Abstract

In the future, en-route air traffic controllers will have to safely manage increasing numbers of aircraft. To this end, understanding air traffic by constructing a mental picture is a key stage in controller work, since it helps increase their capacity for anticipating and predicting the movement of aircraft. The quality and speed of construction of the controllers’ mental picture of air traffic depend on how the information is presented. This was the basis for an experiment conducted at the EUROCONTROL Experimental Centre to test and validate a method of presenting information on the route part of the flight plans based on a time-line. The concept, known as Dynastrip, involves positioning navigation beacons chronologically and displaying their estimated overflight times on a time line. The time line has a fixed reference point, i.e. the current time. The estimated overflight times for the beacons are updated on the basis of radar data. With this presentation method, the controller can at any time see, without having to make any calculations, the present and future positions of the aircraft in relation to the beacons and among themselves. 16 operational en-route controllers and 16 student controllers took part in the experiment, which involved comparing Dynastrip with the traditional method of presenting information in tests involving traffic analysis, integrating aircraft and locating aircraft in space. Measuring performance as regards analysis time, conflict detection and number of errors, as well as interviews with the subjects, demonstrate that Dynastrip has considerable potential for improving the mental air traffic picture of controllers.

Introduction

The principle of presenting flight plan data on a time line was proposed at the beginning of the 1970s by Nobel and Spérandio [1]. Taking up these ideas, the "Innovative Research" business area of the EUROCONTROL Experimental Centre discovered that this concept had promising functional potential for the development of new ATC tools to improve the mental picture of controllers. This potential seems to be even more considerable given the current progress of information technology, which allows powerful interaction tools to be associated.

Presenting flight plan data to controllers is no straightforward matter. As mentioned by Bisseret [2], air traffic controllers do not have direct access to the physical world encompassing the process they have to monitor. The mental picture enabling them to understand the situation and take the decisions required for effective air traffic management is constructed on the basis of systems with interfaces which present them with information that they have to process and prioritise. Both the choice of information presented and the way in which it is presented are factors which influence how controllers build their mental picture.

At present, time information relating to the flight plan is presented for each beacon, irrespective of the support used. The hypothesis used in the experiment conducted at the EUROCONTROL Experimental Centre was that presenting flight plan information on a time line would make it easier to analyse and understand air traffic. The concept, called "Dynastrip", involves presenting beacons on the route of the flight plan and the estimated arrival times by means of a dynamic time line updated regularly on the basis of radar data.

This paper sets out the data gathered in an initial operational validation of the Dynastrip concept. The paper has three separate sections:

• the first part discusses the theoretical concepts of mental representation and how they are associated with the ways in which ATC information is presented,
• the second part describes the experiment conducted at the EUROCONTROL Experimental Centre with operational controllers and student controllers,
• the third and final part reports presents the results and conclusions of the experiment.

Understanding is Related to How Information is Presented

Mental Representation

It is by building a mental picture that we understand what is going on [3]. In occupational psychology and cognitive ergonomics, Ochanine [4] introduces the concept of the operative image to describe the specialised information structures which form in the course of action towards a given goal. Leplat [5] who looked at the activity of operators in work situations, refers to these structures as functional representations. Functional representations facilitate planning and guide action. They comprise a figurative aspect, which characterises how the various statuses of the situation are represented, and an operative aspect corresponding to its various transformations. Functional representations can differ between operators even though they are functionally equivalent, since they depend on their knowledge and experience. When subject to time constraints, Leplat describes a reduction in representation, which can be attributed to two mechanisms: (i) only the most important elements of the situation are taken into account, and (ii) subjects refer to simpler and more familiar representations.

