Future Area Control Tools Support (FACTS)

Peter Whysall

National Air Traffic Services

Bournemouth Airport, Dorset BH23 6DF, UK.

+44 (0) 1202 472439 / pwhysall@atmdc.nats.co.uk

Abstract

The Future Area Control Tools Support (FACTS) R&D project aims to develop advanced computer assistance tools using trajectory prediction and medium-term conflict detection It is intended to support the future operation of The New En Route Centre (NERC) at Swanwick and the New Scottish Centre (NSC) at Prestwick, in particular by providing extra capacity to meet increasing traffic demand. The objective of providing assistance from such tools to the sector controller team is to reduce the workload associated with each flight as it passes through the sector, and thus enable an increase in the sector capacity. This paper provides a brief description of the FACTS operational concept, the FACTS tools, and an overview of the results obtained from the 'FACTS1' trial held in May 1998.

Introduction

Control of most air traffic over England is due to move to the New En Route Centre (NERC) at Swanwick within the relatively near future. However, it is anticipated that increasing levels of air traffic will exceed the capacity of the Swanwick Centre within perhaps 5 years of its becoming operational, and hence changes will be necessary to increase its capacity. In order to address this, National Air Traffic Services (NATS) has set up a research project to develop ATM support tools for introduction at Swanwick within that timescale. This project, Future Area Control Tools Support (FACTS) is being undertaken by the Department of ATM Systems Research (DASR), and held its first real-time trial in May 1998. This paper provides a brief description of the concept and tools being developed within the FACTS system and an overview of the results obtained from the first trial.

Operational Concept

The FACTS concept is based strongly on the Swanwick 'O' Date concept, oriented around the use of separate planner and tactical controllers for each airspace sector. In order to be successfully introduced into Swanwick, the aim of the tools provided within the FACTS concept is to provide genuine support to the current controller roles, rather than to change those roles significantly.

Planner Controller

The role of the Swanwick planner controller is primarily to agree entry and exit conditions with adjacent sectors. Initially, a planner is offered an aircraft for entry into the sector obeying certain conditions, typically a proposed entry flight level. The controller must consider this aircraft in the context of other aircraft approaching or within the sector in order to assess whether the proposed conditions are acceptable. In fact, it seems that the planner controller typically attempts to distinguish between three different types of situation:

Acceptable — The offered aircraft will be well spaced from other aircraft within the sector and hence, if accepted, only routine monitoring of the aircraft would be necessary.

Uncertain	The offered aircraft will not be well spaced from other aircraft and hence, if accepted, active monitoring would be required to ensure separation is maintained.
Unacceptable	The offered aircraft is likely to be close to other aircraft and hence, if agreed, early action would be necessary to avoid breach of separation.

Having made this judgement the controller can either accept the offer, or make a counter-proposal until agreement is reached. Similarly the planner controller will assess the situation for aircraft leaving the sector in order to make reasonable offers to controllers in subsequent sectors.

The aim of the FACTS tools for the planner controller is to provide a view of the situation at and beyond the boundary in order to help identify whether an offered aircraft is likely to be in conflict with other aircraft, and hence whether the situation is acceptable, uncertain, or unacceptable.

Tactical Controller

The role of the Swanwick tactical controller is to receive and hand over active control of the aircraft and to issue tactical instructions to aircraft under their control in order to maintain separation between aircraft, and to achieve exit conditions agreed by the planner controllers. A key part of achieving this aim is a process of continuous monitoring of the tactical situation, in order to identify potential problems, and hence to identify the need to issue these tactical instructions. Again they may typically distinuguish between acceptable situations requiring no action, unacceptable situations requiring actions now, and uncertain situations requiring close monitoring prior to possible future action if the situation becomes unacceptable.

The aim of the FACTS tools for the tactical controller is primarily to help the tactical controller to identify situations which are unacceptable or uncertain, in order to reduce their continuous monitoring process. As a secondary benefit, the FACTS tools may provide support to identifying the appropriate tactical instructions to address a situation.

