if controller actions are driven by reminders, and the reminders occur later than the optimal time for action implementation.	1. The timing of MONA reminders need to be carefully chosen with respect to the time for an optimal action implementation. 2. The prescribed working method should reflect the timing of reminders. A strategy according to which reminders are used as triggers for an action (rather than as a means for recovery) can only be recommended if reminders are issued early enough.	HMI, system design, working method.	Medium
I9	Flight Progress Monitoring	MONA	In case planning and tactical functions are split, the PC may be less able to support the TC in Flight Progress Monitoring tasks with FASTI. This arises as a consequence of the PC not scanning the traffic in the sector to the same extent any more.	If MTCD is used as a planning tool, the PC is supposed to work primarily from the separation prediction display. Scanning of traffic on the PVD, especially of traffic within the sector, may not be a PC task any more. In this case, the PC does not provide a back-up function to Flight Progress Monitoring any more.	The issue is already addressed by the provision of automatic support to Flight Progress Monitoring (MONA). However, it needs to be ensured that MONA, in fact, adequately supports the controller in Flight Progress Monitoring tasks.	HMI, system design	Low
I10	Co-ordination & Transfer	SYSCO	Co-ordination can involve more time and workload if the PC starts a change request using SYSCO and then has to move to the phone.	The electronic medium is only suitable for certain forms of communication. The controllers had very strong strategies for deciding between voice and electronic co-ordination. However, there is a workload and time cost associated with any errors in this decision.	Train controllers to recognize this situation and how to deal with it.	Training	Low
I11	Co-ordination & Transfer	SYSCO	For PCs initiating co-ordination requests, there is a possibility of several requests being open at the same time. This adds to working memory load.	With SYSCO, there will be necessarily a delay before the response to a co-ordination request is received. Therefore, the PC is more likely to initiate another co-ordination request with SYSCO than by phone. Before a co-ordination is closed, though, the PC cannot "forget" it.	Support controller's recollection of open co-ordination through external memory aids, such as the FASTI SYSCO MESSAGE OUT window.	HMI, system design	Medium

Number	Goal	Tool	Issue	Justification	Recommendation	Recommendation category	Priority
I12	Co-ordination & Transfer	SYSCO	SYSCO change requests may not be answered in time. This may make the request redundant or delay other PC actions.	A co-ordination request is associated with a conflict solution and a plan for the wider airspace management. If the initiating PC cannot get an answer in sufficient time then they will chose a different strategy (calling the PC, for example).	Time-out parameters for co-ordination requests should be set so that a balance is found between: (a) requests are not open for an excessive time period, and (b) the receiving controller has a realistic chance to answer the request.	HMI, system design	Medium

APPENDIX A: COGNITIVE ARCHITECTURE

Human information processing involves a number of different processes, such as attention and decision making, and a number of cognitive resources, such as memory. Each of these processes and resources is limited in terms of its performance. For example, the number of pieces of information that a person can hold in their working memory is limited. Hence, all humans have a finite capability to process information as a result of these cognitive limitations.

A cognitive architecture is a model of the basic limits and functions of human information processing (Kieras and Meyer, 1998). It is a prerequisite for CTA because it provides the 'background' against which information processing concerns can be captured.

The cognitive architecture that was used is shown in Figure 49. This cognitive architecture consists of the following cognitive processes / components:

- Attention (a processing resource that can be directed to visual, auditory, spatial, symbolic, spatial-symbolic, manual and verbal processing)
- Detection (a sensory store)
- Perception (a processor)
- Cognition & decision making (a processor)
- Memory (a store)
- Response Execution (a processor).

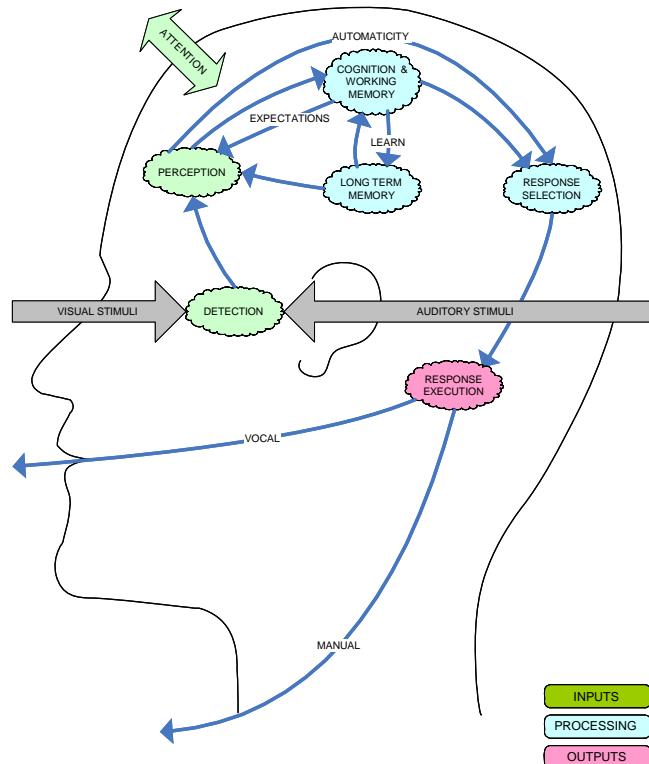


Figure 49 - Cognitive Architecture

The architecture is loosely based on the Model Human Processor and is compatible with the HERA-PREDICT method (EUROCONTROL, 2004).

APPENDIX B: THE ATM 'BARRIER' MODEL

In order to link the CTA to the wider systems and safety engineering activities, an ATM barrier model was used in the study. A barrier model is a means of ordering the various components of ATM service provision in order to illustrate how functional components form a series of 'barriers' protecting against accidents. The barrier model used by this study can be seen in Figure 50:

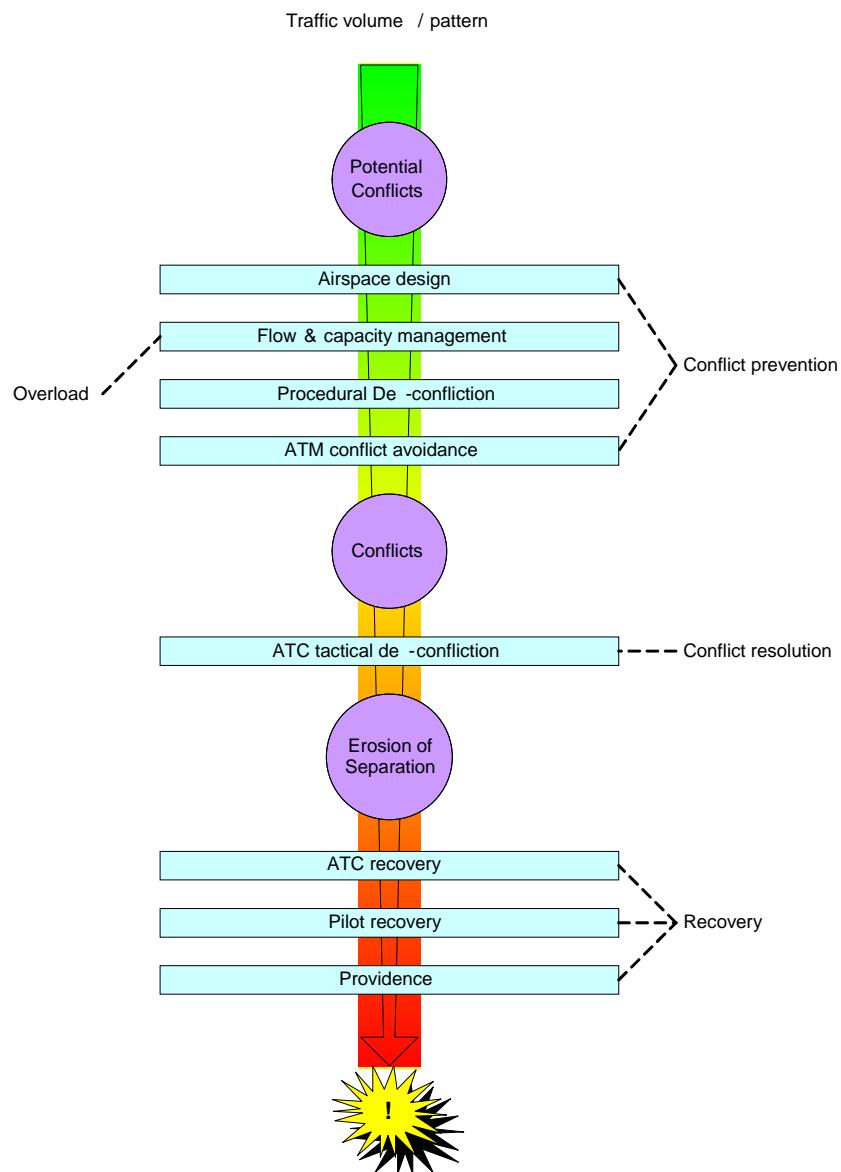


Figure 50 - An ATM Barrier Model

In the CTA, the functional elements (for example, conflict avoidance) were taken as the top level goals.

APPENDIX C: ASSUMPTIONS MADE IN THE CTA

Controller tools and working environment

Although the implementation of FASTI tools often coincides with the introduction of a (paper) stripless environment, changes in controller tasks that result from the replacement of paper strips are beyond the scope of this study.

It is assumed that controllers work with a predominantly graphical HMI (i.e., the HMI may have electronic flight strips but flight information can be displayed / recorded through the aircraft label on the PVD). The document 'EATMP Generic HMI Specification: Human Machine Interface Baseline' (Version 1.0, 2000) was used to represent the baseline system.