The mental model concept developed by Johnson-Laird [6] in studies on text comprehension is particularly interesting. It incorporates the dynamic aspect of how the model is constructed and constantly updated on the basis of new proposals gleaned from reading the text. The mental model is a representation which is formed when the individual interacts with the world (Norman, 1983) and which is valid only for the time needed to process the situation. It is a dynamic process which evolves by integrating, constructing and incrementing the information present in the environment. The mental model associates perception and reasoning by allowing an image to be built up which serves as a basis for reasoning and comprehension. The subject’s comprehension has to be consistent with how the environment is evolving and plausible in terms of his knowledge of the world. Ehrlich and Tardieu [7] demonstrate that comprehension depends on the subject’s knowledge, but also that in the same situation, the objectives pursued by the subject lead to different cognitive and semantic structures, which define the degree of comprehension. But as Denis and deVega [8] stress, comprehension does not require a totally equivalent model of the situation - an abstract and simplified representation can be sufficient, depending on the subject’s objectives.

Air Traffic Control

In the construction of a mental picture of air traffic, information is the reflection of the environment and its dynamics. The quantity of information, its nature, its accuracy, and also how it is presented, will have a direct impact on the controller’s mental representation. Thus, Bisseret’s work on controller representation shows that controllers have recourse to two types of mental operation to construct their mental pictures of traffic on the basis of the information support they have available: logico-mathematical operations for alphanumeric symbolic information (e.g. on the existing paper strips) and perception operations associated with analogue intermediaries such as radar. These two information systems each have their advantages and disadvantages:

• The logico-mathematical system is based on the application of algorithms which have an associated time and cognitive cost, but which do not have an inherent element of uncertainty, if the information is valid. However, the safety margins (separation criterion between aircraft) allowed for such logico-mathematical operations are large and cannot easily be reconciled with an increase in traffic density.
• The perceptive system uses a system of coding which is closer to the operator's mental representation. But unlike the logico-mathematical system, perception operations are "vague" and "risky" because they force controllers to manage their own uncertainty. However, the information is more accurate,
which makes it possible to apply smaller separation standards between aircraft.

In practice, these two systems are complementary in the majority of existing control situations. They account for the high level of performance and safety in air traffic control. Controllers constantly have two complementary information presentation systems. They can compare them, but they can also prefer one system or the other, depending on the control situations encountered. However, they appear to be stretched to the limits when controllers have to cope with denser traffic and still maintain current safety levels.

With Dynastrip, it is proposed to introduce a method of analogue presentation of information on the route part of the flight plan and on such predictions as can currently be made on the strips. The analogue method selected is time. This choice was made on the basis of the cognitive constraints of air traffic control, in particular those relating to anticipation and planning. Time deadlines are essential markers of control activity since they make it possible to identify future events with a view to preventing dangerous situations and preparing conditions conducive to the movement of air traffic [9]. By proposing a method for the representation of air traffic movements based on time, we are assuming that this makes it easier for controllers to construct a more relevant mental picture of the air traffic and its development. This approach provides cognitive assistance to the operator by pre-processing information which is in a form directly compatible with the controller’s mental picture [10], and which facilitates the management of uncertainties and risk [11]. Thus, the advantage of Dynastrip is to introduce a symbolic method of representing information on the route part of the flight plan, which is different from that used in conjunction with radar in order to make extrapolations in time.

The “Time-Line" Support: Dynastrip

Information presented on the route part of the flight plan is currently presented in en-route control centres on paper or in electronic form, in boxes. Irrespective of the characteristics of the various en-route control centres, the following boxes are generally used (e.g. Figure 1):

- An "identification" box, showing the aircraft callsign, transponder code, speed, aircraft type, aerodromes of departure and destination, etc.
- A series of boxes available for levels (Aircraft Flight Level, Cleared Flight Level, Exit Flight Level, etc.).
- A series of boxes to designate the route followed by the aircraft, comprising a series of beacons printed successively with the estimated times over (ETOs).

