Cockpit avionics and their perception by Air Traffic Controllers

Raïlane Benhacene

Cockpit Avionics
And
their perception by Air Traffic Controllers

Raïlane Benhacène
Centre d'Etudes de la Navigation Aérienne
7, avenue Edouard Belin
31055 Toulouse cedex, France
benhacen@cena.fr

Abstract : The perception controllers have pilots' work and working environment is an interesting subject for people working in the field of human factors. Intuitively, it seems that a better understanding of this area may yield interesting results for the improvement of the tools used by both parties to exchange and communicate data, or merely to improve the way they work together. Later applications for the design of new tools could be envisaged, taking these notions into account. This study focused on a specific aspect of the environment, the cockpit avionics.
This paper presents the results of a brief survey that was conducted on a sample of 131 French Air Traffic Control Officers (ATCO). Its aim was to try and determine and explicit how cockpit avionics such as FMS or TCAS were perceived and judged or appreciated by ground ATCO. It further tried to explore potential means or ways of enhancing co-operation between controllers and pilots. The underlying expectation was that sharp-end operators, confronted to their task on a daily basis, were likely to have formulated criticisms or remarks on the tools they have to work with, and that this informal but precious and motivated information was seldom passed on to the designer. So the survey was also in part oriented as a call for remarks, suggestions and criticisms on the environment currently in operation. Results show an overall distance and lack of information about these avionics on the ground side. They reveal the potential benefits controllers could draw from having a better knowledge of these tools.
The FMS more vividly suffers from this lack of information or training, and data it incorporates are clearly of some interest to controllers. The TCAS seems much better known, and more salient in controllers' perception. Its implementation is clearly felt as the source of added safety, but also an intrusive and sometimes destabilizing intervention, pointing out a problem of lack of clarity as to responsibilities in cases of emergency.

Key words : Human factor, avionics, FMS, TCAS, ATC.

Introduction :

The task an ATCO conducts on his working position is mainly of the cognitive type. To him, aircraft are plots on a radar screen, flight plans which are downsized to be summarised on a paper strip… So, fundamentally, apart from the voice on the radio frequency (admittedly carrying plenty of information and emotion), the ATCO processes information and makes decisions that affect a distant and remote world, and upon which he has little information or 'intimate' knowledge or experience. Adversely, one could also argue that similar distance, not to say ignorance, exists on the other side of the fence. So the fact is that these two highly interdependent worlds ignore almost everything about one another. Being intimately convinced that any means of increasing mutual awareness or knowledge is a potential means of achieving better communication, thereafter yielding an overall better performance (be it qualitative, in terms of comfort, or quantitative, in terms of expeditiousness or amount of traffic treated, or merely but no least interestingly , to enhance a 'natural' prevention of errors or a better recovery thereof), we have tried to establish and get a better feeling of what this perception really consists of. One idea that triggered this survey needs mentioning here. There exists, on any common FMS, a special built-in function called the off-set, which enables the pilot to very easily change the course of his flight trajectory, and shift his flight a given number of nautical miles to the left or to the right. The key point to be remembered here is that the effort, from the pilot side, is minimal, negligible. This

function also happens to correspond to a fairly common need ATCOs have, in their daily task. In order to separate aircraft on the same route that are likely, because of a speed difference, to lose separation, they commonly put these aircraft on 'parallel headings'. But the series of actions the ATCO takes to achieve this result in a traditional way is not only lengthy and time consuming, but also yields a significant mental load. The ATCO must first give a heading to direct an aircraft away from his initial route. Then, he must wait a certain amount of time, a 'time lag' until the distance to the initial route is deemed sufficient (say 5 or 8 NM), which can last one minute, or so. Then, and then only, can he give the aircraft his initial heading again, to set it back on a track parallel to its initial course. It this seems easy, one should first bear in mind that if the route legs make an angle some distance further, the new heading needs to be given again. But more than that, the time lag we mentioned earlier, this delay, before 'turning' the aircraft back to its heading, is not free of charge for the ATCO. Even though no action at all is required, memory is solicited to remember the action that is left to be done. And probably some kind of process is initiated, that 'somehow' counts down, or estimates when to 'pop up' again and trigger the adequate action. Even though not visibly solicited, the controller is under workload, far more by all means than with this existing possibility of an off-set which is more of the 'give clearance and forget' type, and which lets his cognition free once said, free and available. In the traditional way of shifting a route, a memorisation an awaiting and a stress are somehow generated.

So it is this potential gain and benefit to the controller that has seemed of interest and worth at least some closer examination. Especially knowing how easily and readily close at hand it lies : all it takes is knowing that this function exists, and to think of using it. More generally, our belief is that if one knows of the pilot's environment, tasks, tools, etc., one is more likely to find and use more efficient means to perform his task.

