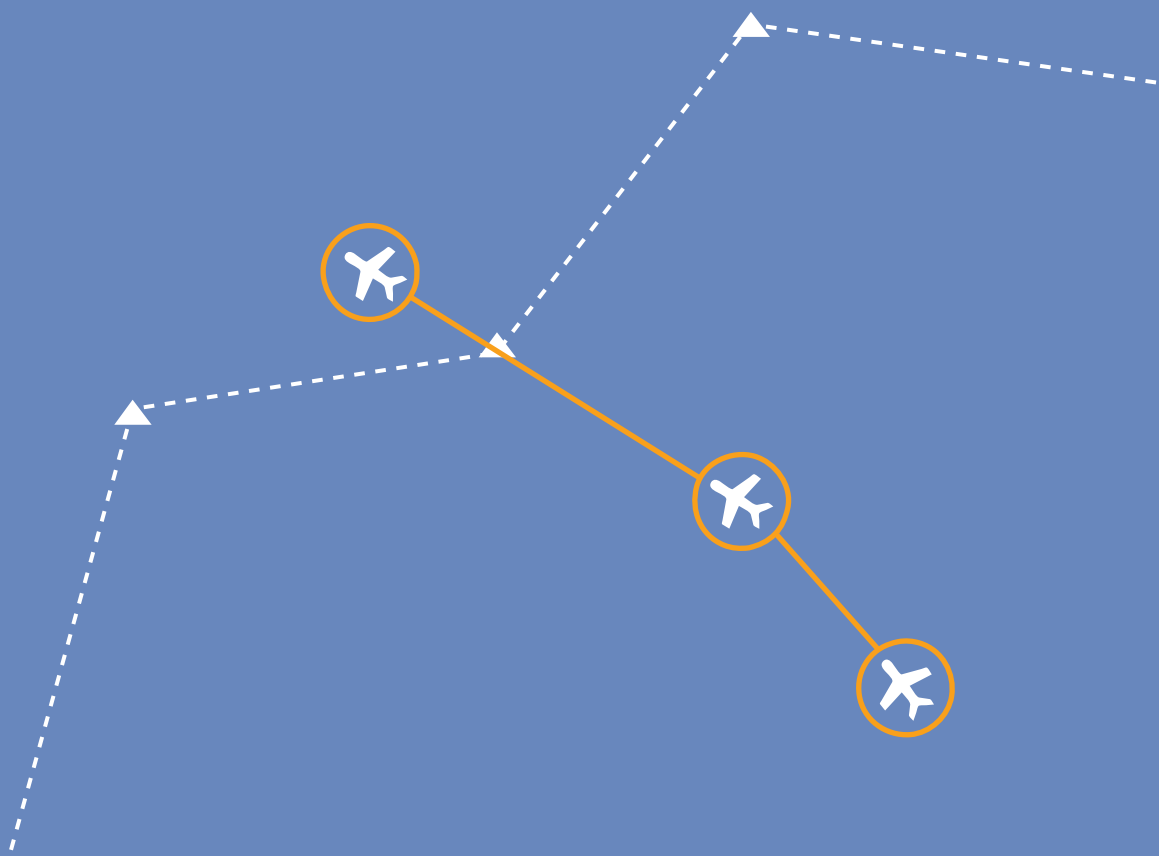




**MFF PROGRAMME**  
**MEDITERRANEAN FREE FLIGHT**  
2000/2005





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# 1

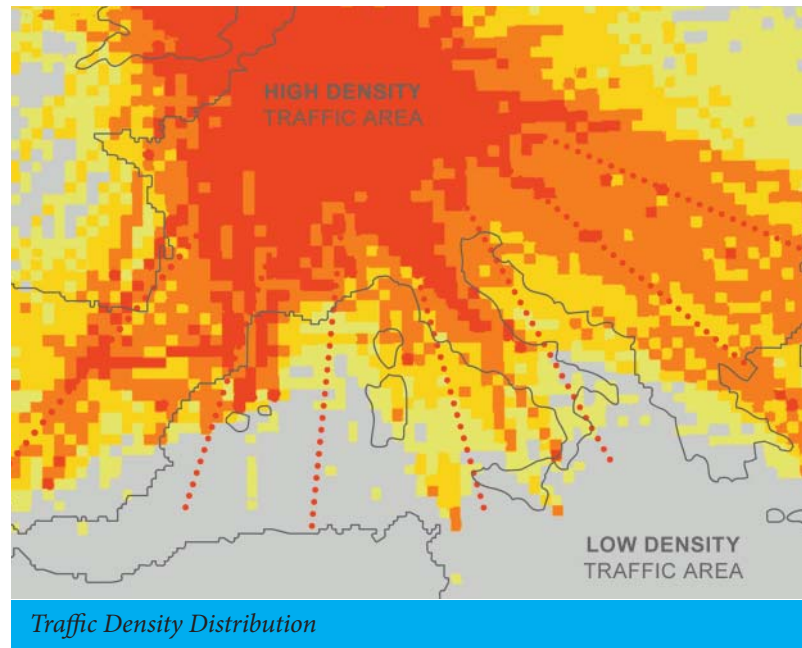
## MFF PROGRAMME OVERVIEW

**The extraordinary growth trend of air traffic requires significant changes in Air Traffic Management (ATM) concepts, procedures and systems, beyond the currently agreed objectives of ATM Strategy 2000+.**

**Thanks to the foresight and funding provided by the European Commission, the Mediterranean Free Flight Programme (MFF) was an effective exercise in international co-operation to develop European consensus on innovative ATM techniques and technology options.**

It enabled experts from all over Europe to co-operate in overcoming the operational and technical hurdles in defining and validating future concepts and their safety implications. The MFF partners agreed to focus on a structured series of increasingly innovative and challenging applications.

The project developed advanced simulation facilities and new validation techniques plus a live trials environment including fully equipped flight test aircraft. MFF studied innovative concepts based on a set of defined operational and technical requirements designed to improve the management of air traffic in the Mediterranean area. The key aspects were user preferred trajectories, redistribution of tasks between controllers and aircrew and making use of the possibilities offered by ADS-B services.



Between 2000 and 2005, MFF validation activities ranged from Free Routing applications enabling user preferred trajectories to Free Flight in which aircraft maintain their own separation from others in designated airspace. Seven European ATM service providers (ENAV-Italy, AENA-Spain, DSNA-France, HCAA-Greece, MATS-Malta, NERL-UK, and SCAA-LFV-Sweden) participated in the project along with Eurocontrol, NLR-The Netherlands and military agencies.

## THE MEDITERRANEAN OPERATIONAL SCENARIO

The Mediterranean airspace is a transition area between the Core Area (high density traffic and good Communication, Navigation and Surveillance “CNS” infrastructure) and the North African airspace (low density and poor CNS infrastructure). The North African airspace will be the first candidate to evolve towards Satellite navigation and Free Flight operations. In the same area, projects such as ADS MEDUP (led by ENAV) have provided a complete Automatic Dependent Surveillance Broadcast (ADS-B) network to support Airborne Separation Assurance System (ASAS) operations.

## OBJECTIVES

MFF is a pre-operational Programme aimed at defining, testing and validating ASAS applications and procedures within en-route scenarios in Free Flight Airspace (FFAS) and Managed Airspace (MAS) as well as the transition between the two. Furthermore the definition, testing and validation are performed for free routing applications and procedures within MAS en-route scenarios.

MFF intended to provide a technical and operational evaluation of CNS/ATM technologies and applications suitable for operational implementation in the Mediterranean area. The main objectives of MFF are listed below:

- Define operational requirements and procedures based on the use of new CNS/ATM technologies enabling the introduction of ASAS operations;
- Verify appropriate new operational procedures in Free Route and ASAS scenarios based on 5 selected applications: Free Route, Air Traffic Situational Awareness (ATSAW), ASAS Spacing, ASAS Separation and ASAS Self-Separation (Free Flight);
- Pursue the exploitation and support standardisation of the new CNS/ATM technologies;
- Define guidelines for the implementation of ASAS operations in appropriate airspace.