Prototype Display Tools

From a controller’s perspective, FACTS is visible through four main display tools, each of which provides support to (part of) the role of the planner or tactical controller. The principal display tools are:

- the coordination list (CL);
- the vertical risk tool (VRT);
- the lateral risk tool (LRT);
- the conflict risk tool (CRT).

These separate display tools are each described in the sections below.

Co-ordination List

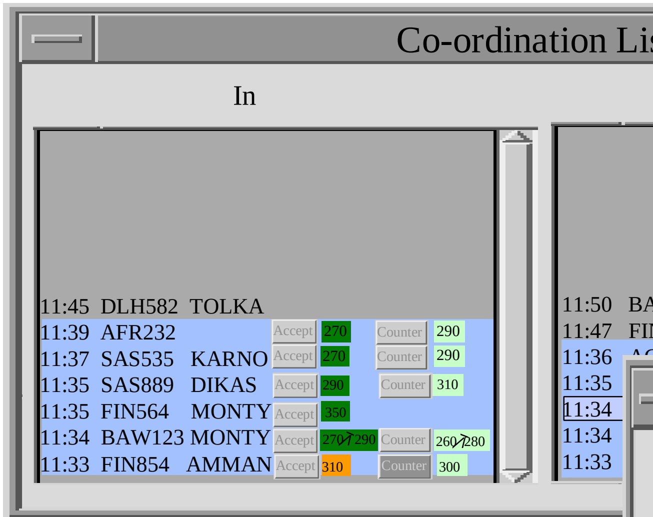
The co-ordination list (CL) is a tool designed to support the planner controller in carrying out the co-ordination process, identifying the key tasks which need to be undertaken, and providing an interface to allow the progress of these tasks to be recorded within the system.

The list is split into two separate parts, the co-ordination in-list (CIL) and coordination out-list (COL). It shows the planner controller all of the outstanding co-ordination tasks and provides a direct mechanism for accepting, offering and counter-proposing flights to adjacent sectors.

The planner controller receives advance notice of aircraft which are planned to route through the sector. When the aircraft is accepted into the previous sector, an entry appears in the coordination in-list. The CIL entry shows the predicted time at the sector entry boundary, the callsign, and a significant fix, and is further annotated with the status of the co-ordination and offered levels as the co-ordination proceeds.

When the controller accepts an aircraft into the sector, the aircraft’s entry in the CIL is replaced by an entry in the COL which shows: the time at the sector exit boundary, the callsign, a significant fix and a default exit flight level (XFL), and again this contents will evolve during the co-ordination process.

An example of the co-ordination list is shown in the figure below.



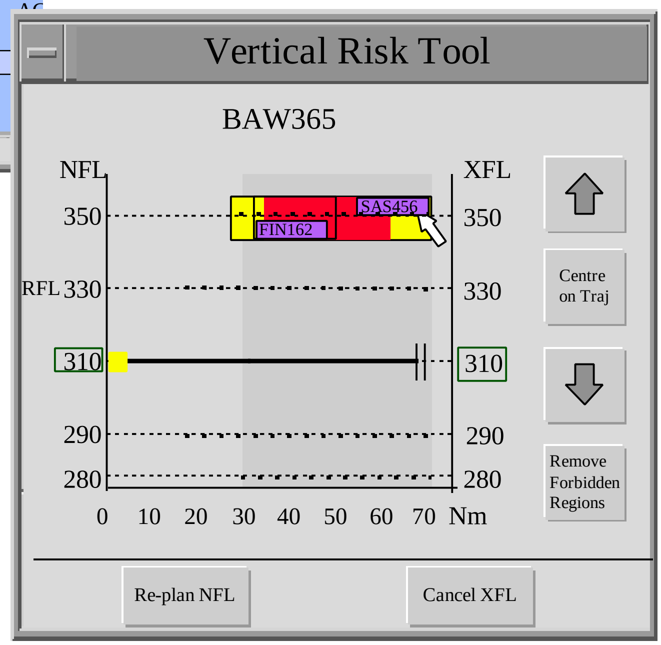
Vertical Risk Tool

The Vertical Risk Tool (VRT) provides a display of distance along the predicted route of an aircraft against altitude, showing the predicted profile of the aircraft. It identifies unacceptable and uncertain situations on the proposed profile, and at alternative flight levels. This tool is primarily intended for use by the planner controller in order to assist in identifying alternative handover conditions when an initial offer is not aceptable.