Table 3 - Mapping from ATM Barrier Model to Controller Tasks

Tasks	Barriers						Capabilities				
	Strategic Conflict Management	Separation Provision		Collision Avoidance							
		Airspace Design	Flow & Capacity Management	Procedural De-confliction	Conflict avoidance	Tactical De-Confliction	ATC Recovery	Pilot recovery	Providence	Flight Progress Monitoring	Co-ordination & Transfer
Search for planning conflicts					✓						
Solve planning conflicts					✓						
Initiate co-ordination											✓
Respond to co-ordination from adjacent sector											✓
Assist in tactical conflict detection						✓					
Assist in tactical conflict resolution						✓					
Assist in flight progress monitoring										✓	
Monitor TC's workload						✓					
Search for tactical conflicts						✓					
Solve tactical conflicts						✓					
Monitor flight progress										✓	
Transfer aircraft											✓
Descend aircraft to achieve exit flight level											✓
Change aircraft heading to follow designated route										✓	✓
Record instructions given					✓	✓				✓	✓
Confirm & update mental picture - Maintain SA					✓	✓				✓	✓
Monitor own workload					✓	✓					
Control process: action plan / hierarchy					✓	✓				✓	✓

Controller tasks and characteristics

In order to keep the data to a manageable amount, the CTAs focus on those tasks that are expected to be influenced by the introduction of the FASTI. This influence may task the form of changes to the task in terms of how it is performed, the duration/frequency of the task, or the importance of the task. Furthermore, FASTI can introduce new tasks. The scope of tasks to be considered is presented in Table 3.

The CTA is designed to reflect the way that controllers who are experienced using the FASTI tools will perform tasks. The CTA is based on the assumption that the user of the tools is also experienced at controlling the type of airspace under consideration.

Allocation of FASTI Related Tasks to Controller Roles

Table 4 (based on information from the FASTI HMI Handbook) shows the assumed basic responsibilities and division of tasks for Sector Team Operations (PC and TC).

Table 4 – Task Allocation for PC&TC Staffing Option

Planning Controller	Tactical Controller
<p><i>Executes the overall planning for flights entering, transiting and exiting the sector.</i></p> <p>Tasks include, but are not limited to:</p> <ul style="list-style-type: none">• Plan entry/exit levels and/or trajectories, to solve (or provides TC with a solution to) any detected potential conflict.• Execute input of any agreed modification to the trajectory of a flight not yet assumed by the TC.• Execute EFL and XFL inputs for all flights.• Delegate the solution of potential conflicts to the TC and propose a solution to such conflicts, as appropriate.• Assist the TC in detecting & solving tactical conflicts, and in reacting to MONA warnings.	<p><i>Executes the control of traffic within the sector.</i></p> <p>Tasks include, but are not limited to:</p> <ul style="list-style-type: none">• Assume flights about to enter the sector and transfer flights about to leave the sector.• Control all flights in the sector, and climb/descend flights to resolve conflicts and achieve planned exit levels.• Execute input of CFL and trajectory modifications for all assumed flights, as required.• Resolve potential conflicts in the sector.• Follow-up of any traffic in the sector, in particular with regard to any new potential conflicts or MONA warnings.

Traffic Density and Complexity

The CTAs represent controller tasks when the traffic density and complexity is medium to high. The CTAs do not reflect controller tasks in relation to systematic variations of density and complexity.

Airspace

FASTI generally aims to support the following types of airspace:

- Extended TMA (E-TMA): An en-route environment with more than 50% of traffic being in vertical evolution.
- Upper Airspace (FL 245 and above): An en-route environment with less than 50% vertical movement of the traffic.
- Lower Airspace (below FL245 and outside the TMA).

Ideally, the FASTI CTA would cover the controller's tasks within each of these airspace environments. However, the FASTI demonstrator is only capable of simulating an upper airspace environment, with around 70% level flights. It was therefore not possible to examine FASTI tools within an E-TMA or lower airspace environment.

System performance and behaviour

That MTCD is distinct from Trajectory Prediction (TP). MTCD is taken to refer to the data processing and HMI components that are based on a separate TP algorithm. It is assumed that the FASTI MTCD works in accordance with its specification. Therefore, detailed consideration of issues of system imperfection and controller trust is beyond the scope of this CTA.

However, where necessary to capture a potential human factors issue, it is assumed that cognitive strategies in response to imperfect automation will vary along dimensions of 'reliance' (defined as the strategies adopted by the controller when MTCD is not annunciating potential conflicts) and 'compliance' (defined as the strategy adopted by the controller when MTCD does annunciate a potential conflict) broadly in accordance with the framework for understanding offered by Meyer (2001).

APPENDIX D: COGNITIVE TASK ANALYSES FOR PC/TC STAFFING

The purpose of this section is to present the details of the cognitive task analysis for the PC/TC Staffing Option. Each sub-section follows the same format. For each high-level goal, the following information is provided:

- The detailed CTA table. This table contains both the pre and post FASTI tasks and plans in the same table. The table contains the following fields:
 - The task number
 - The task name
 - The **Pre-FASTI** plan (if relevant)
 - The **Post-FASTI** plan (if relevant)
 - The **Controller** that performs the task under FASTI
 - Whether the task is **Unique to FASTI**
 - Whether the task is fundamentally **Changed by FASTI**
 - The **FASTI tool** that is used during the task

Table 5 contains the detailed FASTI CTA.

Table 5 - Detailed FASTI CTA

Number	Task	Plan	Controller	Task Unique to FASTI	Task Changed by FASTI	Tool
	Provide Air Traffic Control Services	do concurrently 1-3; then do (4) ; based on action plan (do all in any order 5-7) do in sequence 1-3; if mismatch in expectations (do in sequence 4-5)		✓	✗	
1	Confirm & update mental picture - Maintain SA		Both PC and TC	✗	✗	
1.1	Access existing 'sentry parameters' and mental picture		Both PC and TC	✗	✗	
1.2	Update picture	Based on consideration of sentry parameters (optionally do any 1-3)	Both PC and TC	✗	✗	
1.2.1	Update objects and object relations	do all in any order 1-2	Both PC and TC	✗	✗	
1.2.1.1	Integrate sector information	optionally do any 1-5	Both PC and TC	✗	✗	
1.2.1.1.1	Consider weather		Both PC and TC	✗	✗	
1.2.1.1.2	Consider airports		Both PC and TC	✗	✗	
1.2.1.1.3	Consider airways / routings		Both PC and TC	✗	✗	
1.2.1.1.4	Consider information on neighbouring sectors		Both PC and TC	✗	✗	
1.2.1.1.5	Consider sector boundaries / TSAs		Both PC and TC	✗	✗	
1.2.1.2	Integrate aircraft information	optionally do any 1-5	Both PC and TC	✗	✓	
1.2.1.2.1	Consider incoming a/c		Both PC and TC	✗	✗	
1.2.1.2.2	Consider a/c changing FL		Both PC and TC	✗	✓	VAW
1.2.1.2.3	Consider a/c proximity to other objects		Both PC and TC	✗	✓	PPD,PVD,VAW

1.2.1.2.4	Consider 'background' a/c		Both PC and TC	x	x	
1.2.1.2.5	Consider flight data consistency		Both PC and TC	x	✓	N/A
1.2.2	Update event representations	do all in any order 1-4	Both PC and TC	x	x	
1.2.2.1	Consider any current unexpected events		Both PC and TC	x	x	
1.2.2.2	Consider potential conflicts	Pre-FASTI [do not do 1; 2] - Post-FASTI [do all in any order 1-2]	Both PC and TC	x	✓	
1.2.2.2.1	Scan the separation predictions		Both PC and TC	✓	x	PPD
1.2.2.2.2	Detect potential conflicts		Both PC and TC	x	x	
1.2.2.3	Consider flight progress events		Both PC and TC	x	x	
1.2.2.4	Update future event representations (Level 3 SA)		Both PC and TC	x	x	
1.2.3	Update control strategy	do 1	Both PC and TC	x	x	
1.2.3.1	Refer to 'update action plan' tasks		Both PC and TC	x	x	
1.3	Evaluate new information against sentry parameters		Both PC and TC	x	x	
1.4	Diagnose difference in expectations: retrieve explanation from LTM		Both PC and TC	x	x	
1.5	Revise sentry parameters and picture		Both PC and TC	x	x	
2	Workload monitoring	do concurrently 1-2	Both PC and TC	x	x	
2.1	PC tasks	do all in any order 1-2	Planning Controller	x	x	
2.1.1	Monitor own workload	do in sequence 1-3	Planning Controller	x	x	
2.1.1.1	Assess current workload	do all in any order 1-2	Planning Controller	x	x	
2.1.1.1.1	Assess the number of flights approaching sector		Planning Controller	x	x	

