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SIMULATION AND FLIGHT TEST PLAN – D32

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PROJECT CO-ORDINATOR : BAE SYSTEMS

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- EEC (France)
- Airtel ATN Ltd (Ireland)
- ETAG (Germany)

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Record of changes

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1 Introduction

1.1 Scope of Document

This document describes the integration, verification and validation testing of the delivered Avionics Package (AvP) within both WP2 and WP3 across all the airborne and ground platforms. It also covers all of the integration testing necessary to check the basic functionality and connectivity of the simulated Air/Ground ATM environment prior to the validation tests. This allows an iterative approach to be taken during the integration phase, leading to a reduced risk of the basic systems failing during the validation tests.

1.2 Avionics Package

The AvP will be delivered in five phases allowing increasing levels of in-built MA-AFAS functionality to be provided. The phased avionics builds, their envisaged functionality and expected delivery dates are as stated in Table 1-1.

Build	Function
A 3 Jun 02	Display (Manager, MCDU, EFIS)
	Database (Manager, Navigation, Meteo, Performance, Aircraft State, Configuration, Logs)
	4D Navigation (Trajectory Generation and Guidance)
	VDLM4 Comms
	ADS-B
	Database (Traffic)
	CDTI - Air
	TIS-B
	Taxi Map Display
	AOC OOOI
	Comms Manager (Context Management, Non-ATN)
	AOC Flight Plan (Generation and Uplink)
	AOC FMS Meteo Uplink
	Comms Manager (Context Management, ATN)
	CPDLC Baseline 1 + New comms applications
	AOC Free Text
	CDTI – Ground
B 1 Jul 02	Lateral Crossing and Passing
	Vertical Crossing
	Spacing (In-Descent and Level Flight)
	PAD Curved Approaches (Curved STAR, Handover from SBAS to GBAS)
C 5 Aug 02	CPDLC Taxi Management (Taxi Clearances)
	AOC Position Reports (Infrastructure Uplink and Report Downlink)
	Runway Alert
D 2 Sep 02	Autonomous Operation (Conflict Detection and Resolution)
	PAD Missed Approaches (Handover from GBAS to SBAS)
	AOC Loadsheet
	FIS-B
	ADS-C
	AOC SNAG Reports
E 16 Sep 02	
	AOC In Flight Traffic Management
	Curved Departures (Curved SID, SBAS)

Table 1-1 Avionics Package Phase Build Schedule

The progression of the AvP testing closely follows, from top to bottom, the defined Air/Ground Integration Plan represented schematically in Figure 1-1. In addition, piloted trial evaluations of crew operating procedures and associated workload using NLR's flight simulator will be carried out. Validation of the AvP is planned to culminate with the Certification Preparation Flight Tests carried out in Rome, to include the BAC1-11, ATTAS aircraft and AMS ground station, operating within the overall MA-AFAS operational scenario as defined in the Operational Services and Environment Definition (OSED D14).

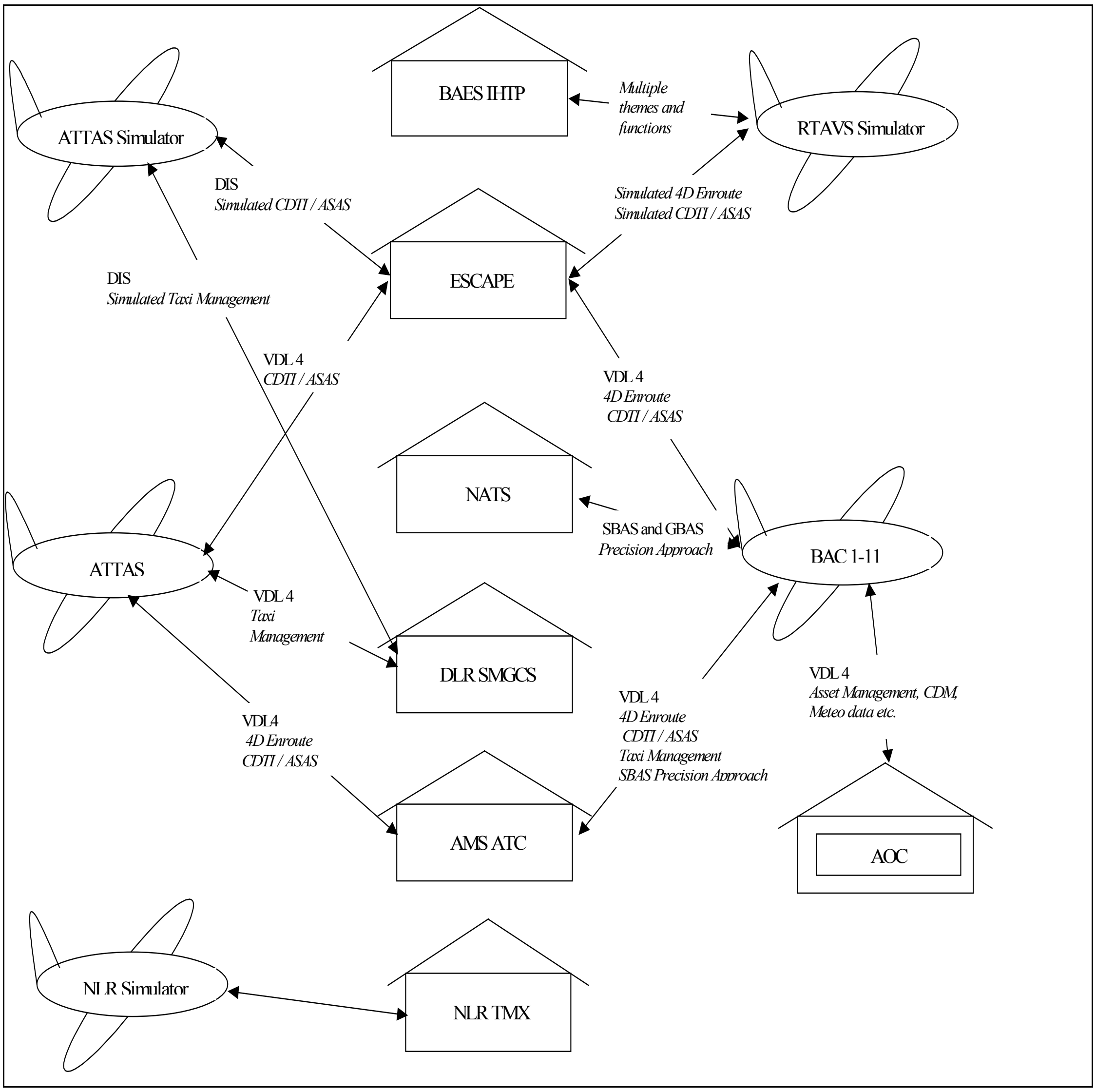

Figure 1-1 Air/Ground Integration Plan

The test activities have been split into the integration and verification testing of the AvP, previously tested in a local environment with the IHTP, within both the flight simulators and test aircraft followed by validation testing on the flight test aircraft. The integration and verification tests are based on each specific link between a single airborne and ground system simulator as defined in Figure 1-1. The validation testing will be carried out within three flight trial environments, based on the airborne platform's geographic location, within which identified themes and functionality will be tested and evaluated. Details of the tests can be found in the following chapters:

Chapter 2 details the QinetiQ RTAVS trials with the IHTP.

Chapter 3 details the QinetiQ RTAVS trials with the ESCAPE ATC simulation platform.

Chapter 4 details the DLR ATTAS Simulator trials with the ESCAPE ATC simulation platform.

Chapter 5 details the DLR ATTAS Simulator trials with the DLR SMGCS facility.

Chapter 6 details the Research Flight Simulation trials at NLR.

Chapter 7 details the QinetiQ flight trials at Boscombe Down with the ESCAPE ATC simulation platform and local facilities.

Chapter 8 details the DLR taxi and flight trials at Braunschweig with the ESCAPE ATC simulation platform and SMGCS facility.

Chapter 9 details the QinetiQ and DLR flight trials in Rome with the AMS Shadow ATC facility.

1.3 Integration And Verification

The major activities include the integration tests necessary to check the basic functionality and connectivity of the simulated ATM Air/Ground environment. The integration tests may be further broken down into small-scale integration tests for stand-alone testing of both the simulated airborne and ground systems, followed by large-scale integration tests, to verify the functionality of the communications link between them. Full definitions of these terms are as follows:

Unit Tests – Stand-alone tests carried out on one item of equipment. These tests will normally be limited to a single site, in terms of geographical location, and a single consortium partner who is responsible for their definition and action. They are not contained within this document.

Small Scale Integration Tests – Stand-alone tests to verify the basic functionality of either a simulated ground or airborne system or test aircraft. These tests will normally be limited to a single site, in terms of geographical location, but may involve several of the consortium partners (e.g. the simulator owners and the equipment providers).

Large Scale Integration Tests – These are tests to verify the communications link and theme functionality between the simulated ground and airborne platform or test aircraft. The aim is to verify correct avionics functionality across all the themes and correct interaction with the ground (on a functional basis without representative communication link). These tests will normally involve several sites, in terms of geographical location, and several of the consortium partners.

1.4 Test Procedures

This document identifies each test to be carried out. However, the description provides only a brief overview of the objectives of the test, the simulated environment, and the main actions required to perform the test. Detailed test procedures and schedules will be generated where appropriate, referenced from within this document, and retained by the platform provider.

1.5 Validation

These tests are intended to validate the functionality of the AvP within the overall future ATM environment and are fundamentally based on the overall validation scenario defined within the OSED. The validation scenarios are split into four trials environments, defined by geographical location, using the real airborne platforms together with selected ground platforms and an evaluation trial involving the RFS as follows:

A. QinetiQ BAC1-11 at Boscombe Down;

B. DLR ATTAS at Braunschweig;

C. Both aircraft at Ciampino, Rome.

D. NLR Research Flight Simulator at Amsterdam.

The four scenarios will be generated as 'living' documents within separate annexes referenced from this document. Hence, this document only provides an overview of each scenario.

The validation testing will follow the process defined within the Validation Guideline Handbook generated from the MAEVA programme. Each of the flight trial environments will enable a selection of MA-AFAS themes and functionality to be tested. In addition, the testing schedule, ground support and equipment, data gathering and analysis requirements together with success criteria will be provided within each scenario definition.

1.6 Platform Description

Detailed descriptions of the MA-AFAS simulated and real airborne platforms are included within the appendices. Detailed descriptions of the MA-AFAS ground platforms can be found in document D38 – CNS/ATM Ground System Requirements, and therefore are not duplicated within this document.

2 RTAVS Flight simulator - BAES In House Test Platform (IHTP)

2.1 Introduction

The objective of these tests is to prove the successful integration of the Flight Management System (FMS) AvP within the RTAVS simulation environment linked to the BAES IHTP. Demonstration of a representative set of basic AvP functions is required to satisfy the objective. Steps in the process have been divided into small and large-scale tests as defined in the document introduction. The tests will be carried out at QinetiQ Bedford.

2.2 Small Scale Integration Tests

2.2.1 FMS/RTAVS

These tests are to ensure that the AvP is correctly receiving aircraft state information from the RTAVS aircraft simulator, and that the FMS can be coupled to the autopilot and guide the aircraft during the desired phases of flight. Correct basic operation of the Electronic Flight Instrument System (EFIS) display and FMS Multifunction Control and Display Unit (MCDU) will also be established during these tests. Figure 2-1 shows the test environment, red indicating active interfaces.

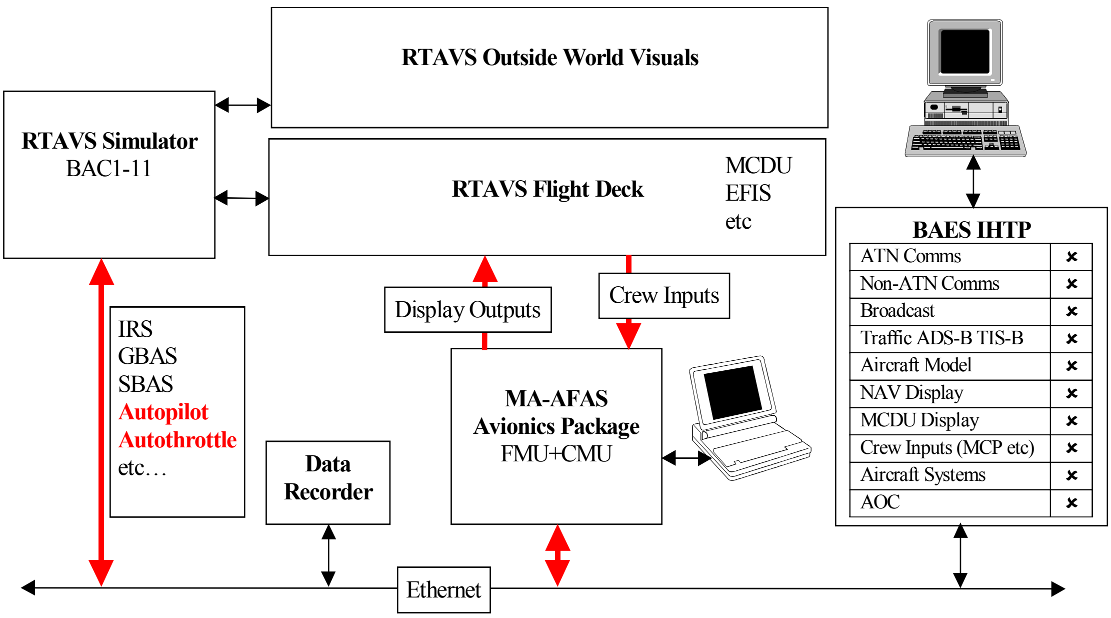

Figure 2-1 RTAVS/IHTP Small Scale test environment

The tests require the RTAVS simulator to be configured with the BAC 1-11 aircraft model and supporting flight deck, all manual inceptors, outside world visuals and the BAC 1-11 digital autopilot. A technical overview of the RTAVS facility including configuration information can be found in document D36 - QINETIQ/FST/TPN030139.