The making of the questionnaire :

- The question was whether or not the Air Traffic Controllers were aware of the existence of such capabilities as the 'off-set' on an FMS. The question is worth considering given the fact that, when asked, some controllers replied by saying that 'probably they wouldn't use this function simply because they are not used to doing so, because it's not part of their habits or practice, etc.' Those same controllers would even reply, when asked about the value added one could expect from sending a questionnaire to learn more about this subject, that one should not expect to get much information from that. In other words : what Air Traffic Controllers know of FMS or cockpit avionics ? Probably not much.
- The idea was then expressed that the questionnaire should be expanded to TCAS. Admittedly, controllers have heard of TCAS. They have experienced the existence of such a tool, and have even been confronted with 'problems' or issues related to that tool. And everyone has a feeling or an opinion about the pros and cons of this system, how much 'danger' or 'safety' it introduces into current ATC .
- The third type of questions that were introduced into the questionnaire was aiming at determining whether there would be room for a potential cooperation between pilots and controllers via their tools. Some question were therefore elaborated to have controllers explicit if such an idea would please them, or be rejected. Some examples were proposed to illustrate how such a cooperation could take place, and see how those would be appreciated.
- The fourth category of questions tried to capture suggestions and to get some feedback as to what needs, ideas or experience controllers could bring from the field of operations. Indeed, it is seldom given for designers of new tools or concepts to have a realistic and faithful feeling about what the workplace really looks like ant what problems are met there. Moreover, knowing that many ATCO are also private pilots, we thought they may have interesting remarks to make on this subject.

So the questionnaire was made of a list of statements which were to be evaluated . Opinions on each statement were to be selected among the following :

Completely Disagree / Rather Disagree / Rather Agree / Completely Agree.

Detail of the questions and the corresponding results is given in appendix.

Population :

The questionnaire was sent to several regional control centres in France, and at two approaches. Further, the questionnaire was also handed to a class of students halfway through their 3-year long training to become ATCOs. So the sample breaks down as follows :

Origin	*Code*	*Number*
South-East En-Route Control Centre - Aix	**Aix**	19
Blagnac Approach (Toulouse Twr) and Brest (Brest Twr)	**Appr.**	14 (12 + 2)
South-West En-Route Control Centre - Bordeaux	**Bordeaux**	18
West En-Route Control Centre - Brest	**Brest**	17
ATC students at the French Civil Aviation School (ENAC)	**ENAC**	17
East En-Route Control Centre - Reims	**Reims**	46

Total : 131

Most noticeable facts are the predominance of questionnaires from the Reims Control Centre, which may therefore affect the overall statistics accordingly. One should also bear in mind that the population of this centre is noticeably younger the other centres. Last remark, the students of this sample are in majority assigned to approach control when they finish their studies.

Results and Analysis :

[Question 1 : FMS - You are familiar with the functioning of this tool]. The first and most striking fact is that *few* ATCOs declare they know this tool well. Less than half of them agree with this statement, the majority remaining more reserved. This, we believe, is rather surprising, when one considers the fact that the FMS went into service on modern aircraft a good 20 years ago. One might be inclined to think that such a tool would by then be fully integrated into the aeronautical landscape. A glance at [Question 23 - TCAS - You are familiar with and understand the logic of the TCAS (TA, RA…)] gives a much more clear-cut answer: a vast majority of ATCOs declares rather knowing and being familiar with the tool (50%) or even better, completely agree (an additional 39%). This results seems rather paradoxical given that TCAS was introduced much more recently than the FMS.

Note : FMS appeared since the early 80s
TCAS : mandatory equipage since 1994 in the US, year 2000 for ACAS II in Europe, norm which is fulfilled by TCAS II v.7. In other words, and according to ATCOs : we've seen them around since 4 years, more or less.

Even so, this result comes as no surprise : TCAS is more sensitive, since it directly interferes into ATCOs' work, as it make aircraft do things not foreseen by the control. Indeed, and results clearly tell this, this tool very soon impacted aircraft trajectories, and in a very intrusive manner. An aircraft, seen by the controller, and supposed to have and maintain such trajectory, such climb rate, or stable in cruise, suddenly and abruptly changes its course, and deviates brutally from its expected trajectory or path. And as the odds are that part of the control task consists of a surveillance and monitoring process, any aircraft going out of the domain that was attributed to it would constitute a strong trigger of alarm and vigilance. As opposed to this, the FMS which is more devoted to the execution of trajectories planned in the flight plan, seem to act most of the time below the perceptive threshold, and its effect is less visible.
If we look more in detail at this specific aspect, we find out that, in the breakdown of origins for the answers to this question, students of the ENAC school tend to massively answer 'rather agree' to [Question 1] (82%), which leads us to believe that the latter have been granted a training for the FMS tool. Still on this trail, we tried to confirm this result and looked at Reims answers (the youngest centre, with an average of 6 years' experience): surprisingly, the 'completely disagree' answers were the most numerous (37%) of the whole sample. So we wondered whether this could not be explained by the fact that training for FMS was only recently introduced into the curriculum. That would explain this feeling of 'ignorance' even stronger for young ATCOs than for older ones, as the latter have had opportunity to learn some knowledge 'en passant', making flights in the cockpit, on the job training so to speak. We contacted the ENAC school which confirmed :