The planner controller's VRT also supports coordination. The planner controller can use it to assess, modify and coordinate levels into or out of the sector in a similar way to that supported by the co-ordination list. The tactical controller also uses the VRT to identify suitable flight levels for conflict resolution or to identify whether it is safe to issue a level change clearance.

For each aircraft, the planner controller's VRT shows the trajectory of the aircraft as far ahead as can be usefully predicted (15-20 minutes ahead); the vertical profile of the aircraft; and also identifies the requested flight level, entry flight level and exit flight level. Shading within the VRT identifies the geographical extent of the relevant sector, while 'forbidden regions' representing conflicts with other aircraft, are shown in yellow or red, depending on whether they are uncertain or unacceptable. Such forbidden regions are shown not only for the current flight profile, but also for adjacent flight levels were the flight to be given a climb or descent.

An example of the planner's VRT is shown in the figure below.



The tactical controller's VRT is similar to the planner controller's except that it only shows the trajectory for 10 minutes ahead and there are no buttons to support coordination.

Lateral Risk Tool

The Lateral Risk Tool (LRT) provides an overlay of the predicted route of an aircraft onto the situation display, identifying regions in which the aircraft is predicted to be in unacceptable or uncertain situations. This tool is primarily intended for the planner controller in order to provide a quick assessment of whether a proposed offer is acceptable.

The LRT appears on the situation display when a controller "hooks" an aircraft by clicking on the callsign with the computer mouse, showing the trajectory of the hooked aircraft and any conflicts predicted along it. The trajectories of the conflicting aircraft are also shown. Conflicts are shown as coloured regions of the trajectory, red indicates an unacceptable conflict whilst yellow indicates an uncertain conflict. An example of the LRT is shown in the figure above.

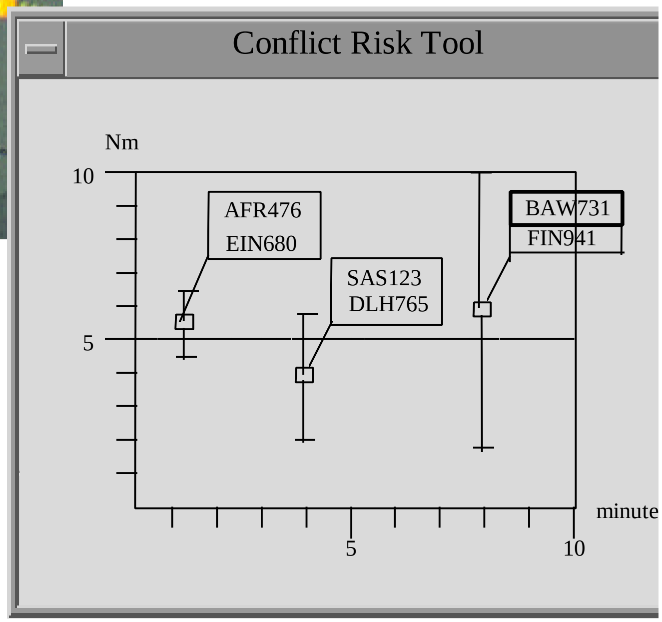
Tactical controllers would use this tool to assess conflicts and to identify possible lateral solutions. Planner controllers would use the tool to decide whether a coordination offer is acceptable.

The tactical and planner controller's LRT are similar except that the length is 10 minutes for the tactical controller, and for up to 6 minutes into the next sector for the planner controller.

