INTEGRATION OF DOWNLINK AIRCRAFT PARAMETERS IN A FRENCH EN ROUTE ATC CONTROLLER WORKING POSITION

Vincent Kapp
DSNA – Toulouse, France
Sous Direction pour les Etudes et la Recherche – formerly CENA
vincent.kapp@aviation-civile.gouv.fr

Abstract

The purpose of the Downlink Aircraft Parameters (DAPs) study is to evaluate and compare different implementations of DAPs in terms of access and visualisation in an ATC En Route HMI. Although there have been numerous studies on the DAPs, most of them address cost/benefits issues [1][2]. The originality of our work relies mainly on the following points:

- The DAPs addressed here are directly used by the controllers,
- The study focuses on the En Route context,
- The study aims at giving very practical recommendations (the DAPs will be used in the French operational environment soon).

The study is divided in two principal parts. In the first part we focus on the controller needs. Then, in the second part, we perform comparative evaluations of several proposals of DAP integration in an ATC En Route HMI.

The results obtained enable us to make recommendations to the DNA technical service in charge of the system specifications. We do not point out a "good solution", but rather recommend a mixed implementation.

Introduction

The DAP application consists in aircraft internal information captured in real time on the ground thanks to the Mode S Enhanced Surveillance. Its principle is to use selective interrogation of Mode S equipped aircraft to extract aircraft parameters for ground use (either for system purposes or controllers' direct use) [3][4]. The Mode S Enhanced Surveillance, foreseen in 2007 in France, corresponds to the second stage of the implementation of the Mode S in Europe, following the Mode S Elementary Surveillance. The studied DAPs are: the magnetic heading, the indicated air speed (or Mach number) and the instantaneous rate of climb/descent.

Our study, which started at the beginning of 2004, focuses on the implementation of the DAPs on a French En Route ATC HMI. It includes two main parts.

In the first part, we analysed the controllers' needs for aircraft parameters. A set of working hypotheses was built using classical methods in the field of operators' needs collection (questionnaires, interviews and observations). Real time simulations were then conducted to test and refine these hypotheses enabling to formalise a set of conditions that the future HMI shall comply with.

Then, in the second part, four HMI propositions were specified and implemented on an ATC simulator taking into account the data obtained in the first part and technical and operational constraints. These propositions, presenting the same level of functionality, were based on different access modes (mouse and digital screen) as well as different ways of showing the DAP information on the aircraft label or on a dedicated on screen window. Real time simulations enabled us to evaluate these solutions.

In this paper we present the two parts of the DAP study and the main results of the experiments that were conducted in the simulated environments. General methodological considerations are also presented.

Part 1: DAP needs collection

The controller's needs collection followed the following steps.

Gathering of subjective data

We gathered information about the practices and the operators' points of view about the DAPs in order to formalise a first set of hypotheses. The data collection was achieved through a questionnaire, distributed to 55 French ATC controllers currently working at ENAC (French school of civil aviation)

but who were previously working in different ATC centers. This work was completed with observations carried out in Paris ACC during a whole week.

The main limit of the method comes from the fact that the controllers currently use aircraft parameters, they ask the pilots their values via VHF. Therefore, part of their expressed needs tends to stay on the level of functionality they currently have (i.e. only what enables the VHF) and the other part is based on the operators' projection of their understanding of the application.

The following working hypotheses were formulated:

- The indicated air speed (IAS) is an interesting DAP for the controller and is useful for aircraft not on frequency yet,
- The IAS should be available only at controllers request,
- The IAS may be used to supervise an aircraft's speed evolution,
- The IAS may be monitored for several flights,
- The rough visualization of the instantaneous rate of climb / descent is not fitted for use,
- The magnetic heading is an interesting DAPs only for the aircraft that are on frequency,
- The magnetic heading should be available only at controllers' request,
- The magnetic heading may be used to supervise an aircraft evolution,
- The magnetic heading is useful for only one aircraft at a time,
- The controller will always give priority to the use of DAPs rather than request the parameters by VHF,

Evaluation of the needs collection hypothesis with real time simulations

In order to validate the hypotheses described in the previous paragraph and to refine them, we conducted real time simulations where some controllers "worked" with a basic HMI allowing them to access the DAPs.