ENAC : First TCAS training for ATCOs – around 1993
First FMS training for ATCOs – around 1998

Truly, the FMS training wasn't even granted to the youngest controllers of the Reims ACC. This fact pushes them even more radically in the category of people knowing almost nothing of this tool, having not even had the chance to learn in the field. This also explains the result of the answers to [Question 26 - TCAS - You have had, in you training period, a familiarisation or training for that tool] where more than 70% of ATCOs declare having had, more or less, training about TCAS. Even in ACCs, training courses were set up to

familiarize ATCOs with TCAS, probably because this tool vividly raises some juridical or regulatory questions as to what attitude one should adopt when confronted to a TCAS alarm…

The general idea is all embedded in this early result : the point is that one is generally more sensitive to what has an impact on our activity, and sends us a feedback. We then have a sharper image, perceive better, are more led to react at what calls at us. Other information is certainly also perceptible, but experience makes it so that we soon put a filter on this data which reach us, in order to avoid saturation and overflow. We try to save our attention to what deserves treatment, action or analysis from our behalf. So what this is saying is : an ATCO, in order to manage his traffic, build expectations as to the behaviour of aircraft, plausible scenarios of evolution of the situation, to which he associates parameters, criteria or ranges for those parameters. And those parameters only are monitored, and checked for coherence or remaining inside the assigned range. In short, the FMS does not significantly affect these parameters, and is therefore less salient and more easily ignored by the ATCOs.

Besides, most common requests for having access to data contained in the FMS where for the Flight Plan Route (cited 18 times for [Question 14]), in the sense that this "FMS flight plan" sometimes differs from the flight plan filed in the Flight Data Processing System (FDPS), i.e. the one they see written on the paper flight strips. This is evidence that the FMS, as a flight management tool, becomes particularly salient and bothersome precisely when it contradicts the expectations of the control, and therefore triggers an unpleasant surprise. Apart from that case, the FMS remains considered as a tool for the pilot, for him to manage 'his flight', whereas an ATCO manages 'his traffic'.

Another example to illustrate this : 3 mentions are made in answer to [Question 5 - In general, you think FMS has some potential for simplifying certain situations in ATC / Question 6 - Which ones ?] of the fact that the FMS makes aircraft cut the curves, and smoothes away their trajectory. One answer is even illustrated with a little sketch drawing illustration that aircraft no longer fly vertical of a beacon, but start turning earlier, to be able to reach the second segment of their planned route tangentially. And there are some 'famous' cases when this shortcut is such that the aircraft violates a forbidden zone, a military area noticeably.

The answers to [Question 3 - FMS is an aid for long term navigation] reveal even further this aspect. This question was initially intended to discriminate whether ATCOs thought of the FMS as a tool to manage the flight on the long term, or if they perceived that some punctual clearances could also be managed via the FMS, using the 'selected' mode. Apparently, this question troubled many people. Many question marks or blank responses were made. As for those who answered, they concur to believe the FMS is used for strategic flight or for the long term. (agree rather – 69% and completely – 23%) The FMS is seldom seen as a tool capable of dealing with the short term, or of being involved in the treatment of an ATC clearance. To this respect, ENAC students are more categorical than the rest of ATCOs.

Still on this topic, [Question 12 - You are familiar with the notion of engaged FMS mode (selected, managed)] reveals that there is a clear perceived limit in the tasks and responsibilities sharing. The notions referred to in this question are seen as something belonging to the pilots' domain : this is pilots' work. And truly, more than 60% of ATCOs declare they know nothing about that. Again here, ENAC students are an exception. Contrary to the rest of ATCOs, none of them (0%) declares completely ignoring these FMS mode notions, and more than 80% declare they do know what these modes mean. This can reasonably be attributed to a fairly recent training on the topic.

To make a comparison, here are the results for [Question 23 - TCAS - You are familiar with and understand the logic of the TCAS (TA, RA…)] : 50% rather agree and 39% completely agree. Quite an impressive result for a cockpit instrument.

Back to the FMS : [Question 5 - In general, you think FMS has some potential for simplifying certain situations in ATC]. This question brings out all nuances and difficulties that lay between the world of control and that of flying. The answer is rather favourable, but it is a limited agreement. 30% rather disagree with this statement, and 12% completely disagree. They are reserved, and someone even crossed out "simplifying" and marked "complicating" instead. So if apparently some are prepared to acknowledge that this tool may be useful, they are not willing to go too far, in what could be perceived as a 'support' for automation, or even more, as

an agreement to 'use' a tool which is and remains of the pilots' side, design and intended to serve their own operational needs. The interesting thing is that the toll of sceptical decreases when answering more precise questions where the FMS is presented as facilitating the work. The example of the route 'off-set' illustrates this quite well : this example is spontaneously cited 27 times in answer to [Question 6]. It seems that ATCOs are more receptive to an operational speech, to the presentation of precise examples. It is then possible to declare with no reserve that yes, in that case, there is an improvement. This seems easier to envisage than to think in a more general way, in principle and approve of a philosophy of tool usage.