Conflict Risk Tool

The Conflict Risk Tool (CRT) provides a display of predicted conflicts, showing the time until the conflict, and expected separation between aircraft, but also supplementing this with uncertainty information relating to the conflict. This tool is primarily intended for use by the tactical controller in identifying and prioritising situations which may require action in order to avoid possible conflicts.
The planner controller can use the CRT to gain an idea of the tactical controller's workload; if the tactical controller is busy, the planner may be less willing to accept aircraft in circumstances that the tactical controller will have to monitor closely.

The CRT shows all predicted conflicts lying within the sector over the next 10 minutes. It shows the predicted separation at closest approach for potential conflicts, indicated by the boxes on the vertical bars which can be seen on the figure below.



The uncertainty associated with the predictions is shown by the length of the vertical bars attached to each box. The callsigns of the aircraft concerned are also shown.

The time to the conflict is indicated by the position along the horizontal axis. The time shown depends on whether the conflict is unacceptable or uncertain:

- for unacceptable conflicts, where the closest approach is predicted to be below the separation standard the time to the breach of standard separation is given;
- for uncertain conflicts, where standard separation is not predicted to be breached the time to closest approach is given.

As time progresses, conflicts move to the left and the uncertainty bars shorten as the uncertainty in the prediction decreases. The nominal separation which is shown by the position of the box, changes as the accuracy of the prediction increases. It is possible that a conflict can disappear entirely as the accuracy of the prediction increases, without controller intervention. Conversely, it is possible that a conflict may appear with less than 10 minutes to run, as the result of tactical intervention or other unexpected aircraft behaviour.

Trajectory Predictor

At the heart of the FACTS system is the trajectory predictor (TP) which, in common with other trajectory predictors, generates a representation of the expected future behaviour of aircraft based on available information about the aircraft, flight plan controller instructions and weather. However, while most TP research has focused on predicting a single 'most accurate' trajectory, FACTS takes account of the inherent uncertainty in trajectory prediction in order to try to satisfy the specific support needs of the planner and tactical controllers.

Classes of Trajectory

The role of the planner controller requires an assessment of the the likely situation at and beyond the next sector boundary, looking some 15-20 minutes ahead. Hence when predicting the trajectory of an aircraft in order to provide useful information to the planner controller, it is necessary to provide a strategic view of the aircraft's behaviour over a 20 minute period. In particular, it may not be appropriate to directly take account of all short term tactical instructions if it is expected that these would be changed before an aircraft reaches the boundary.

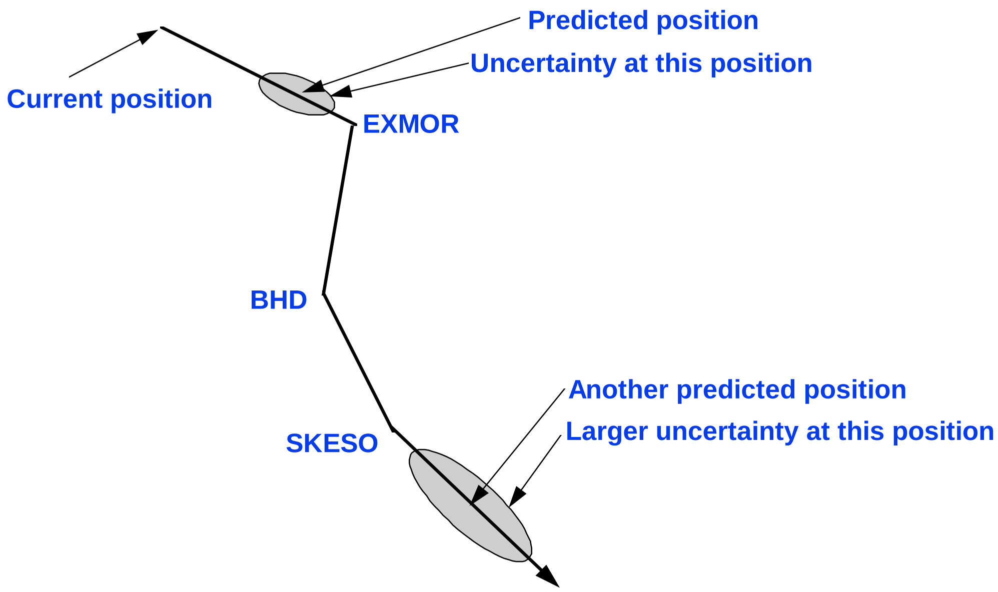
The role of the tactical controller requires assessment of the likely behaviour of the aircraft over the next 5-10 minutes in order to identify whether intervention is necessary to avoid potential problems. Hence when predicting the trajectory of an aircraft in order to provide useful information to a tactical controller, it is necessary to provide a tactical view of what the aircraft will do without further controller intervention. Hence the requirements for trajectory prediction to support tactical and planner controllers are in fact different, and the FACTS system generates two separate trajectories to support their needs.

