



## CARE INO III

### 3D IN 2D PLANAR DISPLAY PROJECT

### D3-2 DESIGN EVALUATION REPORT (LOT NO. 7 WP 3)

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## 1. INTRODUCTION

This document reports on the outcome of evaluations of the Year 3 software prototypes from the 3D-in-2D Displays for ATC project. In Year 2 we developed tools for the management of approach energy in terms of space and time (the 4D-Energy Trajectory, or 4DET, display) (Wong et al., 2008). In Year 3, we modified it with the purpose of investigating how the 4DET display could support a modified concept of Target Windows and better punctuality in ATC. We refer to this as the 'Pinch and Pull Target Windows' concept (Han et al, 2009). For a variety of reasons, including the lack of concrete SESAR information, this prototype was not evaluated in a formal way. In Year 3, we also developed a proof of concept implementation of the Multi-Conflict Display (MCD), a display that aims to simplify conflict detection. As this prototype was not dependent upon SESAR information, we managed to develop this concept further and were eventually able to evaluate it with controllers, engineers at both EUROCONTROL Experimental Centre and at NATS UK.

We then assessed how industrial evaluation process such as the E-OCVM could be used to take the prototypes to a state when they become operational tools.

In ATC, at the present as well as under a future SESAR environment, controllers have two key goals: the safe and expeditious control of air traffic. In practice the first goal involves maintaining separation between aircraft. Although under SESAR there may be some changes in procedure, such as self-separation and free flight, controllers will still have to monitor the airspace for separation, and detect impending problems. Increasing the complexity of the airspace and decreasing controller input are likely to have significant negative impacts on controller performance.

The second goal includes practices to ensure aircraft transit the airspace efficiently so that they arrive at their destination punctually. One of the ways being considered about how punctuality can be achieved involves the operation concept of contract of objectives as a means of delivering aircraft to specific places at specific times. These places and times are called Target Windows (TW's) and will possibly be a core component of SESAR. .

We have developed an overall system concept, where the current 2D radar display is augmented with two additional screens: an MCD to aid separation and another display that helps controllers ensure compliance with target windows.

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## 1.1 Maintaining Separation

Although faced with many tasks, maintaining aircraft separation can be considered one of the primary objectives of the modern air traffic controller. To ensure that the airspace is safe, aircraft must be separated by minimum horizontal and vertical distances. Ensuring that these constraints are met is already a challenging task even under current conditions, but the predictions upon which SESAR is based suggest that we will need to double airspace capacity by 2030 (SESAR Consortium, 2006).

There is a squared relationship between the number of aircraft a controller must manage and the number of possible conflicts – thus, doubling the number of aircraft a controller must handle could entail a fourfold increase in workload (SESAR Consortium, 2006).

Contributions to managing this workload can be found in several disciplines. Distributing some of the work to pilots, improved navigation and communication technologies, and improved procedures could all be instrumental in achieving the goals of tripling capacity. This paper describes one specific approach, a visualisation of aircraft relationships that shows how significant gains can be made by presenting controllers a display that aids visual detection and invariants that support decision making.

In operational contexts, controllers will still spend most of their time using to plan view to perform tasks unrelated to conflict avoidance. To facilitate this, the MCD provides decision-making information via a rapid visual search heuristic, rather than requiring constant attention. The rapid search is enabled by displaying the pair's relationship with a trace, showing its recent history. This trace is similar to that found on the current radar display. However, as controllers look at a trace on the radar plan view and interpret the heading and speed of an aircraft, they can look at a trace on the MCD and estimate the likelihood of a conflict.

## 1.2 Compliance with the target windows

In this stream of work, we proposed an alternative use of the concept of Target Windows (TWs) that has been previously proposed by the CATS (Contract-based Air Transportation System) programme (ref?). Instead of limiting the use of TWs as boundary objects for coordinating timing between sectors in order to manage punctuality as aircraft as they transit between sectors, we propose a more flexible approach. We suggest that there can be more TWs distributed across the entire 4D trajectory of an aircraft's flight, and not just at sector boundaries. However, as this will increase the amount of coordination required between

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pilots and controllers, a mechanism is required to rapidly and dynamically share the necessary information to enable the smooth coordination. In Year 2 we developed a 'pinch-and-pull' interface that would enable a controller to rapidly, dynamically, and directly, 'pinch-and-pull' the 4D trajectory and to immediately see the consequences of the trajectory change on energy dissipation. We called such a display, the '4DET' or '4D Energy dissipation Trajectory' display. The display would, for example, instantly re-calculate and show whether the aircraft would arrive too high, too fast leading to a missed approach, or just right, at an airport's final approach fix. Trajectories would be also presented to the pilots who can modify or accept the new trajectory, and that trajectory information would be directly inserted into the aircraft's flight navigation systems. To make this possible, this 'pinch-and-pull' interface for pilot-controller coordination would require a real-time data-link, such as would be provided under the SESAR SWIM (System-Wide Information Management) net-centric information environment. The timeframe for this concept is anticipated in 2025, under SESAR ATM Level 3 Capability

Although the maintenance of separation is vital, controllers currently spend much of their time meeting delivery conditions – those that must be met as an aircraft leaves a sector. This may, for instance, mean an altitude and speed change.

Under SESAR, this burden is likely to increase, as the concepts of controlled time of arrival, target windows and the contract of objectives are introduced. With targets in both space and time, the problem is very much a 4D one. We have investigated ways in which target windows are likely to affect a controllers work, and have begun early prototype that help us to determine how the 4DT display developed in Year 2 might be adapted for use by controllers in SESAR.

Unfortunately, this stream of work could not be taken further and had stopped before we were able to carry out formal evaluations with air traffic controllers and will therefore there will not be an evaluation of this included in the report.

## **2. THE MCD**

The current plan view display was developed incrementally from the radar displays more than 50 years ago (Nolan, 2003). In that time, the amount and quality of information have increased, but the type of information has remained the same. The plan view shows information about individual aircraft, from which the controller infers details of the relationships between aircraft (e.g. distance, closing speed and safety). The controller then



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We were able to interview eight EUROCONTROL domain experts at the EUROCONTROL. Our goal in these interviews was to assess the potential utility of the MCD and its underlying concepts. To this end, we used structured interviews to evaluate:

- Whether the MCD provided useful information for controllers
- How the MCD could be useful to controllers
- How controllers would use the MCD in day to day operations
- How the MCD might help controllers achieve the goals set by SESAR
- What information would need to be added or removed in order to make the display more useful to controllers
- Potential improvements to the MCD
- Whether the underlying concept of displaying relationships was useful

### 3.1 Participants

Three non-operational air traffic controllers [C1, C2 and C3], each with between 20 to 25 years of operational experience, one computer scientist [E1] with 15 years of experience designing HMI's for 2D radar, three engineers with 15-25 years of experience with separation tools [E2, E4 and E5], and one human factors engineer with 15 years' experience took part to the evaluation session at the EUROCONTROL's Experimental Centre in Bretigny.

### 3.2 Procedure

Before the interviews, we gave a 30 minute presentation to most of the participants. We explained the concepts underlying the MCD, and implementation that would be evaluated, and the way that the interviews would work. Participants were asked not to discuss the MCD with each other before their interviews.

They were then invited to use the MCD and to explore its features in detail. They were able to use the MCD in the context of an en-route traffic situation, to see the effects of dynamic traffic flows and aircraft movements on the information contained in the MCD.