ID	Test Procedure	Description
1.	D36 - QINETIQ/FST/TPN030139	Fly a set of pre-defined manoeuvres to check that the correct aircraft state data is being continually received by the MFMS
2.	D36 - QINETIQ/FST/TPN030139	Generate a trajectory on the MFMS, engage the autopilot and couple the MFMS to the autopilot to check operation of the guidance

2.2.2 Simulated GBAS/SBAS

These tests are to ensure correct integration of the GBAS/SBAS models with the RTAVS simulator and that the generated signals are being correctly received by the FMS. Note that these tests are not intended to validate the GBAS/SBAS models as it is assumed that they will have been previously validated.

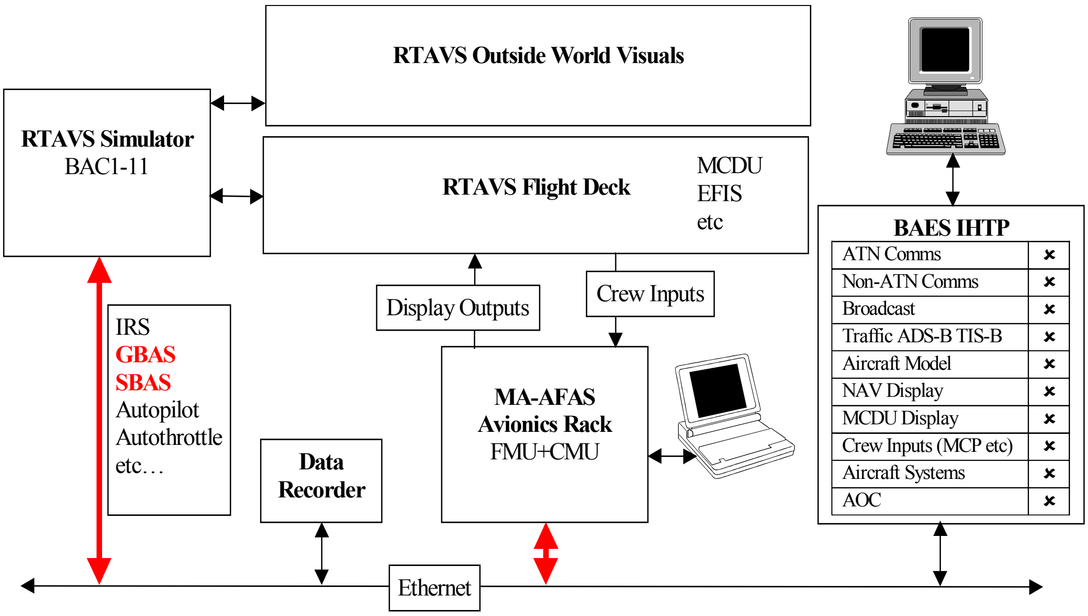

Figure 2-1 RTAVS/IHTP PA test environment

The tests require the RTAVS simulator to be configured with the BAC 1-11 aircraft model and supporting flight deck, all manual inceptors, outside world visuals and the BAC 1-11 digital autopilot. A technical overview of the RTAVS facility including configuration information can be found in document QINETIQ/FST/TPN030139.

ID	Test Procedure	Description
3.	D36 - QINETIQ/FST/TPN030139	Approach the aircraft to a pre-defined point on the precision approach path to a representative airfield.

2.2.3 FMS/IHTP

These tests are to ensure that the AvP is correctly communicating with the BAES IHTP. This is a short test, as the functions will have been tested in detail during unit testing at BAES Rochester. The test will confirm that all connections are made, that the Avionics have been configured correctly to use Ethernet, and that the correct functions in the test platform have been enabled.

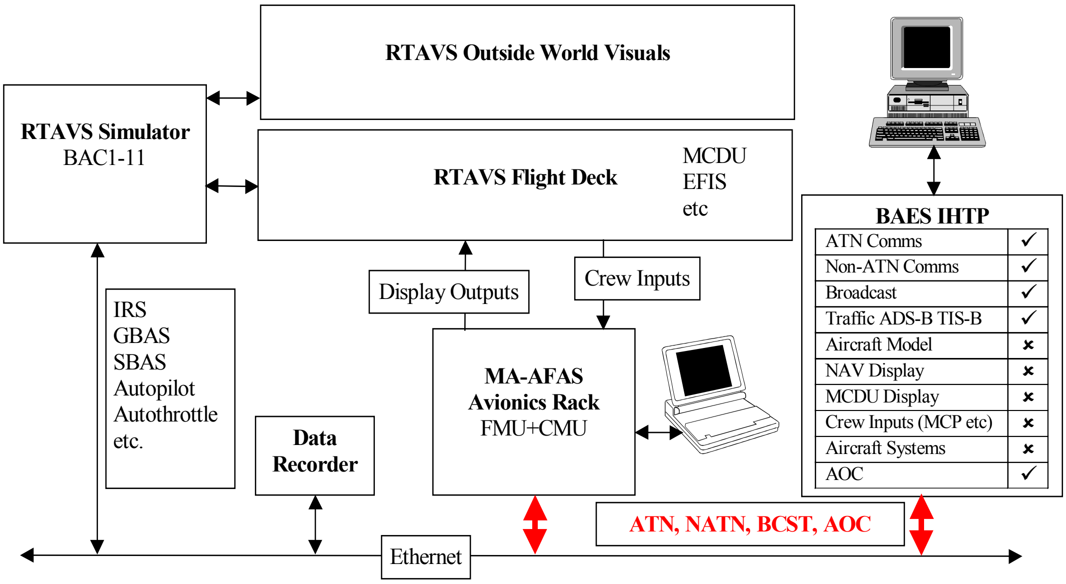

Figure 2-1 RTAVS/IHTP comms test environment

The tests require the RTAVS simulator to be configured with the BAC 1-11 aircraft model and supporting flight deck, all manual inceptors, outside world visuals and the BAC 1-11 digital autopilot. A technical overview of the RTAVS facility including configuration information can be found in document DERA/AS/FMC/TN000352. The tests are as stated in Table 2-1.

ID	Test Procedure	Description
4.	D36 - QINETIQ/FST/TPN030139	Check ATN link status becomes LOGGED ON when IHTP starts ground function then check CPDLC messages in both directions.
5.	D36 - QINETIQ/FST/TPN030139	Check Non-ATN link status becomes LOGGED ON when IHTP starts ground function then check CPDLC messages in both directions.
6.	D36 - QINETIQ/FST/TPN030139	Check Broadcast communications received from IHTP, including FIS-B, TIS-B, and ADS-B
7.	D36 - QINETIQ/FST/TPN030139	Check AOC link status becomes LOGGED ON when IHTP starts AOC function then check AOC messages in both directions.

Table 2-1 Small-scale integration test procedures

2.3 Large Scale Integration Tests

2.3.1 Air/Ground Systems

These tests are to confirm that the Avionics Package is functioning correctly with the RTAVS simulator and the BAES In-house Test Platform. This is a short test, as the functions will have been tested in detail at BAES Rochester. The test will exercise the complete system to confirm that all functions operate at a basic level and that the Avionics, IHTP, and RTAVS simulator have been configured for the correct functions.

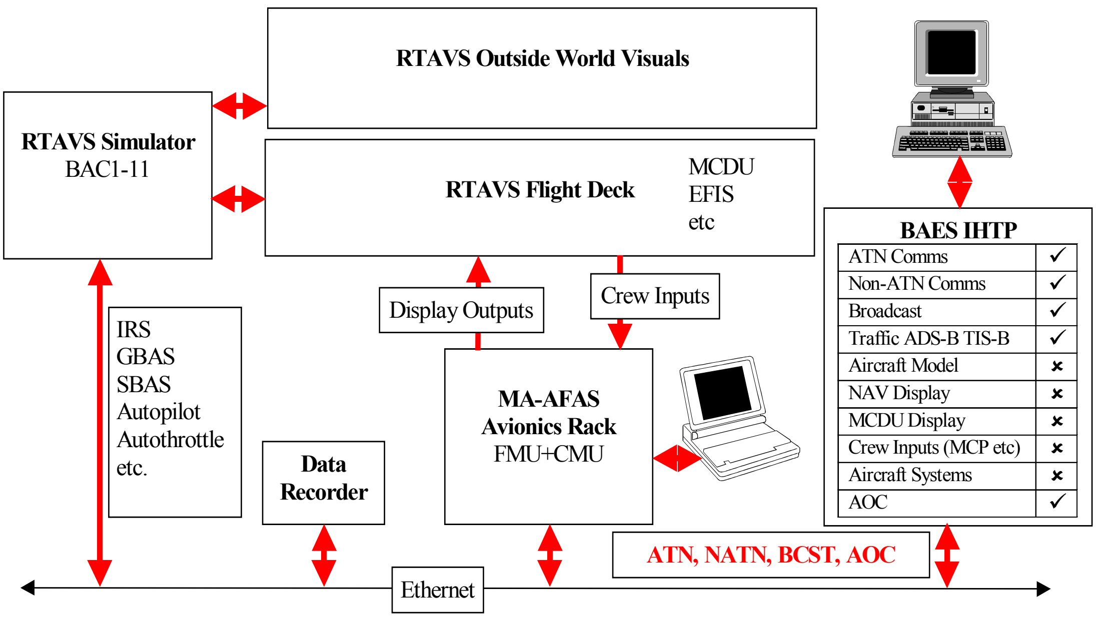

Figure 2-1 RTAVS/IHTP Large Scale test environment

The tests require the RTAVS simulator to be configured with the BAC 1-11 aircraft model and supporting flight deck, all manual inceptors, outside world visuals and the BAC 1-11 digital autopilot. A technical overview of the RTAVS facility including configuration information can be found in document DERA/AS/FMC/TN000352.The testing schedule based upon the phase build delivery dates and provided FMS functionality are as stated in Table 2-1.

Build	ID	Test Procedure	Description
A	1.	D36 - QINETIQ/FST/TPN030139	Exercise sub-set of ATN and non-ATN communications (CM, CPDLC free text), verify correct RTAVS HMI (Display manager and MCDU operation), and check data recording.
	2.	D36 - QINETIQ/FST/TPN030139	Exercise 4D Navigation (Trajectory Generation and Guidance), verify correct RTAVS HMI (Display manager, MCDU operation and EFIS) and check database (Manager, Navigation, Meteo, Performance, Aircraft State, Configuration, Logs).

Build	ID	Test Procedure	Description
	3.	D36 - QINETIQ/FST/TPN030139	Exercise sub-set of AOC functions, OOOI, Generation and uplink of flight plan, FMS meteorological uplink, AOC free text
	4.	D36 - QINETIQ/FST/TPN030139	Exercise Taxi Management function (Database - ground traffic) and verify RTAVS HMI (Taxi map display and CDTI-Ground).
B	5.	D36 - QINETIQ/FST/TPN030139	Exercise sub-set of CDTI/ASAS functions (In-descent and level flight spacing), receive, store (Database - traffic) and display ADS-B and TIS-B airborne traffic. Ensure display can be zoomed and de-cluttered.
	6.	D36 - QINETIQ/FST/TPN030139	Exercise sub-set of CDTI/ASAS functions (Lateral/Vertical crossing and passing), receive, store (Database - traffic) and display ADS-B and TIS-B airborne traffic. Exercise PA curved approaches. Ensure display can be zoomed and de-cluttered.
C	7.	D36 - QINETIQ/FST/TPN030139	Exercise Taxi Management functions (CPDLC – Taxi clearances, runway alert) and verify RTAVS HMI (Taxi map display and CDTI-Ground, MCDU).
	8.	D36 - QINETIQ/FST/TPN030139	Exercise AOC Position Reports (Infrastructure Uplink and Report Downlink), verify RTAVS HMI (MCDU).
D	9.	D36 - QINETIQ/FST/TPN030139	Exercise CDTI/ASAS autonomous operation (Conflict detection and resolution), verify correct RTAVS HMI (Display manager, MCDU operation and EFIS), receive, store (Database - traffic) and display ADS-B and TIS-B airborne traffic. Exercise PA Missed approaches. Ensure display can be zoomed and de-cluttered.
	10.	D36 - QINETIQ/FST/TPN030139	Exercise ATN communications, FIS-B and , AOC. Verify correct RTAVS HMI (Manager, MCDU). Check data recording (Manager, Meteorological, Logs).
	11.	D36 - QINETIQ/FST/TPN030139	Exercise AOC Loadsheet and SNAG Reports, verify RTAVS HMI (MCDU).
E	12.	D36 - QINETIQ/FST/TPN030139	Exercise AOC In-flight traffic management, verify RTAVS HMI (MCDU) and PA Curved Departures.
	13.		

Table 2-1 RTAVS/IHTP integration test schedule

3 RTAVS Flight Simulator – ESCAPE Ground Platform & Network

3.1 Aims And Objectives

The primary objective of these tests is to verify that the MA-AFAS AvP can communicate and operate with the ESCAPE ground platform prior to the BAC1-11 flight trials at QinetiQ Boscombe Down.

MA-AFAS AvP functionality will be exercised within the RTAVS flight simulator, located at QinetiQ Bedford, with the ESCAPE ground platform, located at Bretigny, in a progressive manner based on the AvP phase build delivery schedule and associated set of priorities.

3.2 Test Configuration And Infrastructure

To reduce risk and minimise effort it is required to connect the respective platforms using a communication datalink, which will emulate as near as possible that to be used for the flight trials. The RTAVS flight simulator will use physical links between the FMS/CMU and ESCAPE as follows:

- Communications via VDL Mode 4.

The real VDL Mode 4 airborne transceivers and ground radio stations directly connected via a suitable attenuator will be used for the simulation trials. Hence, 'hardware-in-the-loop' for broadcast information (ADS-B/TIS-B) as well as point to point protocols can be used.