2.1.1.1.2	Assess number of planning potential conflicts	Pre-FASTI [do not do 1; 2] - Post-FASTI [1; 2]	Planning Controller	✗	✓	
2.1.1.1.2.1	Detect planning potential conflicts in separation predictions		Planning Controller	✓	✗	PPD
2.1.1.1.2.2	Judge number of potential conflicts		Planning Controller	✗	✗	
2.1.1.2	Retrieve other complexity issues	Pre-FASTI [do in sequence 1-2; do not do 3] - Post-FASTI [do all in any order 1-3]	Planning Controller	✗	✓	
2.1.1.2.1	Consult Radar Display		Planning Controller	✗	✗	
2.1.1.2.2	Consult flight information		Planning Controller	✗	✗	
2.1.1.2.3	Estimate blocked levels / context of any evolving flights		Planning Controller	✓	✗	VAW
2.1.1.3	Assess future workload		Planning Controller	✗	✗	
2.1.2	Monitor TC's workload	do in sequence 1-2	Planning Controller	✗	✗	
2.1.2.1	Assess TC's current workload	optionally do any 1-3	Planning Controller	✗	✗	
2.1.2.1.1	Assess number of aircraft on frequency		Planning Controller	✗	✗	
2.1.2.1.2	Assess number of tactical potential conflicts	Pre-FASTI [do not do 1; 2] - Post-FASTI [do all in any order 1-2]	Planning Controller	✗	✓	
2.1.2.1.2.1	Detect tactical potential conflicts in separation predictions		Planning Controller	✓	✗	PPD
2.1.2.1.2.2	Judge number of tactical potential conflicts		Planning Controller	✗	✗	
2.1.2.1.3	Assess other complexity issues		Planning Controller	✗	✗	
2.1.2.2	Assess TC's future workload		Planning Controller	✗	✓	PPD
2.2	TC tasks	do 1	Tactical Controller	✗	✗	
2.2.1	Monitor own workload	do in sequence 1-2	Tactical Controller	✗	✗	

2.2.1.1	Assess current workload	optionally do any 1-3	Tactical Controller	x	x
2.2.1.1.1	Assess number of flights currently on frequency		Tactical Controller	x	x
2.2.1.1.2	Assess number of tactical potential conflicts	Pre-FASTI [do not do 1; 2] - Post-FASTI [do all in any order 1-2]	Tactical Controller	x	✓
2.2.1.1.2.1	Detect tactical potential conflicts in separation predictions		Tactical Controller	✓	x PPD
2.2.1.1.2.2	Judge number of tactical potential conflicts		Tactical Controller	x	x
2.2.1.1.3	Assess other complexity issues		Tactical Controller	x	x
2.2.1.2	Assess future workload		Tactical Controller	x	✓ PPD
3	Control process: action plan / hierarchy	Based on ongoing work (do all in any order 1-2)	Both PC and TC	x	x
3.1	Update action plan / hierarchy with new tasks	do in sequence 1-2	Both PC and TC	x	x
3.1.1	Set mental reminder including cue to perform task		Both PC and TC	x	x
3.1.2	Set details of actions required to memory		Both PC and TC	x	x
3.2	Identify requirement to perform action	do in sequence 1-3	Both PC and TC	x	x
3.2.1	Identify cue for action		Both PC and TC	x	✓ PPD,MONA,SYS CO,Red dots
3.2.2	Retrieve mental reminder		Both PC and TC	x	✓ PPD,MONA,SYS CO,Red dots
3.2.3	Retrieve action requirements		Both PC and TC	x	x
4	Conflict Avoidance	do 1	Planning Controller	x	x
4.1	PC tasks	do concurrently 1-3; then do (4)	Planning Controller	x	x

4.1.1	Detect any potential conflicts within planning timeframe	Pre-FASTI [do not do 1; do in sequence 2-3; if FL or trajectory seems problematic do (4)] - Post-FASTI [do all in any order 1-3; if workload allows or problem suspected (4)] In the case of FASTI do [1; when displayed on HMI do (2)] - pre-FASTI [do not do 1-2]	Planning Controller	✗	✓	
4.1.1.1	Monitor separation predictions		Planning Controller	✓	✗	
4.1.1.1.1	Monitor PPD		Planning Controller	✓	✗	PPD
4.1.1.1.2	Detect time-related warning in a/c label ('red dots')		Planning Controller	✓	✗	Red dots
4.1.1.2	Check a/c flight level		Planning Controller	✗	✓	VAW
4.1.1.3	Check a/c lateral trajectory and destination		Planning Controller	✗	✓	Probes - Flight Legs
4.1.1.4	Consider a/c speed		Planning Controller	✗	✗	
4.1.2	Further analyse potential planning conflicts	do all in any order 1-4	Planning Controller	✗	✓	
4.1.2.1	Interpret geometry of conflict		Planning Controller	✗	✓	PVD,Probes - Flight Legs
4.1.2.2	Interpret temporal information		Planning Controller	✗	✓	PPD,PVD
4.1.2.3	Judge minimum separation distance		Planning Controller	✗	✓	PPD,Probes - Flight Legs
4.1.2.4	Estimate uncertainty	Pre-FASTI [do not do 1; do all in any order 2-3] - Post-FASTI [do all in any order 1-3]	Planning Controller	✗	✓	
4.1.2.4.1	Consider knowledge or experience / beliefs concerning MTCD		Planning Controller	✓	✗	N/A
4.1.2.4.2	Judge if the conflict will expire or not actually occur		Planning Controller	✗	✓	PPD,PVD,Probes - Flight Legs
4.1.2.4.3	Consider extent of uncertainty		Planning Controller	✗	✓	N/A

4.1.3	Decide how to handle any potential conflicts	do in sequence 1-4	Planning Controller	✗	✓	
4.1.3.1	Consider factors that influence solution	do all in any order 1-5	Planning Controller	✗	✓	
4.1.3.1.1	Consider degree of uncertainty		Planning Controller	✗	✓	N/A
4.1.3.1.2	Consider time to conflict		Planning Controller	✗	✓	PPD
4.1.3.1.3	Consider time to sector boundary		Planning Controller	✗	✗	
4.1.3.1.4	Evaluate current and future workload		Planning Controller	✗	✓	PPD,SYSCO
4.1.3.1.5	Evaluate current and future workload of TC		Planning Controller	✗	✓	PPD
4.1.3.2	Identify options for executing a conflict solution in planning timeframe		Planning Controller	✗	✓	PPD,Probes - Flight Legs
4.1.3.3	Identify options for resolving the conflict tactically		Planning Controller	✗	✓	PPD,VAW,Probes - Flight Legs
4.1.3.4	Recall any familiar solutions for conflict		Planning Controller	✗	✗	
4.1.4	Implement method for dealing with potential conflict	do only one 1-4	Planning Controller	✗	✓	
4.1.4.1	Do nothing at this point in time		Planning Controller	✗	✗	
4.1.4.2	Co-ordinate change of PEL or XFL		Planning Controller	✗	✓	SYSCO
4.1.4.3	Co-ordinate change of entry point or XPT		Planning Controller	✗	✓	SYSCO
4.1.4.4	Plan tactical conflict resolution & transfer to the TC	do in sequence 1-3	Planning Controller	✗	✗	
4.1.4.4.1	Plan a flight level change to be executed within the sector		Planning Controller	✗	✓	VAW
4.1.4.4.2	Inform the TC of the planned solution		Planning Controller	✗	✓	N/A
4.1.4.4.3	Transfer the conflict to the TC		Planning Controller	✓	✗	PPD
5	Tactical De-confliction	do concurrently 1-2	Both PC and TC	✗	✗	

5.1	PC tasks	if workload allows (do in sequence 1-2) do (1) ; if workload allows (do in sequence 2-4)	Planning Controller	x	x
5.1.1	Assist in tactical conflict detection	do in sequence 1-2	Planning Controller	x	✓
5.1.1.1	Evaluate if own current workload permits assisting the TC	Planning Controller	x	x	
5.1.1.1.1	Retrieve outcome of own and TC's workload assessment	Planning Controller	x	x	
5.1.1.1.2	Judge spare capacity available	Planning Controller	x	x	
5.1.1.2	Detect and recognise potential conflicts	Planning Controller	x	✓	
5.1.1.2.1	Recall potential conflicts that were transferred to the TC	Planning Controller	✓	x	PPD
5.1.1.2.2	Scan for potential conflicts in tactical timeframe	Pre-FASTI [1; do not do (2) ; 3] - Post-FASTI [do all in any order 1-3]	Planning Controller	x	✓
5.1.1.2.2.1	Scan Radar Display inside sector	Planning Controller	x	x	
5.1.1.2.2.2	Monitor separation predictions for tactical timeframe	Planning Controller	✓	x	PPD
5.1.1.2.2.3	Consider uncertainty	Planning Controller	x	✓	N/A
5.1.1.3	Judge if TC has identified potential conflicts in tactical timeframe	Planning Controller	x	x	
5.1.1.3.1	Compare recalled and current potential conflicts	Planning Controller	x	x	
5.1.1.4	Inform TC of urgent potential conflicts that may not have been noticed	Planning Controller	x	x	
5.1.2	Assist in tactical conflict resolution	do 1; if required do one of (do in sequence 2-3) ; if required (4)	Planning Controller	x	x
5.1.2.1	Evaluate if own current workload permits assisting the TC	do in sequence 1-2	Planning Controller	x	x
5.1.2.1.1	Retrieve output of own and TC's current workload assessment	Planning Controller	x	x	
5.1.2.1.2	Judge spare capacity available	Planning Controller	x	x	