**Table 3.1 Probes used in the interviews**

Part 1: From your short experience with using the MCD:
<ol style="list-style-type: none"> <li>1. Please describe your first impressions of it?</li> <li>2. Assume I'm a trainee, please explain or show me, how I should use and interpret the visualisation presented on the MCD?</li> <li>3. What features of the MCD attracted your attention? What features did you like or dislike? Why?</li> <li>4. What makes the display easy or hard or confusing to learn, and to use? Why?</li> </ol>
Part 2: Drawing on your knowledge and experience of, or familiarity with the work of a controller:
<ol style="list-style-type: none"> <li>4. In what day-to-day ATC circumstances or situations would or could you use the MCD? <ol style="list-style-type: none"> <li>a) What other features or functions might we add?</li> <li>b) How would you use the MCD in day-to-day control work?</li> <li>c) What kind of effect do you think this display could make towards the goals of SESAR?</li> </ol> </li> <li>5. What things do you think you could do with the MCD that you can't do today?</li> <li>6. What kinds of effects do you think the MCD might have on your work?</li> <li>7. Think of someone with much less experienced than yourself having to use the MCD for work: <ol style="list-style-type: none"> <li>a) What mistakes or omissions might such a person make when using the MCD? When do you think, would such mistakes occur? Why?</li> <li>b) If you were their supervisor, what tips or tricks would you give such a person to overcome those mistakes / omissions?</li> </ol> </li> <li>8. What training or experience would be helpful or necessary to help you interpret / use the information on the MCD?</li> <li>9. What, if any, information would you add to the MCD? Why? <ol style="list-style-type: none"> <li>a) What, if any, features you think are unnecessary? Why?</li> </ol> </li> <li>10. Finally, in what ways do you think the MCD could be improved?</li> </ol>

After using the MCD for a few minutes, subjects were interviewed using the probes, or questions, described in Table 3.1. The interviews followed a semi-structured, open-ended interview technique. Each participant was asked to give their assessments of the display, in particular, the ease with which they were able to understand the information about relative positions in the way it was presented, how it could be used to detect conflicts, the likely biases and the problems that it could cause and hence the kinds of mistakes that one could make, and how an expert could potentially use it to extend his or her capabilities.

The evaluation procedure took approximately 45 minutes per participant. Interviews were recorded with a voice recorder, and notes were also taken to highlight important points and record information, such as gestures that were not captured by voice recording.

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It should be noted that the interviews with three participants deviated from this procedure. One engineer [E2] did not wish to be formally interviewed, but instead offered a number of comments. Two other engineers [E4 and E5] were interviewed simultaneously, due to time constraints. This interview was harder to structure, but the main goals of the evaluation were addressed.

### 3.3 Results

#### 3.3.1 General utility

The controllers were generally positive about the system. They uniformly felt that the display could be useful for helping controllers to detect impending conflicts. However, they also felt that it would take effort during training and practice to remind new controllers that it was a secondary tool – there was concern that some new controllers may come to use the MCD more than the radar display.

The reactions of engineers were mixed. Some engineers liked the system in its current form, feeling that it conveyed the necessary information well. Others felt that although a display for de-confliction was useful, the nature of the display could be different. Their primary concern was with the lack of vertical information and the similarity to the radar display.

- C1 In the context [of multi-sector planning] I can immediately see its usefulness.
- C3 It is very quick and easy to use. So if I'm focusing at my radar screen and I'm looking at the MCD, it is very easy to see that maybe there is going to be a problem with something. It is very quick. There is nothing awkward about it.
- E1 This could be a good support tool... Giving you an understanding of how long you have before a conflict is much nicer than STCA. This tool is more flexible, it lets you work at a range of times. Even if a problem is a long way away, you can still go and have a look at it... What is missing today in the chain of support is the idea of supporting the STCA with a tool like this. The STCA just comes 3 minutes before the conflict. It's

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a bit like this, but this is much more graphical. It is interesting this idea of having the possibility of seeing, even much in advance... Used as a tool to support my check of the conflict, it's a good tool. This idea of movement towards something is very interesting.

E2 The MCD is elegant, it is very simple.

E3 The thing I like about it I that they have a very simple and visual way of displaying the likelihood of separation infringements, that's good... I like the fact that conflicts and possible infringements of separation are displayed in a graphical way... The thing I like about it is that they have a very simple and visual way of displaying the likelihood of separation infringements, that's good.

E4 This is giving you a very good, very graphical view of propinquity, how seriously, how close aircraft have come to each other.

E5 I do like separation oriented displays... What's nice about this is that says "OK, what's our core business? Separation, let's design a display that has got that as a number one picture, and then everything else, let's see what happens and falls out." So, it is separation oriented, you've got to give it that. And I even like the fact that the altitude is incorporated on that display as well. So it's pretty good in that sense.

One controller felt that it would not fit well with current ways of working, because the display supports reaction, not planning.

C2 For over-flight, when the traffic is moderate, you might use it. A tool needs to be used when there are a lot of conflicts, and difficult complexity. But I'm not sure, when you have an area that is highly complex, because, let's say, you are losing this mental picture. I see that. The danger with this is that you are behind, you are waiting for

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something.

Only one engineer was truly pessimistic, mostly for practical reasons. He felt that the number of rules involved in any functional system would make the core algorithms too complicated to run in an operational environment.

E4     When I first saw it, I thought "Technically nice, practically impossible. By the time you take account of the different flight rules for different conditions, the eight line algorithm you have here will be 8000 lines."

### **3.3.2 The role of the MCD**

#### ***3.3.2.1 Workflow***

The participants felt that it was useful as a support tool, but that it would be bad to use it as a primary tool. They said that the radar display should remain the primary focus of the controller's attention. While some of the engineers were able to control the display while barely looking at the radar display, they felt that this capability might lead to problems if controllers were to depend on the display in the same way. These problems mainly related to loss of situation awareness and shifting from planning the airspace to reacting to the airspace.

C1     When you're not experienced, in order to have a quick reference as to whether two aircraft are in conflict or not, this is your friend. The MCD is your friend. So you'd look at it, and you'd see if there were any pairs or RPVs are heading toward the "never to enter circle" then you know you have a problem... For me it's an aide - it's a quick safety check to see, ok, have I got everything. And this is something I would through an eye on, to make sure that I had everything covered.

C2     When I have time. Let's say I do some planning, and I know I have to move this one in three minutes, then this one then this one, I have a strategy which is based on the radar display. Then if have time, I will use it to see if my strategy is correct. But not as a prime tool not to elaborate a strategy. To confirm if my strategy is correct? Why not?

C3     It's changing the way, from a controller's point of view, the way you would look at things. Because, today, the concentration is to try and have everything so that your focus is on the radar

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screen. To spend a lot of time looking at a support tool is not the way that we would recommend working. However, if I was to sit here, and not think about air traffic control and how I was trained, I could sit here and use this. So, I could focus very easily here, if I know that I could really depend on the tool. If I was to go back to my training as a controller, I would focus on the radar display, looking at the MCD occasionally. If I wasn't trained as an air traffic controller, I could come in here, watch the MCD, and solve problems as they arise. But there would be situation where you have aircraft at levels, but requesting higher. But at the moment, I'm really doing nothing. The traffic is going through the system, if any conflicts come up, I solve them. That's really the way that it's set up. I don't have to worry about a letter of agreement - this guy must be at 240 before he leaves my airspace. So that would cause you to have to focus that you would need on the radar display.