## EXPECTED BENEFITS

The MFF Programme trials validated proposed concept and procedure compliance mainly with the following objectives:

- Increased safety
- Reduced costs
- Increased capacity
- Reduced delay
- Increased schedule reliability
- Increased flight efficiency

## DEFINITION OF CONCEPTS AND PROCEDURES

On the basis of User expectations and current traffic constraints, MFF defined operational concepts, requirements and procedures for the future implementation of ASAS applications in the Mediterranean area.

ASAS is an airborne system which supplies the flight crew with information regarding surrounding traffic and decision support tools that aid the provision of separation from that traffic. This allows the flight crew to participate with controllers in ensuring separation from proximate traffic, and ultimately, to provide the primary, and possibly sole means for separation.

Defined in coherence with other major projects (e.g.: CARE / ASAS, FREER, FRAP, FARAWAY, MA-AFAS, ADS MEDUP, NUP, etc.) and in compliance with the EUROCONTROL Strategy for 2000+, the MFF partners adopted a harmonised and coherent approach to ensure a complete description of the overall concept and a high level of compatibility with similar American initiatives.

Once the concept had been defined, MFF partners concentrated their efforts in a same timeframe on both the validation strategy definition and the development and setting up of technical platforms.



# VALIDATION STRATEGY

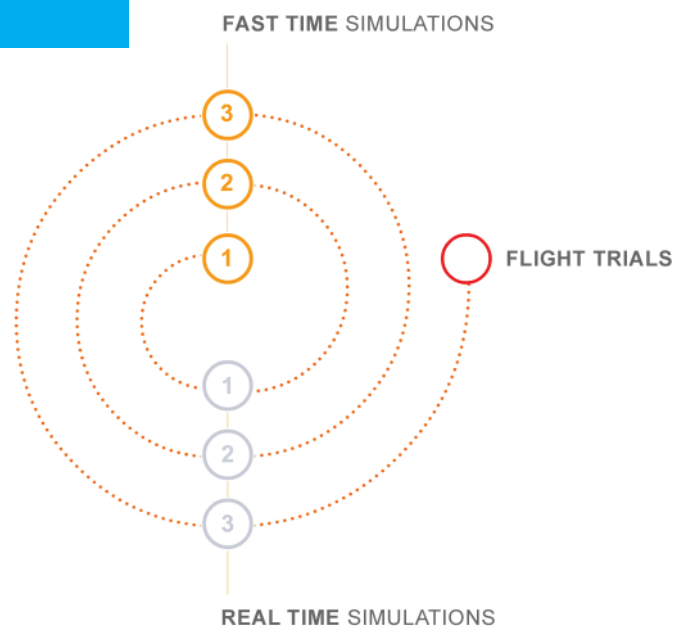
## METHODOLOGY

The purpose of the validation process in MFF was to determine whether the MFF concepts and procedures address the ATM problem of concern, delivering performance benefits. For that, MFF applied the MAEVA methodology to assure a structured, focussed and effective approach to concept validation.

The Validation Data Repository (VDR) tool was used to assure the management and the storage of validation data and to support the reporting activity.

Concepts and procedures were validated against a predefined set of Validation Objectives through a co-ordinated and integrated set of exercises based on different techniques.

*The Validation Cycle*



## VALIDATION OBJECTIVES

MFF validation objectives selected by MFF partners addressed:

- **Procedures and tools** to assess if controllers and pilots are able to operate effectively a given MFF application;
- **Safety** implication to demonstrate that each method of operation is at least as safe as, or safer than existing procedures (including degraded and failure modes);
- **Economic assessment** to measure economic impact of each MFF Concept against a do nothing option;
- **Military aspects** to assess the impact of MFF concepts on the interactions between civil and military traffic;
- **Capability aspect** to assess the capability of MFF concepts to cope with 2005 and 2010 traffic forecasts;
- **Environmental impact** to assess the impact of the MFF applications on the environment;

- **Transition issues** to assess the airspace management transition;
- **Architecture aspects** to check the appropriateness of the proposed ATM architecture.

These validation objectives have been used to define the detailed objectives and contents of the different MFF studies.

## VALIDATION TECHNIQUES

Validation techniques used in MFF included Model Based and Real Time Simulations, Flight Trials and paper studies. These were designed to provide answers to the key validation objectives previously introduced.

### Model Based Simulations

The purpose of Model-Based Simulations (MBS) was to investigate the performance of different MFF/ATM scenarios, implementing the MFF selected applications under various conditions to gain confidence in their operation and feasibility. The goals of the MFF Model Based Simulation scenarios were:

- To investigate the performance of candidate MFF ATM reference scenario;
- To recommend improvement, modifications and refinement actions on scenario definitions;
- To contribute to other MFF Programme activities, including Safety Case, Operational benefits as well as technologies and applications assessment.

### Real Time Simulations

The purpose of Real Time Simulations (RTS) was to:

- Further study the MFF concepts and procedures through the active participation of pilots and controllers in these simulations;
- Recommend improvement, modifications and refinement actions on concepts and procedures based on users' feedback;
- Provide input to safety studies;
- Complement the results obtained during the MBS.

RTS operational preparation phase involved the preparation of all traffic and static data to be used during the Real Time Simulation. Pre-simulation documentation was prepared including training and briefing documents. Analysis methods and an analysis plan were agreed. The simulation experimental plan was prepared taking into account all relevant operational, human factors and analysis aspects.

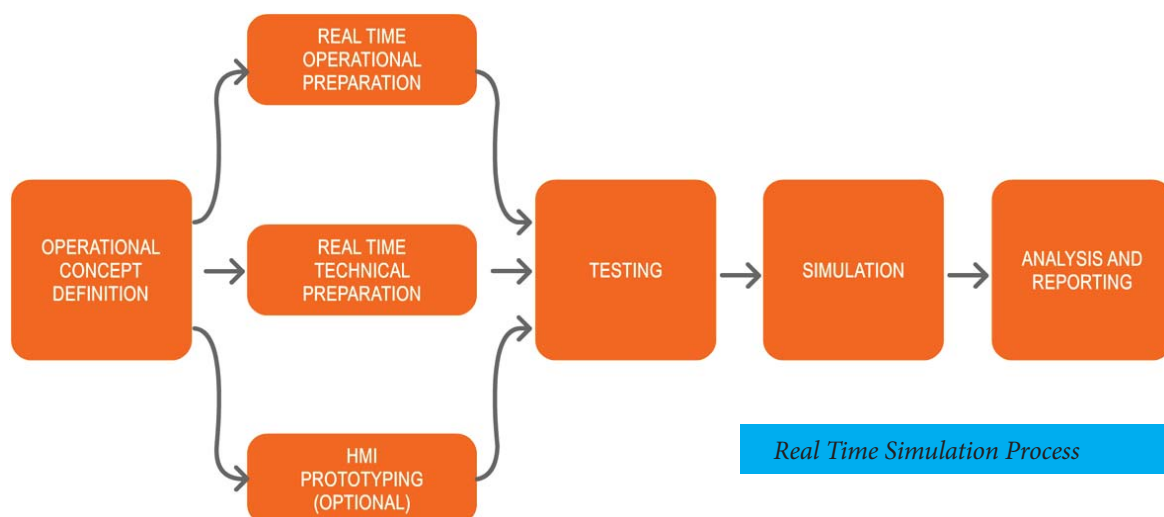
RTS technical preparation included tasks to configure the software and hardware platform resulting in a completed simulation facility ready to start the testing phase.

