CENA PD/3 FINAL REPORT
Annex E: Airborne aspects

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1. INTRODUCTION

The CENA PHARE demonstration with the NATS BAC1-11 live aircraft took place on the week 2-5 June 98. It was a specific exercise within the whole CENA PD/3 demonstration. Its objective was to show to visitors the capabilities of an air/ground integrated system based on the PHARE concepts via an experimental Aeronautical Telecommunication Network so-called PATN.

That exercise was the result of a co-operation work between:

--- **DERA** which operated the BAC1-11 laboratory aircraft,
--- **CEV** Bretigny ("Centre d'Essai en Vol") which hosted the aircraft and operated the flights,
--- **CRNA** Paris which hosted CEV controllers,
--- **CENA** which ran the PD/3 simulation exercise including the live aircraft.

![Figure E. 1-1 : BAC 1-11 at Centre d'Essai en Vol (Bretigny France)](image-url)
2. CONFIGURATION

2.1 OVERVIEW

BAC1-11 flights were operated from Brétigny Airport (LFPY) and CRNA in Athis-Mons by CEV controllers. Air/ground datalink applications supported by the PATN network allowed to integrate the real aircraft into the PD/3 simulation being run at CENA Athis-Mons.

![Telecommunication Diagram]

Figure E. 2-1 : Telecommunication Diagram

A specific UHF R/T had been installed for direct vocal communication between the aircraft and the CENA simulation, but technical problems prevent to use it during the demonstration.

2.2 AIRBORNE CONFIGURATION

The BAC 1-11 flying laboratory is operated by the Defence Evaluation and Research Agency (DERA) and is based at Boscombe Down airfield near Salisbury in the UK. The aircraft itself has a typical endurance of between 3 to 4 hours and a maximum ceiling of around 35000 feet, which allows it to perform flight profiles representative of modern short to medium haul jet airliners. The test environment in which it is flown, permits flexibility in these flight profiles without being constrained to everyday airliner operations. Internally, the BAC 1-11 has been modified to allow the installation of experimental avionics permitting trials to be performed in to future Air Traffic Management systems.
For the EFMS flight trials, the cockpit was configured to provide the left-hand pilot with an EFIS screen interfaced with a rollerball and a touch-screen CDU (see Figure E. 2-2), the software for each having been developed within the AHMI project. The rollerball was mounted on the right-hand arm-rest of the pilots seat, while the CDU was mounted in the centre pedestal, just behind the throttles. The standard BAC 1-11 instrumentation is retained on the right-hand side of the cockpit in order to allow the aircraft's operation to be monitored by a safety pilot. Repeater EFIS screens and CDU were available within the cabin to allow monitoring by the researchers and visitors during the trials and demonstrations. Similarly, intercom facilities are installed in the cabin in order to allow trials co-ordination between the pilot and the researchers, as well as providing visitors the ability to listen to commentary by the pilot during demonstration flights. There was sufficient space for up to 3 visitors at a time to view the systems being demonstrated in the cockpit during the PD/3 flights.

The EFMS/AHMI software was run on two computers within the aircraft's cabin. A VME-based Sparc20 was used to host the AHMI and the trajectory predictor and negotiation functions. Originally a MVME-167 card ran the guidance and aircraft interface software, communicating via ethernet with the Sparc20 computer. This configuration was flown until the end of March 1998 when another VME-based Sparc20 was installed in place of the 167 card. This required some modifications to the guidance and aircraft interface software in order to build a system that was able to run on the new hardware.
The BAC 1-11 has been equipped with various digital avionics in line with more modern civil airliners. These use the standard Arinc 429 data bus protocol in order to transfer data. The EFMS obtains data from several systems on board the aircraft:

1. Digital Air Data Computer (DADC)
2. Attitude and Heading Reference System (AHRS)
3. Global Navigation Satellite System (GNSS), with reversion to a multi-DME/inertial position fixing system
4. Engine Instrumentation Unit (EIU)
5. Digital AutoPilot

Guidance demands are output from the EFMS to the digital autopilot. The autopilot is part of the experimental equipment on board the aircraft and the software can be configured, if required, for different trials. This was the case when the autopilot was modified in order that it could work with the EFMS operating in either continuous or target guidance modes.

Data link capability was provided via an interface to the airborne PATN workstation which in turn communicated through a Satcom system with the ground ATC simulations run by CENA. Ethernet was the communication medium between the EFMS and the PATN workstation (which was also a VME-based Sparc20). In order to handle the communication protocol with the PATN system, an additional process, called the Name Server, needed to be run alongside the EFMS. This Name Server required a certain amount of configuration work to be carried out in order to produce a functional system, although similarly, some of the EFMS software had to be updated as well.