5.1.2.2	Assist with transferred potential conflicts	do in sequence 1-2	Planning Controller	✗	✗
5.1.2.2.1	Recall planned solution for transferred potential conflicts		Planning Controller	✗	✗
5.1.2.2.2	Inform / remind TC of suggested solutions		Planning Controller	✗	✗
5.1.2.3	Assist with new potential conflicts	do in sequence 1-2	Planning Controller	✗	✗
5.1.2.3.1	Identify possible conflict resolutions	Pre-FASTI [do not do 1-2; 3] - Post-FASTI [do all in any order 1-3]	Planning Controller	✗	✓
5.1.2.3.1.1	Use what if trajectories to identify possible heading / waypoint / XPT		Planning Controller	✓	✗
5.1.2.3.1.2	Use vertical conflict display to identify possible flight level changes		Planning Controller	✓	✗
5.1.2.3.1.3	Evaluate effects of changing speed or rate of descent		Planning Controller	✗	✗
5.1.2.3.2	Inform TC of possible changes		Planning Controller	✗	✗
5.1.2.4	Perform co-ordinations as required		Planning Controller	✗	✗
5.2	TC tasks	do (1) ; if required do (do in sequence 2-4) Pre-FASTI [do not do 1; if alerted by PC do (2) ; do all in any order 3-4; if FL or trajectory seem problematic do (5)] - Post-FASTI [do (1) ; if alerted by PC do (2) ; do all in any order 3-4; if FL or trajectory seem problematic do (5)] pre-FASTI [do not do 1-2] - post-FASTI [do (1) ; if time limit expires (2)]	Tactical Controller	✗	✗
5.2.1	Detect any potential conflicts within the sector		Tactical Controller	✗	✓
5.2.1.1	Monitor separation predictions		Tactical Controller	✓	✗
5.2.1.1.1	Monitor PPD		Tactical Controller	✓	✗
5.2.1.1.2	Detect MTCD 'red dots' warning		Tactical Controller	✓	✗
					Red dots

5.2.1.2	Listen to PC regarding advice on potential conflict		Tactical Controller	x	x	
5.2.1.3	Check a/c flight level	Pre-FASTI [1; do not do 2] - Post-FASTI [1; if necessary (2)]	Tactical Controller	x	✓	
5.2.1.3.1	Scan Radar Display (a/c label)		Tactical Controller	x	x	
5.2.1.3.2	Check vertical conflict display		Tactical Controller	✓	x	VAW
5.2.1.4	Check a/c lateral trajectory and destination	Pre-FASTI [1; do not do 2-4; 5] - Post-FASTI [1; if potential conflict shown in PPD or alerted by PC optionally do (2) ; if necessary to support mental picture (optionally do any 3-4) ; 5]	Tactical Controller	x	✓	
5.2.1.4.1	Scan Radar Display		Tactical Controller	x	x	
5.2.1.4.2	Check POF		Tactical Controller	✓	x	Probes - Flight Legs
5.2.1.4.3	Check AOF		Tactical Controller	✓	x	Probes - Flight Legs
5.2.1.4.4	Use manual MTCD		Tactical Controller	✓	x	Probes - Flight Legs
5.2.1.4.5	Consider flight intentions		Tactical Controller	x	x	
5.2.1.5	Consider a/c speed		Tactical Controller	x	x	
5.2.2	Further analyse potential tactical conflicts	do all in any order 1-4	Tactical Controller	x	✓	
		Pre-FASTI [do not do 1-3; do in sequence 4-6] - Post-FASTI [optionally do any 1-4; if time allows or PC questions MTCD (5) ; 6]	Tactical Controller	x	✓	
5.2.2.1	Interpret geometry of conflict		Tactical Controller	✓	x	Probes - Flight Legs
5.2.2.1.1	Inspect problem flight leg		Tactical Controller	✓	x	Probes - Flight Legs

5.2.2.1.2	Display manual MTCD trajectory for problem a/c	Tactical Controller	✓	✗	Probes - Flight Legs
5.2.2.1.3	Inspect vertical conflict display	Tactical Controller	✓	✗	VAW
5.2.2.1.4	Inspect Radar Display	Tactical Controller	✗	✗	
5.2.2.1.5	Use mental projection of a/c trajectory	Tactical Controller	✗	✗	
5.2.2.1.6	Establish general characteristics of conflict	do all in any order 1-4		Tactical Controller	✗
5.2.2.1.6.1	Identify if crossing conflict	Tactical Controller	✗	✗	
5.2.2.1.6.2	Identify if conflict with TSA	Tactical Controller	✗	✗	
5.2.2.1.6.3	Identify if catch up conflict	Tactical Controller	✗	✗	
5.2.2.1.6.4	Identify if ascending / descending conflict	Tactical Controller	✗	✗	
5.2.2.2	Interpret temporal information	Pre-FASTI [do not do 1; do all in any order 2-5] - Post-FASTI [1; if necessary (do all in any order 2-5)]	Tactical Controller	✗	✓
5.2.2.2.1	Inspect separation prediction information	Tactical Controller	✓	✗	PPD
5.2.2.2.2	Consider weather conditions	Tactical Controller	✗	✗	
5.2.2.2.3	Consider a/c type and performance	Tactical Controller	✗	✗	
5.2.2.2.4	Consider a/c flight phase	Tactical Controller	✗	✗	
5.2.2.2.5	Consider a/c intentions	Tactical Controller	✗	✗	
5.2.2.3	Judge minimum separation distance	Pre-FASTI [1; do not do 2-4] - Post-FASTI [do not do 1; 2; if time or required (optionally do any 3-4)]	Tactical Controller	✗	✓
5.2.2.3.1	Estimate using mental projection	Tactical Controller	✗	✗	

5.2.2.3.2	Read separation prediction display (e.g., PPD) conflict label	Tactical Controller	✓	✗	PPD
5.2.2.3.3	Check problem-orientated flight leg	Tactical Controller	✓	✗	Probes - Flight Legs
5.2.2.3.4	Use manual MTCD trajectory	Tactical Controller	✓	✗	Probes - Flight Legs
5.2.2.4	Estimate uncertainty	Pre-FASTI [do not do 1; do all in any order 2-3] - Post-FASTI [do all in any order 1-3]	Tactical Controller	✗	✓
5.2.2.4.1	Consider knowledge / experience / beliefs concerning MTCD functioning	Tactical Controller	✓	✗	N/A
5.2.2.4.2	Judge if the conflict will expire / not actually occur in the future	Tactical Controller	✗	✓	
5.2.2.4.3	Consider extent of uncertainty	Tactical Controller	✗	✓	
5.2.3	Decide how to handle any potential tactical conflicts	do in sequence 1-4	Tactical Controller	✗	✓
5.2.3.1	Consider factors that influence solution	do all in any order 1-6	Tactical Controller	✗	✓
5.2.3.1.1	Consider time to conflict	Pre-FASTI [do not do 1; do (2)] - Post-FASTI [do (1) ; if necessary do (2)]	Tactical Controller	✗	✓
5.2.3.1.1.1	Inspect PPD axis	Tactical Controller	✓	✗	PPD
5.2.3.1.1.2	Mental assessment based on distance and speed	Tactical Controller	✗	✗	
5.2.3.1.2	Consider a/c destination	Tactical Controller	✗	✗	
5.2.3.1.3	Consider a/c performance	Tactical Controller	✗	✗	
5.2.3.1.4	Consider vertical and lateral distance to sector boundary or TOD	Tactical Controller	✗	✗	
5.2.3.1.5	Consider degree of uncertainty	Tactical Controller	✗	✓	N/A
5.2.3.1.6	Evaluate current and future workload	Tactical Controller	✗	✓	PPD
5.2.3.2	Recall any familiar solutions for conflict	Tactical Controller	✗	✗	

5.2.3.3	Identify options for resolving the conflict		Tactical Controller	x	✓	VAW
5.2.3.4	Decide the action to be taken		Tactical Controller	x	✗	
5.2.4	Implement method for resolving potential tactical conflict	Pre-FASTI [1; do only one 2-3; optionally do (4)] - Post-FASTI [1; do only one 2-3; do (4)]	Tactical Controller	x	✓	
5.2.4.1	Identify action required	do in sequence 1-3	Tactical Controller	x	✗	
5.2.4.1.1	Identify cue to perform action		Tactical Controller	x	✗	
5.2.4.1.2	Retrieve mental reminder		Tactical Controller	x	✗	
5.2.4.1.3	Retrieve details of issue and required action from action plan		Tactical Controller	x	✗	
5.2.4.2	Ask PC to make co-ordination	do only one 1-2	Tactical Controller	x	✗	
5.2.4.2.1	Ask PC to co-ordinate XFL		Tactical Controller	x	✗	
5.2.4.2.2	Ask PC to co-ordinate new XPT		Tactical Controller	x	✗	
5.2.4.3	Issue instruction to pilot		Tactical Controller	x	✗	
5.2.4.4	Update the system	Pre-FASTI [if possible and required (optionally do any 1-5)] - Post-FASTI [due to increase in reliance on information (optionally do any 1-5)]	Tactical Controller	x	✓	
5.2.4.4.1	Update system with Direct to Waypoint		Tactical Controller	x	✗	
5.2.4.4.1.1	Click on XPT on the aircraft's track label		Tactical Controller	x	✗	
5.2.4.4.1.2	Detect & read waypoints in sub-menu		Tactical Controller	x	✗	
5.2.4.4.1.3	Click on desired new waypoint		Tactical Controller	x	✗	
5.2.4.4.2	Update aircraft speed		Tactical Controller	x	✗	