The ground network will provide a connection for data delivery to ESCAPE. The ground communications infrastructure definition can be found within document D56.

3.3 Themes And Functions

The following themes and associated functionality are to be tested in the following order of priority:

CDTI/ASAS (Partial Delegation).

Longitudinal Spacing

- Remain Behind
- Merge Behind

Lateral Spacing

- Resume When Clear Of Target Aircraft
- Pass Behind
- Overtake Using Offset

Vertical Crossing

- Climb/Descend Pass Above/Below
- Level Instruction Then Resume Climb/Descent

CDTI/ASAS (Autonomous Operations);

- Entry clearance into Free Flight Airspace
- Conflict detection and resolution using priority mode
- Conflict detection and resolution using co-operative mode
- Reversion from priority to co-operative
- Exit clearance from Free Flight Airspace

4D En-route

- Trajectory generation and guidance
- Trajectory clearance
- Tactical functions

3.4 Testing Schedule

All three areas of functionality, having been verified under RTAVS laboratory conditions will be tested with the ESCAPE ground platform between September and December 2002.

3.5 Data Recording

Data is to be recorded in as many areas of the simulation exercise as possible. It is expected that recording of the aircraft state vector will occur within RTAVS, the MFMS performance in the MFMS/IHTP, the data link messages and characteristics in the data link server and all ATC information by ESCAPE.

After each trial has been completed, the recorded data will be examined offline for correct use of constraints, correct incorporation of weather data and aircraft phase data, and optimum 4D trajectory generation.

3.6 Assessment Criteria

The assessment criteria for the MFMS in the ESCAPE environment will concentrate on the overall system capability of performing the required manoeuvres as instructed by the ESCAPE ATC operator. The ability of the MFMS to provide correct HMI information, acceptable communications performance, reliable trajectory generation and guidance will be assessed.

Trajectory generation is to be assessed in real time by the pilot and trials engineers monitoring the generated trajectory against the scenario definition, which should give indications of what it expected. Checks will be made for annunciated errors, that the constraints have been preserved as expected, that the trajectory between the constraints has an acceptable shape, that the aircraft flight envelope is not exceeded, and that there is no visible conflict with the ground or other traffic.

The pilot and trials engineers will provide subjective feedback on ease of use, workload impact, trajectory presentation, and timeliness of generation.

The 4D Guidance and HMI functions will be assessed in real time by the pilot and trials engineers who will observe the subjective stability of the aircraft control, noting any lateral, vertical or speed oscillations. They will also note any perceived transients during trajectory activation, MFMS engagement, MFMS enactment of tactical commands and precision approach engagement. Speedbrake prompting will be assessed for ease of use. Finally, the pilot and trials engineer will also note the speed of response of the system to commanded changes in mode. These changes will include the activation and change of trajectory and activation of tactical commands.

The system's capability of accepting ATC commands both over the data link and by voice will also be assessed. A subjective assessment, by the pilot, will determine whether there is an acceptable workload associated with the two forms of operation.

4 ATTAS Flight Simulator – ESCAPE Ground Platform & Network

4.1 Aims And Objectives

The primary objective is to integrate the MA-AFAS AvP into the demonstration cockpit as it provides the same interface as the ATTAS aircraft's experimental cockpit. The specific tests will also aim to verify that it can communicate and operate with the ESCAPE ground platform prior to the ATTAS flight trials to be flown from Braunschweig, which will use the real air to ground communication links.

4.2 Test Configuration And Infrastructure

To reduce risk and minimise effort it is required to connect the respective platforms using a communication datalink, which will emulate as near as possible that to be used for the flight trials. The ATTAS flight simulator will use physical links between the FMS/CMU and ESCAPE as follows:

- Communications via VDL Mode 4.

The real VDL Mode 4 airborne transceivers and ground radio stations directly connected via a suitable attenuator will be used for the simulation trials. Hence, 'hardware-in-the-loop' for broadcast information (ADS-B/TIS-B) as well as point to point protocols can be used.

The ground network will provide a connection for data delivery to ESCAPE. The ground communications infrastructure definition can be found at figure 5.1 and within document D56.

4.3 Themes And Functions

The following themes and associated functionality are to be tested in the following order of priority:

1. CDTI/ASAS (Partial Delegation).
    - In descent and level flight spacing;
    - Lateral/Vertical crossing and passing;

2. CDTI/ASAS (Autonomous Operations);
    - Negotiation and entry into Free Flight Airspace
    - Conflict detection and resolution using priority mode
    - Conflict detection and resolution using co-operative mode
    - Conflict detection and resolution using reversionary mode
    - Negotiation and exit from Free Flight Airspace

4.4 Testing Schedule

The ATTAS simulation tests are scheduled to take place in early 2003.

4.5 Data Recording

Data is to be recorded in as many areas of the simulation exercise as possible. It is expected that recording of the aircraft state vector will occur within the ATTAS flight simulator, the MFMS performance in the MFMS/IHTP, the data link messages and characteristics in the data link server and all ATC information by ESCAPE.

4.6 Assessment Criteria

The assessment criteria for this trial is as defined in Section 3.6.

5 ATTAS Flight Simulator – DLR SMGCS Ground Platform

5.1 Aims and Objectives

The principal aim is the pre-flight trial testing of the taxi management functions provided by the MA-AFAS AvP.

5.2 Test Configurations And Infrastructure

The demonstration cockpit will be used for the trials with the Frankfurt or Braunschweig Airport visual database providing the external view. An interface to provide traffic information via data link will be implemented.

In the following the system architecture and the data flows for the simulation trials and MA-AFAS A-SMGCS ground installations in Braunschweig are described.

5.2.1 A-SMGCS System Architecture

Figure 5-1 shows the infrastructure as well as the main data flows for the MA-AFAS A-SMGCS ground installations in Braunschweig. In general the system will consist of the taxi management subsystem and the surveillance subsystem.

The A-SMGCS taxi management subsystem consists of the Clearance Panel and the Taxi Application, connected via the IHTP (In-House Test Platform) to the VDL-4 Ground Station.

The Taxi Panel provides the selection of clearances, instructions and taxi route elements for outgoing clearances, and the presentation of incoming clearances. It is driven by the Taxi Application, which generates the appropriate text messages. Inside the IHTP, the text clearances then will be converted to the ANS.1-format and transferred via the ATN Air Ground Router to the VDL-4 ground station, from where they are sent up-link. Down-link messages will go the opposite way, and will be displayed at the Taxi Panel.

The A-SMGCS surveillance subsystem is based on a multi-sensor system with a Sensor Data Fusion (SDF). It will comprise the following set of surveillance sensors:

- VDL-4
- ASCS (ERA Mode-S multilateration system)
- ARMI (Aircraft Registration Mark Identification System)

Further on it comprises the SDF, which merges and tracks the position reports received from the surveillance sensors, a DBMS (Data Base Management System), which holds all necessary background data as well as flight plans, and the Surveillance Display, which shows the actual ground traffic situation.

The surveillance subsystem interfaces to the VDL-4 via the IHTP and the Broadcast Server, which provides the data format conversion between the VDL-4 specific BLIS and ASTERIX Cat021 for ADS-B as well as ASTERIX Cat022 and Cat062 for TIS-B.

The existing A-SMGCS, as described above, will be enhanced by an ASTERIX Cat021 Input Converter, by which it receives the Cat21 ADS-B reports from the Broadcast Server.

Likewise a TIS-B server will be provided which receives fused traffic situation pictures from the SDF, and generates an ASTERIX Cat022 TIS-B management message and diverse Cat062 TIS-B position reports for every traffic picture. The ASTERIX TIS-B messages will be sent to the Broadcast Server, converted into the VDL-4 BLIS format, transferred via the IHTP to the VDL-4-Groundstation and finally transmitted up-link.

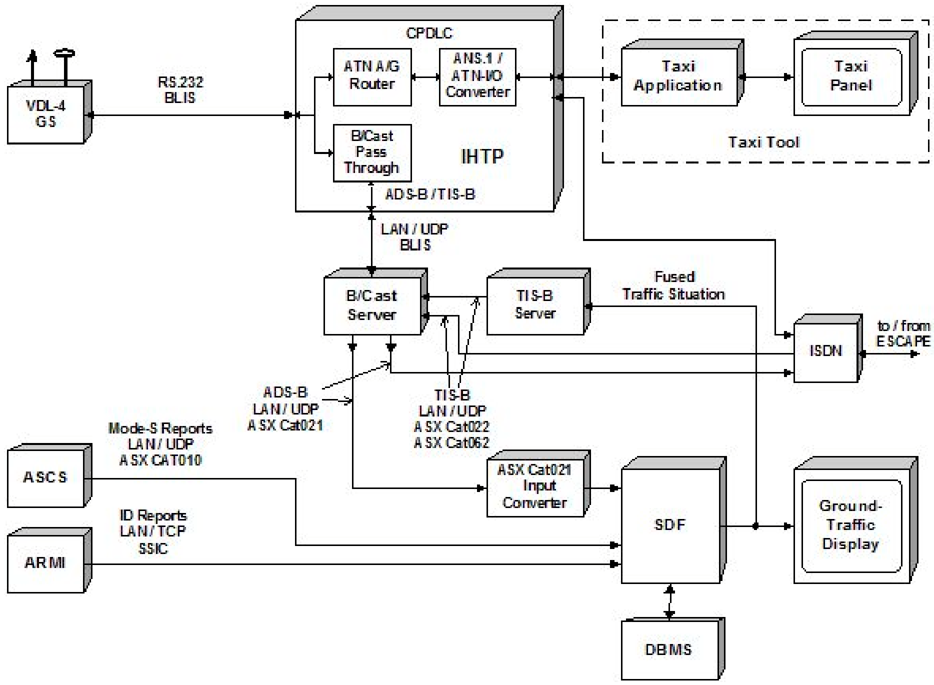

Figure 5-1: A-SMGCS Ground Infrastructure at DLR Braunschweig

5.2.2 Cockpit Simulator

The demonstration cockpit of the DLR is a fixed based generic cockpit simulator built up modularly for the assessment and demonstration of onboard flight guidance functions.

It consist of a flight mechanical model on the basis of the experimental aircraft VFW614 (ATTAS) as it is operated in the DLR. This performance model can be fast modified to simulate other aircraft types. The cockpit geometry as well as the operating devices corresponds to an AIRBUS 320.

The cockpit is equipped with 12 inch LCD displays. These permit a resolution of up to 1280 x1024 pixels. These displays are connected to the signal sources over a RGB-matrix switch box so that the display configuration can be changed dynamically.

Standard displays like PFD, ND and ENG-display are available in the cockpit. All systems are open and can be adapted to user specific requirements. For individual aerodromes different traffic scenarios can be modelled to simulate the taxiing process on the ground realistically. This aerodrome traffic can be controlled separately. A radio communication between pilots and controllers is in addition possible within the cockpit.

The complete simulation is controlled and administrated about an Instructor. All external conditions and settings like weather, simulation starts and stops, and new positioning as well as the other traffic is adjusted and controlled. The central data distribution is carried out about a so-called EXO vector in which all variables are collected from the simulation.

In figure 5-2 a survey of the data interchange between the individual systems is given.

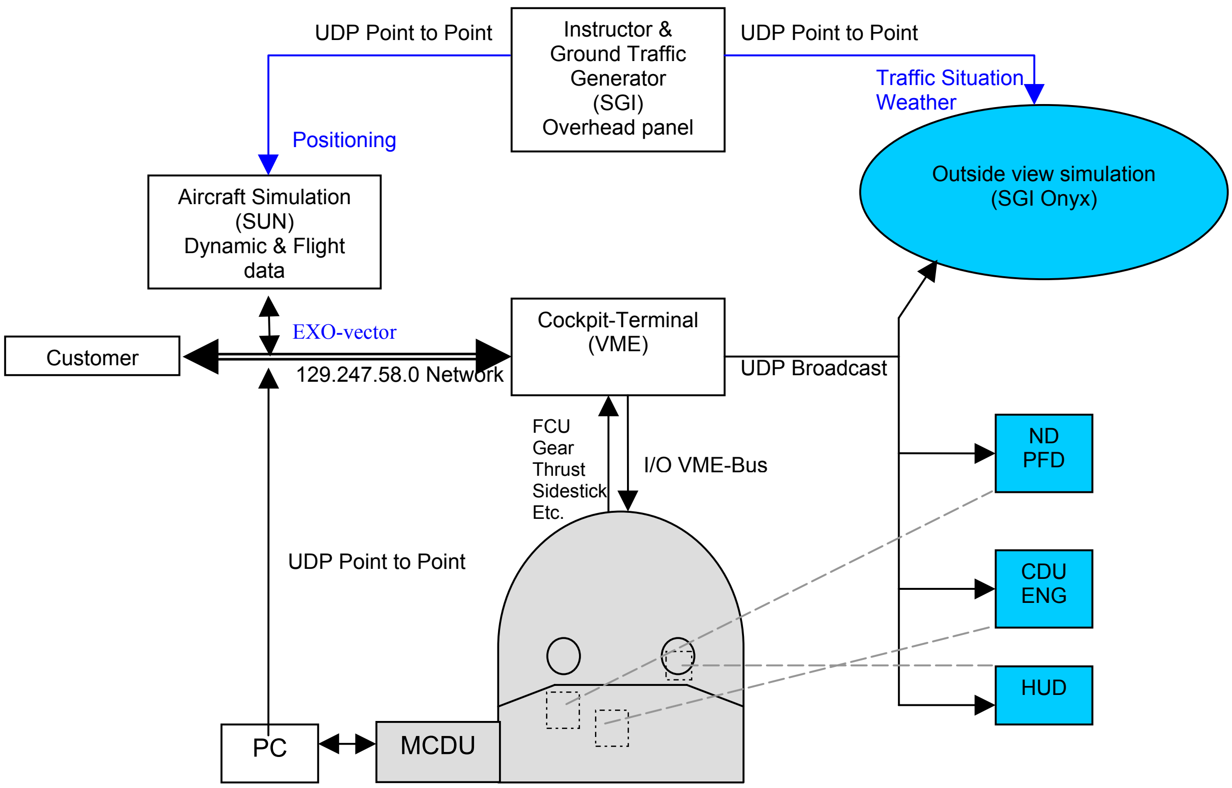

Figure 5-2: Data flow between the individual systems of the cockpit simulator.