A closer look at the answers to this [Question 5], looking at the breakdown by centre, gives a noticeable difference between ACC ATCOs and those of Approach. People in the approach are comparatively less sensitive to the usefulness of an off-set which offers the possibility to shift an aircraft on a parallel route. This function is much better appreciated by en-route controllers obviously as they have to deal with long lasting overtakes. On the other hand, approach controllers are more interested in the ability to make an aircraft follow a holding pattern on any R-Nav point. This is rather logical, given that their work most of the time consists of sequencing aircraft for the runway, in a reduced space, and the possibility of delaying a given aircraft can be very helpful, and corresponds to a common practice and need.

[Question 4 - FMS - When giving a clearance to resolve a conflict, you disturb a flight plan that was scheduled in the FMS]. This question is difficult to use, and in any case does not provide visible benefit. Opinions are mixed, with a slight advantage to positive answers (56% broken into rather – 41% and completely – 15%). The idea was to check whether ATCOs has a mental image of the FMS Flight Plan as something rigid and frozen, difficult to modify in real time. It seems that there is no such feeling, and that in any case, the ATCOs remains in control, and is in no way affected by the existence of this tool in the pilots' loop.

[Question 9 - FMS - You think the behaviour of pilots has changed since the emergence of this tool] A majority agrees with this (75% broken into rather – 39% and completely – 36%). We can state that the appearance of the FMS has changed something in the French sky. This is not so true for the approach controllers, probably due to the fact that they are in charge of aircraft in a more tactical phase of the flight, during which pilots tend to take over. The details of the following question are more enlightening.

[Question 10 - FMS – Examples] Appendix gives the details of the answers. In general, the examples of pilots' change of behaviour (and in practice, that of aircraft) are more positive (25 answers) than negative (17 answers). Ease and rapidity of reaction of pilots due to the FMS are appreciated. The same goes for precision in trajectories. In other words, ATCOs appreciate what makes aircraft behaviour more reliable, predictable, and conform to their expectations.
Adversely, they do not like those features that require lengthy manipulations. This is particularly true for the approach controllers, who mention the "famous" change of runway, presumably a nuisance for pilots, be it on take-off or for landing. More subtly, a criticism is made about this mental rigidity that the FMS may introduce in pilots' minds, in the sense that it makes them focus on *their* mission, *their* flight plan, *their* navigation. This seems to make them less receptive, or aware of the more global and complex task that the ATCOs are in charge of. In this respect, we could re-word it as : the FMS would have increased the gulf between the ground and the board, and would have contributed to their fencing. We can note the slip that occurred here : a criticism of the tool becoming a reproach made to the users of the tool…

Nonetheless, we should keep in mind that these negative opinions are a minority, which is illustrated by the following results :

[Question 11 - FMS - You think this results is a progress for your work] scores a clear support of this tool (80% broken into rather – 65% and completely – 15%). As a parallel, results for [Question 2 - FMS - You think this tool has had an overall beneficial effect on ATC] gave an overall 87% satisfaction score (broken into rather – 68% and completely – 19%). So here is strong evidence that controllers appreciate the value of this instrument, and are apparently satisfied with its existence and its intervention in their work. Only the approach controllers stand out for this aspect in being slightly less affirmative for both [Question 11] and [Question 2], remaining highly positive however.

[Question 13 - You would find the knowledge of some data in the FMS flight plan useful] (70% broken into rather – 39% and completely – 31%). So we can see that there exists a need for information from the cockpit among ATCOs. The following question [Question 14 - FMS - Examples] gives the information ATCOs mostly expect in order of preference (see Appendix for detail) :

- route planned and entered into the FMS flight plan
- top of descent
- climb or descent rate

The first item is rather annoying : if all went well, i.e. if all pilots had, in their FMS, the same flight plan as the one officially sent to the FDPS, ATCOs should not have to ask for such an information, as they should normally have it on their paper strips. But such is not always the case in practice, and some unpleasant surprises do occur. So this information is requested more for confirmation or contradiction purposes. It is a request for a theoretically already available information, not for a new and missing information.

The top of descent, on the other hand, would constitute a new information for the ATCOs, and which would be of great interest to them. Currently, ATCOs resort to making hypotheses about the point where the aircraft will start its descent. And they do so, in order to anticipate on some traffic situations and the potential conflicts this might generate. Clearly, the pilot, who follows the execution of his flight plan on the FMS, has a more accurate and up to date information. Knowing this information in advance might probably inflict a control decision long in advance, in a very simple way, and allow a better anticipation. In other words, ATCOs see it as a means to be more 'ahead of traffic', and they are willing to take that.