- E1 Not being a controller, I am using it, instead of the screen. If I could trust it, I would just look at it, and use the radar as a secondary tool... A controller would probably use it as a support tool, to give him early indication of possible conflicts, before the STCA.
- E3 You need a linkage between the primary display and the secondary display that allows the controller to stay focussed on the primary display, and then seek information on the secondary display, not the other way around. You noticed the way I was working here, I was using it as a primary display, and not looking at the radar display at all. I was completely unaware of the traffic situation. If an aircraft had started a descent without being authorised, I would have completely missed it... Once you have a version that which is more acceptable to controllers they may start using it. They may use it to monitor for potential conflicts, and that's a risk, isn't it, that you actually spend more time on this, and it becomes a little bit like a head-up/head-down time problem. That your attention is drawn away from the prime radar source to something that is and will remain the radar screen, to something else... Controllers often point out that they want additional systems to be integrated into the one screen, or at least have it physically close to it. There may be exceptions like an arrival management, departure management system and all the rest of it, but once you start talking about STCA and MTCD this information has to be integrated into the radar

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screen so that I don't have to take my eyes away from the radar screen. Maybe a slimmed down version of this could be integrated into the radar display... You could argue that it would have a beneficial effect on safety, if you avoid some of the risks about head-down/head-up time

### ***3.3.2.2 Effects of different information types on controllers' representations***

There were, however, concerns that switching between the displays might disrupt the controller's mental representation of the airspace. The non-geographical nature of the MCD was seen as a potential problem because the controller maintains a geographical representation of the space, and controllers felt that the two types of information might not be compatible. Participants were uncertain about whether this would be a problem for someone trained to use the system.

C1      When I first saw it, I began immediately to think of it in terms of a tactical controller, and the first thing I thought was "you have your dimensions and you have your time dimension in your head. Now you're being asked to look at it in a different way." And I said "things change very rapidly, and for example, when a controller gets overloaded he immediately returns to procedural control. He ditches all of the five miles, just 1000 feet. That's all he thinks of, until he regains control of the situation." In a situation like that, you're being asked to look at something that is completely different to the dimensions that you have in front of you and in your mind... A controller thinks in 3D constantly, he's looking at all of these [aircraft on the RD] on a normal basis, this is the normal 2D view that he has of a 3D situation, he applies the third dimension himself. He also uses a little bit of the time dimension, ok so he sees a potential conflict there, but he takes a look at it "Climbing, yeah, he'll get through." He's making projections in his mind's eye about where these two aircraft are going. Here you're asking him to look at a different dimension... In the tactical side of things, where things change all the time, you really are more comfortable dealing with the dimensions that you are familiar with. So for the most part, it is three dimensions and you use a little bit of time for projection. You turn to another scope which handles the reality you see there in a different way could well be off-putting. I don't

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know, it's 20 years since I last practiced - the young people today are very adaptable. Perhaps they could easily do it.

- C2 As a controller, when I manage an aircraft, I manage the past, the present and the future. I try to make sense of this and build a trajectory. The difficulty is that I lose the ability to build a regular trajectory and to update a picture of the complete traffic situation. It's very complex. When I look over here, it's a different picture. I need to move there, and I need to keep the traffic information in mind. What is this aircraft doing? What happens to it? What could interfere? Maybe the situation now is that with this type of device, I don't have to think as I thought before. It's a new way of approaching the situation. So we have to build a new way of tackling the problem. So with my old way, classic way, of building it might disturb me. Because it takes my resources - I was using the RD to build a traffic situation permanently. And then here with this tool, I am just reacting. I am not in the planning anymore. You see I'm waiting until the point where something has to be done, I am behind the traffic. Control is not that. Control is, you must always be before. You know what the situation is and you can anticipate how the situation will evolve. So in that sense, what you propose is a kind of game, a reaction to the traffic, and no controller would like to work like this.
- C3 It's changing the way, from a controller's point of view, the way you would look at things. Because, today, the concentration is to try and have everything so that your focus is on the radar screen. To spend a lot of time looking at a support tool is not the way that we would recommend working. However, if I was to sit here, and not think about air traffic control and how I was trained, I could sit here and use this. So, I could focus very easily here, if I know that I could really depend on the tool. If I was to go back to my training as a controller, I would focus on the radar display, looking at the MCD occasionally. If I wasn't trained as an air traffic controller, I could come in here, watch the MCD, and solve problems as they arise. But there would be situation where you have aircraft at levels, but requesting higher. But at the moment, I'm really doing nothing. The traffic is going through the system, if any conflicts come

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up, I solve them. That's really the way that it's set up. I don't have to worry about a letter of agreement - this guy must be at 240 before he leaves my airspace. So that would cause you to have to focus that you would need on the radar display.

E5 OK, it's a second display, so you're already into a difficult game, you're suggesting they change their concentration. The thing is it's not giving them any added information. Normally, when you switch from the "god's eye" view, it's to give them some vertical complement. And that's not cashing in on that.

### ***3.3.2.3 Free Route flight***

The participants identified free route flight as an area where the MCD might make a positive impact.

One participant noted that a major problem for free route flight was that controllers could not be sure that the solution was valid. They were unable to calculate a crossing event as precisely as the ASAS computer, and so would not feel comfortable when ASAS decided that separation for a given situation would be exactly five miles. By using a display that showed the separation between pairs of aircraft, subjects felt that this kind of trust may become possible.

Others felt that this system would be a good support tool where there were no waypoints, mainly because such systems have fewer conflicts, but these conflicts are harder to detect and resolve.

C1 It could support free route flight. It could also be useful in the context of ASAS. From a controller's point of view, ASAS can be unpredictable, you actually cede control of a flight's trajectory to the pilot. This can produce unpredictable results, with regards for instance to an aircraft turning out of your sector. It could also be useful in the crossing and passing. Crossing and passing was part of ASAS package 1, but then they realised that well, in the situation where ASAS can tell precisely that 5 mile separation is going to be maintained, a controller looking at a 2D scope cannot. So if you see that for example, it's just too tight for me to be comfortable, you are duty bound, responsibility-wise, to turn the aircraft, which defeats the whole purpose of ASAS crossing and passing. So that is one thing which has to be looked at in this situation, and I think this could be a useful application here. It helps

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the controller to see that the ASAS machine is working properly, and it's not going to conflict. It might be a bit close, but you can at least see that it's safe.

C2 The origins of air traffic control were "concentrate the aircraft at a single point, it will be easier to find the conflicts." Of course, with free flight techniques, there is no waypoint, and there are no tools today to find the conflicts. Maybe this could be a possibility. But again, it must be looked into the role of the different human. It is possible, for a free route trajectory, it could be a first filtering technique to say "what's the probability of having a conflict in this area?"

E1 If you didn't have a route network, this could be a good support tool.

E2 Maybe you can judge the small precise thing, maybe that indication of whether is going to go to the circle, and maybe it is easier to judge than looking at 2 aircraft which have different speeds at slightly different headings. So maybe it reduces the source of error.

There are still errors in there because your velocities could be wrong, there is error in those velocities, there is error in the actual speed the aircraft is flying out, there is error in direction in the flying in.

You could do the same thing with STCA, the question is do you want to make it the primary thing? But then you become reliant on the rules that you will have to build in.