In this part we were only looking at controllers' needs, our goal was not to evaluate any HMI choices (this is the subject of the second part of the project). We emphasized therefore this point in the instruction briefing.

Simulation setup

The experiments were conducted with a sample of 2 controllers of Paris ACC and 4 controllers corresponding to the remaining 4 ATC Centers. Therefore, two different sectors were used, a Terminal sector of Paris ACC (sector TP) for the controllers from Paris, and a more classical En Route sector (sector MF) used as a generic sector for the other controllers. We made this choice because of the singularity of traffic that can be found in terminal sectors and also because some hypotheses about the Terminal control activity had to be verified. The use of a generic sector for the other controllers enabled us to spend less time in exercise preparation.

Each controller worked on three different scenarios that presented different traffic situations that can occur in the operational environment.

With regard to the experiment objective it was not necessary to put the controllers under stress. Therefore, we used an average traffic load. This choice enabled the controllers to work more easily on a sector they were not familiar with.

Simulator

The real time simulator used for the experiments was designed as a single controller working position. The interface was rather rudimentary: a radar image duplicating the current functionalities, paper strips and an access to the DAPs, through a specific menu on a dedicated digital screen. The simulator can be seen in the following image.

Figure 1. Experimental setup for DAP needs collection

As long as the desired DAP was selected, its value was displayed on all flight labels of the radar image (all the aircraft were considered DAP-equipped). When the controller lifted his finger from the DAP button, the information was not shown anymore. The menu and the aircraft label with the DAPs can be seen on the following images:

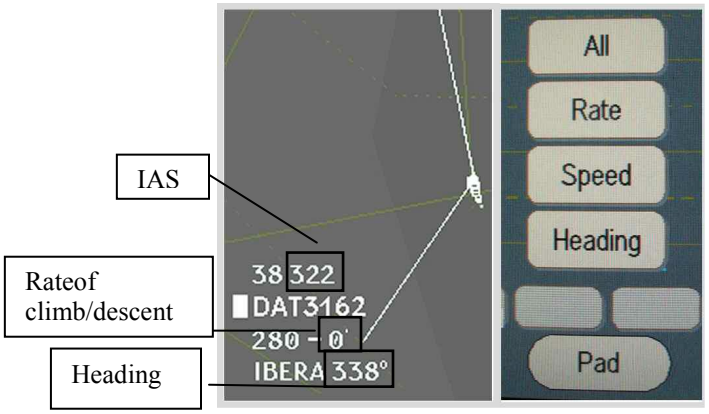

Figure 2. Interface used during DAP needs collection

Data used for the experiments

The independent variables were: the considered controller (classical or Terminal En Route), the direction given to the controllers during the experiments (to authorise or prohibit the request for parameters by voice), the type of conflicts presented to the controllers. The dependent (or observed) variables were mainly qualitative although DAP accesses were recorded. The recorded parameters were: the type of the requested DAPs, the duration of the DAP visualisation, the number of aircraft and their configuration (evolutionary or stable) involved by the request.

The automatic archive was completed with video recordings and each simulation ended with a debriefing. A final questionnaire was completed at the end of the experiments. During the simulations, an observer stood behind the controlling position. A rather intrusive methodology was applied: for every DAP request, questions were asked about the context corresponding to the request (number of aircraft, type of detected conflicts, etc.), when necessary the simulation was "frozen" in order to gather all the data. The overall collected experimental data are issued from 6 simulations per each one of the 6 controllers, that is to say 27 hours of video, 36 recorded data files, 6 questionnaires and 5 hours of debriefing with numerical support.

Results

One of our main concerns is the way the controllers use the DAPs. Whenever the controllers use the DAPs for punctual information, which corresponds to a use close to what allows the VHF, we talk of short consultations. On the opposite, when the controller monitors some of the DAP parameters, we talk of long consultations.