5.2.3 Simulation Ground Infrastructure at DLR Braunschweig

Figure 5-3 shows the simplified infrastructure and some main data flows of the MA-AFAS ground installations in Braunschweig for the simulation trials. In general, the system will consist of the ATTAS test aircraft simulation and the A-SMGCS simulation.

The ATTAS simulation comprises the demonstration cockpit as well as the MA-AFAS Avionics Package and the VDL-4 transponder. Not shown in Figure 5-3 are the MA-AFAS cockpit displays, integrated into the demonstration cockpit.

The A-SMGCS simulation comprises more or less the same infrastructure as described in chapter 5.2.1.

The main functionality of this configuration shall be described shortly.

Within the demonstration cockpit, the simulated own track is generated by the track generator, which gets its input from the cockpit steering devices, and controls the actual own position, visible through the cockpit windows via the simulated outside view. The consecutive position reports are transferred as state vectors to the FMS within the MA-AFAS Avionics Package and transmitted via ‘forced’ ADS-B reports by the VDL-4 onboard transponder to the VDL-4 ground station, from where they will be fed into the SDF and displayed at the A-SMGCS ground traffic display.

The traffic of other aircraft within the environment of the simulated airport is generated by the ground traffic generator inside the Demo Cockpit. This traffic generator is based on the replay of airport traffic scenarios. Simulated aircraft passing or ahead of the cockpit become visible through the cockpit windows at the outside view simulation. The respective position reports are fed directly into the SDF and displayed at the A-SMGCS ground traffic display likewise, thus providing full situation awareness on ground.

The merged traffic situation, comprising the simulated movements of the Demo Cockpit as well as of the other simulated aircraft, is transferred via TIS-B over VDL-4 into the Cockpit, where it is displayed at the MA-AFAS navigation display, thus providing full situation awareness on board.

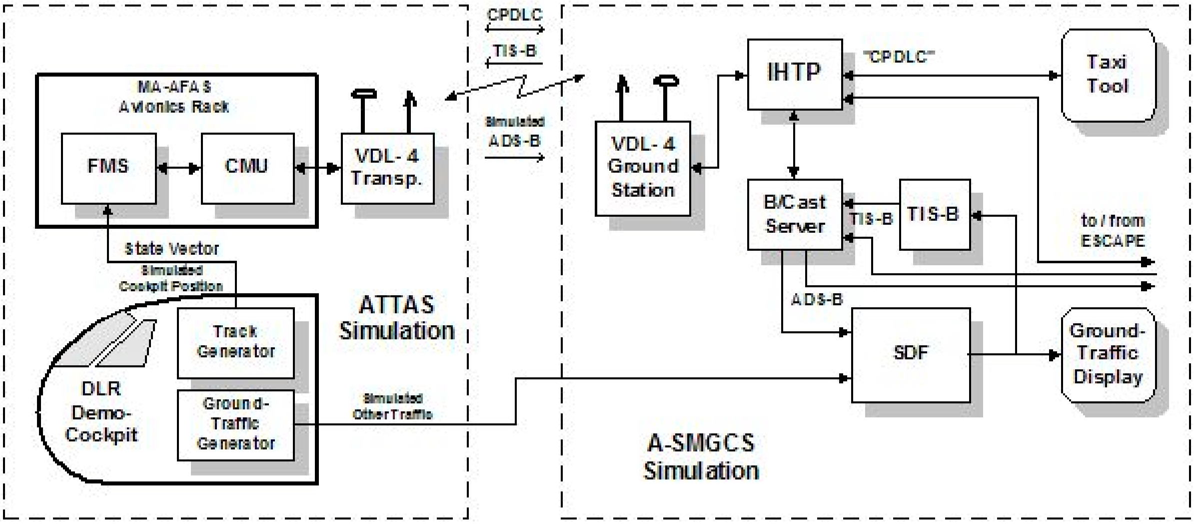

Figure 5-3: Simulation Ground Infrastructure at DLR Braunschweig

5.3 Taxi Functions

5.3.1 Map Display

To test the map display function of the application, the aircraft will follow the normal taxi-in and taxi-out operations while the taxi map display is activated. This requires that the simulated airport at which these tests are conducted be contained in the taxi map database. This will be true for the following airports: Frankfurt, Braunschweig and Ciampino in Italy. Tests should also be conducted under low visibility conditions.

5.3.2 Ground CDTI

By using simulated or real traffic data, typical scenarios will be investigated. The traffic should include aircraft and ground vehicles, following standard tracks like taxi-in/out, follow-me operations in both fine and degraded weather conditions, etc.

5.3.3 Uplink of Taxi Route

With either a simulated or real SMGCS system, taxi routes shall be generated and up-linked to the aircraft. These routes shall include all kinds of possible route information, including hold-short instructions. To determine the benefits, the same tests should be conducted without the taxi management system in the aircraft being activated and with the crew following the normal procedure of writing down and reading back the taxi instructions.

5.3.4 Taxi CPDLC Messages

Typical CPDLC messages during ground operations shall be sent and received. The aircraft shall conduct several ground operations with either normal voice communication or with the CPDLC system.

5.3.5 Runway Alert

Several situations where an aircraft enters the active runway shall be simulated/demonstrated and the alerts being issued recorded.

5.4 Test Scenarios

The following test scenarios have been defined.

Taxi out	Normal taxi-out operation, starting before the clearance request, consisting of these steps: - aircraft crew asking for clearance from clearance delivery - reception of clearance - request for / reception of push-back clearance - request for / reception of engine start-up clearance - request for / reception of taxi instructions - optional: changes / updates of taxi instructions - taxi-out up to holding position at take-off runway This test should be conducted with a large number of combinations of activated taxi management functions, taxi routes, visibility conditions, airports, and traffic density. Abnormal situations (such as runway incursions) are not part of this scenario. Both voice and CPDLC shall be used for these tests.
Conditions	Good and low visibility
Functions to be tested	Map display, CPDLC, CDTI, taxi route uplink
Estimated simulator time / test	5 to 10 minutes per test
Number of simulation tests	Multiple (various combinations of functions, conditions and taxi routes)
Priority	High

Table 5-1 Taxi Out Scenario

Taxi in	Normal taxi-in operation, starting right after touch-down, consisting of these steps: - tower controller providing instructions on runway exit and on contacting ground control - request for / reception of taxi instructions - optional: changes / updates of taxi instructions - taxi in up to engine shut-down at parking position / gate This test should be conducted with a large number of combinations of activated taxi management functions, taxi routes, visibility conditions, airports, and traffic density. Abnormal situations (such as runway incursions) are not part of this scenario. Both voice and CPDLC shall be used for these tests.
Conditions	Good and low visibility
Functions to be tested	Map display, CPDLC, CDTI, taxi route uplink
Estimated simulator time / test	5 to 10 minutes per test

Number of simulation tests	Multiple (various combinations of functions, conditions and taxi routes)
Priority	High

Table 5-2 Taxi In Scenario

Runway Alert	Aircraft approaching a runway with various speeds and then either stopping at holding position or actually entering the runway.
Conditions	Good and low visibility
Functions to be tested	Map display, runway alert
Estimated simulator time / test	2 - 5 minutes per test
Number of simulation tests	10 - 20
Priority	High

Table 5-3 Runway Alert Scenario

Runway Incursion	The aircraft is at the holding position and receiving a line-up or take-off clearance. A simulated aircraft or vehicle is approaching of occupying the runway intended for take-off. The crew shall become aware of this situation via the ground CDTI application.
Conditions	Good and low visibility
Functions to be tested	Map display, CDTI
Estimated simulator time / test	2 - 5 minutes per test
Number of simulation tests	10 - 20
Priority	Medium

Table 5-4 Runway Incursion Scenario

Hazardous Traffic	The aircraft shall be in several situations where its movement is restricted due to other aircraft or vehicles. These situations should include: - push-back operation with other aircraft / vehicle passing behind - entering taxiway with other aircraft / vehicle in opposite direction - approaching taxiway intersection while other aircraft vehicle does the same
Conditions	Good and low visibility
Functions to be tested	Map display, CDTI
Estimated simulator time / test	5 - 10 minutes per test
Number of simulation tests	30 - 50
Priority	High

Table 5-5 Hazardous Traffic Scenario

Follow procedures	The crew shall be instructed either via voice or CPDLC to follow another aircraft or vehicle. The crew shall use either the outside vision or the CDTI display to identify and follow that aircraft / vehicle.
Conditions	Good and low visibility
Functions to be tested	Map display, CDTI
Estimated simulator time / test	10 minutes per test
Number of simulation tests	10 - 20
Priority	Low

Table 5-6 Follow Procedures Scenario

5.5 Testing Schedule

It is envisaged that the Taxi function validation exercises will be completed May 2003.

5.6 Data Recording

Data is to be recorded in as many areas of the exercise as possible. It is expected that recording of the aircraft state vector will occur within the ATTAS simulator data recording system, the MFMS performance in the MFMS/IHTP, the data link messages and characteristics in the data link server and all ATC information by the SMGCS ground platform.

5.7 Assessment Criteria

5.7.1 Map Display

In addition to the obvious task of checking the fulfilment of the specified requirements, the objective of this test is to verify that the taxi map is coherent to the actual layout of the airport. The aircraft position shown on the display shall be compared to the actual position in the real world or simulated scenario.

Furthermore, the crew testing the system shall provide comments on the value of the displayed information and it shall be checked if orientation and situation awareness is enhanced under low visibility conditions. We would also like to have an indication on how quickly the pilot can retrieve the necessary information from the taxi display (head-down time).

5.7.2 Ground CDTI

The main objective is to see how much the crew will benefit from the displayed information. To estimate this, the pilots should provide comments on any increase or reduction in their workload and provide an indication of their situation awareness with and without the ground CDTI display.

5.7.3 Uplink of Taxi Route

A major goal of these tests is to check how much the pilot workload can be reduced with this application. Also, the crew should provide information on how well the system helps in understanding and following the taxi route.

5.7.4 Taxi CPDLC Messages

The measurement of pilot workload is again of major interest. Since CPDLC will be limited to a sub-set of all the possible voice communications, it is likely that a combination of both voice and CPDLC will be used. The crew should provide an indication of how much benefit they see in the CPDLC system and it should be noted if the crew prefers sending a request via CPDLC or via voice if both are possible.

5.7.5 Runway Alert

Comments from pilots about the value of these functions are of major interest. In addition, the behaviour of the system shall be checked for different taxi speeds when the crew is intending to stop at the holding position to verify that no nuisance alerts are generated under normal taxi conditions.

The results will mainly be used for the following purposes:

- Checking that high-level requirements are fulfilled and documenting this in the respective acceptance test protocols.
- Using crew comments and observations to fine-tune the system for future product developments.
- Storing test data (aircraft state, CPDLC, CDTI) for later replay. This will be useful for both demonstration and further development.

5.7.6 Runway Incursion

Comments from pilots about the value of these functions are of major interest.

The results will mainly be used for the following purposes:

- Checking that high-level requirements are fulfilled and documenting this in the respective acceptance test protocols.
- Using crew comments and observations to fine-tune the system for future product developments.
- Storing test data (aircraft state, CPDLC, CDTI) for later replay. This will be useful for both demonstration and further development.

6 NLR Research Flight Simulator – Traffic and Scenario Manager

6.1 Aims And Objectives

The NLR flight simulator will be used for pilot evaluation of the MA-AFAS system and the initial definition of operational procedures for its use. The objectives of the flight simulator trials of MA-AFAS are:

- To evaluate the MA-AFAS system with its HMI in a simulated environment regarding:

  - Pilot acceptance;
  - Crew task distribution;
  - Crew workload;
  - Acceptance of applied procedures;
  - Crew error.

All the above mentioned will be rated against current type of operation. In other words, the trials will evaluate what is changing in the MA-AFAS proposed type of operation compared to current operation.

6.2 Test Configuration And Infrastructure

The NLR Research Flight Simulator (RFS) will be configured to include the MA-AFAS Flight Management System (MFMS) as hardware in the loop. Being a prototype FMS, the MA-AFAS equipment only supports single crew functionality, so only one MCDU and one CCD will be connected to it. The MFMS will generate a navigation display image, which will be split into two signals to drive both the left and right cockpit displays. Communication will be facilitated by Ethernet connections between the MFMS, RFS host computer, the Traffic Manager and the In-House Test Platform (IHTP) for which the NLR will provide a Windows NT computer.

6.3 Themes And Functions

The MA-AFAS functions, which are relevant for evaluation in the flight simulator, are those functions that affect pilot behaviour significantly [1]. Those functions changing the operation the most (e.g. changes in roles and responsibilities) are seen as the most critical. The detailed definition of the tests is contained in D32 Annex D. The following themes and associated functionality are to be comprehensively tested:

6.3.1 CDTI/ASAS (Partial Delegation).

- Merge Behind;
- Remain Behind;
- Lateral Spacing;
- Vertical Crossing;

6.3.2 CDTI/ASAS (Autonomous Operations);

- Entry clearance into Free Flight Airspace
- Conflict detection and resolution using priority mode

- Conflict detection and resolution using co-operative mode
- Reversion from priority to co-operative
- Exit clearance from Free Flight Airspace

6.3.3 CPDLC.

CPDLC commands will be used to support the delegated functions.