The other screen somehow you understand, your normal understanding of the world. Where as this one, it is nice in the sense that allows you just to focus on other problems, rather than looking at everything you see, all the incoming problems are but that would be the intention with TCT. STCA has such a short look-ahead that is only to catch something that the controller is missing, but the intention of TCT would be to show the controller incoming problems. I'm sure that is has some type of display that shows time-to-go.

E3 The effect that you observe in free flight is that there are much fewer conflicts. But each conflict is more difficult to detect and more difficult to resolve because you don't have standard procedures. If you have a fixed route network, then in your sector there are only two or three crossing points

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where conflicts can occur and there's a fixed number of traffic situations that you are likely to encounter as a controller and you have standard solutions for all of these. You're mentally prepared. While in a free route environment then these conflicts can occur anywhere and they are more difficult to discover. This is an assumption that we are always using. Whether it's true or not needs to be seen, because once you have a free route network, aircraft will still fly between fixed airports and there's only one shortest route between these airports. That'll probably produce a traffic flow which is also bundled into certain routes. So how free route translates into more or less conflict geometries will still need to be seen. One of the conclusions in our experiments with free route is that the controller and also the pilot needs some sort of support tool for conflict detection. Without that it's not going to work.

### 3.3.3 Implementation problems

The users pointed out a number of problems relating to the way we had implemented the MCD. These are not conceptual problems that would be shared by all possible embodiments of our concept, but rather specific problems caused by design decisions.

#### 3.3.3.1 Clutter

There was a general agreement that the MCD did not need to show the green dots that denote RPV's with sufficient vertical separation. The controllers were comfortable with the MCD making the decisions based on vertical separation, provided that it was reliable.

It may even be possible to remove RPVs that have flight plans that never intersect and RPVs that have passed their closest point of approach.

- C1 Only provide what is helpful. A controller has all the information he needs here. If you're going to provide something extra, you need to make sure it is helpful.
- C2 If all the greens are not problems, then why do you present them? They're no use... The green ones, you can ignore. They shouldn't be there.
- E1 This colour coding is a bit difficult, but all this colour takes a lot of information... There is too much information of the screen. My understanding is that green dots very far from the circle, I don't need to see them. White dots that the system knows

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will never enter the circle, I don't need to see them. I need to see what is happening around the circle, the sense of the probability of entering. I need to know about the possibility of vertical infringement, it can happen so suddenly.

- E2 I see a problem here with clutter. A great many of the dots on there are completely unnecessary.

There were also numerous observations of participants attempting to click on white (non-vertically separated) RPV's and accidentally selecting nearby green (vertically separated) RPV's. This gave them an impression of safety that was not accurate, and could have caused severe problems in an operational environment.

### ***3.3.3.2 Similarity to the Radar Display***

In some cases, there were concerns that the display was too much like a radar display – the use of points with tails meant that some people might get confused, or that they might forget that the MCD presented non-geographical information. However, these concerns were mostly raised by engineers – the controllers themselves felt that this problem would be overcome with training.

- E1 I could imagine that this idea of the vector not being geographically sensible could be a bit confusing. If there was a way of having aircraft in the first quadrant displayed in the first quadrant it might be useful. There is a point, geographically, at which the conflict appears. The angle of the dot could reflect this.

- E3 Other than the fact that it's like a radar, there's nothing that makes it hard or confusing to learn to use... My first impression is that this will be very confusing for controllers because this pretends to be a 2D map display, even the fact that you have the history dots, this looks like a radar display. So the controller will assume that this is a radar display. The information and the quality of the information that you are showing is very useful, very helpful. But the way in which you are displaying it is misleading because the controller expects radar display functionality behind it and it's not... [Do you think that problem will be permanent?] I think it will stay permanent because you have to switch between these two displays. They are too similar, these two displays. In the one you have aircraft and the aircraft blips and the aircraft history. And in the other you have a very similar display, you have the RPV and its history. So, it's a question of getting used to it, but it

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will not totally go away, I think.

- C1 It's straight forward.
- C2 It looks like a radar screen, but it is not. So the way you treat the information might be confusing for some people. You need to make an effort to remember that the information on the MCD is different from the information on the RD. Apparently, the information is presented the same way... The concept is easy, it's not the display. Once you have understood what you have to do.
- C3 To understand the tool it is important to understand that it is not a geographical tool. Because controllers would look, for instance at this dot, for me is heading south, but on the MCD it is nothing to do with that. So once you have got over that sort of idea, that is not a radar screen with geographical directions and 360 degree sphere, and it is actually relative to the position of other aircraft, it is very easy to use, so that is the thing that people need to get past. But it is not a difficult thing to get past, I didn't find it difficult.

### ***3.3.3.3 Loss of vertical information***

Some participants argued that combining the lateral and vertical could lead to problems, since the speed at which aircraft climb and descend, relative to the size of vertical separation distances, is so much greater than the speed at which they fly horizontally. This could mean that a sudden violation of assigned altitude might not be detected until it was too late.

- E1 I need to know about the possibility of vertical infringement, it can happen so suddenly.
- E2 I think you are mixing together vertical and lateral separation and the controllers could find that disconcerting.
- E4 It's going to be intuitive once you've done it a few hundred times. This is where you have vertical separation, this is where you don't. It's potentially going to level off, it potentially isn't going to level off. I still want to know that that aircraft is something that could potentially be going to cause a problem, which is where sort of STCA using different configurations could come in.
- E5 70% of aircraft in Europe are climbing and

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descending. So it's not trivial, knowing what the rate of vertical change is. I find you lose something when you smear it into the lateral... You expect to get some vertical complement, because the RD is dedicated to the lateral, and just numerical for the altitude. So, in that sense, it's a shame that the vertical is not coming through. But I do like separation oriented displays.

### 3.3.4 The utility of relationship displays

The concept of displaying relationships graphically was well received, and users felt that information about the relationships between aircraft could be useful for controllers, even if the particular relationship that is displayed in the MCD was not exactly what was needed.

- C1 In order to, when you're not experienced, in order to have a quick reference as to whether two aircraft are in conflict or not, this is your friend. The MCD is your friend. So you'd look at it, and you'd see if there were any pairs or RPVs are heading toward the "never to enter circle" then you know you have a problem.
- E1 Surely this idea of relative conflict is quite interesting... What is missing today in the chain of support is the idea of supporting the STCA with a tool like this. The STCA just comes 3 minutes before the conflict. It's a bit like this, but this is much more graphical. It is interesting this idea of having the possibility of seeing, even much in advance... Used as a tool to support my check of the conflict, it's a good tool. This idea of movement towards something is very interesting.
- E3 I like the fact that conflicts and possible infringements of separation are displayed in a graphical way... The thing I like about it is that they have a very simple and visual way of displaying the likelihood of separation infringements, that's good.
- E4 This is giving you a very good, very graphical view of propinquity, how seriously, how close aircraft have come to each other.
- E5 I do like separation oriented displays... What's nice about this is that says "OK, what's our core business? Separation, let's design a display that has got that as a number one picture, and then everything else, let's see what happens and falls out." So, it's separation oriented, you've got to give it that. And I even like the fact that the

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altitude is incorporated on that display as well.  
So it's pretty good in that sense.

### 3.3.5 Further Development

In general the attitude of the controllers was that the display was worthy of further development. The engineers felt that the system was worth exploring further, but that it was likely that it would require significant changes in order to actually function in a real environment. The changes suggested were mostly related to the need to provide more vertical information to controllers.