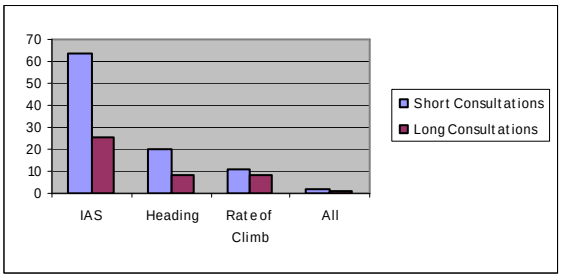

Figure 3. DAPs and type of use

The first interesting result is that DAPs are obviously used to monitor aircraft parameters. Actually, these long consultations are exclusively possible thanks to the DAPs. Without the DAPs, controllers would never congest the frequency to reach this level of functionality in the current VHF environment.

In general, the controllers need relatively short consultations in order to become acquainted with the DAPs. Finally, about 8% of the DAP consultations lasted more than 10 seconds (very few consultations lasted about 30 to 40 seconds). It should be mentioned that to make long consultations, the controllers had to keep their fingers pressed on the digital screen, position which is quite uncomfortable. Thus, some consultations were interrupted for reasons of comfort.

The subjective data show that in some cases there is a need for permanent display of speed and magnetic heading.

Concerning the rate of climb/descent there is a strong quantitative and qualitative variability throughout the experiments. Because the use of this DAP is highly dependent on the sectors' geography, the collected data do not enable us to make any general statement on the rate of climb/descent controllers need.

The controllers often used consultations when they thought something unusual was happening. In that case, the DAPs provided them with information that clarified the situation.

As it appears in figure 3, the main consultations were short consultations, the duration of which is less than one second. Short consultations are actually close to what can be found in the current operational environment without DAPs. We can therefore conclude that, to a certain extent, the controllers just transposed a current practice to a DAP environment.

It is interesting to mention that, during the simulations, short DAP consultations were made for three or more flights. This circumstance would never occur in an environment without DAPs because of the resulting VHF congestion.

The number of aircraft concerned by the consultations is one of the parameter taken into account in the analysis.

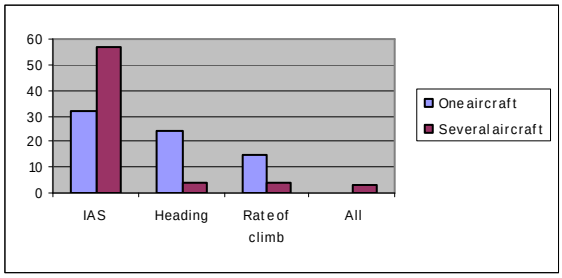

Figure 4. DAPs and concerned aircraft

The proportion of aircraft concerned by the consultations is inverted when speed is considered as opposed to the other DAPs. The speed information was very often requested for several aircraft entering the sector and converging towards the same exit point. In fact, in some conflict detection cases, strong correlations between those DAP requests can be found.

We can thus conclude that it is necessary to give the controllers two ways of displaying the speed: displaying the speed on all DAP-equipped aircraft or displaying the speed on aircraft that have been previously selected by the controller. This last functionality avoids the controllers' radar image to be polluted with permanent parameters which are not always of interest.

Most of the consultations of the magnetic heading involve only one aircraft. The observations show a patent heterogeneity of use among controllers. As a conclusion and on the basis of the data collected during the experiments, it is not possible to conclude that the magnetic heading is a useful DAP for only one aircraft.

During the experiments, controllers had access to the DAPs for aircraft that were not on frequency yet. A very significant number of DAP consultations for such aircraft was observed (nearly 10% of the consultations). Most of them related to aircraft which were entering the sector.

Conclusions

There is a clear evolution in the use of the DAPs due to the fact that the controllers gradually gained familiarity with the capabilities of the new tool. It turns out that even if the DAPs do not modify the conflict detection activity, they enable the controllers to sort the conflicts more accurately and to modify the scheme of resolution as well as the time at which it occurs.

Practical conclusions on the HMI can be formulated to start the study of the DAP integration in a controller working position.