The last item is just as interesting : if the radar and the strip provide such vital and accurate information to visualize the geographical position of an aircraft, and anticipate on its future course, the vertical evolution remains the weak point of the representation. And all ATCOs generally concur to say that it is one of the most difficult things to visualise for the following reasons. First, the radar image is 'flat' and therefore not the most convenient thing to get the vertical position information. This information is accessed to via a 'reading' of flight level on the labels, which means using a symbolic representation in the form of a figure. The other reason is that it is very difficult to forecast the climb rate of an aircraft, because this value can vary a lot depending on many criteria. One can easily enough extrapolate the future position of an aircraft in the horizontal plane, given its past positions. It is much more difficult to memorise present and past levels (figures on a label) to infer a rate of climb. More over, depending on the type of aircraft or engines it has, the conditions of the day, the weight of the aircraft, or even airline policy, the rate of climb or descent can vary by an order of magnitude. All this explains why the prospect of having real time access to such a volatile data could surely constitute a good value to ATCOs and a plus for control.

[Question 15 - The knowledge of the FMS flight plan could change some of your control decisions.] also confirms what was mentioned just above, namely the need to have access to up-to-date and relevant information in order to be able to make the best and most judicious decisions. A slight majority – 56% - concurs with this statement, but this result is somewhat penalised by the ENAC students' answers. They clearly disagree with the statement, which would otherwise have scored a 63% of positive answers. This result was a good surprise to us, as we feared that this statement be rejected : by questioning the ability of ATCOs to make good decisions, it could have been perceived as slight 'aggression' as it were. This good will, or readiness to question oneself is, in our opinion, reassuring in that it reveals the ability to think back and consider one's daily work with a critical eye, hence an open mind to potential changes as long as these changes are supported by relevant, reliable and up-to-date information.

Similarly, [Question 16 - You believe a better knowledge of the FMS would be useful in your work] reveals the same will and readiness to change. It is almost surprising in this respect, and the consensus is so clear that only 7% of answers disagreed with this statement. This result was not a priori natural, as we could very well imagine that ATCOs be in majority in favour of the FMS ([Question2] and [Question11]) without this necessarily impacting their daily work or customs. Here, clearly, one can see the potential for 'recycling' the tool, for a usage by or a benefit for the ground control. And if we go further along this trail, [Question 17 - FMS - You think this tool could be used to facilitate a co-operation between pilot and controller] we find the same large approval : 79% (broken into rather – 49% and completely – 30%). It seems a good and generous idea to declare that people should co-operate, help each other etc.

But maybe this is mere lip service that cost little to say ? Not exactly. Evidence for this comes when the same question is formulated for TCAS. The result is just the opposite : no joint utilisation of TCAS by control and pilots. (65% disagree - rather : 23% and completely : 42%). Two elements can explain this last point. First is the regulatory aspects, which we ignored at the time the questionnaire was written. Training for TCAS is very clear about this : on should not use TCAS to make separations, one should not 'cross aircraft' on the TCAS, phraseology such as 'we see him on TCAS' have no legal value and should be banished. A TCAS expert reviewing the questionnaire jumped on this question and said : this one is a trap. So legally, the rejection of a potential co-operation via the TCAS is normal, and even reassuring. The other reason, which comes from the same origin, is that it is intuitively natural not to get involved in a tool one does not control, and about which one should be careful, as it is likely to step in and counter a control decision, and disturb or complicate an already tense situation. In such case, where a resolution advisory is already urgent and complex to execute, interfering and giving other clearances could put the pilot in a position to chose an option, and could therefore impair his response time. It is therefore safer and sounder to let the TCAS do in such cases, and not to interfere whenever it is triggered, even if one must later take over.

Having established this, we had the intuition that the TCAS would have a poor image among ATCOs, and we expected [Question 19 - TCAS - This tool can yield more security in the flight] to be rejected. Truly, this tool is perturbing and interfering with the classical control, and can ruin a whole strategy that an ATCO was building to resolve conflicts in his sector. Much to the contrary, ATCOs are very supportive of this safety notion and 94% agree (44% rather – 50% completely). It is even more evident when phrased in [Question 20 - TCAS - This tool is useful mainly on very short term, occasionally, in emergency] : 97% agree (28% rather – 69% completely). So obviously, the TCAS is useful, is perceived as beneficial, and foremost, appreciated as an ultimate protection, a safety device in support of the human operator.

If one stopped there, we could believe that the TCAS is a great invention, and that even ATCOs who are in no way the people for whom this tool was designed, acknowledge the benefits brought by this tool. Some further questions temper somewhat this positive image. [Question 21 - TCAS - You think this tool is an intrusion in your work] 66% disagree (40% rather – 26% completely). Not too bad a result, but nonetheless a step down from earlier approval. So the tool is approved of as a safety device, but it is still capable of introducing confusion in the control as is. And here, approach controllers are much more reserved (64% approve the statement 21) and they describe situations where the TCAS complicates a situation, or is poorly adapted to the specifics of approach. Again this comes as no surprise : in a converging funnel leading to the runway, alerts and TCAS interventions are more frequent and more disturbing. Note that some company policies even complicate further this.