One of the engineers felt that the technical tasks would be too daunting:

- E4     The required separation changes depending on the types of airspace, the types of aircraft... The system would quickly become very complex. This isn't necessarily too bad, but the major benefit of the MCD is that the simplicity of the algorithm is what makes it reassuring for controllers.

#### *3.3.5.1 Addition of trajectory-based prediction*

A predictive element could be added to the current state-based design, reducing false negatives and positives. This prediction would mean a much more complicated system, but this could be justified by the improvement in controller's ability to plan and the decrease in clutter on the screen. Trajectory-based prediction is difficult, and this is made worse by the difficulty of presenting meaningful prediction information to controllers. The MCD might provide an intuitive way to understand the predictions made by the system.

- C1     It's not necessarily correct, because it takes an actual and historical view, it doesn't make any predictions at the moment. But it gives you an idea of the possibility of conflicts which experienced controllers see by instinct... I think the prediction element is very important. We all know what has happened and what the situation is, we just want to know what the possibility of something happening in the future.
- C2     [What about predictions?] I would need to see how it was done. I can't be sure right now.
- C2     MTCD is a perfect example of that. It isn't implemented anywhere because it doesn't work. People are telling you that MTCD is great, it helps to improve efficiency. f\$%f@!f\$%. It doesn't work, because the quality of the prediction has not been addressed sufficiently. No one can make a sound assumption of what the quality of the prediction 10-

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12 minutes ahead. One day we will know, but with the current system, as it is, it is useless.

- C3 The only thing would be the flight path, the trajectory prediction particularly in the vertical plane, because if you descend an aircraft to the same level as another, and you don't give a white dot warning on this until it is at the same level, then it might be a bit late if they are right on top of each other.
- E1 It would be useful to have some kind of prediction of where the aircraft were likely to go.
- E3 It boils down to anticipating whether the lines will hit the red circle or not. It might be, because you look at those, you assume that they will continue moving straight, which is only the case if the two aircraft are going to continue on a straight line forever. That's kind of what you're doing because you're not taking into account the flight plan information. What you're doing as you try to mentally extend the straight line. If you had prediction functionality available for the user, that would make it easier. . . Integrating the flight plan information into the MCD would lead to the possibility to predict the conflict lines beyond linear extension... If the aircraft follows its flight plan, then it could move towards a conflict. So there is a problem that a conflict that is predictable according to the flight plan trajectory is not anticipated in this display, because this display is based on the assumption of linear tracks.
- E4 Instead of predictions being made by machine with the information with the machine potentially knows, it's now based on predictions of a human being based on a display that has transformed things radically from the normal space that he is used to... Maybe it's going to be intuitive once you've done it a few hundred times. This is where you have vertical separation, this is where you don't. It's potentially going to level off, it potentially isn't going to level off. I still want to know that that aircraft is something that could potentially be going to cause a problem, which is where sort of STCA using different configurations could come in.
- E5 This is such a low level algorithm that I wouldn't call automation. Because you could read it, probably in a page of A4, and say "I'm comfortable with monitoring that, rather than trusting myself as a human for two hours each day, to pick up what that

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algorithm is doing.” And that algorithm would go through a lot more testing than I could give it. So that’s not automation, in the sense that you’re talking about trajectory prediction. That’s why he’s not using trajectory prediction, because he knows that when he goes down that road, he’ll run into the automation problem. The MCD wouldn’t be classed as automation.

### ***3.3.5.2 Other opportunities***

Participants also suggested uses for the MCD outside of tactical sector control.

One participant felt that if the MCD were available to a multi-sector planner, they may be able to use it to understand the overall level of safety within the various sectors under their control.

Another felt that the MCD could be used as a way to evaluate losses of separation during a review. By seeing the conflict displayed in terms of separation, controllers may get a better grasp of how the situation occurred.

- C1 I can see its usefulness, but I can see its usefulness not so much for a tactical controller, because future tools are going to allow a tactical controller to actually access a resolution advisory, but where I do think it can be useful is in the multi sector planning stage... If you look at it in the context of SESAR, for example, the planning controller’s role will either be done away with completely, or will change. It will get more involved with the tactical side of things. In the case of a planning controller’s role actually going, chances are that planning will be done because we’re looking a more network-wide basis, on a multi sector basis. Now, that seems a very logical idea, but it’s not actually very practical at the moment. The reason that it’s not practical is that sectors tend to have a finite area within a radar scope, to be seen. A large sector, with a lot of aircraft, means that you have a smaller scale to look at than is probably comfortable. In a multi sector planning situation, the disadvantage is really amazing to watch, because several big sectors put together are nothing but a mass of dots over the screen. So one area where I see this being useful are for the multi-sector planner. He has a certain separation criteria, that circle - 5 miles, 10 miles, whatever it is - and he’s able to look at a situation where

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aircraft or not so much forced into a small geographical space, as they are in a 2D screen, but it's more in a different dimension. For me, I can see that being useful in that situation. In other words, he's interested in a long term situation; he's looking at this situation here, this critical area, of which he must make a decision about whether to change the trajectory of an aircraft, or whether to take account of particular complexity that's arising. Here you have a 5<sup>th</sup> dimension, it's something that transcends all of the dimensions which are here, it goes through lateral/horizontal, height and time. And it's focussing on one essential area. For example, I could extend the scale of it - I could have the circle there, and that's it. It allows me to look at three or four different sectors, but only with reference to safety. This is where it probably has an application. This, to me, is an ideal multi-sector planning tool. It gets over the problem of trying to squeeze multiple sectors into a standard sized radar display.

- E4 There's a notion of "propinquity," which is giving relative weightings to the vertical and horizontal distances. It's kind of interesting to see, as an alternative version of this display, how would it be if you showed cases where there are losses of separation on this display. So you're turning it around and saying "Is this a useful tool for analysing cases where you've had very near misses?" Because this is giving you a very good, very graphical view of propinquity, how seriously, how close aircraft have come to each other. In which case, instead of having one little red circle in the middle of the screen, you basically have one very large circle that covers nearly all of the screen, and then you have inner bull's-eyes inside it, which would show you how serious an incident is progressing at different times in an incident. And that's kind of interesting, which is turning the thing on its head. You haven't given an example of that, but that would be something that I would consider to be something interesting to propose.

#### **4. USABILITY AND UTILITY EVALUATION WITH NATS STAFF**

We conducted an evaluation session with research staff at the NATS Corporate and Technical Centre. The evaluation session was informal, consisting of a half-hour

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presentation, followed by an hour and a half of discussion. From the evaluation session, we found that:

- Trajectory based prediction would be essential in an operational model of the MCD. With appropriate prediction, it is easier to filter the data, and there is a reduction in both false negatives and false positives.
- The display is easy to understand. The information provided by the MCD is clear, providing what controllers need to know without overloading them with information.
- The use of RPVs is a novel perspective on the relationship between aircraft.
- Without warning about impending manoeuvres, the current system may provide a false sense of security.

The NATS staff felt that there may be other areas where the MCD could be useful.