The planning trajectory is used in the coordination list (for example giving the times at which sector boundaries are crossed) and in the planner controller's VRT and LRT (for example providing the route shown to the planner controller in the LRT). The planning trajectory is based on coordination information and flight plan information, but not on any short-term tactical instructions issued to the aircraft.

The tactical trajectory is used by the CRT and by the tactical controller's version of the VRT and LRT (for example providing the altitude profile shown to the tactical controller in the VRT). It is based on radar data and on instructions issued to the aircraft. The tactical trajectory is a shorter term prediction than that for the planner. Coordination is not taken into account in the construction of the tactical trajectory, so, for example, an aircraft which has been cleared by the tactical controller to climb to FL260 will have a tactical trajectory which climbs to FL260 and then continues indefinitely at that level, even if the planning controller has agreed an exit level of FL280.

Uncertainty

The role of both tactical and planner controllers at Swanwick requires controllers to distinguish between acceptable, uncertain and unacceptable situations. Uncertain situations are caused when the likely variability in the aircrafts' trajectory means that it is not clear whether conflict with other aircraft will be avoided. In order for FACTS tools to support the controller in distinguishing these situations it is necessary for them to have a representation of this uncertainty.



In FACTS, the trajectory predictor generates not only a central "most likely" trajectory, but also provides information about the likely uncertainty in aircraft position and height at all points along its route based on uncertainty in meteorological data, and in how the aircraft will fly the planned trajectory or obey the tactical instructions. It does not however take account of the possibility that the aircraft may not operate in accordance with the plan or any future tactical instructions, these problems being addressed by monitoring the actual behaviour of the aircraft against the predicted trajectory.

Consider an example in which an aircraft is flying a planned route over a sequence of reporting points. The FACTS TP calculates where the aircraft will be at each of a number of time steps into the future. The further ahead the prediction, the greater the uncertainty will be. The aircraft's ground speed is affected by a number of uncertain factors - such as wind and performance of the aircraft in climbs and descents. On the other hand, aircraft can fly along routes relatively accurately, so the 'uncertainty zone' tends to grow more rapidly along the route (due to ground speed uncertainty), than laterally (due to navigation uncertainty). The route and uncertainty of an aircraft in such an example are illustrated in the figure below.

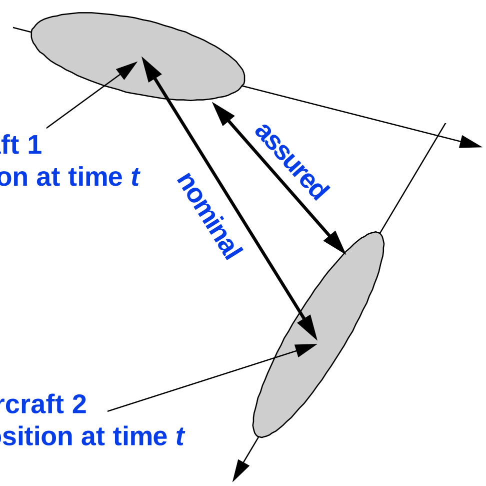
Medium Term Conflict Detector

The primary use of the trajectories generated by the FACTS trajectory predictor is for conflict detection. The FACTS MTCD detects all of the conflicts shown in the CRT, VRT and LRT by comparing pairs of predicted trajectories in order to identify whether the aircraft will remain sufficiently separated. The principle behaviour of the FACTS MTCD is similar to other conflict detectors, however, there are two differences introduced to support the specific needs of the FACTS concept.