5.2.4.4.2.1	Left click on asp in aircraft label	Tactical Controller	x	x
5.2.4.4.2.2	Left click on the new speed	Tactical Controller	x	x
5.2.4.4.3	Update system with new rate of climb / descent	Tactical Controller	x	x
5.2.4.4.3.1	Left click on arc menu in aircraft label	Tactical Controller	x	x
5.2.4.4.3.2	Left click on new rate or climb / descent	Tactical Controller	x	x
5.2.4.4.4	Update system with changed CFL	Tactical Controller	x	x
5.2.4.4.4.1	Left click on CFL in aircraft label	Tactical Controller	x	x
5.2.4.4.4.2	Left click on new flight level	Tactical Controller	x	x
5.2.4.4.5	Update system with newly assigned / changed heading	Tactical Controller	x	x
5.2.4.4.5.1	Slide mouse over aircraft callsign to display label	Tactical Controller	x	x
5.2.4.4.5.2	Left mouse click on ahdg menu	Tactical Controller	x	x
5.2.4.4.5.3	Move cursor to required new heading & click	Tactical Controller	x	x
5.2.4.4.5.4	Right click on the XPT in the aircraft's label	Tactical Controller	x	x
5.2.4.4.5.5	Detect white lateral trajectory line	Tactical Controller	x	x
5.2.4.4.5.6	Click on and drag lateral trajectory line to the required position	Tactical Controller	x	x
6	Flight Progress Monitoring	do concurrently 1-3	Both PC and TC	x
6.1	PC tasks	do in all cases (1) ; if time or workload allows do (2)	Planning Controller	x
6.1.1	Monitor flight progress	do (1) ; if time and workload allows do (2)	Planning Controller	x
6.1.1.1	Monitor progress of flights outside sector of responsibility	do in sequence 1-2	Planning Controller	x

6.1.1.1.1	Search & detect aircraft approaching sector	optionally do any 1-2	Planning Controller	x	x
6.1.1.1.1.1	Scan radar display		Planning Controller	x	x
6.1.1.1.1.2	Scan Sector Inbound List (SIL)		Planning Controller	x	x
6.1.1.1.2	Check current flight parameters against entry conditions		Planning Controller	x	x
6.1.1.2	Assist TC in flight conformance monitoring	do (1) ; if time available or required (do in sequence 2-3)	Planning Controller	x	x
6.1.1.2.1	Search and detect aircraft within and entering sector		Planning Controller	x	x
6.1.1.2.2	Identify TC flight progress actions required	optionally do any 1-4	Planning Controller	x	x
6.1.1.2.2.1	Identify that an aircraft ready to be assumed	do in sequence 1-2	Planning Controller	x	x
6.1.1.2.2.1.1	Detect and recognise that aircraft is near the sector boundary		Planning Controller	x	x
6.1.1.2.2.1.2	Detect that a/c status permits being assumed		Planning Controller	x	x
6.1.1.2.2.2	Decide if heading required to follow designated route	Pre-FASTI [do (1) ; do not do 2; do (3)] - Post-FASTI [do only one 1-2; do (3)]	Planning Controller	x	✓
6.1.1.2.2.2.1	Detect retrieval cue that appropriate time to instruct a/c		Planning Controller	x	✓
6.1.1.2.2.2.2	Detect MONA route reminder		Planning Controller	✓	x
6.1.1.2.2.2.3	Compare required route with current lateral trajectory		Planning Controller	x	x
6.1.1.2.2.3	Decide if change of FL is required to achieve XFL	Pre-FASTI [do (1) ; do not do 2] - Post-FASTI [do only one 1-2]	Planning Controller	x	✓
6.1.1.2.2.3.1	Detect retrieval cue that appropriate time to instruct a/c		Planning Controller	x	✓
6.1.1.2.2.3.2	Detect and read Top of Descent reminder		Planning Controller	✓	x
6.1.1.2.2.4	Decide that an aircraft can be transferred	Pre-FASTI [do (1) ; do not do 2; do (3)] - Post-FASTI [do only one 1-2; do (3)]	Planning Controller	x	✓

6.1.1.2.2.4.1	Detect retrieval cue that appropriate time to transfer a/c	Planning Controller	✗	✓	MONA
6.1.1.2.2.4.2	Detect MONA transfer reminder	Planning Controller	✓	✗	MONA
6.1.1.2.2.4.3	Identify that aircraft meets transfer conditions	Planning Controller	✗	✗	
6.1.1.2.3	Inform TC of action required	Planning Controller	✗	✗	
6.1.2	Assist TC to monitor clearances	Dependent on time available and contents of action plan (optionally do any 1-4)	Planning Controller	✗	✗
6.1.2.1	Detect if actual flight level is inconsistent with cleared level	Pre-FASTI [do (1) ; do not do 2] - Post-FASTI [if able do (1) ; do (2)]	Planning Controller	✗	✓
6.1.2.1.1	Compare cleared flight level with actual flight level		Planning Controller	✗	✓
6.1.2.1.2	Detect and recognise MONA warnings - FL BUST FL DEV		Planning Controller	✓	✗
6.1.2.2	Detect if actual heading is inconsistent with cleared heading	Pre-FASTI [do not do 1; do (2)] - Post-FASTI [if able do (1) ; do (2)]	Planning Controller	✗	✓
6.1.2.2.1	Compare cleared heading with actual heading		Planning Controller	✗	✓
6.1.2.2.2	Detect and recognise LAT DEV MONA warning		Planning Controller	✓	✗
6.1.2.3	Detect if aircraft speed non conformant		Planning Controller	✗	✗
6.1.2.4	Detect other a/c non conformance		Planning Controller	✗	✗
6.2	TC tasks	do all in any order 1-2; if required do (3)	Tactical Controller	✗	✗
6.2.1	Monitor that a/c follow clearance	do all in any order 1-4	Tactical Controller	✗	✓
6.2.1.1	Detect if actual flight level is inconsistent with cleared level	Pre-FASTI [do (1) ; do not do 2] - Post-FASTI [if able do (1) ; do (2)]	Tactical Controller	✗	✓
6.2.1.1.1	Compare cleared flight level with actual flight level		Tactical Controller	✗	✗

6.2.1.1.2	Detect and recognise MONA warnings - FL BUST, FL DEV		Tactical Controller	✓	✗	MONA
6.2.1.2	Detect if actual heading / route is inconsistent with cleared	Pre-FASTI [do (1) ; do not do 2] - Post-FASTI [if able do (1) ; do (2)]	Tactical Controller	✗	✓	
6.2.1.2.1	Compare cleared heading with actual heading		Tactical Controller	✗	✗	
6.2.1.2.2	Detect and recognise LAT DEV MONA warning		Tactical Controller	✓	✗	MONA
6.2.1.3	Detect if aircraft speed non conformant		Tactical Controller	✗	✗	
6.2.1.4	Detect other a/c non conformance		Tactical Controller	✗	✗	
6.2.2	Monitor progress of flights in tactical timeframe	do (1) ; as required (optionally do any 2-5)	Tactical Controller	✗	✓	
6.2.2.1	Search & detect aircraft within and entering sector		Tactical Controller	✗	✗	
6.2.2.2	Identify that an aircraft ready to be assumed	do in sequence 1-3	Tactical Controller	✗	✗	
6.2.2.2.1	Detect and recognise that aircraft is near the sector boundary		Tactical Controller	✗	✗	
6.2.2.2.2	Receive communication from a/c		Tactical Controller	✗	✗	
6.2.2.2.3	Detect that a/c status permits being assumed		Tactical Controller	✗	✗	
6.2.2.3	Decide if change of heading required to follow designated route	Pre-FASTI [do (1) ; do not do 2; do (3)] - Post-FASTI [optionally do (1) ; do in sequence 2-3]	Tactical Controller	✗	✓	
6.2.2.3.1	Detect retrieval cue that appropriate time to instruct a/c		Tactical Controller	✗	✓	MONA
6.2.2.3.2	Detect MONA route reminder		Tactical Controller	✓	✗	MONA
6.2.2.3.3	Compare required route with current lateral trajectory		Tactical Controller	✗	✗	
6.2.2.4	Decide if change of FL is required to achieve XFL	Pre-FASTI [do (1) ; do not do 2] - Post-FASTI [do only one 1-2]	Tactical Controller	✗	✓	
6.2.2.4.1	Retrieve cue that appropriate time to instruct a/c		Tactical Controller	✗	✓	MONA

6.2.2.4.2	Detect and read Top of Descent reminder		Tactical Controller	✓	✗	MONA
6.2.2.5	Decide that an aircraft can be transferred	Pre-FASTI [do (1) ; do not do 2; do (3)] - Post-FASTI [do only one 1-2; do (3)]	Tactical Controller	✗	✓	
6.2.2.5.1	Retrieve cue that appropriate time to transfer a/c		Tactical Controller	✗	✓	MONA
6.2.2.5.2	Detect MONA transfer reminder		Tactical Controller	✓	✗	MONA
6.2.2.5.3	Identify that aircraft meets transfer conditions		Tactical Controller	✗	✗	
6.2.3	Implement required action	do (1) ; if required do (2)	Tactical Controller	✗	✗	
6.2.3.1	Contact pilot	as required (do only one 1-2)	Tactical Controller	✗	✗	
6.2.3.1.1	Issue instructions		Tactical Controller	✗	✗	
6.2.3.1.2	Query current status		Tactical Controller	✗	✗	
6.2.3.2	Update system		Tactical Controller	✗	✓	N/A
7	Co-ordination & Transfer	do concurrently 1-2	Both PC and TC	✗	✗	
7.1	PC tasks	do only one 1-2	Planning Controller	✗	✗	
7.1.1	Initiate co-ordination	Pre-FASTI [do (1) ; do not do 2-3; do (4)] - Post-FASTI [do in sequence 1-2; if SYSCO best tool do (3) ; if phone best tool or SYSCO message gets no response or cannot be resolved do (4)]	Planning Controller	✗	✓	
7.1.1.1	Retrieve reminder for co-ordination		Planning Controller	✗	✗	
7.1.1.2	Decide best means of proposing co-ordination		Planning Controller	✓	✗	N/A
7.1.1.3	Conduct co-ordination using electronic messaging	do in sequence 1-3	Planning Controller	✓	✗	