![Figure 1. Current Presentation of Information from the Flight Plan](image1)

The Dynastrip is identical to the previous strip as far as the identification boxes and flight levels are concerned. However, the beacons are no longer presented in the boxes showing the ETOs. They are presented on a time line, calibrated in minutes (e.g. Figure 2). The point of reference for the time line is a fixed point on the strip which corresponds to the present time (current time). The fixed reference point is situated on the left of the time line. Beacons are positioned on the time line according to their ETOs, which are determined from radar coverage at the current time. All the strip time lines indicate the current time for reference. Beacons are displayed chronologically, i.e. in the direction of flight. All the time lines and beacons move towards the fixed reference point as the aircraft advances.

![Figure 2. Dynastrip](image2)
**Functional Characteristics**

Consequently, the processing mechanisms for the information presented on a Dynastrip go beyond simple acquisition of information and speed of reading. They relate to the very nature of the mental operations that this method of representation encourages. The result of such processing should mean that the way information is presented is closer to the mental picture of the controllers than current methods permit.

Functionally speaking, Dynastrip has the following characteristics:

- The gaps between beacons conform strictly to the time taken to travel the corresponding distances.
- A column corresponds to a given time in a Dynastrip table, whereas the position of beacons in a column has no particular significance in the case of traditional strips.
- Dynastrip provides an isomorphic representation of the space travelled as a function of time, unlike the pseudo-isomorphic geographical representation of the traditional strips.

A Dynastrip board (e.g. Figure 3) makes it possible to predict the future progress of flights without calculations, which in itself simplifies analysis and comprehension. On a single column, it is possible at any time to know, without calculation, the relative and future positions of the various aircraft. Controllers have an overview of air traffic movement, which must improve their comprehension of traffic and therefore their corresponding mental picture. Depending on the time scale selected, controllers can thus have an air traffic movement anticipation aid of more than 40 minutes.

**Conflict Identification**

Conflicts are identified on the basis of the current and future relative positions of aircraft in relation to the characteristic navigation points. Comparing the vertical alignments of the aircraft times gives the control a direct view of the relative positions of the various aircraft at a given moment in time. If the same beacon appears in a single column, this means that the aircraft will be there together at the same time. For aircraft at the same level or with vertical separation lower than the minima selected, simultaneous positions over the same beacon or with a time spacing lower than the standards selected allow a conflict to be diagnosed between the aircraft. It is possible to define various conflict search algorithms, depending on the nature of the conflict:

- Merging conflicts for aircraft at the same level are shown when a single beacon is vertically aligned for aircraft with crossing tracks.
- Opposite conflicts are indicated by a reversed order of identical beacons. Vertical overlapping of all or part of the common segment indicates that the aircraft are, or soon will be, on this route segment at the same time.
- Overspeeding conflicts are indicated by a sequence of identical beacons route segments vertically overlap wholly or partially at a given moment. It is identified by identical beacon sequences which overlap, while the intervals between the beacons are shorter for at least one of the aircraft. An aircraft which has passed a beacon on the route ahead of a given aircraft is to be found over the following beacon at the same time or after the other aircraft.

![Figure 3. Dynastrip Board](image-url)
**Experiment**

The objective of the experiment is to validate the usefulness of a time-line presentation of information on the route part of the flight plan, while demonstrating that:

- Dynastrip facilitates comprehension of air traffic which is as operative or even better than with traditional presentation tools;
- Dynastrip makes it possible to detect conflicts at least as well as with traditional presentation tools;
- Safety can be at least the same, or even better with Dynastrip for high traffic.

The experiment involves comparing the results of subjects undergoing tests of analysis and comprehension of air traffic both with traditional strips and with Dynastrip. The experiment was conducted in a static way, with paper support.

The experiment subjects are operational controllers at a French en-route control centre (Brest) and student controllers at the Ecole Nationale de l’Aviation Civile Française (ENAC - French Academy of Civil Aviation). The reason for selecting operational controllers was to subject Dynastrip to operational expertise and to the constraints of current air traffic control. Broadly speaking, we expected controllers to be in a position to judge Dynastrip and determine whether it could be transferred into the operational environment. Student controllers were chosen to evaluate how easily Dynastrip could be learnt and whether it could be adapted to the principles of air traffic control without needing too much operational experience. These two expert appraisals are different, but complement each other in the evaluation process.