But the most surprising thing is that if the majority of other (en-route) controllers are more tolerant towards the TCAS for its intrusive aspect, the concur with the approach for [Question 22 - TCAS - You think some functionalities of this tool can have adverse effects on your task] 74% agree (51% rather – 23% completely). So this sheds a different light on the results of [Question 20]. ATCOs acknowledge the merits of this tool, but only in a limited domain : emergency situations, as an ultimate shield against a mistake that could happen to anyone. Nonetheless, this intervention is troublesome, it is not always coherent with the plan an ATCO is conducting, and can therefore sometimes perturb him, reduce his efficiency. One can envisage, and even cite case where the TCAS prompted reactions from the pilot that were not in the direction of greatest efficiency.

Last item about the TCAS : [Question 24 - TCAS - You can easily imagine how a conflict resolution on a TCAS would be perceived by the pilot]. We had in mind the mental image here : we thought that from the ground, it must have been fairly complex to imagine and visualise how the TCAS would yield an effect on the aircraft behaviour. For a better reason, how could one project oneself mentally inside the cockpit, and figure the TCAS instruction. We felt it was crucial to verify this subtle issue, because if such was the case, then there was room for d misunderstanding, poor perception of aircraft situation and conditions, and therefore potentially inadequate decision making. Results tend to show that this worry is not meeting any ATCO concerns : on the

contrary, 73% of them think they have adequate image in their minds (46% rather agree – 27% completely)

The last questions of the questionnaire are more there to give ATCOs a chance to express spontaneously their needs and feelings. As a preamble, [Question 27 - You think other cockpit instruments could provide you with information relevant to your work] was aimed at determining if any information was felt missing by ATCOs, and to learn whether they had ideas or intuitions about what might serve them, noticeably amidst 'on-board information'. And truly, only 16% of them feel there is nothing for them in the cockpit that could be of use to them. For the offers proposed in [Question 28] , results are details in Appendix.

The intention we had when we wrote this question was missed somehow. We wanted ATCOs to select those information they felt useful, and mention their importance. What they did is grade all choices offered as important or not. Even so, we could find a degree of classification which is worth considering. The first point is that the weather information is missing, or is felt as missing by ATCOs and would be useful in the accomplishment of their tasks. The other information is definitely what ATCOs are led to request (via the radio) most commonly. What would be your Mach number at such Flight Level, what is your present heading, what is your indicated airspeed ? The daily life of controllers is very well rendered by those questions, we feel. So apart from the weather data, this questionnaire did not reveal any special or new need. The rest of the questionnaire is similar, and bears no surprise : the last item felt as necessary is the rate of climb or descent that we already mentioned when discussing [Question 13].

General Comments on the Questionnaire

The most striking feeling is that a majority of commentaries reveal of a feeling of 'guilt', which prove that this questionnaire was perceived as a test, rather than an opinion poll. The wording that accompanied the questionnaire was of no use : it seems that being questioned on one's professional activity is perceived as inquisitive, or with a judgement in the back of our mind. Our belonging to a the civil aviation authority and being an engineer, traditionally a managing category of personnel, may have caused this. However, we can also consider the likeliness that a number of controllers felt the lack of knowledge of cockpit systems, and conclude that it is a gap worth filling.

In the same flow of ideas, many suggestions (whether formulated positively or in a critical way) call for more communications and exchanges with pilots, and to better knowing each other. All go in the same way of a wish for progress, or a concern for the improvement of the way the 'system' works, and again, a willingness to question ones' self which is not often suspected in the body of ATCOs, and probably seldom valued or put forth. To illustrate this, we were often welcomed by sentences such as : 'it's good of you to be interested in what we do', 'not so common', 'if more could do like you' etc. And despite a certain suspicion as to what could be done of what they said; we strongly felt a pleasure people had in talking to us, explaining, discussing, concern about the trade and its future, and many thinking about possible means of improving the work. The habit of working in teams and in shifts with night times or other less busy periods leaving time to discuss probably help this.

Last, we need to mention that some comments express a certain suspicion as to what potential changes an inquiry could be hiding. And for example, many ATCOs mentioned that adequate usage of the radio already (and very easily) enabled to get any of those information one might be needing. Similarly, many mention the Data-link technology as being the most natural way for an ATCO to get aircraft data on the ground. Some, though, are concerned about the risk of information overflow, thus drowning vital information that is currently deemed as very useful *and* familiar. We also noted that the data-link was rather well perceived, but especially because it is seen only from the download perspective : get information from the aircraft, hence potentially get more power to decide. The other way of the exchange, the uploading or sending of data, is clearly never mentioned here…

Discussion and Conclusion :

The aim of this brief survey was to simply have an idea about the controllers' reality. One of the main results of this study is probably the confirmation that indeed, there is a need for more accurate, up to date information from the aircraft on the control position. And that some benefit could reasonably be expected from having this information that pilots currently have.