When trials were carried out without the ground system, a portable Sun computer could be used in the cabin of the BAC 1-11 to run a simplified ATC simulator. This provides the means to exercise the full negotiation functions of the EFMS in an ATM environment, although clearly it does not simulate the presence of other aircraft. It is possible, however, to receive downlinked trajectories and to modify and uplink ground constraint lists, as well as send trajectory approvals and clearances. This portable Sun was also used to display the EFMS Supervisor screens from the systems running on the two Sparc20’s. This allowed the researcher in the cabin to monitor various aspects of the performance of the EFMS. Additionally, error messages from the EFMS software would be displayed on the portable Sun.

2.3 GROUND CONFIGURATION

The configuration of the ground platform used for the demonstrations was the same as the one used for the measured experiments, that is to say, three control working positions (Departure, ETMA, En route) manned by six controllers, three adjacent controllers and pseudo-pilots. A specific traffic sample, with a reduced number of aircraft, had been built for that purpose in order to facilitate the integration of the real aircraft among the simulated traffic and also to let time to controllers to answer the visitors questions.

(refer to DOC 99-70-01 / Volume 2 of 4 / Section 1 of 2 / chapter 4 for a detailed description of the ground platform).
2.4 **PATN CONFIGURATION**

The following drawing describes the telecommunication environment operated for these trials:

![Diagram of PATN configuration](image)

**Figure E. 2-3 : Detail Network Protocol**

2.5 **DATALINK APPLICATIONS**

The Aircraft EFMS and its AHMI (Airborne HMI) communicated with PD/3 CENA simulation via datalink through the PATN network. That allows the aircraft to be also controlled from the PD/3 CENA simulation.

Three datalink applications were used to exchange data between aircraft and the CENA simulator located at Athis-Mons:

- the CPDLC-PR application (Position Reporting), before take-off and during the flight,
- the CPFLC-FC application (Frequency Change), during the flight,
- the TN (Trajectory Negotiation), before take-off and during the flight.

2.6 **DEMONSTRATION ENVIRONMENT**

As part of the PHARE Demonstration 3 (PD/3), it was planned that the BAC 1-11 aircraft be involved with the CENA simulation of the ATC sectors to the north and east of Paris, Charles De Gaulle airport. The simulation was to consider the handling of departure traffic from this airport. The BAC 1-11 was to use the PATN satellite-based data link in order to communicate with the simulation being run at CENA, Athis-Mons.

The aircraft was to pretend to be operating a flight from Paris, Charles De Gaulle to London, Heathrow, departing from runway 27 at Charles De Gaulle and following the BNE8A Standard Instrument Departure (SID) routing to Boulogne. The aircraft would carry out initial trajectory negotiations with the ATC simulation prior to take off and then further negotiations would take place once it was airborne. Due to a possible problem
with the ATC simulation not being able to handle the STAR information for routing in to Heathrow, the trajectories that were downlinked from the BAC 1-11 finished at either waypoint BNE25 or BNE35 which took the aircraft beyond the simulated ATC sectors. This also meant that the negotiated trajectories terminated in the cruise.

Another factor to be considered was that the aircraft would not be able to fly the actual SID from Charles De Gaulle, but had to operate out of the airfield at Bretigny. The BNE8A SID was therefore translated to coincide with a departure from runway 05 at Bretigny. This required all position and track data relating to the aircraft and its route to be translated between the two reference frames (Charles De Gaulle for the ATC simulation, Bretigny for the BAC 1-11), every time data was transmitted or received via the PATN data link on the aircraft. Software was installed in the EFMS to provide this function.

The route of the flight had been divided in two parts. On the first part of the flight, CENA demonstrated the capabilities of air/ground datalink applications through the PATN network and on the rest of the flight DERA demonstrated the EFMS capabilities using an airborne ATC simulator.

![Figure E. 2-4 : Real and Simulated Flight Plans](image-url)
2.7 THE DEMONSTRATION FLIGHTS

(the text below is extracted from the DERA report on the BAC1-111 flight: EFMS Operation With PATN On Board The DERA BAC 1-11 During PD/3)

2.7.1 Introduction

Prior to the BAC 1-11’s departure to Bretigny on the 2nd June, the EFMS on the aircraft had never really been linked to the ATC simulation at Athis-Mons. The plan for the 2nd June involved ground testing with one or two test flights of the route. Then, on the following three days, two demonstration flights would be carried out per day with invited guests on board the aircraft to view the system. Due to the ATC simulation only covering the departure situation, when the aircraft reached a waypoint BNE25 (25 miles beyond the simulated point for Boulogne), the EFMS would need to be reset. This allowed the aircraft to continue to use the EFMS through the cruise and descent back to Bretigny, utilising an on board facility to simulate the trajectory negotiation functions.