Depending on the situations, Human Machine Interface (HMI) prototyping was part of the Real Time Simulation process. As a minimum it provided hands-on experience of the interface to be simulated to ensure that everyone involved fully understands its capabilities and limitations.

During the testing phase, small and large scale tests were conducted using scenarios agreed with the operational team to ensure that the simulation facility reached an acceptable level of technical maturity and reliability enabling the simulation objectives to be achieved.

The simulation phase was carefully planned to obtain the maximum benefit from the simulator and ensure the participation of all involved actors.

A large set of data was recorded and subsequently analysed, including aircraft trajectories, controller and pilot inputs, system and safety related events. The Real Time Simulation process ended with the analysis of collected data and the production of result reports.



## Flight Trials

The purpose of Flight Trials was to:

- Test and verify the overall operational procedures, for both pilots and controllers, supported by the enabling technical solutions;
- Verify and validate (technological) assumptions made in simulations;
- Assess the technology on board the aircraft under various conditions.

## SAFETY

Safety of MFF concepts and procedures was assessed to guarantee that their adoption do not increase and, where possible, decrease the number of ATM induced accidents. This issue was addressed by the safety team from two perspectives.

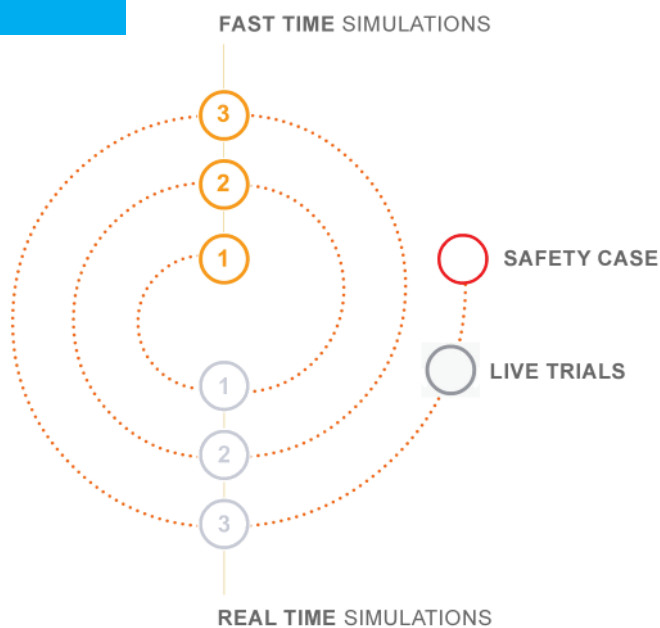
First, on the level of activities architecture, the MFF safety was designed with an iterative and incremental structure. The safety plan was largely derived from state-of-the-art safety methodologies, such as the EUROCAE guidelines (ED78A), to ensure coverage at the end-to-end service level, complemented by the EUROCONTROL Safety Assessment Methodology (SAM), for developing a risk based assessment. In this robust framework, MFF integrated an iterative feedback loop in the form of different versions of the Safety Case. More in detail, according to the knowledge of the system available at different moments, three versions of the Safety Case were produced to provide early feedback to the redesign and refinement of concepts and procedures, or to clarify which were the main open issues from a safety point of view. Rather than presenting an established body of knowledge, the Safety Case was used to highlight the current focus of the safety work. The iterative loops were also designed to better suit the developmental nature of concepts and procedures, going in parallel with their progressive refinement and redesign as the project was evolving.

The second perspective addressed the operational level, as operational knowledge most of the time is the richest source of safety information. The extensive set of validation exercises (i.e. Real Time Simulations and Flight Trials) were used to solve the problem of the limited knowledge and experience of the operational experts on the specific concepts and procedures investigated in MFF. The simulation exercises allowed a progressive involvement of the operational experts (pilots and controllers) with a growing familiarization of the new concepts and procedures, in parallel with the refinement and consolidation of those procedures.

Safety hazards were simulated to reproduce the hazards identified by the safety team and gather more information about controllers' reactions or potential mitigation means. Simulated hazards also included system failures on board and on the ground. Safety scenarios also offered the operational experts the opportunity to experience abnormal events during the execution of the procedures. In this way they could experience how things work, but also how they fail having the opportunity to reason about what did not work when the system has failed and about the potential consequences of the failures. This offered the possibility to record safety knowledge as experts were developing it.

Before delivering the Final Safety Case, the main results of the safety assessment were validated using the operational experience of air traffic controllers and pilots, who had been involved in the Real Time and Cockpit Simulations, through a set of validation sessions that involved also concept and procedures designers.

*The Safety Approach*



# 2

## MFF SCOPE

In order to meet the MFF objectives, partners agreed to focus on 5 specific applications, each of which represented steps towards implementation of ASAS Self-Separation. The selected applications are described below, along with their key enablers.

### MFF APPLICATIONS

This classification allows for a progression of different Operational Concepts or Applications, investigated within MFF. MFF applications were described with their operational requirements and procedures and validated in the project along with some issues related to their interoperability and transition between different airspace types.



#### A1 - FREE ROUTES

The Free Route Concept was defined by MFF as the simplest option for the implementation of user preferred trajectories. Free Route airspace, when part of Managed Airspace (MAS), is one within which the aircraft operator may freely select his optimum route, but remain subject to normal air traffic control.

#### A2 - AIR TRAFFIC SITUATIONAL AWARENESS

The definition of the Air Traffic Situational Awareness (ATSAW) application in the context of the MFF Programme is:

“The flight crew’s knowledge of the aircraft’s own state and of the external operational environment relevant to the flight, which consists of the surrounding traffic situation in the air and that will provide enhancements to flight crew situational awareness to improve flight management and safety”.

The MFF ATSAW application, as a stand alone application, was not applicable nor appropriate to the Mediterranean area. It was thus considered as an enabler application implicitly validated through the other ASAS applications. Concept definition efforts were thus focused on the four remaining MFF applications.

### **A3 - ASAS SPACING**

The concept of ASAS Spacing in Managed Airspace is based on the equipping of aircraft with a Cockpit Display of Traffic Information (CDTI) to enable aircrew to accept new tasks delegated by ATC. The objective is to assure more consistent aircraft spacing and reduced controller workload, potentially increasing capacity. There is no change in the responsibility of the controller to monitor the behaviour and compliance of the aircraft with instructions (including ASAS instructions) to assure that standard separation is not infringed.

### **A4 - ASAS SEPARATION**

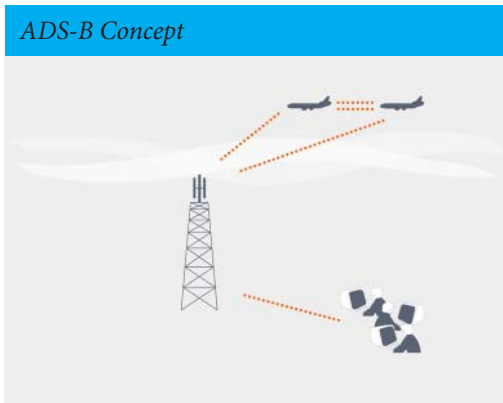
The MFF ASAS Separation application defined for a Managed Airspace, can be seen as part of the co-operative ASAS applications, where the flight crew of suitably equipped aircraft is responsible for ensuring separation values (provision and monitoring) from one aircraft designated by ATC, in compliance with “airborne separation minima” (independent from separation minima applicable by ATC) required for safe operations, and deciding on the means by which to apply them under possible ATC restrictions (related to the surrounding traffic or airspace). Except in these specific circumstances, limited in time, space and scope, where the flight crew takes responsibility for separation, ATC remains responsible for separation.