The primary difference is the use of the trajectory and associated uncertainty information in order not only to identify predicted conflicts, but also to classify the them as uncertain or unacceptable.

Additionally, the FACTS MTCD generates separate sets of conflicts based on planner and tactical trajectories, in order to support the different needs of the controllers in carrying out their control tasks.

The figure below illustrates how the predicted future positions of aircraft and the associated uncertainty information can be used to calculate 'nominal' and 'assured' separation distances for aircraft pairs. In the figure, 'nominal' separation refers to the expected separation of the aircraft at some time, t, in the future (not necessarily the closest point of approach) ignoring uncertainty. 'Assured' separation is the minimum possible separation between the aircraft if, at some future time t, each aircraft is indeed within its predicted uncertainty zone. Thus the "assured" separation assumes that each aircraft is on the edge of its zone which is nearest to the other aircraft. (The zones are defined so that the actual future position of the aircraft is expected to lie somewhere in the zone 95% of the time, given the variability in meteorological information etc. Thus the aircraft could lie outside the zone.)



The categories of interaction between two aircraft are then defined as follows:

Acceptable:
 assured separation ≥ separation threshold
Uncertain:
 assured separation < separation threshold; and
 nominal separation ≥ separation threshold
Unacceptable:
 nominal separation < separation threshold

The MTCD may be configured to use different separation thresholds when comparing planning and tactical trajectories. In the trial, the separation threshold for tactical trajectories was set at the separation standard, 5Nm, and the planning separation threshold was set at 8Nm.

It is important to note that the calculation of uncertainty does not produce an absolute guarantee that the aircraft's position will in fact fall within the predicted zone at some future time. Indeed, there is a trade-off between making more conservative assumptions about the potential variability of the flight's actual trajectory, which would increase the size of the uncertainty zone and hence flag more aircraft pairs as being potentially in conflict, versus alerting the controller to many events which will very probably not turn out to be actual conflicts.

Results

The first trial of the FACTS concept and tools took place in May 1998. This was a development trial designed to assess the ability of the controllers to control traffic using the tools, and to generate detailed feedback on the effectiveness of each tool. However, comparative measurements against a baseline system were not carried out during this trial

The trial was conducted using the NATS' Research Facility (NRF), a real-time simulator based at NATS' Air Traffic Management Development Centre at Hurn. The Facility was configured to have 4 measured controller positions (2 tactical and planner controller pairs); 3 un-measured feed sector positions; and 5 aircraft position operators (ACPOs). Eight traffic samples were used during the trials; two at each of 100%, 125%, 150% and 175% traffic level loading, where 100% represents the peak hour traffic for July 1996. Each sample lasted 75 minutes.

The results of the trial are derived from the usability assessment, which had three main components:

- *Observation*: The controllers were observed overtly to assess subjective measures (such as frustration and its causes), and their responses to particular events (such as coordination and conflict detection).
- *Debriefs*: In formal debrief sessions, the controllers were asked to comment on their experiences of using FACTS and to discuss various aspects of the system.
- *Quantitative Assessment*: A post-task questionnaire, the Software Usability Measurement Inventory, was completed by each controller to elicit their opinions of the system.

Planning concept

The tools and method of operations for the planner controller were generally acceptable and the controllers felt that the suite of tools did indeed support the planner's task.

Electronic coordination seemed for the most part to work well. In particular, multi-level co-ordination - i.e. an agreement that the aircraft will cross the sector boundary within a band of levels rather than at a single specified level - was popular. The VRT implementation of this by dragging to select a band of levels was found to be effective. Indeed, the controllers' comments about electronic coordination largely concerned extending it to encompass more of the types of co-ordination typical at LATCC and NERC which are not currently included in FACTS (for example, co-ordination on a specified heading).