2.7.2 EFMS Software State

The EFMS had been built to Update 4 of the Release 5 software from the Integration Team. In addition, on the 29th May, three revised files were provided by the Integration Team, relating to the EFMS interface with the CMS data structures.

When the BAC 1-11 arrived at Bretigny on the 2nd June, ground tests were carried out, which included linking the EFMS via PATN to a CENA ATC simulator. On attempting to downlink a trajectory, however, the EFMS believed it had sent the trajectory, but the PATN system on the aircraft did not receive any data. Following consultation with the EFMS Integration Team, it was found that two files within the PATN area of the EFMS, which were currently moved out of the compilation path, needed to be built in to the EFMS (initially it was suggested that there were four files required, but this introduced additional problems).

2.7.3 Flight Test On 2nd June

The aircraft was scheduled to carry out a test flight around the PD/3 route in the afternoon of the 2nd June. An attempt was to be made to run the systems with the EFMS linked via PATN to a CENA ATC simulator. While the aircraft was still on the ground, problems were encountered with the EFMS, which at this stage had the four additional files built in to its PATN area.

The EFMS was rebuilt with these two files removed and this time the EFMS started successfully and established communication with the PATN system on board the aircraft (this version of the EFMS, for use with the PATN, remained unchanged throughout the rest of the week). At this stage, the “DL” symbol remained in place on the EFIS display, indicating that a trajectory negotiation capability had not yet been established with the ground ATC system. At this stage, it was not clear whether the EFMS should be sending a request down to the ground system or whether it was awaiting the ground system to make the connection. It subsequently transpired that it is the ground system that establishes the communication links with the aircraft that allow trajectory negotiation, frequency change and position reporting to take place. After a period of time with the aircraft still on the ground and with engines running, there was still no contact with the ground system and it was decided to reset the EFMS to use the on board ATC simulator during this flight.
2.7.4 Ground Test Following Flight On 2nd June

Following the test flight, further ground tests were carried out with the EFMS, PATN and the CENA ATC simulation. On this occasion, a link with the ground system was established, although a full trajectory negotiation could not be accomplished. The following is a list of some of the messages transmitted or received by the EFMS during the course of the test. The time shown is the EFMS system time, which is about two minutes twenty seconds behind UTC.

1541:12 Generated trajectory for CDGLHR company route to finish in cruise at waypoint BNE25 and with no height constraints.

1543:26 Further generation carried out.

1550:16 Trajectory Negotiation capability established on receipt of ground message.

1550:23 Position Reporting capability established and triggered on receipt of ground message. Position reports transmitted every 12-13 seconds.

1550:38 Frequency Change capability established on receipt of ground message. This includes the automatic transmission of a response message (36 bytes) back to the ground system from the EFMS. There is also a ‘Monitoring’ message (72 bytes) which is sent from the EFMS.

1551:14 Trajectory downlinked to ATC (4832 bytes).

1552:23 Frequency Change monitoring acknowledgement message received. This in turn leads to automatic transmission of message back to the ground. At the end of this, the EFMS appears to think that another message is being received, but an error, ‘Resource temporarily unavailable’, occurs.

1557:16 Trajectory Negotiation abort message received, disabling this capability.

1603:43 Generated new trajectory (updated take off time via CDU).

1610:37 Position Reporting abort message received, which was acknowledged automatically.

1616:47 Frequency Change abort message received, acknowledged automatically.

1625:40 Connection cancelled on receipt of ground message.

2.7.5 Ground Test Prior To First Flight On 3rd June

Further work was carried out to try and get the air/ground communications functioning. On this occasion, frequency change messages were received and acknowledged successfully, while a trajectory was transmitted from the EFMS and received by the ground system, although no negotiation uplink was achieved. Messages relating to the Frequency Change dialogue appear to generate automatic acknowledgements on receipt, these acknowledgements being transmitted back to the original sender. These automatically generated messages have been omitted from the list below (it is noted, however, that the response time is of the order of 40 seconds for an acknowledgement to be received following a downlinked message).

0712:00 Generated trajectory for CDGLHR route, finishing in cruise at BNE25.

0728:30 Generated trajectory again.
A number of ‘Subscription’ messages were passed between the ground and air systems over the next few minutes.