Our main conclusions are the followings:

- DAPs should be located close to the flight label (further tests would be needed to verify this assumption).
- At least speed and magnetic heading of any of the DAP-equipped aircraft should be available to the controller whenever he requires this information.
- The DAPs enable the controller to better monitor the aircraft. An ON/OFF type of access of some DAPs for selected aircraft shall be available.
- The problem of potential confusion between the various presented values must be taken into account. For example, the IAS and the heading are both three digits numbers.
- The operational implementation of DAPs will change the priority of access to already existing information.

Part 2: Comparative evaluations of the DAP integration

General evaluation method

The above results were presented and discussed with a group of controllers in charge of the operational HMI design and with people from the Direction of Operations. At the end of the meeting, a certain number of requests regarding the integration of the DAPs on a controller working position, complying with the assumptions defined in the first part of the study, were collected. We studied and sorted these requests in order to initiate a step based comparative evaluation of various configurations in a simulated context.

The two sectors that we simulated in Part 1 of the study were used again while 16 new simulation exercises were created. These exercises were actually real traffic samples modified with specific tools. The various resulting exercises had to meet different criteria such as comparable proportion of conflicts and relatively homogeneous workload. The controllers had 10 minutes at the beginning of each simulation to get used to the new interactions.

Configurations

- Tactical screen: the Touch Input Device (TID) was modified in order to support two DAP access options: an "ON/OFF" function on a page

different from the priority page and the activation buttons option available on the priority page. These two options can be seen below, DAPs were available via the C, V and T buttons on the TID.

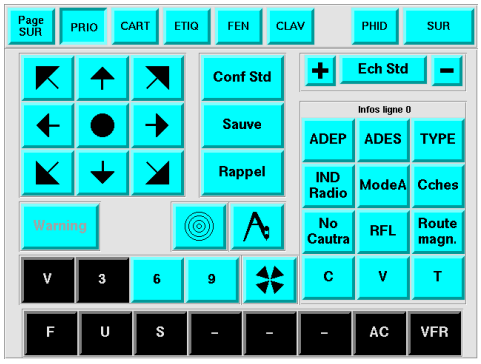

Figure 5: DAP Activation buttons on priority page

For the activation button option, as long as the controller held his finger on the desired DAP button, the corresponding DAP was displayed on all flight labels. Whenever he lifted his finger from the tactical screen, the DAP was not displayed anymore. It was therefore not possible to use this access option to display more than one type of DAP at the same time.

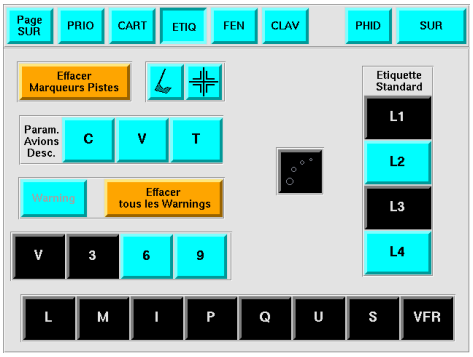

Figure 6: DAP ON/OFF buttons on different page than the priority page

For the ON/OFF option, the controller had to press on the desired button of the TID in order to see the DAP on all aircraft labels. But unlike the previous option; the DAP information would remain displayed until the controller performed a new action on the corresponding button. With this TID access option, it was thus possible to display different types of DAPs.

In both cases, the selected DAP were displayed on the flight labels of all DAP-Equipped aircraft, as it is shown on the following picture:

Figure 6: DAP selected by the TID

- On the radar image, two DAP access options were simulated. The first one is the "symbol option" in which a symbol was displayed on DAP-equipped aircraft. When the controller selected the symbol, all 3 DAPs were displayed in a dedicated on screen window. The second option is called the "mouse option" in which the 3 DAPs were displayed when the mouse pointer was over the flight label. In this configuration, the controller had the capability to force the DAP display by selecting the desired parameter. These two options can be seen below:

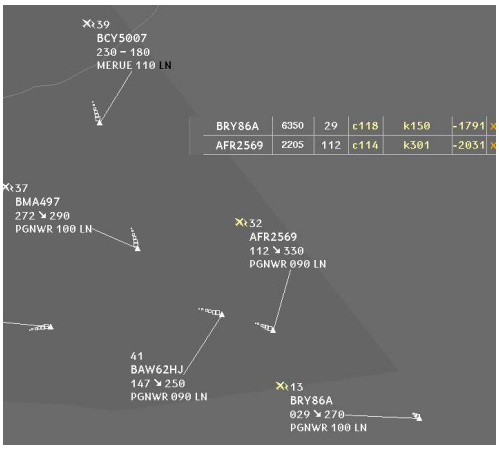

Figure 6: display of DAPs in on screen window by selecting the symbol

The on screen window with the DAPs could be moved along the vertical axis by the controllers.