The workload of the planner controllers often seemed relatively light, even for reltively heavy traffic samples. A significant contributor to this was the planner controllers' principal tool, the coordination list. Only relatively minor changes to the CL were requested: display of destination and either aircraft type or speed; and CL entries to persist after the aircraft is accepted out of the sector, at least until it crosses the sector boundary.

The controllers also found the VRT a useful planning tool, although there were some problems with the underlying trajectories which are discussed below. The VRT's support to the coordination process (offering, selecting level(s) for counter-proposals etc) seemed to be effective, although the controllers preferred to use the co-orination list when this was possible.

A difficulty, however, concerned some of the assumptions made in the planning trajectory. The planning trajectory assumes more than just the coordination conditions, for example showing how the tactical controller is expected to descend an aircraft to meet a standing agreement. Conflicts shown along such a descent are relevant to the planners, not just to their task of managing sector workload, but also to the coordination itself - ie the task of ensuring separation. However, the existence of those conflicts, and the non-existence of others, depends on assumptions about how the tactical controller would control the traffic, which felt to the planner controllers like duplication of effort. The key point here is that the LRT and VRT could be showing a significant number of conflicts, and the task of deciding which of them was relevant to the task of coordination was substantial: it is not clear from the trial that making assumptions about what the aircraft will do *beyond* the boundary helps the planner coordinate *at* the boundary.

Contrary to the current NERC concept, in FACTS the planner controller does not plan flights out immediately after accepting them in, but delays this until until the aircraft is nearer to the next sector. In the trial, planner controllers were observed on occasion to plan out immediately, but this seemed to result from lack of familiarity with the concept or eagerness to get the job done, rather than from fundamental difficulties with waiting. On balance the trial seems to suggest that delayed planning could indeed be a viable option, meaning that later, and therefore more accurate, trajectory prediction may be achievable.

Tactical concept

On paper, the FACTS operational concept for tactical control was little changed from NERC, apart from the removal of flight progress strips. In practice, the tactical controllers found that using the FACTS tools considerably changed their method of working: they were reacting to the traffic - aircraft-by-aircraft - rather than scanning and monitoring based on a picture of the complete traffic situation.

The results for the tactical operational concept reflect the fact that more attention had been paid during the development to the planner controller's role and interface. The tactical controller's interface included some elements of a stripless system, for example entering the cleared flight level through a flight level menu in the TDB as had been tried in Eurocontrol's Operational Display and Input Development. However, the interface also retained elements of NERC, such as hooking and the tactical data entry component. The resulting 'hybrid' system caused some difficulties. The tactical controllers felt that the FACTS tools forced them into aircraft-by-aircraft control, rather than supporting them in building a picture of the traffic. A significant contributor to this was slow performance of the tools, but the balance in FACTS between looking at a single aircraft and scanning the whole traffic situation does need to be reviewed.

Trajectory Prediction

Prediction of the tactical trajectory appeared to be largely successful, although there were occasionally problems when tactical instructions affecting the trajectory had not been entered into the system. The planning trajectory, however, exhibited some problems.

The current FACTS planning trajectory assumes that aircraft will climb or descend within a sector to meet a required exit level. The trial showed that, although this is useful in some cases, in others it is not. In particular, in circumstances where there is any doubt about how this transition would be made, the controllers preferred no assumption to be made (that is, an aircraft should be predicted to continue in level flight at its entry level), otherwise the resulting trajectories and conflicts required too much interpretation.

Medium Term Conflict Detection

Performance issues with the system during the trial meant that conflict calculations were often based on out-of-date trajectory predictions because the MTCD was too slow. Allowing for this, the conflicts shown often seemed plausible, but it was difficult to draw any firm conclusions about the effectiveness of conflict detection. However, the trial did highlight two important conceptual issues, and suggested a number of changes to the information that should be displayed about conflicts. These points are discussed here.

The first conceptual point concerns separation and conflict. To the controllers, the emphasis in FACTS on responding to conflicts seemed a significant change from how they saw their current role, which is more about maintaining separation - ie continually surveying and refining the whole traffic situation - than about resolving conflicts - ie looking at a sequence of problems between pairs of aircraft.