0729:26 Generated trajectory (entered new take off time via CDU).
0733:14 Frequency Change establish dialogue message received.
0733:20 Trajectory Negotiation establish dialogue message received.
0733:27 Position Reporting activation message received.
0735:23 Frequency Change message (to 125.000 Mhz) received.
0736:01 Pilot acknowledgement of Frequency Change message is sent.
0753:37 Generated trajectory again.
0754:48 Trajectory Negotiation abort dialogue message received.
0754:54 Position Reporting abort message received.
0755:07 Frequency Change abort dialogue message received.
0805:32 Frequency Change establish dialogue message received.
0805:38 Trajectory Negotiation establish dialogue message received.
0805:45 Position Reporting activation message received.
0806:22 Trajectory downlinked to ATC (it was confirmed that this was received on the ground, although no uplinked approval or constraint list was received).
0808:24 Frequency Change message (to 126.900 MHz) received.
0808:45 Pilot acknowledgement of Frequency Change message sent.
0812:24 Trajectory Negotiation abort dialogue message received.
0814:50 Frequency Change message (to 124.000 MHz) received.
0815:30 Pilot acknowledgement of Frequency Change message sent.
0818:47 Frequency Change termination message received.

The subsequent flight in the morning of the 3rd June used the ATC simulator on board the aircraft rather than the PATN in order to perform trajectory negotiations. The reason for this was that CENA were using the PATN test suite (operated from Toulouse) which could not produce realistic ground constraint lists for uplink to the aircraft.

2.7.6 Second Flight On 3rd June

For this flight, the EFMS was configured to operate with the PATN. The time in the EFMS was synchronised with the time in the ATC simulator at Athis-Mons, such that 1238:24 UTC was equivalent to 0721:30 in simulation time. Prior to take off, communication could not be established between the EFMS and the CENA ATC simulator, via the data link, therefore a trajectory was generated by the pilot and then activated without negotiation.

The aircraft took off on runway 23 (the route is based on a take off from runway 05) and consequently a tear-drop manoeuvre had to be followed in order to join the simulated route. During the climb out from the runway, position reporting was triggered in the EFMS by a message received from the ground system (this was at about 1315 UTC, or 0758 in simulation time). The position reporting did not last very long before the data link had to be reset, due to the problem of the Satellite Data Unit losing contact with the satellite following take off. This problem was encountered on each of the flights.
from Brétigny and was possibly due to external interference. The ground system may only have received about a couple of minutes worth of position reports at best, before the data link was reset.

As the aircraft approached the cruise altitude of FL250, position reporting was triggered again by a message from the ground system. No trajectory negotiation or frequency change messages were, however, exchanged between the aircraft and the ATC simulator. On reaching waypoint BNE25, the aircraft had passed outside the simulated ATC sectors and therefore the EFMS was reset soon afterwards in order to use the onboard ATC simulator for the return route to Brétigny.

2.7.7 Ground Test Following Second Flight On 3rd June

On this occasion, some uplink of trajectory negotiation data from the CENA ground system to the EFMS was achieved. With the data link functioning and trajectory negotiation dialogue established, a trajectory was downlinked to the CENA ATC simulator. This trajectory consisted of the CDGLHR route, shortened to waypoint BNE25, and finishing in the cruise.

In response to this trajectory, a ground constraint list was transmitted back to the aircraft. This constraint list, however, appeared to contain double, and in some cases triple, instances of the same waypoints. On advice from CENA, a go direct to waypoint VAKSO was implemented in order to remove some of the duplicates. This cleared some of the waypoints, but there were still too many points in the list. Further deletion of points reduced the constraint list to a more valid route from the departure airport (Brétigny simulating being Charles De Gaulle) to waypoint BNE25. The constraint list now consisted of the waypoints:

<table>
<thead>
<tr>
<th>Ground Constraint List</th>
<th>EFMS CDGLHR Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>00003</td>
<td>N 48 36.6 E 002 21.2</td>
</tr>
<tr>
<td>CGN</td>
<td>N 48 37.0 E 002 21.7</td>
</tr>
<tr>
<td>00002</td>
<td>N 48 38.1 E 002 23.3</td>
</tr>
<tr>
<td>00001</td>
<td>N 48 34.5 E 002 33.4</td>
</tr>
<tr>
<td>VAKSO</td>
<td>N 48 23.5 E 002 57.2</td>
</tr>
<tr>
<td>BNE</td>
<td>N 47 40.0 E 004 22.0</td>
</tr>
<tr>
<td>BNE25</td>
<td>N 47 24.0 E 004 51.1</td>
</tr>
</tbody>
</table>

The positions quoted above, show that there was a reasonable agreement between the data transmitted to the ground system and that received back in the constraint list. It should also be remembered that all the position co-ordinates that were transmitted from and received by the EFMS were translated between the area being simulated by the ground system and that in which the aircraft was to actually fly. It is assumed that waypoint 00003 relates to waypoint THR09 of the CDGLHR route, 00002 relates to D268I and 00001 relates to D331I. It will be noted that the waypoint 00001 is actually just over 3 miles south of D331I. In the end, waypoint 00001 was replaced by D331I, in order to produce a reasonable route.