### **A5 - ASAS SELF-SEPARATION (FREE FLIGHT)**

ASAS Self-Separation application, also referred to as “Free Flight”, is defined in the Eurocontrol OCD as the flight through Free Flight Airspace (FFAS). In Free Flight Airspace, suitably equipped aircraft are able to fly user-preferred routes with flight crews having permanent responsibility for providing separation from other aircraft within the entire FFAS. Ground based service is limited to flight information, alerting service and provision of assistance to aircraft in the event of failure of onboard equipment restricting their ability to assure ASAS Self-Separation.

# TECHNOLOGICAL FRAMEWORK

Based on the Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service-Broadcast applications (TIS-B), the implementation of MFF concepts introduces new requirements on aircraft and ATM systems as well as communication infrastructure.



## AUTOMATIC DEPENDENT SURVEILLANCE BROADCAST (ADS-B)

Automatic Dependent Surveillance-Broadcast (ADS-B) is the enabling technology for ASAS and many other new ATC applications. It is a function on an aircraft that periodically broadcasts its identity, state vector (horizontal and vertical position, horizontal and vertical velocity), intent and other information. Through ADS-B techniques, ADS information is sent in a broadcast mode to all interested users on the ground and in the air.

## TRAFFIC INFORMATION SERVICE BROADCAST (TIS-B)

Traffic Information Service-Broadcast (TIS-B) enables ATM ground systems to provide ASAS equipped aircraft with radar derived information on aircraft that are not transmitting ADS-B information. This technique may be especially useful during the equipage transition period. The advantages of ADS-B over e.g. SSR are the low cost of ground equipment and the enhanced data available from the aircraft in addition to identity, position and altitude. These enhanced data include current speed, rate of climb/descent plus a range of other data such as route and pilot preferences.

## AIRCRAFT SYSTEMS

From the airborne side, aircraft need to be equipped with:

- An ADS-B equipment that broadcasts the aircraft position associated with other information and receives traffic information from surrounding traffic and ground systems;
- A Cockpit Display Traffic Information (CDTI) that is a generic avionics device in an aircraft cockpit capable of displaying position information of nearby aircraft. It may also include display of ground reference point and navigation information to increase pilots situational awareness. Displayed information may be obtained from one or more sources, ADS-B or TIS-B for example. Requirements for CDTI information vary depending on the intended use of the data (i.e. ASAS applications).



A Cockpit Display of Traffic Information

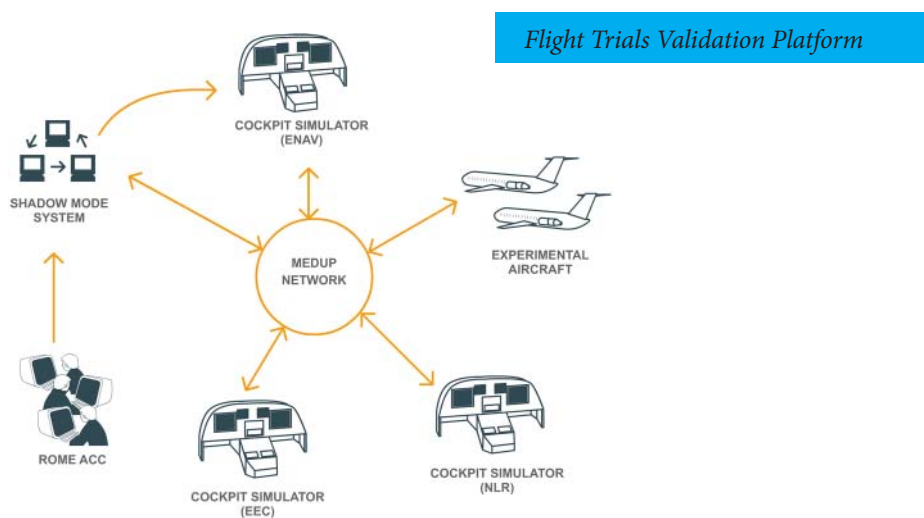
## COMMUNICATION INFRASTRUCTURE

For the data exchange between aircraft and Air Traffic Services (ATS) Providers, an air-ground data link communication means is required. The MFF Programme utilised the ADS MEDUP infrastructure based on VDL Mode 4 data link technology, which is the ICAO and ETSI standards supporting ADS-B.

## IMPACT ON AIR TRAFFIC MANAGEMENT SYSTEMS

To realise the MFF objectives, the ATM systems used in experimentations and trials had mainly to be upgraded with Monitoring Aids, Safety Nets and Medium Term Conflict Detection (MTCD), with the use of ADS-B data including intent information and TIS-B. Specific system functionalities and Human Machine Interface were prototyped and implemented to support Free Route and ASAS operations.

The Flight Data Processing Systems had to be adapted to effectively manage long Free Route segments and for several MFF applications the use of Controller Pilot Data Link Communication (CPDLC) is recommended.





# 3

## MFF REAL TIME SIMULATIONS

Three large-scale simulations were conducted between 2002 and 2005. These simulations were carried out using several facilities:

- ENAV Ground ATM Real Time Simulator, located in Rome (based on the Eurocontrol ESCAPE platform);
- LFV SMART Real Time Simulator, located in Malmoe (Sweden);
- DSNAT Free Route Simulator, located in Toulouse (France);
- ENAV Autonomous Cockpit Simulator “ACS”, located in Rome (Italy);
- NLR Research Flight Simulator “RFS”, located in Amsterdam (The Netherlands);
- EUROCONTROL Multi Cockpit Simulator “MCS”, located in Bretigny (France).



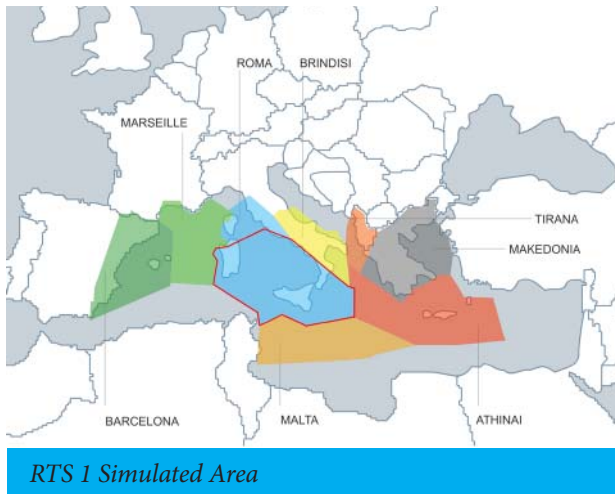
*ENAV Advanced Cockpit Simulator*

### REAL TIME SIMULATION 1

The Real Time Simulation 1 (RTS1) was a Free Route and ASAS Spacing simulation in an en route Italian environment conducted at the ENAV CNS/ATM Experimental Centre between April and May 2002.

The objectives of the MFF RTS1 Rome simulation were:

- To evaluate a baseline “do nothing” scenario and establish measurements against which the effect of the implementation of the MFF applications can be compared;
- To evaluate MFF Free Route Concept and Procedures in a suitable airspace volume of the Mediterranean area;
- To evaluate the MFF ASAS Spacing Concept and Procedures in the con-



*RTS 1 Simulated Area*

text of the transition from Free Route Airspace to Fixed Route Airspace as traffic converges on Free Route exit points both in level flight and in descent towards airports;

- To evaluate the management of the transition between fixed route airspace and Free Route airspace and vice versa.