Figure 7: display of DAPs in the mouse option

During the real time simulations, the controllers had both accesses: through the TID and the radar image. It follows that 4 configurations were tested with all the controllers.

Table 1: real time simulation configurations

Sample Description	TID	Radar Image
Configuration 1	ON/OFF	Mouse option
Configuration 2	Activation button	Symbol
Configuration 3	Activation button	Mouse options
Configuration 4	ON/OFF	Symbol

Results

DAP access modes

The figure below shows the number of accesses through the TID compared to the number recorded on the radar image.

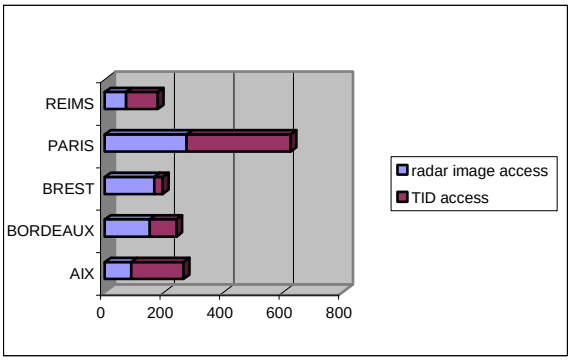

Figure 7: Number of DAP access: tactical vs. radar image

From these data, we cannot say which access was preferred by the controllers. In fact, the heterogeneity of the observed practice together with the comments of the operators, seem to show that both access modes should be kept. The need for this "double entry" option was confirmed by the majority of the controllers.

One of the main problem in a DAP environment is that controllers must use the DAPs without letting the radar image be cluttered to such an extent that it jeopardizes the control activity.

The experimental data show that it is relevant to keep the two access types in the future. They are indeed complementary: the TID enables to draw a mental overall picture of the traffic while the radar image enables to focus on some relevant flights.

We noticed that most of the controllers performed permanent display of a DAP through direct actions on the radar image. This access was often judged more "logical" and "natural". On the other hand, for some controllers, the increase of the TID use was possible thanks to the TID position which was closer to them during the simulations than it is in the real operational world.

The following recommendations can be stated:

- The access through the radar image together with the access through the TID should be kept.
- The TID should be displaced on the controller working position in order to be more easily reachable by the two controllers.

TID access mode

Each access mode (through either the radar image or the digital screen) had two different options. In the analysis of the TID access modes, two parameters were taken into account:

- Access localisation on the TID (page PRIO/page ETIQ),
- Access mode (activation button or ON-OFF).

A major point for all the controllers was that the DAP access should be located on the priority page (PRIO) of the TID.

The use of the activation button requires a quiet uncomfortable position of the controller, especially for long consultations. The access was thus mainly used for short consultations for which it proved to be well adapted. Skirting strategies were nevertheless used to overcome the above drawback, for example by repeating the actions on the DAP activation button.

Average time of the displays and especially the associated dispersion remain more important in the ON/OFF mode. This interaction mode makes long consultations easier and enables even permanent display of DAPs in some cases.

In the TID ON/OFF access mode case, various strategies were adopted depending on the controller's role. The activation button logic was better suited to tactical controllers, as they often used short

consultations through the TID and avoided overloading the radar image too long. Because the radar image cluttering is not of major importance for the planning controller, he did less mind if information was displayed for a longer time.

In view of the analysis we are able to make the following recommendations:

- The TID DAP access shall be on the priority page of TID,
- The tactical controller shall be provided with an access to the DAPs compatible with the activation button logic,
- The planning controller shall be provided with a mixed DAP access mode (where the activation button and the ON-OFF mode depend on the duration of button pressure).