6.4 Testing Schedule

It is envisaged that ten airline crews will participate in the trials, each for two consecutive days, resulting in twenty days of trials.

Within two days, a crew must be trained on the simulator, trained on the MA-AFAS system and fly a number of flights evaluating a subset of the MA-AFAS system. Why a subset? Two days will be too short to evaluate all MA-AFAS functions and some functions are better evaluated in real aircraft (e.g. tracking performance, communication performance).

The simulation trials are independent of the MA-AFAS flight trials and will be conducted in the time period December 2002 and January 2003

6.5 Data Recording

Data will be recorded to support the cockpit workload and procedures analysis. The data sets will include:

- Subjective pilot data on acceptance, preferences, mental workload which will be gathered using questionnaires and rating scale.
- Objective pilot data on human performance and human behavior e.g. CCD actions, response times, data entry errors, etc.
- Performance data on the limited delegation and autonomous operation tasks, such as time to acquire required spacing, tracking performance of the required spacing, infringement of and margin relative to instructed spacing.

6.6 Assessment Criteria

The trials will concentrate on the role and behaviour of the crew with respect to the system. System behaviour and system performance in itself is more relevant for the aircraft flight trials rather than for the simulator trials, again unless the performance is not solely a system matter (e.g. when pilot selection strategies or pilot response times are involved). Assessment of the role of the crew with respect to the system will cover:

- Rating mental workload;
- Pilot acceptance (for combination of functions, HMI and procedures);
- Usability of system functionality;
- Usability of HMI;
- Usability of applied procedures in normal situations;
- Usability of applied procedures in non-normal situation;
- Rating effects of crew errors.

The above criteria will be compared between various flights in the simulator changing the environment settings (like traffic densities, weather situation, behaviour of other traffic in the vicinity) or system settings. These variations in environment and/or system will be applied for situation and/or functions, which yield as critical from a human-system point of view.

Example: two flights applying the in descent spacing function, first behind a comparable aircraft and second behind a prop aircraft which reduces speed by more than can be handled by the MA-AFAS aircraft.

7 Flight Scenario 1 - Boscombe Down

7.1 Introduction

This section provides an overview of the Boscombe Down flight scenarios. An annex (Annex A) is being produced which contains a comprehensive description of the complete ground and airborne testing of the MA-AFAS AvP using the QinetiQ BAC1-11 aircraft and selected ground platforms. The annex is intended to be a living document, which will be updated as the operation of the functions becomes fully defined.

7.2 Test Configuration And Infrastructure

To fully test the operation of CDTI and HMI interactions, flights will be required within the coverage of the Boscombe Down VDL4 ground station. To enable testing of the above functions the following datalink will be required:

- VDL4 on 138.5MHz. A non standard frequency has been allocated as, within the UK, the recommended operating frequency of 136.95MHz is not licensed. The system is supplied by SC-TT and networked to the ESCAPE ATC simulator at EEC, this will provide the transfer mechanism for both broadcast and point to point services
- R/T as a backup to the data link services.

The flight trials will be conducted within the UK FIR. The test routes flown will generally be arranged so as to minimise the use of airways, but inevitably some trials will require airways crossings. Such routes will be negotiated with ATC. Use may also be made of specialist airspace such as MTAs and will be co-ordinated through the appropriate agencies.

7.3 Platforms, Themes And Functions

Each of the platform links will enable the testing of selected themes and an associated subset of functionalities, as listed below. The details of these tests are contained in D32 - Annex A.

7.3.1 IHTP

The In House Test Platform will host the AOC ground platform and Taxi Management ground platform. It will be connected to the ground network giving data access to the aircraft MFMS via the data link sub-network.

7.3.2 ESCAPE

The objectives are to evaluate the feasibility and usability of CDTI/ASAS and 4D guidance in order to validate the MFMS in an operational environment using real datalink communication systems. The focus of the trials will be to test the robustness of communication links when proving MA-AFAS specific FMS functionality.

The following themes and functions are to be tested in order of priority:

- Level flight spacing/in-descent spacing with CDTI for enhanced situation awareness;
- Lateral/Vertical Crossing and Passing;
- Autonomous operations;

7.3.3 NATS PAD

The objective of the test is to demonstrate the complementary nature of SBAS and GBAS. SBAS provides navigation for en-route through to an approach capability. GBAS extends this approach capability. Thus for flights in poor weather there will be a changeover from one system to the other. The nature of this changeover requires investigation.

Integration tests are required to ensure that the MFMS works with the SBAS (storage of database) and GBAS/SBAS (reception of signal). A unit test will be required to ensure that the MFMS computes its navigation solution as designed. Even though they are proven user platforms and are part of a proven installation, a check unit test of both the SBAS and the GBAS User Platform (UP) will be conducted. The main actions required when performing the test are to:

- Fly a typical ILS approach and precision departure using BAC 1-11 at Boscombe Down.
- Switch the source of the data displayed to the pilot at an agreed changeover point.
- Log SBAS data.
- Log GBAS data.
- Obtain pilot's opinion.
- Exercise display functions.

7.3.4 AOC Ground Platform (AGP)

The AGP will be hosted in the ground based IHTP. It is envisaged that a single AGP system will also be initially located on the aircraft during the MA-AFAS flight trials to enable AOC functions to be tested in parallel with other MA-AFAS functionalities.

All functions require testing, however those explicitly stated as flight trial requirements will be prioritised within the flying programme. The others will be included within the flight trials as and when appropriate.

The AOC functions to be tested are as follows:

- Meteo Uplink
- Company Flight Plan
- Load Sheet
- Slot Allocation
- Constraints list
- Trajectory Downlink
- OOOI
- Free Text
- Flight Progress
- Active Trajectory Request
- Met Report Request
- Aircraft Systems Data Request
- Snag Report Request
- Pilot requests for TAF, METAR and SIGMETs

7.4 Testing Schedule

The aircraft tests will be conducted in three phases. The first, a series of tests to verify the basic operation of the FMS and communications in the aircraft while on the ground. The second, the flight test phase will provide a period of flying to allow any system performance changes, having translated to the flight environment, to be assessed and corrected if necessary. As many functions as possible will be tested in the time available. The third, the flight assessment phase, will provide a series of repeated flights exercising a specific subset of the MFMS functions. These tests will take place from December 2002.

7.5 Data Recording

Most importantly, flight performance data relative to the required path will be recorded for subsequent analysis. In addition, both the FMS and CMU as required shall record UTC time stamped ADS and TIS messages showing when messages arrived at the aircraft and were subsequently displayed to the pilot. During flights all aircraft ARINC 429 data will be recorded on the airborne DAT system. ADS-B and TIS-B UTC times stamped data will also be recorded in the ground system.

NATS will perform the post processing of the Precision Approach flight data. A report containing analysiswill be provided

7.6 Assessment Criteria

The assessment criteria for the MFMS in the Aircraft/ESCAPE environment will concentrate on the overall system capability of performing the required manoeuvres as instructed by the ESCAPE ATC operator. The ability of the MFMS to provide correct HMI information, acceptable communications performance, reliable trajectory generation and accurate guidance will be assessed.

Trajectory generation is to be assessed in real time by the pilot and trials engineers monitoring the generated trajectory against the scenario definition, which should give indications of what it expected. Checks will be made for annunciated errors, that the constraints have been preserved as expected, that the trajectory between the constraints has an acceptable shape, that the aircraft flight envelope is not exceeded, and that there is no visible conflict with the ground or other traffic.

The pilot and trials engineers will provide subjective feedback on ease of use, workload impact, trajectory presentation, and timeliness of generation.

The 4D Guidance and HMI functions will be assessed in real time by the pilot and trials engineers who will observe the subjective stability of the aircraft control, noting any oscillatory lateral and vertical motion, and throttle hunting. They will also note any perceived transients during trajectory activation, MFMS engagement, MFMS enactment of tactical commands, autoland engagement, and general levels of comfort. Speedbrake prompting will be assessed for ease of use, especially with regard to frequency of application. Finally, the pilot and trials engineer will also note the speed of response of the system to commanded changes in mode. These changes will include the activation and change of trajectory and activation of tactical commands.

The 4D Guidance function will be assessed off line after a trial by comparing the recorded aircraft 4D position, heading, speed, and body rates with the recorded trajectory throughout the flight. This will produce a profile of errors that can be related to pilot actions, ASAS manoeuvres, automatic trajectory re-generations, passing trajectory points, meteorological effects, precision approach transitions, and autopilot mode. Quantitative analysis will be performed to establish stability of control of pitch, roll, and throttle commands through the full flight regime, as well as system delays in responding to commanded mode changes, including activation and change of trajectory and activation of tactical commands.

The systems capability of accepting ATC commands both over the data link and by voice will also be assessed. A subjective assessment, by the pilot, will determine whether there is an acceptable workload associated with the two forms of operation.

The detailed approach to the tests is presented in Annex A to this document.

8 Flight Scenario2 – Braunschweig

8.1 Introduction

This section provides an overview of the Braunschweig flight scenario. Annex B contains a comprehensive description of the complete ground and airborne testing of the MA-AFAS AvP using the DLR ATTAS aircraft and selected ground platforms.

8.2 Test Configuration And Infrastructure

To fully test the operation of CDTI and HMI interactions, flights will be required within the coverage of the Braunschweig VDL mode 4 ground station. To enable testing of the MFMS functions the following datalink will be required:

- VDL mode 4 on 136.95MHz. The system is supplied by SC-TT and networked to the ESCAPE ATC simulator at EEC, this will provide the transfer mechanism for both broadcast and point to point services
- R/T will be operated on a trials frequency and used as both a technical engineering link as well as a backup to the data link services.

8.3 Platforms, Themes And Functions

Each of the platform links will enable the testing of selected themes and an associated subset of functionalities as follows:

8.3.1 ESCAPE

The objectives are to evaluate the feasibility and usability of CDTI/ASAS and 4D guidance in order to validate the FMS in an operational environment using real datalink communication systems.

The following themes and functions are to be tested in order of priority:

- Level flight spacing/in-descent spacing with CDTI for enhanced situation awareness;
- Lateral/Vertical Crossing/Passing;
- Autonomous operations + datalink;
- 4D guidance without negotiation – provided as an enabler for ASAS functions.

8.3.2 SMGCS

The following taxi functions are to be tested whilst performing a series of test scenarios fully defined within Annex B:

- Map Display

To test the Map display function of the application, the aircraft shall follow the normal taxi-in and taxi-out operations while the taxi map display is activated. This requires that the airport at which these tests are conducted, i.e. Braunschweig be contained in the taxi map database. Tests should also be conducted under low visibility conditions.

In addition to the obvious task of checking the fulfilment of the specified requirements, the objective of this test is to verify that the taxi map is coherent to the actual layout of the airport. The aircraft position shown on the display shall be compared to the actual position in the real world or simulated scenario.

Furthermore, the crew testing the system shall provide comments on the value of the displayed information and it shall be checked if orientation and situation awareness is enhanced under low visibility conditions. We would also like to have an indication on how quickly the pilot can retrieve the necessary information from the taxi display (head-down time).

- Ground CDTI

By using simulated or real traffic data, typical scenarios shall be investigated. The traffic should include aircraft and ground vehicles, following standard tracks like taxi-in/out, follow-me operations, winter service, etc. These tests should also be performed in low visibility conditions.

The main objective is to see how much the crew will benefit from the displayed information. To estimate this, the pilots should provide comments on any increase or reduction in their workload and provide an indication of their situation awareness with and without the ground CDTI display.

- Uplink of Taxi Route

With either a simulated or real SMGCS system, taxi routes shall be generated and up-linked to the aircraft. These routes shall include all kinds of possible route information, including hold-short of instructions. To be able to estimate the benefits, the same tests should be conducted without the taxi management system in the aircraft being activated and with the crew following the normal procedure of writing down and reading back the taxi instructions.

A major goal of these tests is to check how much the pilot workload can be reduced with this application. Also, the crew should provide information on how well the system helps in understanding and following the taxi route.

- Taxi CPDLC Messages

Typical CPDLC messages during ground operations shall be send and received. The aircraft shall conduct several ground operations with either normal voice communication or with the CPDLC system.

Again, the measurement of pilot workload is of major interest. Since CPDLC will be limited to a sub-set of all the possible voice communications, it is likely that a combination of both voice and CPDLC will be used. The crew should provide an indication of how much benefit they see in the CPDLC system and it should be noted if the crew prefers sending a request via CPDLC or via voice if both are possible.

- Runway Alert

Several situations where the aircraft approaches or enters a runway shall be simulated/demonstrated and the alerts being issued recorded. Comments from pilots about the value of these functions are of major interest. In addition, the behaviour of the system shall be checked for different approach speeds when the crew is intending to stop at the holding position to verify that no nuisance alerts are generated under normal taxi conditions.

8.4 Testing Schedule

Flight validation with ESCAPE	14 hours	May 2003
Taxi validation with SMGCS	14 hours	May 2003

8.5 Data Recording

The ATTAS data recording facility will be used to record all aircraft state data. Additionally the MFMS will record time-stamped events concerning the interaction of the pilot and communication links with the system.

8.6 Assessment Criteria

The results will mainly be used for the following purposes:

- Checking that high-level requirements are fulfilled and documenting this in the respective acceptance test protocols.

- Using crew comments and observations to fine-tune the system for future product developments.

- Storing test data (aircraft state, CPDLC, CDTI) for later replay. This will be useful for both demonstration and further development.

9 Flight Scenario3 - Rome

9.1 Introduction

This section provides an overview of the Rome flight scenario. Annex C. Annex C contains a comprehensive description of the complete ground and airborne testing of the MA-AFAS AvP using the QinetiQ BAC1-11 aircraft, DLR ATTAS aircraft and selected ground platforms.
The MA-AFAS validation process will utilise the MEDUP system to cover the following scenarios:

- Interaction of the BAC1-11 with the ground platform;
- Interaction of the ATTAS with the ground platform;
- Interaction between the two aircraft.