All the uplinked constraints were defined as Start_Of_Turn waypoints, whereas only D268I and D331I were of this type in the CDGLHR route. This meant that the route path derived from the ground constraint list would not have overlaid the original one for the CDGLHR route. There were also no values set for the turn radii, therefore the EFMS would have used default values to calculate the lateral route. It was found that the turn radius at 00002 had to be set at 1 nm in order for a “Lateral Route Error” not to be raised.
Attempts to generate a trajectory to this modified ground constraint proved to be unsuccessful, a “Prediction Failed” message appearing on the EFIS. By this stage of the evening, however, there was no further time to investigate the problem because the power to the aircraft was to be shut down. It was probable, though, that all the waypoints were defined as part of an En-Route segment, the EFMS needing waypoints defined as part of a SID at the start of the route before it will generate when the aircraft is on the ground.

2.7.8 Ground Test Prior To First Flight On 4th June

The EFMS time was synchronised with the time of the CENA ATC simulator (0809:31 UTC being equivalent to 0844:13 in simulation time). Position reporting was triggered by the receipt of a ground message and trajectory negotiation dialogue established. Once again it was possible to receive an uplinked ground constraint list. This time, the list contained a reasonable sequence of waypoints, although the very first point, LFPG, had to be removed because it was displaced a significant distance from the centre line of the runway (it was actually the reference position for Charles De Gaulle airport translated to the Brétigny area). The position data for this constraint list was as follows:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CGN</td>
<td>N 48 37.0 E 002 21.7</td>
<td></td>
</tr>
<tr>
<td>00004</td>
<td>N 48 38.1 E 002 23.5</td>
<td></td>
</tr>
<tr>
<td>00003</td>
<td>N 48 37.4 E 002 33.3</td>
<td></td>
</tr>
<tr>
<td>00002</td>
<td>N 48 28.3 E 002 49.5</td>
<td></td>
</tr>
<tr>
<td>00001</td>
<td>N 48 25.0 E 002 53.8</td>
<td></td>
</tr>
<tr>
<td>VAKSO</td>
<td>N 48 23.5 E 002 57.2</td>
<td></td>
</tr>
<tr>
<td>BNE</td>
<td>N 47 40.0 E 004 22.0</td>
<td></td>
</tr>
<tr>
<td>BNE25</td>
<td>N 47 24.0 E 004 51.1</td>
<td></td>
</tr>
<tr>
<td>BNE35</td>
<td>N 47 17.8 E 005 02.7</td>
<td></td>
</tr>
</tbody>
</table>

The position of 00004 relates to the waypoint D268I in the CDGLHR route and 00003 relates to waypoint D331I, while 00002 relates to a point 20 nm from CGN on the track to VAKSO. The point 00002 had an height constraint of FL99 associated with it and the point BNE had an height constraint of FL179 (it is assumed that these were meant to be FL100 and FL180 respectively). It is not clear what the purpose was of the point 00001, although its proximity to VAKSO meant that a turn radius of 3 nm had to be applied to it in order to prevent a Lateral Route Error being raised.

A trajectory could not be generated to this modified constraint list as it stood because all the points were defined as part of an En-Route segment. By removing the waypoint CGN and replacing it with a SID consisting of the waypoints THR09 and CGN from the CDGLHR route in the EFMS, it was possible to predict a valid trajectory. Due to all the waypoints in the ground constraint list being defined as Start_Of_Turn points, the lateral route did appear a little strange, running wide at each of the waypoints compared with that produced for the EFMS CDGLHR route.

2.7.9 First Flight On 4th June

The EFMS was configured to work with the PATN and the time was synchronised such that 0747:30 in simulation time was equivalent to 0821:24 UTC. The ground system had been reset earlier after a previous time synchronisation. Position reporting and trajectory negotiation dialogue had been established before this reset. CENA had requested that no trajectory negotiation should be attempted until about 10 minutes
after take off. This would allow the data link to be reset and communications to be re-established before a trajectory could be downlinked to the ATC simulation.