Radar Image access mode

The controller had two ways to access the DAPs via the radar image:

- The mouse option that enables to display the DAPs directly on the last line of the flight label. When a desired DAP was selected, its value was displayed permanently,
- The symbol option that enables to display the DAPs in a specific on screen window.

The controller's role does not seem to have a significant impact on the use of the radar image access modes. Planning and tactical controllers had, from the point of view of display durations, a homogeneous use of the accesses. Regarding the configuration with the symbol, the controllers did not systematically favor short displays durations.

The symbol access mode is relatively similar in terms of functionality with the TID in the ON/OFF access mode. This option "penalises" short display durations, but in the case of the symbol option, as the DAPs are displayed for one flight in a dedicated on screen window, the image congestion is limited. Therefore, when combined with the TID in the ON/OFF access mode, the symbol access was preferred for shorter consultations.

As we saw it previously, the use of the TID in the activation button option is rather uncomfortable for long consultations. When combined with this TID access option, the symbol access became the way of performing longer consultations; even permanent display of the some DAPs. The data prove that the use of the symbol for simple consultation was done rather by default, when the TID access option was considered as an even worse option.

The mouse option was appreciated for DAP access, for its ease of use and quickness, especially when the controllers wanted a quick DAP information on a specific flight. Furthermore, the use of this access enabled the controllers to keep their attention focussed on the radar image while examining the DAPs.

The average durations of display of DAPs selected via the mouse option are longer than the one obtained with the TID. This may partially be explained by the fact that the permanent display of DAPs via the mouse option was located in the last line of the concerned flight labels which induces less cluttering of the radar image than the non-selective TID which displays DAPs on all the flight labels. The permanent display of one or several DAPs was performed in the following situations:

- Several flights on the same flight level, with compatible speeds that were converging to the same exit points. In this case, the displayed DAP was the IAS of the concerned flights,
- Several flights on different flight levels that had to be lowered and that were converging to the same exit point,
- When the controller intended to make a clearance based on these DAPs.

We can now make the following recommendation:

- The DAP access via the radar image shall be performed via the mouse directly by activating the DAP display when on the flight label. Through a single action on a desired DAP; its value shall be permanently displayed on the label.

DAP localisation

The DAP localisation on a specific on screen window has lots of drawbacks. The controllers' criticisms mainly concerned readability and functional problems:

- The number of possible simultaneous flights in the on screen window makes it hard to use,
- The management of the on screen window adds complexity, for example, erasing flights from it

is costly. After some time, many flights that are of no interest are still stuck in the on screen window,

- The on screen window may hide some other information when displayed on the radar image,

- Globally, the use of the on screen window is not intuitive.

The other evaluation point was to compare the two DAP display options on the flight label: on the first line of the label, with the TID access, and on the last line of the label with the mouse option access.

Globally, the display of the DAPs on the last line of the flight label was preferred, although both displays have drawbacks:

- The display of the DAPs on the first line is compatible with a general TID access, but the place is already reserved for a lot of other information.
- The display of the DAPs on the last line of the label suffered a problem of pointing. The information sometimes was located elsewhere than the controller awaited it when trying to erase it from the flight label.

The purpose of the DAP color was mainly to avoid the confusion between DAPs and similar information (in particular the data information system). The choice of a DAP specific color enabled us to limit the costs for new developments without modifying the already integrated colors. The objective was not to evaluate the relevance of the suggested color, but to prevent an eventual problem of data confusion that could invalidate a DAP presentation option. In this optic, the DAP color on the label was appreciated by all the controllers. But still it will be necessary to make a final choice for the DAP coding before the operational implementation.

The following recommendations are given for DAP localisation:

- If the choice to display the DAPs in a dedicated on screen window is made, a specific study should be driven with principles of data display and management that should be different from those adopted during this study.
- It is strongly recommended not to keep two different localisations for DAP display on the same label. A specific line on the label for DAP display would be an acceptable option.
- The DAP presentation shall be the subject of a specific study, this shall have a systemic approach including all data already coded in the system and forthcoming information.
- It is recommended to add feedbacks for selected DAPs when the label is in selected format.