We have no means to study the way this could be performed nor the social implications this transfer of knowledge would imply. We only point out that a 'predatory' attitude (getting information, i.e. power) exists,

together with a more co-operative attitude (mutual exchange and benefit). In all cases, this circulation of information is technically an advantage, and has positive and useful fallouts on the decision making mechanism.
One precaution needs mentioning though : some situations exist where the principle of co-operation can inject more complexity in the system (some TCAS usages illustrate this particularly).
Co-operating via the tools, (or simply retrieving distant functions to one's own benefit) are not only inevitable but also fruitful. They reveal the dynamics of integrating a knowledge, appropriating tools, and building of a comfortable, hence efficient, working environment. However, in order to prevent erroneous usage of the tools, training is required to clearly draw the operational limits, and visualise the consequences of actions. Further clarification is therefore needed to make the responsibilities' sharing explicit.
We should note that the introduction of a co-operative usage is not necessarily the cause of an ambiguity as to the sharing of responsibilities. It is probably only the catalyst that rendered visible ambiguities already present before the tool or usage were introduced. Ambiguities can cover aspects such as : decision making, responsibility, etc. In other words, the TCAS may have forced the emergence of an underlying, yet very important problematic : the implicit. Who is in control, who is in charge, and above all, who will be pursued if anything goes wrong? This questionnaire reveals, in our opinion, that the situation is unclear, and that the controllers take this opportunity to express their trouble about this.

Another interesting result is the benefit which can be expected from having two communities exchange information. Obviously, much can be improved by super-imposing knowledge and data that is currently split between ground and air. Many new ways of working can emerge, without necessarily resorting to complex and sophisticated technologies. To know where a Cumulo-Nimbus is located, or at which rate an aircraft is climbing, are not revolutionary advances, yet they can promote safer or more elegant and expeditious solutions.

We should bear in mind that the tools (or the working environment) described here were designed by an industry whose purpose was to meet a very specific need (the pilots' or the airlines' need). The FMS is thus essentially oriented to flight management to assist the pilot, the TCAS is merely intended as an ultimate protection to safeguard against mid-air collision.
So the utilisation of these tools should be cautiously considered. Evidence for this is that training for TCAS was rapidly implemented, more or less simultaneously with its assembling on aircraft. This training was added to ATCOs' curriculum comparatively much quickly than for the FMS.

We believe that this should be considered when designing and /or implementing new devices in the ATC or in cockpits. Considering the global environment should be paramount and considered early enough in the design cycle, by involving different participants or trades concerned. This requires a good understanding, not only of the operational activities of the stakeholders, but also their interest and motivations. In our opinion, this aspect could be just as important as the technical quality and for the success and acceptance of new tools. New tools require a change from operators, a transfer of competence.

It seems that the latest generations of avionics and FMS are designed with an interface embedded to match the ATC phraseology, and make them easier to use in this respect. To achieve this requires rebuilding the interface from scratch to meet this new specification, representing a heavy investment. This evidence supports the concern we have about importance of achieving a common, shared view for different stakeholders. Design needs to be made from a global perspective, larger than the framework of the envisaged activity.

Author Biography :

Raïlane Benhacène is a former Engine and Propeller Certification specialist. He is now working for CENA since 1999. He is involved in the design of new tools for Air Traffic Controllers, and is more specifically interested in the integration of Human Factors in this design. He is currently working on a new concept of tools for Extended TMA

Appendix – Results

FMS :

1 -You are familiar with the functioning of this tool

Completely Disagree	Rather Disagree	Rather Agree	Completely Agree
26%	34%	37%	3%

2 - You think this tool has had an overall beneficial effect on ATC

0%	13%	68%	19%

3 - FMS is an aid for long term navigation

1%	7%	69%	23%

4 - When giving a clearance to resolve a conflict, you disturb a flight plan that was scheduled in the FMS

14%	30%	41%	15%

5 - In general, you think FMS has some potential for simplifying certain situations in ATC

12%	30%	47%	11%

6- Exemples :

	En Route :	
No answers		75
Advantages	Off set	27
	Route (vs. heading)	11 (no wind effect)
	Easy of direct to Waypoint	7
	FL or speed Constraint :	6
	Downlinked parameters	3
	Vertical path, rate :	3
	Rnav Holding pattern	2
	Expected descent :	2
	4D Objective:	2
	Quicker change in FL	1
Drawbacks	Cutting the curve inside	3

	In approach :	
No answers		9
Advantages	Easy direct to Waypoint	2
	Off set	1
	Estimate available.	1
	Accurate trajectories	2
Drawbacks	Not easy to use lengthy take off, runway change not easily accepted	1

7 - The shifting of a Route ('off-set') could simplify certain situations

Completely Disagree	Rather Disagree	Rather Agree	Completely Agree
4%	20%	39%	36%

8 - Making a holding pattern on any point (R-nav) would be a useful function for control

5%	11%	44%	40%

9 - You think the behaviour of pilots has changed since the emergence of this tool