A trajectory was generated while the aircraft was on the ground at 0751:43 in simulation time, but this was not transmitted over the data link. At 0753:33 simulation time, however, a formalised clearance was received from the ground system (this was 8 + 1080 bytes in size). CENA advised that this was transmitted to the aircraft in error and that it should be ignored. Due to this ground list remaining on the EFIS display, a prediction was attempted, but this raised a Lateral Route Error, probably for the same reasons that were encountered in the earlier ground test. In order to clear up the display and determine a valid trajectory for flight, the CDGLHR company route was re-inserted via the CDU and a new trajectory generated to waypoint BNE25, finishing in the cruise. This trajectory was then activated on the ground, arming the guidance system.

When the aircraft took off, the activation of guidance was triggered, but an exception occurred in the packing of the Phase Table data to be transmitted across to the other Sparc 20 computer which runs the guidance system. This problem required a reset of the EFMS, which took place while the data link was also being reset due to a satellite communications problem. Problems with recovering the data link again meant, however, that the EFMS could not be run with the PATN. Therefore the EFMS was reset to operate with the ATC simulator on board the aircraft.

2.7.10 Second Flight On 4th June

Once again, the EFMS was set up to communicate to ATC via the PATN. Time synchronisation was carried out, resulting in 1325:41 UTC being equivalent to 0803:00 in simulation time. A trajectory was then generated to waypoint BNE35 at 0806:13 in simulation time, while the aircraft was on the ground. Another trajectory was generated at 0811:26 simulation time with a revised take off time. This was then downlinked to ATC at 0811:29 simulation time, the trajectory being packed in to 8 + 5236 bytes. No trajectory approval was received back from the ATC simulator. Further updates of the take off time were carried out via the CDU and a trajectory generated at 0813:33 and 0814:52 simulation time. These trajectories were not downlinked, but were activated, arming the guidance system.

After take off, the guidance system was automatically activated at 0816:00 simulation time. The data link had to be reset following loss of connection with the satellite once the aircraft had taken off. Part of the PATN link would appear to have been recovered at around 0825 simulation time, although communication with the ground system may not have been achieved until about 0829 simulation time. Trajectory negotiation dialogue was established and the ground ATC computer was downlinked to ATC at 0829:52 in simulation time (the trajectory was 8 + 4248 bytes). It was later learnt that the ground ATC simulation could not handle the downlink of an active trajectory (referred to as a pre-emptive trajectory). By now, the aircraft was essentially in the cruise and the pilot modified the lateral route in order to put an offset around waypoint BNE25. A trajectory was generated and downlinked to ATC at 0832:29 simulation time; this was made up of 8 + 3048 bytes. A further trajectory was generated and downlinked at 0833:55 simulation time, consisting of 8 + 3068 bytes. The EFMS recorded data only shows that the data was sent from the EFMS to the PATN computer, there is no information available in the file to say whether the data was actually transmitted from the aircraft. Since no response was received from the ground, another trajectory was generated and then activated in order to actually fly the lateral offset (when a trajectory is negotiated, the Activate button is lost from the EFIS until an approval arrives over the data link from ATC). The reason that the EFMS received no response from ground was that the PATN work station on the aircraft had failed, the Sparc 20 computer
continuously rebooting itself (possibly due to overheating after running for a long period on the ground). The EFMS was reset at about 0842 simulation time due to reaching the end of the outbound route and the need to reconfigure for the return to Brétigny.

2.7.11 Ground Test Following Second Flight On 4th June

During these tests, a complete trajectory negotiation dialogue was achieved with predicted trajectories being downlinked and approvals and constraint lists being uplinked. Unfortunately, there is no EFMS data recording for this test, only the results that were written down as it progressed. Once communication between the ground system and the EFMS had been attained, position reporting, frequency change dialogue and trajectory negotiation dialogue were established. A Frequency Change message (to 127.300 MHz) was then received from the ground and acknowledged via the EFIS. Time synchronisation also took place, 1537:41 UTC being equivalent to 1005:00 in simulation time.

A take off time of 1008 was set and a trajectory generated using the CDGLHR route, as far as waypoint BNE35 (8 waypoints in total) This was then downlinked via the PATN, the trajectory being packed in approximately 8 + 5236 bytes. After about 4 to 5 minutes, a trajectory approval was received back and the trajectory activated. This sent an activation confirmation message to ATC. A ground constraint list was then transmitted from the ground system, although it only contained waypoints in the cruise, defining a lateral offset of around 3 miles to the right of track between waypoints BNE and BNE25. The waypoints in this list were as follows:

- 00002 N 47 59.0 E 003 44.9
- BNE N 47 40.0 E 004 22.0
- 00001 N 47 28.0 E 004 37.2
- BNE25 N 47 24.0 E 004 51.1 Height Constraint FL250
- BNE35 N 47 17.8 E 005 02.7