In order to be able to compare the results for operational controllers and student controllers, the experimental operational support was devised in such a way that the operational knowledge of the en-route centre controllers (operational know-how, knowledge of airspace and familiarity with traffic) could not constitute an advantage in their traffic management. It was therefore ensured that the operational environment met operational criteria, but that the operational elements did not correspond to existing airspace realities or to current traffic. Thus, the control sector and airways differed from what currently exists, but was consistent as regards traffic flows. The beacons were existing beacons, but there were fewer of them. Lastly, the aircraft callsigns did not correspond to existing callsigns. On the other hand, each type of aircraft was known to the controllers. It is quite clear that this limitation on the experiment changed the way the operational controllers worked, since their knowledge of airspace and air traffic is a source of information which complements the other sources of information on the strips or from the radar. However, it was the only way of creating equivalent experimental situations from the point of view of expertise for both groups of subjects.

The control sector is in the north-west quarter of France (e.g. Figure 4). It is 170 NM long (north-south) and 110 NM wide (east-west). A major feature of the sector is the Chartres beacon (CHW), which is in the centre of the sector and is the area of convergence of the south-north and west-east flows. The sector goes from FL 195 to FL 340. Aircraft are in level flight and presented in series of even levels (Reduced Vertical Separation Minima on a network of specific routes). A conflict is considered to exist between two aircraft at the same level when they have separation of less than 5 minutes.

![Figure 4. The Experimental Airspace](image)

5.E.1-5
**Experimental Tests**

There were three tests:

- Analysis of two boards of 15 strips and identification of the potential conflicts. The number of aircraft selected (15) may appear quite high, but this number was chosen to assess Dynastrip in a heavy traffic situation in order to judge its potential for allowing traffic load management which is compatible with the forecast increase in air traffic. This test involves, in terms of cognitive activity, comprehension of traffic and the diagnostic processes used to determine whether or not there are current or future conflicts and if so, which aircraft are involved.

- Integration of strips into the air traffic. The test is repeated with four strips representing different types of problems. It involves updating a mental picture and the associated diagnostic processes.

- Locating aircraft on a radar image on the basis of the strip information. This test is repeated with three different aircraft. It requires an ability to spatialise information on the basis of alphanumeric or analogue symbolic data.

Each subject takes a test with the current information presentation method and another with Dynastrip. At the beginning of each test, subjects are trained in the use of Dynastrip for around 45 minutes. The entire experimental session lasts around 90 minutes for each subject. The subjects analyse the air traffic solely using strips. Radar is used only in the third test, in which the aircraft is located on the basis of the flight plan information.

All the equipment and experimental trials were tested and validated by skilled controllers from the EUROCONTROL Experimental Centre in advance of the test sessions with the operational controllers and the student controllers.

**Variables**

The independent variables are:

- The time taken by the subjects to analyse the situations presented.
- The quality of the answers provided: correct diagnoses and errors.
- The opinions of the subjects as recorded in the debriefings.
- Locating aircraft on a radar image on the basis of the strip information. This test is repeated with three different aircraft. It requires an ability to spatialise information on the basis of alphanumeric or analogue symbolic data.

**Plan for the Experiment**

For each group of subjects (16 controllers, 16 student controllers), the subjects take the tests according to a set plan - a Latin square (e.g. Figure 5): two groups of eight subjects (G1, G2), two information presentation methods (P1 for the traditional method and P2 for Dynastrip), two traffic samples to avoid a learning effect between the two series of successive tests (E1 and E2). Each group successively takes tests using the two information presentation methods, but in reverse order so as to counterbalance the effect of test order.