- Since it provides easily understandable information about the conflicts in an airspace, it might be useful as a review function for assessing controllers' performance. It could be viewed in fast time, to give reviewers an understanding of the relationships in the airspace over a period of time.
- It could be used for training controllers, so that they can understand how the instructions that are given to aircraft affect the relationships between aircraft.
- It may be useful in countries that rely solely on a strip-based system for air traffic control. Trajectory-based prediction is difficult with strip-based systems and some countries will continue to use such systems for many years to come. The MCD may be useful in those situations.

We also saw some of the tools currently being developed by NATS to aid controllers, including the iFACTS (Interim Future Area Controller's Tool Set) that uses a similar concept, but is at a very advanced stage of operational testing. These displays include trajectory-based prediction, and are very easy to use. They may, however, benefit from consideration of some of the concepts used in the MCD.

## **5. CONCLUSIONS OF USABILITY AND UTILITY EVALUATIONS**

The evaluations produced a number of encouraging results. Overall, users liked the idea of a separation display, with some liking the current MCD concept and others suggesting that, while the current embodiment has potential, there are probably other variations that would provide greater benefits.

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The area where the MCD was seen to provide the most benefit was in free-route flight. In free route-flight, aircraft are free to choose their own route through sectors, rather than concentrating at waypoints. This is a problem for controllers because conflicts, although less frequent, are harder to detect and more severe when they occur. Users felt that the MCD might be a useful tool for helping controllers to detect conflicts within free route sectors in time to correct for them.

The participants felt that the display would be a useful support tool, but that care must be taken to ensure that it did not become a primary tool. Some of the participants were able to control the system by focussing on the MCD and only using the radar display as a tool for conflict resolution, but participants felt that this could lead to problems in more complex operational airspaces.

There was also a general consensus that the MCD could be useful in non-tactical settings. One controller felt that it could be useful for multi-sector planners, while others saw application for training or post-event analysis. Training and post-event analysis may also be easier areas to examine early in the development process.

Users worried that the non-geographical relationship information presented on the MCD might not be compatible with the mental models that controllers rely on to manage an airspace. Although the information contained in the MCD was seen to be useful, there was concern that the nature of the information may disrupt the current cognitive techniques that controllers use.

There were a number of specific concerns with the current implementation of the MCD. Some users were concerned with the similarity to the current radar display. The current embodiment of the MCD is deliberately designed to use many of the same cues as a radar display. This is intended to provide controllers with useful information without requiring them to learn a new set of interpretation skills. Some engineers felt that the cost of this strategy – potential confusion with the radar display while using the MCD – would outweigh this benefit. This concern was mostly raised by engineers; controllers felt that a small amount of practice would avoid this problem.

Users were also concerned with the amount of clutter on the screen. It was generally agreed that the green RPVs – designating pairs with vertical separation – were unnecessary. By hiding these, the display becomes clearer.

Perhaps the largest concern was the lack of specific vertical information in the display. The vertical flight profiles of aircraft are very different from their horizontal behaviour. By

combining the vertical and horizontal separations, the ability to make judgements about the severity of a separation infringement may be lost.

One of the main deficiencies of state-based systems like the MCD is that they are unable to promise anything about future trajectories of aircraft. Users would like to see future iterations of the MCD incorporate trajectory based prediction. This would improve de-cluttering, and may also lead to improvements in performance, as users might be able to place more confidence in the information presented on the MCD.

Overall, users were positive about the MCD. Although the display is far from an operational stage, the evaluations produced a degree of confidence that relationship displays may have the ability to improve controller performance.

## **6. STEPS TOWARDS INDUSTRIALISATION OF THE MCD**

This section reviews the path ahead for the MCD concept in its evolution from an early prototype to an operational tool used by air traffic controllers in their daily work. We investigated and report on how the E-OCVM evaluation method could be employed. This is a long process that needs to fully ascertain the feasibility of the concept, understand the needs of the different stakeholders and resolve any technical and operational issues before reaching a production stage.

Many questions on the feasibility of the concept still remain, for instance regarding its integration in the controllers' workflow and tools or its possible interaction when controllers collaborate among themselves or perform tasks different from aircraft conflict avoidance.

This section will detail the full concept validation methodology, and where our current evaluation fits within the larger scheme.

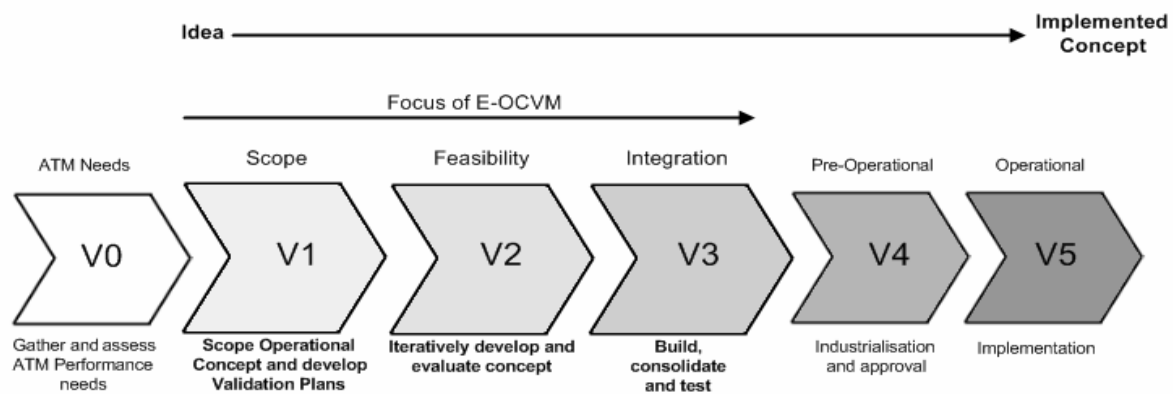
### **6.1 The E-OCVM Concept Lifecycle**

The European Operational Concept Validation Methodology (Programme, 2007) (E-OCVM) provides a common approach to all projects contributing to the validation of operational concepts from early issues identification to full pre-operational validation, the stages prior to industrialisation and operational introduction. The E-OCVM focuses on the consistent provision of information on performance capability and operability from R&D to the different stakeholders in the ATM domain (professionals, regulators, industry...) with the aim to improve the process of getting solutions to operational implementation.

The E-OCVM has three pillars:

- The Concept Lifecycle Model, that establishes the relationship between concept validation and product development and helps to define validation objectives and techniques;
- The Structured Planning Framework, that facilitates planning and transparency of the process;
- And the Case-Based Approach, that structures the process in cases relevant to the various stakeholders.

The “3D in 2D” project has proposed and examined several innovative HMI concepts that could improve performance and safety of ATM activities in the SESAR domain. To understand the next steps that could be taken based on the results of the project it is necessary to analyze the performed work from the prism of the E-OCVM.



**Figure 6.2 – The E-OCVM Concept Lifecycle Model**

Figure 6.2 presents an overview of the Concept Lifecycle Model. The activities carried out in the “3D in 2D” project correspond mainly to the V1 (Scope) phase, and the MCD concept in particular has been taken further to a first iteration of phase V2 (Feasibility). A detailed breakdown of the project activities is presented below.

### 6.1.1 V0 – Identification of needs

The “3D in 2D” project responds to the challenges posed by the future needs of the European airspace. The SESAR scenario foresees an important increase of the utilisation of the airspace in the coming years. In order to cope with the increased demands while meeting safety standards new technical tools will be needed to support the work of air traffic controllers and aircraft crews. Improvements on human-machine interactions may help controllers or pilots to better perform complex tasks and handle increased workloads.