As with previous ground constraint lists that had been received, all the waypoints were defined as start of turn points. They were also all part of an En-Route segment. Therefore, in order to generate a trajectory, a SID was inserted ahead of these waypoints, consisting of THR09, CGN, D268I and D331I from the CDGLHR route. With this SID in place, giving a total of 9 waypoints, a trajectory was generated and downlinked to ATC. A ground constraint list was then transmitted from the ground system, although it only contained waypoints in the cruise, defining a lateral offset of around 3 miles to the right of track between waypoints BNE and BNE25. The waypoints in this list were as follows:

- 00002 N 47 59.0 E 003 44.9
- BNE N 47 40.0 E 004 22.0
- 00001 N 47 28.0 E 004 37.2
- BNE25 N 47 24.0 E 004 51.1 Height Constraint FL250
- BNE35 N 47 17.8 E 005 02.7

As with previous ground constraint lists that had been received, all the waypoints were defined as start of turn points. They were also all part of an En-Route segment. Therefore, in order to generate a trajectory, a SID was inserted ahead of these waypoints, consisting of THR09, CGN, D268I and D331I from the CDGLHR route. With this SID in place, giving a total of 9 waypoints, a trajectory was generated and downlinked to ATC. Once again, an approval was transmitted back and the trajectory activated. The ground system received the activation advisory message from the aircraft.

The SID was extended to include the waypoint VAKSO after D331I and another trajectory generated. This was also successfully downlinked to the ground ATC simulation and an approval message transmitted to the aircraft. On receipt of this approval, the trajectory was activated, the advisory message being sent over the data link to ATC. The time had been reached for the power to the aircraft to be shut down, so no further testing could be accomplished that evening.

2.7.12 Ground Test Prior To First Flight On 5th June

Further tests were carried out prior to the morning flight. The following is a chronological list of the main events (the time reference is the system time derived from the host Sparc 20 computer for the EFMS) :

- 0744:59 Frequency Change dialogue established.
- 0745:14 Position Reporting activation message received.
0745:20 Trajectory Negotiation dialogue established.
0748:00 Generated trajectory on the ground using the CDGLHR route as far as waypoint BNE35, finishing in the cruise.
0751:45 Downlinked trajectory to ATC (packed in 8 + 5236 bytes).
0756:12 Received Trajectory Approval message (8 + 44 bytes) from ATC, 4 minutes 27 seconds after the downlink of the trajectory.
0756:26 Activated trajectory, activation advisory message downlinked to ATC.
0758:33 Received Sector Contract Approval message (8 + 56 bytes).
0801:28 Frequency Change dialogue aborted.
0801:38 Trajectory Negotiation dialogue aborted.
0801:44 Position Reporting abort message received.

2.7.13 First Flight On 5th June

On this flight, it was arranged with CENA that a trajectory negotiation would take place with the aircraft still on the ground in order to demonstrate the process. Providing the negotiation completed successfully, the aircraft would take off following this agreed trajectory while the data link was being reset after the expected loss of communications with the satellite. Time synchronisation was performed, 0823:00 UTC being equivalent to 0800:00 in simulation time. Below is a list of the primary EFMS events in relation to the data link functions (the time given is the simulation time reference):

0756:55 Frequency Change dialogue established.
0757:12 Position Reporting activation message received.
0757:30 Trajectory Negotiation dialogue established.
0808:25 Generated trajectory while on the ground for route CDGLHR as far as waypoint BNE35, finishing in the cruise (estimated take off time 0820).
0808:41 Downlinked trajectory (8 + 5236 bytes) to ATC.
0809:25 Part of data link system reset.
0810:57 Frequency Change dialogue re-established.
0811:03 Position Reporting activation message received.
0811:09 Trajectory Negotiation dialogue re-established.
0812:01 Generated trajectory again with revised take off time of 0823.
0812:08 Downlinked trajectory (8 + 5236 bytes) to ATC.
0813:27 Received Trajectory Approval message (8 + 44 bytes) from ATC, 1 minute 19 seconds after the downlink.

The EFMS data recording seems to indicate that the software tries to read the uplinked Trajectory Approval message twice while decoding it. The second read operation results in an error message, “Error # 11 Resource temporarily unavailable”. This also occurred in the data for the ground test earlier in the day. The EFMS does, however, acknowledge that an approval has been received and handles it accordingly.

0814:36 Trajectory activated and activation advisory message (8 + 52 bytes) downlinked to ATC.
0822:59  Guidance automatically activated after take off from runway 05, directly in to route.
0823:54  Data link being reset after take off following loss of communication with satellite.
0835:03  Frequency Change dialogue re-established.
0835:09  Position Reporting activation message received.
0835:16  Trajectory Negotiation dialogue re-established.
0836:37  Frequency Change message received from ATC.
0837:22  Pilot acknowledged Frequency Change message, acknowledgement downlinked to ATC.
0838:22  Sector Contract Approval (8 + 56 bytes) received from ATC for current active trajectory.