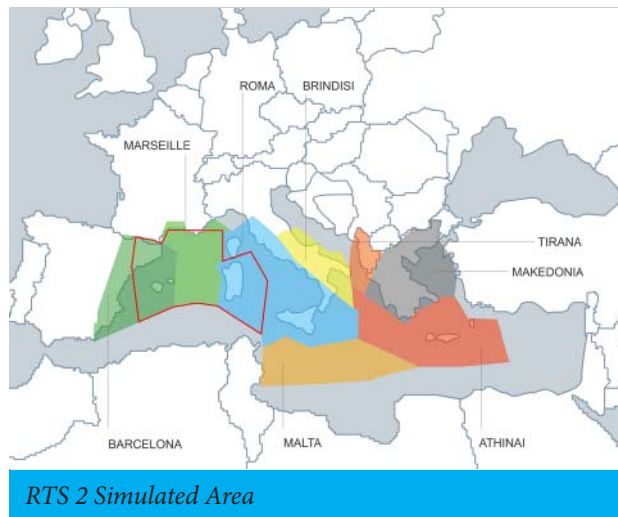
The simulated area was southern Italian airspace mainly over the sea between the mainland and Sardinia which represents a relatively small area. This airspace is bordered to the North by a dense traffic area, which facilitates the use of ASAS Spacing in the transition to Fixed Route on exit from the Free Routes area.

Traffic sample used was 2005-based with RVSM separation (1st September 2000 augmented 30%).

## REAL TIME SIMULATION 2

The high level objectives for the Real Time Simulation 2 (RTS2) exercises were:

- To further study the Free Route Concept and the ASAS Spacing Concept;
- To conduct initial studies on ASAS Self-Separation application;
- To include cockpit simulators and flight deck experiments in simulation exercises;
- To widen the technical scope of MFF RTS so as to include in particular additional ADS-B and CPDLC features.



During the preparation of RTS2, it appeared that the list of detailed objectives could not be achieved through a single simulation.

This resulted in the organisation of three different simulations:

### RTS2 "GROUND FOCUS" SIMULATION

RTS2 Ground Focus Simulation was conducted by ENAV between January and February 2003. Its aim was to study the objectives associated with ground control aspects involving air traffic controllers.

This simulation featured a very large Free Route area above FL285 including sectors from Barcelona, Marseille and Roma ACCs. The Free Route area extended beyond the geographical boundaries of the simulation area therefore entry and exit of the Free Route airspace was only possible in the vertical sense. This lower airspace was simulated as extended TMA (Terminal Area) sectors. ASAS Spacing – Sequencing and Merging techniques were applied as traffic flows converged towards the Free Routes exit points in the descent from cruise level to FL280.

The simulation compared the transition from Free Routes airspace to fixed routes airspace using conventional methods with using ASAS Spacing Sequencing and Merging techniques.

## RTS2 “AIR FOCUS “ SIMULATION

RTS2 “Air Focus“ Simulation was conducted at ENAV CNS/ATM Experimental Centre between February and March 2003. The objective focused on ASAS Spacing procedures and relevant Human Factors issues from the cockpit point of view.

The “air” focus exercises used one of the sectors from RTS1 which included overflying traffic and the arrival flow to Catania.

The simulation featured 3 full fidelity cockpits (ACS-Rome, MCS-Bretigny, RFS-Amsterdam) connected the ESCAPE facility in Rome. Controllers managed ground aspects of the simulation in Rome whilst aircrews located in 3 different countries manned the 3 cockpits simultaneously.



*Spanish Controllers during RTS3*

## RTS2 SELF SEPARATION SIMULATION

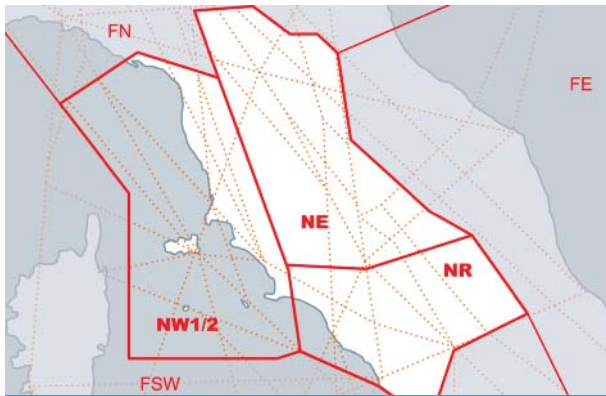
RTS2 Self Separation Simulation, conducted at NLR premises in November 2002, concentrated on ASAS Self-Separation from a cockpit point of view to specifically investigate the procedures defined for transitions between Managed Airspace (MAS) and Free Flight Airspace (FFAS) and in particular the change of responsibility for traffic separation between ground and air.

Both Airborne Traffic Situational Awareness (ATSAW) and Airborne Self-Separation Assurance were addressed in Managed and Free Flight Airspace, respectively.

## REAL TIME SIMULATION 3

Within Real Time Simulation 3 (RTS3), five Real Time Simulations were conducted between October 2003 and February 2004 to complement the previous validation exercises.

## RTS3 GREECE-MALTA ASAS SEPARATION SIMULATION



*RTS3 Simulated Area*

RTS3 Greece-Malta ASAS Separation Simulation was conducted by ENAV in Rome in October 2003.

Its objective was to evaluate the MFF ASAS Separation Concept and Procedures in middle/upper airspace including an area of non radar coverage simulated in the Maltese sector.

One Maltese and one Greek sector were simulated, and five controllers from Athens ACC and Malta ACC participated in the simulation.

The ASAS Separation technique involved the transfer of separation responsibility from the controller to the pilot. The pilot followed the specific procedure specified by the controller and applied “airborne separation” between his aircraft and one other specified aircraft. The procedures simulated included sequencing and merging as well as crossing (“pass behind”, “pass above/below”, in trail climb/descent) and overtaking.

### RTS3 ROME ASAS SPACING SIMULATION

RTS3 Rome ASAS Spacing Simulation was conducted by ENAV in February 2004.

The objective of the simulation was to study in depth the application of ASAS Spacing – Sequencing and Merging techniques – on arriving traffic flows to the Rome, Italy terminal area (2 major airports: Fiumicino, Ciampino). The simulation compared the in-trail spacing of Rome arrival flows using conventional methods with using ASAS Spacing S&M techniques.

Italian controllers from Roma ACC and Brindisi ACC participated in all measured exercises. Maltese and Spanish controllers also participated in the main simulation but were only utilised in the scenario and experimental exercises.



*Representation of ASAS Application*

### RTS3 MALMÖ INTENT SIMULATION

RTS3 Malmö Intent Simulation was conducted by LFV in November 2003. The objective of this simulation was to study the potential benefits of aircraft Flight Management System (FMS) intent information downlinked using ADS-B technology.

The chosen scenario was that of Greek airspace with Free Flight Airspace to the south and Managed Airspace to the north providing a line of transition between the two. Free Route and Fixed Route scenarios were simulated in Managed Airspace. A feature of this simulation was the provision of a CDTI facility on the standard simulation pilot positions allowing the pilot a very realistic “cockpit view” of the traffic situation.

### RTS3 NLR ASAS SELF-SEPARATION SIMULATION

RTS3 ASAS Self-Separation Simulation was conducted by NLR in Amsterdam in February 2004.



*French controllers during RTS 3*

The objective of the simulation was to investigate the effect of weather, military activities and failures in the ASAS Self-Separation concept.

The original starting point of the experiments was directly related to hazards identified in the intermediate Operational Hazard Analysis (OHA) for the Free Flight application.

The experimental conditions were en-route, but transitions between Free Flight Airspace and Managed Airspace, as studied in RTS2, were available in case of failures.

## RTS3 DSNA FREE ROUTES SIMULATION

MFF RTS3 DSNA Free-Route was conducted by the DSNA/SDER in Toulouse between January and February 2004.

The main objectives were to finalize the study of the Free Route concept in a busy Mediterranean area and to evaluate a new set of Free Route ATC tools designed to assist the controllers in dealing with Free Route scenario.

The simulated Free Route area was included in the Marseille UIR and corresponded to a choice of two simulated measured units above FL285. The only interface between Free Route area and Fixed Route was the vertical transition at FL285. The dynamic activation of the military area (linked to this FR area) was simulated.