DAP equipment indication

In the symbol configuration, the symbol had two main functions: to allow the controller to display the DAPs in a specific on screen window and to indicate to the controllers if the aircraft was DAP-equipped.

If the assumption that the fleet will be almost completely equipped in the near future is confirmed, most controllers think that it is the absence of equipment that shall be indicated. This proposal reflects their concern of not overloading the flight label.

- The indication of the level of equipment shall be in relation to the expected number of DAP-equipped aircraft.
- It is strongly recommended not to change the logic of the DAP equipment indication once being in operational service.
- If an indicator on the label is foreseen, its localisation shall be re-examined in order not to take a place which could have been valuable for technologies to come (for example data-link).

DAP general presentation

In a general way 9 controllers out of 10 found the simulations rather realistic.

The general presentation of the DAPs was overall satisfactory for all the controllers. There was no problem of legibility nor of data presentation. The controllers pointed that there were satisfactory similarities to existing HMI such as they know in ATC Center.

Conclusions

We tried, throughout this study, to be as exhaustive as possible within the limits of time and means which were imposed on us. We therefore tried to apply some rules:

- Conduct a serious study on the controllers' needs and have a better understanding of controllers' activity before working on any proposal.
- Test different configurations, the evaluation of several types of implementation that meet the same needs helps in the formulation of recommendations for the future implementation.

- Do not work with the objective of finding an "ideal solution" but evaluate advantages and disadvantages of various logics, accesses and means of display.
- Work with the controllers in situations of activity whenever it is possible. Be prudent in the way their opinions on a static representation are taken into account.
- Always take quantitative data with precaution, try to make correlations between the measured events and the qualitative data (observations, remarks, etc).

Still, in spite of the efforts spent on the study, a certain number of essential points could not be satisfactorily answered:

- The logic of DAP presentation still requires work. The assumption not to modify already existing data presentation on the flight label is not satisfactory. A systemic approach should be adopted to integrate DAPs in a relevant and consistent flight information presentation.
- The question of flight label congestion raises key questions that are not only specific to the DAPs. We showed that relieving the flight label of any information can be quite tricky. This issue should be the subject of a dedicated study.
- Even if we pointed out enough correlations to make useful recommendations for the specifications of the future system, we can not state with any certainty how the operators will adapt to the DAPs and how the tool will finally be integrated in their future working environment. A specific attention shall be paid on this issue when installing the definitive operational tool.

For more information concerning the results of this study, two reports have been made available [6][7] focussing respectively on needs collection and on implementation evaluations.

References

[1] NLR, 1999, Assessment of controller benefits using displayed downlinked aircraft parameters, Ref: NLR-CR-9917.

[2] CENA, 1997, Assess the benefits of the CAP service in the context of approach control (ESCAPADE), Ref: CENA-NT97-078

[3] Bruno Favennec & Yves Sagnier, 1996, A datalink that meets the requirements: ModeS, Fourth European ATS Datalink Forum

[4] Eurocontrol, 1999, DAP Technical Characteristics for Mode S Enhanced Surveillance, Ref. SUR.ET2.ST03.2020

[5] Eurocontrol, 2001, Operational Hazard Assessment of Elementary and Enhanced Surveillance, Ref. Mode S/OHA/0001

[6] Vincent Kapp, 2004, Bilan des expérimentations besoin PAD en contexte En Route, Ref. CENA-NT04-1024.

[7] Céline Classe Vincent Kapp, 2004, Bilan des expérimentations intégration des PAD dans une plate-forme ODS En Route, Ref. CENA-NT04-1038.

Keywords

Air Traffic Control, DAP, Mode S, Needs Collection, Real Time Simulations

Biographical Notes

Vincent Kapp has an engineering degree in aeronautics. Since he joined the research center of DSNA (Direction des Services de la Navigation Aérienne, formerly DNA), he worked on studies related to data-link applications. He is currently working in a team responsible for ATC En Route HMI evaluations and was in charge of the DAP En Route study.