<table>
<thead>
<tr>
<th></th>
<th>G1</th>
<th>G2</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>E1 (8 subjects)</td>
<td>E1 (8 subjects)</td>
</tr>
<tr>
<td>P2</td>
<td>E1 (8 subjects)</td>
<td>E1 (8 subjects)</td>
</tr>
</tbody>
</table>

Figure 5. Plan for the Experiment
Results

Analysis Time and Errors

For the "board analysis" and "strip integration" tests, there is no significant difference (Anova, p<0.05) between the two presentation methods as regards analysis time and the number of errors made (e.g. Tables 1 and 2). There is, however, a tendency for controllers to take longer to analyse the situations with Dynastrip, but on the other hand they make fewer errors. There is no correlation between analysis time and number of errors made, irrespective of the presentation support (z=0.19; p=0.13).

Table 1. Results of Board Analysis

<table>
<thead>
<tr>
<th>Analysis of subjects</th>
<th>ATCOs</th>
<th>Senior</th>
<th>Students</th>
<th>Probability (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>71.94 sec.</td>
<td>82.05 sec.</td>
<td>69.12 sec.</td>
<td>p=0.43</td>
</tr>
<tr>
<td>Dynastrip</td>
<td>71.94 sec.</td>
<td>82.05 sec.</td>
<td>69.12 sec.</td>
<td>p=0.43</td>
</tr>
<tr>
<td>Probability (ANOVA)</td>
<td>p=0.32</td>
<td>p=0.27</td>
<td>p=0.59</td>
<td></td>
</tr>
</tbody>
</table>

As far as difficulties experienced with the integration of aircraft (number and nature of conflicts to be identified) were concerned, the results for the number of errors made for the aircraft which were most difficult to integrate were significantly, but not consistently, better with Dynastrip (Anova). This was not the case for aircraft which were easier to integrate.

The comparison between operational controllers and student controllers shows that the analysis time results for Dynastrip were significantly better for the student controllers. The student controllers also make fewer errors with Dynastrip than the operational controllers, but the difference is not significant. In the case of the traditional strips, there is no significant difference between operational and student controllers. The student controllers analyse more quickly, but make more errors.

In the "identification" test, more precise diagnoses were made with Dynastrip (e.g. Table 3), although the result was not significant (p<0.05). Similarly, analysis times tend to be better with Dynastrip, unlike the “board analysis” and “integration” tests.

Table 3. Results of Aircraft Identification

<table>
<thead>
<tr>
<th>Average of subjects</th>
<th>ATCOs</th>
<th>Senior</th>
<th>Students</th>
<th>Probability (ANOVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>86.97 sec.</td>
<td>94.94 sec.</td>
<td>79.09 sec.</td>
<td>p=0.47</td>
</tr>
<tr>
<td>Dynastrip</td>
<td>66.97 sec.</td>
<td>84.94 sec.</td>
<td>79.09 sec.</td>
<td>p=0.36</td>
</tr>
<tr>
<td>Probability (ANOVA)</td>
<td>p=0.04</td>
<td>p=0.14</td>
<td>p=0.06</td>
<td></td>
</tr>
</tbody>
</table>

There is no significant difference (Anova) in the errors made in the detection of convergence and head-on conflicts (e.g. Table 4). There is, however, a tendency to make fewer errors with the Dynastrip support, irrespective of the subject group. As far as gaining conflicts are concerned, there is a significant difference (p=0.002) in favour of Dynastrip as regards the number of errors made. Lastly, the results are significantly better (p=0.03) for Dynastrip as regards the number of false conflict detections.

It is noted that the results for the student controllers, although not significant, are better than those for the operational controllers with the Dynastrip support, while the reverse is true with traditional support.