Airspace below FL285 was conventional Fixed Route airspace while airspace above FL285 was all Free Routes airspace in the simulated area.



*HMI Training at DSNA*

## FLIGHT LEVEL ZERO SIMULATIONS

The Flight Level Zero simulations filled the gap between Real Time Simulations and the Flight Trials and focussed mainly on cockpit issues. They took place during December 2004 and January 2005.

The Flight Level Zero experiments were directed towards assessing the usability of the Cockpit Display of Traffic Information (the actual equipments that would be subsequently used in Flight Trials) and investigated the task allocation between the Pilot Flying (PF) and the Pilot Non-Flying (PNF) for ASAS Spacing applications. Four ASAS Spacing geometries were included in the experimental scenarios:

- ASAS “Merge”,
- ASAS “Heading then Merge”,
- ASAS “Remain Behind”,
- ASAS “Heading then Remain Behind”.



# 4

## FLIGHT TRIALS

**MFF Flight Trials have represented the first opportunity to bring the ASAS operational improvements into the real world through an extensive trial campaign that tested the full range of ASAS applications and fully integrated air-ground concept in the Mediterranean area using the same experimental avionics in combination with the ground ADS MEDUP infrastructure.**

The MFF Flight Trials objectives are:

- To test and verify the overall operational procedures, for both pilots and controllers, supported by the enabling technical solutions;
- To verify and validate (technological) assumptions made in simulations;
- To assess the technology on board the aircraft under various conditions (day/night, low/high density traffic, etc.).

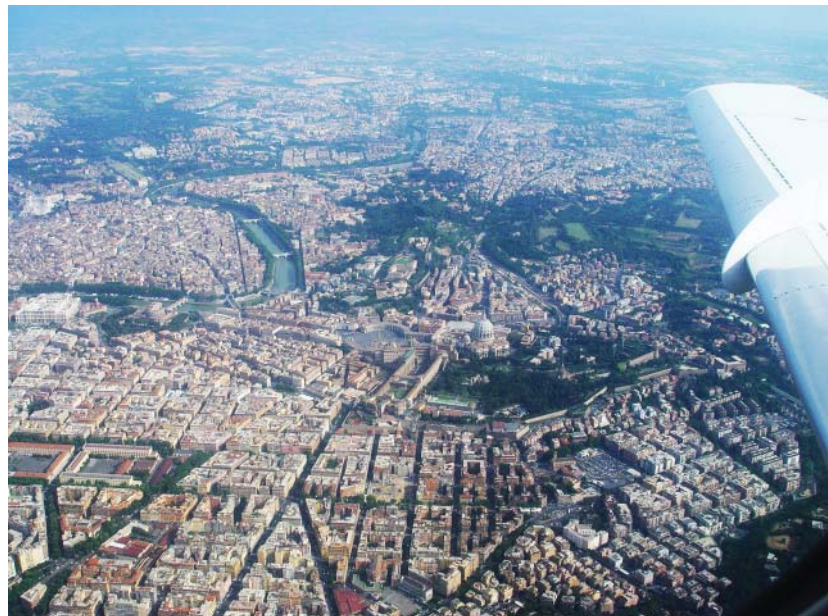
During a seven month-time period, comprised between 9 December 2004 and 10 July 2005, MFF real aircraft and cockpit simulators performed a large number of ASAS applications exercises – namely ASAS Spacing, ASAS Separation and ASAS Self-Separation or Free Flight – over the Mediterranean.

This complex and extensive experimentation phase saw the involvement of five aircraft, two cockpit simulators, an ATC Shadow Mode system and telecommunications infrastructure spanning over the Mediterranean Sea.

The execution of the Flight Trials also required a complex organizational structure, distributed on ENAV's following sites:

- CNS/ATM Experimental Centre, where the ground Shadow Mode system is based and the MFF “experimental” controllers executed the MFF Flight Trials exercises with the support of an overall experiment leader, a safety coordinator and a Military Liaison Officer;
- Roma ACC, where a dedicated team of controllers supervised the MFF Flight Trials operations carried out inside the dedicated area and intervened in case of difficulties;
- Flight Inspection Department Base (Ciampino Airport)

all in strict and fruitful coordination with the Italian Air Force.



*An Overview of Downtown Rome taken during Flight Trials*

# FLIGHT TRIALS PLATFORM

The platform designed for the Flight Trials was composed of three segments: airborne, ground and communication.

## AIRBORNE SEGMENT

It is composed of five aircraft and two high fidelity cockpit simulators, each equipped with experimental avionic packages to support ASAS applications and ADS-B surveillance. The aircraft composing the MFF fleet were :

- Beechcraft KingAir 100 (AENA)
- Cessna Citation SII (ENAV)
- Dassault Falcon 20 (ENAV)
- Cessna Citation II (NLR)
- Fairchild Metroliner (NLR)



*ENAV Cessna Citation*

Aircraft were equipped with two types of ASAS Systems. Both types of ASAS Systems exploited the ADS-B and TIS-B communication protocols over a VDL Mode 4 data link. Two cockpit simulators (ENAV and Eurocontrol), completed the configuration.

Real aircraft and cockpit simulators were all equipped with the MFF ASAS avionics which consisted of a VDL Mode 4 transponder and a Cockpit Display of Traffic Information (CDTI) where the ASAS Software was installed.

## GROUND SEGMENT

This segment comprises the MEDUP network of ground ADS-B stations and an ATC system, similar to those installed in the ENAV ACCs, connected in “shadow mode” to Rome ACC to form a fictitious ACC called “Agri Centre” during the Flight Trials. The Shadow Mode system (SHM) was fed with “live” radar traffic data and the ADS-B and TIS-B information exchanged with the MEDUP network to produce a comprehensive air situation picture, which could be up-linked to aircraft via TIS-B.



*Human Factors Activity during Flight Trials*

## COMMUNICATION SEGMENT

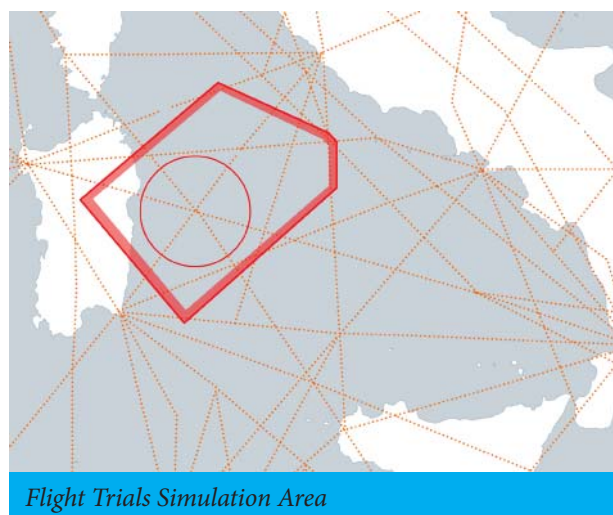
The Communication Segment supported voice communications between the “Shadow Mode controllers” and pilots, via Rome ACC VHF communication stations and surveillance data exchange among Rome ACC, Shadow Mode Platform and ADS MEDUP network.



## FLIGHT TRIALS SCENARIO

An area of the Italian airspace, located over the Tyrrhenian Sea between Sardinia East Coast and Italy's mainland, was selected to perform the MFF Applications during the in-flight tests.

During the MFF Flight Trials this area was interdicted to other traffic with an AIP Supplement and NOTAMs. The effectively usable dimensions were 70 by 90 NM with an additional 15 NM safety buffer around.



The minimum dimensions to ensure the airspace availability to perform ASAS exercises manoeuvres, including Free Flight experiments, were as follows:

- Short side of 100NM;
- Diagonal of 180NM;
- Vertical limits of 6000 ft not above FL195.