In fact, the sharpness of this distinction is more apparent than real: it owes much to the controllers having had little opportunity to become confident in the FACTS tools, to difficulties in building a picture of the traffic situation when using the tools and to a different interpretation of 'conflict'. In FACTS, conflicts are all of those predicted separations which, when taking the uncertainty of prediction into account, could be less than the required minimum. To the controllers, it made no sense to talk of a 'conflict' in a sector until, for example, entry conditions for both aircraft were agreed; in some cases FACTS was highlighting, as conflicts, circumstances that would not arise because controllers would coordinate aircraft so as to maintain separation.

The implication is not that FACTS needs to change fundamentally what is being calculated, but that it needs to change the emphasis on what is being shown to the controllers, and also how they are taught to use the tools. For example, the principle of the current CRT is to show all separations which have some possibility of being less than the 5Nm minimum. The controllers, in addition, wanted to be shown pairs of aircraft whose separation was somewhat larger. The lesson for FACTS is that a change of emphasis from conflicts to separation in the concept, tools and training, could improve the acceptability of FACTS.

The second conceptual point about the use of FACTS concerns uncertainty in future predicted aircraft positions. A key innovation in FACTS is that it explicitly models the uncertainty in its predictions, so it is important to understand how best to use and to communicate this uncertainty to controllers. FACTS uses uncertainty to categorise conflicts into acceptable, uncertain and unacceptable. These categories seemed natural to the controllers who confirmed that's how they think of it. However, there was resistance to being shown uncertainty directly and the presentation of uncertainty based on these categories certainly caused some confusion.

Uncertainty is an inherent part of the ATC task. In the current ATC system, controllers have an appreciation of possible variations in the future position of aircraft and plan their actions accordingly. FACTS makes that uncertainty more explicit than the 'rules of thumb' currently used.

However, the emphasis in the tools on showing conflict position uncertainty left the controllers feeling that they were being shown conflicts, but not being given the information they needed to solve those conflicts (or to maintain separation). Some of this lack of information will be solved by changes to tools while other issues require a more detailed statement of the method of operations, including particular examples of how different types of conflicts could be solved using the information provided.

Conclusions

The FACTS1 trial was the first formal demonstration of the FACTS prototype concept and tools, designed to guide the next stages of development.

Support by FACTS of the planner controller stood up to the assessment in many respects, especially co-ordination of a band of levels. Electronic support to co-ordination would be more helpful if FACTS embraced further types of co-ordination, such as co-ordination on a heading. The principal difficulty with the FACTS planning concept is that it is not clear from the trial that making assumptions about what the aircraft will do beyond the boundary helps the planner to co-ordinate at the boundary.

The tactical operational concept and tools were not an efficient system. The tactical controllers felt that the FACTS tools forced them into aircraft-by-aircraft control, rather than supporting them in building a picture of the total traffic. The balance in FACTS between focusing on a single aircraft and scanning the whole traffic situation does need to be reviewed.

Although the tactical trajectory performed adequately, difficulties with the planning trajectory have highlighted both the need for a more detailed statement of the method of ATC operations which use the tools and the need to use this to analyse the impact on such operational use of delays or mistakes in using FACTS.

The controllers felt that they would find it easier to use the results of the MTCD calculations as displayed in the VRT, CRT and LRT:

- if there were more emphasis on showing predicted separation than on showing only aircraft which could be in conflict;
- and if it were clearer how the tools supported typical tasks of conflict resolution - this has design and training implications.

This initial trial was intended for development purposes, and has identified a number of areas where further work is required to bring FACTS to a pre-operational status. Nevertheless, the trial does give grounds for confidence that FACTS is a viable approach to the future growth of en-route ATC capacity, especially in its provision of tactical trajectory prediction, medium-term conflict detection and electronic support to co-ordination.

Five further trials are planned over the 1999-2002 period to fully develop the FACTS system to a point where a large scale simulation can be undertaken, leading to a fully operational system at NERC by around 2005/006.