6%	24%	56%	13%

10 - Examples

No answers		98
Advantages	Easy for direct on Waypoints	5
	Small reaction time :	5
	More Accurate trajectory	5
	Easier Navigation :	3
	Vertical Profile, rate of climb	2
	Work with Route (vs. heading)	1
	FL or speed Constraint:	1
	Downlink Parameters	1
	Pilots more 'handy'	1
	Estimates available.	1
Drawbacks	Trajectory (because of accuracy : all fly over same points, reduced pilot awareness, overconfidence, ignorance of points outside route, anticipated turns (3))	7
	Pilots' behaviour (passive, bothersome, self centred, focused vision, less attentive on frequency)	5
	Difficulty of use (change of clearance or runway difficult to accept)	5
	Vertical behaviour 'economic' ?	1

11 - You think this results is a progress for your work

Completely Disagree	Rather Disagree	Rather Agree	Completely Agree
1%	19%	65%	15%

12 - You are familiar with the notion of engaged FMS mode (selected, managed)

55%	21%	17%	7%

13 - You would find the knowledge of some data in the FMS flight plan useful

7%	23%	39%	31%

14 – Examples :

No answers	4 saying : need to know FMS better to be able to make suggestions	69 + 14 (app)
Advantages	Aircraft Data	
	Rate of climb/descent	8
	Airspeed / Mach	7
	Heading	5
	Immediate Flight level	2
	IAS expected for descent	2
	Speed for climb	1
	Rate of turn	1
	Trajectory :	
	FMS Plan Route	18
	Top of Descent/climb :	12
	Next/other available waypoints	4
	Vertical Profile	4
	Scheduled RFL	4
	optimum FL	2
	max FL.	2
	Aircraft Route	1
	Type of flight : (economical or quick)	2
	Wind	3
	Mach Range available for a FL	1
	Estimates available	2
	Request for an FMS demo. :	3

Drawbacks	Pilots domain, (not ATC' s responsibility)	1
	Too many info is harmful	1

15 - The knowledge of the FMS flight plan could change some of your control decisions

Completely Disagree	Rather Disagree	Rather Agree	Completely Agree
13%	30%	46%	11%

16 - You believe a better knowledge of the FMS would be useful in your work

4%	3%	52%	41%

17 - You think this tool could be used to facilitate a cooperation between pilot and controller

3%	18%	49%	30%

18 - You have had, in you training period, a familiarisation or training for that tool

47%	14%	18%	21%

TCAS

19 - This tool can yield more security in the flight

Completely Disagree	Rather Disagree	Rather Agree	Completely Agree
1%	5%	44%	50%

20 - This tool is useful mainly on very short term, occasionally, in emergency

1%	2%	28%	69%

21 - You think this tool is an intrusion in your work

26%	40%	28%	5%

22 - You think some functionalities of this tool can have adverse effects on your task

5%	20%	51%	23%

23 - You are familiar with and understand the logic of the TCAS (TA, RA…)

1%	11%	50%	39%

24 - You can easily imagine how a conflict resolution on a TCAS would be perceived by the pilot

6%	20%	46%	27%

25 - You think this tool could be used in conjunction by the pilot and the control

42%	23%	30%	5%

26 - You have had, in you training period, a familiarisation or training for that tool

15%	11%	42%	32%

General

27 - You think other cockpit instruments could provide you with information relevant to your work

5%	11%	54%	31%

28 - Select only those types of information you think you would need, and chose a degree of importance

	Needed		Usefulness	
Weather info	❑ often	❑ seldom	❑ major	❑ average
Indicated Airspeed	❑ often	❑ seldom	❑ major	❑ average
Mach for a given FL	❑ often	❑ seldom	❑ major	❑ average
Requested FL	❑ often	❑ seldom	❑ major	❑ average
Heading	❑ often	❑ seldom	❑ major	❑ average
Actual Route	❑ often	❑ seldom	❑ major	❑ average
Time Top of Descent	❑ often	❑ seldom	❑ major	❑ average
Descent Speed	❑ often	❑ seldom	❑ major	❑ average

28 - Results :

Parameter(*)	# of occurrences (often useful)	Usefulness major -average
Weather info	113 - (77)	89 - 26
Mach at a given FL	108 – (96)	90 - 14
Heading	106 – (91)	84 - 22
Indicated Air Speed	103 – (85)	78 - 25
RFL	100 – (70)	48 - 51
Top of Descent	99 – (46)	30 - 65
Speed for descent	97 – (71)	62 - 36
Route followed	84 – (42)	38 - 45

(*) classified in ATCO preferred order

29 - Other suggestions (parameters deemed useful).

Rate of climb or descent : 8
(including expressed in ft/min, ou ft/NM)
Weather information : 2
Achievable Mach Range (or airline policy) for a given FL : 2
Indicated Airspeed : 1
FL actually input by the pilot : 1

Miscellaneous information :

	Average experience (in years)	Private Pilots	IFR pilots.
AIX	12,8	58%	0%
Appr	12,2	57%	14%
Bordeaux	9,6	67%	6%
Brest	19,4	18%	6%
Reims	5,8	46%	0%
ENAC	**0**	**71%**	**0%**

Enac Students Assignment : Approach - 71%
En-Route - 29%