The Flight Trials Dedicated Area (FTDA) was defined by:

- Vertical limits between FL125 and FL195
- Horizontal delimitation (border waypoints)
- Vertical delimitation (upper and lower FLs)
- Horizontal and Vertical buffers definition
- Entry/Exit points definition and naming
- Holding Points definition and naming ( aa/cc repositioning points before next exercise; safe points during abnormal procedures)
- Exercises waypoints definition and relevant naming (WPTs)
- Area Restriction procedures (AIP Supp. August 2004)
- Reduced impact on normal ATC operations

## MFF ASAS AVIONICS

**A dedicated avionic package – called Avionic Retrofit Package (ARP) – was developed to provide pilots with the necessary tools to perform the ASAS exercises.**

It included an ad hoc hardware solution, the MFF CDTI, i.e. a control and display unit that provides the crew with a picture of surrounding traffic and specific ASAS tools. The CDTI made use of the ADS-B and TIS-B traffic data received by the VDL-4 transponder to perform Conflict Detection, Conflict Resolution and Conflict Prevention.

The CDTI software also performed the calculation related to Spacing, Separation and Free Flight applications through several software modules.

Typical data shown to the pilot were: ownship navigation data, surrounding air traffic information, their relationship with the ownship, separation conflict detection and relevant resolution advises.

The CDTI, specifically developed for MFF, was based on a commercial CDTI unit upgraded with a set of software modules embedded in.



*AENA King Air 100*



*ENAV Falcon 20*

## TRAINING

Intensive training was required for pilots and air traffic controllers participating in Flight Trials. Training started with a common stage for pilots and controllers where lectures were presented on ASAS procedures and phraseology, followed by several dedicated stages. Additional lectures on the use of the CDTI Human Machine Interface were presented to pilots. Practice in the cockpit simulators was made on the CDTI use and typical applications were studied, enabling each crew to become familiar with this tool. Controllers training was followed with practical instructions on the Shadow Mode system tools and related Human Machine Interface.

## AN EXAMPLE OF FLIGHT TRIALS MISSION

**A total of 234 ASAS exercises were performed and a large amount of data collected, for the first time in Europe, during real flights. Each single flight trial day required the involvement of about forty people.**

To perform the mission, the aircraft involved in the experiment departed from Ciampino Airport and reach the FTDA, where the exercises took place. At the end of the experiment the aircraft returned back to Ciampino Air Base. During the transfer legs between Ciampino Air Base and FTDA, and back to Ciampino, standard IFR rules apply. Once within the FTDA and after changing the flight rules from IFR to VFR the Captain was responsible for maintaining the aircraft separation from other traffic.

Before each mission a briefing with pilots and controllers was held at LIRA (Ciampino Airport), Rome ACC and the Experimental Centre using teleconference support to review mission objectives, flight plans and procedures.

Each aircraft involved in the experiment departed from LIRA with an FPL Y (IFR to VFR), as a normal IFR flight under Rome ACC control, till it reached the FTDA boundary. Entering the FTDA the aircraft cancelled IFR and was instructed to contact the Experimental Centre (“Agri”) controllers on the experiment dedicated frequency assigned by Rome ACC.

The exercises within the FTDA were conducted under VFR according to prescriptions in AIP Italy RAC 1. The MFF experimental phraseology and procedures were conventionally used within the exercise dedicated area to execute MFF applications in a realistic environment. At the end of the exercise sequence, the aircraft left the FTDA at the designated exit point to receive the IFR clearance from Rome ACC to return back to LIRA.

After each mission, pilots, controllers, aircraft and systems support technicians and engineers, human factors observers, site coordinators and experiment leaders had debriefings to exchange feedbacks and review the mission.

Further, all flight data recorded by each aircraft were downloaded for statistical analysis.



*NLR Cessna Citation II*



*NLR Fairchild Metroliner*

## FLIGHT TRIALS RESULTS

**The exercises were performed with increasing levels of complexity and realism using one real aircraft and one cockpit simulator, two real aircraft, and two real aircraft and one cockpit simulator. During the experimentation a total of 240 hours were flown with real aircraft; in addition 135 flight hours were flown with the cockpit simulator.**



The results are therefore based on the experience gained and on the observations collected during a significant amount of flight hours under different conditions.

In general, all the applications tested revealed to be feasible and can be considered promising, although the number of flight hours dedicated to ASAS Separation and ASAS Self-Separation suggests that further experimentation is needed to gain more statistical confidence on the results obtained.

No unacceptable level or peaks of workload was experienced during the experiments, both by pilots and controllers, despite a certain amount of workload increase was observed. The ASAS Self-Separation application seems to require lesser workload to pilots, if compared to ASAS Spacing and ASAS Separation. The workload increase could be lowered improving the HMI of the CDTI. The air traffic situational awareness is adequate.

The allocation of responsibility and tasks between ATC and aircrew are both acceptable. Some refinements are necessary to the definitions of the ASAS applications to introduce the concept of tolerance, to decrease the G/A/G voice communications, to specify the point where the requested spacing/separation should be achieved and to clarify the intended end of delegation.

VDL Mode 4 proved to be an adequate data link to support the ADS-B for ASAS purposes, especially air-to-air.

The onboard ASAS tools need to be connected - and whenever possible - integrated with the aircraft avionics. Appropriate aural and visual warnings are needed in case of foreseen separation infringements. Aircraft performances and passenger comfort should be taken into account by the ASAS systems to evaluate the feasibility of the requested delegation 'a priori'.

Flight Trials provided significant information for the completion of the MFF Validation Objectives and Safety Cases; they gave full value to Model Based and Real Time Simulations on a wide range of aspects such as workload, situational awareness, acceptability, training, HMI, suitability of tools, safety objectives and hazard mitigation strategies.

# 5

## CONCLUSIONS

**MFF, a five years Programme made possible by the co-funding of the European Commission, represents one of the largest multinational initiatives in the history of European Programmes to enhance the future ATM System.**

Experts from nine countries with different cultural backgrounds contributed to the successful achievement of the MFF goals. Considering the wide scope, the range of development work and validation efforts undertaken by MFF, the whole Programme provided valuable scientific results which can, with further studies based on “lessons learned”, facilitate the highly needed improvements of the European ATM system and concept of operations.



Four innovative operational applications were investigated in detail by MFF:

- Free Route;
- ASAS Spacing;
- ASAS Separation;
- ASAS Self-Separation (Free Flight).

Air Traffic Situational Awareness (ATSAW), originally in the MFF applications list, has been considered as an enabler for the above applications and therefore implicitly evaluated.

## PROGRAMME BENEFITS

### METHODOLOGIES AND PROCEDURES

In order to assure a structured, focused and effective approach to the concept validation, MFF applied the MAEVA methodology. Concepts and procedures were validated against a predefined set of validation objectives, through a coordinated set of validation exercises based on different validation techniques (Paper Studies, Model Based Simulations, Real Time Simulations, Flight Trials and Safety Cases). The preparation of the validation report and the storage of MFF validation data and result were supported by the use of the Validation Data Repository (VDR).

Significant attention was paid to the Safety Assessment of MFF concepts and procedures, in order to guarantee that their implementation will decrease or at least not increase the number of ATM induced accidents. A specific Safety policy was prepared (based on the ED78A guidelines and EUROCONTROL's Safety Assessment Methodology) and reviewed by the Safety Regulation Commis-

sion. Operational Hazards were captured with hands on activities during Real Time Simulations and Flight Trials and with an extensive use of workshops with operational experts.

Human Factors related issues were object of in-depth studies to assess human-related aspects (usability of the tools, situational awareness, cognitive workload, etc.) of the new concepts and procedures. Many different investigation techniques were used such as observation, questionnaires, video tape analysis, scenario based analysis and so forth.