7.1.1.3.1	Propose co-ordination	do in sequence 1-3	Planning Controller	✓	✗
7.1.1.3.1.1	Select desired change	do only one 1-3	Planning Controller	✓	✗
7.1.1.3.1.1.1	Select desired change to entry flight level	do in sequence 1-2	Planning Controller	✓	✗
7.1.1.3.1.1.1.1	Click on PEL of the aircraft's track label		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.1.1.2	Click on desired new PEL		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.1.2	Select desired change to exit flight level	do in sequence 1-2	Planning Controller	✓	✗
7.1.1.3.1.1.2.1	Click on XFL on the aircraft's track label		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.1.2.2	Click on desired new XFL		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.1.3	Select desired change to lateral trajectory / heading	do in sequence 1-3	Planning Controller	✓	✗
7.1.1.3.1.1.3.1	Click on XPT on the aircraft's track label		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.1.3.2	Detect white lateral trajectory line		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.1.3.3	Click on and drag lateral trajectory line to the required position		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.2	Detect message in MESSAGE OUT window		Planning Controller	✓	✗ SYSCO
7.1.1.3.1.3	Check message is correct		Planning Controller	✓	✗ SYSCO
7.1.1.3.2	Interpret co-ordination response from next sector	do in sequence 1-3	Planning Controller	✓	✗
7.1.1.3.2.1	Detect message in MESSAGE IN window		Planning Controller	✓	✗ SYSCO
7.1.1.3.2.2	Read and interpret message in MESSAGE IN window	do only one 1-3	Planning Controller	✓	✗ SYSCO
7.1.1.3.2.2.1	Identify that co-ordination request has been accepted		Planning Controller	✓	✗ SYSCO
7.1.1.3.2.2.2	Identify that adjacent sector has proposed an alternative value		Planning Controller	✓	✗ SYSCO
7.1.1.3.2.2.3	Identify that the co-ordination request has been rejected		Planning Controller	✓	✗ SYSCO

7.1.1.3.2.3	Evaluate if further co-ordination proposal is required		Planning Controller	✓	✗	VAW,Probes - Flight Legs
7.1.1.3.3	Deal with co-ordination request response	do only one 1-3	Planning Controller	✓	✗	
7.1.1.3.3.1	Accept co-ordination response	do 1	Planning Controller	✓	✗	
7.1.1.3.3.1.1	Double click the action button on the proposed value in the aircraft label		Planning Controller	✓	✗	SYSCO
7.1.1.3.3.2	Propose another value	do in sequence 1-2	Planning Controller	✓	✗	
7.1.1.3.3.2.1	Click action button on proposed value in the aircraft label		Planning Controller	✓	✗	SYSCO
7.1.1.3.3.2.2	Click on another value in the pop-up menu		Planning Controller	✓	✗	SYSCO
7.1.1.3.3.3	Reject co-ordination response	do in sequence 1-5	Planning Controller	✓	✗	
7.1.1.3.3.3.1	Click on proposed value in the aircraft label		Planning Controller	✓	✗	SYSCO
7.1.1.3.3.3.2	Click on 'reject' in the pop up menu		Planning Controller	✓	✗	SYSCO
7.1.1.4	Call neighbouring sector and verbally conduct co-ordination		Planning Controller	✗	✗	
7.1.2	Receive co-ord request from adj. sector	Pre-FASTI [do (1) ; do not do 2] - Post-FASTI [do only one 1-2]	Planning Controller	✗	✓	
7.1.2.1	Conduct co-ordination discussion over telephone	1; do only one 2-3	Planning Controller	✗	✓	
7.1.2.1.1	Answer phone		Planning Controller	✗	✗	
7.1.2.1.2	Discuss request		Planning Controller	✗	✗	
7.1.2.1.3	Agree on changes to flight details		Planning Controller	✗	✗	
7.1.2.1.4	Reject any proposed changes		Planning Controller	✗	✗	
7.1.2.2	Conduct co-ordination through electronic messaging	do in sequence 1-3; when workload or action plan allows (4)	Planning Controller	✓	✗	
7.1.2.2.1	Detect electronic co-ordination request		Planning Controller	✓	✗	SYSCO

7.1.2.2.2	Read and interpret message		Planning Controller	✓	✗	SYS CO
7.1.2.2.3	Manage co-ordination responses	do all in any order 1-3	Planning Controller	✓	✗	
7.1.2.2.3.1	Scan MESSAGE IN window		Planning Controller	✓	✗	SYS CO
7.1.2.2.3.2	Decide whether to accept a request or not		Planning Controller	✓	✗	PPD,VAW, Probes - Flight Legs
7.1.2.2.3.3	Prioritise and plan co-ordination request responses		Planning Controller	✓	✗	SYS CO
7.1.2.2.4	Respond to co-ordination request	do only one 1-3	Planning Controller	✓	✗	
7.1.2.2.4.1	Accept co-ordination request	do 1	Planning Controller	✓	✗	
7.1.2.2.4.1.1	Double click the action button on the proposed value in the aircraft lab		Planning Controller	✓	✗	SYS CO
7.1.2.2.4.2	Propose another value	do in sequence 1-2	Planning Controller	✓	✗	
7.1.2.2.4.2.1	Click action button on proposed value in the aircraft label		Planning Controller	✓	✗	SYS CO
7.1.2.2.4.2.2	Click on another value in the pop-up menu		Planning Controller	✓	✗	SYS CO
7.1.2.2.4.3	Reject co-ordination request	do in sequence 1-2	Planning Controller	✓	✗	
7.1.2.2.4.3.1	Click on proposed value in the aircraft label		Planning Controller	✓	✗	SYS CO
7.1.2.2.4.3.2	Click on 'reject' in the pop up menu		Planning Controller	✓	✗	SYS CO
7.2	TC Tasks	When required (do only one 1-2)	Tactical Controller	✗	✗	
7.2.1	Receive a/c from neighbour sector	do only one 1-2	Tactical Controller	✗	✗	
7.2.1.1	Receive from 'external' sector	do in sequence 1-4	Tactical Controller	✗	✗	
7.2.1.1.1	Left click on the CS in the aircraft label		Tactical Controller	✓	✗	SYS CO
7.2.1.1.2	Detect and read CS/NS submenu		Tactical Controller	✓	✗	SYS CO

7.2.1.1.3	Click on 'assume' in the submenu	Tactical Controller	✓	✗	SYSCO
7.2.1.1.4	Left click on the 'CS' in the aircraft label	Tactical Controller	✓	✗	SYSCO
7.2.1.2	Receive from 'internal' sector	Tactical Controller	✗	✗	
7.2.2	Hand-off a/c to neighbouring sector	do only one 1-2	Tactical Controller	✗	✗
7.2.2.1	Hand-off to 'external' sector	do in sequence 1-4	Tactical Controller	✗	✗
7.2.2.1.1	Left click on the NS in the aircraft label	Tactical Controller	✓	✗	SYSCO
7.2.2.1.2	Detect and read CS/NS menu	Tactical Controller	✓	✗	SYSCO
7.2.2.1.3	Click on 'transfer' in the submenu	Tactical Controller	✓	✗	SYSCO
7.2.2.1.4	Left click on the 'transfer' reminder in the aircraft label	Tactical Controller	✓	✗	MONA
7.2.2.2	Hand-off to 'internal' sector	Tactical Controller	✗	✗	

APPENDIX E: INFORMATION PROCESSING CHANGES AND POTENTIAL ERROR MODES

Table 6 presents a summary of the information processing changes and human error modes for the FASTI Sector Team Operations CTA. The table contains all of the tasks that are changed by FASTI, even if there is no change to the underlying nature of the task (i.e. shifts in information processing). For example, the task 'Integrate aircraft information' is better supported by tools under FASTI, but the underlying nature of the task does not change.

It should be noted that the assessment is restricted to the lowest level of the task analysis. Thus, changes to parent tasks (as a consequence of FASTI changing components tasks) are not listed separately in the table. For example, even though the task of 'integrating aircraft information (1.2.1.2) was assessed to be changed by FASTI, the human error assessment was performed on the component tasks, such as 'consider aircraft changing flight level' (1.2.1.2.2). This served to avoid 'double-counting' of human error modes.