At this stage in flight, the aircraft was around the top of climb, mid-way between waypoints VAKSO and BNE, entering the cruise at FL250. The resultant tube extended to a point about 10 nautical miles beyond waypoint BNE.

0842:12  Ground Constraint List (8 + 756 bytes) received from ATC. This constraint list consisted of the waypoints BNE, BNE25 and BNE35.
0842:41  Generated trajectory based on this Ground Constraint List. The aircraft had just passed BNE.
0843:02  Downlinked trajectory (8 + 1924 bytes) to ATC.
0844:28  Trajectory Approval message (8 + 44 bytes) received from ATC, 1 minute 26 seconds after downlink of trajectory and 2 minutes 16 seconds after receipt of ground constraint list.
0844:33  Trajectory activated, activation advisory message downlinked to ATC.

When the trajectory was activated, an exception was raised in the packing of the phase table data for transmission to the EFMS guidance computer. This meant that the guidance system did not receive the new trajectory and continued to control to the previous one. This was the same problem that occurred at the start of the first flight on the 4th June. In both cases, the trajectory involved finished in the cruise at waypoint BNE35 and the generation of the trajectory had been preceded by the receipt of a ground constraint list (although on the previous day’s flight, the trajectory had not been predicted based on the uplinked constraint list). This activation problem also caused Phase_Table.Id_Error exceptions to be continuously raised in the EFMS CDU Page_Cntrl.Page_Cntrl_Obscs package (the raising of this exception is probably linked to the current page that the pilot had selected on the CDU).

0845:10  Generated trajectory again.
0845:14  Tried to activate this trajectory, but this raised a Tasking_Error exception in the AHMI_Interface.Action_Softkey_Command area and as before guidance never received this trajectory (following the previous exception, it is not possible to activate any further trajectories).
0845:33  Frequency Change message (8 + 48 bytes) received from ATC.
0845:42  Pilot acknowledged Frequency Change message, acknowledgement (8 + 48 bytes) downlinked to ATC.
0846:31  Ground Constraint List (8 + 1020 bytes) received from ATC.
0847:37 Attempted to generate trajectory to this Ground Constraint List, but failed due to Lateral Route Error.
0849:35 EFMS reset after reaching end of outbound route.

2.7.14 Second Flight On 5th June

The aim was to repeat the activities of the previous flight, i.e. an initial negotiation on the ground followed by further negotiations when airborne and the data link had been reset. Time synchronisation was 0754:00 in simulation time being equivalent to 1220:51 UTC.

0753:32 Frequency Change dialogue established.
0753:49 Position Reporting activation message (8 + 48 bytes) received from ATC.
0754:01 Trajectory Negotiation dialogue established.
0758:57 Generated trajectory while on the ground for route CDGLHR as far as waypoint BNE35, finishing in the cruise (estimated take off time 0811).
0759:05 Downlinked trajectory (8 + 5236 bytes) to ATC.
0803:14 Trajectory Approval message (8 + 44 bytes) received from ATC, 4 minutes 9 seconds after the trajectory was downlinked.
0803:24 Activated approved trajectory, activation advisory message (8 + 52 bytes) downlinked to ATC.
0810:55 Guidance automatically activated after take off from runway 05.
0813:56 Position Reporting abort message (8 + 48 bytes) received.
0820:24 Trajectory Negotiation dialogue re-established.
0820:48 Frequency Change dialogue re-established.
0820:58 Position Reporting activation message (8 + 48 bytes) received.
0823:27 Frequency Change dialogue abort message (8 + 48 bytes) received.
0823:37 Position Reporting abort message (8 + 48 bytes) received.
0827:34 Frequency Change dialogue re-established.
0827:50 Position Reporting activation message (8 + 48 bytes) received.
0828:32 Trajectory Negotiation dialogue re-established.
0829:57 Generated trajectory direct to waypoint BNE while the aircraft was in the cruise at FL250.
0830:01 Downlinked trajectory (8 + 1676 bytes) to ATC, although the ground system did not receive it due to a problem with the PATN stack that prevented the trajectory data from being transmitted.
0835:37 Trajectory Negotiation dialogue abort message (8 + 44 bytes) received.
0836:47 EFMS reset at the end of the outbound route.

This was the final PD/3 flight by the BAC 1-11 from Brétigny, having completed all the planned sorties for the demonstration week. The aircraft departed back to Boscombe Down later on in the afternoon with no further EFMS/PATN trials being possible.