All validation data, experiments and results were duly reported in the Programme deliverables and are available to the ATM research community through the VDR ([www.eurocontrol.int/eatmp/vdr](http://www.eurocontrol.int/eatmp/vdr)) and the MFF website ([www.medff.it](http://www.medff.it)).

## TOOLS AND FUNCTIONALITIES

In order to support the validation of the MFF operational procedures, a complete set of new functionalities and the related controller/pilot support tools have been prototyped and developed both for the ground and airborne systems. When possible, results from other projects and available tools have been used as starting point for the MFF development. The international network based on VDL Mode 4 technologies implemented by the ADS MEDUP project has been used as the enabling infrastructure for the Flight Trials.

## CONTRIBUTIONS TO STANDARDISATION OF PROCEDURES



The MFF Programme has investigated an extensive set of procedures having different level of maturity with a comprehensive approach (procedures, phraseology, technologies, etc.).

Even if an explicit task for standardisation of the procedures was not initially planned in the project plan, cross-fertilization from and to parallel related projects (e.g. AFAS, MA-AFAS, CoSpace, NUP, SEAP) and standardisation fora (e.g. Requirements Focus Group) were assured.

At the beginning of the MFF Programme, it was identified the need of a close co-ordination with the military authorities to take onboard the military requirements and constraints while developing the MFF applications. Representatives of the military authorities were involved in various phases of the Programme (e.g. MBS, RTS, Flight Trials, etc.).

The validation scope within MFF was also partly refocused on European Commission request to participate in the definition and validation of Package 1 procedures.

## STAKEHOLDERS EXPECTATIONS

During the initial phase of the MFF Programme a user workshop was held in Rome on 8 February 2001 jointly with the CEC-sponsored project MA-AFAS. Users of the air navigation system include airlines, Airlines Operations Centre (AOC), General Aviation (GA), aircrews; ATS service providers, controllers, airport authorities and the military. Airframe and avionics suppliers may be viewed as stakeholders, who are influenced by, and influence, the development of new systems and concepts. Participating user representatives in the MFF Rome workshop as well as in other public seminars and workshops emphasised that the ATM environment should:

- Accommodate a wide variety of capabilities and provide differing levels of services adapted to the users' needs;
- Provide seamless flight management services gate-to-gate in which flights will be managed continuously within the ATM environment throughout all phases of flight;
- Be predicated and executed on processes which are based on user-requested flexible and dynamic trajectories;
- Keep the aircraft operator as the final decision maker in the planning and execution of the flight;
- Ensure the co-existence of general air traffic (GAT) and operational air traffic (OAT) operations.

Now, more than ever, there are major technology decisions to be made in ATM on which the results of MFF can have a positive impact. New technologies tested in MFF such as data links and global navigation satellite systems (GNSS) enable new operational concepts that meet user requirements. The choice and design of new technologies is critical for ATM and MFF has incorporated many of the opportunities offered.

## GUIDELINES FOR A POSSIBLE FOLLOW-UP

MFF has carved new ground in the validation of the studied operational Concepts, allowing the collection of extensive experimental results. However, in order to cover the next steps towards implementation, it appears necessary to involve a larger group of stakeholders (including Airlines, Aircraft manufacturers, Avionic Industries, Airports and so forth).

On explicit indication of the European Commission, SESAR shall be the framework in which the MFF results could be further explored and successively exploited ensuring at the same time the participation of an adequate group of stakeholders.

# ACRONYMS

<b>ACS</b>	Advanced Cockpit Simulator
<b>ADS-B</b>	Automatic Dependent Surveillance – Broadcast
<b>ADS MEDUP</b>	ADS MEDiterranean UPgrade Programme
<b>AENA</b>	Aeropuertos Espanoles y Navegacion Aérea
<b>AOC</b>	Airlines Operations Centre
<b>ARP</b>	Avionic Retrofit Package
<b>ASAS</b>	Airborne Separation Assistance System
<b>ATC</b>	Air Traffic Control
<b>ATM</b>	Air Traffic Management
<b>ATS</b>	Air Traffic Services
<b>ATSAW</b>	Air Traffic Situational AWAREness
<b>CARE</b>	Co-operative Actions of R&D in Eurocontrol
<b>CDTI</b>	Cockpit Display of Traffic Information
<b>CNS/ATM</b>	Communication Navigation Surveillance / Air Traffic Management
<b>CPDLC</b>	Controller Pilot Data Link Communication
<b>DSNA</b>	Direction des Services de la Navigation Aérienne
<b>EATMP</b>	European Air Traffic Management Programme
<b>ENAV</b>	Società Nazionale per l'Assistenza al Volo
<b>ESCAPE</b>	EUROCONTROL Simulation CAPability for Experimentation
<b>FARAWAY</b>	Fusion of Radar & ADS data through two Way data link
<b>FFAS</b>	Free Flight Airspace
<b>FMS</b>	Flight Management System
<b>FR</b>	Free Route
<b>FRAP</b>	Free Route Airspace Project
<b>FTDA</b>	Flight Trial Dedicated Area
<b>GA</b>	General Aviation
<b>GATM-TB</b>	Ground ATM Test Bed
<b>GNSS</b>	Global Navigation Satellite System
<b>HCAA</b>	Hellenic Civil Aviation Authority (Greece)
<b>HMI</b>	Human Machine Interface
<b>MA-AFAS</b>	More Autonomou Aircraft in the Future ATM System Programme
<b>MAEVA</b>	Master ATM European Validation Plan



<b>MAS</b>	Managed Airspace
<b>MATS</b>	Malta Air Traffic Services
<b>MBS</b>	Model Based Simulation
<b>MCS</b>	Multi- aircraft Cockpit Simulator
<b>MFF</b>	Mediterranean Free Flight Programme
<b>MTCD</b>	Medium Term Conflict Detection
<b>NATS</b>	National Air Traffic Services
<b>NERL</b>	NATS En-Route Ltd
<b>NLR</b>	National Lucht-en Ruimtevaartlaboratorium
<b>NM</b>	Nautical Miles
<b>NUP</b>	Nean Update Programme
<b>OAT</b>	Operational Air Traffic
<b> OCD</b>	Operational Concept Definition
<b> ODS</b>	Operational Display System
<b> PF</b>	Pilot Flying
<b> PNF</b>	Pilot Non-Flying
<b> RFS</b>	Research Flight Simulator
<b> RTS</b>	Real Time Simulation
<b> RVSM</b>	Reduced Vertical Separation Minima
<b> S&amp;M</b>	Sequencing and Merging
<b> SCAA-LFV</b>	Swedish Civil Aviation Administration – Luftfartsverket
<b> SDER</b>	Sous-Direction Etudes et Recherche Appliquées
<b> SEAP</b>	Large Scale European ADS pre-implementation Programme
<b> SESAR</b>	Single European Sky ATM Research
<b> SHM</b>	Shadow Mode
<b> SSR</b>	Secondary Surveillance Radar
<b> TEN-T</b>	Trans – European Transport Networks
<b> TIS-B</b>	Traffic Information Service – Broadcast
<b> TMA</b>	Terminal Manoeuvring Area
<b> TSA</b>	Temporary Segregated Airspace
<b> UIR</b>	Upper Information Region
<b> VDL 4</b>	VHF Digital Link Mode 4
<b> VDR</b>	Validation Data Repository

## REFERENCES

Further information about the Programme can be found on the Programme official website: [www.medff.it](http://www.medff.it).

More in depth information on the final results are contained in the MFF Final Report available on [www.medff.it/public/archive/public\\_deliverables/wa8.asp](http://www.medff.it/public/archive/public_deliverables/wa8.asp)

The interactive presentation “MFF at a Glance” and the DVD-video “Flight Trials in MFF” can be requested by email to the MFF Programme Manager (Maurizio Zacchei) at [mzacchei@enav.it](mailto:mzacchei@enav.it).





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