Table 6 - Information Processing Changes and Potential Error Modes

ID	Task	Controller	Task Unique to FASTI	Task Changed by FASTI	IP Domain	Baseline IP Modality	FASTI IP Modality	Baseline Cognitive Function	FASTI Cognitive Function	Potential error modes
1.2.1.2.2	Consider a/c changing flightlevel	Both PC and TC	✗	✓	Perception	Spatial	Visual	Judgement	Identification	Mis-see
1.2.1.2.3	Consider a/c proximity to other objects	Both PC and TC	✗	✓	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see
1.2.1.2.5	Consider flight data consistency	Both PC and TC	✗	✓	Decision making	Symbolic	Symbolic	Decision making	Decision making	Poor decision or poor plan, Late decision or late plan, No decision or no plan
1.2.2.2.1	Scan the separation predictions	Both PC and TC	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
2.1.1.1.2.1	Detect planning potential conflicts in separation predictions	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see
2.1.1.2.3	Use vertical conflict display to estimate blocked levels / context of any evolving flights	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see
2.1.2.1.2.1	Detect tactical potential conflicts in separation predictions	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see

2.1.2.2	Assess TC's future workload	Planning Controller	✗	✓	Decision making	Symbolic	Spatial - Symbolic	Previous actions	Judgement	Mis-see, Poor decision or poor plan
2.2.1.1.2.1	Detect tactical potential conflicts in separation predictions	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see
2.2.1.2	Assess future workload	Tactical Controller	✗	✓	Decision making	Symbolic	Spatial - Symbolic	Previous actions	Judgement	Mis-see, Poor decision or poor plan
3.2.1	Identify cue for action	Both PC and TC	✗	✓	Perception	Visual	Symbolic	Prospective memory	Identification	Mis-see, No visual detection
3.2.2	Retrieve mental reminder	Both PC and TC	✗	✓	Perception	Symbolic	Spatial - Symbolic	Previous actions	Perceptual information	Forget information, Misrecall information
4.1.1.1.1	Monitor PPD	Planning Controller	✓	✗	Perception	Visual	Visual	Detection	Detection	Mis-see, No visual detection
4.1.1.1.2	Detect time-related warning in a/c label ('red dots')	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
4.1.1.2	Check a/c flight level	Planning Controller	✗	✓	Perception	Spatial	Visual	Judgement	Detection	Mis-see, No visual detection
4.1.1.3	Check a/c lateral trajectory and destination	Planning Controller	✗	✓	Perception	Visual	Visual	Detection	Detection	Mis-see, Misprojection
4.1.2.1	Interpret geometry of conflict	Planning Controller	✗	✓	Perception	Spatial	Visual	Judgement	Detection	Mis-see
4.1.2.2	Interpret temporal information	Planning Controller	✗	✓	Perception	Spatial - symbolic	Visual	Judgement	Detection	Mis-see, Misprojection
4.1.2.3	Judge minimum separation distance	Planning Controller	✗	✓	Perception	Spatial	Visual	Judgement	Detection	Mis-see
4.1.2.4.1	Consider knowledge or experience / beliefs concerning MTCD functioning	Planning Controller	✓	✗	Memory	n/a	Symbolic	n/a	Procedural or declarative knowledge	Forget information, Misrecall information
4.1.2.4.2	Judge if the conflict will expire or not actually occur in the future	Planning Controller	✗	✓	Decision making	Spatial - symbolic	Spatial - Symbolic	Judgement	Judgement	Poor decision or poor plan, Late decision or late plan, No decision or no plan
4.1.2.4.3	Consider extent of uncertainty	Planning Controller	✗	✓	Response selection	Symbolic	Symbolic	Judgement	Judgement	Poor decision or poor plan, Late decision or late plan, No decision or no plan

4.1.3.1.1	Consider degree of uncertainty	Planning Controller	✗	✓	Decision making	Symbolic	Symbolic	Judgement	Judgement	Poor decision or poor plan, Late decision or late plan, No decision or no plan
4.1.3.1.4	Evaluate current and future workload	Planning Controller	✗	✓	Perception	Symbolic	Visual	Immediate or current actions	Identification	Mis-see, No visual detection
4.1.3.1.5	Evaluate current and future workload of TC	Planning Controller	✗	✓	Perception	Symbolic	Visual	Immediate or current actions	Identification	Mis-see, No visual detection
4.1.3.2	Identify options for executing a conflict solution in planning timeframe	Planning Controller	✗	✓	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see, No visual detection
4.1.3.3	Identify options for resolving the conflict tactically	Planning Controller	✗	✓	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see, No visual detection
4.1.4.2	Co-ordinate change of PEL or XFL	Planning Controller	✗	✓	Response selection	Verbal	Manual	Communication	Selection	Omitted or late action, Selection error, Incorrect information
4.1.4.3	Co-ordinate change of entry point or XPT	Planning Controller	✗	✓	Response selection	Verbal	Manual	Communication	Selection	Omitted or late action, Selection error, Incorrect information
4.1.4.4.1	Plan a flight level change to be executed within the sector	Planning Controller	✗	✓	Perception	Spatial	Visual	Decision making	Identification	Mis-see, No visual detection
4.1.4.4.2	Inform the TC of the planned solution	Planning Controller	✗	✓	Response selection	Verbal	Verbal	Communication	Communication	Unclear information, Incorrect information
4.1.4.4.3	Transfer the conflict to the TC	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Omitted or late action, Selection error
5.1.1.2.1	Recall potential conflicts that were transferred to the TC	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.1.1.2.2.2	Monitor separation predictions for tactical timeframe	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
5.1.1.2.2.3	Consider uncertainty	Planning Controller	✗	✓	Decision making	Symbolic	Symbolic	Judgement	Judgement	Poor decision or poor plan, Late decision or late plan, No decision or no plan
5.1.2.3.1.1	Use what if trajectories to identify possible heading / waypoint / XPT	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, Poor decision or poor plan, Selection error

5.1.2.3.1.2	Use vertical conflict display to identify possible flight level changes	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, Poor decision or poor plan, Selection error
5.2.1.1.1	Monitor PPD	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.1.1.2	Detect MTCD 'red dots' warning	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
5.2.1.3.2	Check vertical conflict display	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.1.4.2	Check POF	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.1.4.3	Check AOF	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.1.4.4	Use manual MTCD	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.2.1.1	Inspect problem flight leg	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, Selection error
5.2.2.1.2	Display manual MTCD trajectory for problem a/c	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, Selection error
5.2.2.1.3	Inspect vertical conflict display	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.2.2.1	Inspect separation prediction information	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.2.3.2	Read separation prediction display (e.g., PPD) conflict label	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.2.3.3	Check problem-orientated flight leg	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.2.3.4	Use manual MTCD trajectory	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.2.4.1	Consider knowledge / experience / beliefs concerning MTCD functioning	Tactical Controller	✓	✗	Memory	n/a	Symbolic	n/a	Procedural or declarative knowledge	Forget information, Misrecall information
5.2.2.4.2	Judge if the conflict will expire / not actually occur in the future	Tactical Controller	✗	✓	Decision making	Spatial - symbolic	Spatial - Symbolic	Judgement	Judgement	Poor decision or poor plan, No decision or no plan
5.2.2.4.3	Consider extent of uncertainty	Tactical Controller	✗	✓	Response selection	Symbolic	Symbolic	Judgement	Judgement	Poor decision or poor plan, No decision or no plan

5.2.3.1.1.1	Inspect PPD axis	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection
5.2.3.1.6	Evaluate current and future workload	Tactical Controller	✗	✓	Perception	Symbolic	Visual	Previous actions	Detection	Mis-see, No visual detection
5.2.3.3	Identify options for resolving the conflict	Tactical Controller	✗	✓	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see, No visual detection
6.1.1.2.2.2.1	Detect retrieval cue that appropriate time to instruct a/c	Planning Controller	✗	✓	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.1.1.2.2.2.2	Detect MONA route reminder	Planning Controller	✓	✗	Perception		Visual	n/a	Detection	Mis-see, No visual detection
6.1.1.2.2.3.1	Detect retrieval cue that appropriate time to instruct a/c	Planning Controller	✗	✓	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.1.1.2.2.3.2	Detect and read Top of Descent reminder	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.1.1.2.2.4.1	Detect retrieval cue that appropriate time to transfer a/c	Planning Controller	✗	✓	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.1.1.2.2.4.2	Detect MONA transfer reminder	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.1.2.1.1	Compare cleared flight level with actual flight level	Planning Controller	✗	✓	Perception	Visual	Visual	Identification	Identification	Mis-see, No visual detection
6.1.2.1.2	Detect and recognise MONA warnings - FL BUST FL DEV	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.1.2.2.1	Compare cleared heading with actual heading	Planning Controller	✗	✓	Perception	Spatial	Visual	Judgement	Comparison	Mis-see
6.1.2.2.2	Detect and recognise LAT DEV MONA warning	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.2.1.1.2	Detect and recognise MONA warnings - FL BUST, FL DEV	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.2.1.2.2	Detect and recognise LAT DEV MONA warning	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.2.2.3.1	Detect retrieval cue that appropriate time to instruct a/c	Tactical Controller	✗	✓	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.2.2.3.2	Detect MONA route reminder	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.2.2.4.1	Retrieve cue that appropriate time to instruct a/c	Tactical Controller	✗	✓	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.2.2.4.2	Detect and read Top of Descent reminder	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see, No visual detection

6.2.2.5.1	Retrieve cue that appropriate time to transfer a/c	Tactical Controller	✗	✓	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.2.2.5.2	Detect MONA transfer reminder	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
6.2.3.2	Update system	Tactical Controller	✗	✓	Response selection	Manual	Manual	Selection	Selection	Selection error
7.1.1.2	Decide best means of proposing co-ordination	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Decision making	Poor decision or poor plan, Late decision or late plan, No decision or no plan
7.1.1.3.1.1.1.1	Click on PEL of the aircraft's track label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.1.1.1.2	Click on desired new PEL	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.1.1.2.1	Click on XFL on the aircraft's track label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.1.1.2.2	Click on desired new XFL	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.1.1.3.1	Click on XPT on the aircraft's track label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.1.1.3.3	Click on and drag lateral trajectory line to the required position	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Positioning	Selection error
7.1.1.3.1.2	Detect message in MESSAGE OUT window	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	No visual detection
7.1.1.3.1.3	Check message is correct	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Judgement	Poor decision or poor plan, Late decision or late plan, No decision or no plan
7.1.1.3.2.1	Detect message in MESSAGE IN window	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	No visual detection
7.1.1.3.2.2.1	Identify that co-ordination request has been accepted	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Decision making	Mis-see, No visual detection
7.1.1.3.2.2.2	Identify that adjacent sector has proposed an alternative value	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Decision making	Mis-see, No visual detection
7.1.1.3.2.2.3	Identify that the co-ordination request has been rejected	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Decision making	Mis-see, No visual detection