9.2 Test Configuration And Infrastructure

The MEDUP system provides the following:

- VDL Mode 4 as A/G and A/A datalink for broadcast and point to point communications;
- Ground communication network based on IP protocol;
- Integration with 'shadow' ATC centres;
- Support of A/G co-operative air traffic services.

The trials will be conducted within the Italian airspace to the West of Rome at Flight Level 210. The test routes flown will be arranged with the Italian agency (ENAV).

9.3 Platforms, Themes And Functions

These tests are intended to validate the full functionality of the MA-AFAS AvP within a 'Gate-to-Gate' scenario representative of a future ATM environment, described within the OSED.

Each of the platform links will enable the testing of selected themes and an associated subset of functionalities, as listed below. The details of these tests are contained in Annex C.

9.3.1 The AMS Shadow ATC

This will enable the test and the validation of the following MA-AFAS applications:

- Longitudinal spacing;
- Lateral spacing;
- Vertical crossing;
- Autonomous operations;
- Taxi application (taxi clearances);

9.3.2 Precision Approach Using SBAS

An approach to runway 33 will be generated using a 4.5º glideslope. The approach will be flown under visual conditions only using the onboard SBAS system guidance.

9.3.3 Simulated AOC

The AOC functions to be tested are as follows:

- Meteo Uplink
- Company Flight Plan
- Load Sheet
- Slot Allocation
- Constraints list
- Trajectory Downlink
- OOOI
- Free Text
- Flight Progress
- Active Trajectory Request
- Met Report Request
- Aircraft Systems Data Request
- Snag Report Request
- Pilot requests for TAF, METAR and SIGMETs

9.4 Testing Schedule

MA-AFAS tests to be implemented on the MEDUP platform will start at the beginning of 2003.

The final validation flight trials involving the BAC1-11 and ATTAS aircraft will be carried out during 24-30 March 2003.

9.5 Data Recording

- On board, data will be collected using the aircraft DAT system, supplemented when required by dedicated PC's or specialist dedicated recording systems.
- Equivalent records will be taken from the ATTAS flight systems.
- The MFMS/IHTP will record the flight management functionality and actions.
- On the ground, the MEDUP recording system will be used to log all the messages exchanged with the MA-AFAS avionics during the flight.

9.6 Assessment Criteria

The assessment criteria for this phase will be the same as for the Boscombe and Braunschweig flight tests. The flight tests will be conducted for the first time using two real aircraft. Emphasis of this assessment will be placed on the real-time interaction between them.

Assessment of the system performance will take place using the quantitative data collected during each flight and subjective assessment by the trials pilot.

10 Abbreviations

A/A	Air to Air
ADS-B	Automatic Dependant Surveillance – Broadcast
ADS-C	Automatic Dependant Surveillance – Contract
A/G	Air to Ground
AGP	AOC Ground Platform
AOC	Airline Operations Control
AP	AutoPilot
ASAS	Airborne Separation Assurance System
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Tele-communications Network
AvP	Avionics Package
CCD	Cursor Control Device
CDTI	Cockpit Display of Traffic Information
CM	Context Management
CMU	Communications Management Unit
CNS	Communication Navigation Surveillance
CPDLC	Controller Pilot Data Link Communication
DAT	Digital Audio Tape
EFIS	Electronic Flight Instrumentation System
EIU	Engine Instrumentation Unit
FIR	Flight Information Region
FIS-B	Flight Information System – Broadcast
FMS	Flight Management System
GBAS	Ground Based Augmentation System
HMI	Human Machine Interface
ICCS	Integrated Civil Cockpit Simulator
IHTP	In House Test Platform
ILS	Instrument Landing System
IP	Internet Protocol
ISDN	Integrated Services Digital Network
LCD	Liquid Crystal Display
MA-AFAS	More Autonomous Aircraft in the Future Air traffic management System
MCDU	Multi-function Control and Display Unit
METAR	Meteorological Aerodrome Report
MFMS	MA-AFAS Flight Management System
MTA	Managed Terminal Area
OOOI	Out, Off, On, In
OSED	Operational Services and Environment Definition
PAD	Precision Approach and Departure
RFS	Research Flight Simulator
R/T	Radio Telephony
RTAVS	Real Time All Vehicle Simulator
SBAS	Space Based Augmentation System
SID	Standard Instrument Departure
SIGMET	Significant Meteorological Report
SMGCS	Surface Movement Guidance Control System
STAR	Standard Arrival
TAF	Terminal Area Forecast
TCAS	Traffic alert and Collision Avoidance System
TIS-B	Traffic Information System – Broadcast
UP	User Platform
UTC	Universal Time Co-ordinated
VDLM4	VHF Data Link Mode 4
WP	Work Package

Appendix A - RTAVS Integrated Civil Cockpit Simulator (ICCS)

The RTAVS Integrated Civil Cockpit Simulator (ICCS) is a twin-seat, fixed based, engineering research simulator. The cues provided consist of outside world visuals, both head down and head up displays, tactile feedback through pilot inceptors, aural cues representing engine whine, undercarriage transport and landing screech, radio altimeter etc. The simulator has been used for flight control and handling quality investigations, ground taxi management and air-to-air refuelling studies.

In its ‘hardware-in-the-loop’ configuration it combines an advanced Flight Management System (FMS), Digital Autopilot (AP) and associated displays to provide a facility for civil flight research. The commonality of the FMS and DAP with those onboard the BAC 1-11 experimental aircraft make this an ideal platform for piloted simulation trials of new flight management concepts prior to flight test.

The cockpit houses both the crew and user control stations and can be configured with conventional centre mounted control columns or a sidestick located at the captain’s position. Other inceptors include: rudder pedals with toe brakes, four lever manual throttles with reverse thrust capability, leading and trailing edge flap multi-position levers, pitch trim and undercarriage control levers, etc.

The visual cues available to the pilot can be displayed via four calligraphic/raster monitors mounted within a collimating optical system. The outside world view is generated by an IMAGE 600PT system using selected airport databases. An alternative visual system can be provided using a PC generated image system. A data logging facility also enables quantitative data to be recorded for future analysis.

RTAVS

The Real Time All Vehicle Simulator (RTAVS) is a simulation harness developed to enable high fidelity mathematical models to be interfaced and controlled real-time, forming the basis of a cost effective distributed man-in-the-loop flight simulation facility. RTAVS is implemented as a multitasking environment currently able to run under Windows 95™, Windows 98™ and Windows NT™.

ICCS Architecture

The main components of the system i.e. the RTAVS Host, Avionics cabinet, Input Provider and re-configurable Electronic Flight Instrument System (EFIS) displays are linked by Ethernet, Figure A-1. In addition:

- The aircraft mathematical model is housed within the RTAVS host and runs under the RTAVS simulation harness. For MA-AFAS the model used is representative of the QinetiQ BAC1-11 Series 200.
- The autopilot mode control panel located in the centre of the coaming has duplicated EFIS control panels fitted either side for operation by the captain and first officer. Both the autopilot and navigation display functionality are based on the BAC1-11 and controlled via the combined mode control panel. The autopilot panel provides control over system engagement, speed mode selection, heading mode selection, altitude mode selection and vertical control mode selection.
- The Input Provider consists of a PC containing Analogue and Discrete IO cards and serves as an interface between the cockpit inceptors and the aircraft model, RTAVS environment and displays.
- The avionics cabinet enables avionics hardware such as FMS, Communications Management Unit (CMU) and AP to be integrated into the RTAVS simulation

environment. The cabinet provides housing for standard 19” racks and supplies aircraft power (115V AC, 28V DC) along with the facility to interface to Analogue, Discrete, Synchro and ARINC 429 signals via the Hardware Interface Rack.

- A yet to be defined Communications Interface PC, may be required to emulate the airborne VDL2 and VDL4 transceivers to provide the expected ARINC 429 and RS422 signals required by the CMU. It will also have to convert ARINC 429 and RS422 output signals to a form suitable for transmission over Ethernet or ISDN to remotely located ground platforms.

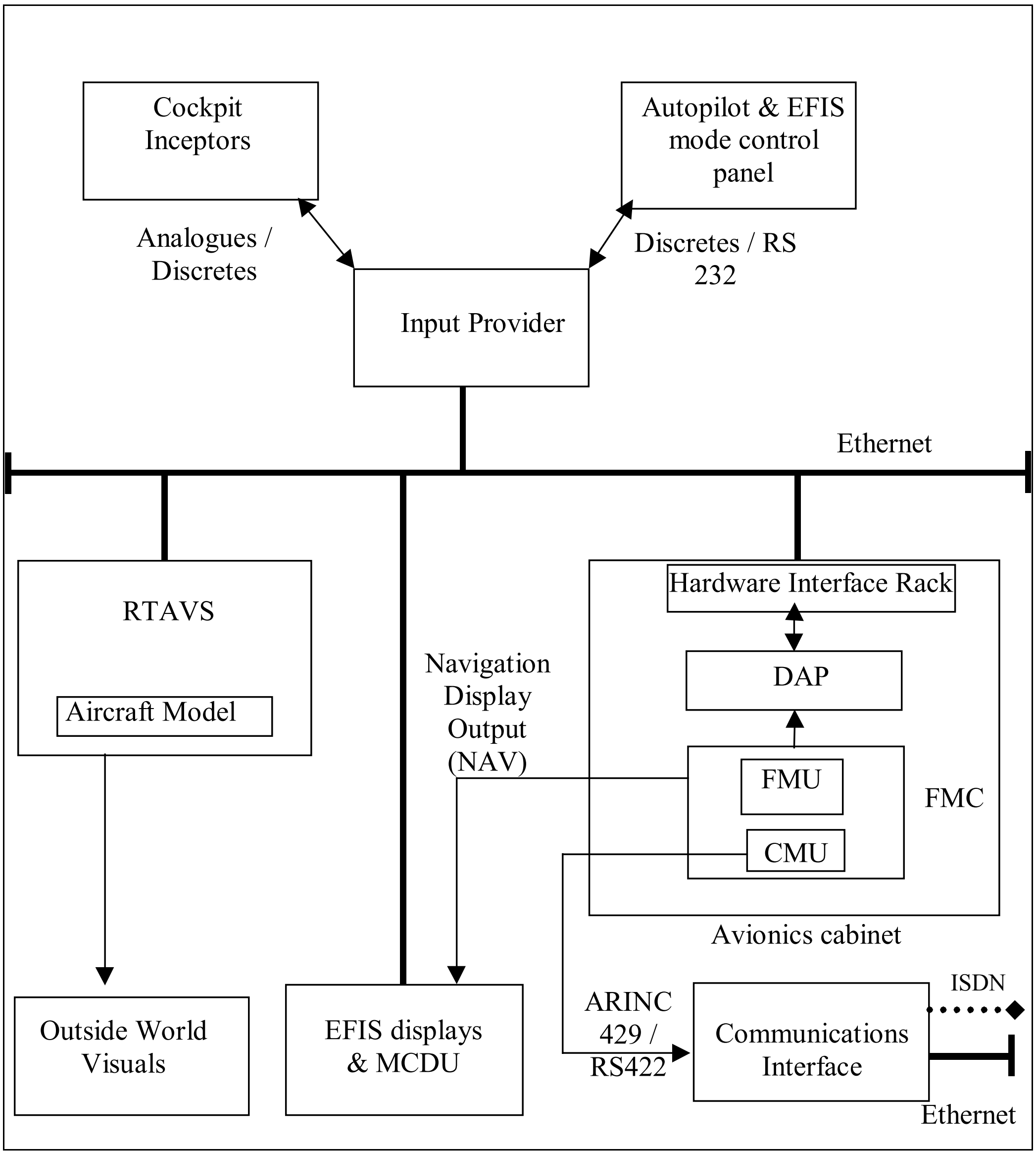

Figure A-1 RTAVS/ICCS architecture (“Hardware-in-the-loop” configuration)

- The EFIS configured for MA-AFAS will consist of six re-configurable colour LCD displays, Figure A-2. Four of the displays consist of a pair of Primary Flight Displays (PFD) and Navigation (NAV) displays located side by side in front of both captain and first officer. The PFD is based on the Airbus A320/340 format whilst the NAV display can provide moving maps with weather radar/TCAS overlay. The large centrally located display provides Engine Instrumentation Unit (EIU) information together with leading and trailing edge flap position etc. The Multi-function Control and Display Unit (MCDU) provides the communication link between the pilots and Flight Management Computer (FMC).