Table 4. Errors in Error Detection

<table>
<thead>
<tr>
<th>Number of errors</th>
<th>ATCOs</th>
<th>Senior</th>
<th>Students</th>
<th>Probability (Chi2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Merging</td>
<td>Traditional</td>
<td>27</td>
<td>33</td>
<td>14</td>
</tr>
<tr>
<td>Opposite</td>
<td>Traditional</td>
<td>67</td>
<td>74</td>
<td>32</td>
</tr>
<tr>
<td>Head-on</td>
<td>Traditional</td>
<td>53</td>
<td>62</td>
<td>39</td>
</tr>
<tr>
<td>Probability (ANOVA)</td>
<td>p=0.43</td>
<td>p=0.47</td>
<td>p=0.77</td>
<td></td>
</tr>
</tbody>
</table>

An analysis of the results on false conflict detections shows that Dynastrip has significantly better results (Chi2, p=0.03) with fewer false detections (e.g. Table 5). The student controllers have better results than the operational controllers with Dynastrip.
Table 5. False Conflict Detection

<table>
<thead>
<tr>
<th>Number</th>
<th>ATCOs</th>
<th>Senior Students</th>
<th>Probability (Chi2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>29</td>
<td>18</td>
<td>11</td>
</tr>
<tr>
<td>Dynastrip</td>
<td>15</td>
<td>14</td>
<td>1</td>
</tr>
</tbody>
</table>

Results of the Interviews

Analysis of the subjects’ opinions makes it possible to identify the following points:

- All the subjects are in favour of Dynastrip and consider this alternative way of presenting the data relating to the en-route part of the flight plan to be useful. Dynastrip’s analogue characteristics would seem to represent a useful advance in the understanding of air traffic and detection of conflicts. Although it was not possible to explore Dynastrip’s dynamic characteristics in the experiment, the subjects as a whole were never in a position where lack of comprehension prevented them from analysing air traffic and carrying out tests.

- The use of Dynastrip requires the implementation of specific air traffic comprehension and conflict identification procedures. However, the operational controllers are more prudent than the trainee controllers regarding the final validity of the concept. Without calling Dynastrip into question, they consider that a dynamic simulation is required for a genuine understanding of its pros and cons.

- The controllers particularly stressed that it is essential for there to be complementarity between a general information processing level based on flight plan data and controllers’ knowledge of the sector and air traffic flows, and a local processing level based on data presented on Dynastrip in order to be able to analyse and carefully resolve problems. This complementarity is vital in order to ensure optimal management of cognitive resources where traffic is high by setting processing priorities.

- Alignment of the time bases makes it possible to have immediate access, without complex processing, to a reference frame common to all aircraft, hence facilitating traffic management. The subjects, and in particular the trainee controllers, said that they had a better mental image of air traffic with Dynastrip, particularly in terms of the presentation of changes in air traffic. The colouring of the sector facilitates the presentation of inbound traffic with its timeframes, which helps the controllers plan their own work.

- On conflict detection, the consensus between the two groups of subjects is that Dynastrip would appear to be useful for steady aircraft in cruise. Regarding conflict types, merging detection would appear to be easy with Dynastrip, but the controllers mention that the traditional display support tool is just as straightforward. In the case of opposite and overspeeding conflicts, the consensus of the trainee controllers is that detection is easier with Dynastrip. The extrapolations required for their detection are simpler and, above all, can be carried out more quickly than with the traditional support tool. The operational controllers expressed more mixed feelings, with no consensus, although none of them found Dynastrip to be worse than the traditional support tool.

- In terms of mental anticipation, the spatialisation of air traffic components and airspace gave the subjects the impression that anticipating future traffic developments was easier. This anticipation covers both the assumption of responsibility for inbound traffic and medium-term changes in aircraft trajectories. Although complementarity with radar was not tested, several subjects (particularly amongst the operational controllers) see greater anticipation as an element which will
At this stage of the analysis, account must be taken of the degree of the subjects’ familiarisation with both methods of presentation. Even without quantifying this degree of familiarisation, it is possible to say that in terms of experience in the use of the two types of support, there is a major difference between the traditional support tool and Dynastrip. This difference is more marked for the operational controllers, who have several years’ experience of the current support, than for trainee controllers, who have only a few months’ experience. The experience of the subjects as a whole with Dynastrip is limited to this experiment. This bias was identified at the very start of the experiment, but proved impossible to avoid. One can therefore hypothesise that greater familiarisation with Dynastrip might produce better results than with the traditional support by accentuating the tendencies observed. On the other hand, it is harder to ascertain whether a significant difference would emerge in favour of Dynastrip.