7.1.1.3.2.3	Evaluate if further co-ordination proposal is required	Planning Controller	✓	✗	Decision making	Symbolic	Symbolic	Judgement	Judgement	Poor decision or poor plan, Late decision or late plan, No decision or no plan
7.1.1.3.3.1.1	Double click the action button on the proposed value in the aircraft label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.3.2.1	Click action button on proposed value in the aircraft label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.3.2.2	Click on another value in the pop-up menu	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.3.3.1	Click on proposed value in the aircraft label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.3.3.3.2	Click on 'reject' in the pop up menu	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.1.4	Call neighbouring sector and verbally conduct co-ordination	Planning Controller	✗	✗	Response selection	Verbal	Verbal	Communication	Communication	Unclear information, Incorrect information
7.1.2.1	Conduct co-ordination discussion over telephone	Planning Controller	✗	✓	Response selection	Verbal	Verbal	Communication	Communication	Unclear information, Incorrect information
7.1.2.2.1	Detect electronic co-ordination request	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	No visual detection
7.1.2.2.2	Read and interpret message	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Decision making	Poor decision or poor plan
7.1.2.2.3.1	Scan MESSAGE IN window	Planning Controller	✓	✗	Perception	n/a	Visual	n/a	Detection	Mis-see, No visual detection
7.1.2.2.3.2	Decide whether to accept a request or not	Planning Controller	✓	✗	Decision making	n/a	Spatial - Symbolic	n/a	Decision making	Poor decision or poor plan, Late decision or late plan, No decision or no plan
7.1.2.2.3.3	Prioritise and plan co-ordination request responses	Planning Controller	✓	✗	Decision making	n/a	Symbolic	n/a	Planning	Poor decision or poor plan, Late decision or late plan, No decision or no plan
7.1.2.2.4.1.1	Double click the action button on the proposed value in the aircraft lab	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.2.2.4.2.1	Click action button on proposed value in the aircraft label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error

7.1.2.2.4.2.2	Click on another value in the pop-up menu	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.2.2.4.3.1	Click on proposed value in the aircraft label	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.1.2.2.4.3.2	Click on 'reject' in the pop up menu	Planning Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.2.1.1.1	Left click on the CS in the aircraft label	Tactical Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.2.1.1.2	Detect and read CS/NS submenu	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see
7.2.1.1.3	Click on 'assume' in the submenu	Tactical Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.2.1.1.4	Left click on the 'CS' in the aircraft label	Tactical Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.2.2.1.1	Left click on the NS in the aircraft label	Tactical Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.2.2.1.2	Detect and read CS/NS menu	Tactical Controller	✓	✗	Perception	n/a	Visual	n/a	Identification	Mis-see
7.2.2.1.3	Click on 'transfer' in the submenu	Tactical Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error
7.2.2.1.4	Left click on the 'transfer' reminder in the aircraft label	Tactical Controller	✓	✗	Response selection	n/a	Manual	n/a	Selection	Selection error

Table 7 only contains the tasks where the attentional resource or the cognitive function has changed (therefore, this is a subset of the information presented in Table 6). In other words, FASTI may change tasks in a number of ways, but the table presents only the tasks where information processing changes have been recorded. As can be seen from the table, the major change in the combination of attentional resource and cognitive functions is from spatial-symbolic mental projection to visual recognition. This is a benefit as visual attention can be successfully directed to the perception of visual patterns (given sufficient time, workload, and qualities of the interface). The major change in cognitive functioning is from memory-based processes (involving prospective memory) to visual identification processes.

Table 7 - Tasks with Changed Cognitive Functions

ID	Task	Controller	IP Domain	Baseline IP Modality	FASTI IP Modality	Baseline Cognitive Function	FASTI Cognitive Function	Potential error modes
1.2.1.2.2	Consider a/c changing flightlevel	Both PC and TC	Perception	Spatial	Visual	Judgement	Identification	Mis-see
1.2.1.2.3	Consider a/c proximity to other objects	Both PC and TC	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see
1.2.2.2	Consider potential conflicts	Both PC and TC	Perception	Spatial	Visual	Judgement	Detection	Mis-see, No visual detection
2.1.2.2	Assess TC's future workload	Planning Controller	Decision making	Symbolic	Spatial - Symbolic	Immediate or current actions	Judgement	Mis-see, Poor decision or poor plan
2.2.1.2	Assess future workload	Tactical Controller	Decision making	Symbolic	Spatial - Symbolic	Immediate or current actions	Judgement	Mis-see, Poor decision or poor plan
3.2.1	Identify cue for action	Both PC and TC	Perception	Visual	Symbolic	Prospective memory	Identification	Mis-see, No visual detection
3.2.2	Retrieve mental reminder	Both PC and TC	Perception	Symbolic	Spatial - Symbolic	Immediate or current actions	Perceptual information	Forget information, Misrecall information
4.1.1.2	Check a/c flight level	Planning Controller	Perception	Spatial	Visual	Judgement	Detection	Mis-see, No visual detection
4.1.2.1	Interpret geometry of conflict	Planning Controller	Perception	Spatial	Visual	Judgement	Detection	Mis-see
4.1.2.2	Interpret temporal information	Planning Controller	Perception	Spatial - symbolic	Visual	Judgement	Detection	Mis-see, Misprojection
4.1.2.3	Judge minimum separation distance	Planning Controller	Perception	Spatial	Visual	Judgement	Detection	Mis-see
4.1.3.1.4	Evaluate current and future workload	Planning Controller	Perception	Symbolic	Visual	Immediate or current actions	Identification	Mis-see, No visual detection
4.1.3.1.5	Evaluate current and future workload of TC	Planning Controller	Perception	Symbolic	Visual	Immediate or current actions	Identification	Mis-see, No visual detection
4.1.3.2	Identify options for executing a conflict solution in planning timeframe	Planning Controller	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see, No visual detection

ID	Task	Controller	IP Domain	Baseline IP Modality	FASTI IP Modality	Baseline Cognitive Function	FASTI Cognitive Function	Potential error modes
4.1.3.3	Identify options for resolving the conflict tactically	Planning Controller	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see, No visual detection
4.1.4.4.1	Plan a flight level change to be executed within the sector	Planning Controller	Perception	Spatial	Visual	Decision making	Identification	Mis-see, No visual detection
5.2.3.1.6	Evaluate current and future workload	Tactical Controller	Perception	Symbolic	Visual	Immediate or current actions	Detection	Mis-see, No visual detection
5.2.3.3	Identify options for resolving the conflict	Tactical Controller	Perception	Spatial - symbolic	Visual	Judgement	Identification	Mis-see, No visual detection
6.1.1.2.2.2.1	Detect retrieval cue that appropriate time to instruct a/c	Planning Controller	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.1.1.2.2.3.1	Detect retrieval cue that appropriate time to instruct a/c	Planning Controller	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.1.1.2.2.4.1	Detect retrieval cue that appropriate time to transfer a/c	Planning Controller	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.1.2.2.1	Compare cleared heading with actual heading	Planning Controller	Perception	Spatial	Visual	Judgement	Comparison	Mis-see
6.2.2.3.1	Detect retrieval cue that appropriate time to instruct a/c	Tactical Controller	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.2.2.4.1	Retrieve cue that appropriate time to instruct a/c	Tactical Controller	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection
6.2.2.5.1	Retrieve cue that appropriate time to transfer a/c	Tactical Controller	Perception	Spatial - symbolic	Visual	Prospective memory	Identification	Mis-see, No visual detection

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ACRONYMS AND ABBREVIATIONS

ABI	Advance Boundary Information (OLDI)
ACT	Activation Message Designator (OLDI)
ACTA	Applied Cognitive Task Analysis
AFL	Actual Flight Level
AOF	Aircraft Orientated Flight Leg
ATM	Air Traffic Management
BFD	Basic Flight Data Message (OLDI)
CFD	Change to Flight Data Message (OLDI)
CFL	Cleared Flight Level
CTA	Cognitive Task Analysis
DFS	Deutsche Flugsicherung
EFL	Entry Flight Level
ELW	Extended Label Window
E-TMA	Extended Terminal Manoeuvring Area
FASTI	First ATC Support Tools Implementation
FL	Flight Level
HTA	Hierarchical Task Analysis
HMI	Human Machine Interface
LOA	Letters of Agreement
MAC	Message for the Abrogation of Co-ordination (OLDI)
MONA	Monitoring Aids
MTCD	Medium Term Conflict Detection
MSP	Multi-Sector Planner
NATS	National Air Traffic Services
PC	Planning Controller
PEL	Planned Entry Level
POF	Problem-orientated Flight Leg
PPD	Potential Problem Display
PVD	Plan View Display
REV	Revision Message (OLDI)
RFL	Requested Flight Level
ROC	Rate of Climb
ROD	Rate of Descent
SIL	Sector Inbound List
SMW	Separation Monitor Window
SPO	Single Person Operation
SYSCO	System Supported Co-ordination
TC	Tactical Controller
TDB	Track Data Block
TED	Trajectory Editing Flight Leg
TOD	Top of Descent
TP	Trajectory Prediction
VAW	Vertical Aid Window
XFL	Exit Flight Level
XPT	Exit Point