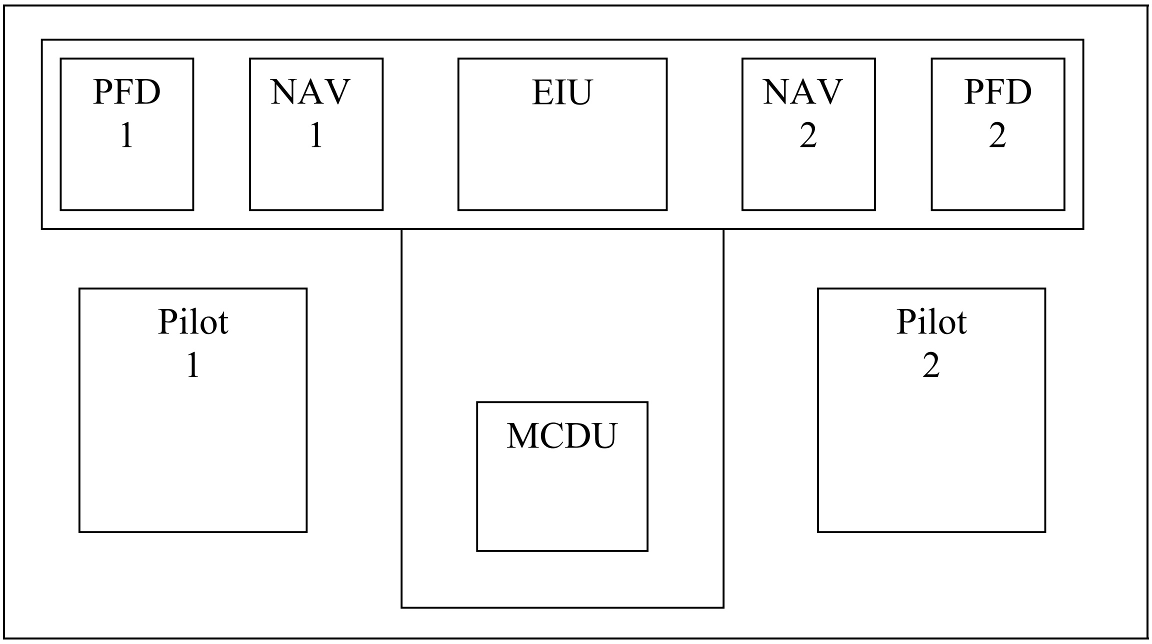

Figure A-2 EFIS display layout

Appendix B - BAC1-11 Avionics Research Aircraft

Figure B-1 QinetiQ BAC1-11

The QinetiQ BAC 1-11 Series 200 aircraft is equipped as a flying laboratory, retained on the military register. It is a unique facility, not only in terms of the comprehensive suite of installed civil avionics equipment, but particularly with regard to how they have been completely integrated to provide a total avionics research system.

The aircraft's normal operating envelope is:

- Max altitude 37,000 ft
- Max Speed 0.78 Mach/325 kt IAS
- Endurance up to 5 hrs
- Max weight 35,834 kg

The flight deck has been significantly modified to enable the aircraft to be used as a research vehicle; in particular, the left-hand pilot's station is equipped with programmable CRT displays in place of the normal flight instruments. The right-seat pilot (safety pilot) has conventional instruments driven from standard avionics systems, thus allowing the left-hand pilot to fly the aircraft using experimental systems and display formats. The BAC 1-11 is the only civil research aircraft in Europe with this capability in the actual cockpit. Other advantages are QinetiQ airworthiness certification, provision of specialist test pilots and observers, and seating capacity for up to 20 passengers for trial support and customer demonstrations.

With the BAC 1-11 operating from Boscombe Down, researchers are able to install experimental ground equipment (e.g. VDL4 ground station), recording systems, etc. on the airfield and can also utilise existing airfield facilities (e.g. NATS PA Platform).

The extensive fit of modern Communications/Navigation/Surveillance (CNS) equipment is shown in Table B-1.

Avionics Equipment Fit		
Navigation Systems	Experimental Flight Management System (EFMS)	4D capable FMS which can be coupled to the Digital Autopilot (DAP)
	Racal RNS 5000 RNAV System	Commercial system with LNAV capability which can be coupled to the AP
	Datapuddle Integrated Navigation System	In-house designed Multi-DME position fixing system
	Trimble 2100 GPS Navstar XR4 GPS Navstar XR5 GPS Novatel 951 R GPS Garmin BRNAV GPS Honeywell GNSSU Ashtech Z X11 GPS	
	Inertial Reference Units – dual Litton LTN-90 platforms	
	VOR/DME/ILS receivers	
	SBAS Novatel Millennium	Provides position and velocity data to EFMS and pseudo-ILS signals to digital autopilot and Primary Flight Display (PFD)
	GBAS Novatel Millennium, PC and Harrris VHF Datalink Radio	
	MLS – CMC 2000 processor + PDME	
Automatic Flight Control System (AFCS)	Dual Digital Autopilot/Autothrottle	In house designed DAP comprising 2 computers with autothrottle unit.
	Digital Air Data Computer (DAC)	Dual system
	Attitude and Heading Reference System (AHRS)	Dual system

Communications	Voice – UHF, VHF, HF, Intercom	Full intercom/RT facilities at six aircraft stations and intercom monitoring for all passengers
	Datalink – Racal MCS 3000 data-3 Satcom, Rockwell/Collins VDL2	
Surveillance	TRT Mode S Transponder + ADLP	ADS-B capable
	Traffic Alert and Collision Avoidance System (TCAS)	Switch selectable between TCAS and Mode S transponders
Recording	Compact tape system with Leica GPS time stamping	In-house designed system records all Arinc 429 data distributed around the aircraft.
Power Supplies	Standard A/C – 200v/115v 400Hz, 28v dc	
	Experimental – 200v 400Hz 3-phase stabilised, 115v/26v single-phase stabilised, 240v 50Hz 'mains' uninterruptable, 26v dc	Provides ability to use laboratory test equipment on-board the aircraft.

Table B-1 BAC1-11 Equipment fit

Appendix C - ATTAS Experimental Research Aircraft

The Advanced Technologies Testing Aircraft System (ATTAS) aircraft is a VFW 614 twin engine jet transport aircraft modified for research purposes. It has been equipped with a full fly-by-wire system to support flight controls research and an additional cockpit with flexible HMI-layout is available for Flight Management and HMI research.

For the MA-AFAS trials the Experimental Cockpit will be used within the ATTAS. It provides a central interface to the aircraft's sensor systems relevant for flight management as well as full controls of the aircraft and autopilot. The aircraft can be flown in any mode (manual via sidestick or fully automatic) from this cockpit under visual conditions and above 500 ft altitude. There is no control of nose wheel or brakes in the Experimental Cockpit, so the taxi trials will be carried out from the front cockpit.

Experimental equipment, like the MA-AFAS FMS system, can access the aircraft's state sensor and control the autopilot via a TCP/IP connection, the displays can be driven either by two Silicon Graphics workstations that can be freely programmed, or directly via RGB connection. A touchpad as well as touchscreens are available for cursor control and can be connected via serial interface. The cockpit also provides sufficient space to install the MA-AFAS MCDU. The experiment can be controlled from an operator station in the cabin.

For the taxi trials an additional flat panel display will be mounted in the front cockpit. This display will be directly driven by the MA-AFAS system via RGB connection.

The following figure shows the main dataflows between the MA-AFAS system and the ATTAS aircraft:

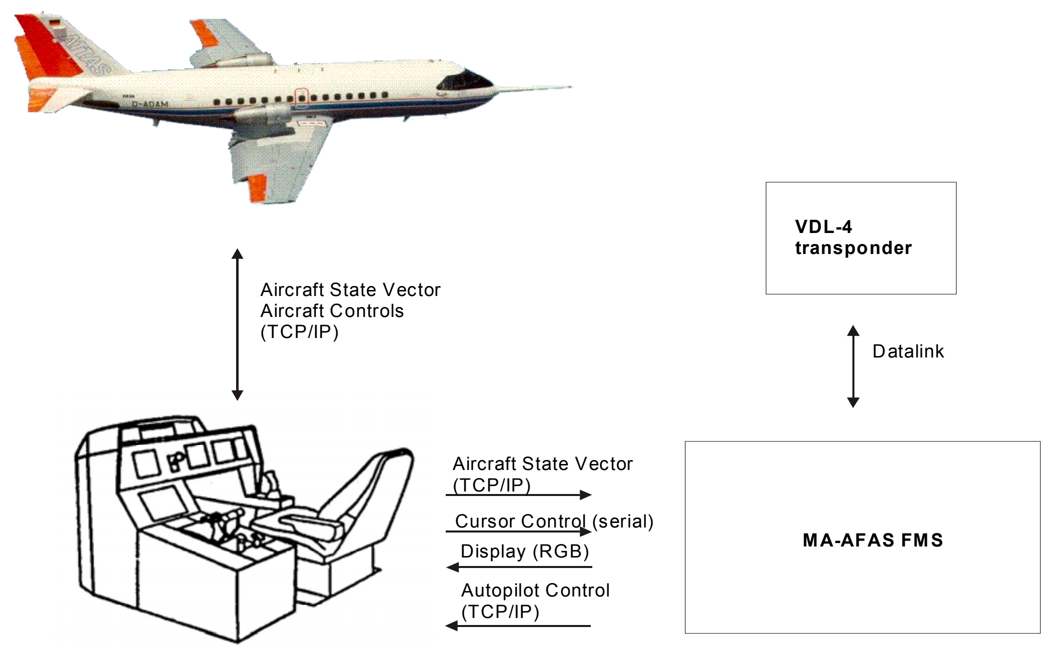

Figure C-1 ATTAS aircraft

Summary of ATTAS functions:

	Function	Remarks
1.	Comms	All MA-AFAS Comms are provided by the MA-AFAS system itself. The transponder to be used is part of the MA-AFAS equipment and will be supplied to DLR by SCTT.
2.	Aircraft State	The aircraft state vector is provided via a UDP broadcast over a local ethernet.
3.	Nav Display	A 13" flat panel display with 1280x1024 pixel resolution which can be directly controlled via RGB (standard SXGA or similar signal). To obtain the desired smaller size of the display a window of the desired size will have to be produced by the video controller of the MA-AFAS system. For taxi trials a similar display is available in the front cockpit.
4.	MCDU	The MA-AFAS CDU will be installed in the Experimental Cockpit. This will not be available to the pilot during taxi trials.
5.	Experiment Control	The experiment can be monitored and controlled via a laptop (installed in Experimental Cockpit rack) that can connect to any computer on the local ethernet.

Table C-1 ATTAS functions

Appendix D - ATTAS Flight Simulator

The MA-AFAS integration in Braunschweig is supported by the Institute of Flight Guidance's ground simulation environment. This simulation environment is optimised for pre-flight trial integration as well as customer demonstrations. Two cockpits may be used for the integration, the Experimental Cockpit and the Demonstration Cockpit. Both have identical interfaces, but the Demonstration Cockpit features a more airliner like layout and an excellent external view system. It is anticipated that only the Demonstration Cockpit will be available in the timeframe of the MA-AFAS trials.

The setup is essentially the same as for the flight trials, the only differences are that a standard workstation simulation replaces the aircraft and some stimulation device replaces the physical datalink. Such a device is not available at DLR, but it is anticipated that this will be a PC using some software designed to communicate with the MA-AFAS CMU and with external simulators via DIS and this software can be made available to DLR.

Figure D-1 shows the simulation environment:

Figure D-1 ATTAS simulation environment

Summary of ATTAS simulator functions:

	Function	Remarks
1.	Comms	All MA-AFAS Comms are provided by the MA-AFAS system itself. It is anticipated that the software for the datalink stimulation can be provided to DLR.
2.	Aircraft State	The aircraft state vector is provided via a UDP broadcast over a local ethernet.
3.	Nav Display	A 13" flat panel display with 1280x1024 pixel resolution which can be directly controlled via RGB (standard SXGA or similar signal). To obtain the desired smaller size of the display a window of the desired size will have to be produced by the video controller of the MA-AFAS system.
4.	MCDU	The MA-AFAS MCDU will be installed in the Demonstration Cockpit.
5.	Experiment Control	The experiment can be monitored and controlled via any computer connected to the local network.

Table D-1 ATTAS simulator functionality

Appendix E - NATS Precision Approach Platform

Airborne Equipment

The airborne equipment to be used in the MA-AFAS Precision Approach (SBAS/GBAS) trials, comprises the SBAS and GBAS User Platforms, cockpit indicators, the autopilot and the MA-AFAS FMS.

Both SBAS and GBAS are augmentations to GPS. The individual error uncertainties are used by the receiver to compute an error model of the navigation solution. This is done by projecting the pseudorange error models to the position domain. The Lateral Protection Level (LPL) provides a bound on the horizontal position error with a probability derived from the integrity requirement. Similarly, the Vertical Protection Limit (VPL) provides a bound on the vertical position. If the computed LPL exceeds the Lateral Alert Limit (LAL) or the VPL exceeds the Vertical Alert Limit (VAL), then integrity is not adequate to support the operation. The avionics then alert this to the pilot.

SBAS

The SBAS (EGNOS System Test-Bed) navigation solution is provided on board the BAC1-11 by the User Platform (discussed in detail later). This includes an EGNOS receiver, which receives GPS signals and those from one or more geo-stationary satellites. As these signals are broadcast at GPS frequencies, no other antenna is required.

GBAS

The GBAS navigation solution is provided on board the BAC1-11 by the User Platform (discussed in detail later). This includes a GBAS receiver, which receives GPS signals and the VHF Data Broadcast (VDB) via a VHF antenna.

Cockpit

The analogue ILS scales on the primary flight display are shown in Figure E-1.

Figure E-1: EFIS Display Layout

Figure E-2 Airborne User Platform

User Platform (UP)

The PC-based User Platform (UP) is shown in Figure E-2. There is one UP for GBAS and another for SBAS. They are located in the cabin so that the flight test engineers can operate them.

The User Platform (UP) was developed by Stanford Telecom (ITT) to support evaluation of the Wide Area Differential GPS concept for enhancing the accuracy, integrity and availability of the Global Positioning System. The UP provides a navigation position, velocity and time. Based on a PC, the UP fits in a large and rugged PC base unit, with the GPS receiver external to this. The PC requires a 220V 50Hz power supply and cooling.

The UP (currently running version 6.2), supports the following features:

- Interface to several commercial GPS/GEO receivers.
- Position, Velocity and Time (PVT) output to CRT display and RS-232 serial port at least once per second.
- Complies with the message formats for wide area corrections as described in the 1996 and 1997 versions of the Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment (DO-229 and change 1 to DO-229).
- Differential and non-differential navigation modes.
- VHF radio and GEOsynchronous satellite (GEO) datalinks for satellite corrections.
- Ranging from the geostationary satellite.

SBAS UP

The SBAS UP consists of:

- ITT User Platform
- Novatel Millennium WAAS Receiver
- GPS Antenna
- ARINC data card
- Processing compliant with DO-229 Change 1
- ARINC PVT and digital ILS outputs

GBAS UP

The GBAS UP consists of:

- ITT User Platform
- Novatel Millennium WAAS Receiver
- Harris VHF Data Link Receiver

- GPS and VHF antennas
- ARINC data card

The processing performed within the ITT UP is compliant with DO-253, and is capable of receiving and decoding Message Types: 1, 2 and 4. The UP provides ARINC PVT and digital ILS as outputs. GBAS steering information is integrated into the aircraft displays.