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One of the changes envisioned to maximise the capacity of the European skies is to augment the flexibility in the airspace utilization by relaxing the restrictions imposed by airways and allowing the aircraft to follow more efficient trajectories. The consequence for controllers is that the task of preventing conflicts between aircraft will become more complex. The MCD is proposed as a dedicated display in the CWP that can reduce the effort needed by the controllers to perform this task.

### **6.1.2 V1 – Scope**

The identification of new concepts and possible solutions to different aspects of the work of air traffic controllers and pilots has been constant during the “3D in 2D” project.

- The creativity workshops done in the 1<sup>st</sup> year identified several concepts like “3D In Your Hand” and the Tabletop Display (Wong et al., 2007).
- The 2<sup>nd</sup> year of the project saw, among others, the conception of the MCD and the development of the 4-DET “pinch and pull” display for energy management in the cockpit (Wong, Gaukrodger, Han, Loomes, & Shepherd, 2008).

The aim of phase V1 is to explore different concepts, match solutions with needs and select what ideas should be developed further and focus the efforts of phases V2 and V3. In consequence, the concepts mentioned above were refined, some of them prototyped, and presented to domain experts for a first evaluation.

Among these concepts the MCD was selected to be explored in more depth. The technological requirements of the MCD are simple, as it does not require any HMI technology that is not present in a current CWP. This indubitably helped the concept to gain support from the experts. More reserves were found in the operability aspect, so it was decided to develop a prototype system that could be used for early usability evaluation with air traffic controllers.

Regarding the rest of the concepts, at this stage they are not ready to enter a feasibility analysis. This does not mean that they are not to be considered, as the specification of the SESAR scenario is continuously evolving and it may bring new opportunities. In particular, the study of the Target Windows concept started in the 3<sup>rd</sup> year is a work in progress that will be refined in parallel to the clarification of the CATS concepts.

### **6.1.3 V2 – Feasibility**

The phase V2 consists of the iterative development of a concept until it can be considered operationally feasible, that is, until any unknown or unclear aspects can be solved to the satisfaction of all the stakeholders.

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The first prototype of the MCD, implemented in the 2<sup>nd</sup> year of the “3D in 2D” project, made it possible to present the concept to experts and prospective users and gather their opinions. However, conclusions could not be drawn without performing actual evaluations. To this end, a new prototype suitable for usability evaluation has been developed during the 3<sup>rd</sup> year, and a formal evaluation has been performed with domain experts (ATM researchers) and users (controllers).

The usability evaluation of the MCD described in sections 3 and 4 was the first iteration of phase V2.

#### **6.1.4 V3, V4 and V5 – Integration, Pre-Operational and Implementation**

Integration in pre-industrial prototypes and further development cannot begin until the feasibility of the MCD concept has been fully proven at the end of phase V2. Nonetheless, it is worth considering at this point how these stages would be undertaken. Phase V3 is built upon the outputs and the knowledge gained from V2, so it is important that the products of these phase are later useful.

One way to maximise the reusability of the work from V2 to V3 and later is Model-Driven Engineering (MDE): by basing the development in domain-specific models that may be realized in different software systems, it is possible to reuse a formalized conceptual framework along the different phases of a concept from prototyping to production environment.

## **6.2 Further Development of the MCD Concept**

### **6.2.1 Pending efforts for V2**

The results so far obtained from the feasibility study of the MCD are promising, but as stated above important issues still remain to be solved. The software platform that has been so far developed has proven to be useful for the evaluation of several usability aspects of the system, but it is clear that testing in a more realistic and complex environment will be also needed. In that sense, the remaining efforts to prove the feasibility of the concept can be divided in two groups:

- Those that can be done with the current evaluation platform: iterative refinement of the display in order to determine its final aspect (symbolism, look and feel), algorithms (de-cluttering, visualization of different restrictions) and interaction (user inputs, inter-display communication).

- Those that require a more complete simulation environment: analysis of the performance and interactions in realistic ATM scenarios that represent the actual work of a team of air traffic controllers.

The effort required to integrate an MCD prototype in a high-fidelity simulation and testing environment is large, but it is clear that it is necessary to prove the feasibility of the concept. In order to maximise the returns of this work, the simulation platform should be chosen so that it can easily evolve into a pre-industrial prototype during V3, for instance by using MDE.

It must be also pointed out that the improvement of the GUI aspects of the MCD could potentially be done in parallel with the development of a new software platform. Due to the cost and difficulty to secure domain experts and prospective users for evaluations the software development iterations for the display mechanics may be slow.

### **6.2.2 Addressing the stakeholder's needs**

A different aspect that requires effort is the analysis of the MCD concept regarding the different actors that would be involved in its possible evolution into an operational implementation. E-OCVM recommends the so-called Case Based Approach, which consists on identifying key stakeholders (operators, users, regulators...) and structuring the work in specific cases (usability, technology, safety...) that address their particular questions and requirements. This systematic approach should reduce uncertainty and allow stakeholders to take well informed decisions.

In this regard, the work done so far has been centred in a single stakeholder, the end user (air traffic controller) and in the usability case. It must be noted that technological experts have also been interviewed, but no analysis of their specific needs has been performed.

In order that the feasibility analysis (phase V2) can be completed, further work is necessary to identify all the interested or concerned parts in the development of the MCD concept. Next, the needed information cases (technology, regulations, safety...) should be formally defined so that they will drive the information requirements of the phase. Only when the questions of all the key stakeholders have been satisfactorily answered can the integration phase (V3) begin.

### **6.2.3 Simulation Platform**

As mentioned in Section 6.2.1, in order to progress in the evaluation of the MCD concept it is necessary to integrate a prototype of the system in a more sophisticated ATM simulation and experimentation platform and to conduct exercises with the new display integrated in a realistic CWP.

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Several industrial ATM simulation environments exist. Among them, this section will briefly describe ESCAPE and ATRES as two possible platforms that could be used to validate the MCD concept. These were the two platforms selected for CWP evaluation in the AD4 project (see). The MCD evaluation platform developed in the “3D in 2D” project is already integrated with the AD4 system, and this will ease the interaction with any of these two simulation platforms.

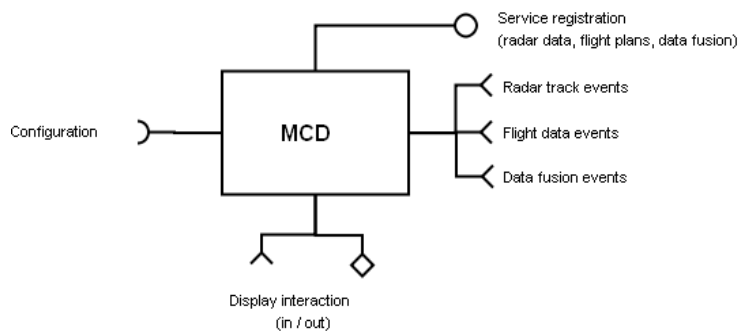
### ***6.2.3.1 Integration with ESCAPE***

The EEC’s ATC real-time simulator ESCAPE (EUROCONTROL Simulation Capability And Platform for Experimentation) is a system that emulates an ATC/ATM environment with the air traffic controller as the main player. It provides a complete simulated environment and the possibility to connect to live data. The ESCAPE platform allows the simulation of En-Route and Approach ATC Units.