Discussion

As regards the results, there is no significant preference for one or other of the methods for presenting flight plan data. This lack of preference applies to both subject groups: operational controllers and trainee controllers.

These results make it possible to say that there are no factors militating against Dynastrip. At worst, performance and safety are the same as for the traditional strips. However, a tendency to make fewer errors with Dynastrip has been identified, while analysis times seem shorter than with the current method of presentation. The trainee controllers achieved better results than the operational controllers with Dynastrip. The advantages of Dynastrip are more marked in the case of complex situations, particularly when new aircraft are integrated. For example, in the case of problems relating to aircraft moving against the flow of traffic and the detection of conflicts where one aircraft is gaining on another, Dynastrip would seem to have greater safety potential than the traditional method of presentation.

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The subjects, and in particular the trainee controllers, see Dynastrip as constituting a clearer and more meaningful method of presentation when it comes to identifying the relative positions of aircraft on beacons and detecting conflicts. The terms used by the subjects to describe Dynastrip refer to the mental image of air traffic and its development. For example, the terms "intuitive" or "obvious" reflect the effectiveness of Dynastrip’s pre-processing of raw data, and the closeness between the representation of the situation provided by the information support and the operative representation of the controller, which encourages anticipation and forecasting of air traffic changes. The benefits of Dynastrip are not limited to the simple collation of data and speed of reading. They relate to the very nature of the mental processes favoured by this method of presentation.

As a result, Dynastrip facilitates the air traffic comprehension (tendency towards better analysis times and greater accuracy in the “identification” test). The construction of the representation of changes in traffic is of higher quality with Dynastrip (tendency towards fewer errors in the "analysis" and "integration" tests) but requires a greater mental effort (tendency towards longer analysis times). This may seem to contradict the opinions of the controllers, who see Dynastrip as a
tool facilitating the development of their representation. This feeling of facilitation is probably the result not of the use of the cognitive processes necessary for the tasks to be carried out, since the subjects are not very familiar with these, but of the feeling of confidence or comfort afforded by Dynastrip regarding the validity of the mental representation. In this respect, Dynastrip actively contributes to comprehension of the situation [12] and can be envisaged as an important safety tool.

Dynastrip was developed on the basis of an analogue representation. The strategies developed by some operational controllers show that it is also possible to work using a logico-mathematical method. This method, more expensive than the perceptive method, is interesting because it constitutes a redundancy which may be of help in the event of difficulty in comprehending air traffic. The redundancy is in addition also useful in that it gives the controllers greater leeway for adjustment in their work, and allows them to be more effective in helping maintain safety. Dynastrip would therefore seem to be a method of data presentation which combines analogue and symbolic characteristics allowing perceptive operations (typically associated with radar work) and logico-mathematical operations (typically associated with traditional paper strips).

Conclusion

In order to improve the controllers’ mental image of en-route air traffic, testing of a method for presenting data relating to the en-route part of the flight plan using a time-based approach was carried out using a static paper simulation for operational controllers and trainee controllers. Despite the limitations of the test, the results would seem to militate in favour of the continued development of such a concept. Dynastrip presents data to the controllers in a form which enables them to construct a more relevant mental image of air traffic in a shorter time. By facilitating the controllers’ mental image, it allows them to work with greater anticipation, making it possible to manage heavy workloads more easily and safely. These results will of course need to be confirmed by dynamic simulations in complex air traffic control and management environments. Initial tests carried out at the time of the preparation and validation of this dynamic simulation platform confirm that controllers are afforded maximum anticipation in the prediction of changes in traffic and detection of potential conflicts. However, these initial results still have to be validated in tests, which will be done in the next phase of the study programme. Pending these results, it would appear that the concepts applied in Dynastrip for the presentation to controllers of data relating to the en-route part of the flight plan will, together with other resources, be of undoubted benefit in meeting the safety constraints linked to the increase in air traffic.

References