Autopilot

The planned trial will perform automatic approaches, where the navigation source is coupled to the autopilot. This section gives a brief overview of relevant aspects of the autopilot.

- Digital autopilot with associated auto-throttle
- Cleared for use over aircraft's flight envelope, down to 50ft VMC or Decision Height in IMC, when coupled to ILS-type system
- Accepts pilot-selected altitude, speed and heading target values, as well as LNAV and VNAV demands from an FMS for automatic trajectory guidance (capable of supporting 4-D FMS control)
- ILS guidance mode can be selected by pilot or automatically initiated by the FMS
- Developed in-house, during mid-eighties, to replace previous analogue version
- Required to provide greater flexibility for supporting increased system integration onboard the aircraft and investigate advanced FMS guidance modes for future 4-D ATM operations
- Thus the BAC 1-11 autopilot is compatible with current autopilot design philosophy. However, it does lack selectable vertical speed hold, go-around and autoland capability. In preparation for the MA-AFAS trial, NATS contracted DERA (QinetiQ) to perform an update to the installation.

An overview of the systems architecture can be seen in Figure E-3.

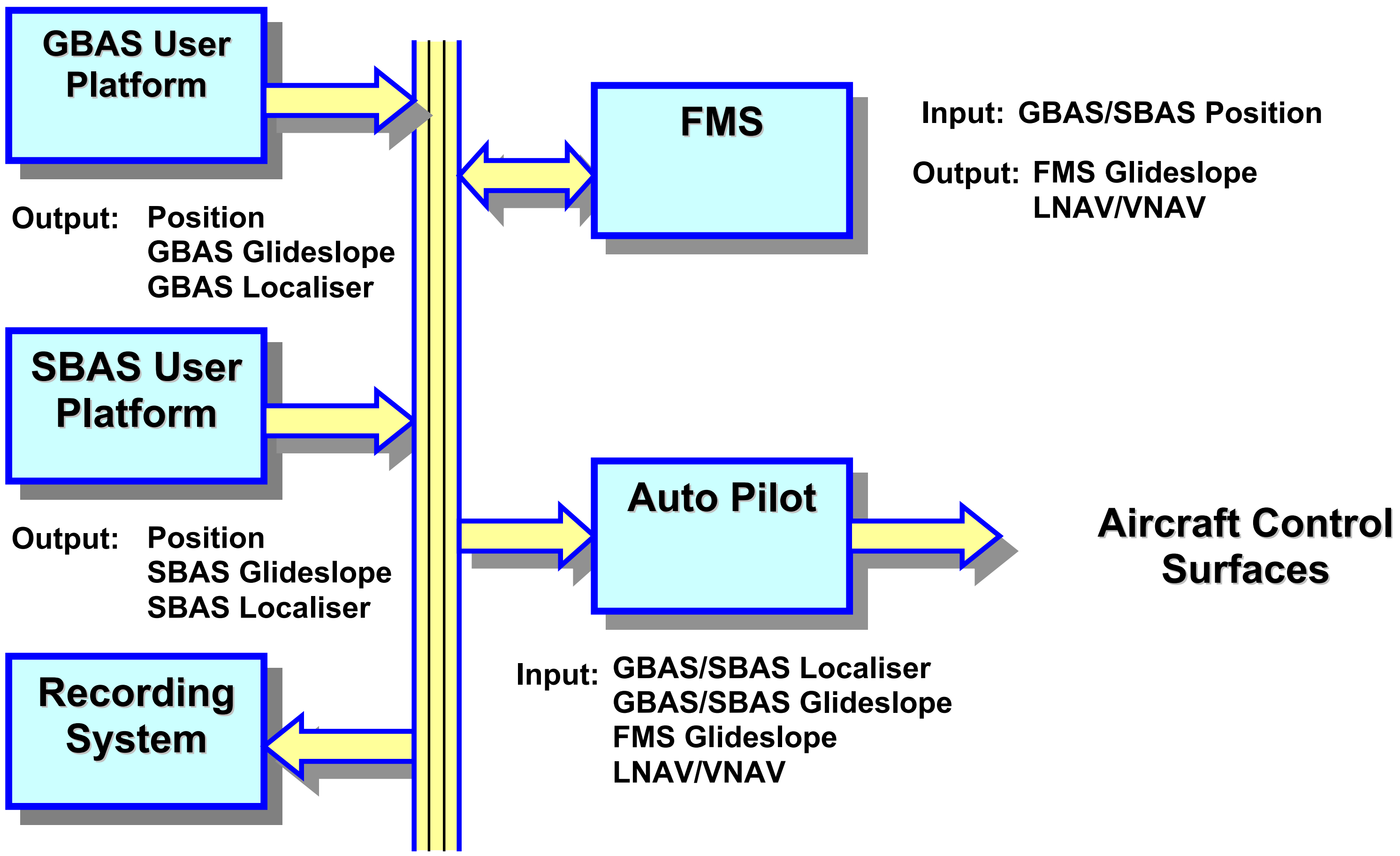

Figure E-3: Aircraft Installation

Appendix F - NLR Research Flight Simulator

The National Aerospace Laboratory NLR operates two large flight simulation facilities: the National Simulation Facility (NSF) and the Research Flight Simulator (RFS), both full motion simulators. The following will concentrate on the RFS.

Transport cockpit{tc ""}

The RFS transport cockpit is a side-by-side full glass airliner cockpit with a layout as in modern aircraft, equipped with up to five CRTs and four LCDs. The fully programmable EFIS can be extended with several enhancements: TCAS symbology, tunnel-in-the-sky, and dynamic weather radar picture including windshear symbology correlated to custom defined wind fields.

The Research Flight Management System

The Research Flight Management System (RFMS) is a FMS look-alike with full FMS functionality and free play capability. Special features of the RFMS are ARINC compliant ATC datalink interface, 4D functionality (both RTA and Tunnel/bubble concept). A simulated Ground Proximity and Warning System (GPWS) is available with standard GPWS functionality and corresponding sounds. The displays are interchangeable with conventional instruments or real EFIS displays. An ARINC-429 bus connects most of the avionics.

Pilot controls

Various electrohydraulic control-loading systems are available such as wheel/column, centre stick or sidestick. Pilot primary flying controls, throttle, flap and trim handle are servo driven.

Sound system

A combination of analogue and digital sound is available for creating cockpit-sampled sounds such as aerodynamic hiss, engine sound and aural warnings. A development workstation is available to modify or create new sound libraries, e.g. three-dimensional sounds.

Air Traffic Control

For a realistic Air Traffic Control (ATC) environment, the NLR Traffic and Scenario Manager (TMX) can be linked to the flight simulators. Traffic, including R/T background for both data link and voice R/T scenarios can be generated in the simulations. Another option is to use the Traffic Manager on the Experiment Manager Program. In this way both automatic and interactively controlled traffic can be generated.

Out-the-window view

The RFS makes use of an Evans & Sutherland ESIG-3000 computer image generation system. This system offers three output channels one of which is used to create the out-of-the-window view of the simulator. The other two remain available for generating for example a radar image.

A database modelling system is available. Several geo-specific large area databases have been created including the USA Hunter-Liggett area, San Francisco Bay area and Frankfurt airport. Customer-specific database development can be carried out, and the system can import DTED/DFAD and MIL-STD 1821 data in combination with photos for geo-specific terrain modelling.

In addition to the ESIG-3000 platform, the VEGA image generation system is available for the RFS. Multigen is used to develop visual databases for VEGA. For these applications, a SGI Onyx II is available.

The transport cockpit uses wide angle collimating displays to present the out-the-window-view to the pilot. The field of view of these displays is 48° horizontal and 36° vertical.

Motion system{tc "Motion and Force cueing"}

The RFS is mounted on a four degrees-of-motion platform, equipped with hydrostatic actuators that facilitate controlled washouts. Movements are +40°/-20° in pitch, ±19° roll, ±29° yaw and ±0.28 m in heave.

Control room

The RFS is operated from a control room that allows close monitoring of the simulator operation. All relevant instrument displays are regenerated in the control room and the operators can view the pilots in the cockpit through a video channel. Simulations can be started and terminated by the operators. Several conditions, such as weather can be changed during flight from the control room.

Distributed Interactive Simulation{tc "Distributed Interactive Simulation"}

Both computer infrastructure and software have been implemented for participation in Distributed Interactive Simulation (DIS) with other vehicle simulation facilities.

Human factors measurements{tc "Human factors measurements"}

Instrumentation and fittings in all cockpits allow variables such as heartbeat, respiration rate, blood pressure, EEG, and eye point of gaze, pupil size and blink rate to be measured. A HEART (Human factors Evaluations, data Analysis and Reduction Techniques) tool allows the physiological measurements to be correlated with recordings of for example stick input and aircraft response.

Computing and interfacing{tc "Computing"}

Three Silicon Graphics computers are available for real-time operation each with four processors. One Origin 200 and two Challenge L computers (one with a total of 180 Mwhetstones and one with 360 Mwhetstones). A similar computer system is used for software development.

A fibre optics based Flight Simulator Interface System (FSIS) connects computer and hardware systems in a ring via SCRAMNet. Integration of actual flight hardware can be achieved through the FSIS Cockpit Avionic Node capable of connecting systems with the military bus system MIL-STD-1553B or the civil bus system ARINC-429.

A fast Ethernet Local Area Network is also attached to the host computer. Currently, nine high performance workstations are attached to this network. Six of these are used to generate the image signals for the cockpit's MFDs, while the other three are connected to the Command Display Units of the simulated FMS system.

Graphics workstations{tc "Graphics workstations"}

Various graphics workstations are used for cockpit display generation.

Aircraft software{tc "Software"} models

Aircraft models available for the MA-AFAS project are the Boeing 747-200/400 and Fokker 100.

Figure F-1 illustrates the schematic overview for the RFS.

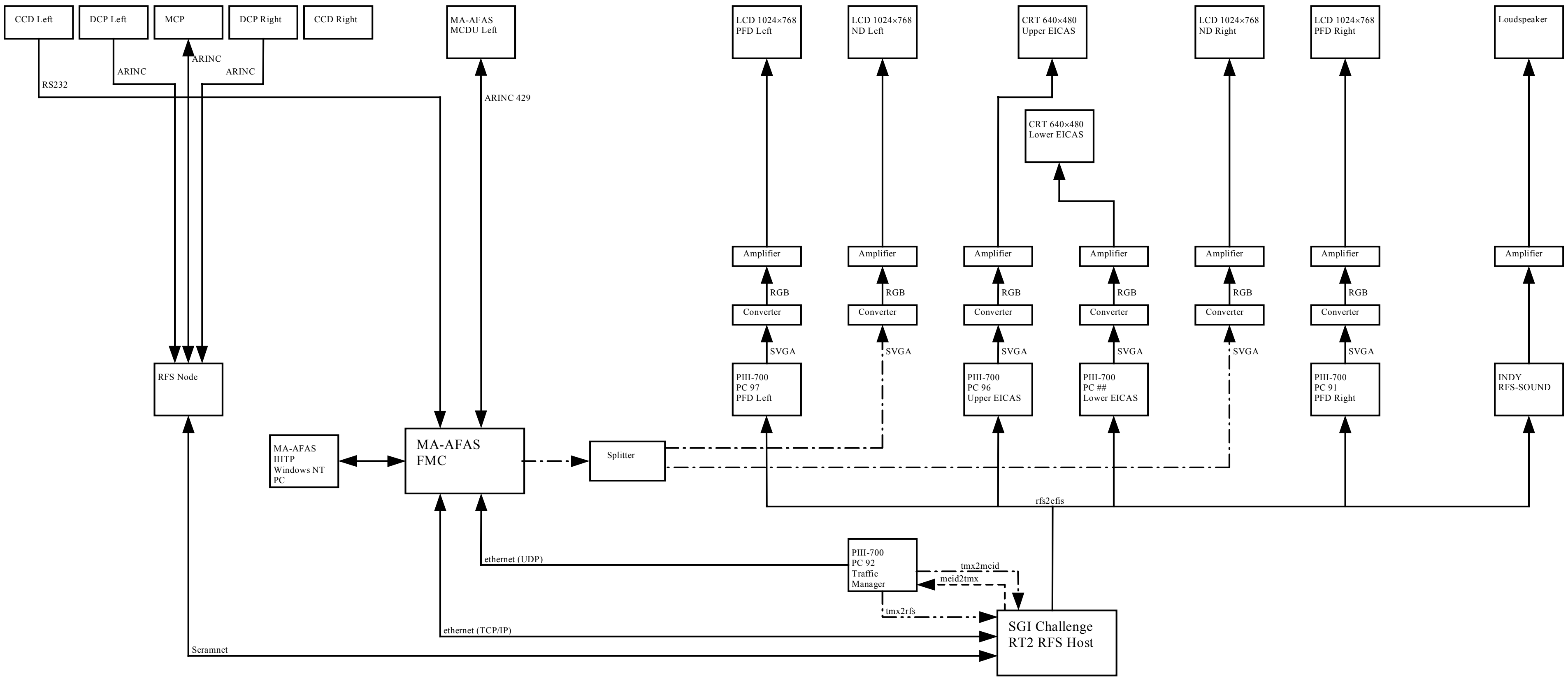

Figure F-1

Page: 23
[HFD1]Why? Is denk ik te simpel, sluit voor de toekomst heel wat uit. Voorbeeld: een andere flight director (e.g. Z-bar ipv crossbar or V-bar) is ook relevant voor eval in een sim. "Functions affecting pilot behaviour" is het eerste wat in mij opkomt.