The simulator can be used, among others, for the validation of platform components and for the prototyping of controller HMI. The EONS (EUROCONTROL Open and Generic ATC Graphics Systems) component, responsible for the simulation of the CWP, is the one that would integrate the MCD prototype.

ESCAPE uses CORBA-CCM as its middleware solution that enables the interaction of different components and systems. The CORBA standard enables heterogeneous software components to work together regardless of platforms or implementation languages. CCM augments CORBA with an application framework that handles services such as notification, authentication, persistence or transaction management, which helps to reduce the complexity of the application logic.

The current MCD evaluation platform was designed with interoperability in mind, and it also uses CORBA as middleware platform. It is in fact thanks to CORBA that the prototype of the MCD graphical display, written in C# and running in Microsoft’s .NET platform, communicates with the AD4 Server and Radar Display applications which are written in C++. Figure 6.3 below displays the structure of the current MCD prototype in terms of CORBA-CCM.



**Figure 6.3 – Component model of the MCD**

It must be pointed out that, although CORBA-CCM is a standard, some incompatibilities among different vendors' implementations exist. In order to integrate an MCD prototype with ESCAPE a compatibility analysis would be required. However, the compatibility issues affect only the CCM part of the specification, so a solution based on plain CORBA would be always possible.

ACE (AVENUE Compliant ESCAPE) is a version of the ESCAPE platform compatible with the AVENUE architecture and logical model. AVENUE defines a set of interfaces and data dictionaries that has been agreed among different key actors (service providers, suppliers, researchers) in the ATM domain.

The current MCD evaluation platform uses CORBA interfaces based on AVENUE for the communication among its distributed components. This strategy was chosen to balance the solid design base provide by AVENUE and the lower implementation effort of a simplified solution. However, the transition from this ad-hoc solution to the AVENUE interfaces is possible, and it would enable the MCD prototypes to interact not only with ESCAPE but also with other systems that support AVENUE.

In particular, the MCD prototype should make use of the following AVENUE modules (possibly among others):

Controller Working Position (CWP): interactions of the controllers with the system

Air Surveillance (AS): radar surveillance data

Flight Data Processing and Distribution (FPDP): flight plan data

In order to perform evaluations, it must be taken into account that the ESCAPE platform is only available in limited locations. This means that the adequate access to the facilities, either locally or remotely through a secure gateway, should be considered when planning any feasibility study or validation exercise using ESCAPE.

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### 6.2.3.2 *Integration with ATRES*

The ATRES (Air Traffic Environment Simulator) system is an ATM simulator for controllers training and systems testing developed by Vitrociset. It can simulate combined air-ground traffic scenarios and reproduce a control tower environment, and it provides facilities for training and testing like a pilot position.

ATRES is a distributed system that uses TCP/IP sockets for communication. The integration of the MCD prototype would require an interface layer to adapt its internal data representation. The ATRES system supports the ASTERIX (All purpose STructured EUROCONTROL suRveillance Information eXchange) format to exchange surveillance data. (Rozzi et al., 2007)**Error! Reference source not found.** describes an example of how it was possible to integrate a system like AD4 with ATRES using an adaptor gateway.

An important advantage of ATRES for the purposes of performing user evaluations is that a portable version of the system exists. This version, originally developed for controller's self-training, can be run in a laptop computer and includes a voice recognition functionality that can replace to some extent a human acting as a pseudo-pilot. Although it is not known if this system would be compatible with an MCD prototype, it's certainly a possibility worth to explore.

### 6.2.4 **Model-Driven Engineering**

Model-Driven Engineering (MDE) is an approach to building software systems that focuses on creating domain-specific models of an application which are independent of an implementation platform. The Model-Driven Architecture (MDA), developed by OMG, is the best known methodology for MDE. It explicitly distinguishes between PIM (Platform Independent Models) models and PSM models (Platform Specific Models). PIM models encompass the functional logic of a system while PSM models represent target platforms specific elements.

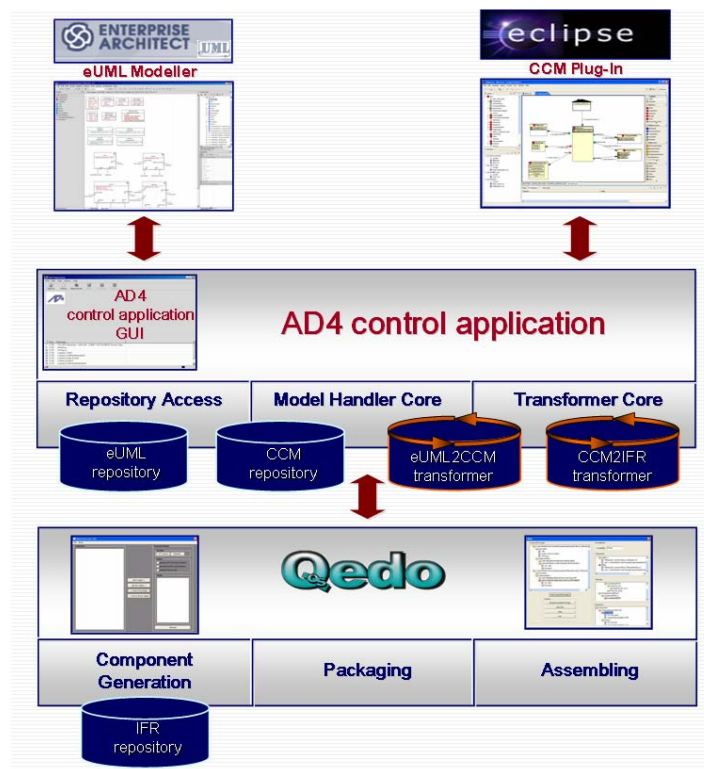
The aim of MDE methodologies is to make the application logic and the implementation details independent of each other, and let them evolve at its own pace and adapt to the business needs or the evolution of the computing platforms.

Safety-critical software systems can benefit greatly from an MDE approach to development. In a business application it is positive if changes in the business logic do not affect the platform-specific elements. In a safety-critical system, it also means that the platform-specific elements will not need to be certified again for compliance with the safety requirements after the change.

In the case of the MCD concept, the adoption of a MDE methodology already in the prototyping phases might be useful. Such approach would make possible to address first the non-critical issues of the application logic and presentation, and later integrate the MCD into a critical environment without having to rebuild the application logic and validate it again.

The adoption of MDE methods may have an important upfront cost in terms of development effort. Nevertheless, once the first prototyping and evaluation exercises with the MCD have shown some potential in the concept, it must be considered if adopting MDE practices already in the feasibility study phase (V2) will reduce the cost of later stages of the concept lifecycle.

One requisite for successful use of MDE methodologies is an adequate tool support to transform the application models into source code and allow round-trip, i.e. reflect changes in the code into the models. (Spa, 2006) describes the tool chain used for MDA development in the AD4 project, which is summarized in Figure 6.4.



**Figure 6.4 – Overview of the AD4 tool chain**

The AD4 tool chain displayed in Figure 6.4 is composed of:

- eUML Modeller (plug-in for Enterprise Architect): modelling tool

- Eclipse CCM Plug-in: complementary modelling tool for model edition, used for issues foreign to the application model such as deployment or security details
- AD4 control application: manages the model repositories and transformations, from eUML to CCM, and from CCM to IFR (format used by Qedo)

Qedo: an ORB (Object-Request Broker) that supports CORBA-CCM

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